1983 Mineral Resource Studies in the Kantishna Hills & Dunkle Mine Areas Denali National Park and Preserve

VOLUME I

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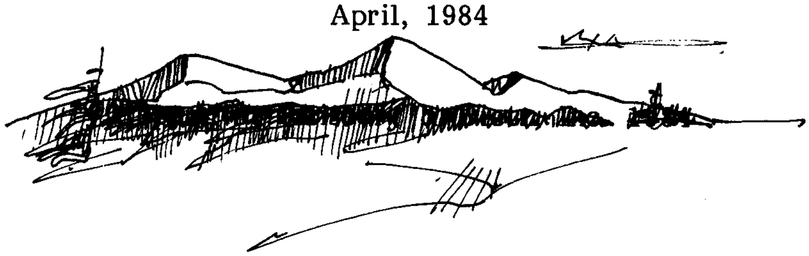


VOLUME I - TEXT

CONTENTS

FIGURES

K - Kantishna Hills Study Area   D - Dunkle Mine Study Area

TABLES

K - Kantishna Hills Study Area D - Dunkle Mine Study Area

V O L U M E   II   -   A P P E N D I C E S

CONTENTS

APPENDIX A - PLACER

APPENDIX E - GEOPHYSICS

APPENDIX F - SURVEYING

V O L U M E III - P L A T E S

OVERVIEW

ABSTRACT

In 1983 Salisbury & Dietz, Inc., under contract to the U. S. Bureau of Mines, conducted mineral resource studies in the Kantishna Hills and Dunkle Mine study areas of the Denali National Park and Preserve, Alaska. Field work included geologic mapping, geochemical and geophysical surveys, placer studies, and drilling.

Production from the Kantishna Hills study area through 1983 totaled 85,000 oz gold, 265,000 oz silver, 504,000 lb lead, and 4,400,000 lb antimony. The Dunkle Mine area has produced approximately 64,000 tons of coal.

The Kantishna Hills area contains an estimated 688,000 oz of placer gold in 43 million cy of gravels. The gold was probably derived by erosion of precious-metal vein deposits. Lode mineralization appears to be principally related to the Spruce Creek Sequence of metamorphosed sedimentary and volcano-sedimentary deposits which contain modest reserves of antimony, gold, silver, lead, and zinc in vein and stratiform deposits. The area also contains black shale and volcanic environments exhibiting newly identified evidence for stratabound base- and precious-metal mineralization. Regional geochemical anomalies indicate other potentially mineralized areas.

Mineralization in the Dunkle Mine study area appears to be related to an igneous complex and two regional structural zones hosted by sedimentary, metasedimentary, and metavolcanic rocks. Geochemical and geophysical evidence suggests the igneous complex is permissive for the formation of potentially large-tonnage breccia pipe deposits containing copper and gold, and for porphyry-type deposits of copper and molybdenum. Numerous small structurally-controlled base- and precious-metal deposits are present in the area but none has yet proven to be economic in character. Up to 350,000 tons of coal may be present in Tertiary sedimentary deposits.

INTRODUCTION

By Wm. G. Salisbury

The Alaska National Interest Lands Conservation Act (ANILCA) was passed by Congress on December 2, 1980. Section 202(3)(b) of this act mandated the Alaska Land Use Council (ALUC) to conduct studies of the Kantishna Hills and Dunkle Mine areas (fig. 1), in the newly established Denali National Park and Preserve. In addition to other resource studies, the ALUC was directed to: (1) evaluate mineral resources, (2) compile information related to mineral potential, (3) estimate the cost of acquiring mineral properties, and (4) assess the consequences of further mineral development.

On May 24, 1983, the U. S. Bureau of Mines awarded to Salisbury & Dietz, Inc. (S&D) Contract No. S0134031 to evaluate mineral resources and compile information related to the mineral potential of the two study areas. Professional personnel were provided by Salisbury & Dietz, Inc., and by subcontractors C. C. Hawley and Associates, Inc. and WGM, Inc. A list of project personnel is shown in table 1.

Normally a study of this magnitude would take place over two or more field seasons and would be preceded by months of planning and preparation. The time restrictions imposed by ANILCA were overcome by utilizing a large staff with extensive experience in resource evaluations. Key personnel on the project collectively had more than 110 years experience in mineral resource assessments, including over 80 years in Alaska.

A preliminary report summarizing mineral resource information pertaining to the study areas was begun on May 24 and presented to the U. S. Bureau of Mines on June 6. Field work began on the project on June 6 and was completed by September 14. During that period professional personnel worked approximately 11,000 hours on the project. Because of time and budget constraints, work was concentrated on existing claims in areas of known mineralization, but reconnaissance surveys were conducted throughout both study areas.

Table 1 - Project Personnel

SALISBURY & DIETZ, INC.

*Wm. G. Salisbury - Project Supervisor
*V. V. Thornsberry - Project Manager
*C. J. McKee - Senior Geologist - Precious Metal Veins and Dunkle
*J. H. Levell - Senior Geologist - Placer Evaluations
R. J. Hall - Computer Analyst
F. G. Kruger - Project Geologist - Diamond Drilling
C. H. Carter - Project Geologist - Diamond Drilling
W. L. Srock - Geologist - Placer
G. Slagle - Laborer

C. C. HAWLEY & ASSOC., INC.

C. C. Hawley - Project Advisor
*T. K. Hinderman - Senior Geologist - Regional Geology
C. D. Hale - Project Geologist - Lode
G. J. Garcia - Project Geologist - Placer
W. R. Hammond - Geophysicist
C. H. Nerud - Assistant Geophysicist
R. Langston - Assistant Geophysicist
D. Babcock - Geological Technician

WGM, INC.

C. G. Bigelow - Project Advisor
*J. R. Bressler - Senior Geologist - Massive Sulfides and Regional Geology
M. H. Stevens - Project Geologist - Lode
D. Edgerton - Assistant Geologist
T. Pearia - Senior Surveyor
J. Fernette - Permitting and Liaison
D. Burton - Surveyor
B. Mudd - Assistant Surveyor

CONSULTANTS

*D. A. Smith - Geophysics Consultant - Supervisor Geophysics
C. F. Herbert - Placer Consultant

U. S. BUREAU OF MINES

U. J. Jansons - Technical Coordinator
*R. B. Hoekzema - Reconnaissance Placer
*J. M. Kurtak - Antimony
S. A. Fetchner
L. W. Harper
N. J. Rathbun

INTERNATIONAL AIR TRANSPORT

W. Carroll - Pilot
M. Scott - Mechanic

DIAMOND DRILLERS	CABLE TOOL SAMPLERS	BACKHOE
B. Burton	J. Nicholson	C. Kyllonen
N. Anderton	L. Kjack	
L. McFerron		
L. Speirs		
M. Nixon		
G. Panther		
M. Chisholm		
B. Sheldon		
M. Schell		
J. Belcher		

* Author

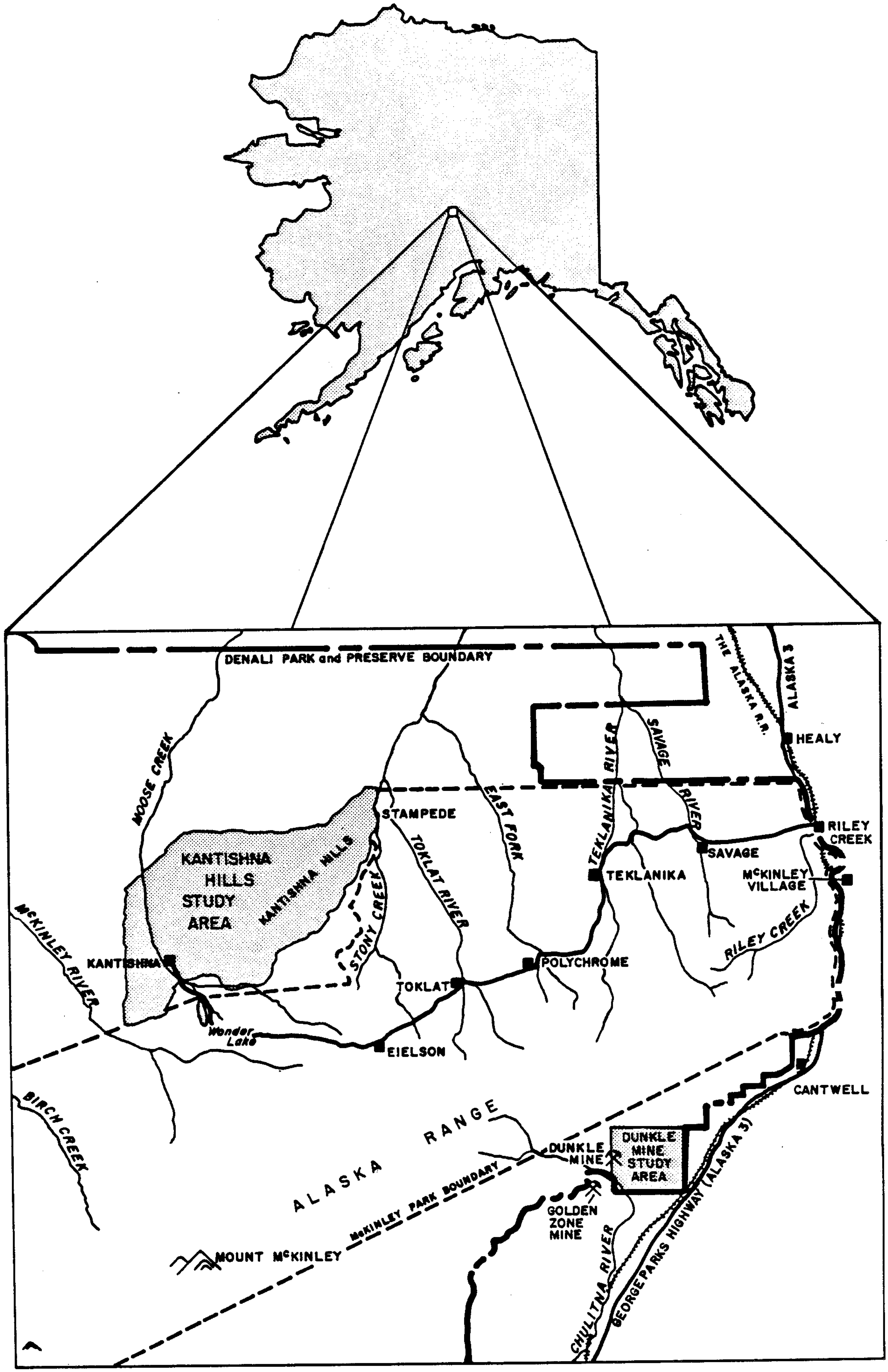


Figure 1 - Index Map

A 40-man field camp was established at the townsite of Kantishna near the junction of Eureka and Moose Creeks. All project activities were conducted from this camp except for a two-week period during the Dunkle Mine area study when a crew of ten was housed in a cabin at the townsite of Colorado.

In addition to 20 sleep tents, the Kantishna camp included a main office, placer laboratory, geophysical laboratory, and large tent for storage of equipment and supplies. Major equipment consisted of an assortment of geophysical instruments, two portable diamond drills, a crawler-mounted backhoe, a Diester concentrating table, and later in the season, a Nodwell-mounted cable tool sampler. Field activities were supported by a Hughes 500D helicopter under subcontract from International Air Transport (IAT). Ground vehicles included three trucks, five motorcycles, and three 3-wheelers.

In the Kantishna Hills study area, 67 square miles were geologically mapped and more than 2,000 samples were collected for geochemical analysis. Over 100 individual deposits and mineral occurrences were mapped and sampled. Core drilling, which was limited to patented claims because of restrictions imposed by ANILCA, aggregated 4,909 ft in 22 holes. Over 400 core samples were assayed for metal content, and detailed drill logs were prepared for each of the holes. Placer deposits were evaluated by various means at 202 sites; 227 placer samples were analyzed for gold and associated by-products. Operations were closely monitored at 14 active placer mines and observed periodically at the remaining seven, so that results from actual mining could be assessed. Approximately 200,000 line-ft of geophysical surveys were conducted, primarily in the Kantishna area. Survey grids, drill holes, sample sites, and mineral occurrences were surveyed at 380 locations. Analytical data were treated statistically by computer assisted methods and were compiled on computer tapes for future use.

Field work in the Dunkle Mine study area consisted of geological mapping, geochemical sampling, and evaluation of pre-study data. Nine prospects were mapped in detail and sampled. The entire study area was examined on a reconnaissance basis, except where completely covered by overburden. More than 275 stream sediment, panned concentrate, rock chip, and soil samples were collected for analysis. Placer potential was evaluated in several gold-bearing drainages, and samples were taken at nine locations. Several line-miles of magnetometer surveys were completed to augment previous coverage. Survey stations were established at 27 points to tie in sample grids and other pertinent features. Core drilling could not be done because no patented claims are located in the area.

Each of the two study areas are discussed separately in the report that follows. Authors are cited at the beginning of each section. Findings are summarized and discussed generally in the text of Volume I. Detailed technical data are contained in appendix form in Volume II. Much information is summarized on maps included as figures in the text and for additional detail the reader is referred to the plates contained in Volume III.

ACKNOWLEDGMENTS

Many individuals outside of the study group contributed substantially to the 1983 study. U. Jansons was the technical contracting officer representing the Bureau of Mines during the project. His sound geologic judgment and true professionalism guided project activities throughout the study. Other Bureau personnel monitored field activities and provided many constructive suggestions during the course of the project. Bureau personnel, Robert Hoekzema and Steven Fechner, conducted independent placer gold reconnaissance studies and some of their data is included in this report. Joe Kurtak participated in regional and local geologic studies and was largely responsible for authoring the section in this report on antimony deposits. Nathan Rathbun and Lee Harper assisted with many project activities and their willing help is greatly appreciated.

Tom Bundtzen of the Alaska Department of Natural Resources (DNR), Division of Geological and Geophysical Surveys (DGGS), has conducted most of the recent geologic work in the Kantishna Hills area prior to the current study. His knowledge of the area surpasses that of any other investigator and much of his work is referenced in this report.

Mr. Bundtzen visited the project for a week during mid-June and guided members of the study group on orientation traverses throughout the study area. His consultation and advice were called upon throughout the project and his amended geologic map of the region is included with this report (plate 1, fig. K-6).

Dan and Roberta (Berta) Ashbrook provided meals during our stay at Kantishna and allowed us to invade what had been their peaceful home. International Air Transport (IAT) pilot Wm. (Buddy) Carroll provided safe and efficient helicopter support for the project. Morris (Mo) Scott, in addition to his duties as helicopter mechanic, assisted with camp construction and a host of other chores that were beyond the call of duty.

Phyllis McClanahan, with Salisbury & Dietz, Inc., typed many drafts of this report, exhibiting her usual patience, and made many useful suggestions which have been incorporated. Drafts of the report were edited by Cory J. Samia of the Bureau of Mines and Kathy Stege with Stege Communications, Inc. and we respect their perserverance.

Drafting and graphics personnel included John Brineman, Patti Young, Gary Panther, and Ritch Gibson with Salisbury & Dietz, Inc., Anne Fleetwood with C. C. Hawley and Associates, and Leonard Nelson with WGM, Inc. All of these people worked tirelessly in producing, in a very short time frame, the many maps and figures which accompany this report.

Cindy Ross compiled thousands of analytical results into a computerized data base and produced the statistical analysis, print-outs, and computer generated maps necessary for interpretation.

Finally we would like to thank the Kantishna and Dunkle miners without whose cooperation many significant portions of this study could not have been accomplished. The miners all freely contributed information, and cooperated in every aspect of the project in spite of apprehension and concern many felt about potential effects of the study on their future livelihood. Many times they interrupted or altered their operations to accommodate our activities and their hospitality and generosity surpassed even that which has become an Alaskan tradition.

SUMMARY AND CONCLUSIONS

By Wm. G. Salisbury

KANTISHNA HILLS STUDY AREA

Mines in the Kantishna Hills study area have produced more than 85,000 oz of gold, 265,000 oz of silver, 504,000 lb of lead, 4,400,000 lb of antimony, and an undetermined amount of zinc. More than 90% of the gold was produced by small- to medium-scale placer operations. This area is the source of most of the antimony production in Alaska and ranks as the second largest antimony producing district in the United States. Gold, silver, lead, and zinc have been mined from several relatively small vein deposits, primarily in the vicinity of Quigley Ridge. Studies during the 1983 season indicate the presence of geologic environments which could contain base- and precious-metal massive sulfide deposits. These environments are not covered by claims and because of restrictions imposed by ANILCA could not be tested by drilling (fig. K-2).

Seventeen small- to medium-sized (5 cy/d to 1500 cy/d) placer operations, employing about 125 people, were active in the Kantishna area during the 1983 season. Significant reserves of gold-bearing gravel remain unmined both on and off existing claims.

Characteristically, the precious/base-metal veins are limited in tonnage but high in dollar value per ton of ore. Several of the deposits could probably support small-scale mining. Seventeen new gold and silver occurrences were found during the study, and a high probability exists that similar deposits remain undiscovered.

Known antimony mines and prospects contain modest proven reserves. Five previously unreported antimony occurrences were located during the 1983 study. It is probable that additional reserves could be discovered or developed as extensions of known deposits. Antimony production from the district could continue to be significant in terms of U.S. production but probably not in terms of U.S. consumption or free-world supply.

Geologic environments favorable for deposition of massive sulfide deposits are indicated by surface mapping, geochemical sampling, and geophysical surveys. Eight previously unreported massive sulfide occurrences were identified within these geological environments. Several zones of iron precipitates are drained by streams which are highly acidic and anomalous in color. Except for surface data, the mineral potential of these environments remains unevaluated. Deposits hosted by similar environments contain high-grade reserves measured in millions of tons.

Placer Deposits

The Kantishna Hills study area is one of about 37 producing placer gold districts in Alaska. Production in recent years has increased from 800 oz in 1974 to an estimated 7,500 oz in 1983. For comparison, total United States lode and placer gold production in 1982 was 1,400,000 oz of which 174,900 oz were produced in Alaska.

Placer gold is a natural alloy or mixture of gold, silver, and other metals. Fineness of the placer gold is the percentage of gold to other metals expressed in parts per thousand. The average fineness of placer gold samples obtained during the study was 750. Average fineness of placer gold produced at operating mines was 729. Sampling of operations active during 1983 indicates that recovered placer gold grades ranged from 0.005 to 0.062 oz/cy and averaged 0.022 oz/cy. Gold content, adjusted for fineness, ranges from 0.004 to 0.045 oz/cy and averages 0.016 oz/cy.

It is estimated that the district contains 43 million cy of minable stream and terrace gravels containing 688,000 oz of gold (fig. K-3). Of this total, 18 million cy are covered by existing claims and contain an estimated 288,000 oz of gold.

Fine-grained placer gold from the Kantishna District is sold for contained gold value after adjustment for fineness. Coarse-grained gold is marketed to jewelers at prices ranging from one to two times the spot price of gold. The price received for placer gold from operations monitored in 1983 averaged 0.83 times the spot price of gold. If the average placer gold grade is multiplied by 0.83, at $400/oz the in-ground value of unmined placer gold within the district is estimated at $314 million of which $131 million (or less than one-half) would be derived from gravels covered by existing claims.

Another 21 million cy of terrace gravels contain anomalous amounts of gold. More than 200 million cy of terrace and alluvial fan gravels are currently unevaluated but could contain significant reserves amenable to large-scale mining.

Improvements in placer gold processing systems have increased recovery of fine gold, expanded mining capacities, and enhanced plant portability. About 500,000 cy of gravel were processed during 1983. Operating at maximum capacity, current operations could process approximately 800,000 cy of gravel per year. At this production rate, 20 to 50 years would be required to mine the indicated reserves on existing claims. Mining of potential reserves in the terrace and floodplain gravels could significantly increase production from the district, but they would probably be mined at a much higher rate and impact more on annual production than on mine life.

Lode Precious-Metal Deposits

Precious-metal production from lodes in the Kantishna region has been from several small but very high-grade vein deposits on Quigley Ridge and from the Banjo Mine about 1 mile east of the ridge. The Banjo Mine (fig. K-4), developed primarily for its gold content, was the largest precious-metal lode mine in the region. It produced 13,693 tons of ore averaging 0.50 oz Au/ton and 0.52 oz Ag/ton.

Eight smaller but higher grade deposits on Quigley Ridge were mined primarily for their silver content. Together, they produced 1,655 tons of ore containing about 258,000 oz of silver, 450 oz of gold, and more than 500,000 lb of lead. The largest, the Little Annie Mine (fig. K-4), produced 715 tons with an average silver content of 162 oz/ton and an average gold content of about 0.1 oz/ton. The Red Top Mine (fig. K-4), another important deposit, produced 184 tons containing 237 oz Ag/ton and 1.0 oz Au/ton.

Mining of these deposits was confined to high-grade lenses. Substantial tonnages of lower grade material probably remain in the Red Top, Little Annie, and several other Quigley Ridge deposits.

During 1983, the only precious-metal lode production came from the Wieler Prospect (fig. K-4) near the Banjo Mine. An estimated 156 tons of ore reportedly averaging 2.8 oz Au/ton and 65.3 oz Ag/ton were mined from this deposit and trucked to Fairbanks for milling.

The Spruce Creek Sequence assemblage of rocks extending both northeast and southwest of Quigley Ridge, hosts the majority of the precious-metal vein deposits (fig. K-4). Seventy-six precious-metal vein occurrences were identified, either within the Spruce Creek Sequence or near the Spruce Creek-Birch Creek contacts. This entire trend is favorable for the occurrence of precious-metal vein deposits. Significant new discoveries were found during the course of the 1983 study, and more deposits are probably present, both on and off existing claims.

Three potential mining scenarios are indicated for the Kantishna Hills study area: (1) one or more deposits could be developed on a small scale, similar to historic production; (2) ore grade and reserves in several deposits may be sufficient to sustain operations in the 100 ton/d class; and (3) the metafelsite unit of the Spruce Creek Sequence could host potential large-tonnage, low-grade occurrences of precious metals similar to new discoveries in the lower 48 states. Such deposits may be amenable to bulk mining methods.

Lode Antimony Deposits

Antimony-bearing vein deposits are scattered throughout the southern and eastern parts of the study area. Several of the deposits have been mined primarily during periods of wartime antimony demand. In general, production has been restricted to high-grade deposits. Attempts to beneficiate lower grade ore at the Stampede Mine were only marginally successful.

The Stampede Mine (fig. K-4), historically the largest antimony producer in the district, produced 3,700,000 lb of antimony to rank second in size among domestic antimony mines. The Slate Creek Mine (fig. K-4) has produced 800,000 lb of antimony including approximately 26,000 lb shipped in 1983. The Last Chance Mine (fig. K-4) on Caribou Creek, site of the first lode antimony production from the region in 1905, has produced about 74,000 lb of antimony. About 50,000 lb of antimony were mined from a deposit on Eureka Creek in 1915.

The Stampede Mine contains a known reserve of 6,280 tons of antimony ore based on drill and underground sampling information. Three other deposits in the region have developed reserves totaling 5,650 tons. Additional reserves probably exist along geologically favorable but as yet untested extensions of the known deposits. Total potential resource estimates range from 40,000 to 560,000 tons of ore grading approximately 12% antimony.

Given favorable demand, the region most likely could reach a production rate on the order of 500,000 lb/yr of antimony. Operations could be sustained for several years if lower grade ore could be economically beneficiated. Production would be significant in relation to U.S. antimony production (about 1,100,000 lb in 1982) but not in terms of annual domestic consumption (66,400,000 lb in 1982).

Other production could result from small-scale surface development of several small deposits of easily accessible veins and pods of massive stibnite. This ore could be shipped directly without further processing. Because of the geologic nature of the antimony occurrences, probably no single mine would be larger than the operation at Stampede which employed 30 people during peak production.

Stratabound Massive Sulfide Deposits

The Kantishna Hills study area is underlain by rocks permissive for the occurrence of stratabound massive sulfide deposits. Three potential host environments have been identified: (1) quartzite units within the Precambrian Birch Creek Schist, (2) black slate/schist terranes in the Birch Creek Schist and the Devonian Keevy Peak Formation, and (3) volcanogenic environments in the lower Paleozoic (?) Spruce Creek Sequence.

Geologic similarities to known mines, and geochemical and geophysical evidence, suggest that several prospects and occurrences in the study area are broadly analogous to major deposits. The Lloyd Prospect (fig. K-4) is hosted in a quartzite unit containing disseminated to semi-massive sulfides similar to mineralization found in Precambrian Belt rocks at the Troy Mine in Montana. The Red Dirt and Canyon Creek occurrences (fig. K-4), first recognized during the 1983 season, occur in a shale-hosted sulfide environment similar to the black shale terrane of the Red Dog Deposit in northwest Alaska. Volcanogenic rocks predominate in the Spruce Creek Sequence on Quigley Ridge, Glen Creek Basin, and the Spruce Peak-Kankone Ridge Trend. Numerous occurrences of small, stratiform, sulfide-bearing zones indicate that the host environment is present for volcanogenic exhalative, massive sulfide deposits similar in mode to the Delta Mineral Belt of the eastern Alaska Range.

In the absence of subsurface information, none of the stratabound occurrences have been adequately explored. Similar occurrences elsewhere in Alaska are being actively prospected, and while the probability of discovery of a minable deposit is statistically low, the size of potential deposits is large enough to justify considerable effort and risk.

A shale-hosted massive sulfide deposit could contain 10's of millions of tons of ore yielding 5 to 30% combined lead and zinc, recoverable silver, and possible credits of gold and other metals. A quartzite-hosted deposit would characteristically contain plus or minus 1 million tons of ore with up to 10% copper, several percent zinc and lead, and significant silver and gold values.

If one of these deposits were found and developed, it could be of sufficient size and grade to support a large surface or underground mine employing several hundred people. Annual production could be on the order of 500,000 to 5,000,000 tons of ore. The ore would be milled on site producing concentrates which would be shipped for smelting and refining.

Other Deposits and Geochemical Anomalies

Significant mineral occurrences and geochemical anomalies were located by regional mapping and sampling during this study. Figure K-5 shows major geochemical anomalies. Many of the anomalies can be explained by proximity to known occurrences. Significant new anomalies include: (1) the Spruce-Kankone Trend, a 1983 discovery of a structurally-controlled base- and precious-metal zone that may have a strike length of 7,000 ft; (2) zinc anomalies associated with black shale and schist units of the Birch Creek and Keevy Peak Formations; (3) tungsten anomalies in the Canyon Creek drainages; and (4) several scattered, as yet unexplained copper and zinc anomalies in the Birch Creek Formation.

Other deposits of interest include skarn deposits in the Iron Dome-Eldorado Creek areas and garnet-bearing amphibolites containing minor free gold in the Birch Creek Formation.

DUNKLE MINE STUDY AREA

At least four high-grade, gold- and silver-bearing vein deposits occur in the study area along the Chulitna structural zone (fig. D-2). Additional undiscovered deposits may exist along the zone or in associated structures.

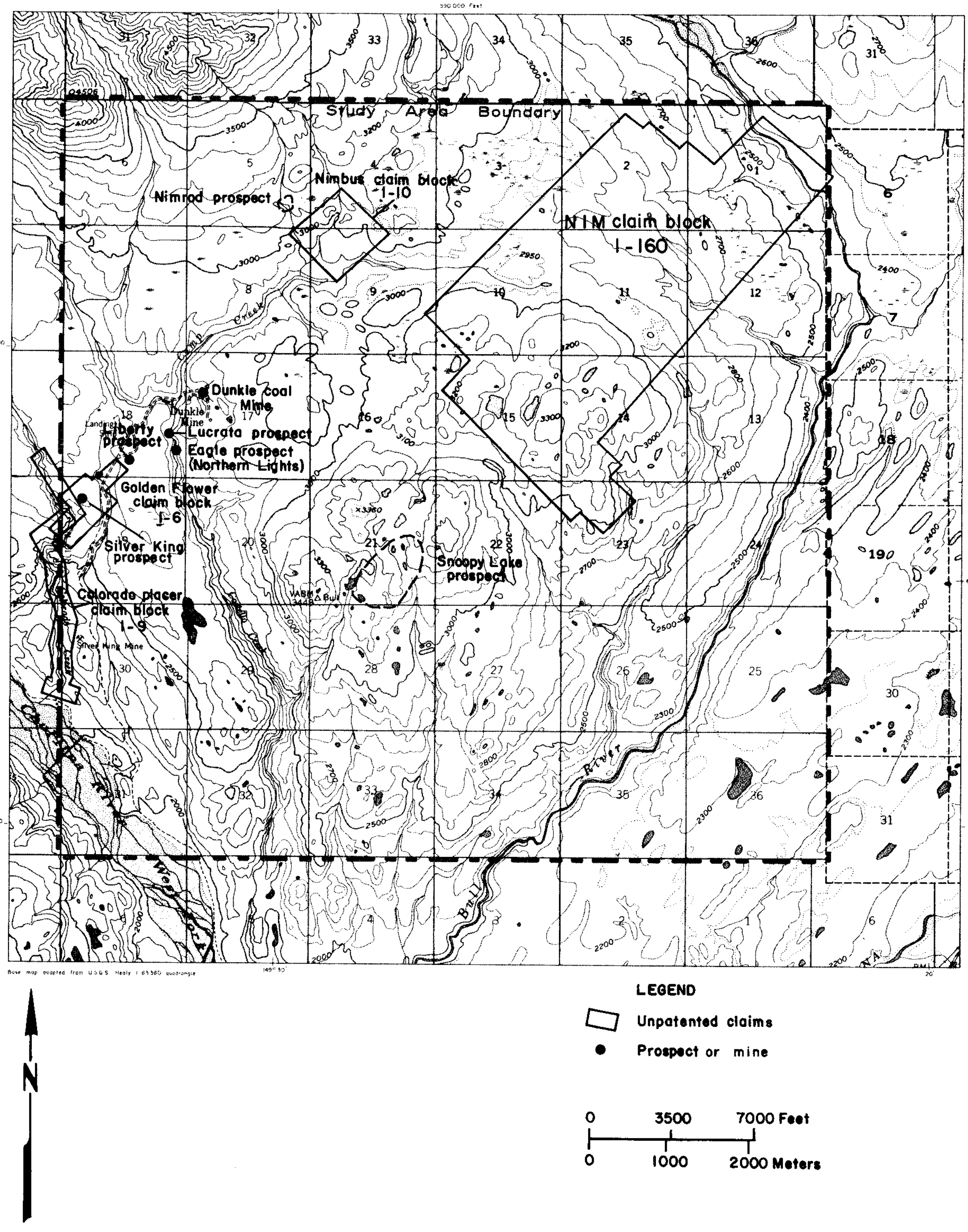


Figure D-2 Claims, Mines, and Prospects - Dunkle Mine Study Area

The vein deposits are narrow and their strike lengths are unknown. This type of target, although probably not attractive to major companies, could prove profitable to companies or individuals mining on a modest scale.

The shear zones in which the high-grade veins are located may contain lower grade precious-metal mineralization across sufficient width to permit bulk mining. Such deposits could be of considerable interest to larger companies.

The Golden Zone Mine (fig. 1) is a gold deposit associated with a breccia pipe located 2 miles west of the study area. The mine has produced in the past and is currently being evaluated for further development. The deposit has a potential for several million tons of low- to moderate-grade gold ore. Geology, structure, and mineralogy associated with the igneous complex in the Dunkle Mine study area present an environment favorable for the occurrence of similar deposits. Geochemical and geophysical evidence (fig. D-3 and D-4) support this interpretation.

Several potential copper/molybdenum and copper/precious metal, porphyry-type targets have been identified within the study area. The area of the NIM claims (fig. D-5) exhibits potential for these types of deposits. These targets have not been adequately tested. Should deposits of this type be found, they could contain 10's or 100's of millions of tons of low-grade ore.

Good quality coal has been mined from the Dunkle Mine (fig. D-2) within the study area. Minable reserves in the range of 100,000 to 350,000 tons have been indicated by drilling. Additional reserves, perhaps several million tons, may be identified with further drilling in the Costello-Colorado-Camp Creek Basin. Small-scale mining by open-cut mining methods may be feasible.

The presence of auriferous gravels in several streams, confirmed during the 1983 project, suggests small-scale placer mining may be feasible in some locations.

Geochemical evidence exists for antimony and tin mineralization. The potential for significant mineralization has not been adequately determined.

The Dunkle Mine study area is a highly metalliferous and geologically complex environment. Except for coal, no mineral deposits have as yet been proven to be commercially exploitable. Adequate subsurface testing of favorable targets has been lacking however and further evaluation is warranted. The proximity of the Dunkle area to the railroad and the Parks Highway further enhances the area's mining potential.

RECOMMENDATIONS

By V. V. Thornsberry

KANTISHNA HILLS/DUNKLE MINE STUDY AREA

The Kantishna Hills and Dunkle Mine study areas are both highly mineralized regions. Should these areas be opened to mineral entry, either through a leasing program or mineral location, the result would be increased exploration and probable development by individual miners and major mining companies. In order for the ALUC to more accurately evaluate and determine the mining potential of the study areas, the following recommendations are made concerning future mineral evaluation activities.

Kantishna Placer Deposits

The lower floodplains of Glacier, Caribou, and Lower Moose Creeks have developed broad terrace and floodplain deposits that contain auriferous, stream-laid gravels. Upper Moose Creek contains both modern floodplain and older terrace gravels of stream and glacial origin. Limited testing indicates that the terrace and floodplain gravels constitute a resource of more than 200 million cy containing recoverable gold. Should these gravels be economic, mining could occur as large-scale dredge operations with greater impact than the current stream operations. These gravels should be evaluated by rotary or churn drilling methods.

Kantishna Lode Deposits

Precious-metal vein and antimony lode deposits account for the majority of the known lode occurrences in the Kantishna Hills study area. Many of the more promising occurrences are on unpatented claims or in unclaimed areas. One hundred thirteen mines, prospects, or occurrences were examined during the 1983 study. Of this number, 76 are precious-metal occurrences and 19 are antimony. The remaining 18 occurrences are stratiform massive sulfides, or sulfide showings for which data are insufficient for classification. To properly evaluate and establish reserve estimations, core drilling is required.

Kantishna Massive Sulfide Deposits

The geologic environment in three distinct areas is favorable for deposition of massive sulfide deposits. Geochemical and geophysical anomalies and surface mineralization are present. Although statistically the chances for developing a mine are low, one of these deposits could contain metal values measured in billions of dollars. A mine of this magnitude would have significant local impact and could produce metals in quantities that would effect world supply. Additional geochemistry and geophysics followed by core drilling are recommended.

Dunkle Mine Study Area

The Dunkle Mine study area has not been adequately evaluated. Although known mineral occurrences and geochemical and geophysical targets have been established, subsurface data are lacking because drilling was not allowed during the 1983 study. Geologically the area is favorable for bulk-tonnage base- and precious-metal deposits similar to the Golden Zone located a few miles west of the study area. There are also known coal reserves, high-grade precious-metal vein systems, and possibly porphyry-type deposits. Access to rail and highway is only a few miles southeast of the study area. Core drilling is recommended prior to final land use decisions.

Kantishna and Dunkle

Large areas of overburden containing geochemical anomalies exist in both study areas. Airborne magnetic and electromagnetic surveys are recommended to further delineate these anomalies and better explain the geologic controls of mineralization. Structural interpretation and delineation of buried intrusives could also benefit from this program. Large areas of the Birch Creek Schist terrane have not been adequately studied in the Kantishna area. An airborne magnetic/electromagnetic program could form the basis for additional detailed work.

GEOLOGY AND MINERAL DEPOSITS OF THE KANTISHNA HILLS STUDY AREA

HISTORY OF MINING ACTIVITY

By T. K. Hinderman

Gold and other metals were discovered within the boundaries of the Kantishna Hills study area in the early 1900's. Economic potential of the district was historically affected by high development and transportation costs associated with the remote location and by fluctuations in metal prices. The price of gold has changed abruptly by federal decree twice in the history of the district, and in the last decade gold and silver prices have fluctuated widely on world markets. Antimony prices have also changed drastically over short periods, reaching peaks in times of war.

Government policies have had significant impact on the mines of the region. Three salient examples are: the mandated closure of the nation's gold mines early in World War II; the withdrawal of large areas from mineral location by the Alaska Native Claims Settlement Act in 1971; and the placement of the study area under U. S. National Park Service jurisdiction in 1980.

A chronology of mineral activity in the Kantishna Hills study area follows. Those wishing additional information are referred to a comprehensive history by Bundtzen (1978).

1903 Gold is first discovered in the northern Kantishna Hills on Chisna Creek by Judge James Wickersham during an attempt to climb Mt. McKinley.

1904-05 Coarse gold discovered in Eureka, Friday, and Glacier Creeks by Joseph Dalton and Joseph Quigley sparks a gold rush involving several thousand individuals.

1905 Discovery of stibnite and other sulfides in sluice boxes prompts exploration for associated lode deposits. A small shipment of antimony is made from the Last Chance Mine in response to high prices caused by the Russo-Japanese War.

1906 Most miners leave the district, discouraged by the limited extent of high-grade placer deposits. However, some placer activity continues nearly every season up to the present.

1906-09 Many of the important lode mineral discoveries in the Eldorado Creek, Glen Creek, and Quigley Ridge areas are staked.

1916 The Slate Creek Mine produces 125 tons of antimony ore. Development work commences on the Stampede Antimony Prospect, but no ore is produced.

1919-24 Most of the currently known prospects are discovered and staked along a 40-mile belt from Slate Creek to Stampede. Approximately 1,435 tons of high-grade silver ore are mined from eight small deposits on Quigley and Alpha Ridges. Only very rich material (from 100 to 1,000 oz/ton) is economic because of the expense associated with access to the region.

1922 Two large-scale hydraulic mining operations are active on Moose and Caribou Creeks; both have only limited success.

1925-30 Placer and lode mining decline because of the remoteness of the district and exhaustion of easily accessible high-grade deposits.

1926 Development is renewed at the Stampede antimony property; there is still no production.

1931 Development work begins on the Banjo property; the property owner is injured in a cave-in and activity ceases.

1932 Road is completed into the Kantishna mining region through McKinley National Park.

1934 The price of gold is raised to $35 an ounce; precious-metal mines of the Kantishna region draw renewed interest.

1936 The Stampede antimony property is acquired by a new owner, and production begins. The Banjo property is also acquired by a new group and development begins again.

1939 A mill is built and the Banjo Mine begins production. A "dry-land dredge" owned by the Carrington Company, Fairbanks, begins mining on Caribou Creek.

1941 The Stampede Mine becomes Alaska's largest antimony producer; the Banjo Mine and Caribou Creek placer operations continue full-scale production.

1942 Gold mines throughout the nation are shut down by federal order. Both the Banjo and Caribou operations are included. The Stampede Mine continues to produce antimony as a strategic material.

1945-60 Mining in the Kantishna Hills does not recover after the war, primarily because of the fixed price of gold and competition for skilled labor from construction and other high-paying activities. Sporadic small-scale placer mining activity continues, and limited amounts of antimony are shipped from the Stampede and Slate Creek Mines during periods of high prices.

1960 The Alaska Road Commission begins construction of a road into the Stampede region along the north flank of the Alaska Range. Work ceases after one season, and the road is never completed.

1960-62 Precious-metal exploration by Moneta-Porcupine Company and the United States Bureau of Mines in the Quigley Ridge area fails to locate a commercial orebody.

1965 Lands in the Camp Denali area north of McKinley Park are withdrawn from mineral location.

1970-72 High prices of antimony because of the Viet Nam conflict result in ore shipments from the Stampede, Slate Creek, and Last Chance Mines.

1971 The Alaska Native Claims Settlement Act withdraws several million acres of land adjacent to McKinley National Park, including all of the Kantishna Hills study area, for possible inclusion in the National Park System. Unclaimed land within the study area is withdrawn from mineral entry.

1972 The fixed gold price is abandoned and undergoes an order-of-magnitude increase. Interest in gold mining in the Kantishna region is renewed.

1972-83 Several small- to medium-scale placer mining operations using hydraulic or mechanized equipment become active. Major mining companies ignore the district because of its proximity to the National Park and the lack of land open to mineral entry.

1973 A lessee builds a small mill at the Red Top Mine and mines and mills 100 tons of silver ore from one of the Quigley Ridge deposits. The concentrates are refined at a smelter in British Columbia.

1980 The Alaska National Interest Lands Conservation Act (ANILCA) places the lands of the study area within the newly created Denali National Park and Preserve.

1983 Twenty placer operations produce approximately 7,500 oz of gold. About 156 tons of high-grade gold and silver ore and 26,000 lb of antimony are produced from two lode deposits.

1983 MINING ACTIVITY

By T. K. Hinderman

All active placer and lode mining operations in the Kantishna Hills study area were monitored during the 1983 program. Mining occurred only in the southern portion of the study area, within an 11-mile radius of the Kantishna townsite. Nineteen individual operations at 23 sites and approximately 125 people were directly involved in mining activities. All but two of the operations were placers.

KANTISHNA PLACERS

Seventeen placer operators mined at 21 locations in the Kantishna Mining District in 1983. Total placer gold production for the year is estimated at 7500 oz. Approximately 30% of the gold was coarse (greater than 14 mesh), nugget, or jewelry grade. Several large nuggets were recovered, two weighing over 3 oz. The remaining 70% was fine gold (less than 14 mesh).

Most of the operations used portable, integrated washing and recovery plants supported by bulldozers, front-end loaders, and large backhoes. The operations ranged in size from one small suction dredge to several large recovery systems capable of processing over 1,500 cy/d of gravel. Total combined capacity for the 17 operators is estimated at 11,500 cy/d. Because many of the operators were mining in new locations during the 1983 season, road construction, freighting equipment, building camps, and new mine site preparation took an abnormal amount of time. Less than 500,000 cy of material are estimated to have been processed.

KANTISHNA LODES

Two lode mines, Slate Creek Antimony and the Wieler Silver property, were mined in the Kantishna Hills study area during 1983. Both were high-grade operations using helicopter support to transfer ore to trucks at the Kantishna townsite.

Approximately 156 tons of ore from the Wieler Prospect were shipped to the Mohawk Oil and Gas Company custom mill in Fairbanks. The shipment reportedly averaged 2.8 oz Au/ton and 65.3 oz Ag/ton (personal communication, Nick Begich, Jr., 1983). The ore was extracted by surface trenching and by driving a 10-ft adit during a 34-day period in August and September.

Twenty-two tons of high-grade antimony ore reportedly averaging approximately 60% antimony, were recovered from the Slate Creek Mine (personal communication, John Millhouse, 1983) during late June and early July. The ore was washed from mine dumps on Slate Creek, hand sorted, and transported outside the park for future marketing.

PREVIOUS STUDIES

By T. K. Hinderman

A substantial amount of literature has been written by previous investigators about the geology of the Kantishna Hills region. A complete list is contained in the bibliography section of this report. Papers by Prindle (1907), Brooks (1911b, 1916b), and Capps (1918) of the U. S. Geological Survey describe geology and mining activity during the original gold rush. A series of bulletins titled "Mineral Resources of Alaska" (Brooks, 1909, 1910, 1911a, 1913, 1914, 1916b) summarize mining activity during the early years of the district. Later publications by the U. S. Geological Survey and the Alaska Department of Geological and Geophysical Surveys, Capps (1940), Reed (1961), Bundtzen and others (1976); Bundtzen and Turner (1979), provide additional geologic information on the region. A comprehensive Master's thesis on the geology, including a regional geologic map, was completed by Bundtzen (1981). A resource summary and discussion of possible mineral development scenarios were also written by Bundtzen (1983).

Detailed discussions of individual mineral deposits or groups of deposits are given in reports by Davis (1922), Pilgrim (1929), Moffit (1933), Capps (1933), Wells (1933), White (1942), Ebbley and Wright (1948), Seraphim (1961, 1962), Barker (1963), Saunders (1964), Chadwick (1976), and Hawley (1978). Regional geochemical sample sites and analytical results are given in reports by Bundtzen and others (1979), Van Eeckhout and others (1979), and Hinderman (1982).

PHYSICAL SETTING

By T. K. Hinderman

The Kantishna Hills are a low, rugged range of foothills on the northern flank of the Alaska Range that trend in a northeasterly direction through the study area. Elevations range from approximately 900 ft in the northwestern portion of the area to 4,987 ft at the summit of Kankone Peak. Streams flow through narrow, steep-walled valleys in their upper reaches and meander across broad alluvium-filled valleys after leaving the hills.

The local climate is heavily influenced by nearby Mt. McKinley, which creates a rain shadow effect over the region. Average annual precipitation ranges from about 12 in/yr in the northern part of the study area to 16 in/yr in the southern part. Mean daily maximum temperature in July is approximately 70° F, and mean daily minimum temperature in January is -8° F (Wahrhaftig, 1965). Most of the region is underlain by discontinuous permafrost.

Outcrops are rare, generally less than 10%, in much of the region. Hilltops and ridges are underlain by locally derived, frost-heave rubble, and slopes are mantled by colluvium and loess. River valleys and lower slopes are timbered with black and white spruce. Thick willow and alder growths occur on active floodplains, untimbered slopes, and areas of placer mining or other surface disturbance. Poorly drained areas are covered by wet tussock tundra.

The southern part of the Kantishna Hills study area is accessible via the Denali Park Highway, a 90-mile gravel road extending from McKinley National Park Headquarters to the Kantishna townsite. This road is closed in winter, and access is restricted by park regulation during the summer months. Numerous roads and tundra trails connect the major placer operations with the road at Kantishna. A winter trail from the north was used extensively in the early days, but receives only rare winter recreational traffic today. The Alaska Road Commission began construction of an all-weather road along the northern route in 1960, but the work was not completed. Unimproved airstrips are located near the Kantishna townsite, at Stampede, and at five of the placer operations.

GEOLOGY

By T. K. Hinderman

REGIONAL GEOLOGIC SETTING

The Kantishna Hills study area is underlain by a crystalline metamorphic basement of schists and gneisses of probable Precambrian age containing thrust slices of Paleozoic sedimentary and volcanic rocks. The area is included in the Yukon-Tanana, tectono-stratigraphic terrane of Jones, Silberling, Berg, and Plafker (1982). This contiguous geologic assemblage underlies much of the region between the Alaska Range and the Yukon River, and extends easterly into Canada's Yukon Territory.

The basement rocks are intruded by Tertiary dikes and small stocks of diverse composition. Tertiary and Quaternary continental sediments occur in structural basins, and in the valleys of most modern streams.

GEOLOGIC UNITS

Geologic units in the Kantishna Hills study area have been divided into six major groups (fig. K-6, plate K-1). Some of these groups have the status of formalized geologic formations. Others are temporarily or genetically related groups of rocks which have been informally combined for ease of description. From oldest to youngest they are:

1) Birch Creek Schist, predominantly a metamorphosed continental shelf sequence of Precambrian and/or early Paleozoic age;

2) Spruce Creek Sequence, metamorphosed sediments and felsic volcanics of early Paleozoic age;

3) Keevy Peak Formation, metamorphosed deep-water marine and submarine fan deposits of middle- to late-Devonian age;

4) Tertiary intrusive rocks, ultramafic to felsic dikes and small stocks;

5) Tertiary sedimentary rocks, continental sediments, locally with coal beds; and

6) Quaternary alluvial, colluvial, and glacial deposits.

Rocks of all six groups have at least some economic significance and all are addressed in this report. Because of the short time frame for the study it was necessary to direct the majority of the field efforts to four geologic assemblages with the highest economic potential. The graphitic schist of the Birch Creek Schist and the black slate of the Keevy Peak Formation are both potential hosts for massive sulfide deposits. The Spruce Creek Sequence hosts most of the region's silver and gold lode mineralization, and is the probable source of most of the placer gold in the district. Quaternary sediments host the gold placers. These four groups were remapped over most of the study area (plates K-1, K-2, and K-3). Other units were field checked and mapped as considered appropriate.

Birch Creek Schist

The entire metamorphic sequence of rocks in the Kantishna region was first grouped as Birch Creek Schist by Prindle (1907). Bundtzen (1981) followed the general usage of Mertie (1937), and the subdivisions made by

Bundtzen and other workers (1977) restricted the term in the Kantishna region to the oldest metamorphic rocks of the district.

Within the study area, rocks of the Birch Creek Schist have undergone at least two episodes of regional metamorphism. Many of the rocks have mineral assemblages that show metamorphic disequilibrium due to retrograde metamorphism of an original prograde metamorphic assemblage (Bundtzen, 1981). Mineralogy suggests that the prograde episode of metamorphism reached amphibolite facies, and the retrograde event degraded the rocks to greenschist facies.

Bundtzen (1981) identified seven subdivisions within the Birch Creek Schist and these units were retained for mapping purposes during the 1983 program:

1) - Greenstone and Greenschist (p€g)

Rocks consists of medium- to dark-green, garnetiferous greenstone, well-foliated amphibolite, and chlorite-rich amphibolitic greenschist. This unit is usually conformable with foliation and compositional changes within the formation. The rocks appear to have been derived from metamorphism of either mafic sills or volcanic flows. Garnet-bearing amphibolite schist collected north of the study area contained free gold in heavy mineral separations for petrographic testing (Bundtzen, 1981, p. 164). Garnetiferous amphibolite was mapped and sampled at several sites during the 1983 field season.

2) - Quartzite (p€q)

Quartzites in this unit are commonly interbedded with pelitic schists. Rocks are fine- to medium-grained, micaceous, light- to medium-gray in color and contain 70 to 90% quartz. The quartzites are locally feldspar-rich and are gradational with quartz-feldspar schist and gneiss (pCf). The quartzite beds form resistant ridges, and the resultant rubble-crop and colluvium tend to mask less resistant material present in the section. Quartzite was mapped as a separate unit in the Stampede Mine area (plate K-4) where it has undergone brittle deformation creating open fractures that preferentially host deposits of antimony.

3) - Graphitic Schist (p€gs)

Rocks of this unit consist of quartz, chlorite, muscovite, biotite, feldspar, and graphite. Beds of graphitic schists form useful marker horizons and are generally less than 300 ft in thickness except where repeated by faulting or folding, as at the Red Dirt occurrence (fig. K-4). The graphitic schist commonly contains disseminated pyrite and most outcrops are limonite stained. This unit is a potential host environment for massive sulfide occurrences.

4) - Calcareous Schist (p€c)

This unit includes light greenish-gray, calcareous, mica schist, impure marble, and micaceous quartzite. These rocks were apparently derived from siliceous or silty limestone protoliths.

5) - Quartz-Feldspar Schist and Gneiss (p€f)

Rocks consist of light-tan, medium-grained schist and gneiss. Feldspar content ranges from about 10% in quartzitic rocks to 50% in the more feldspathic units. This unit is believed to have originated as felsic igneous intrusive and extrusive rocks predating the initial prograde metamorphism (Bundtzen, 1981).

6) - Marble (p€m)

Light-gray, bleached, coarse-grained marble occurs as discontinuous beds and lenses up to 150 ft in thickness. This unit commonly grades into the calcareous schist unit (p€c).

7) - Undifferentiated Schist, Quartzite, and Gneiss (p€sq)

This unit includes undifferentiated schist, quartzite, and gneiss. The predominant rock type is gray to light-green, garnetiferous, quartz-chlorite to quartz-muscovite schist.

Spruce Creek Sequence

The Spruce Creek Sequence was originally defined by Bundtzen (1981) and consists of a series of sedimentary and volcanic rocks that have been regionally metamorphosed to greenschist facies. Mineral assemblages of the rocks of this sequence are in metamorphic equilibrium, indicating a less complex metamorphic history than the Birch Creek Schist.

The sequence extends along the crest of the Kantishna Hills from Eldorado Creek to Canyon Creek, and occupies an area about 20 miles in length and up to 1.5 miles in width (fig. K-6, plates K-1 and K-2). In all areas the Spruce Creek Sequence appears to be in structural contact with the Birch Creek Schist. There is a clear spatial relationship between the precious-metal vein deposits in the region and the Spruce Creek Sequence. Most of the gold-bearing streams of the district also drain this unit.

The entire Spruce Creek Sequence was mapped during this study at a scale of 1:24,000 (plate K-2) and at 1:6,000 in the Quigley Ridge and Eldorado areas (plates K-5 and K-6). It was found that the sequence could be divided into seven recognizable units. The nomenclature used here follows Bundtzen (1981).

1) - Chlorite Phyllite (Pscp)

This unit is the most common in the Spruce Creek Sequence. It consists of light-green to gray, locally feldspathic, quartz-chlorite phyllite and semischist. Rocks of this unit are distinguished from Birch Creek Schist by the general absence of garnet, and by micas which are commonly smaller in grain size. This unit frequently grades into a calcareous chlorite phyllite (Pscc).

2) - Marble (Psm)

Rocks consist of gray-blue to black, phyllitic, graphitic, medium- to coarse-grained marble. The mineralogy of the marble ranges from essentially pure calcite to approximately 85% calcite, with minor amounts of quartz, muscovite, feldspar, chlorite, and graphite (Bundtzen, 1981).

3) - Quartzite (Psq)

This unit is characterized by medium-gray to black, thin-bedded, fine- to medium-grained, phyllitic quartzite. The rock consists primarily of quartz with minor amounts of chlorite, graphite, and feldspar. The unit is gradational to metafelsite in drill core from the Quigley Ridge area.

4) - Interbedded Marble and Quartzite (Psmq)

Fine-grained, vitreous quartzite, and gray-blue marble occur in alternating beds in the headwaters of Rainy Creek. Thickness of the individual beds averages about 10 ft.

5) - Graphitic Phyllite (Psg)

Rocks are composed of graphite with lesser amounts of chlorite, muscovite, biotite, and feldspar and commonly contain about 45% quartz. Individual beds range from a few inches to several 10's of feet in thickness, and are scattered throughout the Spruce Creek Sequence. The unit is not resistant to weathering, and drill core intercepts considerably exceeded thicknesses inferred from surface exposures. Graphitic phyllite is commonly interbedded in the metafelsite and marble units, and is often spatially associated with precious-metal-enriched vein deposits.

6) - Metafelsite (Psfq)

The metafelsite consists of tan-weathering, light- to dark-gray gneiss and semischist. Quartz and plagioclase phenocrysts comprise 15 to 30% of the rock. Groundmass consists of fine-grained quartz, feldspar, sericite, zoisite-clinozoisite, and opaques. Rocks locally contain up to 0.5% pyrite as disseminations and veinlets. On the basis of mineralogy, thin section work, and whole-rock analyses (Bundtzen, 1981) the unit appears to be of igneous derivation. Individual beds and lenses commonly parallel adjacent sedimentary units suggesting that the rocks originated as rhyolitic flows and tuffs. Both the metafelsite and quartzite units preferentially host vein-type mineralization in the Spruce Creek Sequence. Rocks of these units undergo brittle deformation, and appear to be better conduits for ore-bearing fluids than the phyllitic rocks. Surficial evidence indicates that the metafelsite contains anomalous amounts of base and precious metals.

7) - Meta-Andesite and Diorite Semischist (Psa)

These rocks of intermediate to mafic composition occur as small bodies, both conformable and crosscutting volcanic and sedimentary units. They are interpreted to be dikes and sills emplaced in the Spruce Creek Sequence prior to regional metamorphism.

Keevy Peak Formation

The Keevy Peak Formation was named by Wahrhaftig (1968), after a sequence of rocks exposed near Keevy Peak located northeast of the study area. Rocks between Moonlight Creek and Stampede were correlated with the Keevy Peak rocks by Bundtzen (1981). The Keevy Peak Formation is probably of middle- to late-Devonian age, based on fossil evidence in correlative rocks outside of the study area. The unit is in fault contact with the underlying Birch Creek Schist.

Several traverses were made in Keevy Peak rocks during the 1983 study, but no significant changes were made to previous mapping. Anomalous stream sediments from streams draining the Keevy Peak black slate unit may indicate potential host environments for stratiform massive sulfide-type deposits. The formation was divided into four units by Bundtzen (1981):

<u>1) - Calcareous Schist (Pks)</u>

Tan-weathering, light-gray, calcareous schist is the basal unit of the Keevy Peak Formation. The upper portion is graphitic and gradational with the overlying unit.

<u>2) - Interbedded Black Quartzite, Slate, Phyllite, and Marble (Pkq)</u>

A 900-ft-thick section of interbedded black quartzite, slate, and marble overlies the calcareous schist unit. The quartzites are dark-gray, thinly laminated to massive, and locally contain up to 50% graphite (Bundtzen, 1981). The quartzite beds are gradational with dark-gray, limonite-stained, carbonaceous slate and phyllite.

<u>3) - Marble (Pkm)</u>

The slate and phyllite contain interbeds of light-gray to dark blue-gray, schistose marble. These marble beds were included with the rest of the unit, except where they were large enough to map separately.

4) - Conglomerate and Quartzite (Pkc)

The conglomerate and quartzite unit is the most distinctive in the Keevy Peak Formation. A light-tan to medium-gray, stretched-pebble conglomerate occurs at the top of the formation. Clasts in the conglomerate consist of chert, sandstone, and slate. Deformation of the pebbles parallel to the foliation exhibits a 4:1 length/width ratio. The conglomerate contains thin interbeds of quartz-rich phyllite.

Tertiary Intrusive Rocks

Dikes and small stocks of unfoliated igneous rocks intrude all of the rocks described above. The intrusives range in composition from serpentinized ultramafic rocks to rhyolite porphyry. They can be differentiated from older igneous rocks by their lack of penetrative metamorphic textures.

Potassium-argon age dates of three dikes yielded an average age of 49.8 m.y. (Bundtzen, 1981). This correlates with age dates in volcanic units of the Teklanika Formation of Early Paleocene to Eocene age (Gilbert and others, 1976). Rocks of the Teklanika Formation are widespread in the Alaska Range south of the study area, and the majority of the post-metamorphic igneous rocks in the Kantishna Hills region appear to be related to this formation. A sample of another dike dated by potassium-argon methods yielded an age of 81 m.y. Some igneous activity in the study area, therefore, may be late Cretaceous in age.

Bundtzen (1981) divided Tertiary intrusive rocks within the study area into seven groups, some of which have been combined to form the four categories described below:

Undifferentiated Mafic and Ultramafic Intrusives (Tm)

These rocks exhibit a wide range of compositions and textures and include serpentinized ultramafics, lamprophyres, gabbros, and andesitic dikes and plugs.

Basalt (Tb)

The basaltic rocks are usually greenish-brown weathering, dark-gray, fine-grained, equigranular dikes.

Felsic Intrusives (Tf)

Rocks vary in texture from equigranular to porphyritic. Unweathered, they are usually light-gray to light-green, and weather to a tan to light reddish-brown color caused by oxidation of accessory sulfides. The majority of the felsic intrusives occur as small dikes. The stock at the Bunnell Prospect (plate K-6), however, is exposed over an area 4,000-ft long by 1,000-ft wide. The upper portion of the Bunnell stock is an equigranular granite or quartz monzonite which has undergone argillic alteration. The lower part of the stock, located near the prospect workings, is a rhyolite porphyry with moderate chloritic or propylitic alteration. Two small outcrops of similar composition located on Friday Creek were mapped during 1983 (plate K-5).

Hornfels and Skarn (Th)

Hornfels and skarns consisting of recrystallized, calc-silicate minerals occur chiefly in calcareous schist and marble horizons. The most prominent is the Iron Dome skarn north of Eldorado Creek (plate K-6). It is composed primarily of clinozoisite, microcline, idocrase, and garnet, with small isolated pods of pyrite and other sulfide minerals (Bundtzen, 1983). Material of similar composition, occurring in outcrop and float found during this study along the south side of Eldorado Creek, is interpreted as a stratiform hornfels and skarn horizon.

Thin section work indicates that the skarn is imprinted on previous metamorphic textures and post-dates the regional metamorphism (Bundtzen, 1981). Mineralogy of the occurrences and hand specimen textures support this conclusion. Most hornfels and skarn of this type are spatially and genetically related to igneous intrusives. There were, however, no post-metamorphic igneous rocks observed near the Eldorado Creek stratiform skarn occurrence. The intrusive at the Bunnell Prospect exhibits alteration and sulfide mineralization on contacts, but no skarn was observed. The lack of skarn near the Bunnell Prospect could be due to the absence of carbonate units chemically favorable for skarn development.

Tertiary Sedimentary Rocks

Poorly-consolidated continental sediments of Tertiary age occur as erosional remnants in bedrock basins and lowlands of the study area. They are typically covered by a veneer of Quaternary material, and are exposed only in creek cutbanks. Where observed, they consist of sandstone, siltstone, and conglomerate. Locally beds of lignitic coal are reported east of the study area. Some coal was mined for local use in the early days (Moffit, 1933).

No fossils have been found in Tertiary sediments within the study area, but the rocks are similar in appearance to Tertiary sediments of the Nenana coal field northeast of the study area, and the units may be correlative.

Quaternary Deposits

Quaternary sediments of the study area are a complex assemblage of unconsolidated clay, loess, silt, sand, and gravel. They include deposits of glacial, fluvial, eolian, mass wastage, and lacustrine origin. Prior studies of Quaternary deposits have been reconnaissance in nature, and "the details of the stratigraphy of the deposits is much more complex than is shown" (Bundtzen, 1981). The 1983 study contributed to a better understanding of the distribution of various gravel types and their placer gold potential. The study, however, was not intended to be a detailed stratigraphic examination of the Quaternary sediments. Mapping and sampling of Quaternary deposits (plate 3) is discussed further in the placer section of this report.

For purposes of this study, Quaternary deposits were divided into eight categories:

Placer Mine Tailings (Qt)

Placer mine tailings result from working stream gravels by mechanical and hydraulic means. Tailings consist of washed pebble and cobble stream gravel with the fine material removed. Most remain stacked in rows or piles where they were deposited by gold recovery systems.

Landslide Debris (Qsl)

Landslide debris results from slumping of surficial material on steep slopes. Two landslide deposits were mapped during the 1983 study based on characteristic appearances on aerial photographs. The composition and degree of bedrock involvement was not investigated.

Colluvium Deposits (Qc)

Colluvial deposits are common on slopes in the study area. The deposits consist of weathered bedrock, poorly-developed soil, and overlying organic material resulting from the actions of solifluction and soil creep. The colluvium usually supports a thick growth of tundra or brush which obscures bedrock.

Recent Stream Deposits (Qal)

These deposits consist of alluvial clay, silt, sand, and gravel. Lithologies of surface material indicate local origin, but the deposits may contain reworked glacial gravels. Braided streams are common in the floodplains of the study area. Many alluvial deposits in the study area are gold-bearing and most of the present and past placer activity processed this material.

Alluvial Fan Deposits (Qaf)

Alluvial fan deposits occur where steep tributary streams enter larger valleys. Both active and inactive fans are present. The fan deposits consist of locally derived alluvial material that is coarser, less rounded, and more poorly-sorted than that of the stream deposits. Some of the alluvial fan deposits of the region are gold-bearing, and limited amounts of this material have been mined by placer operations in the larger stream valleys.

Stream Terrace Gravels (Qb)

Terrace gravels consist of poorly-stratified sand and gravel deposits. They represent erosional remnants of alluvium deposited by earlier streams in the region. The terrace gravels are similar to recent stream gravels, and in most instances they are also gold-bearing. Although they appear to be lower grade than the alluvial deposits of the modern streams, some have been mined successfully in the past.

Glacial Deposits (Qd)

Glacial deposits in the study area consist of unconsolidated till and moraine of at least two glacial advances (Bundtzen, 1981). Based on comparisons with dated events elsewhere in the central Alaska Range, Early Wisconsinan and Late Wisconsinan advances have been assigned. The deposits consist largely of unsorted till and no attempt was made to subdivide these materials into mappable units.

Undifferentiated Quaternary Deposits (Qu)

Undifferentiated Quaternary deposits cover large sections of the northeast portion of the study area. The deposits are usually covered by a thick mat of vegetation, and most were mapped from aerial photos. The unit includes gravel terraces, glacial drift, swamp, eolian silt and loess, and sand dune deposits.

STRUCTURE

The dominant feature of both large and small structures in the study area is a consistent northeasterly trend (fig. K-6, plate K-1). Regional structural trends in nearby portions of the Alaska Range, and major structural features such as the Denali Fault south of the study area exhibit a similar pattern. Structural features in the Kantishna Hills study area include well-developed foliations and crenulations in some of the metamorphic rocks, folds of varying amplitudes, thrust faults, and high-angle faults.

Five deformational episodes are recognized in the rocks of the region (Bundtzen, 1981):

1) A pre-Jurassic and possibly pre-Devonian episode of multiple deformation resulted in the formation of northwest-trending folds and foliations in the Birch Creek Schist and the Spruce Creek Sequence. This event may correlate with the amphibolite-facies metamorphic event which affected the Birch Creek Schist. The Spruce Creek Sequence did not occupy its present position relative to the Birch Creek Schist and was not metamorphosed to this degree. The episode did not affect the Keevy Peak Formation.

2) An episode of compressional deformation formed northeast-trending folds and a second regional penetrative foliation or rock cleavage. Thrust faulting during this episode superimposed Birch Creek Schist over the younger Spruce Creek Sequence. This event may correlate with the mid-Cretaceous greenschist-facies metamorphic event which affected the Birch Creek Schist and Spruce Creek Sequence. The most prominent structural feature of the study area, the Kantishna Anticline, was probably formed at this time.

3) A third and final episode of folding formed northwest-trending broad open folds. This episode resulted in the formation of structural domes, such as Busia Mountain and Wickersham Dome, where northwesterly folds intersected northeasterly folds of the second period of deformation.

4) An episode of high-angle block faulting and fracturing along northeasterly-trending structures coincided with the emplacement of Tertiary igneous rocks. Topographic lows created by block faulting were the sites of deposition of Tertiary continental sediments.

5) Northwesterly-trending faults that became active in Late Tertiary to Recent time offset the northeasterly features. These structures are related to a general uplift in the Kantishna Hills and are still active today.

Several of the structures, or sets of structures, are important in an understanding of the mineral potential of the region. Thrust faulting positioned older and less mineralized Birch Creek Schist on top of the Spruce Creek Sequence. Warping of the area into the Kantishna Anticline and subsequent erosion resulted in the long, narrow exposure of rocks of the Spruce Creek Sequence. Spruce Creek rocks may extend for some distance under the older rocks, and it is possible that other unrecognized windows exist.

The axis of the Kantishna Anticline is a possible control for emplacement of gold and silver vein mineralization. Many veins in the region occupy fractures that appear structurally related to tensional forces created by folding of the Kantishna Anticline. The axis of the anticline has been displaced by later folding and faulting complicating the structural continuity of mineralized areas. Results of mapping during 1983 indicate significant mineralization occurs in structurally-controlled environments in both the Spruce Creek Sequence and Birch Creek Schist.

Faults and shear zones of various magnitude appear to have localized many of the mineral deposits. Probably the best known is the Stampede Fault, where the footwall contains most of the ore shoots at the Stampede Mine. Other recognizable faults and shears may be favorable sites for undiscovered lode deposits.

PLACER DEPOSITS

By Jeffrey H. Levell

INTRODUCTION

Placer gold is found in most of the streams that originate in the southern Kantishna Hills. The gold-bearing streams show a strong correlation with rocks of the Spruce Creek Sequence (fig. K-7). Since discovery of placer gold in the early 1900's, placer deposits have been mined on Spruce, Glen, Rainy, Eureka, Friday, Eldorado, Moose, Yellow, Glacier, and Caribou Creeks in the southern Kantishna Hills. Placer gold has also been extracted from Stampede, Little Moose, Crooked, and Canyon Creeks in the central Kantishna Hills area, and the Bearpaw River in the northwest corner of the study area. Placer gold accounts for 92% of the gold which has been produced from the Kantishna District.

An estimated 7,500 oz of gold were produced in 1983. During the 1983 season, 17 placer operations mining at 21 different locations were active in the southern Kantishna Hills on all the creeks listed above except Eldorado and Moose (fig. K-8). A detailed discussion of individual operations is contained in Appendix A, "Placer Mine Operation Reports." Bundtzen, (written communication, 1983) utilizing published and unpublished information, calculated total gold production from the Kantishna Mining District at over 85,000 oz. At $400/oz, this gold would have a value in excess of 34 million dollars.

In the past several years, the district has seen improvement in mining methods and recovery systems. Several million dollars have been invested in mining equipment and in building new recovery plants. Five relatively large (approximately 1,000 cy/d), portable plants have been introduced into the district. These plants are largely responsible for the steady increase in production since the mid-1970's because of their large volume capacity, portability, and more efficient recovery systems capable of recovering relatively fine gold.

PHYSIOGRAPHY

Headwaters of most of the streams in the southern Kantishna Hills are in open V-shaped valleys formed by the convergence of two or more smaller tributaries. The lower portions of the streams occupy relatively narrow and steep, bedrock-walled canyons. Rapid regional uplift and attendant erosion formed deeply weathered and steep terrain in the Kantishna Hills. The gravel deposits are, as a consequence, poorly-sorted, and contain coarse fragments and subangular clasts of locally derived rocks. At the mouth of the canyons the streams flow into the broad, terraced, gravel-covered lowlands of Moose, Lower Glacier, and Lower Caribou Creeks.

SOURCE OF PLACER GOLD

Gold in stream gravels is often coarse and angular, contains attached quartz and exhibits crystalline textures. These features indicate that the gold has not traveled far and was derived from nearby auriferous lode deposits. Proximity to lode deposits is also demonstrated by the recovery in placer mine concentrates of galena, pyrite, arsenopyrite, scheelite, stibnite, and other minerals commonly found in lode deposits.

The variability in gold fineness and other characteristics indicate varying origins and processes of deposition of placer gold. The majority of the producing gold placers were deposited in streams that drain rocks of the Spruce Creek Sequence. The richer deposits of Friday and Eureka Creeks

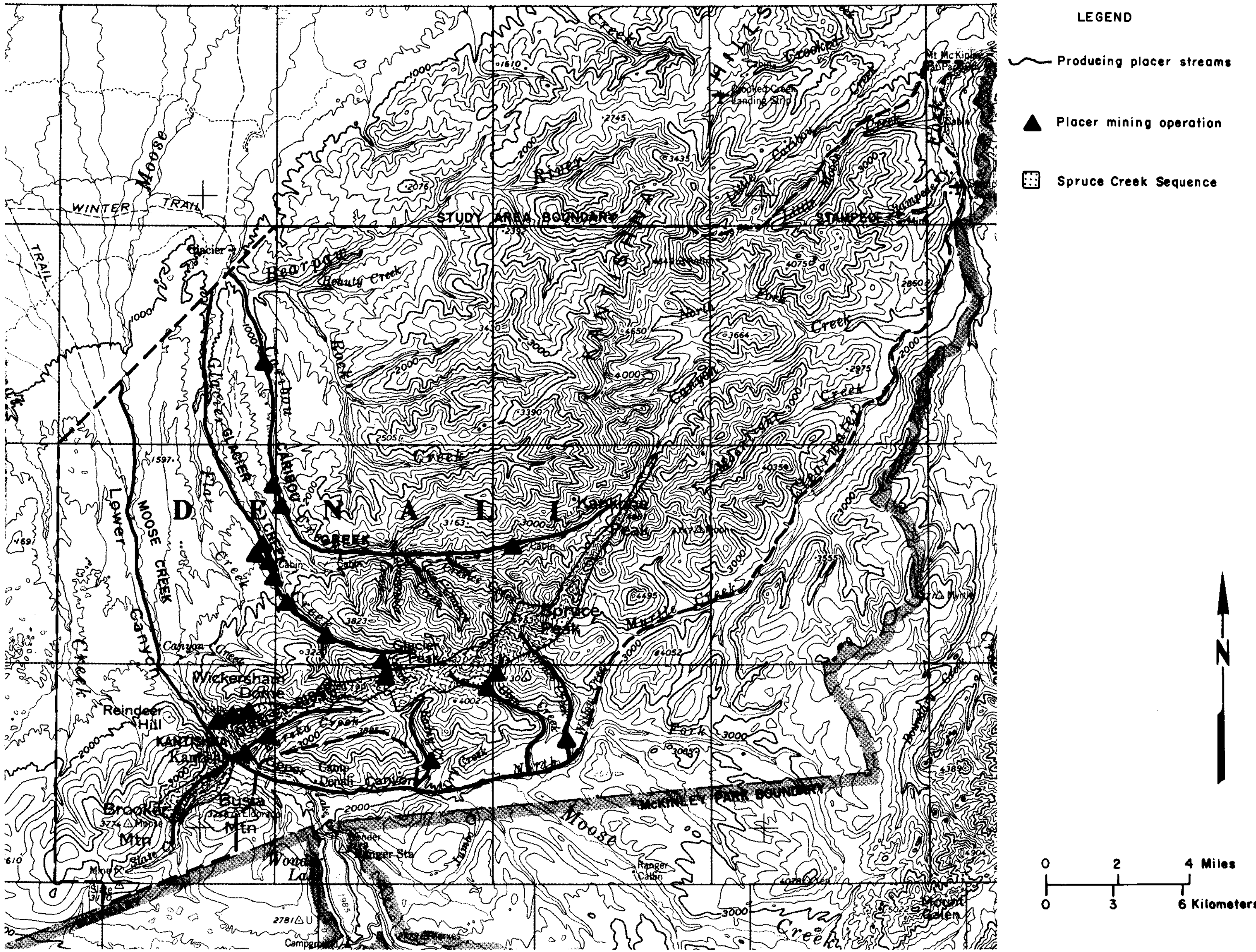


Figure K-7 Spatial Relationship of the Spruce Creek Sequence and Producing Placer Streams and Mining Operations in the Kantishna Hills Study Area came from the immediate Quigley Ridge-Banjo/Jupiter-Mars area. Drainages such as Caribou Creek could have derived their gold from the Spruce-Kankone Trend (fig. K-33).

Placer gold is also associated with antimony lodes of Stampede, Last Chance, and Slate Creeks. Other possible source areas are the garnet-amphibolite unit of the Birch Creek Schist, structural contacts of the Spruce Creek Sequence and Birch Creek Schist, and numerous fault and shear zones throughout the district. Drilling during the 1983 project indicates the metafelsite unit of the Spruce Creek Sequence on Quigley Ridge contains detectable to moderately anomalous precious-metal values.

GOLD CHARACTER AND GRADE OF DEPOSITS

The majority of gold recovered in the Kantishna District is fine-grained (less than 16 mesh) and ranges from small flattened to rough angular particles. Approximately 30% is coarse nugget or "jewelry" gold that is sold at a significant premium over spot gold prices. Nuggets weighing several ounces are common; nuggets weighing as much as 32 oz have been recovered in the past (Bundtzen, 1981). During the 1983 season, several 1- to 3-oz nuggets were recovered from mining operations. Gold fineness values of placer gold obtained from 44 samples collected in 1983 varied widely, often within the same drainage. Values ranged from 532 to 952 and averaged 750. Appendix A, table A-1 shows the results of fineness studies conducted on placer gold in both the Kantishna Hills and Dunkle Mine study areas.

Studies of gold fineness from 800 creeks in Alaska show that Kantishna placer gold has the lowest mean value 789, lowest individual value 567, and the largest coefficient of variation, 16 versus a state average of 4.33, of any district in Alaska (Bundtzen, 1981). Gold recovered from drainages containing reworked, glaciofluvial gravels has consistently higher fineness values than gold found in the tributary streams. This can be attributed to the reworking and milling effect of the glaciofluvial gravels which is thought to cause larger surface areas on the gold particles and result in preferential leaching of impurities or to increasing precipitation of gold on small gold nuclei (dust) in placer deposits farther downstream (Boyle, 1979).

Fine-grained placer gold from the Kantishna District is sold for contained gold value after deductions for fineness. Coarser placer gold is marketed to jewelers at prices ranging from one to two times the spot price of gold, regardless of its fineness. Where the percentage of fine- and coarse-grained gold is known, an adjustment factor was calculated in order to place a realistic value on placer gold extracted at each locality. The method used in calculating adjustment factors is shown in table K-2.

Table K-2 - Calculation of gold value adjustment factor

[weight % fine-grained placer gold (less than 1/16 in.)] x [gold fineness] x [spot price of gold]	=	Value A fraction
[weight % jewelry gold (1/16 in. to 1/4 in.)] x [spot price of gold]	=	Value B fraction
[weight % nugget gold (greater than 1/4 in.)] x [1.5 x spot price of gold]	=	Value C fraction
100%		Total Value

Total Value/100%	=	Value of Gold
Gold Value/Spot Price	=	Price Adjustment Factor

The adjustment factor can be multiplied by the current spot price of gold to determine the approximate value of placer gold in the vicinity of the deposit studied. Overall, the value of all placer gold extracted and sold from the Kantishna District during 1983 averaged 0.83 times the spot price of gold.

Table K-3 shows pertinent production data from placer mining operations monitored in 1983. Gold grades of the monitored placer deposits ranged from 0.005 to 0.062 oz/cy and averaged 0.022 oz/cy. Gold content after adjustment for fineness ranged from 0.004 to 0.045 oz Au/cy and averaged 0.016 oz Au/cy. The measured gold grades represent the recoverable grades which are dependent on the equipment used to process the placer material. In most cases, less than 100% of the gold present was actually recovered during mining operations.

Table K-3 - Kantishna Mining District placer mine monitoring summary

Mine Location Number	A Placer Gold (oz)	B Fineness (.000)	C A • B (oz)	D Gravel Volume Mined (cy)	Placer Gold Grade (A/D) (oz/cy)	Gold Grade (C/D) (oz/cy)	Fine Gold (Wt. %)	Jewelry Gold (Wt. %)	Nugget Gold (Wt. %)	Adj. Factor*
1	41.00	0.700	28.700	3300	0.012	0.009	73	?	27	0.92
2	3.10	0.800	2.480	100	0.031	0.025	18	30	52	1.22
3	0.21	0.800	0.168	40	0.005	0.004	100			0.80
4A	312.00	0.710	221.520	5000	0.062	0.044	?	?	?	
4B	364.86	0.710	259.051	14000	0.026	0.019	72	15	13	0.86
4C	210.64	0.710	149.554	25000	0.008	0.006	?	?	?	
5	65.46	0.700	45.822	2200	0.030	0.021	51	19	30	1.00
6	354.30	0.680	240.924	13000	0.027	0.019	86	11	3	0.74
7	110.70	0.700	77.490	2400	0.046	0.032	87	7	6	0.77
8	173.60	0.800	138.880	9400	0.018	0.015	60	34	6	0.91
9	41.87	0.800	33.496	2300	0.018	0.015	71	29	?	0.86
10	106.35	0.700	74.445	2800	0.038	0.027	85	15	?	0.75
11	12.79	0.777	9.938	220	0.058	0.045	65	35	?	0.86
12	126.78	0.750	95.085	5500	0.023	0.017	65	35	?	0.84
13	47.90	0.760	36.404	2100	0.023	0.017	85	15	?	0.80
14	1.50	0.760	1.140	60	0.025	0.019	100	?		0.76
15	0.10	0.760	0.076	2	0.050	0.038	1	99	?	1.00
16	200.00	0.760	152.000	14000	0.014	0.011	50	50	?	0.88
17	350.00	0.780	273.000	15000	0.023	0.018	?	?	?	
TOTAL	2523.16		1840.17	116422						
AVERAGE		0.729			0.022	0.016				0.83

* [weight % fine-grained gold (less than 1/16 in.)] x [gold fineness] x [spot price of gold] = Value A fraction

[weight % jewelry gold (1/16 in. to 1/4 in.)] x [spot price of gold] = Value B fraction

[weight % nugget gold (greater than 1/4 in.)] x [1.5 x spot price of gold] = Value C fraction

100% = Total Value

Total Value/100% = Value of Gold

Gold Value/Spot Price = Price Adjustment Factor

DESCRIPTION OF THE GRAVELS

Tributary Stream Gravels

Upper tributaries of drainages originating in the Kantishna Hills are in an erosional stage, and very rich, erratic pay streaks have developed in the tributary streams. These deposits have been mined intensively because of their richness and the ease with which coarse gold is recovered. Due to rapid erosion, the gravel deposits are poorly-sorted and contain coarse, angular to subrounded material. Boulder content is usually less than 2 or 3% by volume or weight. A considerable amount of sand and silt, present as interstitial filling between pebbles and cobbles, occasionally forms irregular beds and lenses.

Stream gravel deposits are rarely more than 10-ft deep and 150-ft wide. Gold is usually concentrated in the lower 2 ft of the gravels or on and within cracked and weathered bedrock. Although rich pay streaks were mined in the past, gold is generally scattered throughout the stream gravels. Lower grade gravels beyond the pay streaks are now being mined with mechanized equipment. In some areas the gravels have been processed at least twice and in rare instances several times. Coarse gold is still being recovered, but enhanced processing systems are now recovering a larger fine gold fraction.

Lowland Alluvial Deposits

The lower portions of Moose, Glacier, and Caribou Creeks flow through flat-lying, broad, terraced valleys and have developed floodplain deposits up to 500-ft wide. Gravel deposits are similar to the previously described stream gravels although boulders are not as common and clasts are more rounded. In some areas, especially on Glacier Creek, the recent stream deposits are underlain by unconsolidated Tertiary gravel deposits. Adjacent terraces are composed of Tertiary gravels capped by Quaternary gravel deposits whose composition and degree of sorting are similar to the recent stream bottom deposits. Quaternary terrace deposits are also stream laid and auriferous. The terraces are covered by a variable thickness of frozen muck, and the underlying gold-bearing gravels are all or partly frozen as well.

Placer gold extracted from the lower floodplain and terrace deposits is fine grained and flaky. Only a small percentage of the gold recovered from mining of these deposits during 1983 was in the form of nuggets. Although most of the gold was much finer grained than that recovered from the steep tributary streams, the value of the gold recovered per cubic yard was not significantly lower. This can probably be attributed to larger production capacity and more efficient recovery systems of the mining equipment being used.

Glacial Origin Alluvial Deposits

Moose Creek occupies a broad valley bordered by several levels of terrace gravel deposits. Glacial ice invaded this drainage during Wisconsin-time, depositing till high along the southern margin of the Kantishna Hills and filling the valley with a deep accumulation of poorly-sorted glacial outwash deposits (Bundtzen, 1981). The lower portions of auriferous tributary streams and Moose Creek itself probably had pre-existing placer deposits scoured out, diluted, or buried by the glacial activity.

Continuing uplift caused repeated base level adjustments and the development of well-preserved terraces in this drainage. The terrace gravels are largely of glacial (Alaska Range) origin but locally contain alluvium contributed by the auriferous tributary streams. The modern floodplain and the older terrace gravels contain reconcentrated fine gold contributed in a large part by the auriferous tributary streams. Terrace and floodplain deposits consist mostly of subrounded to rounded material intermixed with lesser amounts of subangular local material. The gravels are sorted and washed better than those found in the tributary streams but still contain considerable silt and sand.

1983 PLACER EVALUATIONS

The southern portion of the Kantishna Mining District is a significant and active producer of placer gold, which accounts for a majority of the mineral production from the district. Objectives of the study were to determine the type and scale of present mining; the amount, distribution, and probable source areas for placer gold; and the extent and volume of auriferous gravels.

Placer resources of the district were evaluated through an integrated program consisting of mine monitoring, pit sampling, cable tool sampling, regional reconnaissance, and mapping of surficial deposits. Sample locations are shown on plate K-7. Following is a summary of evaluation techniques. A detailed discussion of placer evaluation procedures is contained in Appendix A.

Mine Monitoring

Placer mining operations at 14 separate locations were closely monitored during the 1983 season. The volume of gravel mined in active mine cuts and the gold produced from those cuts was measured and recorded during monitoring procedures. The purpose of the monitoring program was to determine the grade of gold in deposits currently mined. Monitoring also allowed observation of the character of surficial deposits, distribution and character of recovered gold, and provided insight into mining methods being used. The calculated grades represent the recoverable gold from deposits currently being mined. These large samples - usually hundreds or thousands of cubic yards - tend to offset deposit irregularities. Because the large samples average the high and low gold concentrations that affect smaller samples, they give more reliable data for estimation of placer grades. Seven other mining locations were monitored periodically, but measured grades were not possible because of conflict with mining schedules or active mining was not taking place at the time of observation. In some of these instances, gravel volumes and gold production were estimated however. Mine locations are shown on figures K-8 and plates K-3 and K-7.

During this study all producing mines were examined. A report describing each operation is included in Appendix A. A mining operation was classified as "small" if less than 500 cy/d were being processed and "medium" in size if 500 to 2,000 cy/d were being mined. None of the operations were considered to be engaged in "large" scale mining (greater than 2,000 cy/d).

Pit Sampling

During the 1983 season, 26 backhoe-pit samples and two hand-dug channel samples were excavated and processed for contained gold. Samples were taken from the modern floodplain and terrace gravel deposits along Spruce, Glen, Rainy, Eureka, Friday, Eldorado, and Upper and Lower Moose Creeks. Sample locations are shown on plate K-3. Twelve samples contained highly anomalous (greater than 0.005 oz Au/cy), and nine samples contained anomalous (0.001 to 0.0049 oz Au/cy) concentrations of gold. The average gold content of the samples was 0.006 oz Au/cy. Appendix A, table A-2 summarizes the pitting results.

Cable Tool Sampling

Cable tool sampling was used to sample some of the extensive gold-bearing terrace and stream deposits that were too deep, or were frozen or water saturated and could not be tested by pitting. Seventeen holes were drilled aggregating 267 ft. Two of the holes were abandoned and no samples could be taken.

Eight test holes were sampled on Lower Moose Creek terrace and stream gravels, and 11 holes were drilled in terrace gravels near Glacier Creek. Sample sites are shown on plate K-3.

Average gold content of the samples was 0.0074 oz Au/cy. Four highly anomalous (greater than 0.005 oz Au/cy) and five anomalous (0.001 to 0.0049 oz Au/cy) samples were obtained. Appendix A, table A-3 summarizes the cable tool sampling results.

Regional Placer Reconnaissance

During the regional placer resource assessment of the Kantishna Hills study area 139 samples were collected. The sampling procedure consisted of hand digging a pit or trench and processing 0.1 cy increments of gravel using a portable aluminum mini-sluice box or hydraulic concentrator. Recovered concentrate was processed for contained free gold.

Reconnaissance sample results are summarized in Appendix A, table A-4. Sample locations are shown on plate K-7. Of the 139 samples collected, 29 contained highly anomalous concentrations (greater than 0.005 oz Au/cy) and 15 contained anomalous values (0.001 to 0.0049 oz Au/cy).

Mapping of Surficial Deposits

Surficial deposits were delineated on aerial photographs at a scale of 1:15,840. Field checks were made to verify the photo interpretation and determine the character and depth. A planimeter was used to measure the surface area of gravel deposits mapped during the 1983 study. Area estimates of surficial deposits not covered by air photography were extrapolated from Bundtzen's geologic map of the study area (1981) and information obtained from field traverses. Order of magnitude estimates for gravel volumes were made by multiplying the surface area estimates by the average depths of deposits observed in local exposures, mine cuts, sample pits, and cable tool holes. A surficial geology map (plate K-3) was produced at a scale of 1:24,000. Appendix A, table A-5 shows gravel deposit volume calculations for individual drainages. Although the study area boundary runs through the middle of Upper Moose Creek, volume calculations include gravel deposits on both sides of the stream.

Excavations made during present and previous mining operations were mapped by brunton and tape methods to establish approximate volume of processed gravel. Maps were produced for each property and are included in Appendix A.

Geochemical Analysis

Recovered concentrate from all samples was processed for contained free gold by mercury amalgamation after hand picking larger gold particles. Forty-nine of the hand-picked gold samples were assayed for fineness (Appendix A, table A-1).

Concentrates from 14 backhoe-pit and 76 reconnaissance placer samples were analyzed using optical emission spectrography to determine the content of 31 elements. Fifteen backhoe-pit and cable tool samples and 70 reconnaissance placer samples were assayed as character samples by AA, ICAP, Fire-ICAP, and colorimetric methods for 36 selected elements to test for other metals. Results of sample analyses are shown in Appendix A, table A-7. Analytical results should be considered as a qualitative indication of the presence of individual elements because the degree and method of concentration and total volume of the original sample varied considerably from sample to sample.

GOLD-BEARING DRAINAGES

Following is a review of major gold-bearing drainages in the southern Kantishna Hills (fig. K-9, plates K-3 and K-7). The descriptions include physiography, Quaternary geology, 1983 monitoring and sampling results, and a summary of mining history. Placer gold grades along with contained gold values adjusted for fineness are reported for each operation. Field observations made during 1983 were augmented by previous descriptions of the placer deposits by Brooks (1911), Capps (1918), Davis (1922), and Bundtzen (1981). Appendix A, table A-6 summarizes the mineralization, mining history, and placer resource potential of those drainages examined as part of the regional resource investigation of the Kantishna Hills.

Upper Moose Creek

Physiography and Quaternary Geology

Upper Moose Creek (fig. K-10), for purposes of this report, extends for 10 miles from Willow Creek to Kantishna. Most of the stream has a well-developed floodplain 200- to 1,000-ft across, which occupies a wide-terraced valley. The average stream gradient is approximately 50 ft/mile. Floodplain deposits consist largely of well-rounded and reworked glacio-fluvial gravels mixed with local gravels deposited from auriferous, tributary streams, such as Spruce and Glen Creeks. Eight to ten ft of alluvial gravels overlie a schist bedrock or (in most cases observed) an unsorted, clayey-gravel, false bedrock of glacial outwash origin.

Terrace gravels line nearly the entire length of the drainage. The older terrace gravels are similar in appearance to the stream bottom gravels both in composition and degree of sorting. Terrace gravels are from 5- to 50-ft deep and up to 1,000-ft wide. On the north side of the drainage, terrace gravels are overlain by large, inactive alluvial fans emanating from the mouths of Willow, Spruce, Glen, and Rainy Creeks. The lower ends of the fans are truncated by more recent erosion by Moose Creek. Each tributary stream has subsequently adjusted its base level to that of Moose Creek and eroded partially or completely through the fan/terrace complexes. This complex fills most of the north side of the valley and is over 0.5-miles wide in most places. Adjacent to the Glen Creek alluvial fan, a large area on the north side of the drainage is covered by glacial till.

Although pre-existing placer deposits may have been scoured by glacial ice, placer gold is still present in the stream and terrace deposits. The gold is probably reworked from deposits contributed by Spruce, Glen, and Rainy Creeks. Also, preglacial placer deposits, buried by thick outwash gravels, could be present beneath the present gravel deposits.

Sampling

Five reconnaissance samples (A3045-A3046, A3069-A3071) were collected from Moose Creek gravels from the mouth of Rainy Creek to approximately 1-mile upstream. The samples contained from 0.0025 to 0.0074 oz Au/cy. One backhoe pit sample (A1474) was obtained from a 24-ft-deep terrace near the mouth of Rainy Creek. This sample contained 0.0013 oz Au/cy. The 12-ft section above bedrock contained 0.0023 oz Au/cy.

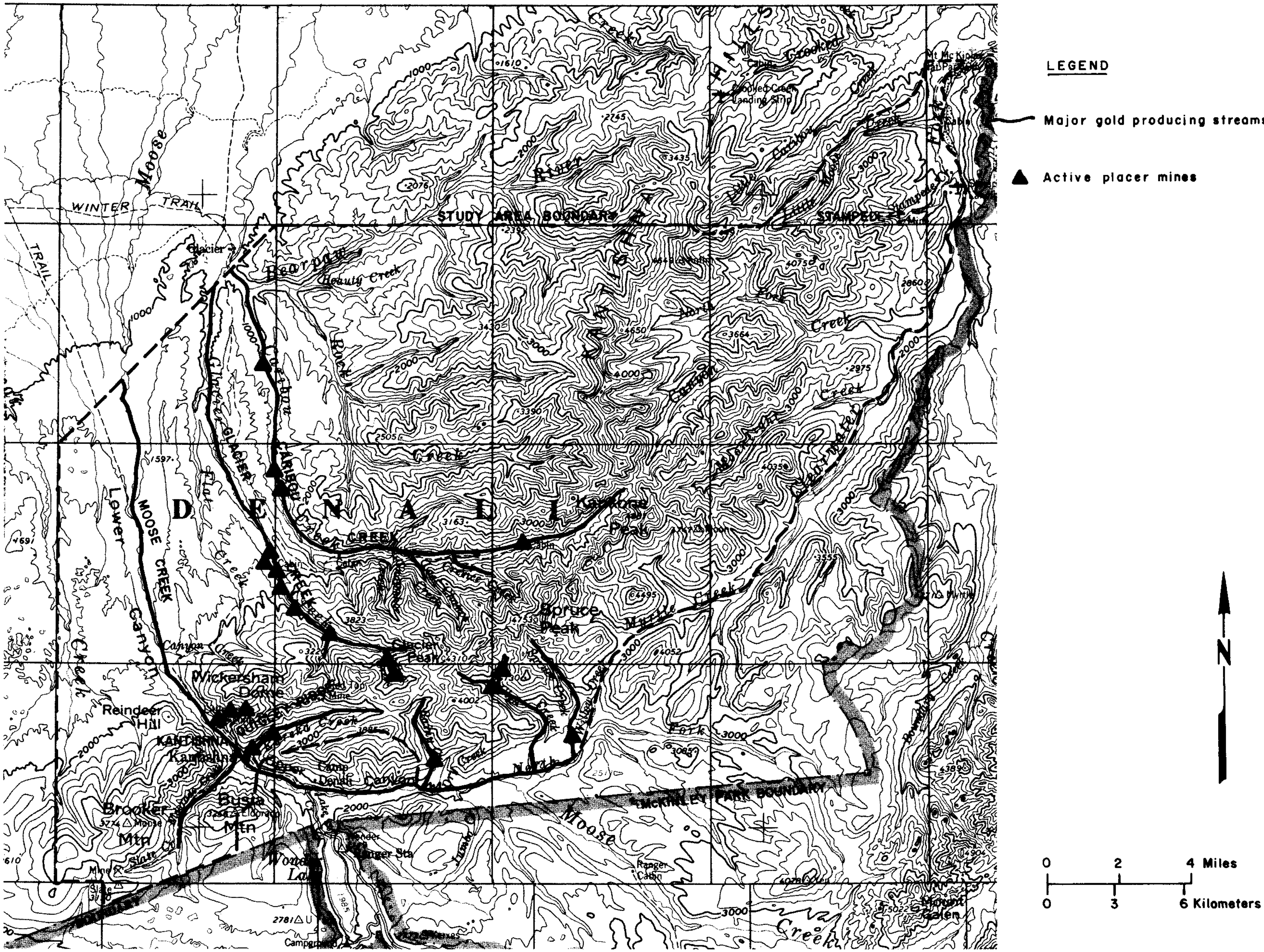


Figure K-9 Major placer gold producing streams and active 1983 placer mining operations in the Kantishna Hills study area

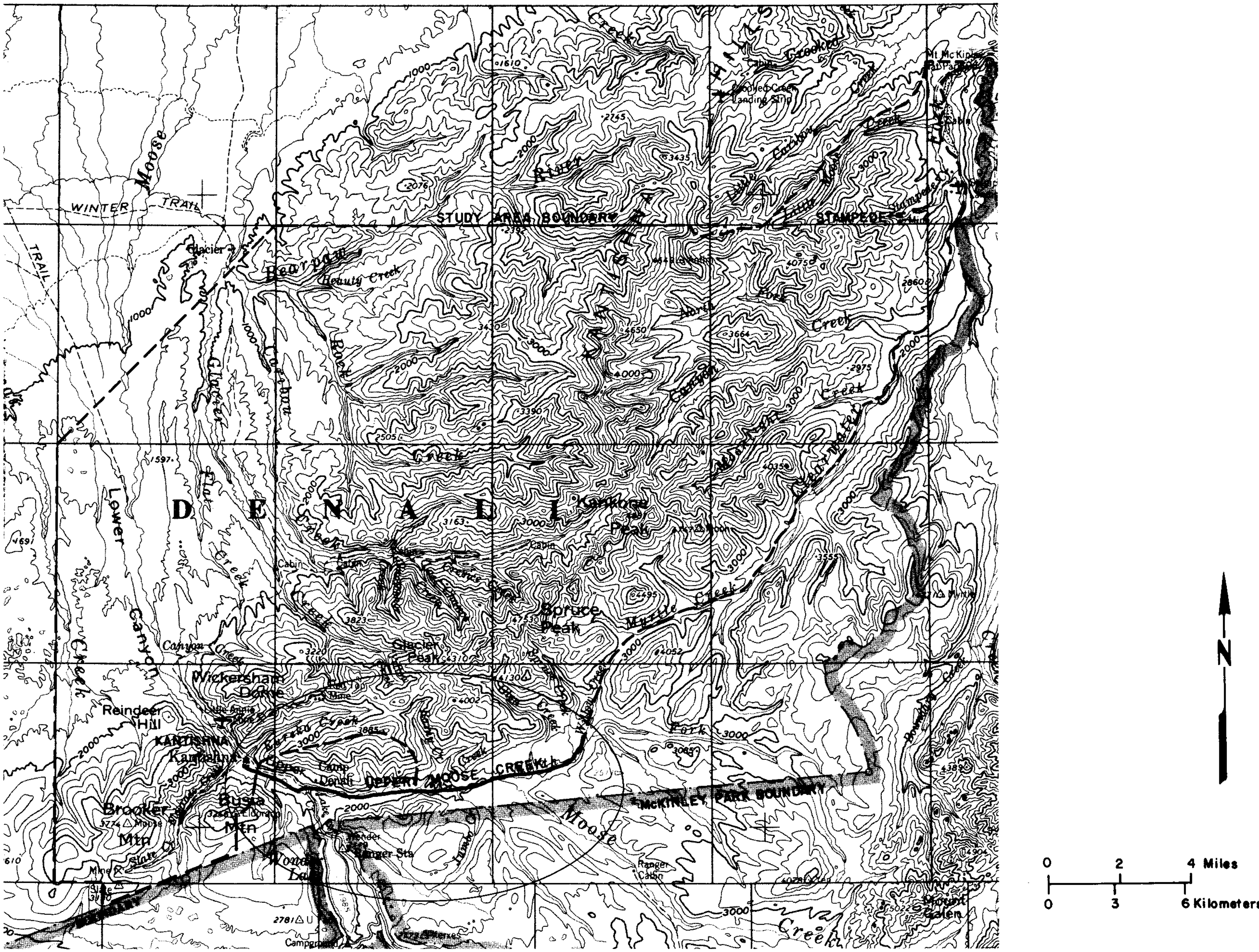


Figure K-10 Upper Moose Creek location, Kantishna Hills study area

Mining

Numerous test pits exist along the terrace and floodplain gravels, and a few areas of placer tailings indicate mining was conducted in the past. A large area was mined in 1982 below the mouth of Glen Creek. The operator mined 12-ft-deep glaciofluvial gravels to a false glacial clay bedrock in the NE 1/4 sec. 24, T. 16 S., R. 17 W. Approximately 30,000 cy of material were mined, and 60 oz of very fine-grained gold were recovered yielding a placer gold grade of 0.002 oz Au/cy (personal communication, Richard Lohr, 1983). Mining was undertaken after a backhoe testing project was completed in 1981. According to a company report, 13 test pits were excavated with an average recovery of 0.0025 oz Au/cy (Rodriguez, 1981). The pits were excavated in stream bottom gravels from the juncture of Glen Creek to 1-mile downstream. Most of the pits did not reach bedrock but were apparently bottomed on a false clay bedrock. Nine samples contained over 0.001 oz Au/cy. The best sample recovered 0.005 oz Au/cy and was bottomed on a schist bedrock. A medium-capacity, shaker-screen/sluice plant was used to mine the cut described above in the near vicinity of the best test result.

A relatively large cut (5,000 to 10,000 cy) at the mouth of Glen Creek was made by the same operator with similar recovery of fine gold. The depth of gravels averaged 10 ft to a false clay and gravel bedrock. The cut was excavated another 20 ft through the false bedrock without hitting true bedrock.

Similar depth of outwash was reported in a mine cut located at the mouth of Spruce Creek where another operator reportedly excavated to a depth of 30 ft without hitting bedrock (personal communication, Dan Ashbrook, 1983).

The only known production for Upper Moose Creek is the 60 oz recovered from the 1981 mining operation. Other areas of placer mine tailings indicate a total of less than 100 oz have probably been produced.

Lower Moose Creek

Physiography and Quaternary Geology

Lower Moose Creek (fig. K-11), for the purposes of this report, is the stream section from the town of Kantishna to the northern boundary of the study area. Near the town of Kantishna, Moose Creek is joined by Eureka Creek from the north and Eldorado Creek from the south. From this point the stream flows northerly for 3 miles through the Kantishna Hills. This portion of the stream occupies a 0.25- to 0.5-mile wide, terraced valley with a well-developed floodplain up to 1,000-ft across. Where the stream flows out of the Kantishna Hills, it passes through a short, narrow bedrock-walled canyon. At this point the stream flows for another 8 miles through broad, flat lowlands. The modern floodplain here is as wide as 1,500-ft across and lined by extensive gravel capped terraces. The stream gradient of Lower Moose Creek averages 50 ft/mile.

The floodplain gravel deposits consist largely of rounded gravels of glaciofluvial origin mixed with locally derived bedrock fragments near the confluence of tributary streams. The gravels are underlain by a false bedrock of clay, silt, sand, or semi-consolidated clayey gravels that are part of the earlier glacial outwash sequence. The terrace deposits adjacent to the floodplain consist of gravels of similar composition and depositional history.

Practically no gold has been found within the false bedrock material. Shafts and churn drill holes excavated to 90- and 100-ft deep reportedly did not reach true bedrock (personal communication, Dan Ashbrook, Arley Taylor, 1983). Although the underlying glacial outwash appears to be relatively deep and largely barren of gold, preglacial concentrations of placer gold may still be concealed beneath it.

Sampling

Numerous sample pits were evident from Eureka Creek to the lower canyon area, and many were excavated by operators currently mining elsewhere in the district. Encouraging results are reported from many of

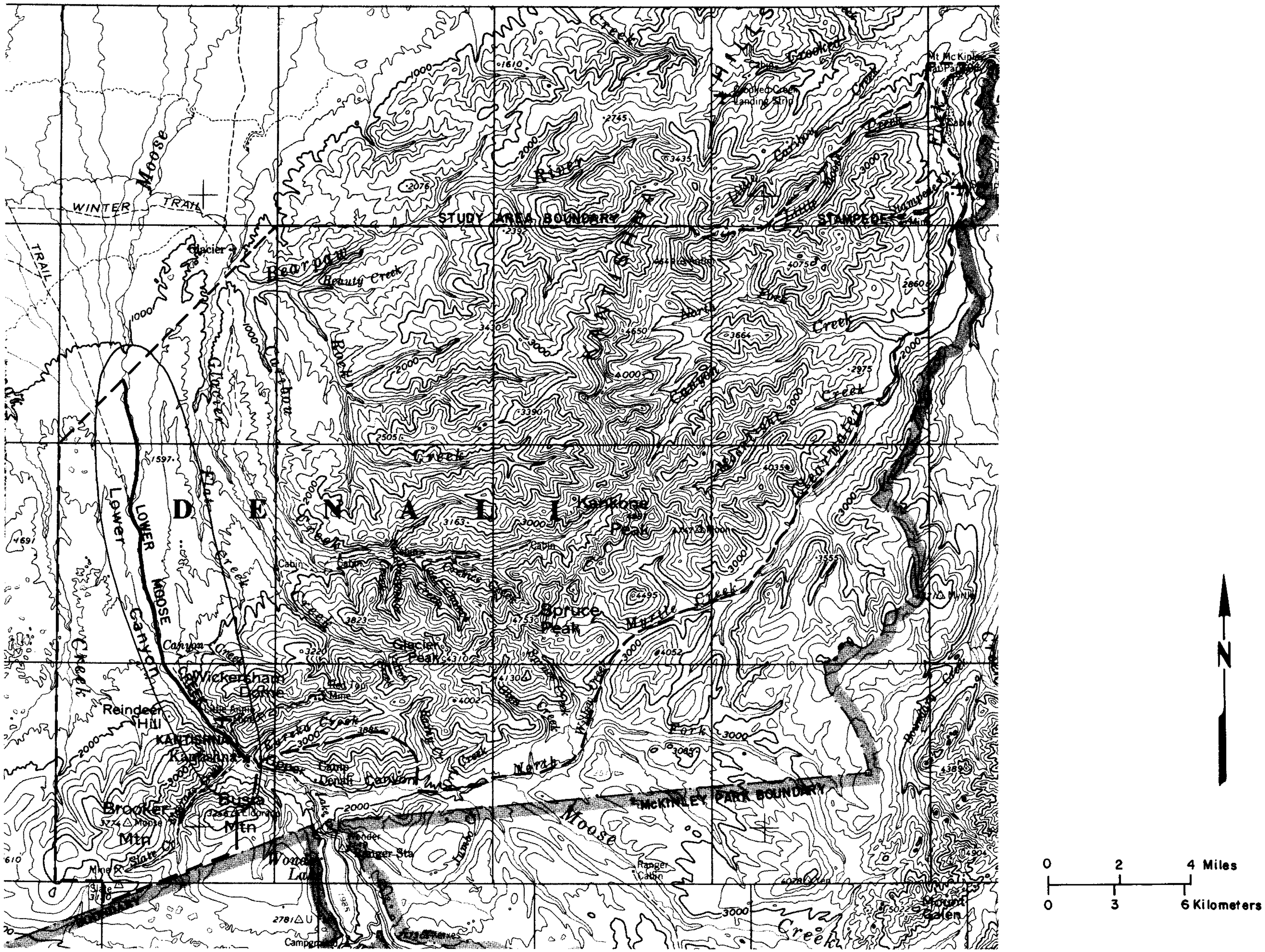


Figure K-11 Lower Moose Creek location, Kantishna Hills study area the pits, and the operators would have mined the areas if the overlying mining claims were not currently under adjudication.

Four reconnaissance samples (A3093, A3094, A959, A961) of floodplain deposits contained 0.0193, 0.0013, 0.015, and 0.0092 oz Au/cy, respectively. These samples were taken between Friday Creek and the lower canyon section. A 1-hr dredge sample (A3058) obtained from floodplain gravels in the lower canyon yielded 0.1519 oz of gold. Four reconnaissance samples (A3100, A958, A960, A962) collected from terrace deposits near the lower canyon yielded 0.001, 0.008, trace, and 0.0167 oz Au/cy, respectively.

Six backhoe-pit samples (A1450-1454, A1461) were collected from terrace deposits. The samples contained 0.001, 0.0002, 0.009, 0.0016, 0.0145, and 0.0012 oz Au/cy, respectively. Four of the pits did not reach the false bedrock because of permafrost, water in the pit, or backhoe reach limitations. Results from these pit samples were probably low since the gold in these deposits is reported to be concentrated on the false bedrock.

Nine cable tool samples (CDH 1, 1A, 2-7, 17) were collected from floodplain and terrace deposits between the mouth of Friday Creek and the lower canyon. Gold content of samples ranged from a trace to 0.009 oz/cy. Four of the samples contained more than 0.005 oz Au/cy, and three of the samples contained more than 0.001 oz Au/cy. All the samples except pit sample A1461 contained fine, flaky gold.

Mining

In the early 1900's rich pay streaks in Lower Moose Creek were mined by hand methods near the mouth of Eureka Creek and in the narrow canyon 3-miles downstream. A large-scale hydraulic mining operation attempted in the early 1900's near the mouth of Eureka Creek was apparently unsuccessful. In the last 5 years, a few, medium-scale, portable washing plants have been used to mine a large area of floodplain and terrace deposits below the mouths of Eureka and Eldorado Creeks. The gravels were mined from 8- to 20-ft deep to a false bedrock of clay or silt. Fine-grained gold was distributed throughout the gravels, but gold was concentrated in rich pay streaks on the false bedrock. The gold was mostly flat and well-worn. Reported production and the amount of tailings present support an estimate that 12,000 oz may have been recovered during that period.

Location 4 (Appendix A, p. 14)

A medium-capacity mining operation on Friday Creek near its juncture with Moose Creek processed terrace gravels and overlying alluvial fan gravels deposited by Friday Creek. Placer gold grades in four large cuts mined in 1982 and 1983 are 0.023, 0.06, 0.026, and 0.008 oz/cy. Gold content for each cut based on a fineness of 710 would be 0.017, 0.044, 0.018, and 0.006 oz Au/cy, respectively. A price factor of 0.74 was determined for placer gold produced at this locality. Approximately 164,000 cy of material has been mined at this location since 1982. The average placer gold grade is estimated to be 0.022 oz/cy. Average gold content is 0.016 oz Au/cy. The terrace deposits currently being mined extend downstream from the mouth of Friday Creek and could contain similar gold values.

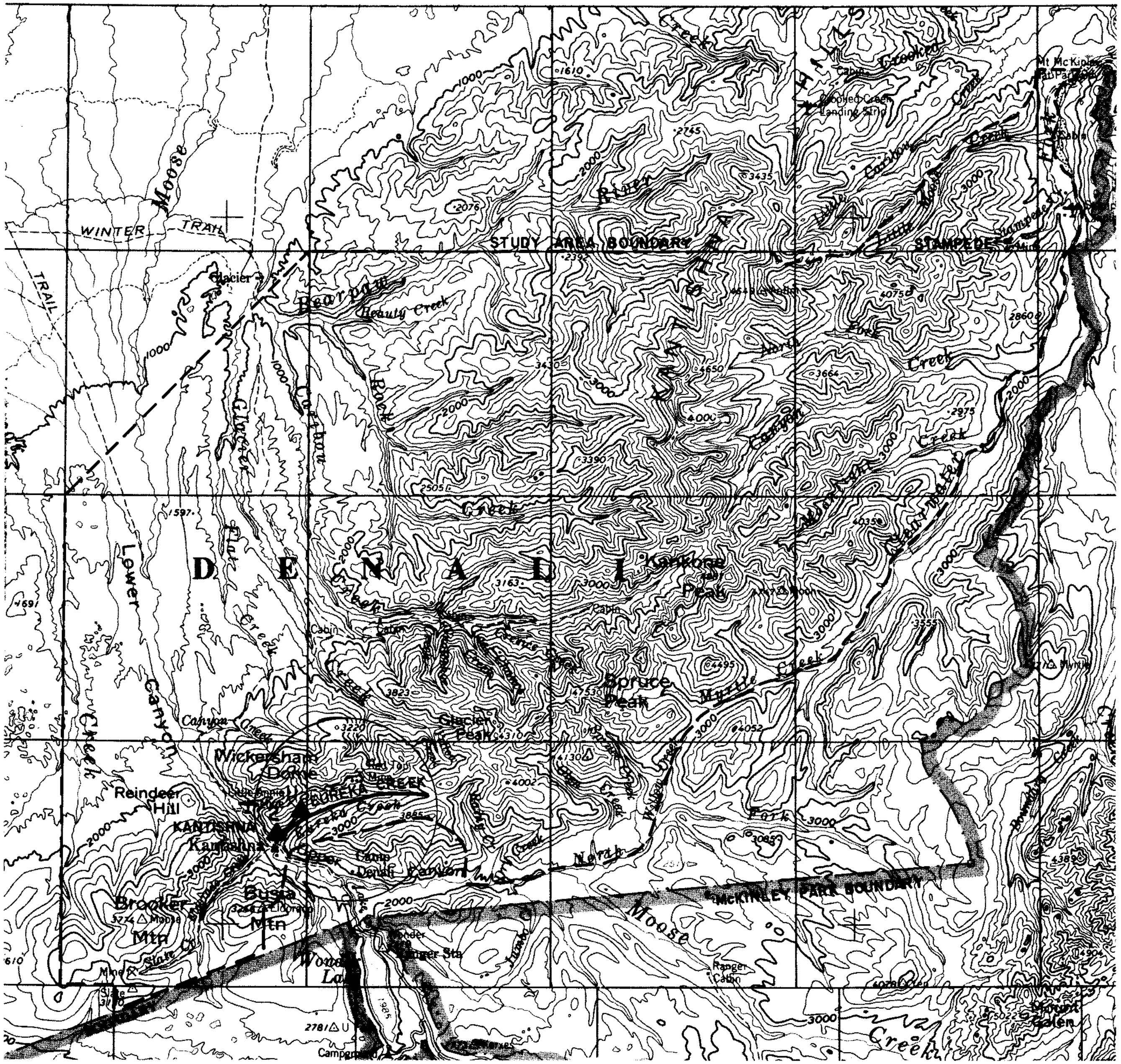
1981 Mining

Approximately 1,140 oz of gold were recovered from about 600 hr of operations in 1981 (personal communication, Sonny Kragnes, 1983). Terrace gravels were mined below the mouth of Eureka Creek. The medium-capacity, shaker-screen/sluice plant reportedly processed 100 cy/hr for a total of 60,000 cy of material mined. Eighty percent of the gold recovered was reportedly under 14 mesh in size, and coarse gold recovered was generally smooth, rounded flakes and nuggets. Placer gold grade was approximately 0.019 oz/cy. Gold grade would be 0.016 oz Au/cy based on a fineness of 850. A price factor of 0.88 was determined for placer gold produced at this locality.

Eureka Creek

Physiography and Quaternary Geology

Eureka Creek is a deeply-entrenched 4-mile-long drainage parallel to Quigley Ridge (fig. K-12). The stream has an average gradient of 250 ft/mile. Gravel deposits in the upper 3 miles are from 50- to 250-ft across



LEGEND

▲ 1983 Placer mine location

N

0 2 4 Miles

0 3 6 Kilometers

Figure K-12 Eureka Creek and placer mine locations, Kantishna Hills study area and are from 4- to 5-ft deep. The gravels are very coarse and poorly-sorted. Gravel benches near the stream bottom are as deep as 12 ft. Although over 40% of the upper segment of the drainage has been heavily mined with mechanized equipment, large strips of unmined gravels remain alongside old mine cuts. Some exposures near the edge of mining cuts show the gravels continue underneath the steep sideslope colluvium. These covered gravels are also gold-bearing but are difficult to mine because of the thick overburden.

A large alluvial fan heads near the Jupiter-Mars/Banjo Lode Mine area in the upper Eureka drainage at the junction with Lucky Gulch. Tests showing that the fan is gold-bearing suggest that lode gold in these mines may be the source of the Eureka Creek placer deposits.

The lowermost mile of Eureka Creek flows through a bedrock-walled canyon which is rarely more than 100-ft wide. This portion of the stream has also been extensively mined. Some sections have reportedly been mined several times. Strips of unmined gravel still remain along the valley walls, and narrow stream sections are still unmined by mechanized methods although evidence of old hand mining operations is usually present.

A large, gravel-capped terrace lies 100-ft above the creek level at the juncture of Eureka Creek and Moose Creek. This terrace is a mixture of glaciofluvial Moose Creek gravels and local gravel from Eureka Creek. Other small terrace deposits similar to the stream bottom gravels line the canyon sidehills along the lower 2,000 ft of the creek. They are largely covered by soil and brush, and often the only evidence of their existence is float material perched well up on the canyon walls. Tests of these gravels by a claim owner show encouraging gold grades, and a mining operation recovered coarse placer gold from the terrace gravels in 1983.

Gold recovered from 1983 mining operations was rough- to well-worn, occasionally crystalline and frequently coated with oxides of manganese and iron. Values were distributed throughout the gravel but were concentrated near and into the bedrock surface, especially where the rock was hard and jointed surfaces created natural gold traps. Eureka Creek has produced nuggets weighing up to 30 oz since its discovery in 1905. A 3.3-oz nugget, recovered during this season from Eureka Creek, was the largest reported in the district during 1983.

A total of 5,576 oz were estimated to have been produced from Eureka Creek by 1968 (Bundtzen, 1981). Recent production and the amount of relatively recent tailings present in the drainage indicate that over 5,000 oz have probably been recovered since that time.

Sampling

A 0.1 cy sample (A3032) of quartz vein material from the Banjo Mine dump yielded 0.1639 oz of free Au/cy. Another 0.1 cy sample (A3023) was taken from Lucky Gulch, a small tributary which drains the Banjo Mine area and is incised into the large alluvial fan deposit. This sample of coarse, predominantly colluvial gravels contained 0.0064 oz Au/cy.

Two backhoe-pit samples were obtained from coarse gravels in the alluvial fan deposit just above Eureka Creek. Sample A1456 contained 0.0088 oz Au/cy, and a sample (A1457) taken from the top of the fan, contained 0.0048 oz Au/cy. The gold recovered ranged from fine to coarse with rough surfaces. Gravels were excavated to a depth of 13 ft but the pit did not reach bedrock.

Two backhoe pits were excavated on Eureka Creek. The first pit was excavated in disturbed colluvium. Man-made articles and oil indicate it was probably a buried junk heap. Sample A1455 taken from this shallow pit contained 0.0007 oz Au/cy but the result is considered inconclusive as to gold content because undisturbed gravels were not sampled. Sample A1458 was taken from 12 ft of low, bench gravels adjacent to a mined area. Although bedrock was not reached, coarse gold was recovered. The gold content of the sample averaged 0.0027 oz Au/cy. This value is probably not representative because most gold in Eureka Creek is characteristically found near bedrock.

Mining

Location 2 (Appendix A, p. 9)

Two men operated a medium-capacity, shaker-screen/sluice plant approximately 1,000 ft up from the mouth of Eureka Creek (fig. K-12). A 3- to 5-ft-deep terrace deposit, 15 ft above stream level, was being mined. Pay gravels were largely covered by steep side-slope colluvium. A large dozer was used to cut into the hillside and push the excavated bedrock, alluvium, and large volume of colluvial material to a stationary washing plant, where a large bucket excavator loaded the pay gravel. A smaller dozer was used to remove and level tailings.

As mining progressed, a bucket count was kept to determine bank measure of the material mined. Approximately 100 cy of material were processed from which 3.1 oz of gold were recovered. Eighty-two percent of the gold recovered was jewelry grade; 52% was over 1/4 in. in size. The placer gold grade of the deposit was calculated to be 0.031 oz/cy. Gold content based on a fineness of 800 would be 0.025 oz Au/cy. A price factor of 1.22 was calculated for placer gold produced at this locality. In addition to gold, the concentrates contained pyrite, galena, and magnetite.

Subsequent to this examination further tests were made by the operator on similar terrace deposits nearby. All the tests yielded encouraging amounts of gold. A small hydraulic operation was being set up in 1983 to mine the terrace gravels. A road is planned for 1984 to transport mining equipment to the terrace deposits above the mouth of Eureka Creek. The washing plant was moved upstream to mine a section of gravel near the mouth of a narrow gorge. The results of that operation are unknown.

Location 11 (Appendix A, p. 38)

A small-scale mining operation was located about 1-mile upstream from the mouth (fig. K-12). The two-man operation used a front-end loader to excavate and feed pay gravels to a sluice-box. This portion of the stream has not been mined by mechanical methods but evidence of old hand workings are present. The deposit is 30- to 100-ft wide and 5- to 6-ft deep.

Gravels are very coarse and contain up to 5% boulders. The gravels and 6 in. to 1 ft of fractured quartzitic schist bedrock were mined. A small cut measuring 220 cy produced 12.79 oz of gold, over 35% of which was jewelry grade. Placer gold grade of the gravels was calculated to be 0.058 oz/cy. Gold content based on a fineness of 777 would be 0.045 oz Au/cy. A price factor of 0.86 was determined for placer gold produced at this locality. The concentrates contained abundant garnet and magnetite with galena, scheelite, stibnite, and some cassiterite. Subsequent to the examination, a 3.3 oz nugget was recovered in another cut in the near vicinity.

Friday Creek

Physiography and Quaternary Geology

Friday Creek (fig. K-13) is deeply incised into Quigley Ridge and flows westerly into the valley of Moose Creek. The drainage is approximately 2-miles long and has a gradient of 400 ft/mile. The upper 1.5 miles range from 10- to 75-ft wide, and the average width is approximately 25 ft. The gravels average 3- to 6-ft deep to quartzite or schist bedrock. This section of the stream has been mined by hand and booming techniques. Approximately 50% has been mined in the recent past with mechanized equipment. Gold is reported to be concentrated in the lower few feet of gravel and to a depth of 2 ft into the fractured bedrock.

The lower 0.5 mile of the stream flows into the valley of Moose Creek. At one time the stream flowed out of the narrow canyon and deposited a large alluvial fan over terrace deposits paralleling Moose Creek. The stream has since cut down through the fan and part of the terrace deposits. The lower section of the stream flows over the remnant terrace deposits for approximately 1/4 mile and then disappears underground. Gravel deposits on the section of stream bottom which dissects the alluvial fan complex average 200 ft in width and were the site of a large-scale mining operation during the last two seasons. The lower 1/4 mile of the stream consists of Moose Creek terrace and floodplain gravels covered in places by gravel deposited by Friday Creek during flood stages.

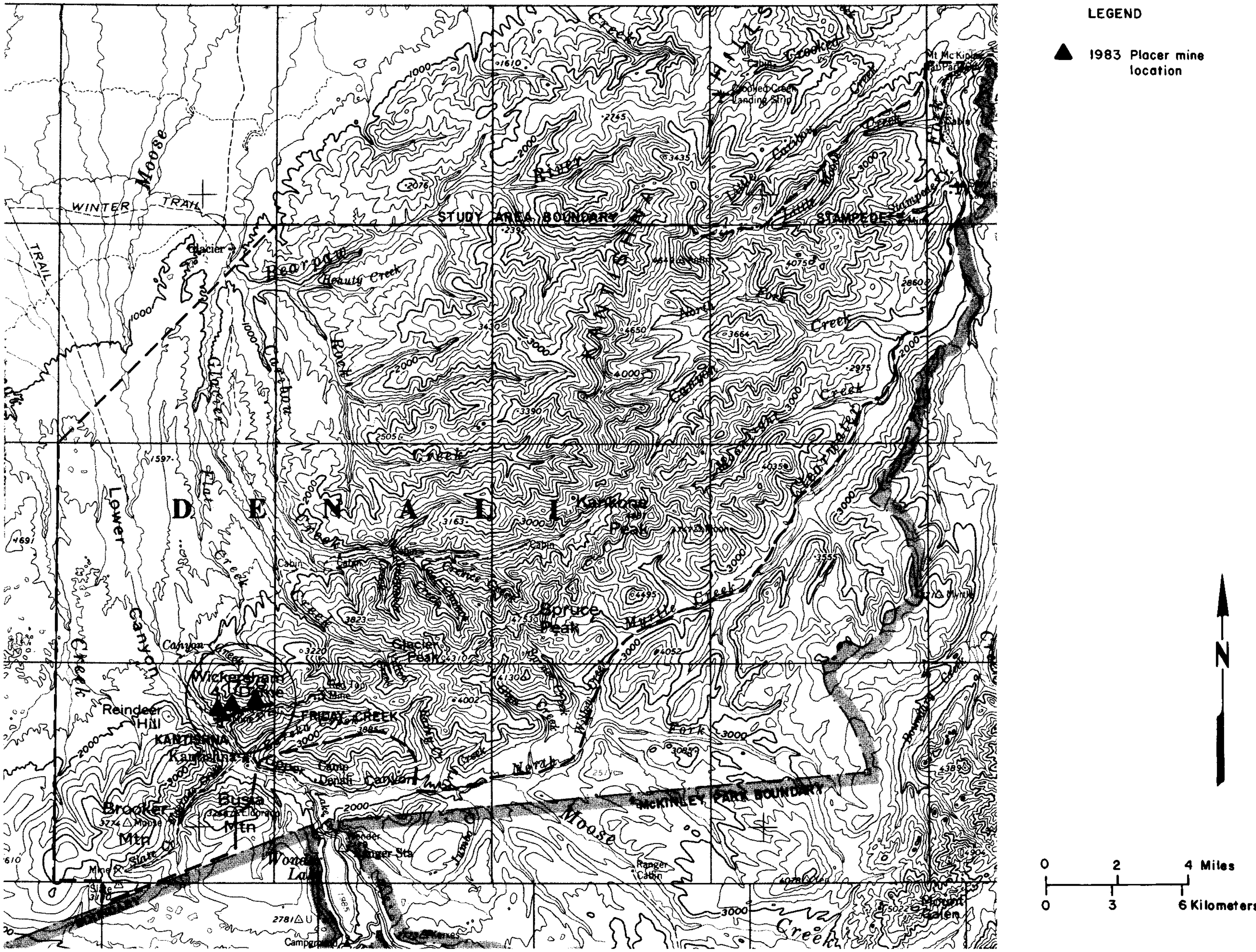


Figure K-13 Friday Creek and placer mine locations, Kantishna Hills study area

The fan gravels are unsorted, subangular, and contain up to 1% large boulders. The underlying terrace deposits are well-washed, glaciofluvial gravels deposited by Moose Creek. The terrace gravels are underlain by a false bedrock of glacial clay and silt or clayey, unsorted glacial outwash gravel. The gravels immediately above the false bedrock are usually stained red by iron oxides, and coarse-grained gold is concentrated in this horizon.

Gold recovered from mining operations is both coarse- and fine-grained. The coarse-grained gold is very rough and often contains abundant attached quartz. Dendritic or wire-like textures are common, and some of the gold is crudely crystalline. Much of the gold is also stained by oxide coatings. Several nuggets from 1 to over 3 oz were recovered from 1983 mining operations. Abundant galena, magnetite, pyrite, scheelite, and occasional stibnite, are recovered in the mine concentrates.

Sampling

An 18-ft channel sample (A1459), taken from glaciofluvial gravels underlying the alluvial fan deposit, yielded 0.0117 oz Au/cy, and a 4-ft sample interval yielded 0.048 oz Au/cy. This sample was obtained from gravels similar to and adjacent to those being mined.

An 18-ft channel sample (A1460), taken adjacent to a recent mining cut, yielded 0.0013 oz Au/cy. This sample was obtained from the overlying alluvial fan gravels.

A backhoe-pit sample (A1454) yielded 0.017 oz Au/cy from a shallow glaciofluvial gravel deposit approximately 500 ft upstream from Moose Creek. Two cable tool samples, CDH-6 and CDH-7, recovered material containing 0.003 and 0.0061 oz Au/cy, respectively. These samples were obtained from similar gravels near pit sample A1454, which contained 0.017 oz Au/cy.

Mining

Recorded production prior to 1968 was estimated at 104 oz of gold (Bundtzen, 1981). Over 4,000 oz were produced in 1982 and 1983. An estimated 300 oz were produced between 1968 and 1982, based on recent production and estimated volumes of tailings in the upper drainage.

Location 20

During 1983 one man was mining intermittently in the upper drainage (fig. K-13). This section of the stream was relatively steep and averaged 10- to 15-ft wide. Gravels from 1- to 3-ft deep were being mined by a booming technique. An unknown amount of coarse gold was recovered. This portion of the stream contains several areas of unmined gravels amenable to small-scale mining.

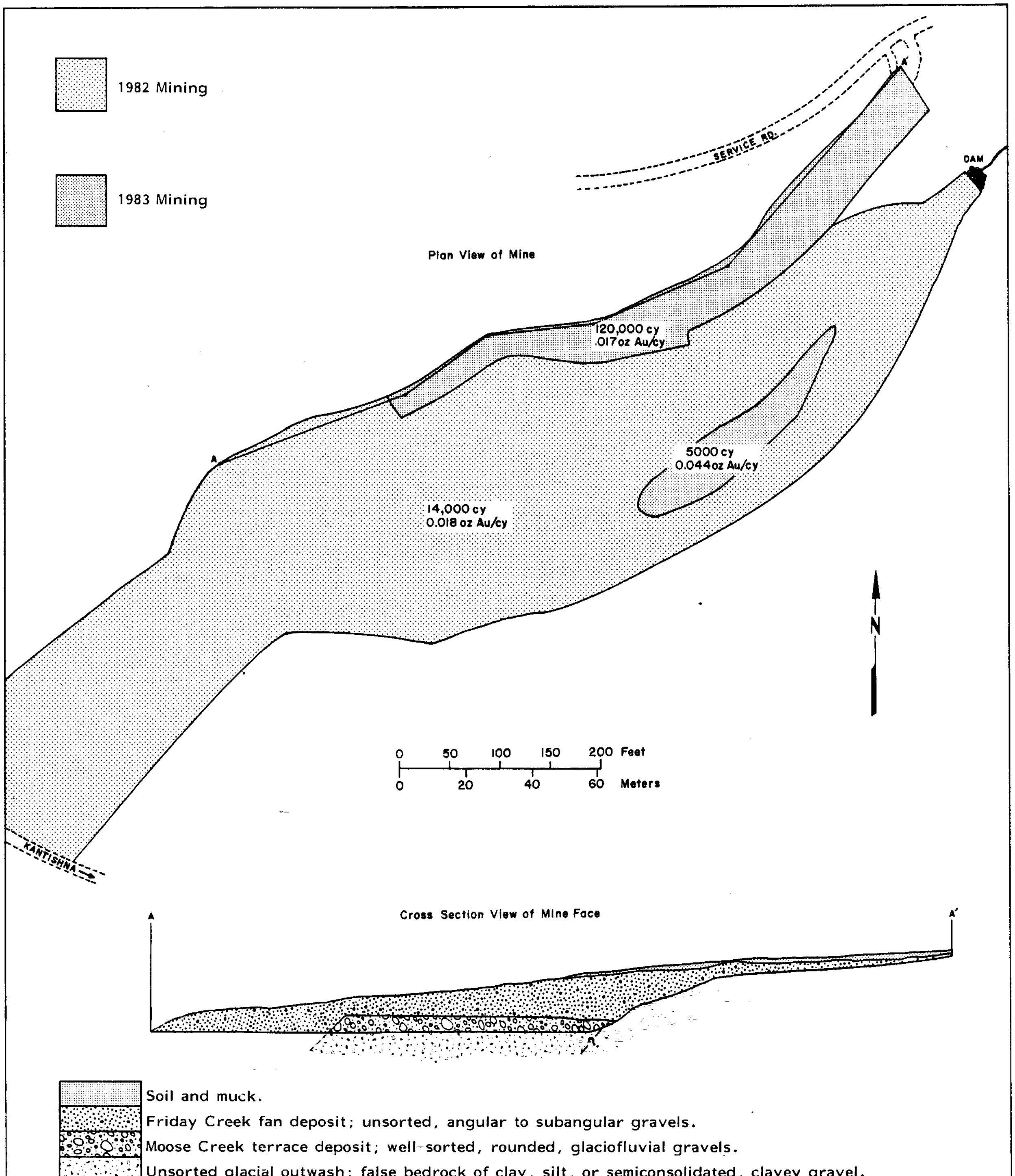
Location 17 (Appendix A, p. 52)

Three men operated a medium-sized, stationary, shaker-screen/sluice plant at the mouth of the canyon and at the end of the alluvial fan deposit (fig. K-13). Coarse gravels up to 30-ft deep had been excavated from the north side of the drainage. On the uphill side of the cut, the gravels continued beneath steep, side-slope colluvium. A large bulldozer excavated gravels to a quartzitic schist bedrock and also pushed the pay gravels to a front-end loader. The loader in turn fed pay gravel into the washing plant. The material above bedrock contained less gold than that found near bedrock. Once bedrock was reached, however, gold production went up considerably. A 1.25- and a 2.75-oz nugget were recovered from the gravels near bedrock.

Several visits were made to the property in 1983 as mining progressed. Approximately 250 hr had been spent on the cut, and several cleanups had been made. The plant was processing approximately 60 cy/hr and an estimated 15,000 cy of gravel had been mined. Over 350 oz were reportedly recovered (personal communication, Larry Goolsbey, Dave Anstett, 1983). The placer gold grade of gravels being mined is approximately 0.023 oz/cy. Gold grade at 780 fine would be 0.018 oz Au/cy. Several areas on this portion of the stream are underlain by similar deposits, and the current operators plan on mining them next season.

Location 4 (Appendix A, p. 14)

A medium-scale, 24 hr/d operation (briefly described on p. 68) mined the fan/terrace deposit on the lower stream section (fig. K-13 and K-14). Several cuts were made during the course of the season. During the 1982



Kantishna Hills Study Area

Figure K-14 Friday Creek Placer Mine

(S.E. Section 11, T. 16 S., R. 18 W., See mine location 4, figure K-13)

mining season the stream bottom deposit was mined, and a portion left behind in the 1982 cut was mined during 1983. This portion of the drainage was over 200-ft wide and over 1/4-mile long. Five to ten ft of coarse Friday Creek gravels overlying a similar depth of glaciofluvial terrace gravels were mined to a false clay or silt bedrock. The 1982 cut was mapped and approximately 120,000 cy had been mined. The operator's recorded production totals 2,812.66 oz of placer gold. Over 30% of this production was estimated to be coarse, jewelry grade gold. In the past several seasons, the operator received more than the spot price for gold because of the higher prices obtained for the jewelry gold (personal communication, Sonny Kragnes, 1983). The 1982 cut had a placer gold grade of 0.023 oz/cy. Gold content based on a 710 fineness would be 0.017 oz Au/cy.

The small area left behind in the 1982 cut contained approximately 5,000 cy of gravel. Processing the concentrates from the 1983 mining of this material recovered 312 oz of placer gold for a placer gold grade of 0.062 oz/cy. Gold content based on a 710 fineness would be 0.044 oz Au/cy.

In 1983, mining began on the 60-ft-high fan and terrace gravel deposits. The first cut averaged 50-ft wide and was mined to up to 40-ft deep. The lower 10 to 15 ft of the cut consisted of coarse, well-sorted, glaciofluvial, terrace gravels overlain by as much as 25 ft of unsorted fan gravels. The glaciofluvial gravels were underlain by a false clay and/or silt and pebble bedrock of glacial origin. Appreciable amounts of gold were recovered from the fan gravels, and some concentration may have been present at the interface of the fan and underlying glaciofluvial gravels. Most of the gold, however, was recovered from the glaciofluvial gravel, and over 30% was coarse, jewelry grade. One nugget recovered in 1983 weighed 3.25 oz.

To mine this deposit, a level bench was prepared with a dozer. A large bucket excavator loaded pay gravels into a medium-capacity, shaker-screen/sluice plant. After mining a top layer, another layer was mined to the false bedrock. This cut measured approximately 14,000 cy. Total gold recovered weighed 364.86 oz for a placer gold grade of 0.026 oz/cy. Gold content at 710 fine would be 0.019 oz Au/cy. A price factor of 0.86 was determined for placer gold produced at this locality.

Another mining cut was made downstream from the above cut. Although the gravels were similar, the underlying glaciofluvial gravels came from a lower Moose Creek terrace. The terrace gravels mined were analogous with terrace deposits downstream from Friday Creek. Approximately 25,000 cy were mined from this deposit, and 210.64 oz of gold were recovered for a placer gold grade of 0.008 oz/cy. At 710 fine the gold content would be 0.006 oz Au/cy.

Approximately 164,000 cy of gravel were mined in 1982 and 1983 for an average placer gold grade of 0.022 oz/cy. Gold content at 710 fine would be 0.016 oz Au/cy.

Eldorado Creek

Physiography and Quaternary Geology

This drainage (fig. K-15) flows through a relatively narrow bedrock-walled valley at a gradient of 150 ft/mile. The lower 0.5 miles of the creek flows through the Moose Creek terrace deposits. The section of the creek between 0.5 and 2.5 miles above its junction with Moose Creek is from 50- to 300-ft across, and coarse gravels are usually less than 8-ft deep.

Eldorado Creek was glaciated during Wisconsin time. Glacial outwash gravels overlain by locally derived alluvium were observed in backhoe pits. In other areas the outwash gravel was not evident, and local gravels were seen overlying bedrock. Gold recovered from gravel samples was bright, well-worn, and flaky.

Sampling

Ten reconnaissance placer samples (A3022, A3052-57, A3068, A3095-96) collected from Eldorado Creek contained from a trace to 0.0706 oz Au/cy. Four of these samples contained in excess of 0.015 oz Au/cy.

Two reconnaissance samples taken from Slate Creek, which is a tributary to Eldorado Creek in its upper end, contained only trace amounts of gold.

Two backhoe-pit samples were obtained on the lower section of the stream just above its juncture with the Moose Creek Valley. Both samples were obtained at location A1476 and yielded 0.0077 and 0.0116 oz Au/cy.

Mining

A short section about 0.25 mile above the mouth of the creek was mined with mechanized equipment in 1980. Gold production was reportedly satisfactory (personal communication, Sam Koppenburg, 1983). Some hand mining and testing have been done on the creek since the early days, but it has never been a large producer. Recent test pits are evident along most of the creek, and evidence of some suction dredging and hand working was also observed. No production is recorded for this drainage. A production estimate of 200 oz is based on the amount of tailings present and test results.

Glacier Creek

Physiography and Quaternary Geology

Glacier Creek (fig. K-16) drains the north facing slopes of the Kantishna Hills. The upper 5-mile section of the drainage is deeply incised into the hills. Stream bottom deposits alternate between relatively flat-lying sections as wide as 250 ft and bedrock-walled canyons 30-ft wide. The average stream gradient is 300 ft/mile. Gravels are between 2- and 5-ft deep and overlie schist bedrock. The upper drainage is fed by several steep and relatively narrow tributaries that have been extensively hand mined. Yellow Creek was being re-mined with mechanical equipment during the 1983 season.

Where the stream emerges from the Kantishna Hills, the stream gradient flattens considerably. The stream flows through a wide valley entrenched in unconsolidated Tertiary sediments. The floodplain averages 200- to 300-

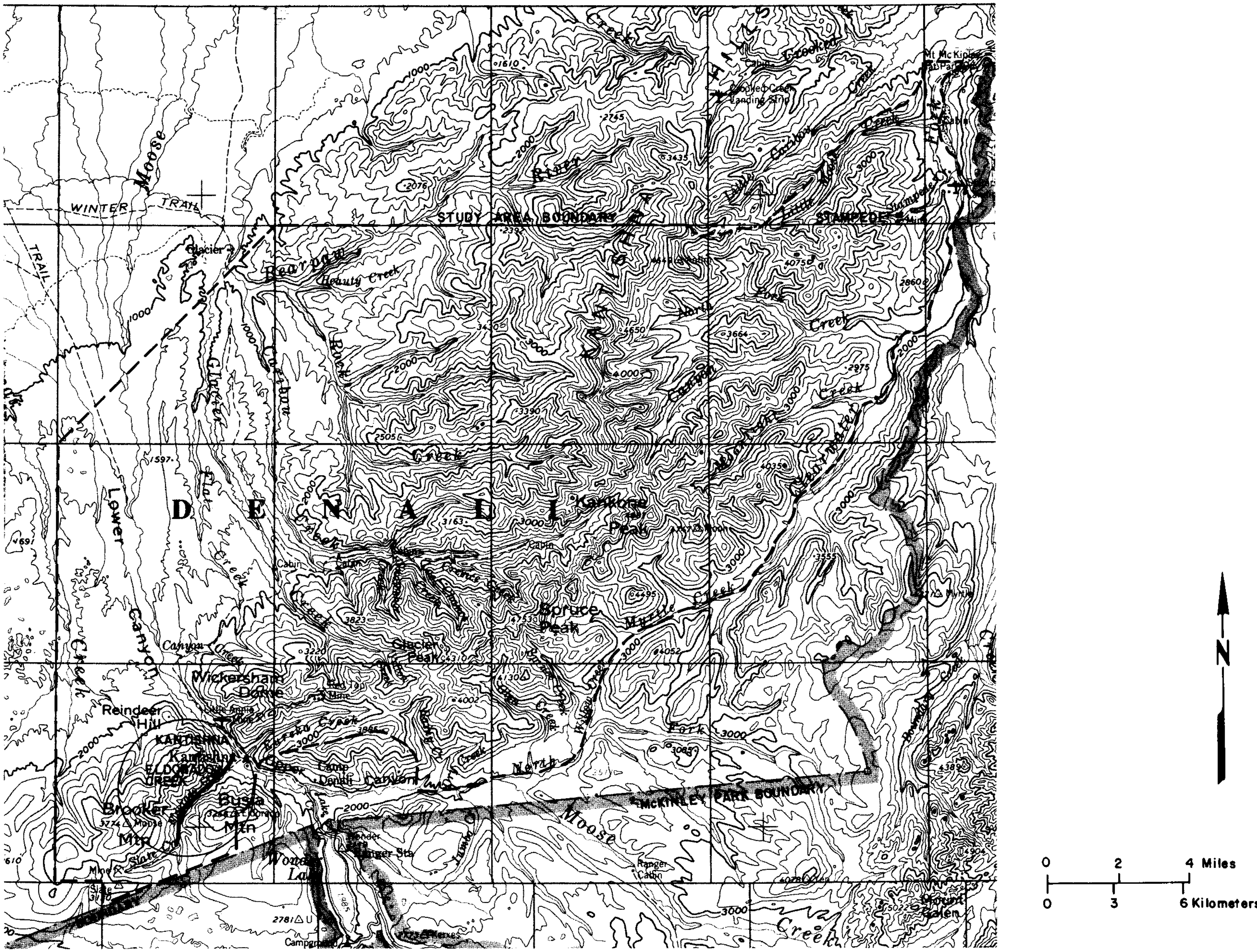


Figure K-15 Eldorado Creek location, Kantishna Hills study area

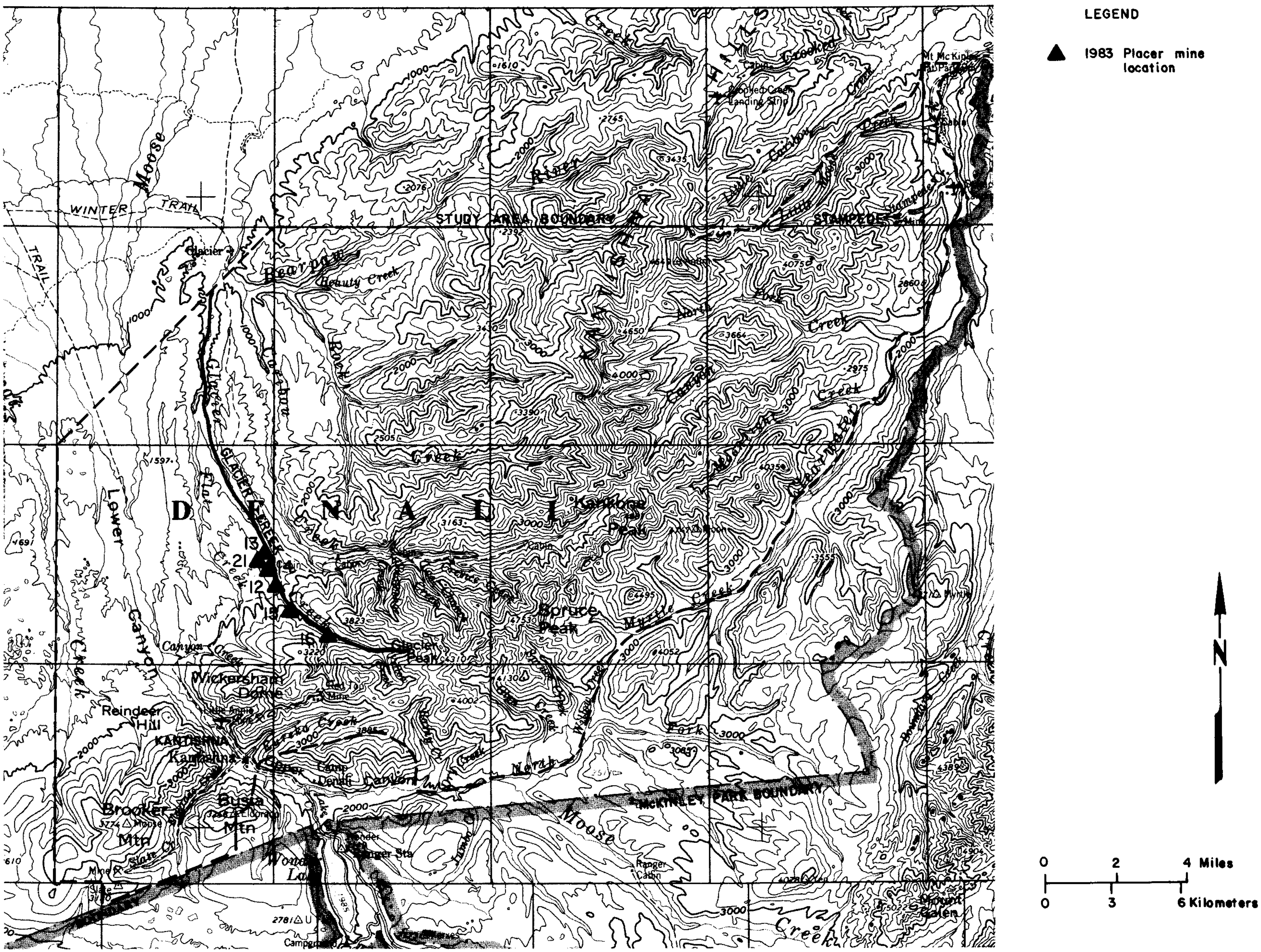


Figure K-16 Glacier Creek and placer mine locations, Kantishna Hills study area ft across, and the gravels are commonly up to 10-ft deep. The stream is lined by substantial terraces, 50- to 75-ft high. Terraces are capped by gold-bearing Quaternary gravels which average 7-ft deep and are covered by frozen muck averaging 8-ft deep. Cable tool sampling and results of mining of terrace deposits in 1983 indicate placer gold is concentrated at and near the interface of the terrace gravels and the underlying Tertiary sediments.

Gold recovered in the upper drainage is mostly coarse-grained, rough and commonly crystalline. The gold becomes progressively flatter and smoother downstream. Mining of the stream bottom and terrace gravels below the canyon mouth produced mostly fine-grained, bright, flake gold.

Sampling

Two short fences of cable tool samples were completed in 1983 in the vicinity of a prepared mine site. The fences were laid out across the western terrace and oriented normal to the stream direction. Six holes (CDH 10, 12, 13-16) averaged 140 ft apart in two fences spaced approximately 660 ft apart. Hole CDH 11 was offset 50 ft from one of the fences.

Sampling showed the gravels varied in depth from 4 to 14 ft and averaged 7-ft deep. The gravels were similar to the adjacent floodplain deposits both in composition and degree of sorting. The terrace deposit was covered by frozen muck which ranged in depth from 3 to 14 ft, and averaged 8 ft. Gold was concentrated in the lower few feet of gravel above the false bedrock. Gold recovered from the samples ranged from 0.0012 to 0.0168 oz Au/cy (these figures do not include the overlying volume of muck which would have to be removed prior to mining). Interpretation of sampling results indicates 66,190 cy of gravel between the two fences with an average weighted grade of 0.0098 oz Au/cy.

Earlier in the 1983 season the same operator stripped an overlying layer of frozen muck from a large area of nearby terrace gravels. The stripping was completed to allow time for the muck and underlying gravels to thaw prior to mining. The operator tested several areas over a 1-mile-long section of the terrace gravels prior to stripping. Panning results were more encouraging than similar tests on gravels currently being mined on the stream bottom deposits.

Mining

Glacier Creek has been mined by hand methods from its source to about a mile below its departure from the Kantishna Hills. A dragline was utilized at the canyon mouth in the early 1940's and produced an estimated 2,000 oz of placer gold (Bundtzen, 1981). During the 1983 season, five small- to medium-capacity operations were mining previously hand worked areas with considerable gold production - an indication that similar results may be expected from future mining of these areas. Estimates based on recent production figures and volume of tailings present indicate that over 4,000 oz of placer gold have been produced since the early 1970's.

Location 16 (Appendix A, p. 50)

Three men were processing gravels with a small-capacity, shaker-screen/sluice washing plant at the juncture of Glacier Creek and Twenty-two Gulch (fig. K-16). Extensive piles of hand stacked rocks indicate approximately one-half of the gravels in Twenty-Two Gulch were mined by hand methods. Glacier Creek is over 80-ft wide at this location, and much of the area had been previously hand mined. Coarse gravels from 3- to 6-ft deep were being excavated with a dozer and front-end loader. Only the lowermost 1 or 2 ft of gravel and an average of 1 ft of bedrock were being processed. Hard, quartzitic sections of fractured bedrock acted as natural riffles, resulting in exceptionally rich concentrations of coarse-grained gold. After clearing the gravel from these areas, visible gold could be hand picked from the bedrock. In addition to gold, abundant galena and stibnite and occasional tourmaline were recovered in the concentrates.

The volume of material excavated in the mine cut was estimated as 14,000 cy. The volume of material actually processed was estimated to be 3,400 cy. Over 100 oz of jewelry grade gold had been hand picked at the time of the examination (personal communication, Milan Martinek, 1983). Several nuggets recovered were in the 0.25- to 0.5-oz range and one nugget weighed over 1.5 oz. An equivalent amount of fine-grained gold is estimated to remain in the concentrates. If 200 oz of gold were recovered, the gravel deposit would contain 0.014 oz/cy of placer gold. The material actually processed would contain a placer gold grade of 0.059 oz/cy. Based on a fineness of 760 the gold content would be 0.011 and 0.045 oz Au/cy, respectively. A price factor of 0.88 was determined for placer gold produced at this locality.

Location 15 (Appendix A, p. 49)

A 4-in. floating suction dredge was used to process gravels in the upper Glacier Valley approximately 1.5 miles below Location 16 (fig. K-16). Gravel was 2- to 6-ft deep to a quartzitic schist bedrock, and the drainage ranged from 25 ft to 100 ft in width. The dredge was floated in a narrow gorge section of the creek, and alluvium was passed through a riffled sluice. Stripping and removal of overlying alluvium and large boulders were done by hand. This portion of the stream has been mined similarly for the last 20 years. Most gold recovered is very coarse, and large nuggets are common. One nugget recovered in 1982 reportedly weighed over 4.5 oz (personal communication, Art Schmuck, 1982).

A test by the operator processed approximately 2 cy of material and yielded just over 0.1 oz of coarse gold (personal communication, Art Schmuck, 1983). The placer gold grade of the material mined was 0.05 oz/cy. Gold content at 760 fine would be 0.038 oz Au/cy. A price factor of 1.00 was determined for placer gold produced from this locality.

Location 12 (Appendix A, p. 41)

A medium-capacity, portable, shaker-screen/sluice plant was operated 24 hr/d just upstream from the mouth of the upper canyon (fig. K-16). Large bulldozers were utilized to strip and level the deposit prior to mining, and a 2-cy backhoe was used to load pay gravels into the plant. Coarse gravels were up to 13-ft deep and overlay a weathered, clayey schist bedrock. Occasional gouge and shattered, quartz-filled shear zones were observed in the bedrock. The stream deposit averages 125 ft in width and was bordered by schist outcrops. The bedrock underlies coarse, terrace gravels, 4- to 8-ft deep. The terrace gravels are similar to those in the stream bottom.

Gold recovered was rough and crudely crystalline to slightly worn. Over 35% was of jewelry size.

Based on mine cut mapping, the volume of gravels mined was approximately 5,500 cy; 126.78 oz of placer gold were recovered resulting in a placer gold grade of 0.023 oz/cy. Gold content at 750 fine would be 0.017 oz Au/cy. A price factor of 0.84 was determined for placer gold produced at this locality. The 84 hr spent mining the cut resulted in production of 1.5 oz Au/hr. Subsequent to the 1983 examination, the operators began mining adjacent terrace deposits. Gold production was reportedly not as high grade but satisfactory (personal communication, Ralph Hamm, 1983). Smaller scale mining methods have been used on similar terrace deposits nearby over the last 20 years. Reportedly high-grade deposits containing coarse gold were mined (personal communication, Art Schmuck, 1983).

Location 14 (Appendix A, p. 47)

A shaker-screen/sluice plant capable of processing 20 cy/hr was operating just below the upper canyon mouth (fig. K-16). Pay gravels were loaded in the washing plant with a small track-mounted backhoe. The washing plant was being utilized to process small areas of unmined gravel left behind by the 1940's dragline operation.

Coarse gravels on the edge of the old tailings area were 3- to 4-ft deep and underlain by schist bedrock. Gold observed in the sluice box was rough to slightly worn. After a 3-hr mining shift, a cleanup of the concentrates produced a little over 1.5 oz gold. Based on an average of 20 cy/hr, the placer gold grade was estimated to be 0.025 oz/cy. Gold content would be 0.019 oz Au/cy at 760 fine. Because the percentage of jewelry gold is not known, a price factor of at least 0.76 is estimated for placer gold recovered from this locality.

Location 13 (Appendix A, p. 44)

A medium-capacity, shaker-screen/sluice plant was utilized to process 4- to 6-ft-deep gravels approximately 0.5 mile downstream from where the stream leaves the Kantishna Hills (fig. K-16). A dozer cleared and leveled the gravel deposit prior to mining, and a large backhoe was used to load pay gravels into the washing plant. The stream gradient is nearly flat, and the gravel deposit was 200- to 300-ft wide at this point. The gravels were underlain by a false bedrock of unconsolidated Tertiary gravels. Most gold was concentrated near the false bedrock. About 15% of the gold was of jewelry size. Although most gold was well-worn, bright and flaky, some pieces showed remnant crystalline textures and a few pieces contained attached quartz.

The active mining cut was mapped. An estimated 2,100 cy had been mined. A placer gold grade for the deposit was calculated to be 0.023 oz/cy. Based on a fineness of 760, the gold content would be 0.017 oz Au/cy. A price factor of 0.8 was determined for placer gold recovered at this locality. Although mines were not active downstream from this operation, the owner reports that test results and recent mining production were similar to current results at the present location (personal communication, Wayne Copley, 1983).

Location 21

Subsequent to the cable tool sampling program, the owner, utilizing the washing plants described at Locations 13 and 14, began mining terrace deposits (fig. K-16). The small plant from Location 14 began mining on a test basis near the location of hole CDH-13, which had yielded a sample containing 0.0162 oz Au/cy. In 16.5 hr of operation the plant recovered 4.63 oz of mostly fine-grained gold (personal communication, Sam Speakman, 1983). Sixteen percent of the gold or 0.72 oz was of jewelry size. Assuming a 20 cy/hr capacity for the plant, approximately 330 cy of material were mined. The placer gold grade of the test cut is estimated to be approximately 0.014 oz/cy. Gold content at 760 fine would be 0.011 oz Au/cy. A price factor of 0.8 was calculated for placer gold produced from this locality. The gold recovered was fine-grained and flaky, similar to that mined in the stream bottom deposits nearby.

The medium-sized plant which was mining stream bottom gravels at Location 13 was moved onto the terrace deposit between the two cable tool sampling lines. After 10 hr of operation mining was suspended because much of the ground was still frozen. Reportedly over 27 oz of placer gold were recovered before mining stopped (personal communication, Wayne Copely, 1983). The plant is capable of processing 60 cy/hr, and if 600 cy of alluvium were processed, placer gold grade would be 0.045 oz/cy. At 760 fine the gold content would be 0.034 oz Au/cy. A price factor of 0.76 to 0.8 is estimated as most of the placer gold recovered was very fine-grained. The operator stated that the gold was not concentrated in any one place but appeared to be homogeneously spread throughout the lower 2 to 3 ft of the gravels.

Open cuts were pan sampled by the operators as mining progressed to determine how much gravel needed to be stripped ahead of mining. In both cases, the miners stripped the upper layers and mined only the lower 2 or 3 ft of gravel. This helps to explain the higher values obtained for mining compared with the cable tool sampling results.

Yellow Creek

Physiography and Quaternary Geology

This narrow tributary of upper Glacier Creek (fig. K-17) is approximately 1-mile long and has an average gradient of 400 ft/mile. Stream deposits are from 20- to 100-ft wide and bordered by steep side slopes. Coarse gravels are from 3- to 8-ft deep, and exposures in recent mine cuts show gravel commonly continues beneath the side slope colluvium. The lower 1,500 ft of the stream averages 25-ft wide and contains an abundance of large boulders.

The gold recovered from Yellow Creek is very rough and is often remarkably crystalline, dendritic, or wiry. Quartz-bearing nuggets are common. The gold is moderately to heavily coated with oxide stains.

Mining

By 1968 203 oz of gold were reportedly produced (Bundtzen, 1981). Based on recent production grades and the volume of tailings present, at least 300 oz of gold have been produced since 1968.

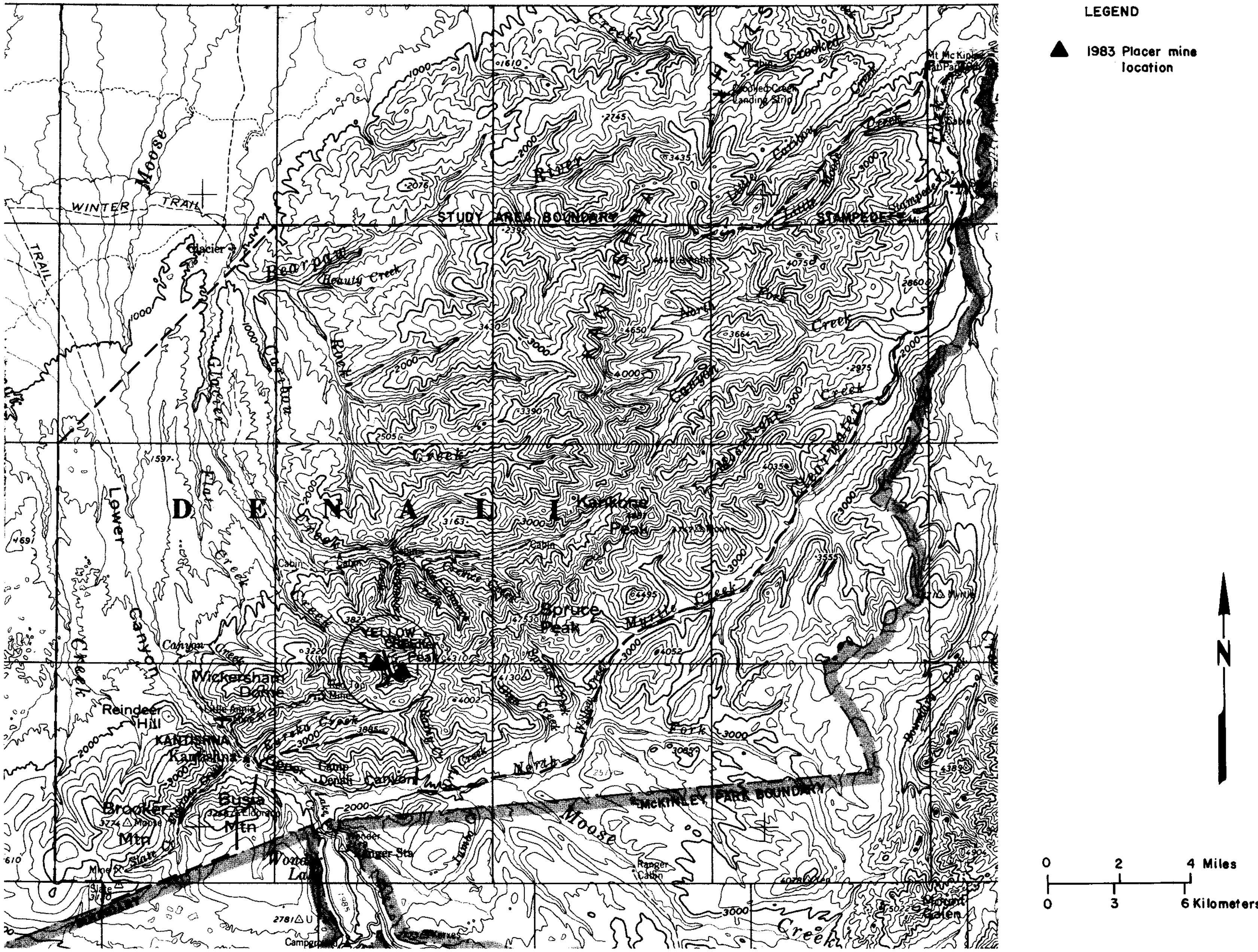


Figure K-17 Yellow Creek and placer mine locations, Kantishna Hills study area

Evidence of hand mining along the stream is pronounced. In 1983 two active operations located in the middle portion of the stream were processing previously mined gravels. Both operators had mined adjacent portions of the stream in 1982.

Location 1 (Appendix A, p. 6)

A medium-capacity, stationary, shaker-screen/sluice plant was located below the juncture of Yellow and Ruby Creeks (fig. K-17). Coarse gravels averaging 5-ft deep were excavated by a large bulldozer. The upper 2 ft of gravel was stripped prior to mining. The lower pay gravels and 6 in. of bedrock were pushed downstream with the bulldozer and fed into the plant with a front-end loader.

Near the stream juncture, the occurrence of occasional limonite-stained quartz pods and float indicate that the bedrock schist and marble may contain quartz-sulfide veins. The veins could be a source of gold in the stream, although panning tests of unmined gravels upstream from the structure showed appreciable amounts of placer gold.

The present cut was measured, and an estimated 3,300 cy of gravel had been excavated. Approximately 1,990 cy of material were processed through the plant. After recovery of all but the very fine-grained gold, a placer gold grade of 0.012 oz/cy was calculated for the gravels. The processed gravels are estimated to contain 0.02 oz/cy. Gold content at 700 fine would be 0.009 and 0.014 oz Au/cy, respectively. A price factor of 0.92 was calculated for placer gold produced at this locality.

Location 5 (Appendix A, p. 18)

Another small-scale, portable, shaker-screen/sluice plant was located 1,500 ft downstream from Location 1 (fig. K-17). Coarse, subangular gravels averaging 6-ft deep and 50-ft wide were being mined. The mining method was similar to that at Location 1, and only the lower 2 ft of gravel and 6 in. of bedrock were being processed.

Measurements indicate that approximately 2,200 cy of gravel had been excavated. Approximately 550 cy of material was processed. Gold recovered from the concentrates weighed 65.46 oz. Forty-nine percent of the gold was jewelry size. The overall placer gold grade of the total volume of gravels was calculated to be 0.03 oz/cy, and the grade of the material actually processed was approximately 0.119 oz/cy. Gold content at 700 fine would be 0.02 and 0.083 oz Au/cy, respectively. A price factor of 1.0 was determined for placer gold produced at this locality.

Caribou Creek

Physiography and Quaternary Geology

The headwater of Caribou Creek is located on the north flank of the Kantishna Hills (fig. K-18). The stream flows westerly for 9 miles at a gradient of 250 ft/mile. At this point the stream turns and flows northerly for 7 miles at an average gradient of 85 ft/mile.

Upper Caribou Creek occupies a terraced valley with wide alluvium filled sections, from 250 ft to 500 ft in width, alternating with occasional narrow gorges. Coarse gravels average 3- to 6-ft deep and contain up to 1% boulders. Terraces are capped by alluvium from 5- to 20-ft deep. Several steep tributaries join the main stream on this portion of the drainage. These streams drain the mineralized areas of the Kantishna Hills and show evidence of being hand mined. Over 1,200 oz of gold are reported to have been mined from them (unpublished U.S.B.M. production reports).

Where the stream turns north, the first 3 miles occupy a bedrock-walled canyon from 30- to 250-ft wide. The canyon walls are also covered by terrace gravels. During the 1983 season, two operators mined stream bottom gravels averaging 5- to 6-ft deep in this section. At the end of the canyon, the stream flows between broad gravel-capped terraces on a wide flat-lying floodplain. This section of the terrace deposit, known as the Lee Bench, is over 2-miles long and up to 1,200-ft across. A large percentage of recent stream bottom gravels on this portion of the drainage were mined by the Carrington dragline operations.

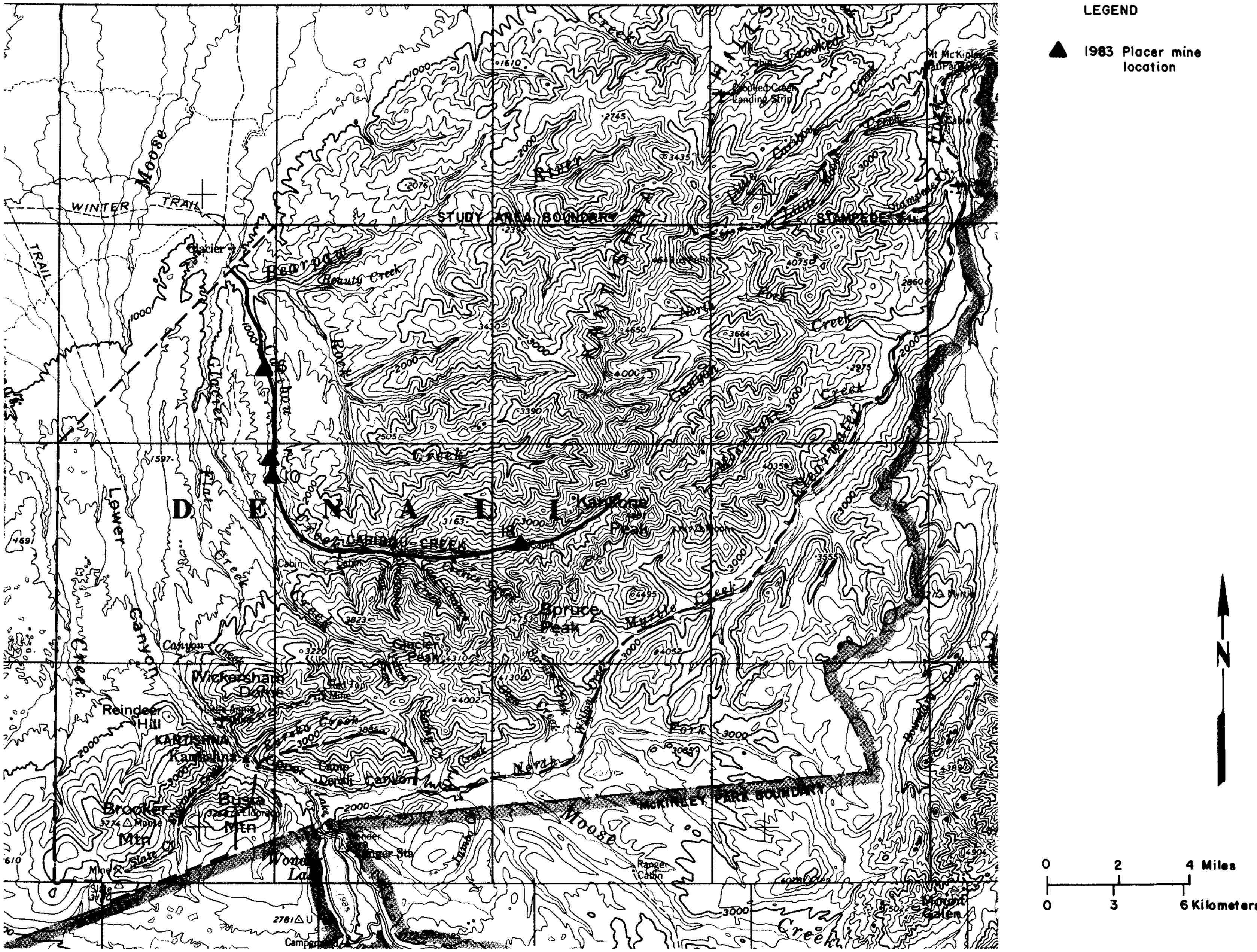


Figure K-18 Caribou Creek and placer mine locations, Kantishna Hills study area

The last 3 miles of the stream flow through a bedrock-walled canyon with occasional openings up to 250-ft wide. This portion of the stream is also bordered by gravel-capped terrace deposits and is currently the site of a medium-scale mining operation.

Terrace gravels line nearly the entire drainage. The gravels were stream lain and resemble those currently being mined. Existing exposures indicate that gravels are relatively shallow, averaging 5- to 15-ft deep, and usually are underlain by bedrock. They are covered by a variable thickness of frozen muck and tundra at least 3-ft deep. The terrace deposits are overlain by small alluvial fans at the confluence of tributary streams. The fans are composed of unsorted, bouldery alluvium. Although no tests were done on the terraces in the upper drainage in 1983, they are reported to be gold-bearing (Capps, 1919). Occasional evidence of relatively recent, small-scale mining activity on the terrace deposits was observed during this study.

The extensive Lee Bench terrace deposits on the lower drainage were tested by churn drilling in 1924 and dozer trenching in 1946 according to a Caribou Creek Mining Company report (Bell, 1979). The report summarizes the results of the sampling programs. Churn drilling conducted by Mt. McKinley Placer Company reportedly blocked out 178,822 cy of alluvium with a grade of 0.021 oz Au/cy. Dozer trenching conducted by the Carrington Company indicated 45,000,000 cy of gravels could be present with an average grade of 0.05 oz Au/cy.

In 1975, a local operator mined a small section of gravel on the Lee Bench. The cut was measured during this study and approximately 2,700 cy of material had been mined. The operator's records showed that 70.5 oz of mostly fine-grained placer gold were recovered for an estimated placer gold grade of 0.026 oz/cy. Based on a 700 fineness figure the gold content would be 0.018 oz Au/cy. The percentage of jewelry gold is not known, and a price factor of at least 0.7 is estimated for placer gold produced at this locality. Panning of other exposures during this study also showed the presence of encouraging amounts of fine gold in the Lee Bench gravels.

All gravel exposures observed were on the edge of the terrace. Overlying frozen muck was usually 2- to 3-ft deep. The gravels are usually underlain by schist bedrock, but some bedrock lows are filled by Tertiary sediments, which in turn are capped by the Quaternary gravels.

Three of the larger operators in the district have expressed an interest in conducting more detailed sampling and/or mining on the bench.

Sampling

Four reconnaissance samples (A3047-A3049, A1411) collected in the upper drainage contained 0.005, 0.0077, 0.0012, and 0.0193 oz Au/cy, respectively. Four reconnaissance samples (A1402, A1404-A1406) collected on the lower drainage and below its juncture with the Bearpaw River contained 0.0261, 0.3045, 0.0057, and 0.0029 oz Au/cy.

Reconnaissance samples (A978-A980) were collected from Crevice Creek, a southern tributary to upper Caribou Creek. Gold grades were 0.0018, 0.1249, and 0.0022 oz Au/cy, respectively. Several tributary streams in the upper portion of Caribou Creek drain the Spruce-Kankone Trend, which contains gold-bearing quartz-vein structures. The rocks along this trend could be one of the sources of the Caribou Creek placer deposits. Samples of vein material and stream sediment samples from the tributary streams draining the trend were highly anomalous in gold.

Mining

Large areas of placer tailings are present in this section of the drainage. The majority of the tailings are from the Carrington dragline mining in the 1940's, although portions of the creek show evidence of recent mining by hand methods, suction dredges, and small mechanized equipment. The tailings are usually bounded by sections of unmined gravel from 10 to 40 ft in width. Gold ranges from fine- to coarse-grained and although concentrated on bedrock, it is distributed throughout the gravels (Capps, 1919). One nugget, recovered prior to 1919, weighed approximately 5.5 oz. A medium-scale operation began mining on this section of the stream in early September, 1983. Over 11,500 oz of gold were reportedly produced from Caribou Creek by 1968 (Bundtzen, 1981). Mining since that time has produced at least 2,000 oz according to recent production figures.

Location 18 (Appendix A, p. 54)

During August, 1983, a mining company mobilized a medium-scale operation into the upper Caribou drainage (fig. K-18). An airstrip, 6 miles of road access, and a large permanent camp were constructed and installed prior to production. By early September this 24 hr/d operation had processed coarse gravels near the end of the uppermost set of Carrington tailings. The gravel deposits at this point are up to 300-ft wide and 3- to 5-ft deep. The gravels are underlain by a weathered schist bedrock. Several shears containing shattered quartz and pyrite were observed in bedrock exposures. These vein/shear deposits could be gold-bearing and may be one source for placer gold in Caribou Creek.

A large bulldozer was preparing and leveling the deposit ahead of the mining plant, and a 2-cy backhoe was loading the pay gravels into a medium-capacity, portable, shaker-screen/sluice plant. Mining had just begun at the time of our 1983 examination, and production is not known. Gold observed in the sluice box was rough; one nugget showed dendritic textures and attached quartz. Abundant magnetite and garnet were also observed in the concentrates.

Location 7 (Appendix A, p. 26)

Two men processed gravels with a medium-capacity, portable, trommel/sluice on a flat-lying stream bottom deposit in the middle portion of Caribou Canyon (fig. K-18). The mine was located on a meander bar up to 150-ft wide by 600-ft long. Coarse gravels up to 9-ft deep were mined to a weathered schist bedrock. The area had been stripped of a veneer of soil by a large bulldozer which was also used to level and contour tailings after mining. The pay gravels were fed into the washing plant with a large backhoe. Fine gold was distributed throughout the gravels but concentrated near bedrock. An average of 6 in. of bedrock was also being mined. A small percentage of the gravel near the edge of the drainage was frozen and not mined. Gold is very flaky, and over 87% of the gold produced was under jewelry size. Nugget-sized gold is well-worn. All the gold is stained with oxide coatings.

Approximately 2,400 cy of material yielded 110.7 oz of gold and resulted in a placer gold grade of 0.046 oz/cy. Gold content at 700 fine would be 0.032 oz Au/cy. A price factor of 0.74 was determined for placer gold produced at this locality. Mining produced about 1.9 oz Au/hr of operation. As mining progressed across the point bar of the stream, gold production increased considerably and the operator states he was producing over 2.5 oz Au/hr (personal communication, Jerome Koppenburg, 1983).

Location 10 (Appendix A, p. 35)

A medium-capacity, portable, shaker-screen/sluice plant was located approximately 1,000 ft upstream (fig. K-18). The gravels at this location were similar to the above deposit and averaged 5-ft deep. An area from 200- to 300-ft wide and 1,000-ft long had been cleared by a bulldozer prior to mining. The mine was located on the outside edge of the present stream meander.

An average of 85% of the gold recovered was fine and platy and distributed throughout the gravels but concentrated on a schist bedrock. Jewelry-sized gold was also flaky and consisted of well-worn nuggets. Most nuggets are relatively small, but a 1.5 and a 0.75 oz nugget were recovered in 1983. An occasional quartz-filled shear was observed in the bedrock, and an average of 6 in. of bedrock was being mined. Concentrates contained abundant garnet and magnetite.

Measurement of a large cut indicated that approximately 2,800 cy had been mined. Processing of the concentrate from this cut recovered 106.35 oz of gold. The placer gold grade of the deposit is estimated to be 0.038 oz/cy. Gold content at 700 fine would be 0.027 oz Au/cy. A price factor of 0.75 was determined for placer gold produced at this locality. Mine production from the cut averaged 1.5 oz Au/hr. The next cleanup reportedly produced 2.1 oz Au/hr of operation. A third cleanup produced 235 oz Au at over 2.5 oz Au/hr. The grade of the deposit increased as mining progressed across the stream bar (personal communication, Sam Koppenburg, 1983).

Location 6 (Appendix A, p. 21)

A medium-scale operation mined 24 hr/d in the canyon on the lower portion of Caribou Creek (fig. K-18). A wide, flat-lying deposit, 100- to 200-ft wide, was being mined to an average depth of 5 ft to a schist bedrock. A bulldozer was used to remove a thin layer of overburden and to level tailings after mining. A 2-cy-capacity backhoe loaded pay gravels and an average of 6 in. of bedrock into a portable, shaker-screen/sluice plant. A small portion of the gravels were frozen near the edge of the drainage and could not be mined.

Fine, flake gold is distributed throughout the gravels and only 3% of the gold recovered was over 1/4 in. in size. The jewelry-size gold was mostly platy or well-rounded nuggets although an occasional, rough, quartz-bearing nugget was recovered. The rough nuggets and a quartz-bearing shear zone observed in the bedrock indicate gold-bearing veins may be nearby and could be a source for gold in the placer deposits.

Measurement of the mine cut indicates that approximately 13,000 cy of gravel had been mined. Processing of the concentrates recovered 354.3 oz of gold, 86% of which was fine flake gold. The placer gold grade of the deposit is estimated to be 0.027 oz/cy. Gold content at 680 fine would be 0.019 oz Au/cy. A price factor of 0.74 was calculated for placer gold produced from this locality. Testing with a suction dredge by the operator of similar deposits upstream indicates grades similar to those being mined here can be expected upstream.

Spruce Creek

Physiography and Quaternary Geology

Spruce Creek (fig. K-19) heads in a V-shaped valley. Gravels in the upper 2 miles of the drainage are from 10- to 100-ft across. The average stream gradient is 350 ft/mile. Evidence of hand workings were observed in this section of the drainage, and Brooks (1911) reports the stream contained narrow and shallow pay streaks of coarse gold.

The lower 2 miles of Spruce Creek lie in the Moose Creek Valley. This portion of the drainage was glaciated at one time, as evidenced by glacial erratics contained in a bench deposit at the valley margin. The bench deposit overlying a topographic low between Glen and Spruce Creeks was formed when nearby Glen Creek apparently flowed into Spruce Creek. The deposit consists predominantly of reworked glacial sediments. Below the bench, the stream bed is incised into a large alluvial fan complex which overlies glacial outwash terrace deposits of Moose Creek. The stream gradient here is 150 ft/mile. The gravels vary in depth from 3 to 20 ft and contain some clasts of glacial origin. Since the gold recovered from test pits and from a mining operation on the stream is very bright, well-worn and flaky, it probably has been reworked.

Sampling

Five test pit samples (A1462-A1466) were obtained from stream bottom deposits and from the bench deposit on the Spruce-Glen Creek saddle. Three of the samples yielded only traces of gold. Sample A1462 was obtained from stream gravels and yielded 0.0012 oz Au/cy. Sample A1466, obtained from a 9-ft-deep deposit of gravel on the lower section of the drainage, contained 0.005 oz Au/cy. A 2-ft interval on bedrock from this sample contained 0.011 oz Au/cy. Approximately 15 pits on the lower drainage were tested by a consulting geologist during the 1983 season. His test results were generally low, but a few samples were in the 0.01 oz Au/cy range (personal communication, Robert O. Lister, 1983). These results also demonstrate the sporadic nature of pay gravels in the lower portion of the Spruce Creek drainage.

Mining

A few large and small mining cuts are present on the lower section of the drainage. Several thousand cy were mined during the 1976 season with considerable amounts of gold recovered (Bundtzen, 1981). A smaller scale mining operation during the 1981 season produced approximately 0.01 oz Au/cy (personal communication, Dan Ashbrook, 1983). A total of 1,183 oz

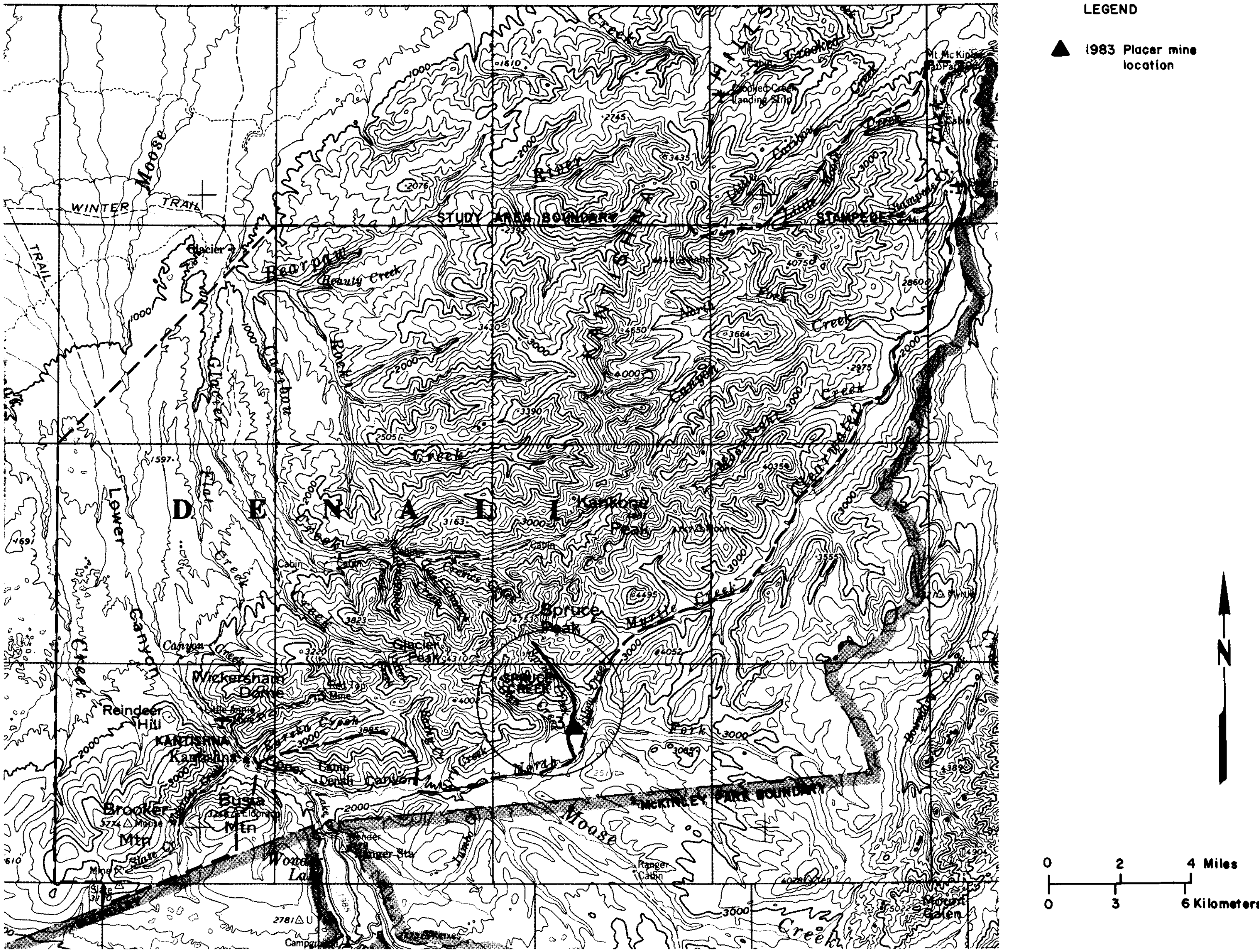


Figure K-19 Spruce Creek and placer mine location, Kantishna Hills study area were reportedly produced by 1968 (Bundtzen, 1981). An estimated production since then of 1,000 oz is based on amount of tailings present and grades reported.

The narrow and restricted nature of the mine cuts and a large discrepancy in test pit results indicate that definite, but discontinuous pay steaks have developed on the lower portion of the drainage. Two mine cuts are located on wide areas where the gradient has decreased considerably. It is interesting to note that recent mining production has been concentrated on the drainage below the Glen-Spruce bench deposit.

Location 3 (Appendix A, p. 12)

In 1983, two men mined shallow gravels on a test basis near the mouth of Spruce Creek (fig. K-19). A large backhoe was used to feed a medium-capacity, shaker-screen/sluice plant. A small, 40-cy test cut produced 0.21 oz of fine, bright, flake placer gold. Placer gold grade of gravel from the cut is estimated at 0.005 oz/cy. At 800 fine the gold grade of the deposit would be 0.004 oz Au/cy. Because the amount of jewelry-size gold is not known, a price factor of at least 0.8 was assumed for placer gold at this locality.

Glen Creek

Physiography and Quaternary Geology

Glen Creek (fig. K-20) forks in its upper reaches; each fork is approximately 1-mile long. Stream gradient is approximately 400 ft/mile. Gravel deposits in the upper section of the creek range from 30- to 200-ft wide and are between 3- and 5-ft deep. Terrace deposits north of the West Fork and on both sides of the juncture are composed of coarse, unsorted alluvium. Terrace gravels average 25 ft in depth, are over 1-mile long, and up to 600-ft across. At the juncture of the two forks is a large basin containing an accumulation of coarse gravel up to 35-ft deep. For the next 2 miles the stream occupies a bedrock-walled canyon, 20- to 150-ft wide. The stream gradient along this section is approximately 200 ft/mile. The last mile of the drainage is located in the Moose Creek Valley and is deeply incised into a large alluvial fan deposit overlying Moose Creek terrace gravels. The lower segment has a gradient of approximately 100 ft/mile. Gravels are up to 10-ft deep and up to 300-ft wide. Some glacial erratics occur in the gravels.

Sampling

Test pit samples A1467 through A1469 contained 0.0127, 0.0043, and 0.0199 oz Au/cy, respectively. Bedrock at sample location A1469 contained a large, pyritiferous quartz vein, which may be one source of placer gold in Glen Creek. Samples A1472 and A1473 taken on lower Glen Creek approximately 0.5 miles upstream from its mouth, contained 0.0063 oz Au/cy and 0.0228 oz Au/cy. Samples A1470 and A1471, obtained from the top and bottom of the terrace deposit on the West Fork, contained 0.0027 and 0.0093 oz Au/cy, respectively. Three independent tests of the terrace deposit by a mine operator's consultant during the 1983 season showed an average value of under 0.002 oz Au/cy according to an unpublished company report (Sandy, 1983). Test results from 46 backhoe pits in recent stream gravels in upper Glen Creek averaged 0.007 oz Au/cy.

Mining

Glen Creek has been mined along its entire length since the early placer gold discoveries. It has been intensively mined with mechanized equipment for the last 10 years. Approximately 48 acres and 590,000 cy of placer gravels have been mined to date, and most tailings are bordered by minable widths of gravels.

Recorded production by 1968 was 2,250 oz gold (Bundtzen, 1981). If the 590,000 cy of recently mined gravels averaged 0.015 oz Au/cy (lowest value being mined presently), an estimated 8,850 oz gold may have been produced since that time.

Location 8 (Appendix A, p. 29)

Two mining operations were active during the 1983 season. One operation utilizing a medium-capacity, shaker-screen/sluice plant was processing 5-ft deep, 100- to 200-ft-wide gravel deposits on the East Fork of Glen Creek (fig. K-20). The mine, capable of operating 24 hr/d, used large mechanical

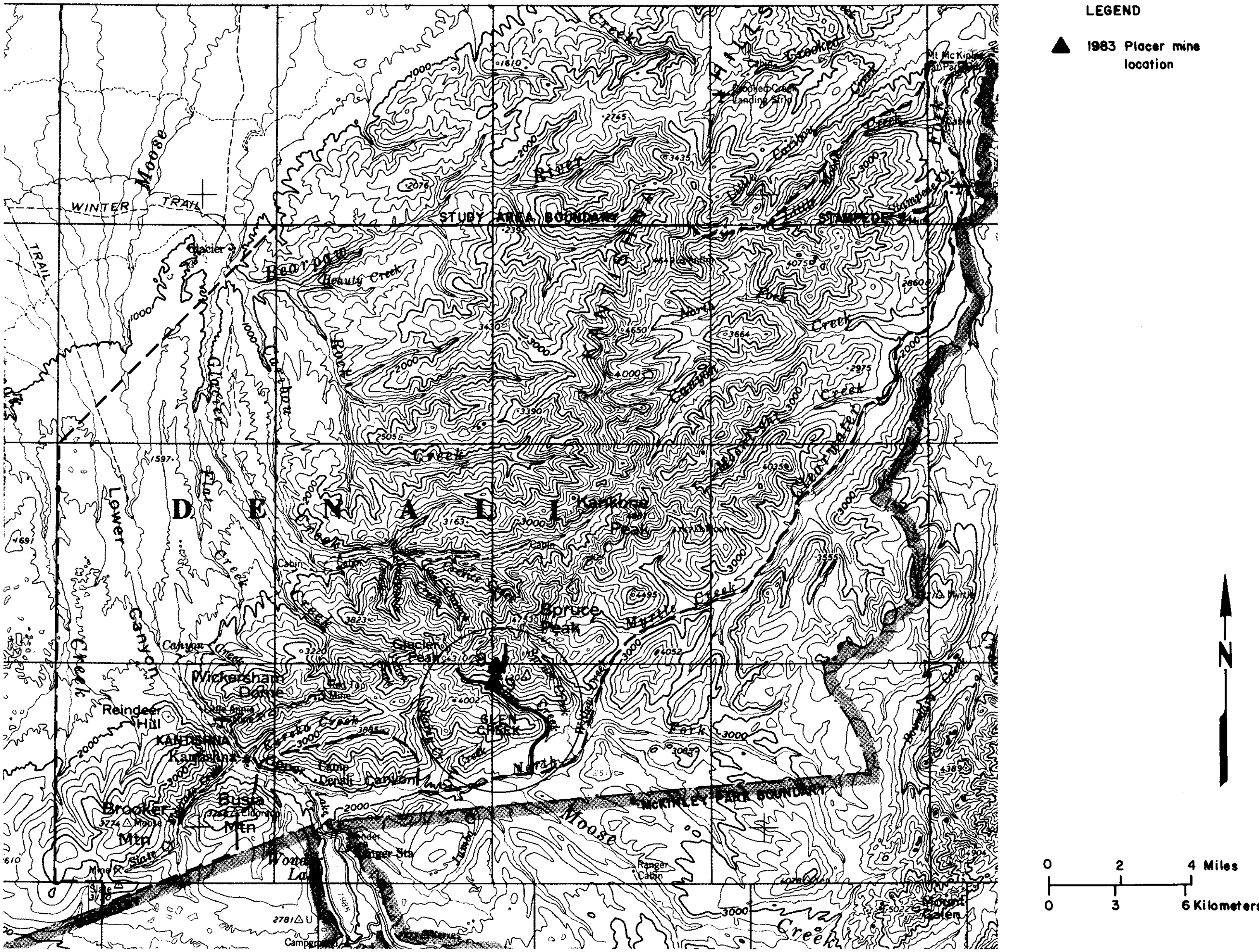


Figure K-20 Glen Creek and placer mine locations, Kantishna Hills study area equipment for stripping and loading the pay gravels and for reclamation work. The deposit consisted of coarse gravels underlain by a weathered quartzitic schist bedrock. Most gold was concentrated at or in the bedrock surface. Harder sections of bedrock created natural riffles where comparatively rich accumulations of gold were mined.

Approximately 40% of the gold recovered from this operation was jewelry- or nugget-size gold. The gold was rough and often crudely crystalline showing dendritic and wire textures. Large nuggets often contain attached quartz. Mine concentrates also contained abundant galena and pyrite with some stibnite, scheelite, and occasional rhodochrosite.

Measurements of the mine cut indicate that approximately 9,400 cy of gravel had been mined. Recovery of 173.6 oz of gold yields an estimated placer gold grade of 0.018 oz/cy. Gold grade at 800 fine would be 0.015 oz Au/cy. A price factor of 0.91 is indicated for the placer gold recovered. Subsequent gold production from gravels adjacent to the measured cut was reportedly higher grade (personal communication, Richard Lohr, 1983). This latter production was from an area of old hand workings and in an area where the company had obtained much lower values in test pits. The lower test values were probably due to nugget effect. Two nuggets weighing 1.5 and 0.75 oz were recovered during the course of the 1983 season.

Location 9 (Appendix A, p. 32)

A medium-scale operation at the juncture of the East and West Forks of Glen Creek was mining a 5-acre area of deep, coarse gravels (fig. K-20). Poorly-sorted gravels were being mined to a depth of 20 ft and bedrock had not been reached. The pay gravels were being pushed as far as 200 ft by a large bulldozer and loaded into a stationary, shaker-screen/sluice plant with a backhoe. Gold is apparently distributed throughout the gravels since bedrock was not reached and new nuggets were recovered from the sluice box each time mining ceased. The gold is typically very coarse, rough, and often crudely crystalline. Larger nuggets commonly have attached quartz. The operators have recovered numerous 1- to 7-oz nuggets from this area (personal communication, Eric and Paul Wieler, 1983). Most gold is coated with manganese and iron oxides. Concentrates from the mining operation also contained abundant galena and pyrite with stibnite, scheelite, and some rhodochrosite.

The volume of gravel mined was estimated to be 2,300 cy. This estimate was made by counting the number of bucket loads processed. Placer gold aggregating 41.87 oz was recovered and a placer gold grade of 0.018 oz/cy was calculated for the deposit. This figure is low as a few ounces of fine gold had yet to be recovered. At 800 fine the gold grade would be 0.015 oz Au/cy. A price factor of 0.86 was calculated for this deposit. A few nuggets in the 0.5-oz range were also recovered from this cleanup.

Rainy Creek

Physiography and Quaternary Geology

Rainy Creek (fig. K-21) is a 15- to 50-ft wide, steep tributary to upper Moose Creek. The upper 2 miles has a stream gradient of over 400 ft/mile. About 1-mile upstream from its mouth the drainage leaves the steep hills and incises a large, inactive alluvial fan. A large terrace gravel deposit borders the stream at the canyon mouth. At this point the drainage appears to have been occupied by glacial ice because reworked till is mixed with the locally derived gravels in the fan. No gold production is recorded for the drainage, and relatively little evidence of mining activity indicates production is probably insignificant.

Sampling

Two reconnaissance samples were obtained in the upper part of this drainage. Sample A3042 contained 0.0003 oz Au/cy, and another (A3043), obtained about 0.25 miles above the site of a 1983 mining operation (Location 19), contained just over 0.01 oz Au/cy.

A backhoe-pit sample (A1475), of mixed fan gravels near the stream yielded 0.0004 oz Au/cy. This sample was obtained about 0.5 miles downstream from a recently cleared mining area and contained mostly reworked glacial till material.

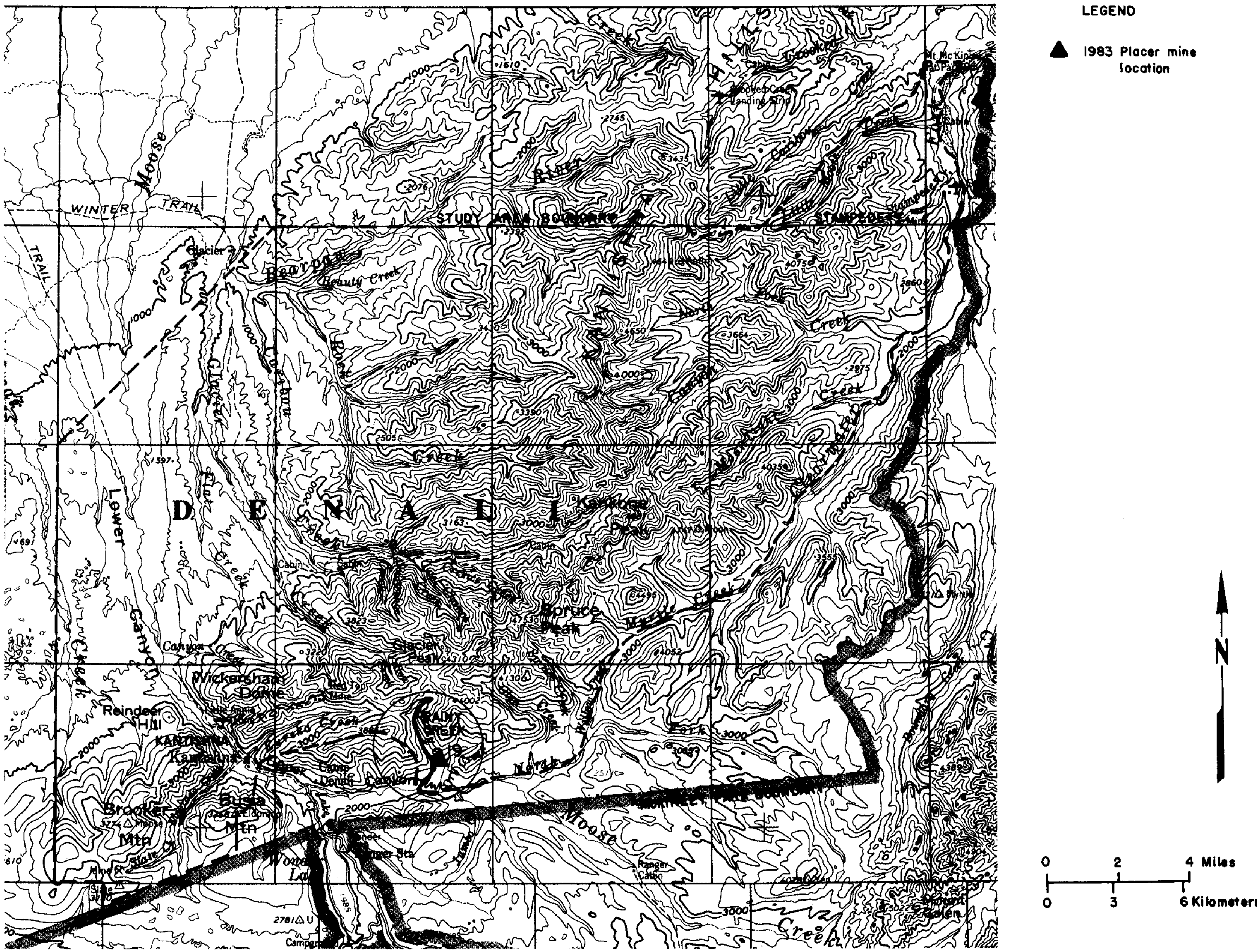


Figure K-21 Rainy Creek and placer mine location, Kantishna Hills study area

Mining

Location 19 (Appendix A, p. 56)

Evidence of previous hand mining exists in the upper stream section. A 0.5-mile-long section of stream located just above the alluvial fan deposit averages 150-ft wide and is up to 15-ft deep. A small portion of this area has been mined in the recent past with mechanized equipment and was the site of a medium-sized placer mining operation late in the 1983 season (fig. K-21). A large area had been cleared for mining and equipment was being installed in early September. Equipment breakdown precluded any 1983 production. Another small mined area was observed in the stream bottom at a point where it begins to cut into the alluvial fan. Results of this mining are not known.

After the washing plant at Location 19 malfunctioned, the operator ran a few tests of the gravels near his prepared mine site and found only traces of gold (personal communication, Gary Miller, 1983).

Willow Creek

Physiography and Quaternary Geology

This drainage (fig. K-22) is narrow and contains relatively shallow deposits of coarse gravel. The average stream gradient is about 240 ft/mile. The lower 0.5 mile of the stream is incised into a large alluvial fan and Moose Creek terrace complex. The entire Willow Creek drainage was glaciated at one time.

Sampling

Two reconnaissance samples (A3059-A3060) contained grades of 0.0002 oz Au/cy.

Several prospect pits were excavated with a large backhoe during the 1983 season by a mine operator along the lower 1 mile of the stream. Results of the testing are not known, but presumably were discouraging.

PLACER RESOURCE SUMMARY

In determining placer resource potential, surficial deposits were categorized as having high, moderate, low, or undetermined potential. This classification was applied to inferred reserves and potential resources both on and off existing claims. Deposits that are covered by claims and have high potential are classified as Inferred Reserves on table K-4. Deposits covered by claims with moderate or undetermined potential are classified as Potential Resources on this table. The classification was used to determine the minimum (Inferred Reserves) and maximum (Inferred Reserves plus Resources) mine life of the deposits under claim using the current production rate of mining operations. Table K-5 summarizes the total placer resource potential of claimed and unclaimed deposits in the Kantishna Mining District. Appendix A, table A-5, shows volume calculations for different gravel types on individual drainages and plate K-3 shows individual resource calculation blocks used in measuring gravel volumes.

Placer gold resource potential was established by combining the 1983 placer evaluation study results with results of previous work reported in private and public reports. Geologic inference was used to project data from current placer mining operations into adjacent and similar unmined areas. Appendix A, p. 92, Placer Evaluation Procedures, explains in detail the criteria and methods used to assess placer resource potential.

Approximately 42.6 million cy of stream, floodplain, and terrace gravel deposits are estimated to have high resource potential. This classification indicates that reserves are established or favorable geologic conditions provide a high probability of establishing minable reserves. These deposits are located on Spruce, Glen, Rainy, Eureka, Friday, Eldorado, Lower Moose, Glacier, Yellow, Caribou, Crevice, Little Moose, and Stampede Creeks and the Bearpaw River. Approximately 17.5 million cy of gravel having high resource potential are currently under mining claim.

An additional 21.1 million cy of primarily terrace gravels are considered to have moderate resource potential. This classification indicates that no reserves are established but geologic conditions are permissive for economic

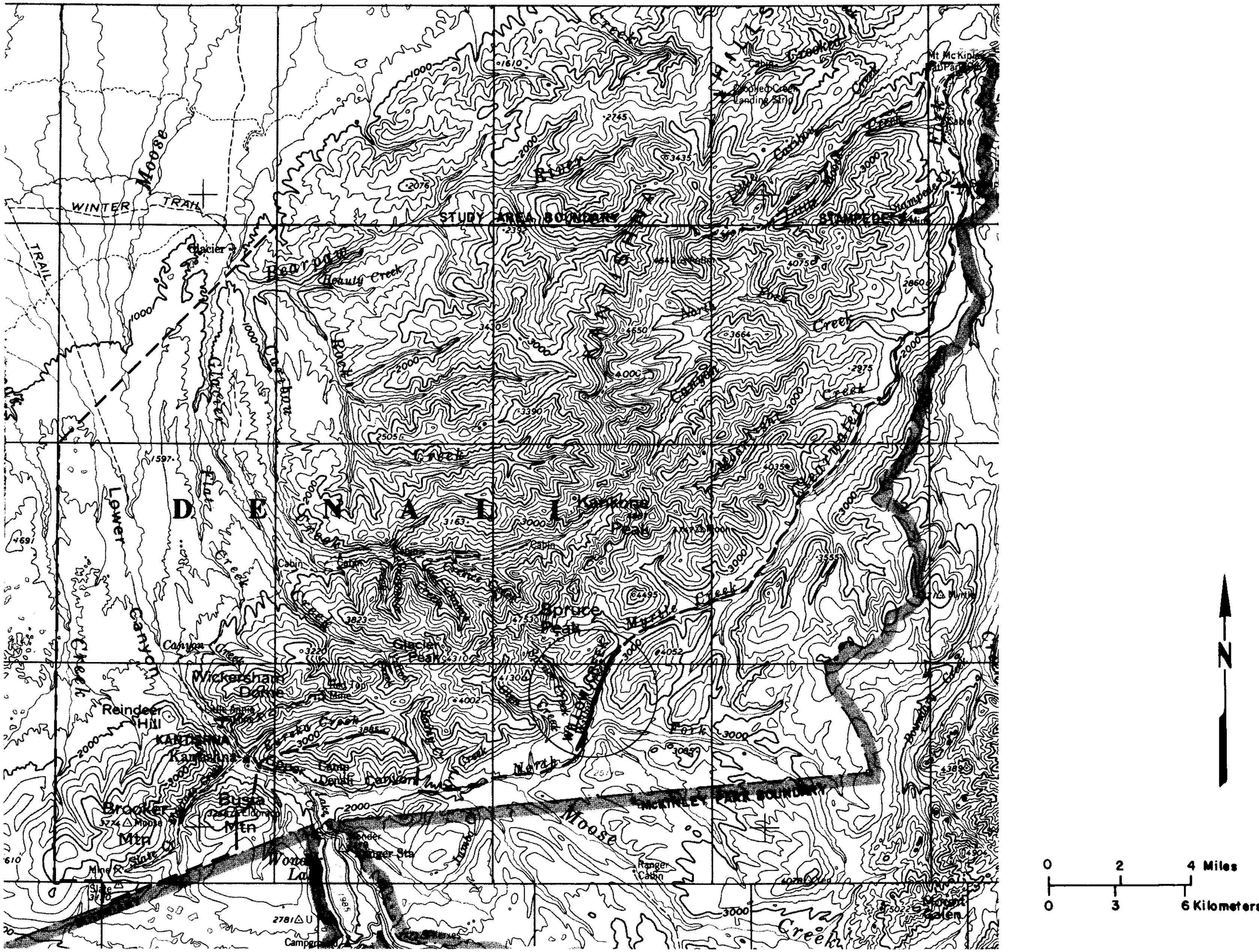


Figure K-22 Willow Creek location, Kantishna Hills study area

Table K-4 - Kantishna Hills Study Area

Estimate of Inferred Reserves and Resources of Gold Placer Deposits Covered by Mining Claims

Drainage	Inferred Reserves[1] (cubic yards)	Resources[2] (cubic yards)	Minimum Mine Life (Inferred Reserves/ 800,000 cubic yards per year)	Maximum Mine Life (Inferred Reserves plus Resources/ 800,000 cubic yards per year)
Willow				
Spruce	500,000	500,000		
Glen	730,000	2,490,000		
Rainy	5,000	810,000		
Eureka	390,000	335,000		
Friday	2,090,000			
Eldorado	300,000	12,000		
Upper Moose		18,430,000		
Lower Moose	3,700,000			
Glacier	2,700,000			
Yellow	30,000	24,000		
Caribou	7,120,000	1,800,000		
TOTAL	17,565,000	24,401,000	17,565,000/800,000 = 22 years	41,966,000/800,000 = 52 years

[1]Volume of gravel covered by mining claims which is estimated to have high resource potential.

[2]Volume of gravel covered by mining claims which is estimated to have moderate potential and/or undetermined potential.

Table K-5 - Kantishna Hills Study Area Placer Resource Potential Estimates

Drainage	High Potential[1] (cubic yards)	Moderate Potential[2] (cubic yards)	Low Potential[3] (cubic yards)	Undetermined Potential[4] [5] (cubic yards)
Willow			250,000	
Spruce	600,000	600,000	1,300,000	
Glen	730,000	2,600,000		590,000
Rainy	15,000			1,010,000
Eureka	425,000	775,000		140,000
Friday	2,090,000		150,000	
Eldorado	300,000			12,000
Upper Moose		12,800,000		79,800,000
Lower Moose	15,100,000		1,200,000	120,600,000
Glacier	6,550,000		230,000	10,500,000
Yellow	35,000			24,000
Caribou & Lower Bearpaw River	15,910,000	1,500,000	1,890,000	1,800,000
Unnamed Caribou Tributary			700,000	
Crevice	100,000			
Last Chance				100,000
Snowshoe				*
Flat		2,600,000		
Little Moose	500,000			750,000
Myrtle		240,000		
Stampede	215,000			500,000
Bearpaw			*	
Canyon			*	
Moonlight				*
Clearwater Fork				*
Rock			*	*
Beauty				*
Upper Bear			*	
Lower Bear				*
TOTAL	42,570,000	21,115,000	5,720,000	215,826,000

1 Established reserves or geologic conditions offer a high probability of establishing minable reserves for an economic operation.

2 No reserves established. Geologic conditions are permissive for establishing minable reserves.

3 No reserves established. Geologic conditions are poorly suited for establishing minable reserves.

4 Untested. Gold-bearing gravels of possible economic grade may reasonably be expected to exist based on geologic projection from known auriferous gravels.

5 Deep dredge deposits amounting to 87.9 million cy are hypothetical and are not included in this total.

* Significant deposits for which volume estimates are not available.

concentration of placer gold. These deposits are located on Spruce, Glen, Eureka, Upper Moose, Caribou, Flat, and Myrtle Creeks. Approximately 14 million cy of gravel having moderate resource potential are currently under mining claim.

Approximately 5.7 million cy of surficial material in the southern Kantishna Hills have low resource potential. A portion of this yardage is in placer tailings but also includes stream gravel deposits on Willow Creek and parts of Spruce Creek. No known reserves occur in these deposits and geologic conditions are poorly suited for concentrations of placer gold. Drainages in the northern part of the study area, for which volume calculations are not available, also have low placer resource potential. These areas include the drainage basins associated with Canyon Creek, including the North Fork of Canyon Creek, most of Rock Creek, and the Bearpaw River above its junction with Caribou Creek. Other areas, incompletely evaluated but suspected to have low placer gold resource potential, include Bear Creek and other streams draining the west slope of Brooker Mountain and Alpha Ridge, and Moonlight Creek.

Approximately 216 million cy of surficial materials are currently unevaluated, but based on geologic projection from known deposits gold-bearing gravels of possible economic grade may exist. Approximately 10.4 million cy of unevaluated gravel are covered by existing claims. These deposits occur primarily in terrace and alluvial fan deposits on Upper and Lower Moose, Glacier, Caribou, Glen, Rainy, Eureka, and Eldorado Creeks. Extensive volumes of unevaluated potential placer resources, for which volume calculations are not available, also exist in other parts of the study area. These include deposits on Last Chance, Snowshoe, Little Moose, Myrtle, Stampede, Moonlight, Clearwater Fork, Rock, Beauty, and Lower Bear Creek.

Portions of the Moose Creek terrace and floodplain gravels are underlain by a thick accumulation of glacial outwash. Although this material is largely barren of gold, it is possible that preglacial deposits are buried beneath them. An estimated 87.9 million cy could be present. Because these deposits are hypothetical and not minable by existing equipment in the district, no resource estimates were assumed in calculating potential mine life of the deposits.

It is estimated that 800,000 cy of material can be processed annually when existing mines are fully operational. At that rate of production it would take 22 years to mine inferred reserves from deposits classified as having high potential on existing claims. An additional 30 years would be required to mine additional resources on existing claims that have moderate potential or are currently unevaluated.

PRECIOUS-METAL VEIN DEPOSITS

By C. J. McKee

INTRODUCTION

Production of precious metals from lode mines in the Kantishna region has come from several small, high-grade deposits. Previous investigators grouped the precious-metal lodes into two types: (1) silver-predominant lodes consisting of galena-sphalerite-tetrahedrite-pyrite-chalcopyrite-silver with siderite gangue, and (2) gold-predominant lodes, consisting of quartz-arsenopyrite-pyrite-(scheelite)-gold. Further work has shown that these deposits may be geologically gradational. In addition, fluctuating precious metal prices in the past 60 years have made the deposit classification less distinct on an economic basis. Several major deposits, however, are sufficiently different to warrant separation and for convenience the deposits are discussed below as being either gold- or silver-predominant.

This investigation attempted to evaluate known deposits and determine the potential for additional high-grade lode deposits along mineralized structures. Work performed in areas of precious-metal vein deposits during this study included core drilling, geophysical surveys, soil geochemical surveys, and geological mapping. Much of the work centered on the Quigley Ridge area because of the high concentration of prospects and restriction on drilling off patented claims (plate K-8).

Twenty-two holes were drilled on nine prospects (fig. K-23, plate K-5). A summary of significant drill hole intercepts is shown in table K-6. Surface samples from the Banjo Mine contain up to 0.72 oz Au/ton, 3.04 oz Ag/ton, and 19% W. Geophysical surveys detected a good conductor near the structure at the Red Top Mine and a moderate resistivity low along the Jupiter-Mars structure. Soil samples collected across projected vein trends at several locations on Quigley Ridge were anomalous in total metals.

MINERALOGY

The following minerals have been identified in vein deposits (including antimony lodes) by previous investigators (principally Wells, 1933, and Bundtzen, 1981): gold, arsenopyrite, pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, freibergite, scheelite, stromeyerite, bournonite, stephanite, stibnite, pyrargyrite, cassiterite, boulangerite, jamesonite, marcasite, covellite, pyrrhotite, polybasite, and the supergene oxidation products scorodite, melanterite, azurite, malachite, cerussite, stibiconite, and kermesite. Identified nonmetallic gangue minerals include quartz, calcite, siderite, and minor tourmaline and barite.

Examination of thin sections and polished sections of vein material indicates five periods of gangue and sulfide deposition (Bundtzen, 1981). While most sulfide mineralization probably occurred in the mesothermal temperature range, the presence of both low- and high-temperature minerals and the complex mixture of sulfides in some of the deposits indicate a wide range of temperatures during several periods of mineralization. An attempt to obtain ages for mineralization through isotopic analyses of lead from galena was unsuccessful (Bundtzen, 1981).

In the depositional sequence of metallic minerals, arsenopyrite and pyrite are deposited early; boulangerite, jamesonite, and stibnite are late stage (Bundtzen, 1981). Silver and antimony sulfosalts, where present, are generally mid- to late-stage. Sphalerite, chalcopyrite, galena, and tetrahedrite occur over a broad range of temperatures of formation and occasionally during several different periods of mineralization in the same deposit.

Deposition of nonmetallic gangue minerals usually began with quartz and/or siderite during the early stages of sulfide mineralization, followed by calcite, barite, and tourmaline.

Previous investigators have differed as to whether the silver in these deposits occurs in lead or copper minerals. A review of assays from previous studies, production records, and numerous samples from the present study indicates that silver is carried in both galena and tetrahedrite although the highest silver assays are usually in copper-rich samples. A combined silver-copper anomaly should, therefore, be a good indicator of high-grade silver deposits in the district.

The bonanza silver lodes usually contained significant amounts of gold. An examination of assays from previous studies and drill core analysis from this study show that gold does not always correlate with silver; but does correlate closely with arsenic, which most likely occurs as auriferous arsenopyrite.

STRUCTURE

Most of the vein deposits in the Kantishna area are apparently fault controlled. The veins occupy structures along the trend of, and usually subparallel to, the Kantishna Anticline. Strikes range from N. 30° E. to N. 70° E. Most previous investigators have described the veins as dipping steeply to the southeast. While this apparently is true near surface, core drilling during this study indicates that several of the veins change attitude quickly with depth, the southeast dip steepening to near vertical and possibly overturning to the northwest.

Several veins with northwest dips have also been recognized in outcrop. The intersection of southeast- and northwest-dipping veins has been proposed as the structural control for bonanza silver lodes on Quigley Ridge (Seraphim, 1961), and the massive stibnite lode at Stampede (White, 1942; and Barker, 1963).

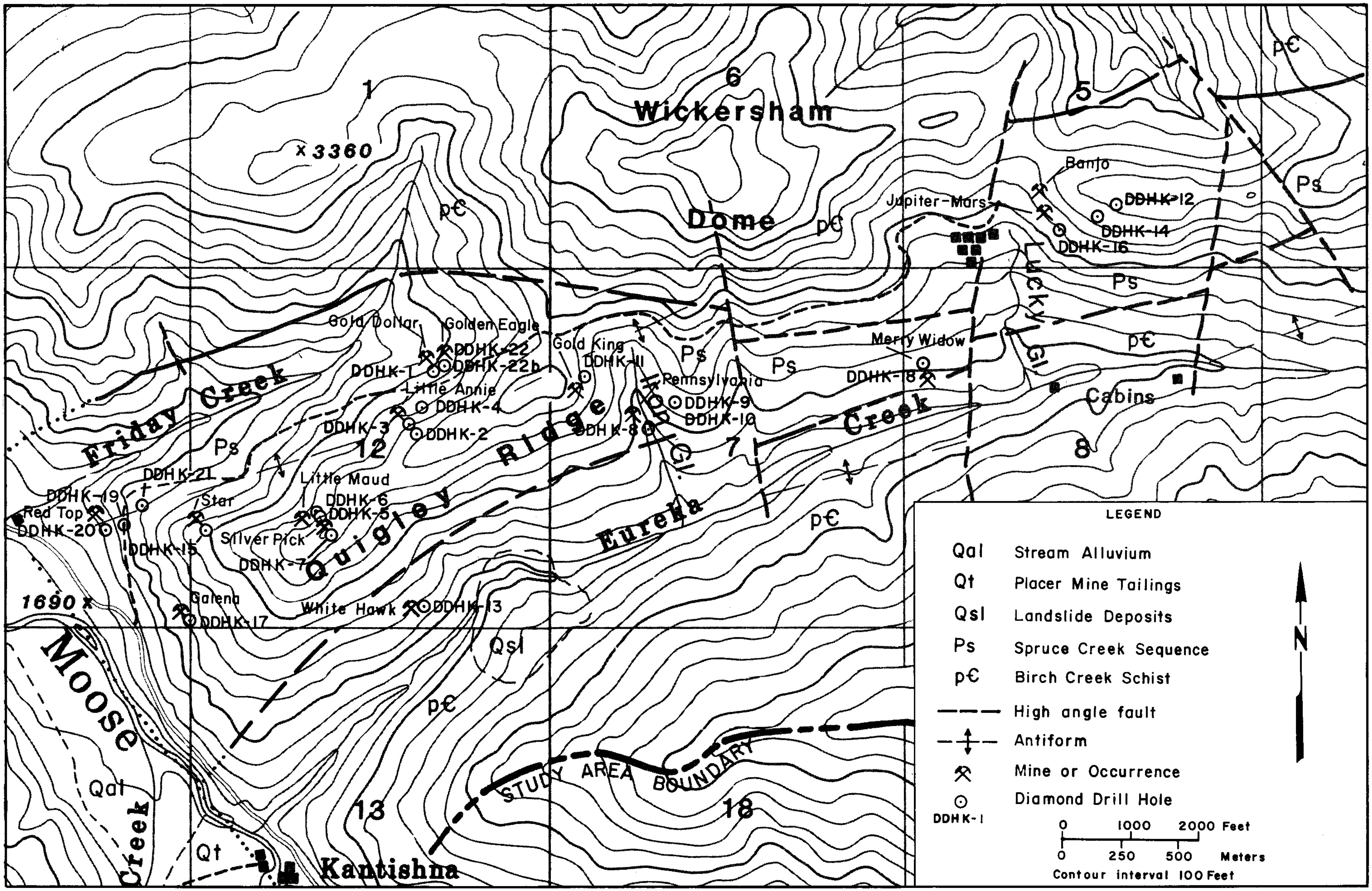


Figure K-23 Drill Hole Index and Geology Map — Kantishna Hills Study Area

Table K-6 - Drill Hole Summary

Hole No. (Total Depth)	Area	Mineralized Intercept (ft) Projected	Actual	Length	Au oz/ton	Ag	Cu % or ppm	Pb	Zn	As	Sb	Remarks
DDH K-1 (158.8')	Gold Dollar	100'	100.5-106.7	6.2'	ND	ND	0.002%	0.002%	0.905%	0.110%	36	Mylonitic crush breccia structure present, weakly mineralized. Psf with qz and cal veinlets, breccia and clay.
DDH K-2 (280.3')	Little Annie	210'	Not reached, 224.2-224.9	0.7'	0.047	1.79	0.006%	0.785%	0.037%	1.95%	65	Hole problems, abandoned at 280.3' due to caving conditions. Badly fractured interbedded Psf, Psfg, and Psg with several small clay and crush zones containing qz and minor sulfides. Anomalous Zn in country rock.
DDH K-3 (166.5')	Little Annie	75'	103.0-141.0	38.0'	0.023	0.44	0.01	0.04	0.08%			Crushed clay and qz heavily lim stained with py and apy within an extremely fractured and broken Psf/Psfq host rock, poor recovery core runs of less than 1 ft.
			112.1-122.3	10.2'	0.69	1.89	0.03	0.02	0.14%			
DDH K-4 (300.7')	Little Annie	100-200'	None	-		*			*			Hole drilled on geophysical target several small clay and crush zones encountered. Interbedded Psf and Psg. Anomaly explained by graphitic schist and pyrite. Slightly anomalous Ag and Au entire hole.
DDH K-5 (195.7')	Little Maud - Silver Pick	50'	33.0-64.5	31.5'	0.022	1.16	0.019	0.062	0.174%	2.981%	54ppm	Qz/calcite breccia vein with strong lim, apy and py 33-64.5'. Second structure with less qz in highly fractured Psf.
			46.0-49.8	3.8'	0.082	8.67	0.039	0.288	0.340%	1.05%	240ppm	
			79.5-88.5	9.0'	0.025	0.046	29ppm	157ppm	827ppm	0.267%	14ppm	
DDH K-6 (186')	Little Maud - Silver Pick	150'	68-76	8.0'	-	-	-	-	-	-	-	Barren qz vein at 68-76', structure is probably cut off by the 1st vein intersected in K-5.
			149.5-168.2	18.7'	-	-	-	-	-	-	-	Structure indicated by cataclastic deformation bounded by qz/lim cemented breccia. Weak to tr mineralization.

*NOTE: See geology map, fig. K-6, for description of geologic units.

Table K-6 - Drill Hole Summary

Hole No. (Total Depth)	Area	Mineralized Intercept (ft) Projected	Actual	Length	Au oz/ton	Ag	Cu % or ppm	Pb	Zn	As	Sb	Remarks
DDH K-7 (281.9')	Silver Pick	170'	128-169	41.0'	-	-	-	-	-	-	-	Qz/cal breccia with fault clay and Psfq clasts, structure weakly mineralizled. Recovery very poor approx. 10% through structure.
			167-169	2.0'	0.028	ND	ND	0.004%	0.008	0.435%	10	
DDH K-8 (182.7')	Iron Gulch	140'	132.5-154.8	22.3	0.052	0.066	Tr	Tr	Tr	0.130%	9	Brecciated Psfq with qz, lim and banded vuggy dolo/qz vein.
			147-150	3.0'	0.294	0.276	10	ND	5	20	6	
DDH K-9 (244')	Iron Gulch	120'	33.5-57	23.5'								Brecciated qz vein w/cal cement and Psfq clasts lim and fault clay. Void 43.5-52.0', poor recovery through entire section.
			34.5-43.5	10.0'	0.12	ND	Tr	Tr	0.003%	535	4	
DDH K-10 (103')	Iron Gulch	30'	24.5-69	44.5'								Brecciated dolo, qz, cal vein material with Psfq clasts and clay several zones weakly mineralized with detectable Au.
			49.3-52	2.7'	0.023	ND	ND	ND	ND	390	2	
			59-60	1.0'	0.029	ND	ND	ND	0.002%	270	4	
DDH K-11 (146.8')	East Gold King	190'	103-108	5'	ND	ND	ND	ND	0.007%	ND	ND	Structure present as fault clay and crush, not mineralized.
DDH K-12 (304.8')	Jupiter-Mars	180'	215-267-8	51.9'	0.017	0.656	0.111%	0.862%	0.756%	1.20%		Brecciated qz vein w/lim py gn sph within Psfq country rock. Hole anomalous in zinc.
			224.7 226.5	1.8'	0.063	7.31	0.665%	4.15%	0.965%	1.65	445	
DDH K-13 (183')	White Hawk	Float	None									No mineralized structure, host rock is Birch Creek Schist.
DDH K-14 (399.1')	Jupiter-Mars	235'	309.2-363.2	54'	0.014	ND	441	144	215%	1.21%	23	Brecciated Psfq and qz vein material w/qz cement vuggy, lim w/py, ap. Highly anomalous in zinc entire hole.
			323-331.3	8.1'	0.025	ND	0.079%	0.269%	1.05%	1.92%	34	
DDH K-15 (201.7')	Star-Friday	150'	None	-	-	-	-	-	-	-	-	Structure not found, minor fracture zone w/clay at30-34'.
			30-37.8	7.8'	0.019	ND	Tr	Tr	22	412	ND	

Table K-6 - Drill Hole Summary

Hole No. (Total Depth)	Area	Mineralized Intercept (ft) Projected	Actual	Length	Au	Ag	Cu	Pb	Zn	As	Sb	Remarks
					oz/ton		% or ppm					
DDH K-16 (237.3')	Jupiter-Mars	125'	162-174.4	9.9	0.052	6.95	160ppm	8.42%	1.21%	1.85%	280ppm	Brecciated, lim qz vein with fragments of Psfq, visible py, apy, gn, and tet.
			165-174.4	6.9	0.71	9.97	210ppm	12.05%	1.75%	2.50%	401ppm	
			0-162	162.0					0.38%			
			174.4-185.9	11.5					1.98%			
			174.4-237.3	62.9					1.01%			
			185.9-237.3	51.4					0.54%			
DDH K-17 (262.5')	Galena	130'	235.8-237.3	1.5	0.23	18.8	0.37%	0.20%	0.24%	9.35%	0.38%	Qz vein material black fault clay and sulfides of apy, py, gn and (?)tet w/red and yellow oxides.
			234.1-242.9	8.8	0.165	5.79	0.112%	0.173%	0.117%	4.33%	0.11	
DDH K-18 (188')	Merry Widow	150'	None	-	-	-	-	-	-	-	-	Very poor recovery zone 168-188' Psf and Psg cuttings recovered only.
DDH K-19 (203.5')	Red Top	150'	148-176.4	28.4	0.137	3.36	304	146	0.48%	2.89%	237	Vein qz breccia w/fragments of Psf and Psg with py, apy, tet vuggy lim and qz.
			148-156.4	8.8	0.179	1.38	183	200	0.90%	5.38%	73	
			167.7-172	10.3	0.201	8.09	656	212	0.39%	2.18%	552	
DDH K-20 (186.6')	Red Top	100'	105-111	6.0	-	-	-	-	-	-	-	Zone of no recovery lim & qz frags and clay 1/2' below zone. Qz breccia vein. Several intercepts in hole carried anomalous Au of +0.005 oz/ton. Geophysical targets projection of vein.
			130.6-132.7	2.1	0.009	ND	ND	30	120	0.150%	2	
DDH K-21 (175')	Red Top	100'	None	-	-	-	-	-	-	-	-	Hole was a geophysical test for faulted extension of vein. May have missed vein by drilling in footwall. Hole contained units of conductive Psg and py.
DDH K-22 (61')	Gold Dollar	185'	-	-	-	-	-	-	-	-	-	Hole lost at 50'.
DDH K-22B (226.3')	Gold Dollar	185'	None	-	-	-	-	-	-	-	-	Drainage east of hole 22 may be a fault offsetting the vein.

The better developed vein deposits in the Kantishna area tend to be located in the metafelsite or quartzite units of the Spruce Creek Sequence, or near the Spruce Creek-Birch Creek contact. Because of the brittle nature of these rocks, tectonic movement has produced shattered zones which are good hosts for mineralization. Lodes as thick as 30 ft have been found in several deposits. In contrast, the veins tend to become very narrow and discontinuous when hosted by chloritic phyllites and schists which deform plastically rather than undergoing brittle deformation. In these rocks, veins usually grade to narrow sheared zones filled with clay gouge and minor sulfides.

An exception occurs in the graphitic phyllite, which is commonly interlayered with metafelsite in the Spruce Creek Sequence. This phyllite hosts narrow but high-grade deposits at several locations.

ORIGIN OF VEINS

Most vein deposits in the Kantishna Hills study area have been emplaced along fracture systems subparallel to and spatially associated with the Kantishna Anticline. These fractures were probably opened in the more brittle rocks during warping of the anticline. The structures were then mineralized by hydrothermal fluids during the introduction of the Tertiary dikes and plugs of felsic- to mafic-composition (Capps, 1918; Wells, 1923, Bundtzen, 1981).

Sulfide vein mineralization at the Bunnell Prospect is spatially related to an altered quartz porphyry. A similar intrusive rock outcropping in Friday Creek may be related to deposits on Quigley Ridge. Emplacement of these intrusive rocks could have provided a heat source for the hydrothermal system and contributed the metal-rich volatiles.

Bundtzen (1981) hypothesizes that much of the metal in the system has been derived from metalliferous horizons in the volcanic-sedimentary portions of the Spruce Creek Sequence. Stratiform copper and iron sulfide mineralization in metafelsite and greenschist units of the Spruce Creek

Sequence could have provided such a source. (This type of occurrence is discussed later in this report in the stratabound deposit section.) This association would explain the apparent affinity of the precious-metal deposits for the Spruce Creek Sequence rocks. In this model, intrusive rocks provide the heat source for remobilization and migration of the metals through fracture systems. Higher temperature minerals are deposited nearest the heat source with lower temperature, more volatile minerals being deposited at progressively shallower depths. Figure K-24 is a schematic representation of this model.

SILVER-PREDOMINANT VEINS

Most of the silver-predominant vein deposits with recorded production are located in the Quigley Ridge area (fig. K-25, plate K-8). Some of the more important of these are the Red Top, Gold Dollar, Little Annie, Silver Pick, and Galena. Other significant silver deposits are the Alpha and Bunnell located southwest of Quigley Ridge, and the deposits in the Spruce Creek-Glen Creek area to the northeast.

Most production from the silver-bearing veins was in the period 1919-1924 when eight deposits produced 1,435 tons. An additional 120 tons were mined from the Gold Dollar in 1973 (Bundtzen, 1983). Ore averaged 156 oz Ag/ton and 0.27 oz Au/ton. Production is summarized on table K-7. There has likely been some additional production for which no records were kept. Mining of the Wieler Deposit during 1983 resulted in the shipping of 156 tons of ore containing an estimated 65 oz Ag/ton and 2.8 oz Au/ton. This material had not been processed as of the writing of this report; the grade is therefore not verified. The Wieler was the only active precious-metal lode mine in the district during 1983.

The high-grade ore bodies have so far proven to be rather small, although some of the mineralized structures are large. The deposits have been the focus of periodic prospecting because of speculation that additional high-grade ore and larger tonnages of low- to moderate-grade ore could be located.

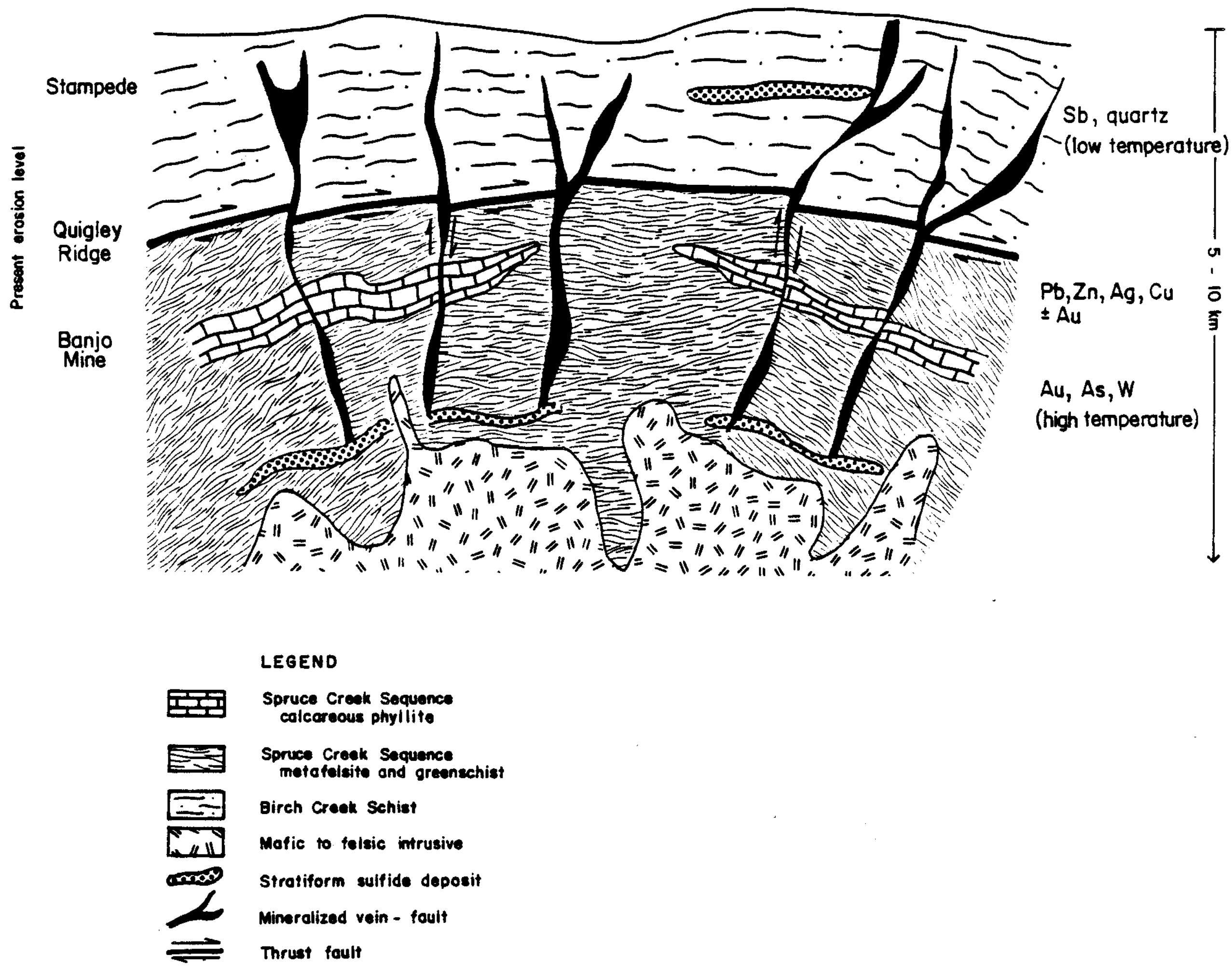


Figure K-24 Model of vein formation (after Bundtzen, 1981)

Table K-7 - Gold, silver, and lead production from the bonanza veins Quigley Hill and vicinity, Kantishna, Alaska (Adapted from Bundtzen, 1981)

	Tons of Ore	Silver (oz)	Gold (oz)	Lead (lb)	Years
Gold Dollar	638	76,120	159.5	273,160	1920, 1921, 1973
Little Annie	715	115,945	74.5	144,400	1919, 1920
Little Annie (upper)	10	1,360	N/A	4,000	1921
Red Top	184	43,664	187.3	93,200	1922, 1923
Galena	100	17,000	N/A	N/A	1920, 1921
Gold Eagle	4	680	N/A	N/A	1920
Martha Q	4	1,136	N/A	N/A	1920, 1921
Alpha	10	2,000	25.0	N/A	1921
TOTALS	1.665	257,905	446.3	514,760	

Note: The Wieler Prospect was mined in 1983. Production was reported as 156 tons of ore with an estimated grade of 65 oz Ag/ton and 2.8 oz Au/ton. This production is not included in the table.

Silver lodes of the Kantishna area have geological and mineralogical similarities to the world-class silver deposits of the Coeur d'Alene District of Idaho and have been compared in various ways with other well-known silver districts (Bundtzen, 1981, 1983). So far, the amount of ore mined or indicated does not support such comparisons, although subsurface exploration has been minimal, and the deposits are essentially untested at depth.

The silver-bearing deposits discussed below are the best-studied and may be representative of the geology and mineralization to be expected elsewhere in the Kantishna Hills study area. The 1983 investigation attempted to determine the potential for additional high-grade deposits along the mineralized structures, either laterally or with depth. The potential for larger tonnages of lower grade ore was also considered, and evidence was sought for such deposits.

Red Top Mine (Appendix B, no. 28)

The Red Top Mine is located on the north slope of Quigley Ridge near its west end. During 1922 and 1923 the mine produced 184 tons of ore averaging 237 oz Ag/ton and 1.0 oz Au/ton. Development consisted of a main adit 300 ft in length, several short crosscuts, a lower and upper stope, and a shaft connecting both stopes to the surface. About 170 ft east of the main portal another shaft was sunk, and several crosscuts were driven exploring the vein. Near this shaft a surface cut was excavated exposing the vein. Underground workings are now inaccessible. A good description of the mine is available in Wells (1933), Davis (1922), and on an underground mine map by Wernecke (1922). The present study consisted of mapping, geophysical surveys, and core drilling.

The vein in the main workings strikes approximately N. 60° E. and dips steeply to the southeast. The thickness varies from a few feet to as much as 22 ft. The vein is predominantly quartz with stringers and lenses of nearly massive sulfide. These lenses contain most of the high-grade precious metals and constitute the majority of the ore produced. Sulfides and sulfosalts reported include arsenopyrite, pyrite, galena, sphalerite, tetrahedrite, jamesonite, and pyrargyrite. Relative proportions of total sulfide to precious-metal content vary considerably throughout the vein. Smelter returns indicate that the highest precious-metal content occurs in the arsenopyrite- and tetrahedrite-rich portions of the vein, and the lowest precious-metal values are in the galena-rich portions. Assays obtained by Davis (1922) also indicate that precious-metal content of the vein is very erratic and high gold values (+0.5 oz/ton) are not always associated with high silver content.

The Red Top structure continues below the main adit level. No development work had been done below this level, except a limited amount in the lower stope near the main portal. Thus, the nature and potential of the vein at depth is unknown. The vein is terminated by a northwest-trending fault on its east end. Several surface cuts have been made beyond the fault in an apparently unsuccessful attempt to locate the extension of the vein at surface. Wells (1933) suggested that the offset is not great and that the continuation of the vein should be found by drifting along the footwall to the northwest.

Geophysical surveys and core drilling during the 1983 study attempted to locate extensions of the vein both east and west, and investigated the nature of the vein at depth.

Geophysical surveys over the Red Top Mine, particularly a MaxMin survey, showed a good conductor near the known structure with possible extensions both east and west beyond existing workings. Holes DDH K-19, DDH K-20, and DDH K-21 were drilled to test these targets (Appendix E, p. 11, fig. E-7, E-8, and E-9, and plate K-9).

Hole DDH K-19 was drilled under the old workings and intercepted the structure at approximately 135 ft below surface. The structure is a brecciated zone approximately 22-ft wide containing from 2 to 30% sulfides. Assays from this zone show gold values from 0.04 to 0.29 oz/ton, and silver values from 0.09 to 63.6 oz/ton. The entire zone averaged 0.16 oz Au/ton and 4.16 oz Ag/ton. While one hole cannot be considered representative of the nature or tenor of the Red Top vein, it does show that the structure is strong and mineralized at depth.

Hole DDH K-20 was drilled to locate the western extension of the vein. Geophysical data and geological projection backed estimates that the vein would be intersected at a down-hole depth of approximately 125 ft (95 ft below surface). At a hole depth of 130 ft, a quartz breccia was intersected which contained traces of arsenopyrite and 0.009 oz Au/ton. This intercept is tentatively identified as being a narrow and weakly mineralized extension of the Red Top vein.

Hole DDH K-21 was drilled to locate the eastern extension of the vein, beyond the fault which terminated the vein in the underground workings. The drill site selection was again guided by interpretation of geophysical and geological data. This hole was drilled to a depth of 175 ft. No structure or mineralization was identified as the Red Top vein. Possibly the structure was intersected but not recognized because of low (54%) core recovery. Location of the eastern portion of the Red Top vein remains unknown.

Little Annie (Appendix B, no. 35)

The Little Annie Mine is located on the north slope of Quigley Ridge, approximately midway along the length of the ridge (fig. K-25). Two sub-parallel northeast-trending veins have been mined, and approximately 700 tons of ore produced. The veins are referred to as the north vein and south vein. All workings are now inaccessible. Underground information was obtained from Wells (1933), Davis (1922), and Capps (1919).

Most of the development was on the north vein, and underground workings consist of a 500-ft drift and 11 crosscuts. The vein is exposed in both the east and west faces of the main drift and appears to be narrowing in both directions. The width of the vein along the drift varies from 3.5 ft at the east end, 23 ft in the center, to 9 ft at the west end. Vein material is principally iron-stained, shattered quartz with minor pyrite and arsenopyrite. Small specks of free gold are reported (Wells, 1933).

The north vein is exposed on the surface by six trenches that trace the vein for approximately 200 ft. The trenches are now sloughed, but the vein can be examined by digging in the trench walls. Vein width varies from 15 to 30 ft and is composed mostly of quartz with some gossan material and unoxidized galena. Sampling of the surface trenches by Wells yielded 0.48 oz Au/ton and 9.8 oz Ag/ton over an average width of about 20 ft and length of 200 ft. Rather extensive sampling of the underground workings by Wells (1933) showed an average of 0.1 oz Au/ton and 2.1 oz Ag/ton over 468 ft of strike length with an average width of 17 ft. Wells (1933) states that the vein at the surface may be slightly enriched by weathering. Assays are highly variable along the vein, and as at the Red Top, high gold and silver values are not always coincident. No production from the north vein has been reported.

An adit approximately 200 ft south of the main portal developed what was known as the south vein. In 1920 about 700 tons of ore were shipped that reportedly averaged 0.16 oz Au/ton, 130 to 150 oz Ag/ton, and 25% lead (Wells, 1933). According to previous reports (Davis, 1922) and from inspection of material remaining on the dump, the ore zone was a massive sulfide lense. It was comprised of nearly solid galena with sphalerite, tetrahedrite, and a minor amount of siderite. Previous investigators have suggested that tetrahedrite carries much of the silver in the Little Annie Mine and several other Quigley Ridge bonanza lodes.

The north and south veins converge towards the east and should intersect on the Little Annie #2 claim (plate K-9). Although some mineralized vein material was found in float, numerous trenches in the area uncovered only minor quartz sulfide veinlets in bedrock (Seraphim, 1962).

Work performed for this study included geologic mapping, three drill holes (plate K-9), a soil geochemical survey (Appendix D, fig. AD-4), and several geophysical surveys.

Drill hole DDH K-2 was drilled to intersect the north vein below the old workings. The vein was described by Wells (1933) as dipping 58 to 75° to the south. The fact that it was not intersected at 210 ft as projected indicates a possible steepening or pinching of the vein with depth. A similar result was noted in several other locations on Quigley Ridge. The hole was abandoned at 280 ft because of very difficult drilling conditions resulting from intensely broken rock.

Hole DDH K-3 was drilled to intersect the vein at a much shallower depth. It intersected the Little Annie north vein, but the extremely crushed and oxidized condition of the vein material and surrounding rock resulted in core recovery averaging only 55%. Assays of core were rather low (an 8-ft section ran 0.06 oz Au/ton and 1.5 oz Ag/ton). The suspicion that portions of the better mineralized rock were lost in coring was supported by drill sludge assays of 0.25 oz Au/ton over a 5-ft interval. The sludge sample was probably somewhat enriched however because of the tendency to concentrate heavy minerals in this type sample. DDH K-3 was used with core holes DDH K-2 and DDH K-4 to provide a geologic profile of the north side of Quigley Ridge. This portion of the ridge is covered with overburden and dense brush or tundra, which make it nearly impossible to gather geologic information from surface mapping.

Hole DDH K-4 was drilled on the Little Annie #2 claim to locate an extension of the veins indicated by a combined geophysical and soil geochemical anomaly. This hole, drilled to 300 ft, failed to encounter any significant mineralization or structure that could be interpreted as the Little Annie vein. The geophysical anomaly is tentatively interpreted as reflecting one of the graphitic layers. The geochemical anomaly is probably a secondary anomaly caused by metals migrating from an upslope source. Additional drilling south of hole DDH K-4 may locate extensions of the Little Annie structures.

Drill holes DDH K-2, 3, and 4 were very useful in interpreting geology on the north side of the ridge. Most of the bedrock was metafelsite of the Spruce Creek Sequence. Graphitic phyllite interlayers were found to be much more numerous and thicker than surface float indicates probably because the siliceous rocks are much more resistant to weathering. Limited outcrop indicates the ridge is an anticline with rather uniform limbs. Examination of the core, however, shows the foliated layers to be extremely variable and highly contorted with numerous faults.

Gold Dollar and Golden Eagle Claims (Appendix B, no. 36)

The Gold Dollar and Golden Eagle are adjacent claims located on the same vein near the head of Friday Creek (plate K-9). About 500 tons of high-grade silver ore were mined from the Gold Dollar in 1921 (Wells, 1933), and in 1973 120 tons of lower grade ore were produced (Bundtzen, 1981). The average grade from total production was approximately 0.25 oz Au/ton and 119 oz Ag/ton.

Davis (1922) reports the Gold Dollar vein as 3- to 4-ft wide, containing galena, sphalerite, tetrahedrite, and stromeyerite. Development on the Gold Dollar claim consisted of a 38-ft shaft and a 250-ft adit. Another adit follows the vein on the Golden Eagle claim for approximately 150 ft. The vein is also exposed by several surface cuts.

Intensity of mineralization decreases markedly with depth in the Golden Eagle workings (Davis, 1922). Two holes (DDH K-1 and DDH K-22B) were drilled in this area to test the vein at depth. Neither hole encountered significant mineralized material. Several major fault structures are recognized in this area. The vein may be displaced by a low angle fault, but available data are insufficient to determine the direction or amount of the displacement. The deposit remains essentially untested both laterally and at depth.

Galena Claim (Appendix B, no. 27)

The Galena claim is located on the west slope of Quigley Ridge. A 30-ft adit, now caved, was driven to intersect the vein, which was then followed for about 30 ft, where a winze was sunk to a depth of 20 ft. The vein is reported by Davis (1922) to be from 2 to 9 ft in width, striking N. 45^{o} E., and dipping 58^{o} SE. It consists of broken quartz with galena, arsenopyrite, sphalerite, and tetrahedrite. About 300 ft northeast of the adit an open cut exposes additional quartz and sulfides. Approximately 100 tons of ore averaging 170 oz Ag/ton and an unknown amount of gold have reportedly been produced (Bundtzen, 1981).

Drill hole DDH K-17 was drilled to locate and test the Galena vein at depth. The intercept was projected at a down-hole depth of 130 ft. A vein was encountered at 234 ft, suggesting an offset or substantial steepening of the structure. A 5-ft intercept averaged 0.29 oz Au/ton and 9.69 oz Ag/ton.

Silver Pick (Appendix B, no. 32)

The Silver Pick Prospect is located on the crest near the west end of Quigley Ridge (plate K-9). This prospect has been developed by numerous trenches, open cuts, and a 190-ft adit. No production has been recorded from the property.

Bedrock in the prospect area is primarily metafelsite and interlayered graphitic phyllite of the Spruce Creek Sequence. Chloritic phyllite and calcareous phyllite are found along the top of the ridge, but these rocks are generally not well mineralized in the study area.

Several veins have been exposed on the surface but are difficult to trace because of extensive overburden cover and sloughing of past surface development. The main veins were cut by a 190-ft crosscut driven from the Little Maud claim under the Silver Pick. The portal is now caved, but good descriptions of the underground workings are provided by Davis (1922) and Capps (1919).

The adit encountered three veins. The first vein is exposed at the portal and can be traced intermittently for several hundred feet to the southwest along a bulldozer cut. It is about 3 ft in width, strikes N. 50° E., dips 70° S., and is composed of quartz with minor galena. Davis (1922) reports some free gold. A sample from the tunnel reported by Davis (1922) contained 0.03 oz Au and 5.7 oz Ag/ton.

The second vein was encountered 55 ft from the portal. The vein consists mainly of rusty quartz with galena, pyrite, and sphalerite. It is approximately 6-ft wide, strikes N. 30° E., and dips 65° NW. Capps (1919) reported that a sample of the galena carried 100 oz Ag/ton. A sample across 6 ft of vein assayed 0.06 oz Au/ton and 10.00 oz Ag/ton (Davis, 1922).

The third vein was encountered near the face of the adit about 165 ft from the portal. It strikes approximately N. 65° E. and dips 67° S. The vein was described by Capps (1919) as consisting of 1 ft of calcite on the footwall and 12 ft of sheeted quartz and schist. The entire zone is brecciated and leached and contains small amounts of pyrite, arsenopyrite, galena, and sphalerite. A sample reported by Davis (1922) across 12 ft of vein assayed 0.05 oz Au/ton and 0.10 oz Ag/ton. Davis felt that this sample was probably not representative as the zone was leached at that level.

Approximately 1,600 ft of stripping was conducted on the Silver Pick and Little Maud Prospects in 1962. Seraphim (1962) discusses this work and describes the best mineralized zone as a shoot 140-ft long and 2.8-ft wide, averaging 0.64 oz Au/ton and 27.5 oz Ag/ton. This zone is part of the vein occurring at the portal of the adit.

Three holes (DDH K-5, 6, and 7) were drilled on the Silver Pick-Little Maud vein system during this study (plate K-9). Hole DDH K-5 apparently intersected the first two veins described above. A 31.5-ft section, from 33.0 to 64.5 ft, consists of a quartz-calcite, brecciated vein material averaging 0.02 oz Au/ton and 1.16 oz Ag/ton. A 3.8-ft section, from 46.0 to 49.8 ft, averaged 0.082 oz Au/ton and 8.67 oz Ag/ton. The second structure intersected from 79.5 to 88.5 ft, down-hole depth, assayed 0.025 oz Au/ton and 0.046 oz Ag/ton.

Hole DDH K-6 was drilled to test the structures at a greater depth. A brecciated zone was encountered from 149 to 168 ft, approximately where the two structures recognized in the first hole were projected to intersect. A barren quartz vein about 8-ft wide was intersected at 68 to 76 ft (fig. K-26). Mineralization was very weak throughout hole DDH K-6.

Hole DDH K-7 was drilled to intersect the third vein exposed in the adit. The projected intercept was approximately 150-ft down-hole depth. Several brecciated zones with minor quartz and calcite veining were encountered. A weakly mineralized structure occurs at a hole depth of 167 to 169 ft. This structure is believed to be the third vein, although this would indicate a considerable narrowing of the vein in a short vertical distance. The host

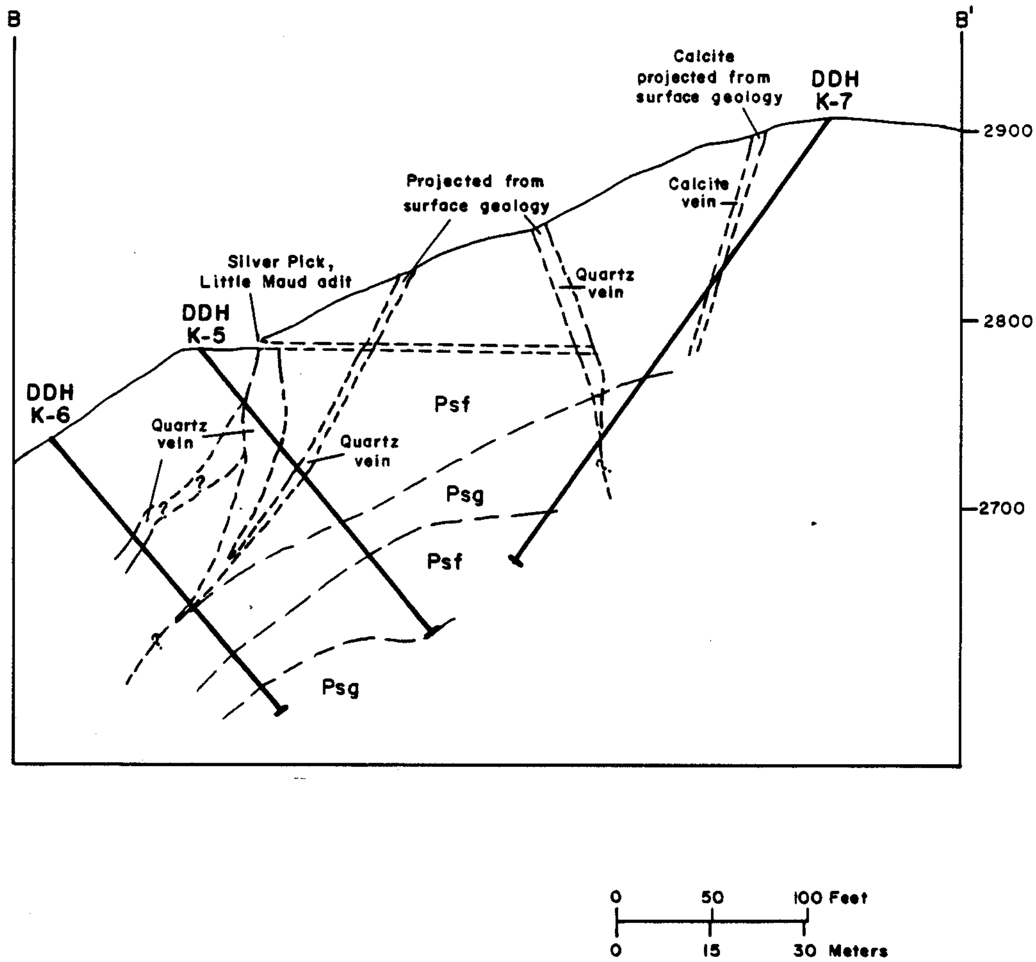


Figure K-26 Cross-section of the Silver Pick prospect, Quigley Ridge, Kantishna Hills study area (looking east) rock enclosing the structure was primarily graphitic schist in which vein pinching would be expected. The vein may widen again at depth upon encountering the metafelsite unit.

Good mineralization is present on the Silver Pick property. The primary structures along which mineralization occurs appear to be continuous. Metal content of the veins is extremely variable, and essentially barren zones are not uncommon. Some surface or near-surface mining of high-grade material may be possible at this time, but considerably more drilling is needed to determine the potential for significant tonnage.

GOLD-PREDOMINANT VEINS

Deposits classified as gold-predominant and consisting mostly of quartz-arsenopyrite-pyrite-(scheelite)-gold veins are less common than the silver lodes. Individual gold lodes, however, have the potential to be larger than the silver deposits. The Banjo Mine, primarily a gold deposit, is the largest precious-metal producer in the district.

The wide distribution of placer gold deposits further underscores the potential for rich gold lodes. The majority of the placer gold is locally derived, sources being within the Kantishna Hills (see placer section). Much of the placer gold has no doubt originated from gold associated with the bonanza silver lodes, but the potential for additional gold-predominant lodes should not be overlooked. Exploration methods would differ somewhat for the two types of deposits, primarily in the geochemical signatures which might be expected. Present evidence suggests that copper may be an indicator of high-grade silver deposits while arsenic and tungsten may be guides to gold mineralization.

Banjo Mine (Appendix B, no. 50)

The largest lode gold production in the study area comes from this mine located near the head of Lucky Gulch north of Eureka Creek (fig. K-27, plate K-5). Production totals approximately 6,260 oz of gold and 7,114 oz

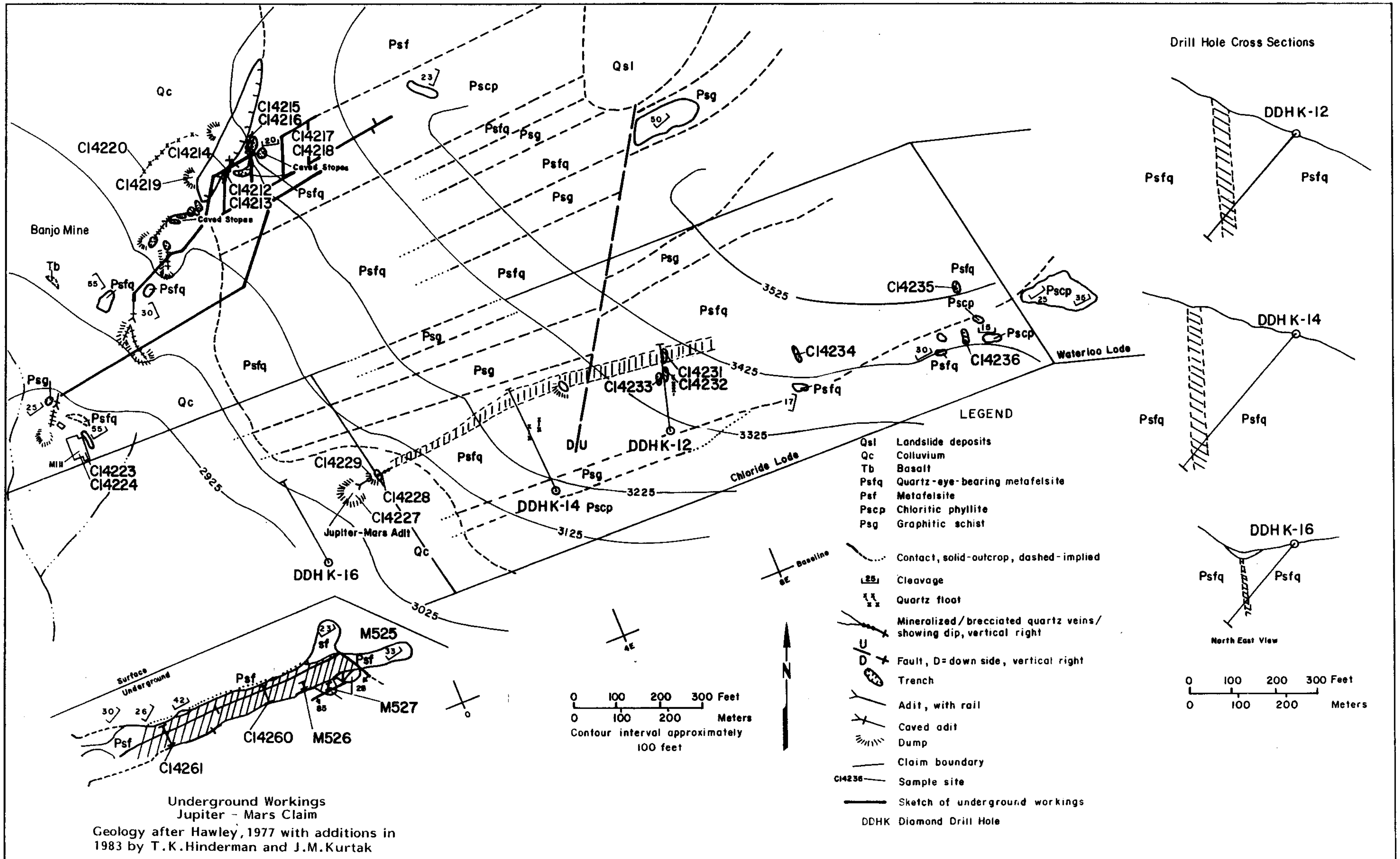


Figure K-27 Banjo Mine, Jupiter-Mars, Chloride Lode, and Waterloo Claims Area-Kantishna Hills Study Area

Topography after Hawley, 1977

Geology by T.K. Hinderman, and J.M. Kurtak of silver mined during the period 1939-1941. The mine was shut down during World War II, and operations were never resumed. Underground workings, currently inaccessible, total 1,700 ft on three levels. A 24 ton/d mill located on the property utilized concentrating tables and flotation cells to recover gold and silver (Bundtzen, 1978, pp. 157 and 159). Mill recovery is unknown, but a sample of mill tailings contained 2.6 ppm gold and 70 ppm silver.

Attempts with a backhoe failed to open any of the caved workings so only poorly-exposed veins at the surface could be examined during this study. Surface mineralization consists of gently dipping quartz vein(s) of unknown width. Visible gold is present with arsenopyrite, pyrite, galena, malachite, and scheelite. Samples contained up to 0.72 oz Au/ton, 3.04 oz Ag/ton, and 19% tungsten. The vein occurs adjacent to a graphitic schist unit but within the metafelsite of the Spruce Creek Sequence. This relationship is of interest as a similar correlation was noted at several other prospects in the area. A wall rock sample of the metafelsite contained 0.8 ppm gold and 1.1 ppm silver. The graphitic schist contained 1.0 ppm gold and 2.5 ppm silver, along with higher values of copper and zinc.

An underground examination in 1929 described a quartz-rich vein more than 12-ft wide with minor galena, sphalerite, and local scheelite. The trace of the underground workings on figure K-27 is from that examination. The vein strikes N. 35° E., dips steeply southeast, and has a carbonaceous schist hanging wall. Samples of the vein assayed from 0.04 to 0.66 oz Au/ton, 0.20 to 27.20 oz Ag/ton, 0 to 2.1% lead, and 0.43% tungsten (Hawley, p. 4-28-29).

Bundtzen (1983, table 3) estimates a reserve of 1,595 tons at 0.49 oz Au/ton and 0.52 oz Ag/ton with a resource estimate totaling 45,000 tons. Blocked-out ore reportedly remained at the time of mine closure.

Jupiter-Mars/Chloride (Appendix B, no. 51 and 52)

The Jupiter-Mars and Chloride claims are adjacent to the Banjo Mine. An unknown tonnage of ore from this lode was processed with the Banjo Mine ore. Development consists of a 120-ft adit cutting a northeast-trending, near-vertical, quartz-gouge zone averaging 8-ft wide. Indicated reserves determined from this study total 2,300 tons at 0.11 oz Au/ton and 3.80 oz Ag/ton. A 237-ft drill hole (DDH K-16) 150 ft southwest of the adit (fig. K-27) cut an extension of the vein 110 ft below the surface. The zone is 9.5-ft thick and assayed 0.052 oz Au/ton and 7.30 oz Ag/ton.

The Jupiter-Mars vein extends northeast across the Chloride lode claim and is exposed on the surface as brecciated vein quartz rubble for a 1,300-ft strike length. Soil samples collected at 50-ft intervals along three grid lines spaced 400 ft apart and normal to the vein strike contained copper, lead, zinc, and silver anomalies coinciding with surface mineralization (see geochemistry section, Appendix D). Horizontal loop (HL), very low frequency (VLF), controlled source audio-magneto-tellurics (CSAMT), resistivity, and magnetic surveys were also conducted along the grid lines. The only anomaly along the Jupiter-Mars structure was a moderate resistivity low coinciding with the quartz breccia zone (see geophysics section). Quartz breccia zones were intersected in two drill holes (DDH K-12 and 14) to a depth of 340 ft below the surface. The vein appears to be oxidized and leached at this depth. A 1.8-ft intercept contained 0.063 oz Au/ton and 7.31 oz Ag/ton. This drilling resulted in an indicated reserve for the zone along its total strike length of 103,800 tons averaging 0.062 oz Au/ton and 5.97 oz Ag/ton.

Keystone-Pennsylvania Claims (Appendix B, no. 39)

On the Keystone-Pennsylvania claims, N. 45° E. trending, steeply-dipping quartz vein(s) cutting metafelsite are intermittently exposed for 600 ft along strike (plate K-5). The veins cross Iron Gulch and are expressed mostly by quartz float in surface trenches. Quartz and calcite are the main gangue minerals along with pyrite, galena, arsenopyrite, sphalerite, chalcopyrite, scorodite, and jamesonite. Sulfides were most predominant on the dump of a caved adit near the bottom of Iron Gulch. A sample of dump material contained a trace of gold and 0.20 oz Ag/ton. Three holes, DDH K-8, 9, and 10, were drilled normal to and along the strike length of the vein. Hole DDH K-9 intercepted a 4-ft vein assaying 0.294 oz Au/ton and 0.276 oz Ag/ton. Mineralization appears to be very discontinuous and spotty.

Soil samples collected across the projected vein trend, east of Iron Gulch, were analyzed by atomic absorption and dithizone methods and found to be anomalous in total metals (Appendix D, fig. AD-9). A separate anomalous zone 170 ft north of the drilled veins was detected on sample lines 340 ft apart. This zone was not tested by drilling.

Davis (1922, p. 24) mentions that free gold could be panned from samples taken along the vein outcrop on the Pennsylvania claim. He also states that a sample taken across 14 in. of vein material in a 50-ft adit on the adjacent Keystone claim assayed 1.6 oz Au/ton and 1.60 oz Ag/ton. He mentions that several ounces of gold were panned from a small open cut near the adit portal. Whether this adit is the same as the caved one located during this study is not certain.

Bundtzen (1983, table 3) estimates a resource totaling 45,410 tons for this vein system but indicates no metal grades.

OTHER TYPES OF PRECIOUS-METAL DEPOSITS

Precious-metal deposits with potential for large tonnage have not been identified in the Kantishna Hills area; however, several geologic environments are favorable for such deposits. Past exploration efforts were exclusively for high-grade lodes, and the potential for low-grade large-tonnage precious-metal deposits has not been adequately determined.

Deposits which might be sought include:

Volcanic-Exhalative Type Precious-Metal Deposits Associated with Vent Areas or Hot Springs Environments in Felsic Volcanic Rocks

The metafelsite unit of the Spruce Creek Sequence is interpreted as being of volcanic or volcanic-sedimentary origin. The unit is rich in both base and precious metals. While most of the known mineral deposits are of hydrothermal origin, several small occurrences are interpreted to be syngenetic. Precious metals in the vein deposits are possibly remobilized from sources within the Spruce Creek rocks. It is possible that these sources could include gold and silver concentrations associated with volcanic vent areas.

Disseminated Silver Mineralization in Metasedimentary Rocks

This type of deposit is known in Precambrian quartzites of the Belt Supergroup in Idaho and Montana. A large silver-copper ore body is currently being mined at Troy, Montana. Mineralization there is interpreted as syngenetic or as a reconcentration of syngenetic metals. Similar quartzites occur in both the Spruce Creek and Birch Creek rocks. Low-grade, apparently syngenetic mineralization noted locally in these rocks warrants further evaluation.

Precious-Metal-Bearing Massive Sulfides

This study has determined that geologic environments in the Kantishna region are favorable for, or at least permissive to, the occurrence of stratabound massive sulfides. These deposits, although primarily base metals, can have significant precious-metal content. Further discussion of this type of occurrence is presented in the stratabound massive sulfide deposits section of this report.

ANTIMONY LODE DEPOSITS

By Joseph M. Kurtak

INTRODUCTION

Antimony was first noted in the Kantishna Mining District by placer gold miners. Boulders of stibnite were found in the stream beds of Eureka, Slate, Caribou, and Stampede Creeks which probably led to the first lode discoveries. On several occurrences lode antimony development in the district has been stimulated by price increases associated with wartime demands. Initial production was in 1905 during the Russo-Japanese War and was revived during World War I. A substantial amount of ore was marketed in the late 1930's with production peaking during World War II. Since that time production has been sporadic, occurring principally during the Korean and Viet Nam Wars. During 1983, 22 tons averaging approximately 60% antimony were shipped from the Slate Creek Mine at the west end of the study area (personal communication, John Millhouse, 1983). The Stampede Mine (fig. K-28), located in the northeast corner of the study area, is historically the largest individual producer and ranks as the second largest antimony producer in the nation.

Antimony lodes in the Kantishna area occur primarily as structurally-controlled, stibnite-bearing quartz veins. At the larger deposits, major shear zones located near or paralleling anticlinal crests host higher grade antimony mineralization. Schistose quartzite within the Birch Creek Schist appears to be the preferred host rock. Stibnite is the major ore mineral and is usually associated with pyrite and arsenopyrite in quartz and calcite gangue. Secondary antimony minerals identified include the oxides kermesite, stibiconite, and cervantite. Small amounts of gold and silver are normally associated with the antimony. In addition to the antimony lode occurrences, many of the precious-metal deposits contain stibnite as an associated mineral.

The majority of the antimony mines and prospects occur in Birch Creek rocks and are roughly zoned peripheral to the Spruce Creek Sequence. Antimony veins are low temperature and both parallel and crosscut higher temperature silver and gold vein systems. Antimony occurrences may serve as a guide to structural features related to the higher temperature vein mineralization in the Spruce Creek rocks.

ANTIMONY MINES, PROSPECTS, AND OCCURRENCES

Major antimony producers in the study area include the Stampede, Slate Creek, and Last Chance Mines. In addition to these mines, there are 16 known antimony prospects (fig. K-28). A description of each mine follows in descending order of total production, and three of the prospects are described. The remaining occurrences are summarized in Appendix B.

Stampede Mine (Appendix B, no. 111)

The discovery date of antimony on Stampede Creek is unknown; however, the first mining activity was reported in 1915, and ore was shipped in 1937. High-grade ore was mined initially from surface pits and later from four underground levels. Early shipments consisted of hand picked ore assaying at least 52% antimony. Production peaked during the late 1930's and early 1940's when the mine accounted for a considerable percentage of the total U. S. production (Bundtzen, 1978, p. 159). From 1937-1941 2,388 tons of ore and concentrate averaging 53.44% antimony were shipped (White, 1912, p. 334). In 1939 a 40-ton gravity mill was built to concentrate low-grade ore. Recovery was poor, with losses of more than 30%. A second mill installed on the property also yielded unsatisfactory recoveries, and subsequently only high-grade ore was mined. Ore was shipped on a fairly regular basis until 1970. Ore shipments were transported during winter months over a 50-mile-long tractor road to Lignite, a station on the Alaska Railroad (White, p. 332-334 and Ebbley and Wright, 1948, p. 8-9). In later years ore was shipped out via aircraft in 5-ton lots from the Stampede airstrip. Total production from the Stampede Mine is reported at 3,733,600 lb of antimony from 3,594.5 tons of ore (and concentrates). The property is currently idle and the underground workings inaccessible.

In 1942 the U. S. Bureau of Mines and U. S. Geological Survey conducted an exploration program in the Stampede Mine area. This program consisted of 1,520 cy of trenching, 750 ft of crosscutting and stoping, beneficiation tests, and sampling (Ebbley and Wright, 1948, pp. 6-19, and Wright, 1942). The U. S. Geological Survey in 1953-1956, working under DMEA funding, conducted additional tests consisting of 613.5 ft of drifting and crosscutting, 1,997.5 ft of diamond drilling, and 16,282 cy of surface trenching.

Antimony deposits at Stampede appear to be preferentially hosted by schistose quartzites of the Birch Creek Schist. The host rocks have been warped into broad, open folds with their axial planes striking approximately

N. 45° E. and plunging to the northeast. The Stampede Mine occurs on the southern limb of a major fold known as the Stampede Anticline (plate K-4). Mineralization is spacially associated with and apparently controlled by the Stampede Fault, which parallels the axial trace of the anticline. Veins and cross faults within the mine appear to be related to a pronounced local change in strike of the fault near the mine area. The veins are commonly wider and higher in grade near pre-mineral cross faults.

Several ore bodies have been mined at the Stampede Mine. Previous investigators have considered these to be either: 1) discrete bodies in a complex system of separate veins which occupy numerous fractures and cross faults (White, 1942, p. 345), or 2) high-grade shoots within the main Stampede vein (Ebbley and Wright, 1948, pp. 10-13).

The high-grade ore bodies occur as veins and pods of massive stibnite from a few inches up to 26-ft wide. These massive deposits grade with depth and laterally along the mineralized structures, into brecciated shear zones containing veinlets of stibnite in quartz and quartzite. The density of stibnite veinlets in these breccias was locally sufficient to produce milling ore.

Other sulfides within the ore include pyrite and arsenopyrite. Antimony oxides identified consist of kermesite, cervantite, and stibiconite. In the mined portions, grades averaged approximately 56% antimony. Mill concentrate samples contained 0.03 oz Au/ton and 0.41 oz Ag/ton. Quartz is the principal gangue mineral with minor calcite and possibly dolomite (White, 1942).

Significant amounts of both low-grade and high-grade ore are known to remain in the workings (Hawley, 1978, pp. 4-43, 44). It is considered probable that further exploration would identify additional reserves.

Much of the previous exploration work attempted to locate extensions of the known ore bodies at greater depth. It is suggested that future investigations concentrate on the areas between known ore bodies and also on geologically favorable units along the trend of the Stampede Fault.

Structural intersections within quartzitic rocks would be favorable targets. Future work should include detailed structural mapping possibly aided by geophysics. Soil geochemical prospecting has been shown by Hawley (1978, pp. 4-36, 42) and by this study to be useful for detecting antimony in this environment. In much of the Stampede area, however, extensive colluvial cover would probably limit the effectiveness of this method.

It is likely that drilling in areas surrounding known ore bodies would identify additional reserves at the Stampede Mine. Further detailed prospecting of the control structures in the area would probably identify favorable targets which could be evaluated by drilling. An increase in antimony price would probably be required to encourage private industry to undertake this work, even if land-use policies in the area were favorable for development.

Slate Creek Mine (Appendix B, no. 1)

Antimony was discovered along Slate Creek in 1905. From that time until the end of World War II approximately 325 tons of ore, averaging 49% antimony, were shipped (Ebbley and Wright, 1948, p. 22). Since the end of World War II sporadic shipments have totaled 354 tons of ore, averaging approximately 60% antimony (including 22 tons mined during 1983).

Antimony mineralization occurs within a N. 50^{o} E. trending shear zone that dips steeply to the south and contains a 25- to 40-ft-wide mineralized zone. The trend of the mineralization parallels that of the shear zone and consists of a reticulated stockwork of quartz containing lenses and pods of stibnite hosted by schistose quartzite within the Birch Creek Schist. Oxide antimony minerals include kermesite and stibiconite. Ore has been mined from an adit and open cuts for approximately 250 ft along strike. Bulldozer trenching has exposed the shear for another 400 ft along strike. Churn drill holes found significant antimony mineralization to a depth of 25 ft below the surface (Ebbley and Wright, 1948, pp. 20-22). In 1983, production methods consisted of hand cobbing massive stibnite out of an old open pit at the mine site.

During this study, previous mapping and sampling were checked and updated and additional rock and soil samples were collected (Appendix B, no. 17). The geology in the immediate area of the prospect was also mapped. Mapping indicates the mineralized shear zone occurs in a quartzite unit of the Birch Creek Schist near the crest of an anticline (plate K-6). The geologic setting is similar to that of the Stampede Deposit located 25 miles to the northeast.

Thirty-four soil samples were collected at 100-ft intervals along four lines oriented normal to the trend of the shear zone. Sampling was conducted along strike beyond existing workings to test for concealed antimony mineralization. Sample results indicate a 200-ft-wide antimony geochemical anomaly extending for 1,100 ft to the east and 500 ft to the southwest of the present workings.

Caribou-Last Chance (Appendix B, no. 61)

The Caribou-Last Chance property, located at the junction of Last Chance and Caribou Creeks (fig. K-28, plate K-8), has produced 75 tons of high-grade antimony ore. The last reported shipment was in 1975. Host rocks in the area are composed of extremely deformed and faulted biotite amphibolite schist. Mineralization occurs along a 3- to 6-ft wide, northeast-trending, quartz-stibnite vein containing pyrrhotite, pyrite, jamesonite, and stibiconite. Hawley (1978, pp. 4-30, 31) reported up to 0.12 oz Au/ton in samples taken from the wall rocks; however, samples collected from wall rocks during this study contained no detectable gold. The vein has been mined on the surface for 150 ft along strike and intermittently exposed for 570 ft. Previous mapping by Bundtzen (1981) was updated, and a 32-ft adit along the mineralized trend was mapped and sampled (see Appendix B, no. 61). Samples from a mined trench contain up to 26% antimony.

A small concentrator is present on the property, and 15 to 30 tons of ore are stockpiled at the mine site. A resource estimate of 62,720 tons containing approximately 14.3% antimony was made by Bundtzen (1983, p. 23).

Eureka Stibnite (Appendix B, no. 33)

The Eureka Stibnite (Pick claims) Prospect is located on Eureka Creek south of Quigley Ridge. Antimony occurs in a 3-in. wide, quartz-stibnite vein trending N. 40° W. Small, high-grade stringers, veinlets, and pods of massive stibnite occur in brecciated Birch Creek Schist up to 50 ft away from the vein. Development consists of a caved adit and sloughed trenches. Approximately 99 tons of antimony have been produced (Bundtzen, 1983); 12 tons mined in 1970 averaged 62% antimony. Analysis of samples taken during this study indicates 0.1 to 1.0 oz Ag/ton and 0.02 to 0.12 oz Au/ton.

Eagles Den (or Don) Antimony (Appendix B, no. 11)

The Eagles Den (or Don) Prospect, located on the south side of Eldorado Creek, has been developed by minor surface workings. Massive, bladed stibnite occurs near the footwall of a quartz vein which is at least 20-feet thick and located adjacent to a fault. Stibnite occurs over a width of 3- to 5-ft in fracture fillings and lenses ranging from 1 in. to 1 ft in width. Stibnite float was found along strike near an outcrop of similar vein quartz and breccia approximately 400 ft northwest of the workings. Samples taken during this study from the prospect contain up to 44% antimony. The prospect has potential for a large concealed antimony deposit. A resource of 8,000 tons containing approximately 28.5% antimony has been estimated for the area (Bundtzen, 1983, table 5).

Moonlight Stibnite (Tosdal Antimony) (Appendix B, no. 102)

The Moonlight occurrence, located north of Moonlight Creek, contains massive stibnite pods in a northeast-trending quartz vein which is up to 10-in. wide. The vein is exposed for 65 ft along strike. Samples collected by Bundtzen (1981, p. 225) contain up to 64% antimony. The prospect is undeveloped, and the area should be explored for vein extensions.

ANTIMONY RESOURCE SUMMARY

Recorded antimony production from four deposits is shown in table K-8. Total production from the district exceeds 4,400,000 lbs of antimony, which represents nearly 40% of the total United States' production. Potential antimony resources in the study area exceeds 560,720 tons (table K-9) averaging 11.93% antimony, which is equivalent to almost 25% of the United States' present reserve base (Bundtzen, 1983, p. 21).

Table K-8 - Kantishna Mining District Antimony Production

Mine Name	Production (tons)	Avg. Grade (Sb%)	Pounds Antimony	Activity Years
Stampede	3,590	52	3,733,600	1937-1970
Slate Creek	679	45	611,100	1905-1983
Eureka Stibnite	99	34?	67,320	1915-1970
Caribou-Last Chance	75	?	?	1906-1975
TOTAL	4,442		4,412,020	

After Bundtzen, 1981, p. 207 and 1983, table 5; personal communication, Dan Ashbrook and John Millhouse, 1983; Ebbley and Wright, 1948, p. 21

Available data on the known antimony deposits permit only rough estimates of resource potential for the entire district. Bundtzen (1983) made the estimates shown in table K-9 for the few deposits for which he had data. Hawley (1978) also estimated reserves and resources for the Stampede Deposit. A summary of his estimates follows table K-9. While both investigators agree there is a substantial amount of antimony remaining, Hawley's estimates are significantly lower. This is partially attributable to differences in computational methods, but primarily to the lack of exploration data.

Table K-9 - Kantishna Mining District Antimony Reserves and Resources (after Bundtzen, 1983)

Deposit	Stampede	Slate Cr.	Caribou-Last Chance	Eagles Den	Total
Known Reserves (tons)	6,280	3,600	300	1,750	11,930
Resource Estimates (tons)	450,000	40,000	62,700	8,000	560,700
Antimony (%)	12.00	18.66	14.30	28.50	12.97 (avg.)(1)
Million Pounds Antimony	108	14.9	17.9	4.6	145

(1)Weighted average

Hawley (1978) estimated reserves at the Stampede Deposit to be several hundred and possibly over 1,000 tons of high-grade (approximately 50% antimony) ore in two of the previously mined ore bodies at Stampede. White (1942) estimated that 6,000 tons of material containing 10 to 15% antimony remained in the workings, and at least 1,000 tons of weathered rock containing 20% antimony was still lying on surface near the original ore outcrops.

Antimony resources at Stampede are believed to be present along the projected vein between several of the known ore bodies. Taking all the above into account, Hawley (1978) suggests a resource of more than 10,000,000 lb of antimony in high-grade and medium-grade (10 to 15% antimony) ore in the immediate Stampede area.

There are several antimony occurrences for which data are insufficient to permit any estimates of potential resources. Further evaluation of these could lead to increases in the estimated antimony resources of the district. All of the known occurrences, with the exception of the Stampede Mine, are located on unpatented claims or on unclaimed land; consequently, no subsurface work was conducted during the study.

Additional testing would refine further resource estimates. Bundtzen's estimates for the Slate Creek Deposit, for instance, were based on an assumed strike length of 400 ft. Geochemical surveys during the present study indicate a potential strike length of up to 1,600 ft. This possible extension of mineralization has not been verified.

Also, further exploration of the Kantishna study area would probably result in the identification of additional antimony occurrences. Geochemical sampling for this 1983 study shows that antimony is widespread within the study area (fig. K-41). Most major streams and their tributaries which drain the Spruce Creek Sequence yielded samples with anomalously high antimony values. Most of the anomalous samples were obtained in streams which drain known lode occurrences, or terrane which is similar lithologically and structurally to known host rock terrane for antimony lodes. High antimony values were also detected in streams draining the Keevy Peak Formation in the upper Clearwater drainage. Isolated anomalies were detected in Rock Creek tributarites and the Bearpaw River.

STRATABOUND MASSIVE SULFIDE DEPOSITS

By Jason R. Bressler

The Kantishna Hills study area is underlain by rocks permissive for the occurrence of stratabound massive sulfide deposits. Three distinct potential host environments have been identified: (1) quartzite units within the Precambrian Birch Creek Schist, (2) black slate/schist terranes in the Birch Creek Schist and the Devonian Keevy Peak Formation, and (3) volcanogenic rocks in the lower Paleozoic(?) Spruce Creek Sequence.

QUARTZITE-HOSTED DEPOSITS IN BIRCH CREEK SCHIST

Quartzite-hosted deposits present in the Kantishna Hills study area are exemplified by the Lloyd Prospect (Appendix B, no. 77), located near the confluence of the East and West Forks of Glen Creek. At this prospect a

30-ft adit has been driven in a stratiform zone containing sphalerite and chalcopyrite. Mineralization is hosted by a folded sequence of very fine-grained, white, vitreous quartzite with minor interlayered garnetiferous quartz-muscovite and actinolite schist. The pure quartzite suggests a chert or well-sorted sandstone protolith. Quartzite crops out discontinuously from the mouth of the West Fork of Glen Creek for at least 5,000 ft along the East Fork of Glen Creek. The unit strikes approximately N. 50^{o} E., dips 10 to 20^{o} W., and is estimated to be 20-ft thick. Locally it is deformed into west-trending tight to isoclinal sigmoidal folds.

Mineralization defines a 1- to 5-ft-thick concordant zone containing disseminated to semi-massive, stratiform laminae of sphalerite, lesser chalcopyrite, and traces of galena and pyrrhotite. The sulfide minerals are medium-grained and define discontinuous layers 0.5-in. thick outlining the layered fabric of the quartzite. The mode of sulfide aggregation indicates a premetamorphic age of metallization. The mineralized horizon is exposed in outcrop continuously over a 125-ft length and mimics the fold geometry in the host rock. The effects of folding have resulted in several repetitions and structurally thickened pods. Outcrop surfaces are locally coated with the secondary minerals smithsonite, malachite, and limonite.

Grab samples of high-grade material collected by Bundtzen (1976, 1981) contained 2.16% copper, 0.09% lead, 3.98% zinc, 0.97 oz Ag/ton, and traces of gold. Samples collected during this study contained up to 1.1% copper, 0.215% lead, 5.6% zinc, 0.85 oz Ag/ton, and nil gold.

Similar mineralization was discovered during this study (Appendix B, no. 82) on a talus covered slope 4,000 ft northeast of the Lloyd Prospect. Pyrite, sphalerite, and traces of chalcopyrite and galena, occurring as disseminations and concordant stringers were found in brecciated, chert-like, tan to white quartzite. A grab sample of high-grade material from this occurrence contained 0.375% lead, 1.3% zinc, 0.47 oz Ag/ton, and nil gold. Outcrops are not present, and the extent of mineralization is unknown. This occurrence is thought to be similar to the Lloyd Prospect.

An unmineralized outcrop of chert-like quartzite located near the mouth of the West Fork of Glen Creek attains a thickness in excess of 20 ft. The exposure is identical to the unit hosting the Lloyd Prospect and is considered to be a strike extension of the Lloyd horizon.

Three lines (L1 to L3) were established across the projected trend of the Lloyd Prospect horizon for geochemical sampling (Appendix D). An induced polarization (I.P.) survey on line L1, which crosses the Lloyd Prospect, shows a distinct zone of high chargeability approximately 200 ft west of the prospect. From limited data it is inferred that the mineralization diminishes or dips westerly.

Geochemical response from line L1, crossing the Lloyd Prospect, showed a single station anomaly, copper (120 ppm), lead (295 ppm), zinc (385 ppm), over a covered hillside adjacent to the adit site (Appendix D). Precious-metal values were consistently low, and background base-metal values were less than 40 ppm copper, 20 ppm lead, and 120 ppm zinc. Soil samples along line L2 yielded no anomalous metal values. Line L3 crossed Lloyd-type mineralization and identified a 500-ft-long lead and zinc anomaly. Lead values ranged from 75 to 130 ppm, and zinc from 225 to 970 ppm. No significant precious-metal response occurred. The anomaly on L3 is more extensive than the L1 anomaly, probably due to greater downslope dispersion from solifluction.

Bundtzen (1981) considers the stratabound base-metal mineralization at the Lloyd Prospect to be hosted by components of the metafelsite unit of the Paleozoic(?) Spruce Creek Sequence. Mapping during this study suggests that the stratabound mineralization is hosted instead by units of the Birch Creek Schist. This contention is supported by detailed mapping results and the presence of garnetiferous components interlayered within the quartzite.

The host rock composition and the type of mineralization at the Lloyd Prospect are broadly analogous to disseminated sulfide deposits known in rocks of the Belt Supergroup of northwestern Montana. Mineralization of this type has not been previously reported in Birch Creek Schist in the Kantishna Hills study area and presents a new and attractive exploration target.

BLACK SLATE/SCHIST TERRANES

Two similar rock units of different geologic ages, the graphitic schist member (p€gs) of the Precambrian(?) Birch Creek Schist and the Devonian Keevy Peak Formation, are potential host units for base- and precious-metal massive sulfide deposits (fig. K-29). Both units are metamorphosed black shale terranes devoid of significant volcanogenic components. Black shale terranes in Alaska and elsewhere host sedimentary exhalative (sedex) lead-zinc deposits which comprise some of the world's largest base-metal ore bodies, including: Red Dog, Alaska; Anvil District, Yukon Territory; Sullivan, British Columbia; McArthur (H.Y.C.), Australia; and Meggan-Rammelsberg, Germany (Large, 1981; Carne and Cathro, 1982).

Sedex deposits are stratiform massive sulfide accumulations of simple mineralogy which are concordantly interbedded in marine sedimentary rocks. The host rocks include black shale, chert, dolomite, micritic limestone, conglomerate, and turbidite sandstones. The host sediment lithology reflects a low energy, locally euxinic, pre-flysch environment. Penecontemporaneous faulting in the basin results in occasional development of conglomeratic fans and breccias (Large, 1981). Deposition of the sulfides occurs on the seafloor by the discharge of metal-bearing hydrothermal fluids from exhalative vent sites. Exhalative conduits can be localized by growth faults or basin hinge areas. Because of their synsedimentary origin, the geometry of sedex deposits record the metamorphic and deformational effects suffered by the host rocks.

Of the two favorable host terranes in the study area, the graphitic schist member of the Birch Creek Schist (p€gs) displays the most vivid suggestions of possible mineralization. The graphitic schist unit consists of a diverse package of intermixed dark-gray to black, fine- to medium-grained, siliceous and locally calcareous schist; tan quartz-sericite plus or minus chloritic schist; and gray to black, schistose and graphitic quartzite. The graphitic schist lithologies are the metamorphic equivalents of black shale, chert, and calcareous shale. Thickness of the graphitic schist varies from a measured 340 ft at the head of Canyon Creek, where the rocks dip homoclinally at shallow angles, to a structurally-thickened 1,500 ft at the Red Dirt occurrence.

Bundtzen (1981) reports that much of the graphite identified in the field may consist of segregations of dark-brown biotite, chlorite, and graphite. Small chloritized garnet porphyroblasts were identified in the graphitic schist unit at the head of Canyon Creek.

The p€gs unit crops out in an irregular belt from Crooked Creek to Rock Creek. Although structural complexities are severe, the graphitic package has been mapped by this study from the headwaters of Canyon Creek to the head of Little Moose Creek, a distance of approximately 7 miles. Two areas, the Canyon Creek and Red Dirt occurrences, along this nearly continuous trend were targeted for detailed geologic, geochemical, and geophysical studies.

Both areas were recognized during the 1983 study by the presence of pronounced color anomalies. Beds of streams draining the graphitic schist are laden with red-orange-colored, iron oxide(?) precipitate after crossing the graphitic unit. The color change is accompanied by a reduction of pH values of stream waters. In one case pH ranged from 6.5 upstream of the graphitic unit to less than 3.5 below the unit. Stream beds are coated with ferricrete deposits. The ferricrete formations and acidic stream waters are attributed to weathering of the pyritiferous p€gs unit. Scattered base-metal stream sediment anomalies of moderate magnitude are associated with the graphitic schist.

Red Dirt Occurrence (Appendix B, no. 105)

The Red Dirt occurrence is located at the divide between Little Moose Creek and a south flowing tributary to Canyon Creek (fig. K-30). The area was targeted for massive sulfide evaluation because of the presence of prominent color anomalies with attendant vegetation kill zones and several red-colored streams draining the immediate area. The occurrence is located above tree line on a talus covered hillside at an elevation of 3,500 ft. Outcrops are sparse.

Red Dirt is underlain by a complexly deformed, mixed assemblage of Birch Creek Schist. The units include graphitic and locally siliceous and calcareous schist, tan-colored quartz-muscovite chlorite schist, and gray to black schistose and graphitic quartzite of the graphitic schist unit (p€gs). The graphitic unit has been substantially thickened by two phases of large scale folding. Thickness is estimated to be approximately 1,500 ft. The first phase folds (F_1) are isoclinal structures folded about subhorizontal northeast-trending axes. Limited structural data indicate that an F_1 hinge zone occurs within the graphitic schist package. The structure is further complicated by the superposition of a later generation of large-scale, tightly appressed folds (F_2) coaxial with F_1. The distribution of lithologies appears to be principally controlled by a major, southwest-plunging F_2 antiform. The p€gs unit appears to be conformably enclosed within garnetiferous, quartz-muscovite, biotite schist and quartzite (p€sq). The graphitic schist is brought into structural contact with calcareous quartz-muscovite schist (p€c) by the northeast-trending, subvertically-dipping Red Dirt Fault to the east.

Only sparse amounts of pyrite were noted in outcrop; however, extensive limonite and jarosite zones coating outcrop surfaces suggest that pyrite or pyrrhotite is a major component of the graphitic schist. One outcrop contained an estimated 3% pyrite as disseminations and irregular lenticular aggregates. No base-metal sulfide minerals were identified.

Red Dirt was discovered by the occurrence of several bright red-orange, hydrous iron oxide precipitate kill zones emanating from discrete areas in the graphitic schist. The zones head at an elevation of 3,400 ft and elongate downslope along the slope drainage. The kill zones are characterized by either a thin veneer of incipient colluvial ferricrete or luxuriant mats of bright green moss. Invariably, the normal vegetation common to the area is absent or dead. According to Levinson (1974, p. 399): "...areas, or terrain with a flora greatly reduced or distinctly different by comparison with the surrounding area, may result from poisoning of the vegetation by unusual concentrations of certain elements in solution with sulfuric acid generated by the oxidation of pyrite."

The exploration of vegetation kill zones has resulted in the discovery of base-metal deposits in Alaska and Yukon Territory. Notably the Greens Creek base- and precious-metal massive sulfide deposits on Admiralty Island, Alaska, (Antony, 1977), the Cirque Prospect, British Columbia, (MacIntyre, 1981), and reportedly the enormous Howards Pass base-metal massive sulfide deposit in the Yukon Territory contained vegetation kill zones.

Two hundred forty-two soil samples were collected along a combined soil sample and geophysical grid. Samples were collected at 100-ft centers from line spacings of 400 ft. Thirteen rock samples were collected from outcrops to document trace element primary dispersion characteristics. Six stream silt samples were collected from streams draining the Red Dirt catchment basin.

Results of the soil sampling show erratic and weak geochemical dispersion patterns for copper, lead, zinc, silver, gold, and arsenic. The mean, maximum, and threshold values are shown in table K-10.

Table K-10 - Red Dirt Occurrence Soil Geochemical Results

	Mean (ppm)	Maximum (ppm)	Threshold (ppm)
Cu	51	125	92
Pb	31	105	57
Zn	84	155	126
Ag	0.09	2.5	0.6
Au	0.01	0.44	0.11
As	13	255	66

Threshold values were defined as two standard deviations above the arithmetic mean. Values considered anomalous are not high in terms of absolute value and are usually single station features that do not define a systematic pattern. The graphitic schist unit displays a geochemical signature distinct from the calcareous schist and quartzite. The graphitic schist appears to be enriched in copper, lead, zinc, and silver, with the greatest concentrations tending to localize near contacts with calcareous schist and quartzite. The precipitate kill zones are not strongly anomalous in base-metal content. They contain single sample anomalies with maximum values of 135 ppm zinc, 120 ppm copper, and 150 ppm arsenic. No significant enrichment in lead content was found. Although silver dispersion is generally erratic, a weak, multi-station anomaly with values to 0.8 ppm occurs over the trace of the Red Dirt Fault. Soil geochemical profiles are included in Appendix D.

Compared to the graphitic schist unit, calcareous schist and quartzite appear to be enriched in gold and arsenic. A coincident gold and arsenic anomaly occurs in the calcareous schist oriented parallel to the Red Dirt Fault. The anomaly is approximately 800-ft long and open to the southwest. Gold values range up to 0.43 ppm and arsenic values to 120 ppm.

Analytical results of 13 rock samples from the graphitic schist unit, including black quartzite, schist, and calcareous schist, do not show significant base- or precious-metal concentrations. Most of the samples were strongly oxidized, and none contained appreciable amounts of visible sulfide minerals.

Streams draining the Red Dirt catchment area below the precipitate kill zones are very acidic with pH values less than 3.5. Stream beds are coated with a precipitate of bright red-orange hydrous iron oxides, and contain ferricrete deposits along the banks and channel. Silt samples from the streams contain uniformly low base-metal values. Copper content ranges from 10 to 55 ppm and lead from 5 to 35 ppm; zinc values below 70 to 85 ppm reflect the high mobility and resultant depletion of zinc in an acidic weathering environment. Downstream from the prospect the pH gradually increases, and zinc values increase to 280 ppm. Silt samples from Little Moose Creek, which drains the north flank of Red Dirt, contain up to 80 ppm zinc immediately below the prospect area and 400 ppm 1 mile further downstream.

A total of 10,500 lineal ft of electromagnetic (EM) and magnetic surveys were completed during the study. Results indicate several narrow conductive zones with coincident strong magnetic response. The available data suggest limited or variable continuity along strike. Although the conductivity of the anomalies suggests either massive sulfide or graphitic zones, the strong magnetic response indicates pyrrhotite may be present in the system.

To summarize, soil geochemistry does not strongly indicate significant near-surface base-metal accumulations within the graphitic schist unit at Red Dirt. Vegetation kill zones could have resulted from circulation of acidic waters derived from the weathering of pyritiferous black schist. The formation of several such base-metal-poor kill zones may reflect the presence of massive pyrite pods or possibly a phenomenon of ground water flushing weakly disseminated mineralization. The strong magnetic response over the prospect suggests massive pyrrhotite sulfides near surface, and the EM response suggests either massive sulfides or graphite.

The geochemistry and geologic setting, coupled with the strong coincident EM and ground magnetic anomalies, constitutes a potential exploration target. Additional work, including exploratory diamond drilling, in the entire graphitic terrane would be required to determine the true significance of these occurrences.

Canyon Creek (Appendix B, no. 98)

The Canyon Creek area is underlain by the same graphitic schist terrane (p€gs) as Red Dirt, and has similar potential for mineralization. In contrast to Red Dirt where the geology is complex and outcrops sparse, Canyon Creek is underlain by a shallow west-dipping sequence exposed continuously in the five stream channels. The unit is 340-ft thick and is gradationally enclosed by garnet-muscovite-quartzo-feldspathic schist. Outcrops typically weather to a rusty red-orange color, and sheltered outcrop surfaces are coated with a thick efflorescence of yellow sulfate(?) minerals.

No secondary zinc minerals were detected, but sparsely disseminated pyrite was noted. Small, chloritized garnet porphyroblasts occur in the more pelitic lithologies.

Work accomplished at Canyon Creek consisted of systematic rock sampling, soil sampling, and 4,000 ft of EM and magnetic surveys. Detailed rock sampling was conducted across the total true thickness (340 ft) of the graphitic schist unit to test for possible metalliferous horizons. Seventeen 20-ft-long chip samples were collected. Analytical results indicate no significant base metal concentrations (fig. K-31). Soil samples collected from stations along the geophysical survey did not yield anomalous metal concentrations.

Transection of the p€gs by several east-flowing major tributaries to Canyon Creek allows stream sediment geochemical sampling at 1-mile intervals along the strike of the unit. Streams draining the graphitic schist are coated with iron oxide precipitate below the p€gs outcrop. The iron oxide precipitate is coincident with a drop in pH from 6.5 above the p€gs to less than 3.5 below the outcrop. Stream silt geochemistry in the vicinity of the soil and geophysical grid shows values to 195 ppm zinc and 10 ppm lead. Zinc values in silt samples increase to 540 ppm 1 mile downstream. Lead content remains constant.

Geochemically anomalous samples were collected from a small drainage cut in graphitic schist 1 mile east of the Canyon Creek occurrence. A stream silt sample (A1252) contained 295 ppm lead and 260 ppm zinc. A panned concentrate sample (A3011) contained 125 ppm lead and 195 ppm zinc. Detailed follow-up stream sediment sampling during a period of high water discharge did not replicate the anomaly. Sulfide minerals were not discovered during follow-up prospecting. This lead anomaly is very significant. Because of lead's immobility in acidic water, anomalies are more likely to be residual. Zinc is mobile in acid environments and tends to be dispersed. Hence, lead is regarded as the prime geochemical indicator of massive base-metal sulfide mineralization in the black shale environment.

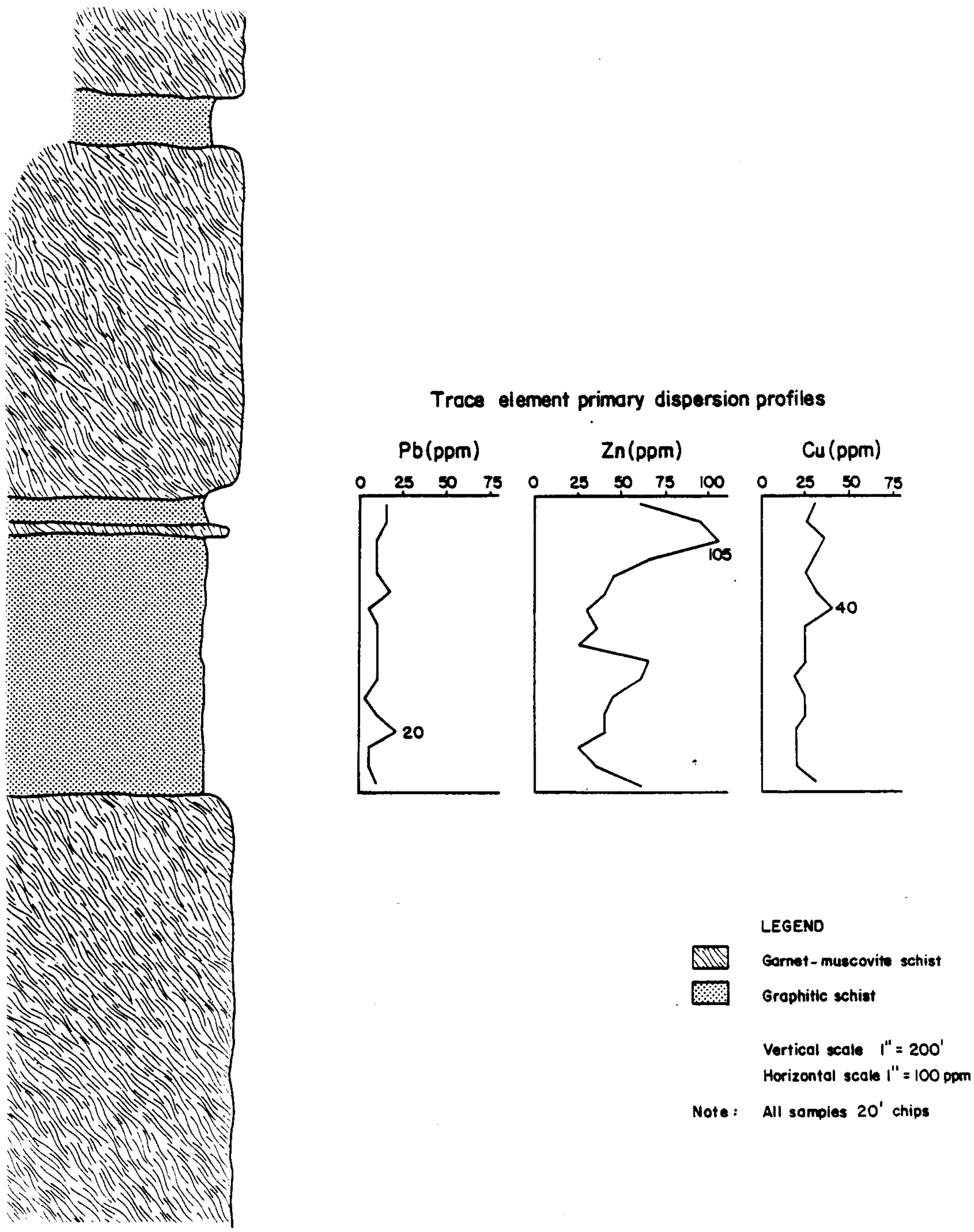


Figure K-31 Canyon Creek graphitic schist section, Kantishna Hills study area

Geophysical survey results indicate strong anomalous EM and magnetic responses from two lines 2,600 ft apart. The EM anomalies are typical of massive sulfide sources. The magnetic response precludes graphite as the conductor in some of the zones.

KEEVY PEAK FORMATION

The Keevy Peak Formation is a varied package of calcareous semischist and phyllite, black quartzite, slate and marble, and metaconglomerate (Bundtzen, 1981). It is a potential massive sulfide host terrane by virtue of favorable lithology and chemistry. The Keevy Peak Formation underlies approximately 8 square miles of the study area, primarily in a fault-bounded slice extending 6.5 miles from the lower reaches of Moonlight Creek northeastward to Stampede Creek (plate K-1). Weathering of the Keevy Peak Formation results in low-rounded topography covered by thick growths of black spruce and tundra. Outcrops are sparse.

The best-exposed section of the Keevy Peak Formation in the study area occurs on the ridge separating the lower reaches of Moonlight and Canyon Creeks (fig. K-32). About 40% of the total outcrop area of the unit exposed in the study area was evaluated by stream silt, soil, and rock sampling, prospecting, and geological mapping. The section consists of fissile, dark-gray to black quartzite, slate and phyllite (Pkq). It contains thick interlayers of calcareous phyllite (Pks), gray micaceous marble (Pkm), and metaconglomerate (Pkc).

Systematic variations in lithology of the Pkg unit are evident but not mappable. The dominant lithology consists of silver-weathered, carbonaceous, and locally siliceous or pelitic slate and phyllite. The siliceous units are riddled with quartz-carbonate veins, most of which are concordant, synmetamorphic structures. Numerous joint-controlled veins, some with disseminated pyrite, are reported by Bundtzen (1981).

Marble (Pkm) is prevalent towards the top of the Keevy Peak Formation and forms a mappable unit 300-ft thick (Bundtzen, 1981) and approximately 1.7-miles long. A distinctive, siliceous, stretched-pebble conglomerate (Pkc) caps this section of the Keevy Peak Formation. The conglomerate is very resistant to weathering and forms prominent knobs and ridges.

The Keevy Peak Formation was probably deposited in a low energy marine environment (Gilbert and Bundtzen, 1979). The upward-coarsening sequence of rocks could represent submarine fan deposits or, alternatively, a rapid influx of coarse clastic material proximal to a basin fault, turbidite flows, or slumping.

The rocks record the effects of penetrative deformation and metamorphism. Bedding surfaces and the tectonite foliation are essentially parallel and generally indistinguishable. Bundtzen (1981) considers that metamorphism culminated in the lower greenschist facies.

Sparse mineralization was discovered in several locations within the Keevy Peak terrane. Minor disseminated pyrite occurs as stratiform aggregates in outcrops along Moonlight Creek, and traces of disseminated galena and pyrite occur in discordant quartz veins cutting dark-gray, aluminous phyllite along Canyon Creek. Slate outcrops are typically limonite stained and, locally, coated with thick blooms of secondary yellow and white sulfate minerals. Several outcrops along Canyon Creek show stratiform sulfate coatings several feet wide which suggest the presence of pyritiferous layers. No secondary zinc minerals were detected. A composite grab sample (C14144) from an outcrop of black carbonaceous slate coated with yellow jarosite stain contained anomalous concentrations of lead (310 ppm) and silver (1.7 ppm). The high lead content suggests the presence of plumbojarosite. Bundtzen (1981) reports that disseminated and massive pyrite occur in dark gray slates on Moonlight and Marten Creeks. The pyrite is fine-grained, forming thin laminations less than 0.5-in. thick in graphitic-rich units in the slate. Stream sediment samples collected by Bundtzen and others (1976) and Hawley (1977) from streams draining these areas reportedly contain up to 1,000 ppm combined lead and zinc.

Streams draining the Keevy Peak Formation do not show the strong red-orange coloration and low pH values exhibited by those draining the graphitic schist unit of the Birch Creek Schist. A single sample (A2951) collected from a stream draining a section of black, siliceous, carbonaceous slate and calcareous phyllite is strongly anomalous in lead (420 ppm) and zinc (720 ppm). No mineralized stream float was noted at the sample site. The anomalous sample site is in the proximity of the minor galena mineralization noted above. No follow-up sampling or prospecting of the anomalous drainage was conducted. A silt sample collected by Bundtzen and others (1976) from the drainage directly south of A2951 contains 49 ppm lead and 438 ppm zinc. Metal contents of silts from other streams draining the Keevy Peak terrane in the area range from 10 to 48 ppm lead and 76 to 154 ppm zinc.

Twenty-two soil samples were collected from a ridge line traverse across the Keevy Peak section. Samples from a broad zone above the anomalous drainages show weak concentration of base metals, up to 50 ppm lead, 110 ppm copper, and 2.2 ppm silver. The slightly anomalous base-metal content suggests that a weak, metal-enriched horizon possibly extends southward from the lead- and zinc-anomalous drainage.

VOLCANOGENIC DEPOSITS IN SPRUCE CREEK TERRANE

The Spruce Creek Sequence consists of metamorphosed volcanic and sedimentary rocks characterized by mafic- to felsic-volcanic and volcaniclastic units, and pelitic, calcareous, and organic-rich epiclastic and carbonate rocks. In places where volcanogenic rocks dominate the section, such as Quigley Ridge, Glen Creek basin, and the Spruce Peak-Kankone Peak ridge, possible volcanic centers are suggested. Zones of depositional intercalation and possible subbasinal environments are indicated where rocks of volcanic and sedimentary parentage interfinger. The depositional environment is permissive for the occurrence of volcanogenic exhalative massive sulfide deposits. Bundtzen (1981) draws an analogy of these environments to the Delta Mineral Belt of the eastern Alaska Range that hosts stratiform massive sulfide deposits. A similar comparison can be made to the Ambler massive sulfide district in the western Brooks Range.

Stratiform sulfide occurrences were noted by Hawley (1977) and Bundtzen (1981) in the Spruce Creek Sequence. Most of the stratiform sulfide showings are contained within the volcanic components of the sequence. Primarily they occur in the metafelsite (Psfq) unit and, to a lesser extent, in the intermediate composition chlorite phyllite (Pscp) unit. The metafelsite is locally sulfide-bearing with disseminations, stringers, thin laminae of pyrite, and traces of chalcopyrite comprising up to 0.5% of the rock.

Stratiform pyrite mineralization in blastoporphyritic metafelsite was noted at two locations: the head of the East Fork of Glen Creek and the ridge dividing Spruce and Crevice Creeks (Appendix B, no. 79 and 86). Bundtzen (1981, p. 48) reports a similar occurrence at the Saddle Prospect (Appendix B, no. 57, plate K-8). At these locations the metafelsite is massive to well-foliated with interbeds of graphitic phyllite up to 10-ft thick. The mineralization forms local layers of parallel pods, 6-in. thick by 2-ft long, containing about 20% pyrite. Outcrops are extensively limonite stained, and sulfide mineralization does not appear to be widespread. Analytical results from the Glen Creek showing contain no base- or precious-metal values. However, a sample of a 1-in.-thick pyrite layer containing visible sphalerite and arsenopyrite from the Spruce Creek occurrence (Appendix B, no. 86) assayed 8.2 ppm gold, 12 ppm silver, 1,850 ppm lead, 1,500 ppm zinc, and 2,600 ppm arsenic. The Saddle Prospect is underlain by blastoporphyritic metafelsite and reportedly contains several discontinuous concordant pods of massive pyrite up to 1-ft thick (Bundtzen, 1981). Examination of the prospect during this study did not reveal mineralization in place. The presence of abundant sulfide-bearing float did confirm the concordant nature of the mineralization. Assays from this study and Bundtzen (1981) do not show significant base- or precious-metal values.

Bundtzen (1981) reported possible stratiform sulfides and gossan zones in an area of mixed metafelsite and graphitic phyllite on the ridge between Spruce and Kankone Peaks. The occurrence (Appendix B, no. 91) is described as a stratiform, silicified, pyrite and gossan zone about 6-ft wide and 240-ft long. A sample collected by Hawley (1977) contains 1.7% zinc, 0.1 oz Ag/ton, and trace copper, lead, and gold. Prospecting the same area during this study revealed lenses of blastoporphyritic and fine-grained metafelsite occurring within graphitic and chloritic phyllite units of the Spruce Creek Sequence. Pyrite occurring as disseminated bands, locally becomes semi-massive to 0.5-in. thick in metafelsite. Limonite staining is abundant. The mineralization is discontinuous and forms lenses over a strike length of at least 2,400 ft. Grab samples (C13770-C13771) collected during this study did contain significant metal values.

The geology between Spruce and Kankone Peaks is interpreted as a zone of intercalated organic-rich sedimentary rocks and felsic volcanics, possibly airfall tuffites. Hawley's (1977) samples showed significant zinc and silver values and indicate a locally metal-enriched environment. The metafelsite is cut by discordant, epigenetic quartz-galena-stibnite-pyrite veins carrying high-grade precious-metal values. One grab sample of a narrow galena-quartz vein contains almost 1 oz Au/ton, over 100 oz Ag/ton, and 33% lead.

The genesis of the crosscutting precious- and base-metal veins is unknown. They are possibly a product of remobilization from a potentially metal-enriched, lower grade, stratabound source. This concept, which is in agreement with Bundtzen's (1981) "metal source bed" hypothesis, is untested, and further detailed studies are needed to document its validity.

Hawley (1977) reports that bulk samples of unmineralized graphitic phyllites interlayered with calcareous units on Eldorado Creek contain up to 160 ppm copper, 255 ppm lead, 575 ppm zinc, 12 ppm silver, and 20 ppm molybdenum. A small showing of podiform, stratiform massive to semi-massive pyrite occurs in the calcareous chlorite phyllite member (Pscc) at Eldorado Creek (Appendix B, no. 21). The stratabound lenses are from 1- to 8-in. thick and up to 50-ft long. A grab sample of massive pyrite contains no significant base or precious metals. The chloritic host rock possibly reflects an intermediate composition tuffite protolith.

The Lloyd Prospect was considered by Bundtzen (1981) to be hosted by components of the metafelsite unit of the Spruce Creek Sequence. The conclusions of this 1983 study are that the Lloyd Prospect is contained within quartzites of the Birch Creek Schist suggesting a much older and unrelated episode of mineralization.

The preferential occurrence of stratiform or stratabound mineralization in Spruce Creek Sequence rocks of volcanoclastic or volcanic parentage point to possible deposition of the sulfides during the waning stages of volcanism. This study was not an aggressive or systematic search for concealed massive sulfide deposits; however, the favorable geologic setting, composition and areal distribution of volcanic lithologies, and the occurrence of concordant stratiform sulfide mineralization indicate that the Spruce Creek Sequence is a favorable host for massive sulfide deposits.

OTHER DEPOSITS AND OCCURRENCES

By Jason R. Bressler

A significant number of new mineral occurrences were identified during regional mapping and sampling. Included in this category are mineral deposits of geologic interest but lesser economic importance.

SPRUCE-KANKONE TREND

A zone of anomalous stream silt, soil, and rock chip geochemistry was delineated along the west flank of the ridge between Spruce Peak and Kankone Peak. Several structurally-controlled mineralized shear zones with high-grade gold, silver, and base-metal veins have been outlined. The area is drained by tributaries of Caribou Creek and is herein termed the Spruce-Kankone Trend (fig. K-33).

The Spruce-Kankone Trend is underlain by interbedded blastoporphyritic and fine-grained metafelsite and graphitic phyllite in structural contact with a thick section of massive metafelsite. Epigenetic mineralization is localized by major northeast-trending faults bounding major lithologic units, including the Spruce Creek Sequence-Birch Creek Schist contact. Near the structural contact between metafelsite and graphitic schist, a steeply dipping secondary shear zone trending N. 15° W. cuts the metafelsite. This shear is filled by a brecciated, 1-ft wide, quartz-carbonate-sphalerite-galena-pyrite vein. A grab sample (C14409) of zinc-rich material contains 0.12 oz Au/ton, 2.94 oz Ag/ton, 2.8% lead, and 8.15% zinc. The vein is strongly oxidized, and wall rocks are coated with jarosite, plumbojarosite, goethite and enveloped by a weakly-developed quartz-sericite alteration halo. Exposed strike length is several 10's of feet. Only one vein was discovered, but the structural setting is favorable for the occurrence of more.

A similar structural setting and associated mineralization are located 2,000 ft northeast of sample C14409 in an area where marble and the underlying metafelsite unit are in fault contact with the Birch Creek Schist. The fault trends N. 35° E., forming pronounced topographic saddles marked by iron-stained soil and sulfide-bearing vein quartz material. Subsidiary shear zones paralleling the major fault also contain quartz-sulfide veins. The highest grade vein samples occur in the more brittle metafelsite unit. Grab samples of quartz-sulfide vein material from three successive saddle zones (plate K-10) over a distance of 2,800 ft yielded the following assay results: (table K-11)

Table K-11 - Assay Results Along Spruce-Kankone Trend

Sample No.	Au oz/ton	Ag oz/ton	Pb %	Zn %	Cu %	As %
C14413	0.93	112.4	33.0	0.265	0.12	2.65
C14444	0.34	53.3	38.3	7.65	0.01	0.57
C14412	0.23	51.3	21.5	14.0	0.325	2.85
C14411	0.22 (ppm)	7 (ppm)	0.19	0.023	0.0003	0.09
C14410	nil	0.4	0.002	0.002	nil	0.013
C14456	nil	nil	0.001	0.002	0.001	0.011

Soil sample traverse lines across three saddles indicate strongly anomalous, but spotty gold, silver, copper, lead, zinc, and arsenic values. The results demonstrate that the mineralization occupies several discrete narrow zones. Maximum values in soils are 70 ppm silver, 2.7 ppm gold, 1,250 ppm lead, and 740 ppm zinc.

Stream silt geochemistry indicates the structure contains anomalous mineralization over an additional 5,000 ft for a total inferred strike length of 7,800 ft. Stream silt samples collected below the saddles with the high-grade veins contain the highest values; up to 0.1 ppm gold, 8.3 ppm silver, 175 ppm lead, 880 ppm zinc, and 530 ppm arsenic. Streams draining the projected northeast trend of mineralization contain metal values of lesser magnitude; up to 60 ppm lead, 0.14 ppm gold, and 1.4 ppm silver.

The Spruce-Kankone Trend is a precious-metal-bearing shear system localized by a major northeast-trending fault similar to the Quigley Ridge vein system. The faults apparently acted as effective conduits, tapping metal-rich fluids at depth and funneling them upwards. The trend displays a possible strike length of 7,800 ft with high-grade precious-metal values for at least 2,800 ft. Persistence and continuity of mineralization are undetermined.

The mineralized shear zones of the Spruce-Kankone Trend are being actively eroded by steep tributary streams of Caribou Creek. The trend is probably a major if not the prime source of gold in the Caribou Creek placer deposits.

Soil samples from several fault-controlled topographic saddles on the ridge extending northeast of Spruce Peak contain anomalous base- and precious-metal values. The saddles form conspicuous orange-red color anomalies which are attributed to zones of iron oxide-stained soil and rubble. Similar stained and anomalous zones are located at the head of the Myrtle Creek drainage basin and the north slope of Kankone Peak.

The saddles are cut by northeasterly-trending shear and fractures zones along which quartz-sulfide veins have been emplaced. The structures are estimated to range in width from less than 1 ft to several 10's of feet; length is undetermined due to limited exposure. These mineralized shear zones roughly parallel the major fault bounding the Spruce Creek Sequence and Birch Creek Schist. The shears cut both rock terranes.

Other than traces of relict pyrite, no fresh sulfide minerals were noted, although abundant vein quartz, goethite, limonite, and jarosite indicate their former presence. Grab samples of iron-stained vein quartz rubble contain up to 710 ppm lead, 9.7 ppm silver, 0.12 ppm gold, 465 ppm arsenic, and 305 ppm antimony. These zones are probably extensions of the Quigley Ridge-type mineralized structures.

GARNET-BEARING AMPHIBOLITE

Bundtzen (1981) reported that during the course of mineral separation studies, certain garnet amphibolite (p€g?) units from the headwaters of Crooked Creek, north of the study area, were found to contain free gold. This presents wide ranging implications as both a metal source for many gold placer deposits and to a lesser extent as a gold resource. During this study well-developed garnet-quartz, plus or minus biotite, amphibolite units exposed at the Last Chance Antimony Prospect were sampled and found to contain nil gold and silver and negligible base-metal values. Results from the very limited data base do not indicate an economically significant gold source in the garnet amphibolite. To fully assess the potential, many additional samples from different locations should be collected.

SKARN DEPOSITS

The Iron Dome skarn occurrence was described by Bundtzen (1981) and sampled by Morrison (1964). Mineralogy of the skarn is described in a previous section of this report. The skarn contains pyrite with minor sphalerite and chalcopyrite as disseminations and discontinuous pods less than 15-ft across (Bundtzen, 1981). The bedrock consists of banded marble with minor phyllite and quartzite of the Spruce Creek Sequence. The marble is variably skarnified, which possibly reflects the original silica and impurity content of the carbonate. Assays by Bundtzen (1981) and this study do not show significant base- or precious-metal contents. The skarn material did not reveal the presence of scheelite under black light examination. A sulfide-bearing sample collected by Morrison (1964) contained 1 oz Ag/ton. Metal concentrations are far below ore grade, and the small discontinuous nature of mineralization does not indicate economic potential.

A possible skarn-type occurrence located on the ridge line south of Eureka Creek straddles the study area boundary. The occurrence consists of float boulders of coarse-grained aggregates of sphalerite, pyrite, galena, chalcopyrite, and hematite in a garnet-actinolite-quartz gangue. No outcrop is present in the area, although the country rock appears to be Birch Creek Schist. No calcareous rocks were noted in the area. A grab sample collected during this study contained 1.05% lead, 11.0% zinc, 0.11% copper, and nil gold and silver (sample C12613). The economic potential of the occurrence is undetermined.

COAL

Bundtzen (1981) reported lignitic to subbituminous coal float in the active floodplains of Glacier and Caribou Creeks. Moffit (1933) describes an outcrop of lignitic coal about 12-ft thick in the upper Moose-Stoney Creek area, southeast of the study area. Coal was reportedly mined from this area in the 1920's for use by prospectors working in the Mt. Eielsen area. Except for some minor lignitic debris noted in the active alluvium of Moose Creek, no coal was noted during the course of this study. The potential for discovering an economic deposit is considered low.

GEOCHEMICAL ANOMALIES

By Jason R. Bressler

More than 400 stream sediment and panned concentrate samples were collected within the Kantishna Hills study area. A complete discussion of the geochemical program and the methodology for determining anomalous values is presented in Appendix D. Sample locations and anomalous samples are shown on plates K-11 through K-15. Anomalous areas are summarized on figures K-34 through K-41 and discussed briefly below.

The Eldorado Creek drainage contains numerous first- and second-order gold, silver, copper, lead, zinc, antimony, tungsten, and arsenic anomalies. Values range up to 8.6 ppm silver, 0.45 ppm gold, 5,650 ppm copper, 500 ppm lead, 1,250 ppm zinc, 15,000 ppm antimony, 3,100 ppm tungsten, and 2,300 ppm arsenic. The drainage is underlain by the Spruce Creek Sequence exposed through a structural window. Numerous prospects, including the Slate Creek, Bunnell, Alpha, and Eagles Den, are located in this drainage basin.

A cluster of gold, silver, copper, lead, zinc, tungsten, and arsenic anomalies occurs in the upper Caribou Creek drainage. Most of the anomalous streams drain the Spruce-Kankone Trend described earlier.

First-order zinc anomalies (to 1,350 ppm) are characteristic of streams draining the Keevy Peak Formation and black graphitic schist and slate units of the Birch Creek Schist. The previously described Canyon Creek and Red Dirt occurrences show background zinc values in stream silt; downstream values increase to 425 to 540 ppm. As described earlier, coincident, first-order lead and zinc stream silt anomalies occur near the Canyon Creek occurrence and in the Keevy Peak Formation. In black shale terrane, zinc greater than 500 ppm and lead greater than 50 ppm are considered anomalous.

A tributary to Bearpaw River found to be anomalous in lead (1,090 ppm; Bundtzen and others, 1976) and zinc (4,750 ppm; Hawley, 1977) was resampled during this study. Results verify the magnitude of Hawley's anomaly but not the extremely high lead value reported by Bundtzen. The drainage is underlain by undifferentiated schist and quartzite (p€sq) of the Birch Creek Schist and a small pod of the graphitic schist (p€gs). A sample from an iron oxide-stained seep contained 5,900 ppm zinc with negligible amounts of lead and copper. The adjacent drainage to the west also drains a portion of the p€gs unit and yielded samples containing up to 550 ppm zinc. A single sample in the upper Rock Creek drainage contains 1,350 ppm zinc with no associated lead content. Upper Rock Creek was determined by Bundtzen (1981) to be underlain by a large section of p€gs. Other scattered lower order zinc anomalies occur in the Rock Creek, Little Moose Creek, and Bearpaw River drainages. The bedrock source is not known.

Anomalously high lead and zinc were detected in several streams draining the Spruce Creek Sequence. Samples with anomalous lead values were also obtained from Rock and Little Moose Creeks.

Anomalously high copper was detected in samples in the Canyon Creek basin, which drains the Red Dirt and Canyon Creek occurrences (fig. K-29). Several streams draining the Spruce Creek Sequence also contained high copper values (fig. K-37). Other copper anomalies were detected in samples from Little Moose Creek and two eastern tributarites to Rock Creek.

Possibly significant tungsten anomalies were detected in the Canyon Creek drainage by regional placer and panned concentrate sampling. Placer samples from the middle fork of Canyon Creek outline a 4-mile-long dispersion train with values from 200 to 17,850 ppm tungsten. Panned concentrate samples from the area contain up to 46 ppm tungsten. Coarse-grained scheelite was detected in the samples. The farthest upstream anomaly, with a value of 1,000 ppm, is located in a stream drainage about 3-miles long. The basin is underlain by schist, quartzite, and graphitic schist of the Birch Creek Schist. No intrusive rocks or calcareous rocks indicative of skarns are currently known to occur in the basin.

Tungsten anomalies are present in many of the streams draining the Spruce Creek Sequence. Minor streams draining the ridge separating

Caribou and Rock Creeks and an unnamed tributary to the upper Bearpaw River contain anomalously high tungsten values. The latter anomalies are in close proximity to major north-trending faults within the Birch Creek Schist (p€s).

Tungsten anomalies were also delineated in the main channel of the North Fork of Canyon Creek (375 ppm), in a small south-flowing tributary draining calcareous schist (265 ppm), and in the Stampede area (up to 2,000 ppm). These anomalies may be related to the projected trend of the Spruce Creek Sequence.

Gold and silver anomalies are present in most of the streams draining known gold and silver lode deposits contained in the Spruce Creek Sequence. Anomalous gold was also detected in samples from Canyon, Stampede, and Little Moose Creeks and in tributaries to upper Bearpaw River. High silver values are present in Canyon, Moose, and Rock Creeks.

Numerous arsenic anomalies were detected in stream silt samples in the Eldorado Creek drainage and in streams draining the Spruce-Kankone Trend. Isolated arsenic anomalies were also detected in the North Fork of Canyon Creek and in an unnamed tributary to Rock Creek.

GEOLOGY AND MINERAL DEPOSITS OF THE DUNKLE MINE STUDY AREA

By Calvin J. McKee

INTRODUCTION

The Dunkle Mine study area is located along the southeastern border of the Denali National Park and Preserve and includes all of T. 19 S., R. 10 W., Fairbanks Meridian (fig. 1).

The study area is part of a larger mineral belt which at one time was referred to as the Broad Pass Mining District and later as the Upper Chulitna District. In this report, the study area refers to the above described township. Comments addressing the geology or mineralization on a broader scale will refer to the Upper Chulitna District or region (fig. D-6).

Field work in the Dunkle Mine study area consisted of geologic mapping, geochemical sampling, and evaluating pre-existing data. All known prospects were mapped in detail and sampled. The entire study area, except where completely covered by overburden, was examined on a reconnaissance basis. Stream sediment and panned concentrate samples were collected from all streams, and placer potential was tested on several gold-bearing drainages.

HISTORY OF MINING ACTIVITY

Lode gold mines were discovered in the Dunkle Mine study area in the early part of this century. Although the deposits initially appeared promising, most of the ore was not free-milling, and other types of mineral processing were prohibitively expensive. In addition, the remoteness of the district made it costly to ship in milling equipment and supplies or ship out crude ore. Consequently, the deposits remained virtually untouched until 1934 when the gold prices increased and railroad transportation was

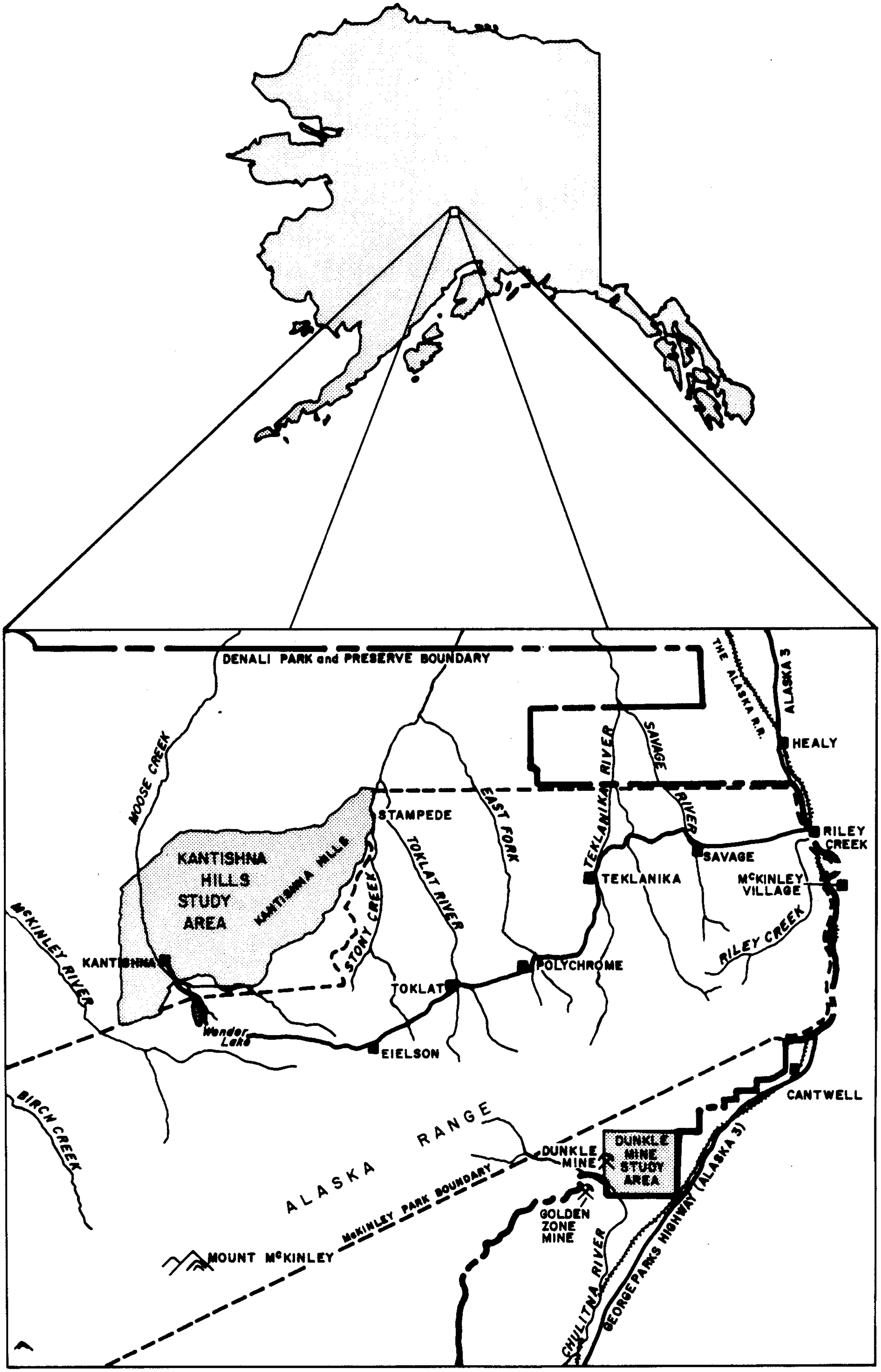


Figure 1 - Index Map

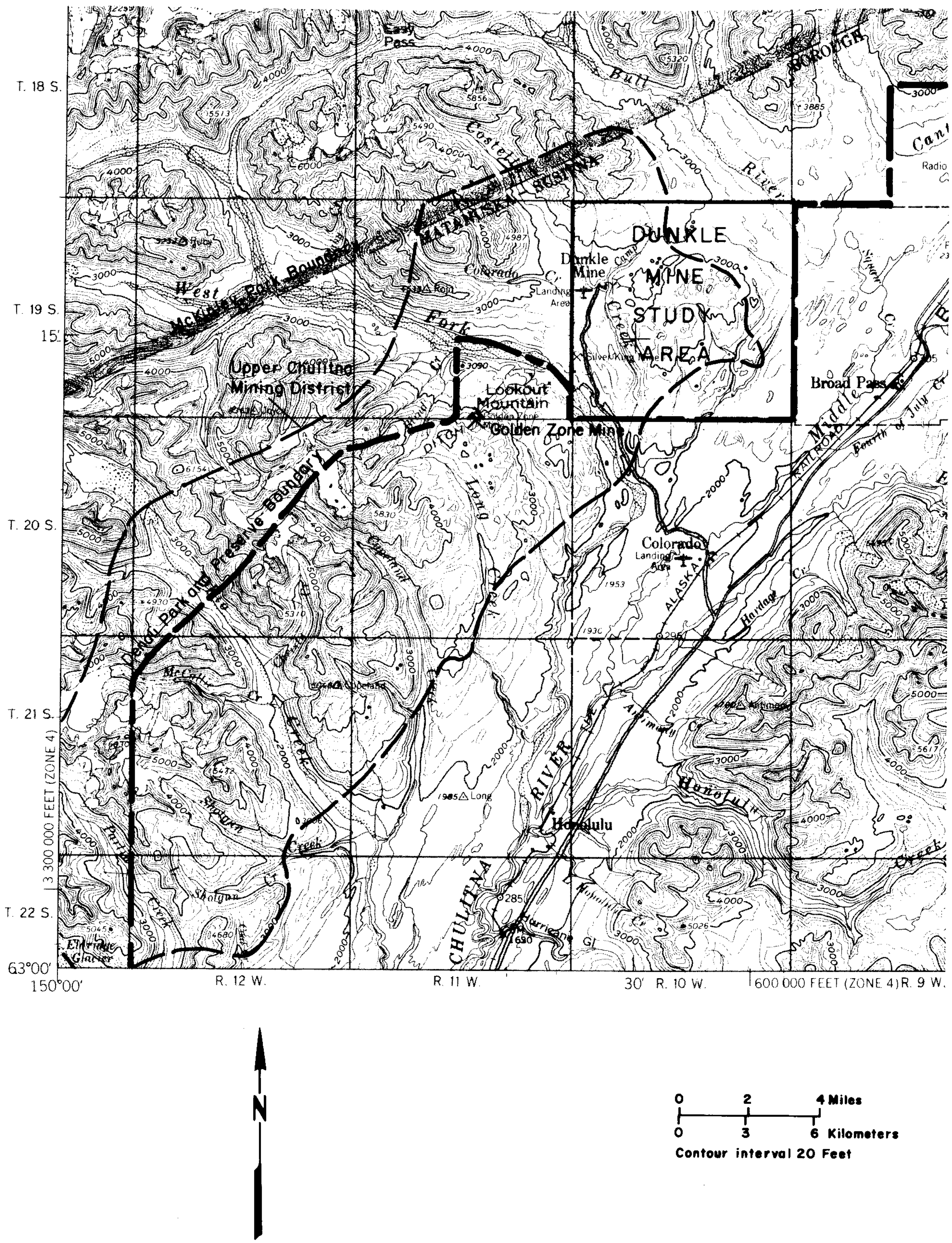


Figure No. D-6 Location of Dunkle Mine Study Area and Chulitna District available. Interest in the area was intensified after publication of U. S. Geological Survey reports by Hawley and others in the late 1960's and early 1980's. Activity soon dwindled, however, because of land and activity restrictions imposed by the Alaska Native Claims Settlement Act in 1971.

Following is a chronology of mineral activity in and near the Dunkle Mine study area.

1907 The first placer claim in the Upper Chulitna District is staked on Bryn Mawr Creek.

1909 The first lode claim in the district is staked on the Golden Zone Deposit, about 2 miles west of the Dunkle Mine study area.

1911 The first claim within the boundaries of the study area is staked on the Eagle Prospect.

1911-15 Most of the high-grade lode deposits in the study area are staked. The Dunkle (Costello Creek) coal deposit is discovered and produces a small quantity of coal for local use.

1929 A prospecting permit is issued for the Dunkle Coal Mine, and again some coal is mined for local use.

1934 With railroad access to the district and the price of gold elevated to $35/oz, prospects are being re-evaluated.

1941-42 The Golden Zone Mine produces 869 tons of concentrate containing 1,581 oz of gold, 8,617 oz of silver, 21 tons of copper, and 3,000 lb of lead.

1941-42 Approximately 5,000 tons of coal are mined from the Dunkle Mine and shipped on the Alaskan Railroad.

1942 Federal order (L-208) closes large U. S. gold mines, including the Golden Zone Mine.

1952-54 The Dunkle Coal Mine is reopened. Approximately 59,000 tons of coal are mined by stripping.

1968-74 Publication of results of U. S. Geological Survey investigations spur renewed interest in mineral deposits of the Chulitna Region.

1971 A large block of claims (the NIM group) is staked in the study area over a potential porphyry copper target.

1971 The Alaska Native Claims Settlement Act (ANCSA) restricts prospecting and mining activity to existing claims.

1980 The Alaska National Interest Lands Conservation Act (ANILCA) places the lands of the study area within the newly created Denali National Park and Preserve.

PREVIOUS STUDIES

An early description of mining activity in and around the Dunkle Mine study area is provided by Capps (1919) as part of his discussion of the Chulitna District and coal resources of the Broad Pass area. During his investigation of the Alaska Railroad route, Ross (1933) examined the major lode prospects and provided valuable assay data and descriptions of prospects. The Dunkle Coal Mine was described by Wahrhaftig (1944) and Rutledge (1948).

Results of extensive work in the Chulitna area by the U. S. Geological Survey were presented in reports by Hawley and Clark (1968), Hawley and others (1969), and Hawley and Clark (1974). Hawley, Clark, and Benfer (1968), described the geology of the Golden Zone Mine, the region's most important deposit.

In the early 1970's Resource Associates of Alaska and Resource Exploration Consultants conducted extensive mineral exploration programs consisting of geological, geophysical, and geochemical surveys. Most of this work was centered on the NIM claim area. Results of these surveys were made available for this study.

Hawley (1978) assessed the potential mineral resources of the area. Jones, Silberling, and others (1980) published a new interpretation of this geologically complex region. Bundtzen (1983), in a State of Alaska investigation on mineral resource modeling for the Kantishna Hills-Dunkle Mine study areas, discussed potential size and grade of mineral deposits which are known or suspected.

PHYSICAL SETTING

The primary topographic feature of the area is the group of low-rounded hills which cover most of the township. The subdued topography of these hills is in sharp contrast to the rugged mountains of the Alaska Range immediately to the north. Several streams draining the hills are deeply incised. Evidence of glaciation is common. A large tundra-covered flat mantles the northeastern corner of the study area.

Vegetation primarily includes low bushes, grass, and moss, although some spruce trees are found at lower elevations in the southern part of the township. Timber is abundant a few miles to the south in the valley of the Chulitna River.

The climate is more severe in the Chulitna region than on the north slope of the Alaska Range. Winter snow accumulation is generally deeper and summer precipitation heavier.

The southeastern corner of the study area is within 2 miles of both the Alaska Railroad and the Parks Highway. A road connecting the highway and railroad with the Dunkle Coal Mine is presently in disrepair and not passable to normal vehicle traffic. Some minor repairs and a bridge would make the road usable. An airstrip at the Dunkle Mine is usable, and several lakes in the area may be accessible to small float planes.

REGIONAL GEOLOGY

GEOLOGY OF THE UPPER CHULITNA REGION

The rocks and structure of the Upper Chulitna region are extremely complex and their origin and history are not completely resolved. Rocks in the region are arranged in several distinct northeast-southwest-trending terranes. These terranes are described as discrete allochthonous stratigraphic and structural blocks separated by conspicuous faults. From northwest to southeast, terranes are described by Jones, Silberling and others (1980), as follows:

> "Eldridge terrane - lies north of the Chulitna terrane and includes deformed graywacke, chert, minor limestone, phyllite, and conglomerate. Early Cretaceous fossils locally are present.
>
> Chulitna terrane - includes Upper Devonian ophiolite, (serpentinite, gabbro, pillow basalt, red radiolarian chert); upper Paleozoic chert, tuff, volcanic conglomerate and sandstone, flysch, and limestone; Triassic limestone, basalt, redbeds, marine sandstone, and shale; Jurassic sandstone shale, and chert; and Cretaceous sandstone, argillite, and chert. This terrane is internally faulted and folded, and structurally overlies the West Fork and Eldridge terranes.
>
> West Fork terrane - includes highly folded and sheared Upper Jurassic chert and argillite with enclosed blocks of Lower Jurassic phosphatic limey sandstone; and massive siliceous crystal tuff, graywacke, and minor conglomerate of Triassic(?) and Jurassic age. This terrane is in fault contact on the southeast with the Broad Pass terrane.
>
> Broad Pass terrane - includes a complexly deformed and little-studied assemblage of chert, tuff, andesitic volcanic rocks, pods, and lenses of limestone, and gray phyllite. Fossils from limestone are Middle Devonian or older; those from tuff and chert are latest Devonian(?) to early Carboniferous. Rocks of this terrane are in fault contact on the southeast with the Susitna terrane.
>
> Susitna terrane - includes highly deformed flysch-like rocks of Cretaceous age and large folded slabs of pillow basalt and associated deep-water tuffaceous sedimentary rocks of late Triassic age. The Cretaceous flysch is generally similar to and of the same age as the flysch of the Eldridge terrane.

> The presence of coeval but unlike rocks in these adjoining terranes suggests that large-scale tectonic juxtapositions have occurred. Thrust faulting may be the dominant structural style, but large amounts of strike-slip displacement may have occurred also. The intimate involvement of Lower Cretaceous rocks in some of these terranes suggest that the main juxtaposition occurred in middle and Late Cretaceous time."

A simplified geologic map (fig. D-7), shows the location of these terranes and major structures. Much of the area shown in figure D-7 is covered by overburden, and distribution of rock units and structures must sometimes be made on limited field evidence. Field investigations during this study have shown that rocks within the Dunkle Mine study area are complex and their relationship to regional geology is not clearly established.

Of economic interest on a regional scale is the apparent correlation with a northeast-trending structure of several mineral deposits containing gold, silver, copper, and antimony, including the Golden Zone Mine and several prospects within the study area. This structure has been referred to as the Chulitna structural zone or Chulitna Fault and may be an important control for localizing mineral deposits.

GEOLOGY OF THE DUNKLE MINE STUDY AREA

Interpretation of the geology of the Upper Chulitna region is based on previous field work, most of which was performed just to the southwest of the Dunkle Mine study area. The character of several of the major structures and the relationship of some of the rocks within this study area to the regional terranes is not well understood. Rocks of the study area have been further complicated by the coalescing or intersection of several regional structures and by the introduction of a variety of intrusive rocks. Widespread intrusive activity has apparently metamorphosed much of the older rock, masking original features. In addition, portions of the area are covered with overburden and geologic interpretation must rely on indirect methods such as geophysics.

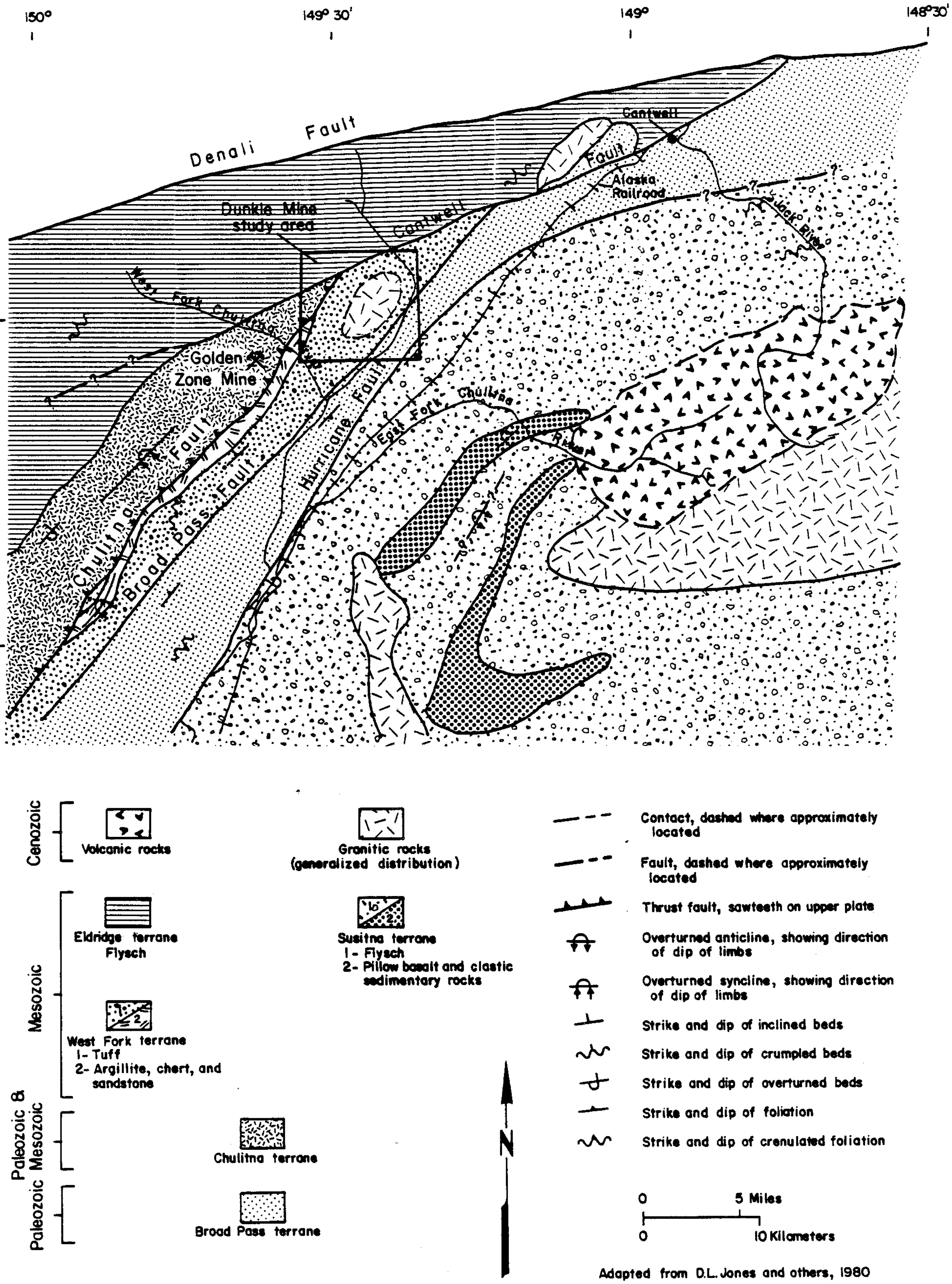


Figure D-7 Regional Geologic Sketch Map of the Upper Chulitna District and Dunkle Mine Study Area

The geologic map (plate D-1) has been adapted primarily from field mapping performed during this 1983 study and mapping done by Resource Associates of Alaska and Resource Exploration Consultants during evaluation of the NIM claim group. Mapping necessarily relied on surface rubble, a few hand dug pits, and very little outcrop. Although this geologic map gives a good idea of the variety of rock types present and their general distribution, the geology could not be mapped in detail. Most of the rubble covering the hills in the study area is believed to be derived locally, although glacial activity has introduced some extraneous material. Limited drilling performed on the NIM claims indicates that some of the rubble, although locally derived, is not directly overlying its source.

Few data are available to determine the absolute ages of rocks in the study area. Ages assigned on the map (plate D-1) were inferred from mapping elsewhere in the Alaska Range.

Rock Types

Three major rock types have been recognized and mapped on a regional basis. These include volcano-sedimentary sequences, intermediate igneous rocks, and felsic igneous rocks.

The oldest rocks appear to be sequences of sedimentary, volcanic, and volcaniclastic units, including conglomerate, graywacke, siltstone, argillite, limey sandstone or limestone, tuffs, and tuffaceous sediments.

Igneous rocks of intermediate composition, mainly hornblende diorite and andesite, occur primarily along the northern border of the central hilly region. These rocks may underlie a large part of the flat tundra-covered swampy area.

Felsic igneous rocks also occur, particularly in the hilly region, and represent the latest intrusive activity. A wide variety of textures and compositions is found in these rocks. Petrographic studies performed during evaluation of the NIM claims identified coarse-grained granite, granodiorite, quartz monzonite, quartz porphyry, diorite porphyry, and granodiorite porphyry. The dioritic and felsic plutons were apparently responsible for the widespread silicification and hornfelsing of the older rocks. The broad extent of this alteration indicates that intrusive bodies may be more widespread at shallow depth than is indicated by surface rubble.

Tertiary sedimentary rock, from which coal has been mined, occurs near the junction of Camp and Costello Creeks.

Much of the northern third of the study area is covered by glaciofluvial deposits. Tertiary sediments exposed on the northern border of the area and rather sharply tilted to the south indicate the region has been tectonically active recently. Rapid uplift is further evidenced by the deeply entrenched character of most of the streams.

The area is structurally complex. Although most of the structures trend northeast, a series of northwest-trending basaltic dikes crosscut the major structures. Brecciated areas are common.

MINERAL DEPOSITS

The only mine production from within the study area has been from the Dunkle Coal Mine. Sulfide mineralization, however, is rather common and widespread, and occurs in veins, breccias and as disseminations. Alluvial gold occurs in several streams. All known prospects were examined and are discussed individually.

GOLD PLACER DEPOSITS

Costello and Colorado Creeks, and the Bull River (plate D-1) were examined during the 1983 field season. These streams occupy relatively steep and often deeply incised, narrow bedrock canyons where little gravel has accumulated. According to Bundtzen (1983), "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 the 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." Gold-bearing lodes, described later in this section of this report, are probably the source of these placers.

Table D-1 describes the mineralization, mining history, and placer resource potential of drainages investigated during the current study.

Costello and Colorado Creeks, and portions of the Bull River have moderate placer resource potential inside the study area and high potential immediately outside of the study area. These streams tend to be difficult to access, and volumes are probably not large enough to warrant mining by heavy equipment. Small-scale suction dredging might be successful on some sections of Costello and Colorado Creeks.

DUNKLE COAL MINE

The Dunkle Coal Mine, sometimes referred to as the Costello Creek Mine, is located in the NW 1/4 sec. 17, T. 9 S., R. 10 W. The mine area was examined during this study, but workings are caved and inaccessible. Most of the information presented in this report is derived from a 1943 U. S. Bureau of Mines study during which the deposit was mapped, trenched, and diamond drilled (Rutledge, 1948).

The coal deposit was discovered during the early days of gold prospecting, between 1911 and 1915. During that time, and again in 1929, a small amount of coal was produced for use by local miners for blacksmithing. During 1941 and 1942, approximately 5,000 tons of coal were produced and shipped on the Alaska Railroad. The mine was worked through two underground developments, Entry #1 and Entry #2, several hundred feet apart. By far the majority of the development was through Entry #2. During 1952-1954, approximately 59,000 additional tons were mined by surface methods (Barnes, 1967).

Table D-1 - Dunkle Regional Placer Resource Summary

Drainage/Location	Summary of Mineralization	Workings and Production	Sample data and resource assessment
Bull River Healy A5, B5 Quads T19S, R10W	The Bull River occupies a relatively narrow bedrock walled valley with an average gradient of about 50 ft/mile. Gold recovered in samples tends to be fine grained, flaky, and bright.	Evidence of mining or significant prospecting was not identified along the Bull River within the study area.	Two samples (A002489, A001419) collected in the study area contained 0.001 oz gold/cy and a trace, respectively. One sample (A001418) collected below the junction of Costello Creek outside the study area contained 0.01 oz gold/cy. An estimated 550,000 cy of gravel occurs along the Bull River inside the study area. The lower portion of the Bull River inside the study area has moderate resource potential for supporting a small to medium sized placer operation.

Compiled by Robert Hoekzema, U. S. Bureau of Mines, 1983.

Table D-1 - Dunkle Regional Placer Resource Summary - Continued

Drainage/Location	Summary of Mineralization	Workings and Production	Sample data and resource assessment
Colorado Creek Healy A6, B6 Quads T19S, R10W	Colorado Creek occupies a very narrow bedrock walled canyon with an average gradient of 250 ft/mile inside the study area. An alluvial fan has accumulated at the mouth of Colorado Creek just west of the study area. Gold is fine grained, flaky, and low fineness.	Evidence of prospecting is present near the mouth of Colorado Creek.	Two samples (A002424, 2429) contained 0.0078 and 0.0047 oz gold/cy, respectively. Very little gravel occurs on the portion of Colorado Creek located inside the study area. At least 350,000 cy of gravel occur in the alluvial fan. Moderate resource potential for suction dredging inside the study area.

Table D-1 - Dunkle Regional Placer Resource Summary - Continued

Drainage/Location	Summary of Mineralization	Workings and Production	Sample data and resource assessment
Costello Creek (below the Dunkle Mine) Healy A5, A6, & B6 Quads. T19S, R10W	Lower Costello Creek mostly occupies a very narrow bed-rock walled canyon and has an average gradient of 175 ft/mile inside the study area. Gold is slightly coarser than that recovered in Colorado Creek and is also flaky and bright. Fineness is low.	Evidence of significant prospecting or mining within the study area was not identified.	One sample (A002431) collected inside the study area contained 0.0029 oz gold/cy. A second sample (A001417) collected 1 mile south of the study area contained 0.033 oz gold/cy. An estimated 150,000 cy of recent alluvial gravel occurs on Costello Creek inside the study area below the Dunkle Mine. Moderate resource potential for small commercial placer operations or suction dredging.

The coal occurs as lenses in gently-dipping, partially-consolidated Tertiary sediments. The sediments are unconformably underlain by steeply-dipping, pre-Tertiary rocks and unconformably overlain by Pleistocene glacial gravels. The coal-bearing formation is rather localized, bounded on the southwest, north, and northeast by faults and eroded on the northwest. Within the previous workings, numerous minor reverse faults were encountered. These faults have displacements of 6 in. to 10 ft, generally strike northwest, and dip 20 to 60°.

Three beds of minable thickness (approximately 6 ft, 4 ft, and 4 ft) were identified at the Dunkle Coal Mine. Total reserves calculated by Rutledge (1948) were approximately 380,000 tons. After deducting the tonnage already mined and assuming a 50% extraction factor, he estimated minable tonnage at 8,400 short tons measured, 116,000 short tons indicated, and 68,300 short tons inferred. These calculations were based on rather widespread drill holes. Rutledge cautioned that since the coal deposits are small and irregular and since correlation between holes is complicated, the estimation of reserves is problematic. Figure D-8 shows the drill hole locations and the projected outlines of the coal beds used for reserve estimates.

At the time of the Bureau of Mines study, the coal was tested by the Bechtel-McCone-Parsons Corporation of Los Angeles, California, and classified as subbituminous A. Results of these tests are as follows:

- The coal can be burned with virtually smokeless combustion.
- The coal produces a hot fire and is efficient for boiler operation.
- The amount of ash and soot is low.
- The ash and clinkers produced break up readily in normal grate dumping.
- The clinker is very porous and does not appreciably retard draft.

Analytical results of coal samples presented in Rutledge (1948) are reproduced in Table D-2.

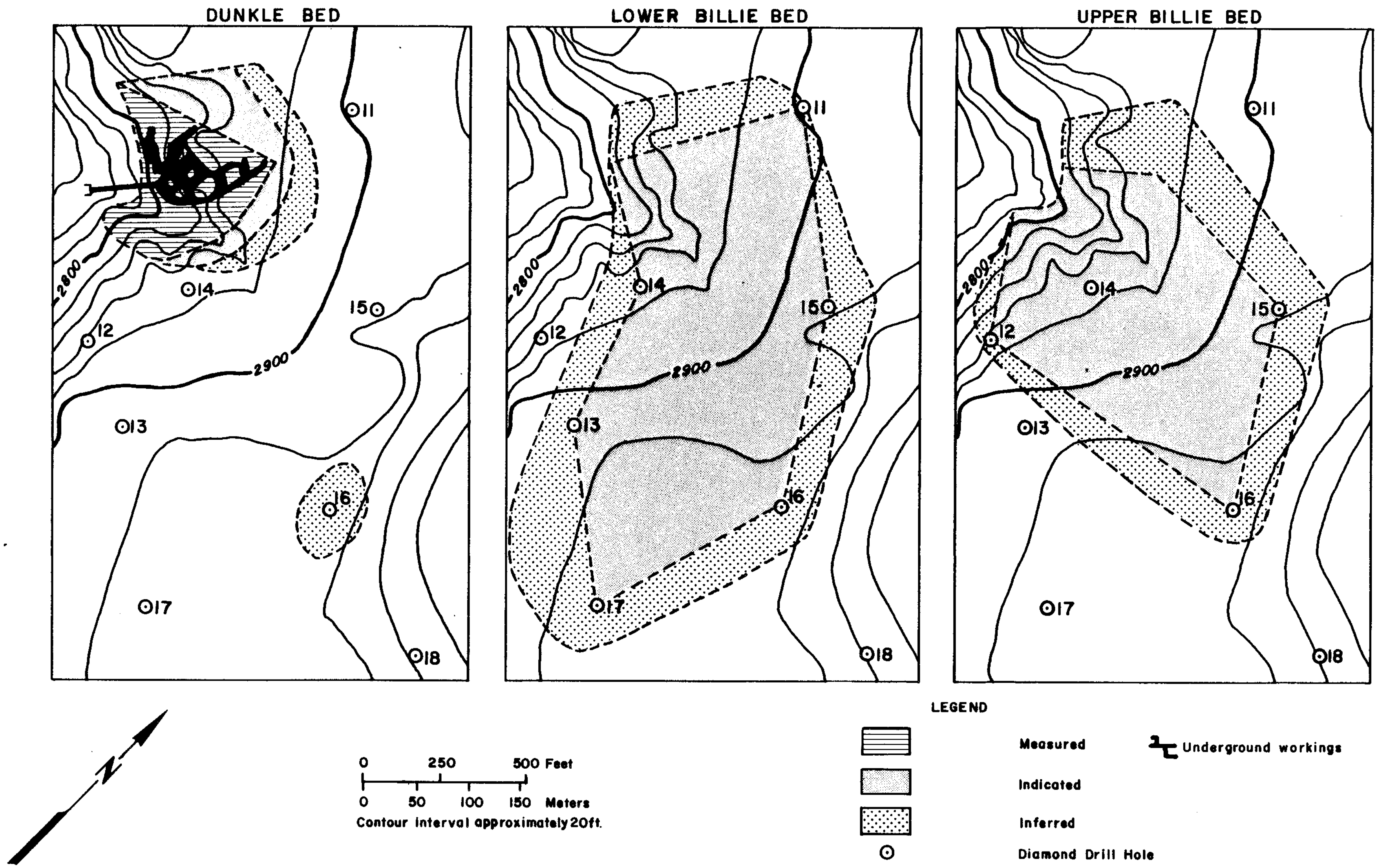


Figure No. D-8 Coal Reserves, W. E. Dunkle Mine - Dunkle Mine Study Area (from Rutledge, 1948)

Table D-2 - Analysis of Dunkle Mine Samples
(Data from Rutledge, 1948)

Sample		Proximate, percent				Ultimate, percent					Calorific value, B.T.U.	Ash-softening temp., °F.	Agglomerating index
		Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen			
Dunkle bed 450 feet from portal, Entry No. 2, at face in haulage way	As-received	18.4	32.0	40.4	9.2	0.6	6.1	55.1	0.8	28.2	9,700	2530	NAa
	Moisture-free		39.2	49.5	11.3	0.8	5.0	67.5	1.0	14.4	11,880		
	Moisture and ash free		44.2	55.8		0.8	5.7	76.0	1.1	16.4	13,380		
Dunkle bed 140 feet from portal, Entry No. 1, 30 feet to face in Room No. 2, north from haulage way	As-received	18.8	33.6	41.4	6.2	0.5	6.3	57.1	0.9	29.0	10,040	2090	NAa
	Moisture-free		41.4	51.0	7.6	0.6	5.2	70.3	1.1	15.2	12,360		
	Moisture and ash free		44.8	55.2		0.6	5.6	76.1	1.1	16.6	13,380		
Dunkle bed 40 feet from portal, Entry No. 2, 120 feet to face in Room No. 1, from haulage way	As-received	15.9	35.9	42.2	6.0	0.5	6.2	59.7	0.9	26.7	10,600	2440	NAa
	Moisture-free		42.7	50.1	7.2	0.6	5.3	71.0	1.1	14.8	12,610		
	Moisture and ash free		46.0	54.0		0.6	5.7	76.5	1.2	16.0	13,580		
Billie bed 40 feet from portal, Entry No. 1, in raise 5 feet above hanging wall of Stevens (Dunkle) Bed	As-received	18.2	34.3	39.9	7.6	0.5	6.3	56.8	0.9	27.9	9,970	2520	NAa
	Moisture-free		41.9	48.8	9.3	0.6	5.3	69.4	1.1	14.3	12,200		
	Moisture and ash free		46.2	53.8		0.6	5.8	76.5	1.2	15.9	13,450		
Dunkle bed 234 feet from portal, Entry No. 2, 12 feet from face	As-received	15.4	37.9	38.0	8.7						9,820		NAa
	Moisture-free		44.8	44.9	10.3						11,605		
	Moisture and ash free		49.9	50.1							12,940		

NIM CLAIM GROUP

The location of the NIM claim block is shown on figure D-9. The property was discovered in 1971 during an exploration program by a joint venture between International Minerals Corp. and Placid Oil Corp. The original claim group of 414 federal lode claims has been reduced to 161, and the property is now under the control of Dr. Richard Swainbank, Fairbanks, Alaska.

The NIM claims were originally staked as a porphyry copper-molybdenum target; subsequent work has suggested that the area has potential for other types of mineralization, including precious metals.

Geology

Bedrock in the NIM claim area primarily consists of Paleozoic metasedimentary rocks and metavolcanics intruded by a variety of igneous rocks. Extensive surficial cover precludes detailed bedrock mapping. Rubble mapping, a limited amount of drill hole data, and extrapolation of mapping in nearby areas have provided an understanding of the general geology but not the interrelationships of the numerous rock types present (plate D-1).

Paleozoic rocks include metamorphosed graywacke, argillite, and mafic to intermediate volcanics. These rocks have undergone widespread silicification, hornfelsing and, locally, sulfidization, apparently related to the emplacement of a hypabyssal igneous complex. The original character of the rocks is often completely masked by metamorphism and alteration.

Numerous breccias, tectonic and intrusive, are found within and surrounding the NIM claims. The existence of these breccias is significant because they invite comparison with the Golden Zone Mine, where brecciation was the main control for gold mineralization.

Both the Paleozoic and later intrusive rocks exhibit local hydrothermal alteration including chloritization, biotitization, silicification, argillization,

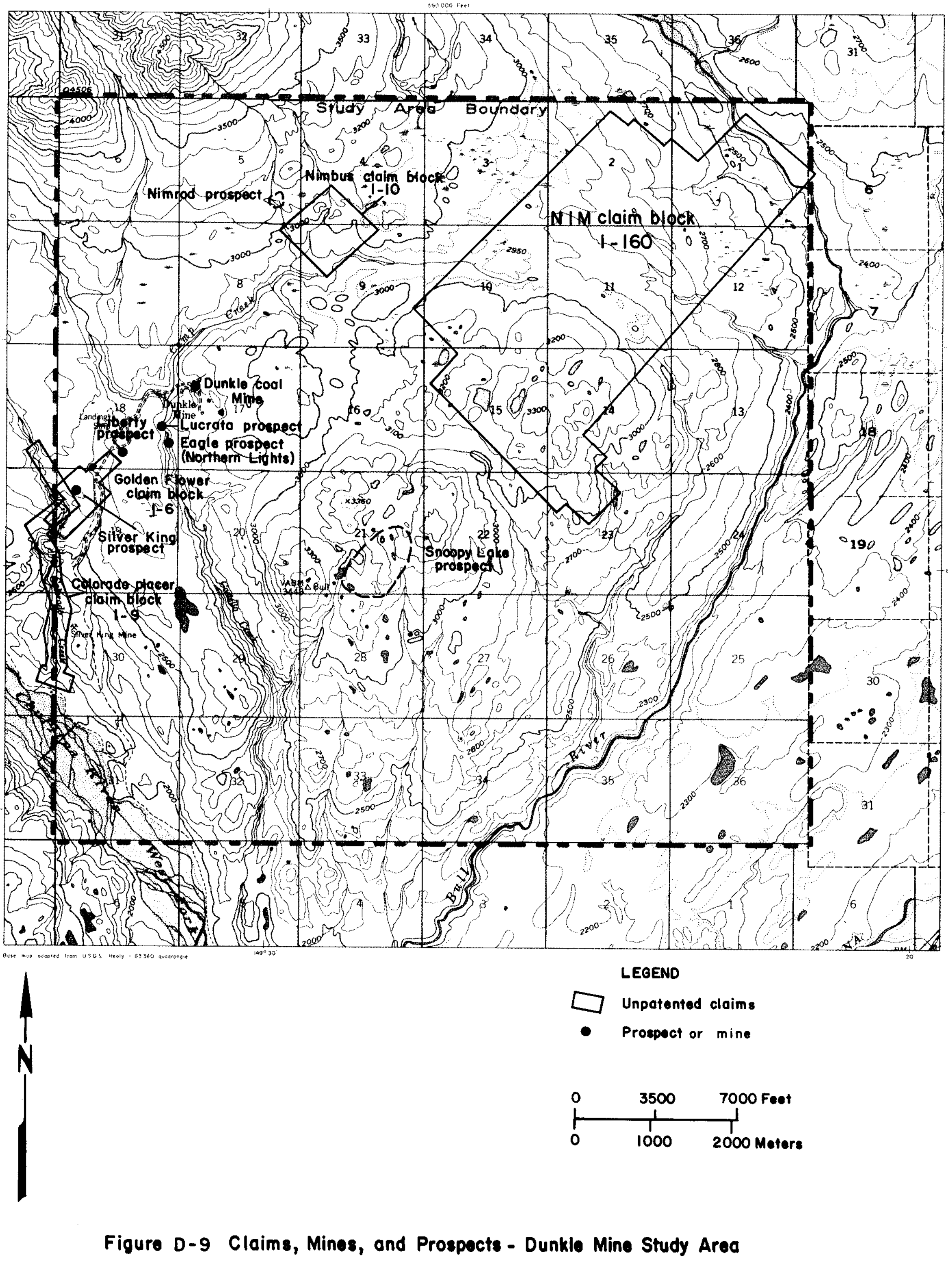


Figure D-9 Claims, Mines, and Prospects - Dunkle Mine Study Area

and sericitization. No definite pattern or zoning is discernible. Any zoning of alteration is probably complex because of the chemical and textural variety of rocks upon which hydrothermal fluids were operating. Further work, including drilling in areas of overburden, would be required to better interpret alteration. Some generalizations, however, can be made:

- Biotitization seems particularly widespread, and several varieties of secondary biotite were noted. Biotite alteration appears to be more intense in brecciated areas, particularly within breccias associated with northwest-trending basaltic dikes.

- Although possibly deuteric, most of the acidic rocks show some degree of argillic alteration. Sericitic alteration is also found in these rocks but is less common.

- Most of the coarse-grained acidic rocks and some of the aphanitic varieties contain abundant limonite, predominantly pseudomorphous after pyrite and arsenopyrite.

- Mafic rocks commonly contain secondary chlorite and epidote.

Sulfide minerals occur in varying amounts throughout the NIM claims. The most common sulfides identified are arsenopyrite, pyrite, pyrrhotite, and chalcopyrite. Also observed or reported are bornite, native copper, chalcocite, molybdenite, galena, tetrahedrite, tennantite, sphalerite, and pyrargyrite.

The hornfelsed rocks commonly contain at least minor amounts of disseminated pyrrhotite and arsenopyrite, usually with traces of chalcopyrite. Locally, particularly near brecciated areas, sulfide mineral content reaches +5% and chalcopyrite becomes the dominant sulfide. Samples from these areas, collected during the study, contain up to 0.9% copper with 0.65 oz Ag/ton (Appendix D). Samples from previous studies report up to 5% copper and 9 oz Ag/ton (Resource Associates of Alaska, 1975).

Many of the acidic intrusive rocks contain disseminated sulfides or limonite pseudomorphs after sulfides. Arsenopyrite appears to be the most common sulfide, locally accompanied by chalcopyrite, molybdenite, and chalcocite. Dimensions of these mineralized intrusives are uncertain. In one area beginning in the SW 1/4 sec. 11, disseminated arsenopyrite in a quartz monzonite(?) can be traced in rubble for several thousand feet to the southwest. This zone corresponds to an induced polarization anomaly (fig. D-10 and D-11). The width of the zone is not known. Samples from this area contain from trace to 0.6 oz Ag/ton, and trace to 0.29% copper. One sample (C14013) contains 555 ppm molybdenum.

Although sulfide minerals most commonly occur as disseminations, veins and veinlets of arsenopyrite and/or chalcopyrite are found in areas of more intense mineralization. Float from a 4- to 6-in.-wide vein of massive arsenopyrite has been found at sample location C14011. This sample contained 0.034 oz Au/ton.

Geochemistry

Geochemical data from extensive soil and rock sampling conducted during previous evaluation of the NIM claims (Resource Associates of Alaska, 1971; and Resource Exploration Consultants, 1980) were made available for this study. The pulps from 125 previous soil samples were re-analyzed to verify previously identified anomalies and aid correlation with samples collected during this study (Appendix E).

Sampling of the NIM area during 1983 consisted of 27 rock and 88 soil samples. In addition, the property owner provided 37 rock samples which he had collected (CS series). Analytical results are shown in Appendix D, and distribution of all samples is shown on plate D-2.

On portions of the NIM claims, the metal content of soil is distinctly anomalous for copper, molybdenum, silver, lead, and occasionally gold. Rock sampling and mapping of the anomalous areas have verified that at least some of the high soil values are derived from and directly overlie mineralization in place. The approximate extent of anomalous soils is shown on figure D-10 and plate D-3. The size and shape of mineralized areas cannot be determined by soil geochemistry until more is known about migration of metals in this environment. There appear to be two major areas with multi-element anomalies, one near the center of sec. 15, and another covering the SW 1/2 sec. 11, T. 19 S., R. 10 W. Another smaller area of lower geochemical values occurs along the northern edge of the NW 1/2 of sec. 23. Whether these areas are separate or part of the same system is unresolved.

The anomaly near the center of sec. 15 may be partially due to secondary reconcentration of metals near the two lakes. Significant mineralization, however, is obvious in the rocks of this area and the soil geochemical anomaly is considered essentially primary.

Up to 1,400 ppm copper and 104 ppm molybdenum occur in soil at the slope break in the northern part of the SE 1/4 of sec. 11. This anomaly may be a reconcentration of metals being transported in solution from an upslope source. Overburden in this area prevents the examination of bedrock for mineralization. This anomaly is of particular interest because it occurs in an area determined by induced polarization surveys to have anomalous chargeability and low resistivity, which could indicate a primary concentration of metals. Further evaluation is warranted.

Geophysical Surveys

Geophysical work performed on and surrounding the NIM claims previous to this investigation included two levels of aeromagnetic surveys, a ground magnetic survey, an induced polarization survey, and electromagnetic surveys. Interpretation of these surveys are summarized on figure D-11 and plate D-3.

The high-level aeromagnetic survey was flown on 1/4-mile line spacing at an altitude of 3,500 ft. This is about 700 ft above ground level over lower elevations on the claims. Part of the area was reflown at approximately 200 ft above ground level. Magnetic features shown by the three surveys correspond well. The low-level airborne and ground surveys, as would be expected, provide more detail than the broader features of the high-level survey.

The most obvious feature of the magnetic surveys is a distinct high beginning near the Bull River in sec. 12 and running in a rather sinuous fashion through the N 1/2 of sec. 11 and into the center of sec. 10 (fig. D-11). This zone is flanked on the north by a distinct low. The anomaly suggests a major east-west-trending structural feature.

The high-level airborne magnetometer survey was flown over a more extensive area than the claim group. It shows that a somewhat discontinuous zone of high intensity magnetic responses corresponds roughly to the Camp Creek drainage to the west of the NIM claims. It has been suggested that this high correlates with the Chulitna structural zone, one of the major structural features of the region. This interpretation, if correct, has economic significance because the Chulitna zone is suggested to be a major control for mineralization in the district (Hawley, 1974).

The anomalous magnetic zone in sec. 10 and 11 could indicate a branch of the Chulitna Fault on the NIM claims. The two anomalies would connect except for a gap in the W 1/2 of sec. 10. This gap was checked and verified during this study with a ground magnetic survey, which indicated that the structures do not quite connect or the magnetic response is subdued in this area.

The induced polarization (I.P.) geophysical survey over the NIM claim group was conducted in September of 1980 by Scintrex, Ltd. who used a 2.5 kW generator and generally pole-dipole arrays with an "a"-spacing of 400-ft (Scintrex, 1980). Inter-dipole separations of 400, 800, and 1,200 ft were used. In the area of deeper overburden on the northern part of the property, two lines were surveyed using a dipole-dipole array and inter-dipole separations of 400 ft multiples up to 2,400 ft. Results of the I.P. survey are summarized on plate D-3. Several areas of anomalous chargeability were located. These were expected because of the abundance of disseminated sulfide in the area.

The magnetic anomaly across sec. 11 was tested by the I.P. survey with generally inconclusive results. Two lines surveyed with the dipole-dipole array detected anomalous chargeability on the deeper readings in the northeast corner of sec. 11. The pole-dipole survey did not indicate zones of anomalous chargeability. Interpretation of the I.P. responses by Scintrex for this part of the survey stated that either the I.P. did not "see" deeply enough or the magnetic anomaly is primarily a geologic structure lacking sufficient conductors to produce an I.P. response.

I.P. response was more pronounced on the southern portion of the property. Chargeability values are generally increased in areas corresponding fairly well with geochemical anomalies. Resistivity values in this area are not particularly low, however. Results were interpreted by Scintrex (1980) as indicating a lack of massive sulfides but suggesting low concentrations of disseminated sulfides. Most of the chargeability anomalies appear to be near surface. At least one area, however, in the SW 1/4 of sec. 11 has a moderately high chargeability, a low range of resistivity, and an associated self-potential low extending to depth. This anomaly is particularly interesting because it corresponds with the very high geochemical values discussed previously.

SNOOPY PROSPECT

The mineralized area referred to as the Snoopy Prospect, located in sec. 21, T. 19 S., R. 10 W. (fig. D-9), was at one time part of the NIM claim group. When the NIM claim block was reduced in size, claims over the Snoopy area were allowed to lapse.

The general geology of the area is similar to that described above for the NIM claims. Country rock is predominantly andesite(?) porphyry and hornfels. An intrusion of the porphyry has locally brecciated the hornfels. Much of the rock has a purple tint which may indicate secondary biotite. Chloritization has occurred locally, particularly near mineralized areas.

Arsenopyrite, chalcopyrite, and pyrite occur as disseminations and fracture fillings in the porphyritic rocks and as part of the cementing matrix for the breccia. Sulfide mineral content varies from a trace to several percent. Mineralized rock chip samples contain up to 0.25 ppm gold and 3.8 ppm silver. A sample (C14174) of a small 1.5-in.-wide veinlet with arsenopyrite and quartz, carried 0.44 ppm gold and 990 ppm silver.

SILVER KING PROSPECT

Mineral occurrences at the Silver King Prospect are located on and adjacent to a small knob on the east side of Colorado Creek in sec. 19 on the western edge of the study area (fig. D-9, plate D-1). Sulfide-bearing material occurs:

- In a group of pits and trenches on and around the knob, and in canyon walls both south and west of the knob.
- On the side of the canyon to the west of the knob.
- In the canyon wall to the south of the knob.

The three areas are located on the Golden Flower claims, a group of six lode claims which extends beyond the study area boundary.

Triassic argillite and limestone at the property have been altered to skarn and hornfels and intruded by diorite porphyry dikes. The hornfels is a light gray-green, aphanitic, highly siliceous rock that commonly has thin laminations corresponding to bedding planes in the argillite. Limey layers within the argillite have been altered to a medium- to coarse-grained skarn with idocrase, calcite, and clinozoisite(?).

The diorite dikes contain feldspar phenocrysts in a light- to medium-green, fine-grained groundmass. The margins of the dikes are commonly marked by a well-indurated breccia with sedimentary and igneous clasts and a fine-grained igneous matrix. These breccias contain fragments of sulfide-bearing material but show little other evidence of mineralization.

Three types of sulfide mineral deposits occur at the Silver King Prospect: pyrrhotite and chalcopyrite, arsenopyrite, and stibnite and quartz. The sulfides occur as disseminations, as irregular pods, and as steeply-dipping, northeast-trending veins. Most of the disseminated and podiform sulfides occur in the skarn and the veins cut both skarn and tactite.

Sampling by Hawley and Clark (1974) showed spotty silver values ranging up to slightly over 2 oz/ton. One of their samples, from sulfide-bearing skarn on the side of the canyon to the west of the knob, contained about 8.5 oz Au/ton. Several other samples from various locations on the property contained traces of gold. Some of these samples were also anomalous for arsenic, copper, and antimony.

Three representative grab samples of sulfides (C13761, C13762, and C13763) were taken from the pits and trenches on the knob during the 1983 study. Arsenopyrite vein material contained 0.85 oz Ag/ton, 0.87 oz Au/ton, and 0.44% cobalt. Stibnite-bearing material had 0.12 oz Ag/ton and 0.29 oz Au/ton. All three types of mineralizaton had traces (3 to 4 ppm) of tungsten. A chip sample (C12744) across a 3-ft wide, pyrite-chalcopyrite-arsenopyrite-bearing vein in the wall of the canyon below the knob contained 0.15 oz Ag/ton, 0.33% copper, 5 ppm tungsten, and 0.03% cobalt.

Vertical extent of the mineralization has not been determined. The small knob with the majority of pits and trenches may be an erosional remnant of a skarn horizon, in which case the depth of those showings could be limited.

Most sulfides in the occurrences on the canyon wall west of the knob were restricted to a skarn horizon. The vein in the canyon wall south of the knob is on strike with the knob and about 200 ft lower in elevation.

Although individual deposits are small, sulfide occurrences are scattered over a considerable area at the Silver King Prospect. The possibility of a bulk mining operation exists should enough precious-metal-bearing material be present. Depth and continuity of mineralization should be established by drilling before the prospect can be more fully evaluated.

LUCRATA

The Lucrata (Lucrative) Prospect is located in the SE 1/4 of sec. 18, on the west side of Costello Creek (plate D-1 and fig. D-9).

A 40-ft-wide sheared zone in hornfels trends slightly east of north with a steep dip to the west. The strike length of this deposit is not known because surrounding areas are covered by deep overburden. Hawley (1974), however, suggests the broad sheared zone may be part of the extensive Chulitna structural zone. The sheared zone contains irregular quartz-rich lenses up to 3-ft wide and 10-ft long with veinlets and stringers of arsenopyrite, pyrite, pyrrhotite, and scorodite. The hornfels is surrounded by dacitic(?) rocks. Development consists of two open cuts and a caved 15-ft adit reported by Ross (1933), which was not found in the 1983 study.

Ross (1933) reported an assay of 1.26 oz Au/ton and 3.8 oz Ag/ton from a sample of unknown width. Samples (C12708, C12709, and C12710) taken during the present study contained 0.17 to 0.86 oz Au/ton, and 2.2 to 2.8 oz Ag/ton over widths of 1 to 3 ft.

Sampling by Ross (1933) yielded values from 0.2 to 0.56 oz Au/ton, and 2.1 to 6.0 oz Ag/ton. Sampling during this study produced values from 0.034 to 2.27 oz Au/ton and 0.1 to 72.2 oz Ag/ton. The sample (C12704), containing 2.27 oz Au/ton, was a chip sample across a 2-ft-wide vein, and the high silver value came from a 3-ft-wide vein.

EAGLE

The Eagle Prospect is located near the Lucrata on the east side of Costello Creek, in the SE 1/4 of sec. 18.

Branching shear zones as wide as 10 ft contain intermittent quartz-sulfide veins up to 3 ft in width. The quartz veins occur irregularly over approximately 200 ft of strike length. The shear zone appears to follow the contact of dacite(?) and hornfels striking ENE and dipping steeply. Massive, stringer, and disseminated arsenopyrite and pyrite occur with the quartz.

Minor amounts of chalcopyrite, sphalerite, galena, malachite, azurite, and scorodite also occur.

Development consists of an open cut and a caved adit which Ross (1933) described as following a vein for 62 ft. He believed the mineralization extended for 300 ft along strike, and Hawley (1974) suggested the structure may be continuous for over 1,600 ft.

LIBERTY

The Liberty Prospect is located in the SE 1/4 of sec. 18 (plate D-1, fig. D-9). This prospect consists of a poorly-exposed sheared hornfels containing disseminated pyrrhotite, pyrite, and arsenopyrite. Some massive sulfide mineralization is found on the dump.

The mineralized zone appears to trend N. 35° E. and dip steeply. Ross (1933) reports a pit exposing a N. 50° W.-trending shear zone. He sampled a 2-ft section of this zone which contained 0.14 oz Au/ton and 8.6 oz Ag/ton. Sampling for this report produced one selected dump grab sample (C12713) containing 0.046 oz Au/ton and 4.56 oz Ag/ton. Two other samples (C12711 and C12714) show no detectable precious metals.

NIMBUS

The Nimbus property is located in the NW 1/4 of sec. 9 on an eastern tributary to Camp Creek.

The occurrence consists of a 6-in. to 2-ft-wide vein of arsenopyrite, pyrite, and sphalerite, in quartz. The vein is exposed for 10 ft but may continue further to the east. Country rock includes andesite porphyry apparently intruding hornfelsed argillite.

The prospect has been explored by several shallow trenches. Hawley (1977) reported analyses for eight samples. The highest result was for a 2-ft sample of the vein which contained 0.27 oz Au/ton and minor silver. Three grab samples (C14157, C14158, and C14159) from the vein, taken during the 1983 study, show 0.42, 0.47, and 0.92 oz Au/ton, with no detectable silver.

NIMROD

The Nimrod Prospect is located on one of the northern tributaries to Camp Creek in the SE 1/4 of sec. 5.

The occurrence consists of a zone of up to 7% disseminated pyrite with sparse quartz veining in an argillized and limonite-stained intrusive. The altered zone is exposed along the creek for about 125 ft. and is cut by several small shear zones. The host rock is a diorite porphyry.

Hawley (1977) mentions a brecciated sedimentary rock with sulfides in the matrix at this location, but the occurrence was not found during this investigation. A grab sample from the breccia reportedly contained approximately 3 oz Ag/ton and trace amounts of gold. Samples (C14764, C14154, and C14155) of the altered zone during this study contained traces of gold and silver and anomalous copper.

OTHER DEPOSITS

The metal-rich, complex, geologic and structural environment of the study area is considered favorable for a variety of mineral deposits other than precious metals. A rather small but high-grade stibnite vein located at the Silver King Prospect suggests that exploration for antimony lodes along the Chulitna structural zone may be warranted. Mineralized rock at the Silver King contains anomalous amounts of cobalt, which could be very significant given the strategic nature of this metal.

The geologic environment in the study area is also considered favorable for the occurrence of tin deposits. Several tin prospects are currently being evaluated elsewhere in the Chulitna District. Blakestad (1981) described the NIM area as a potential tin-precious-metal greisen system. No significant tin mineralization has yet been found in the study area, although panned concentrate sampling (A2424 and A4229) during this study contains high tin values.

Known precious- and base-metal deposits will require drilling to further evaluate and assess their economic potential. Information gained from drilling may lead to new discoveries in the district.

GEOCHEMICAL SAMPLING

Resource Associates of Alaska provided data from an extensive soil geochemical survey which was conducted over the NIM-Snoopy Lake area in 1971. Sampling was centered on the NIM claim block, but wide-spaced samples were also collected outside the claim boundaries. Locations of sample sites are shown on plate D-2. Rather broad anomalies of low to moderate intensity were identified for copper, molybdenum, silver, lead, and zinc. These anomalies are located primarily in the area of the NIM claims. The approximate locations of copper and silver anomalies are shown on plate D-3.

In order to verify these data, Dr. Swainbank, holder of mineral rights of the NIM claims, obtained pulps from 125 of the original soil samples and submitted them for check analysis by the Alaska Department of Geological and Geophysical Surveys. Splits of 21 of these samples were also sent to Skyline Labs at Wheat Ridge, Colorado, for re-analysis.

An additional 88 soil samples were collected during the 1983 study, mostly in areas previously indicated as geochemically anomalous. Locations of these sample sites are shown on plate D-2.

The re-analyzed samples show only moderate correlation with the earlier results. Sampling performed during this study, however, verifies the existence of the soil anomalies but indicates values of lower magnitude than those of the original survey. This is particularly true in the case of silver, which shows much lower values than previously indicated.

Stream sediments analyzed during this study contain anomalously high concentrations of gold in the Silver King, Eagle, and Lucrata Prospect areas. Low but detectable gold values were noted in two streams draining the NIM area. Anomalous silver was detected in upper Camp Creek and in several streams in the Snoopy Lake area. Copper values were generally low considering the copper mineralization noted in the NIM-Snoopy Lake area.

Heavy mineral concentrate samples (A2429, A2431, and A2403) from Camp and Costello Creeks contain anomalously high gold values. A placer reconnaissance sample from the Bull River (A002489) also shows high gold content. Placer gold potential is discussed in another section of this report.

The Bull River sample (A2489), a panned concentrate sample (A2410) taken from the lower part of one of the creeks draining the Snoopy Lake area, and a concentrate sample (A2467) from Camp Creek contained anomalous tin values. Panned concentrate sample A2464, in the NIM claim area, contains high tungsten values.

MINERAL POTENTIAL

COAL

Coal seams in the Dunkle Mine area appear to underlie an area of approximately 3 square miles. Reserves are difficult to estimate because the mining history of the deposit is not clear, and figures given by various investigators are contradictory. Rutledge (1948) estimated minable reserves at 192,700 short tons, measured, indicated, and inferred. Barnes (1967) mentions a 1943 resource estimate of 350,000 tons of indicated coal. He then suggests that most of this coal has since been removed or lost by underground and strip mining. Giving neither details nor references, he states that 64,000 tons were mined between 1940 and 1954, but he leaves the indicated reserve estimate at 350,000 tons.

A reasonable estimate of reserves may be in the range 100,000 to 300,000 tons, but considerable drilling is needed to further assess this deposit.

PRECIOUS METALS

Metalliferous deposits of the Dunkle Mine study area have not been adequately tested. No drilling has been done on any of the vein deposits, and only a minor amount has been done on the large NIM claim block. The area could contain deposits of the types described below (fig. D-12).

Vein/Shear Zones

Deposits of this type occur at the Eagle, Lucrata, Liberty, and Nimbus Prospects. Similar deposits, as yet undiscovered, could occur along the Chulitna structural zone and along a possibly related structure which passes through the NIM claims.

Measurements and projections from very limited exposures indicate that resources of the vein deposits may be in the range of several hundred to 10,000 tons. Grades are indicated in the ranges 0.1 to 1.0 oz Au/ton, and 1 to 5 oz Ag/ton.

A sample across 15 ft of one of the shear zones (Sample C12701) contained 0.034 oz Au/ton. Further exploration along the major structures may locate deposits of sufficient tonnage and grade for moderate-scale bulk mining. This type of deposit could contain reserves in the range of 10,000 to 100,000 tons with ore containing 0.05 to 0.1 oz Au/ton or the equivalent in combined gold and silver. Mining would probably be by surface methods.

Tactite/Breccia Deposits

The Silver King Deposit is a mineralized tactite with possible associated breccia mineralization. This type of deposit has a larger tonnage potential than the vein type and may also be amenable to surface development.

Sampling by Hawley and Clark (1974) and during this study indicates silver values from trace to several oz/ton and gold from trace to 8.0 oz/ton. The best mineralization appears to be in an area approximately 100 ft in diameter. Bundtzen (1983) projected this mineralization to a depth of 100 ft to arrive at a speculative reserve of 85,000 tons for this deposit.

Breccia Zones

The Chulitna structural zone, the proposed branch structure through the NIM claims, and the igneous complex in the NIM claim area are considered favorable locations for breccia-type mineralization similar to that at the Golden Zone Mine to the west of the study area. Geology, structure, and mineralogy similar to the Golden Zone are known in these areas. The Golden Zone deposit is estimated to contain from 581,000 tons of high-grade ore (0.14 to 0.3 oz Au/ton) up to 6 million tons of low-grade material (approximately 0.05 to 0.10 oz Au/ton) (Hawley, 1978). Several potential targets for this type of deposit exist in the study area. None of the breccia zones have been tested adequately and any estimates of potential resources are not possible.

BULK-TONNAGE PORPHYRY DEPOSITS

The NIM claims were originally located as a potential porphyry-type copper-molybdenum or copper-gold target. Subsequent investigations produced evidence for and against the existence of these types of deposits, and other deposit types, such as breccia hosted, are now considered more likely. The possibility of a porphyry-type deposit still exists and must be considered, particularly because of potential for large-tonnage reserves. Ore reserves of such deposits frequently range in the order of 100 million tons. Copper values characteristically range to 0.5%, with additional values in molybdenum, gold, and silver. The existence of a porphyry system has not yet been proven on the NIM claims. Subsurface testing of the rather extensive copper and molybdenum geochemical anomalies, however, is inadequate and further work is warranted.

GOLD PLACER DEPOSITS

Colorado and Costello Creeks, and the Bull River are considered to have moderate placer resource potential within the study area. However, the limited amount of gravel and the narrow, deeply incised nature of the stream canyons would probably preclude large-scale mining. Small-scale operations, such as suction dredging, may be feasible at some locations.

OTHER MINERAL RESOURCE POTENTIAL

Other deposits which may exist in the Dunkle Mine study area include antimony vein deposits and tin deposits. Insufficient data are available to make any estimates of the potential size of such deposits if they do occur.

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