UNITED STATES DEPARTMENT OF INTERIOR

U.S. GEOLOGICAL SURVEY

Mineral Resource Assessment of the Wiseman 1° by 3° Quadrangle, Alaska

by

James D. Bliss[1], William P. Brosgé[1],

John T. Dillon[2,3], J.Thomas Dutro, Jr.[4]

John B. Cathrall[5], and John W. Cady[5].

U.S. Geological Survey

Open-File Report 88-533

1988

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nonmenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

1. U.S. Geological Survey, Menlo Park, CA.

2. Alaska Division of Mines and Geology, Fairbanks, AK.

3. Deceased.

4. U.S. Geological Survey, Washington, DC.

5. U.S. Geological Survey, Denver, CO.

TABLE OF CONTENTS

PREFACE

The mineral resource assessment of the Wiseman 1° by 3° quadrangle (hereafter referred to as the Wiseman quadrangle) has been designed so that readers can easily find topics of interest in the Table of Contents. Because each section describing a given deposit type is intended to stand alone, some material is repeated. An Executive Summary has been included for those interested in the general results and conclusions of the assessment; the summary contains estimates of the number and type of undiscovered deposits in the quadrangle. The assessment focuses on those deposit types containing base and precious metals. Included is a partial review of some ore deposit types and mineral terranes found in the Brooks Range that may have analogs in the Wiseman quadrangle. Tracts in which the geologic or tectonic setting is permissive for certain deposit types are shown on a series of 1:250,000-scale maps (pl. 1-3). This assessment does not address nonmetallic commodities (except for barite), because descriptive or grade-tonnage models are not available nor is there a systematic methodology for evaluating nonmetallic commodities. Mineral fuels are not evaluated but expected not to be present in significant amounts. Geochemical anomalies described by Cathrall and others (1987) are mentioned frequently and reader may find it useful to obtain a copy of that report.

The November 1986 issue of Economic Geology (v. 81, no. 7), devoted to the mineral deposits of northern Alaska, became available just as the Wiseman mineral resource assessment was finalized. Some material from that collection of reports was used in this assessment but the information was not used as completely as might be desired. Explorationists may find this special issue useful for additional background information on undiscovered ore deposits in the Wiseman quadrangle.

Description of gold placers and lode deposits, prospects, and occurrences (including some gossans) in the Wiseman quadrangle can be be found in Bliss and others (1988).

EXECUTIVE SUMMARY

The Wiseman quadrangle contains geology which is permissible for at least 13 deposit types using the classification scheme of Cox and Singer (1986). Tracts which contain geology permissible for each deposit type have been delineated where possible (pl. 1-3). Once this has been done, subjective estimates of numbers of undiscovered deposits where made at the 90th, 50th, and 10th percentile as follows:

Deposit Type Name Name	Composite area of all tracts (km2)	Percentage 90	50	10
Cyprus Massive Sulfides	350	---	---	1
Kuroko Massive Sulfides	2160	1	3	6
Besshi Massive Sulfides	590	---(1)	---	---
Sedimentary Hosted Zn-Pb	8630	1	3	5
Sedimentary Hosted Cu	2000	---	2	4
Carbonate Hosted Pb (Zn)[2]	970	---	1	3
Bedded Barite	8630	---(3)	---	---
Skarns[4]	---(5)	---(6)	---	---
Simple Sb	---(7)	2	5	8
Low-Sulfide Au-quartz veins	---(7)	---	1	2
Gold Placer[8]	4000	2	4	6

1. Subjective estimate not made.
2. Grade-tonnage model modified for this assessment.
3. Guidelines described in text for making estimate of number of undiscovered deposits associated with Sedimentary hosted Zn-Pb deposits.
4. Includes Cu skarn, Pb-Zn skarn, and Sn skarn.
5. Tracts not delineated; guidelines in text describe criteria for permissive areas for Cu and Pb-Zn skarns; one tract of 470 km^2 permissive for Sn skarn.
6. Subjective estimate not made; guidelines described in text suggest no deposit are expected at the 90th and 50th percentile for Cu or Pb-Zn skarns; no estimate of any type made for Sn skarns.
7. Tracts not delineated; guidelines in text.
8. Computer simulation described in text predicts future median gold production of 2750 kg.

INTRODUCTION

The mineral resource assessment of the Wiseman quadrangle (fig. 1) has been made under the Alaska Mineral Resource Assessment Program (AMRAP). The quadrangle is located in the Central Brooks Range between latitudes 67 and 68 degrees north and longitudes 147 and 150 degrees west. Previous and ongoing studies in and adjacent to the Wiseman quadrangle have provided geological, geochemical, geophysical, and other data on which the mineral resource assessment is partly based. The products of this assessment will assist managers at various levels of government in making appropriate land management decisions. Ore deposit explorationists may find the assessment useful in identifying areas in which targets for specific deposit-types may exist.

METHODOLOGY

The approach used in this mineral resource assessment is described by Singer (1975), who suggested that the resource assessment be broken down into discrete parts, each of which is treated separately. Parts may then be combined according to the needs and views of the resource-assessment user. Subsequent revision in any given part can be made without invalidating other parts. A key component of this resource assessment is the use of deposit-type models (Singer, 1975). Data in each model are obtained from ore deposits that share certain characteristics (tectonic setting, host, metals, and so on) and which can be represented by valid grade and tonnage curves (Cox and Singer, 1986). For each model (or at least inferred) are criteria which permit the delineation of areas permissible for the presence of the specified ore deposit type. Eventually some parts and possibly, all of a mineral resource assessment may become obsolete as concepts in geology and resource assessment methods evolve. When an area with predicted undiscovered deposits is exhaustively examined, the validity of certain of these predictions may be confirmed or disproven.

For most deposit types known or suspected to be present in the Wiseman quadrangle, the following are provided: (1) a generalized description of the geologic setting of the deposit type (largely based on descriptions given by contributors to Cox and Singer (1986)), (2) a generalized description of deposit properties (for example, ore minerals, alteration) (also based on Cox and Singer (1986)), (3) grade and tonnage model, (4) description of the geologic setting and features of deposits of the specified deposit-type present elsewhere in the Brooks Range, (5) delineation of tracts permissible for the deposit type in the Wiseman quadrangle, and (6) subjective estimates of numbers of undiscovered deposits of the specified type for the quadrangle as a whole. In some cases, tracts are rank in order of decreasing order of probability of finding an undiscovered deposit. Other search guidelines have been suggested when delineation not used. Criteria for tract delineation is the presence of suitable host rocks. Other factors used in tract delineation include: the presence of known mineralization, geochemical anomalies, and appropriate geophysical features. These factors are listed for each tract as appropriate and (or) available.

The resource assessment of gold placers is more extensive than for other deposit types. This is due in part to the fact that gold placers represent the only major confirmed deposit-type economically developed to date in the quadrangle. Although treatment of other deposit-types concludes with a subjective estimate of number of undiscovered deposits, additional gold production is predicted for discovered and undiscovered gold placers using computer simulation.

DEPOSIT TYPES

Deposit types discussed here are those for which the geology permits an interpretation of their presence in the Wiseman quadrangle. Some of the deposit types are recognized elsewhere in the Brooks Range. Deposit types are further grouped into broad categories using the criteria and format of Cox and Singer (1986). For example, there are several deposit types associated with volcanic rocks; mafic marine volcanic suites may host Cyprus massive sulfides or Besshi massive sulfides; felsic-mafic and marine may host Kuroko massive sulfides. Where felsic-mafic volcanic rocks are associated with older clastic sedimentary rocks, under subaerial conditions, simple antimony deposits may be present (Cox and Singer, 1986).

Deposit types associated with sedimentary rocks alone may also occur in the Wiseman quadrangle. Sedimentary rocks, particularly shale and siltstone, may host sedimentary exhalative zinc-lead, and bedded barite deposits. Sediments which contain more sandstone may contain sandstone-hosted lead-zinc deposits and/or sedimentary-hosted copper. Where there are carbonate rocks, Southeast Missouri lead-zinc and (or) Appalachian deposit types may be present. Where porphyroaphanitic rocks intrude calcarous rocks, copper and other skarns may also develop (Cox and Singer, 1986).

Regionally metamorphosed rocks, particularly those derived from eugeosyclinal rocks and adjacent to intrusive rocks, may host low-sulfide gold-quartz vein deposits. Gold placers are one surficial deposit type which is also found alluvium derived from regionally metamorphosed terranes (Cox and Singer, 1986; Wojcik, 1984).

Deposit types considered in this assessment fall into two groups: (1) those with well-defined descriptive models for which the geologic criteria for permissible rocks and structures, with or without collaborating mineralized occurrences, are reasonably supported by the geologic evidence in the Wiseman quadrangle, and (2) those without well-defined descriptive models (or no model at all) and (or) those for which the geologic criteria for permissible rocks and structures and mineralized occurrences do not match well the mapped geology of the host rocks in the Wiseman quadrangle. For the case of the first category of deposit types, a section describing the deposit type and associated tracts in the Wiseman quadrangle is presented. Deposit types in the second category can be identified in the comments found with each tract description.

TRACTS

Many tracts are permissible for the occurrence of more than one deposit type. Tracts are delineated for each specific deposit type that are considered to be the best target for future explorationists for deposits of that type. Table 1 lists all deposits types and tracts. Mineral occurrences which are described in the companion Open-File Report are summarized for each tract with reference to a specific deposit type. Occurrences generally are considered more significant if they contain attributes (form, mineralogy, and so on) like that of the deposit type. However, this may not necessarily be the case and the user may come to other conclusions using other models. It is conceivable that a specific deposit type may be associated with mineral occurrences quite difference in mineralogy and other features usually not found as part of the mineral deposit.

Tract boundaries usually follow stratigraphic contacts or fault boundaries separating different lithologies in many places.

Table 1. Deposit types and corresponding tracts with permissive geology found in the Wiseman quadrange.

Deposit Type	Tract Designation
Cyprus massive sulfides	CMS-I, CMS-II, CMS-III, CMS-IV
Kuroko massive sulfides	KMS-Ia, KMS-Ib, KMS-II, KMS-III, KMS-IV
Besshi massive sulfides	KMS-IV
Sedimentary hosted zinc-lead (and bedded barite, see text)	SEDX-I, SEDX-IIa, SEDX-IIb, SEDX-IIc,SEDX-III, SEDX-IVa, SEDX-IVb, SEDX-V, SEDX-VI, M-1, M-2
Sedimentary hosted copper	SEDC-I, SEDC-II
Carbonate hosted lead (zinc)	CHB-I, CHB-II, CHB-III, CHB-IV, M-1, M-2
Skarns (copper; lead-zinc; tin)	M-2 (also see text.)
Simple antimony deposits	No formal tracts, see text.
Low-sulfide gold-quartz veins	PLC-I, PLC-II, PLC-III; also see text.
Gold placers	PLC-I, PLC-II, PLC-III

GEOLOGIC SUMMARY

The geologic base used in the Wiseman resource assessment is the map by Dillon and others (1986). Rocks in the quadrangle range in age from Proterozoic to Cretaceous; most are Devonian and older. Most of the rocks were metamorphosed in the late Mesozoic, commonly to the greenschist facies but may range from polymetamorphic gneiss of the amphibolite facies to rocks which are unmetamorphosed.

The younger rocks along the southern margin of the quadrangle consist of Mississippian through Triassic volcanic rocks, graywacke, and chert overlain to the south by Cretaceous marine and nonmarine sandstone, conglomerate, and slate. The unmetamorphosed Cretaceous rocks contain clasts of Brooks Range metamorphic and volcanic rocks which suggests that their deposition post-dated most of the thrusting and metamorphism that affected other rocks in the quadrangle. The northward thrusting of Mississippian to Triassic volcanic rocks and associated sedimentary rocks has superimposed these slightly metamorphosed rocks over schists along the south edge of the Brooks Range. Thrusting occurred along west-trending zone and termed the Angayucham thrust system, which crosses the entire southern edge of the quadrangle. The thrusting apparently took place during late Jurassic to early Cretaceous time.

North of the Angayucham thrust system, most Paleozoic and Proterozoic rocks occur in complexly imbricated and folded thrust plates. Vergence has been dominantly to the north. Generally, both age and metamorphism decrease from south to north.

Schist, marble, and metavolcanic rocks of greenschist facies, some of which are retrograded amphibolite facies, are present in a linear belt 16 to 24 km wide along the south edge of the Brooks Range. This so-called "schist belt" extends across the entire quadrangle. Devonian bimodal volcanic rocks are locally abundant.

North of, and parallel to, the "schist belt" about half the quadrangle consists of metasedimentary rocks--black phyllites and metasiltstones (some chloritic), sandstones, graywacke, conglomerate, marble and dolomite, all of Devonian or older age. Most of the rocks are greenschist facies; those in the southern part may contain biotite. Metamorphism is sufficiently low in the north that primary sedimentary features (bedding, shelly megafossils, etc.) are well preserved. A few metavolcanic rocks, some of which are equivalent to those found in the schist belt, are present and include mafic and mixed mafic and felsic intrusive rocks. Thick metabasite sills are common in some carbonate rocks outcrops. The western part of the belt contains probable Proterozoic schist, calcareous schist, quartzite, phyllite, and metabasite that have been intruded by several small plutons of granite gneiss which are also probable Proterozoic. Disrupting the general pattern of northward thrusting plates in the east and east-central part of the belt is a broad arch more than 80 km long and 18 km wide, termed the Doonerak Fenster, trending northeast, flanked on the northwest and southeast by large synforms. The exposed core of the Doonerak Fenster consists predominantly of Cambrian through Silurian black phyllite and siltstone. Also present, particularly in the southwest part of the Fenster, are green phyllites, argillite, and meta-tuff and metawaches of possible Cambrian to Devonian age. Andesitic to basaltic volcaniclastic rocks mixed with graywacke, tuffaceous phyllite, and basalt and diabase intrusion are prominent in the northeast quarter of the Doonerak Fenster. Whereas metasedimentary rocks are of the lower greenschist facies, volcanic rocks are of prehnite-pumpelleyite facies.

Triassic rocks along the north quarter of the quadrangle are part of the fold and thrust system which is related to the north front of the Brooks Range. In this tectonic block, rocks are predominantly black slate and phyllite of Late Devonian and Mississippian age and Mississippian to Triassic carbonate rocks. A few small mafic sills are also found.

Unconsolidated materials in the quadrangle are predominantly glacial, glacial-fluvial, or lacustrine deposits (Hamilton, 1978) like those found in all large valleys and in the lowlands along the south edge of the Brooks Range.

GEOCHEMISTRY

The Wiseman quadrangle has been examined by several geochemical surveys (Brosgè and Reiser, 1972; Dillon and others, 1981a, 1981b; Los Alamos National Laboratory, 1981; O'Leary and others, 1984; and Cathrall and others, 1984) using a variety of sample media, including rock samples, stream-sediment pebbles, stream sediments, and panned heavy-mineral concentrates. Element concentrations in all these media exhibit extreme differences from one part of the Wiseman quadrangle to another due, in part, to the great diversity of bedrock units and structures. Cathrall and others (1987) reduced this problem by separating some of the geochemical data into six data sets, one for each area with different bedrock suites and geochemical responses. The six areas or "Geochemical Lithologic Subdivision" (Cathrall and others, 1987, Fig. 1) have substantially different anomalous threshold concentrations for both stream sediments and for the nonmagnetic fraction of heavy mineral concentrates (Cathrall and others, 1987, table 1-2). The six subdivisions are: Angayucham (I), Schist Belt (II), Skajit (III), Beaucoup-Whiteface (IV), Doonerak (V), and Endicott (IV). Anomalous element concentrations within assessment tracts used here differ depending on which geochemical subdivision the area falls in. The concentrations of each element, in each of the subdivisions, which must be equal to, or exceeded in order to be considered to be anomalous, are summarized in Table 2 and fig. 2 (modified after Cathrall and others, 1987, table 1, 2).

Within each "Geochemical Lithologic Subdivision" are several geochemically anomalous areas are shown in Cathrall and others (1987, Fig. 1). The rock types and potential ore deposits within each anomalous area are described therein and are generally compatible with our mineral resource assessment. However, some differences represent revisions in interpretation.

GENERAL PROCEDURE

In order to simplify the following discussion on deposit types, tracts, etc., some standard procedures and defaults are adopted. This includes:

1. Geological descriptions are from Dillon and others (1986) unless noted otherwise.

2. Description of locality of known mineralization, be it for lode deposits, prospects, and occurrences; or placers are found in a report by Bliss and others (1988).

3. Definition of geochemical anomalous areas and chemical thresholds applicable are from Cathrall and others (1987). Table 2 give the element thresholds applicable in each; figure 2 gives the six "Geochemical Lithologic Subdivision" anomalous areas within each.

Table 2. Threshold values (in parts per million) of 15 elements for stream sediments (SS) and the nonmagnetic fraction of heavy-mineral concentrates (PC) for stream-sediment samples collected in six "geochemical lithologic subdivisions" in the Wiseman quadrangle (modified after Cathrall and others (1987, Tables 1, 2)). Analytical procedure for each element can be found in Cathrall and others (1987). [>, greater than; <, less than; NA, not anomalous]

ELEMENT	SAMPLE MEDIA	GEOCHEMICAL LITHOLOGICAL SUBDIVISION NUMBER					
		I	II	III	IV	V	V1
Antimony	SS	NA	3.8	3.8	5	12	12
	PC	NA	200	200	200	200	200
Arsenic	SS	NA	26	38	38	26	NA
	PC	1,000	700	1,000	700	1000	1000
Barium	SS	1,500	1,500	1,000	1,500	1,500	1,500
	PC	>10,000	3,000	NA	NA	NA	NA
Bismuth	SS	NA	20	30	15	10	NA
	PC	NA	20	30	15	10	NA
Chromium	SS	NA	300	NA	300	NA	NA
	PC	700	700	NA	NA	700	1,000
Cobalt	SS	NA	150	NA	70	70	300
	PC	NA	500	500	500	NA	500
Copper	SS	150	100	70	100	150	NA
	PC	200	300	1,500	2,000	1,500	5,000
Gold	SS	NA	<0.05	<0.05	<0.05	<0.05	<0.05
	PC	<20	<20	<20	<20	<20	<20
Lead	SS	NA	70	70	50	50	50
	PC	200	1,000	3,000	3,000	300	7,000
Mercury	SS	NA	NA	0.18	NA	0.14	0.14
	PC	NA	NA	NA	NA	NA	NA
Molybdenum	SS	5	10	7	10	15	20
	PC	NA	NA	70	15	15	20
Nickel	SS	NA	200	NA	200	200	NA
	PC	NA	300	NA	500	NA	NA
Silver	SS	1	1	1	1	1	1
	PC	5	5	10	10	5	10
Tin	SS	NA	10	10	10	NA	10
	PC	100	70	70	50	20	100
Tungsten	SS	NA	2.5	2.5	3	3	4
	PC	NA	100	100	100	100	100
Zinc	SS	200	300	200	300	1,000	300
	PC	<500	<500	1,500	2,000	1,500	10,000

CYPRUS MASSIVE SULFIDES (24A)[1]

Introduction

Cyprus massive sulfides are one of at least five metallic deposit-types associated with mafic extrusive rocks and marine sedimentary rocks such as ophiolites (Cox and Singer, 1986). Cyprus massive sulfide deposits are bodies of massive pyrite, chalcopyrite, and sphalerite hosted by pillow basalts (Singer, 1986a). Copper is the primary commodity; byproducts commodities includes silver, gold, lead, and zinc (Singer and Mosier, 1986a).

Geologic Setting

This Summary of geologic setting is taken from Singer (1986a), unless noted otherwise. This deposit type occurs in ophiolites and is most likely formed by submarine hot springs in or adjacent to axial grabens at either oceanic or back-arc spreading ridges. Host rocks include dunite, harzburgite, gabbro, pillow basalts and diabase dikes. Felsic volcanic rocks are rare but, if present, are usually keratophyre (Hutchison, 1982). Regionally, iron- or manganese-rich cherts may be associated with these deposits (Singer, 1986a). Radiolarian cherts are found with some Cyprus massive sulfide deposits (Hutchison, 1982). Although deposits have been found in presumed Archean to Tertiary age rocks, most known deposits are found in Ordovician or Cretaceous rocks.

Deposit Properties

Cyprus massive sulfide deposits are lenticular, concordant bodies, mineralogically dominated by pyrite with lesser amounts of chalcopyrite and sphalerite (Laznicka, 1985); commonly maracasite and pyrrhotite may be present (Singer, 1986a). Deposits may be adjacent to steeply dipping faults. Ore bodies become increasingly siliceous toward their bases, which in turn are underlain by stockworks of veinlets which can extend downward for 700 m (Hadjistavrinou and Constantinou, 1982). These veinlets are made up of pyrite and pyrrhotite with lesser amounts of chalcopyrite and sphalerite locally. They may also contain a small amount of cobalt, gold and silver. Where the stockwork is hosted by basalts which have undergone silicification, chloritization, and argillization, these veinlets contain quartz and jasper Laznicka, 1985). The main ore bodies are capped with goethitic sedimentary rocks (ochre) that contain rock fragments having sulfide banding (Laznicka, 1985). The ochre is restricted to immediately above the sulfide ore bodies. Weathering of these deposits produces limonite gossans and possible stream-deposited gold (Singer, 1986a).

Grade and Tonnage Model

The grade and tonnage model for Cyprus massive sulfide deposits was developed from those deposits that have mafic or ultramafic rocks immediately above and, for at least 500 m, below the deposit. The host rock sequence most contain either pillow basalts or diabase dikes (Singer and Mosier, 1986a). No correlation exists between the various metal grades or between any given metal grade and tonnage. Slightly more than 30 percent of the 49 deposits used for the grade and tonnage model have reported silver, gold and zinc. Less than 10 percent of the deposits have reported lead. In those deposits where lead is

1. These are model numbers as given in the table of contents of Cox and Singer, 1986.

reported, the lead grade is between 0.01 and 0.16 percent (Singer and Mosier, 1986a). Grade plus tonnage are summarized in table 3 (Singer and Mosier, 1986a).

Table 3. Estimate of percentage of Cyprus massive sulfide deposits which equal or exceed a given grade or tonnage (Singer and Mosier, 1986a). Floor values are approximately the lowest value given for each variable in the grade and tonnage model (Singer and Mosier, 1986a). No correlation exists between metal grades and tonnage. [---, not present, or grades not reported.]

Variable	Floor	Percentage 90	50	10
Tonnes (10^6)	.025	0.1	1.6	17.
Copper (percent)	.32	0.63	1.7	3.9
Siver (g/tonne)	.6	---	---	33.
Gold (g/tonne)	0.1	---	---	1.9
Lead (percent)	0.01	---	---	0.01
Zinc (percent)	0.01	---	---	2.1

Identified Cyprus Massive Sulfides in the Brooks Range

At present, no Cyprus massive sulfide deposit have been found in any terrane in the Brooks Range. This may be because of incomplete exploration or this deposit type is not present.

Tract Delination

Four tracts are delineated (tracts CMS-I to CMS-IV, pl. 1) as permissible for Cyprus massive sulfides. Delineation for each tract was guided by the presence of appropriate host lithologies for this deposit type. The four tracts are parts of fault slices of phyllite and volcanic rocks in the Angayucham fault system. Gold placers are found within or adjacent to two of these tracts.

Subjective Estimate of Undiscovered Cyprus Massive Sulfides

Participants in the mineral resource assessment estimate that there is a 10 percent change of one or more undiscovered Cyprus massive sulfide in the four tracts delineated for this deposit type in the Wiseman quadrangle. No ranking of tracts was made.

Description of Tracts for Cyprus Massive Sulfides

Tract No.: CMS-I

a) Geographic description: This is a long, slender east-trending tract in the southeast corner of the quadrangle (pl. 1). The tract, truncated by the east edge of the quadrangle, includes the valley of Hungarian Creek, the mountains to the west of it, and most of the Cathedral Mountains. On the west side of the Middle Fork Koyukuk River, the tract includes Twelvemile Mountain and the area adjacent to Alder Creek where it enters the North Fork Koyukuk River valley. The tract terminates near the Koyukuk River.

b) Permissive rocks and structures: The rocks in this tract are dominantly pillow basalts with radiolarian chert and minor intrusive diabase dikes and sills and minor limestones.
c) Known mineralization: No known lode deposits or mineralized occurrences have been described in this tract. Gold placers are found both to the north (Twelve Mile Creek Placer) and south (Mailbox Creek Placer) of the tract.
d) Geochemistry: One half of the tract intersects anomalous geochemical areas 1 and 2, Angayachum subdivision (I) (fig. 2), as defined in Cathrall and others (1987, table 6). Copper, zinc, and barite are anomalous for area 1; so are lead and nickel but less frequently. Zinc, lead, barium and silver are anomalous for area 2; so are gold, molybdenum, and tungsten but less frequently (Cathrall and others, 1987).
e) Geophysics: The tract coincides with a magnetic high caused by exposed and covered basalt of the Angaycham terrane.

Tract No.: CMS-II

a) Geographic description: This is a small elongated tract in the south central part of the quadrangle. Tract is approxiamtely centered on Florence Creek.
b) Permissive rocks and structures: The permissive rocks are identical to those found in tract CMS-I.
c) Known mineralization: No lode deposits or mineralized occurrences have been described in this tract. No gold placer deposits are located nearby.
d) Geochemistry: Tract neither intersects nor is adjacent to any anomalous geochemistry areas.

Tract No.: CMS-III

a) Geographic description: This is the largest tract for this deposit type, is located in the southwest corner of the quadrangle (pl. 1).
b) Permissive rocks and structures: The permissive rocks are identical to those found in tract CMS-I.
c) Known mineralization: One occurrence of sulfide mineralization has been described in the tract consists of disseminated chalcophyrite and azurite hosted by an aphanitic greenstone (Dillon and others, 1981b). No known gold placers are located nearby.
d) Geochemistry: Half of the area of the tract intersects anomalous geochemical area 5, Angayachum subdivision (I) (fig. 2). Where the tract and area 5 intersect, copper, zinc and less commonly barium are anomolous. Tin is also anomalous but it is probably associated with glacial deposits derived from the Ernie Lake area.
e) Geophysics: One-third of the tract is over two different aeromagnetic highs. One is an elongated area roughly aligned with the tract caused by exposed basalt that extends from about Heart Mountain to the Malamute Fork of the John River. The secondary area is a small part of an aeromagnetic high which intersects the part of the tract south of the Alatna Hills. The second aeromagnetic high is part of an extensive regional high which extends nearly all the way across the southern edge of the quadrangle. It is suspected to be caused by buried rocks that may be basalt similar to that in the other part of the tract.

Tract No.: CMS-IV

a) Geographic description: This is a triangular tract in the southeast corner of the quadrangle (pl. 1).
b) Permissive rocks and structures: The permissive rocks are identical to those found in tract CMS-I.
c) Known mineralization: No known lode deposits are recognized within this tract; gold placers have found near Eagle Cliff. Recently claim staking has been active in and adjacent to the tract.
d) Geochemistry: The entire tract is within anomalous geochemical area 4, Angayachum subdivision (I). Copper, zinc, and less commonly barium are anomalous in this area. Also anomalous, are gold and silver, and less commonly bismuth and tungsten. Gold placers may have developed in surfical material transported into the tract and may contribute to the precious-metal anomalies.

KUROKO MASSIVE SULFIDES (28A)

Introduction

Kuroko massive sulfide deposits are one of at least six deposit types associated with felsic-mafic bimodal extrusive rocks in a marine setting (Cox and Singer, 1986). These deposits are bodies of copper- and zinc-sulfide minerals hosted by intermediate to felsic marine volcanic rocks (Singer, 1986b). Commodities that these deposits contain include copper, zinc, and lead; byproduct commodities include silver and gold (Singer, and Mosier, 1968b).

Geologic Setting

The following description is taken from Singer (1986b) unless noted otherwise. This deposit type is thought to form near the sea floor from hydrothermal fluids associated with bimodal marine volcanism adjacent to volcanic arcs (Hutchison, 1982). Deposition is apparently associated with the upper felsic rocks of either a volcanic or volcanic-sedimentary sequence. The ore deposit hosts are primarily rhyolite and dacite with lesser amounts of basalt, which apparently in most cases, is not as important as the felsic volcanic rocks (Laznicka, 1985). Associated with the volcanic rocks can be shales, which are commonly organic rich; they may also be pyritic or siliceous. Volcanic rocks occur as flows, tuffs, and pyroclastic rocks; breccia is less commonly present. Felsic domes may also be present. Deposits are found in rocks from Archean (greenstone belts) to Cenozoic age. Associated deposits in Japan include epithermal quartz-adularia veins. Associated deposit types found elsewhere include volcanogenic manganese and Algoma-type iron.

Deposit Properties

The following description is taken from Singer (1986b) unless noted otherwise. Kuroko massive sulfides are predominantly stratiform, zoned, massive, and rich in base metals (Hutchison, 1982). These deposits exhibit considerable local variability (Mosier and others, 1983); this has resulted in proposal of a large number of deposit types in the literature (Laznicka, 1985). An idealized deposit could be described as follows. An upper zone of massive black ore made up of pyrite, sphalerite, and chalcopyrite. Other sulfides which may be present in the black ore include pyrrhotite, galena, barite, tetrahedrite-tennantite, and bornite. Below the black ore, is a zone of massive yellow ore dominated by pyrite and chalcopyrite. Other sulfide minerals in the yellow ore zone include sphalerite, pyrrhotite, and magnetite. Beneath this is a stockwork zone composed of pyrite and chalcopyrite stringers which may contain gold and silver. Deposits hosted by fine-grained volcanic sedimentary rocks tend to have more lead. Peripheral to or capping some deposits are zeolites and montmorillonites. Silica, chlorite, and sericite develop in altered zones within the stockwork. Chlorite and less commonly albite may form directly below the stockwork. Metamorphism of these deposits (which is the condition of the permissible tracts in the Wiseman quadrangle) may form anthophyllite and cordierite in the footwall and graphitic schist hanging in the wall. Gahnite ($ZnAl_2O_4$) can occur in metamorphosed ore deposits and can rarely be found in adjacent stream sediments. Weathering of Kuroko massive sulfide deposits typically produces lead- and gold-bearing gossans which can be yellow, red, or brown. A halo of magnesium and zinc enrichment and sodium depletion may be present around these deposits.

The geometry and areas of many Kuroko massive sulfide deposits are summarized in Mosier and others (1983). This type of information is useful in both mineral resource assessment and the search for undiscovered deposits. Length and width of deposits can be used to estimate the area of a deposit where the shape is approximated by an ellipse. About 90 percent of the 110 deposit for which data are reported have an area of 7,100 m^2 or greater. The median area is 36,000 m^2 and about 10 percent of the deposits have areas of at least 310,000 m^2. These areas are appropriate for deposits which are horizontal. However, many deposits have been rotated during tectonism so that the projection of the deposit size onto a horizontal plane (an approximation of the surface) will give targets with smaller areas. About 90 percent of the Kuroko massive sulfide deposits which have been tectonically rotated, and size projected to the surface (Mosier and others, 1983) have an area of at least 700 m^2. This is an order of magnitude smaller than the "true" size. The median target size will have an areas of at least 20,000 m^2. This is 55 percent of the "true" area of the median deposit. About 10 percent of the targets have areas which are 310,000 m^2 or greater; this is identical to the "true" size given for 10 percent of the deposits. This suggests that most deposits of this type, particularly the larger deposits, will provide large drilling targets approximately equal to "true" size despite the effect of subsequent tectonism.

Grade and Tonnage Models

The grade and tonnage model for 432 Kuroko massive sulfide deposits was developed by Singer and Mosier (1986b) for those deposits in felsic or intermediate rocks (Mosier and others, 1983). Also given is the correlation coefficient (r) and the number of deposits (n) used in calculation of the correlations. There is significant negative correlation present between tonnage and copper grade (r=-0.17) and positive correlation between tonnage with gold grade (r=0.19, n=238). Correlation is also present between zinc grade and lead grade (r=0.55, n=184) and with silver grade (r=0.52, n=249). Significant correlation is present between lead and silver grades (r=0.55, n=153) and lead and Au grades (r=0.34, n=124). Gold and silver grades are also correlated (r=0.39, n=227) (Singer and Mosier, 1986b). Just under 80 percent of the deposits used in the model have reported zinc; just under 70 percent of the deposits used in the model have reported silver and under 60 percent have reported gold. Lead is reported in over 40 percent of the deposits. Grades and ore tonnages are summarized in table 4 (Singer and Mosier, 1986b). Analysis of published and unpublished data for deposits in the Ambler River district in the Brooks Range suggests that the median tonnage of deposits is compatiable with that given in Table 4.

Table 4. Estimate of percentage of Koruko massive sulfide deposits which equal or exceed a given grade or tonnage (Singer and Mosier, 1986b). Floor values are approximate lowest value given for each variable in the grade and tonnage model (Singer and Mosier, 1986b). [--, grade is not present or reported.]

Variable		Percentage		
	Floor	90	50	10
Tonnes (10^6)	.025	0.12	1.5	18.
Copper (percent)	0.1	0.45	1.3	3.5
Silver (g/tonne)	1.0	---	13.	100
Gold (g/tonne)	0.25	---	0.16	2.3
Lead (percent)	.01	---	---	1.9
Zinc (percent)	.16	---	2.0	8.7

Identified Kuroko Massive Sulfides in the Brooks Range

Deposits of this type are contained in the Ambler metavolcanic rocks (also found in the Wiseman quadrangle), in the Survey Pass $1^o \times 3^o$ quadrangle which is just west of the Wiseman quadrangle. These deposits include the Sun deposit (also called Sun-Picnic Creek deposit), a large copper-zinc deposit hosted by felsic volcanic rocks which are part of a sequence of low-grade schists of the Amber rock group (Grybeck and Nelson, 1981). The deposit is in a locally mineralized area of about 78 km^2 (Grybeck and Nelson, 1981) and, based on incomplete drilling data, contains over 12.5×10^6 tonnes with 1,8 percent copper, 5.3 percent zinc, and 1.8 percent lead (Hitzman and others, 1986). At least five other sites in the Survey Pass quadrangle have hosting lithologies and depositional style similar to the Sun deposit (Grybeck and Nelson, 1981).

Nine reported volcanogenic deposits of the Kuroko massive sulfide deposit-type were reported in the Ambler River quadrangle, adjacent to and west of the Survey Pass quadrangle (Mayfield and Grybeck, 1978); by 1985 about 17 deposits or prospects were identified in the Ambler River District (Nicholson and others, 1985) which straddles the Ambler River and Survey Pass quadrangles. Massive sulfide deposits in the the Ambler River district include Smucker which contains 8×10^6 tonnes with 0.8 percent copper, 6.8 percent zinc, 2.3 percent lead. The Smucker deposit consists of a single sulfide layer at least 2.2 km long and averaging 3 to 4 m thick (Hitzman and others, 1986). This deposit is associated with felsic schist which probably resulted from the metamorphism of rhyolitic domes and volcanoclastic rocks (Wiltse, 1975; Mayfield and Grybeck, 1978). Hitzman and others (1986) noted that this deposit along with the BT deposit "are associated with anomalous thickness of rhyolitic volcanic rocks which may represent volcanic centers." The Arctic Camp deposit is the best documented and has an estimated 37×10^6 tonnes of ore with 4 percent copper, 5.5 percent zinc, 0.8 percent lead, 47 g/tonne silver and .62 g/tonne gold (Hitzman and others, 1986). The deposits in the Ambler River district are thought to contain more silver than is characteristic of the deposit type, but published data are incomplete for verification. Arctic Camp's silver grade is higher than the median grade for Kuroko massive sulfide deposits (Table 4). The Arctic Camp deposit consists of sulfide-rich lenses (914 x 1220 m), some as much as 14 m thick, through a 6- to 80-m stratigraphic interval (Hitzman and others, 1986). Minerals in the Arctic Camp deposit are dominantly chalcopyrite, sphalerite, and galena; minor sulfide minerals include chalcocite, bornite and tennantite (Wiltse, 1975). As contrast to Arctic Camp, other deposits (Sun-Picnic Creek, Smucker, BT, and Bud deposits) are dominated by iron sulfide minerals (Hitzman and others, 1986). A typical mineral assemblage includes pyrite, chalcopyrite, sphalerite, and galena with subordinate tennantite-tetrahedrite, and rare pyrrhotite, bornite, and arsenopyrite. The Sunshine deposit has atypical pyrite-magnetite and pyrite-magnetite-pyrrhotite assembages (K. Hill, in preparation, as cited by Hitzman and others, 1986). Barite is prominent at Arctic Camp, Dead Creek, and Sunshine Creek deposits. Other nonsulfide gangue minerals include quartz, muscovite, phlogopite, chlorite, dolomite, ankerite, albite, talc and ferroan and nonferroan calcite (Hitzman and others, 1986). Weathering of the mineralized zone at Arctic Camp has created a small gossan cap which can be as much as 4.6 m thick (Wiltse, 1975). Some ore-grade cobbles and boulders are found in ferricrete-rich talus below the mineralized zone (Wiltse, 1975). Of the associated gangue minerals, talc appears only with the deposit and not in the country rock and has been interpreted as genetically related (Wiltse, 1975); it also may be a useful exploration guide as the talc forms envelopes up to about 91 m thick about the sulfide pods and layers which are usually no more than 30 m thick. Calcite can be an important gangue mineral when the ore is massive. Wiltse (1975) suggests that some layered ore may reflect original bedding. The deposit does not exhibit stockwork veining (Wiltse, 1975), which is prevalent in Kuroko massive sulfide deposits in Japan. Vein has been observed both below and above some of the Japanese deposits (Kouda and Koide, 1978; Ryoichi Kouda, June 13, 1986, oral comm.). Hitzman and others (1986) also reported numerous minor mineralized zones in the Ambler River district, typically consisting of disseminated to semimassive pyrite, with lesser amounts of base metal sulfide minerals. The zones are highly siliceous; quartz, yellow muscovite, and lesser amounts of chlorite, calcite and barite may be present. Hitzman and others (1986) suggested that these weakly mineralized zones are better developed in layers above the crystal tuff and aphanitic rhyolite. Mineralization is sufficiently developed that at least one deposit of this style is identified: the BT deposit with 3-4 $x10^6$ tonnes of 1.7 percent copper, 2.6 percent zinc, 0.9 percent lead, and 1.3 oz/tonne silver (Hitzman and others, 1986).

Arctic Camp has local alteration effects, particularly well developed southeast of the deposit in an area about 450 by 760 m and extending at least 300 m both above and below the deposit. All sedimentary and volcanic textures are destroyed in the altered area. Similar strong alteration is found at the Sun-Picnic Creek deposit. Schmidt (1986) gives a more complete discussion of alteration and other aspects of its mineralization at the Arctic Camp deposit.

Regional expression of mineralization in the Ambler River district is restricted to a single type of alteration: persistent alteration of K-feldspars in the crystal tuff and aphanitic rhyolite units (Hitzman and others, 1986). However, this alteration is also present in areas without mineralization. In general, the volume of altered rocks is quit small--it is not even expressed in the chemical data (Hitzman and others 1986).

Tract Delineation for Kuroko Massive Sulfides

The primary criteria used to delineate tracts permissible for Kuroko massive sulfide deposits were the presence of Ambler metavolcanic rocks, significant felsic volcanics, or mixed felsic and mafic volcanic rocks, all of Devonian age.

Subjective Estimate of Undiscovered Kuroko Massive Sulfides

Participants in the mineral resource assessment estimated that there is a 90 percent chance of one or more undiscovered deposits, a 50 percent chance of 3 or more undiscovered deposits, and a 10 percent chance of 6 or more undiscovered Kuroko massive sulfides deposits in the Wiseman quadrangle. Tracts rank in order of decreasing probability of containing undiscovered deposits are: KMS-Ia and KMS-Ib, KMS-II, KMS-III, and KMS-IV.

Description of Tracts for Kuroko Massive Sulfides

Tract No.: KMS-Ia

a) Geographic description: Tract consists of one large irregular but crudely triangular, area KMS-Ia(1) and three small outlier (KMS-Ia(2)-(4)). KMS-Ia(1) extends from the west edge of the quadrangle to the North Fork of the Koyukuk River (pl. 1).
b) Permissive rocks and structures: Tract delineation was based on the rocks shown on Dillon and others (1986); this tract includes the Ambler metavolcanic rocks, which contains interbedded black quartzose schist and quartzite, marbles, and calcareous schist which are Lower (?), Middle, and Upper Devonian. Metamorphosed mafic and felsic volcanic rocks are abundant and were occassionally mapped as (1) felsic metvolcanics, including flows, tuffs, and blastoporphyritic intrusive rocks, (2) metamorphosed bimodel igneous rocks, including complex interlayered felsic and mafic extrusive and intrusive rocks, and (3) metabasites. Most of these volcanic units also are interlayered with metasedimentary rocks. The Ambler metavolcanic rocks host Kuroko massive sulfide deposits elsewhere in the Brooks Range (Grybeck and Nelson, 1981; Mayfield and Grybeck, 1978; Wiltse, 1975). Also included in the tract are Proterozoic and Lower Paleozoic schist, Proterozoic or Paleozoic calcareous schist, Middle or Upper Devonian black calcareous phyllites and possibly other units which are imbricated with the Ambler metavolcanic rocks.
c) Known mineralization: Nine sites with 13 samples have been described in or adjacent to this tract. Host rock at two sample sites is identified as a metavolcanic. The sample host at six sites is identified as schist. Marble is found at two sample sites. Samples were taken from three occurrences described as disseminated, one as layered or vein, one as massive or two as veins. Gossans are also present in two sites. Copper is anomalous in four samples, (at two localities; all collected in KMS-Ia(4) (pl. 1)). Chalcopyrite in significant amounts is present in stockwork hosted by marble in one site and in minor amounts at one other site. The general form, mineralogy, and geochemistry of the occurrences do not correspond well to the deposit model. The tract does not intersect any basins containing known gold placers.
d) Geochemistry: About 80 percent of the tract is located in the Schist Belt geochemical lithologic subdivision (II) (fig. 2). About 10 percent of the tract is located in both the Skagit geochemical lithologic subdivision (III) and the Beaucoup-Whiteface geochemical lithologic subdivision (IV). This tract intersects, wholey or partly, four geochemical anomalous areas in

subdivision II, one is subdivision III and none in subdivision IV. A summary of the geochemical anomalous areas applicable to this tract are as follows:

Subdivision no. II
    Anomalous geochemical area 7 is wholly within tract (KMS-Ia(1)).
      Anomalous elements: copper, arsenic, tungsten
      Locally anomalous: zinc, lead, cobalt, nickel
    Anomalous geochemical area 6 is within the tract (KMS-Ia(1))
      Anomalous elements: copper, zinc, gold, arsenic, tin
      Locally anomalous: lead, barium, cobalt, bismuth, antimony
    Most of anomalous geochemical area intersects part of KMS-Ia(2)
      Anomalous elements: lead, gold, silver, molybdenum, tungsten
      Locally anomalous: copper, cobalt
    Anomalous geochemical area 4 intersects the tract in two areas (all of KMS-Ia(4) and a small section of KMS-Ia(1) east of Michigan Creek).
      Anomalous elements: copper, lead, zinc, gold, tungsten
      Locally anomalous: barium, cobalt, chromium, arsenic, tungsten

Subdivision no. III
    Anomalous geochemical area 6 is wholly contained in the tract (KMS-Ia(1)).
      Anomalous elements: gold, silver, bismuth
      Locally anomalous: lead

f) Comments: Only about 5 percent of the tract area consists of outcrops of felsic and mafic volcanic rocks sufficiently large to be mapped at a scale of 1:250,000.

Tract No.: KMS-Ib

a) Geographic description: The main part of the tract (KMS-Ib(1)) extends east for about 40 km and is between 4 and 5 km wide. The tract extends from the west margin of the quadrangle to about the John River. The tract includes a small outlier (KMS-Ib(2)) in the headwaters of the Sixtymile Creek (pl. 1).
b) Permissive rocks and structures: The main part of the tract (KMS-Ib(1)) contains scattered exposures of Ambler metavolcanic rocks like those found in tract KMS-Ia (also see for details on lithology). This tract likewise contains metamorphosed biomodal volcanic rocks, felsic metavolcanic rocks and metabasite. Other rocks in the tract, not permissible for this deposit type are imbricated with those that are, including the Skajit Limestone, conglomerate, and chloritic and carbonate rocks. The small outlier (KMS-Ib(2)) consists of Ambler metavolcanic rocks and metamorphosed felsic rocks.
c) Known mineralization: Only one site is described in this tract. The outlier of the tract (KMS-Ib(2)) includes a general area identified as being enriched in copper and iron. The site is described as quartz stockwork in dolomite and contains malachite, azurite, galena, and possibly bornite. Copper, antimony and zinc are geochemically anomalous. The occurrence does not correlate well with the deposit model.
d) Geochemistry: The entire tract lies within the Skajit geochemical lithological subdivison (III). The tract does not intersect any of the anomalous geochemical areas in this subdivision.
e) Geophysics: The main part of the tract (KMS-Ib(1)) parallels the same aeromagnetic low as Tract KMS-Ia but north of the aeromagnetic axis.
f) Comments: About 2 percent of the tract area (KMS-Ib(1) consists of outcrops of felsic and mafic volcanic rocks sufficiently large to be mapped at

a scale of 1:250,000.

Tract No.: KMS-II

a) Geographic description: The tract has three parts all in the northeast quarter of the quadrangle. KMS-II(1) and KMS-II(2) are parallel to the southeast side of the Doonerak Fenster, whereas the small KMS-II(3) lies within the southwest corner of the the Fenster (pl. 1).
b) Permissive rocks and structures: The rocks in this tract are probably stratigraphically and lithologically equivalent to some rocks of the Ambler metavolcanic sequence. However, these rocks contain much fewer volcanic strata and are at a lower metamorphic grade than those found in the KMS-I series of tracts.

KMS-II(1) includes Middle or Upper Devonian (?) wacke containing volcanic clasts, Middle Devonian (?) siliceous clastic rocks with interstratified felsic volcaniclastic rocks, metabasite like that associated with the bimodal Ambler metavolcanic rocks, and Devonian or older wacke and limestone containing felsic flows, plugs, and tuffs. Other rocks in the tract, and imbricated with these presumably permissive units, are Middle or Upper Devonian black calcareous phyllite, Devonian or older Skajit Limestone, and Upper Devonian Hunt Fork Shale, among others. Volcanic rocks tend to be more abundant along the northwest margin.

KMS-II(2) includes fewer units. They are Paleozoic wacke and limestone with felsic flows, plugs, and tuffs and Devonian felsic metavolcanic rocks imbricated with black calcareous phyllite. Exposure of felsic metavolcanic rocks are large enough to appear on a 1:250,000 scale map, make up about 4 percent of KMS-II(2).

KMS-II(3) is a small area of Paleozoic metawacke and calcareous meta tuff with abundant clasts of epidote-bearing rock and intermediate plutonic rocks all are possible equivalent to older wacke and limestone exposed in other parts of the tract.
c) Known mineralization: Two undescribed occurrences, a copper occurrence and a barite occurence, are present in KMS-II(1) and in an area east of the Hammond River. No other occurrences are known. No gold placers are in or adjacent to the tract.
d) Geochemistry: Most of KMS-II(1) and (2) are in geochemical lithologic subdivision (V). No part of the tract includes anomalous geochemical areas.

Tract No.: KMS-III

a) Geographic description: This tract consists of four parts in the southeast quarter of the quadrangle. KMS-III(1) is a small area in the headwaters of Michigan Creek. KMS-III(2) is a small area betweeen Michigan Creek and the North Fork Koyukuk River. KMS-III(3) is the largest part--a 50 km long tract running from Wild River to the area between the North and Middle Forks of the Koyukuk. KMS-III(4) is located along, and west of the North Fork of the Koyukuk River.
b) Permissive rocks and structures: The tract as a whole contains scattered areas with felsic rocks, usually of uncertain affiliation. KMS-III(1) is dominated by felsic and mafic volcanic rocks suspected to be part the metamorphosed bimodal igneous rocks similar to those found in the Ambler metavolcanic sequence (Dillon and others, 1986) are present in tracts KMS-I and KMS-II. KMS-III(2) contain rocks thought to belong to the metabasite unit and to chloritic and carbonate rocks. KMS-III(3) contains several units

including scattered volcanic rocks thought to be similar to other felsic volcanic rocks and biomodal volcanic rocks found mapped elsewhere in the quadrangle. The other unit common in this part of the tract is a coarse mica-schist which locally contains black graphitic schist. KMS-III(4) contains Devonian granitic gneiss and tactite in Protozoic schist. Although the identified geology for this section of the tract sounds unpromising, participants in the assessment felt that the area should be included as a permissible area. An argument for exclusion is that the presences of tactite and granite suggest that the area may be too deeply eroded to contain the extrusive volcanic rocks which typically host Kuroko massive sulfide deposits.
c) Known mineralization: The tract contains no known bedrock mineral occurrences. Gold placers on Agnes Creek are located southwest of KMS-III(1). The stream basin does not intersect the tract. KMS-III(3) includes part of a stream basin for the Bourbon Creek Placer a poorly documented placer. One bedrock occurrence in KMS-III(4) consists of a quartz veinlet containing bornite blebs that is hosted by dolomite and limestone. The south edge of KMS-III(4) is included in the basin of Emma Creek Placer.
d) Geochemistry: KMS-III(1) and (2) are located in geochemical lithologic subdivision IV; KMS-III(3) and (4) are located in the Schist Belt geochemical lithologic subdivision II. KMS-III(1) and (2) of the tract do not intersect any geochemically anomalous areas in subdivision IV. The northern part of KMS-III(3) intersects a part of geochemically anomalous area 4, subdivision II, 1). Copper, lead, zinc, gold, and tungsten are anomalous; barium, cobalt, chromium, silver, arsenic and antimony less commonly so. Most of KMS-III(4) is included in geochemically anomalous area 4, subdivision II. Copper, lead, zinc, gold, silver, arsenic, antimony and tungsten are anomalous; barium, nickel and molybdenum less commonly so.

Tract No.: KMS-IV

a) Geographic description: Tract consists of three parts (KMS-IV(1) to (3)) and is found in the northeast corner of the quadrangle. The largest part is triangular, roughly centered on Midnight Mountain and found east of the North Fork Koyukuk River. This part of the tract includes the headwaters of Clear River and Hammond River (pl. 1). Two smaller outliers are also included: a smaller area on Boreal Mountain east of the North Fork Koyukuk River and a small area on the Frigid Craigs west of the North Fork of the Koyukuk River.
b) Permissive rocks and structures: Over half the rocks in the tract, which is in the Doonerak Fenster are andesitic to basaltic with local gabbro and diabase. These rocks locally contain interbedded with tuffaceous grey phyllite and black phyllite. All rocks in the tract are Cambrian (?) and Ordovician. The rocks have not been strongly metamorphosed.
c) Known mineralization: An undescribed copper occurrence may be present in the northeast section of KMS-IV(1).
d) Geochemistry: The tract is located entirely in the geochemical lithologic subdivision V.Anomalous geochemical area 2 includes about 75 percent of KMS-IV(1) and is almost totally within that part of the tract. The following elements are anomalous in stream sediments and (or) panned concentrates: copper, zinc, barium, gold, silver, arsenic, and molybenum. Less commonly anomalous are lead, cobalt, nickel, chrome, antimony, mercury, tin and tungsten.

BESSHI MASSIVE SULFIDE (24B)

Introduction

Besshi massive sulfide deposits are one of at least five deposit types found predominantly in marine and extrusive mafic rocks and may also be included in ophiolites (Cox and Singer, 1986). These deposits are also called "Kieslager" in Europe. Besshi massive sulfide deposits are stratiform bodies of iron- and copper-sulfide minerals in thinly laminated sedimentary rocks and mafic to andesitic tuffs (Cox, 1986a). The primary commodity of these deposits is copper; byproducts include silver, gold, and zinc (Singer, 1986d).

Geologic Setting

The following description is taken from Cox (1986a) unless noted otherwise. This deposit type probably forms near the sea floor by hydrothermal fluids, usually but not exclusively, in deep water. Deposits are rootless (D.A. Singer, oral communication, 1986), meaning they lack feeder veins and, therefore, likely distal. Deposits are hosted by continentally derived clastic rocks, such as deltaic sandstone, hemipelagic mudstone, and siltstone (Fox, 1984); and locally may include black shale, oxide facies of iron formation and red chert. Such deposits in Japan occur in rock sequences made up of approximately equal parts of metasedimentary and metamorphosed mafic volcanic rocks (Laznicka, 1985). These deposits also tend to occur in the stratigraphic horizon, with the most volcanic rocks (Kanehira and Tatsumi, 1970). The tectonics setting most favorable for these deposits is unclear; rift basins in island arcs or back arcs may be appropriate and spreading centers at continental slopes may also be involved. Deposits appear to be predominantly Paleozoic or Mesozoic (Cox, 1986a). No other deposit types are known to be associated with Besshi massive sulfide deposits.

Deposit Properties

Besshi massive sulfide deposits are stratiform; most deposits of this type in Japan, where they have been extensively studied, are metamorphosed and ore bodies are concordant with schistosity (Laznicka, 1985). Pyrite, pyrrhotite, chalcopyrite, and sphalerite are the dominant sulfide minerals (Cox, 1986a). Other sulfide minerals that may be present include magnetite, valleriite, galena, bornite, tetrahedrite, cobaltite, cubanite, stannite, and molybdenite (Cox, 1986a). Common gangue minerals include quartz, carbonate minerals, albite, white mica, chlorite, amphibole, and tourmaline. Deposits generally are not zoned. Some deposits are underlain by what has been interpreted as manganiferous exhalite (Fox, 1984). Other deposits are associated with a magnetite-bearing quartzite, thought result from metamorphism of banded-chert formation (Laznicka, 1985). The Besshi ore deposits in Japan, are among the largest for the deposit type. They extend down plunge for at least 2,500 m and are between 0.3 to 7 m thick (Laznicka, 1985); the average thickness is 3 m (Fox, 1984). Most deposits are massive, but they may also be thinly laminated, disseminated, or brecciated and contain cross-cutting stringer veins with chalcopyrite, galena, shalerite, and calcite (Cox, 1986a). The veins have been interpreted as the result of remobilization during metamorphism, not as footwall feeders (Laznicka, 1985). Gossans may develop on deposits during weathering (Cox, 1986a).

Geochemical expression of these deposits may include copper, zinc, cobalt, nickel, chrome, gold (as much as 4 ppm) and silver (as much as 60 ppm). The copper/nickel ratio is approximately 0.8 (Cox, 1986a).

Grade and Tonnnage Model

The grade and tonnage model was developed using data from deposits in Japan that each contained more than 10,000 tonnes of ore (Singer, 1986d). No correlation is reported among the metal grades or between any given grade and tonnage. About 30 percent of the 44 deposits used for the grade and tonnage model have reported silver and (or) gold grades. Between 10 and 20 percent of the deposits have reported zinc grades (Singer, 1986d). These grades plus copper grade and ore tonnage are summarized in table 5 (from Singer, 1986d).

Table 5. Estimate of percentage of Besshi massive sulfide deposits which equal or exceed a given grade or tonnage (Singer, 1986d). Floor values approximate lowest value given for each variable in the grade and tonnage model (Singer, 1986d). [--, grade not present, not reported.]

Variable	Floor	Percentage 90	50	10
Tonnes (10^6)	0.1*	0.12	0.22	3.8
Copper (percent)	0.4	0.64	1.5	3.3
Silver (g/tonne)	2.5	---	---	9.5
Gold (g/tonne)	0.1	---	---	0.76
Zinc (percent)	0.2	---	---	0.4

* Cutoff has been set by definition

Identified Besshi Massive Sulfides in the Brooks Range

No Besshi massive sulfides deposit have been found in the Brooks Range.

Tract Delineated

One tract (KMS-IV) previously delineated for Kuroko massive sulfide deposit is also permissible for Besshi massive sulfide deposits. The tract is described in the section on Kuroko massive sulfides. The assemblage of volcanic and sediment rocks in that tract are also compatible with the geologic setting for Besshi massive sulfide deposits. All elements commonly found in anomalous concentrations at Besshi deposits have been identified in stream sediments from the tract: copper, zinc, gold, and silver and less commonly cobalt, nickel, and chrome.

Subjective Estimate of the Number of Undiscovered Besshi Massive sulfides

Participants in the mineral resource assessment did not make a subjective estimate the number of undiscovered Besshi massive sulfides in the Wiseman quadrangle.

SEDIMENTARY HOSTED ZINC-LEAD (31A)

Introduction

Sedimentary exhalative zinc-lead deposits are one of at least 16 deposit types found predominantly in clastic sediment rocks (Cox and Singer, 1986). Sedimentary exhalative zinc-lead deposits consist of zinc and lead sulfide and sulfate minerals as lenses and sheets commonly hosted by black shales (Briskey, 1986b). Zinc and lead are the primary commodities; byproducts include silver and copper (Menzie and Mosier, 1986).

Geologic Setting

This deposit type most likely forms near the sea floor, presumably deposited by ascending hydrothermal fluids along normal faults that bound graben complexes in which sedimentation is occurring. Deposits are commonly hosted by fetid, black shales; however, a variety of other clastic and nonclastic sediments may dominate. Analysis of 49 deposits of this type (Menzie and Mosier, 1985) suggests that clastic sedimentary rocks include not only black shale but also siltstone and sandstone. These types of clastic rocks dominate in 65 percent of the deposits; the remaining deposits occur in hosts dominated by carbonate rocks such as dolostone and micritic limestone (Briskey, 1986b). Host rocks may, due to active faulting during deposition, develop such features as slump breccias, fan conglomerates, and changes in bedding thickness, as well as facies changes (Briskey, 1986b). Epicratonic basins or embayments are the favored tectonic settings for deposition of sedimentary exhalative zinc-lead deposits (Briskey, 1986b). Third order basins, those with areas on the order of tens of square kilometers, are particularly favorable for deposition (Briskey, 1986b). Deposits are either middle Proterozoic (1,700-1,400 Ma) or Cambrian to Carboniferous (530-300 Ma) (Briskey, 1986b). Bedded-barite deposits may be either intimately associated or at some distance from these deposits. About half the recognized deposits of this type have associated barite mineralization, some of which is economic.

Deposit Properties

Sedimentary exhalative Zn-Pb deposits are stratiform, zoned, and usually disseminated. Metamorphosed deposits, however, are massive and coarsely, crystalline (Briskey, 1986b), making milling of the ore easier. Deposits tend to be elongated; some have lengths of several kilometers. Several ore bodies may be adjacent. Deposits may cover areas as large as 3.2 km^2. The smaller deposits cover 1,100 m^2. The median area is estimated at 430,000 m^2 based on 20 deposits. Ore horizons thicknesses for 14 deposits commonly ranged from 1 to 120 meters; thickness up to 200 meters have been reported. The median thickness was 7.8 m.

Ore minerals include pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. Locally present in small amounts are marcasite, arsenopyrite, bismuthinite, molybdenite, enargite, millerite, freibergite, cobaltite, cassiterite, valleriite, and melnicovite (Briskey, 1986b). Some monomineralic layering may be present.

Stratiform ore commonly rests on a stockwork zone--, feeder zone-- which may be 170 m deep (Briskey, 1986b). The stratiform ore is commonly zoned both laterally and vertically. Lateral zoning includes a core of chalcopyrite-pyrrhotite surrounded by sphalerite and galena. Peripheral to this is pyrite followed by barite. The same sequence can also be found vertically except galena is more abundant than sphalerite (Briskey, 1986b). Hematiferous cherts may extend laterally away from the ore deposit.

Significant amounts of barite occur with 45 to 50 percent of the currently recognized sedimentary exhalative zinc-lead deposits. Approximately 25 percent of the deposits will have economic barite deposit (G.J. Orris, oral communication, 1986). These associated barite deposits have grades and tonnages which are indistinguishable from bedded barite deposits not associated with exhalative zinc-lead deposits (Orris, oral communication, 1986). See the section on bedded barite contains for grade and tonnage data (Orris, 1986b).

Barite is useful as an exploration guide for sedimentary exhalative zinc-lead deposits. These deposits appear more likely to have associated barite if the deposit host is dominantly clastic. However, statistical analysis of these data (using Chi-square test) suggest that there is no significant association between the type of host (clastic as opposed to carbonate) and the presence of barite. Of the 29, 17 have significant barite and 12 do not have.

Metamorphosed sedimentary exhalative zinc-lead deposits appear to have fewer deposits associated with significant barite. Eleven of the 16 relatively unmetamorphosed deposits have significant barite associated, only 6 out of the 18 metamorphosed deposits have significant barite associated. Statistical analysis of these data (using Chi-square test) suggests that the association of metamorphism and the absence of barite is marginally significant (at the 5 percent level).[1] This analysis may suggest that barite is lost during metamorphism and that it is a less effective exploration guide for sedimentary exhalative zinc-lead deposits in metamorphised areas.

The stockwork of chalcopyite, pyrite, and pyrrhotite which may be beneath the stratiform ore body is commonly hosted by sedimentary rocks which have undergone extensive alteration by silicification, tourmalinization, carbonate depletion, albitiziaton, chloritization, and dolomitization. Some deposits, however, exhibit no alteration (Briskey, 1986b). Other alteration minerals include celsian, Ba-muscovite and ammonium clay minerals (Briskey, 1986b).

Black shale host rocks are usually enriched in metals, including lead with concentrations in the range of 500 ppm, zinc (1,300 ppm), copper (750 ppm), and barium (1,300 ppm). Concentration of these metals in carbonate host rocks are two orders of magnitude lower: lead (9 ppm), zinc (20 ppm), copper (4 pmm) and barium (10 ppm) (Briskey, 1986b). Halos of zinc, lead, and manganese may extend for 2 km from the deposit. Anomalous ammonia may also be present. (Briskey, 1986b).

Zinc and lead are useful indicators in the exploration for sedimentary exhalative zinc-lead deposits in the Selwyn Basin, Canada, where at least six deposits or occurrences have been found (Goodfellow, 1983). A study by Goodfellow (1983) of two of these, the Howard's Pass (XY) deposit and the Nor occurrence, found that zinc, lead, and cadium were anomalous in stream sediments (minus-80 mesh) downstream from the mineralization. For the Howard's Pass deposit, barium was also anomalous, along with moderate to weak increases in nickel, antimony, mercury, molybdenum, silver, and vanadium. In the Nor occurrence, copper, silver, and barium were also anomalous along with moderate to weak increases in cobalt, nickel, iron, manganese, molybdenum, and antimony (Goodfellow, 1983). Water samples collected downstream from the Nor occurrence contained both anomalous zinc and lead whereas water samples collected downstream of Howard's Pass deposit showed anomalous zinc only. Both Howard's Pass and Nor have zinc- and lead-sulfide minerals and pyrite. A possible cause for this geochemical difference is that the Howard's Pass deposit is hosted by shales containing sufficient carbonate to insure that stream-water pH levels are high despite acids generated by the oxidation of pyrite in the deposit. Under such conditions, zinc continues to be soluble, lead does not. At the Nor occurrence, stream water is more acidic and carbonate poor so both zinc and lead are soluble (Goodfellow, 1983). If a

1. There is a 5 percent chance that the computed Chi-square value is due to chance.

depost is buried, zinc and lead solubility in groundwater is an important consideration in geochemical exploration for deposits of this type. Conceivably, ground water entering streams from buried deposits similar to Howard's Pass would have anomalous zinc, without lead; water from deposits similar to the Nor occurrence would have both anomalous zinc and lead (Goodfellow, 1983). Stream geochemical responses to both these deposits are diluted by 3 or 4 km of the deposit. Lead returned to background levels 1 km downstream. Water samples showed a similar rapid dilution except for zinc and cadium which remained at anomalous levels at least 4 km downstream (Goodfellow, 1983).

Weathering of these deposit may product large gossans rich in lead, zinc, and copper silicate, sulfate and carbonate minerals (Briskey, 1986b). Rivers commonly associated with these deposits are stain red by periphyton (a mix of algae, fungi, and bacteria) on the stream bed (Cathrall, 1982).

Grade and Tonnage Model

The grade and tonnage model for sedimentary exhalative zinc-lead deposits was developed from 45 deposits which are commonly identified as belonging in this group (Menzie and Mosier, 1986). Analysis of silver grades suggests that the group is not homogeneous in terms of silver and that two subtypes may be present (Menzie and Mosier, 1986). Lead and silver grades are significantly correlated ($r=0.77$, $n=39$). Silver grades are reported for about 80 percent of the deposits, copper grades for about 25 percent of the deposits (Menzie and Mosier, 1986). Grades and ore tonnage are summarized in table 6 (Menzie and Mosier, 1986).

Table 6. Estimate of percentage of sedimentary exhalative Zinc-Lead deposits which equal or exceed a given grade or tonnage (Menzie and Mosier, 1986). Floor values are approximate lowest value given for each variable in the grade and tonnage model (Menzie and Mosier, 1986). [--, grade not available, not reported.]

Variable		Percentage		
	Floor	90	50	10
Tonnes (10^6)	.8	1.7	15.	130.
Zinc (percent)	1.0	2.4	5.6	13.
Lead (percent)	0.4	1.0	2.8	7.7
Silver (g/tonne)	3.0	---	30.	160.
Copper (percent)	.04	---	---	0.28

Sedimentary exhalative Zinc-Lead Deposits in the Brooks Range

Several deposits and prospects for the sedimentary exhalative zinc-lead deposit type are also identified in the Brooks Range. The most important one recognized so far is the Red Dog deposit. Located in the western Brooks Range, the Red Dog deposit is world class in size. The deposit contains and estimated 77 million tonnes of ore (Menzie and Mosier, 1985), which is in the upper 20 percent of the tonnage for all deposits of the type currently recognized (Menzie and Mosier, 1986). The deposit reportedly has 17.1 percent zinc, 5.0 percent lead, and 82 g/tonne silver (Giegerich, 1986). The cadmium content has been reported to be as high as .25 percent but this is unlikely to be an average grade.

The Red Dog site was initially described by Tailleur (1970). Located in the DeLong Mountains 1^{o} by 3^{o} quadrangle, it is hosted by the Kuna Formation consisting of Mississippian and Pennsylvanian black graphitic shale, chert, and carbonate rocks. The ore body has two parts: the Main deposit and a smaller Hilltop deposit about one-half mile to the south (McMichael and others, 1984). Ore grade and tonnage figures cited above are for the Main deposit only. The Main deposit is reported to be at least 1680 m long and 760 m wide. Maximum thickness is 150 m (McMichael and others, 1984). The average thickness is 30 m (Pratt, 1984). The Main deposit is exposed over at least 1.5 km^2 (Moore and others, 1986). The smaller-sized Hilltop deposit is 850 m long, 610 m wide and up to 91 m thick (McMichael and others, 1984); it may contain as much as 25 percent of the tonnage of the Main deposit (19 million tonnes) but no size has been officially reported. The ore in the Main deposit consists of sphalerite, galena, pyrite, and marcasite. Quartz is an abundant gangue mineral. Barite is also present with lenses up to 46 m thick capping and occurring upsection from the deposit (McMichael and others, 1984) and peripheral to the deposit (Moore and others, 1986). Moore and others (1986) give detail description of the Red Dog Deposit. The deposit makes up part of the Nolatak Zinc Belt, which contains at least 15 "significant" prospects (Alaska Office of Mineral Development as reported in Pratt, 1984) of this deposit type.

Other sedimentary exhalative zinc-lead deposits in Brooks Range include the Lik deposit, which is 20 km southwest of Red Dog (also in the Delong Mountains quadrangle). It reportedly contains 25 million tonnes with 8.8 percent zinc, 3.0 percent lead, and 37 g/tonne silver (Pratt, 1984). The deposit contains sphalerite, galena, and barite and is hosted by an Upper (?) Mississippian black shale and chert (Bundtzen and Henning, 1978). Adjacent to the Lik deposit is the Su deposit for which there is little information (Pratt, 1984).

Two areas in the Howard Pass 1^{o} by 3^{o} quadrangle, Alaska may contain sedimentary exhalative zinc-lead deposits--the Drenchwater and the Story Creek areas. The Drenchwater area has been extensively studied by Lange and others (1985), and Nokleberg and Winkler (1982), among others. Nokleberg and Winkler (1982) found mineralization in a zone 1,830 m long and 6 and 45 m wide. The mineralization includes sphalerite, galena, pyrite, and marcasite associated with disseminated barite. Rarely fluorite is found. Selected samples contain as much as 1 percent zinc, 2 percent lead, 150 g/tonne silver, 500 g/tonne cadmium, .05 percent tin and .15 percent barium. The mineralization is hosted by Mississippian cherts, shale, tuffs and tuffaceous sandstone containing minor keratophyre and andesite flows and sills (Nokleberg and Winkler, 1982). Lange and others (1985) described several styles of mineralization at Drenchwater including disseminated sulfide minerals and barite, particularly in the shale, chert, tuff, tuffaceous sandstone, and quartz exhalite; mineral aggregates in the quartz exhalite; and veins crosscutting the cleavage of the brecciated chert and shale.

Mineralization at Story Creek is described (Uldis Jansons, oral communication to Mayfield and others, 1979) as sphalerite and galena with vein quartz hosted by lower (?) Missippian to Upper (?) Devonian sandstone, siltstone, and shale. Bundtzen and others (1986) describe the deposit as an "epigenetic replacement deposit...hosted in breccia zone in Devonian Kanayut Conglomerate or lower Mississippian Kayak Shale." Fine-grained igneous dikes are present west of the deposit (Mayfield and others, 1979).

At least one sedimentary exhalative zinc-lead deposit is recognized in the Misheguk 1^{o} by 3^{o} quadrangle (Mayfield and others, 1979). The Ginny Creek deposit occurs in the lowest structural sequence (Brook Range thrust sequence) which has been recognized as the site of all occurrences of both sedimentary exhalative zinc-lead deposits and barite deposits in the northwestern Brooks Range (Tailleur and others, 1977; Churkin and others, 1978; Mayfield and others, 1979). Churkin and others (1978) suggested that the rocks of the Brook's Range thrust sequence are from the Lower Mississippian and Upper Devonian Endicott Group into the Mississippian Lisburne Group. The Ginny Creek deposit is hosted predominantly by rocks near the top of the Noatak Sandstone and in some places by a limestone believed to be a tongue of the Utukok Formation (Dutro, 1952; Mayfield and others, 1979), which is interbedded between the underlying Noatak Sandstone and the overlying Kayah shale (Mayfield and others, 1979). Mineralization at Ginny Creek as described by Mayfield and others (1979) is dominantly sphalerite, galena, pyrite, and, locally chalcopyrite. They recognized mineralization over an area of 900 m by 600 m. Surface exposures are veneered with gossan and sandstones are iron-stained (Mayfield and others, 1979). Grab samples of float collected at Ginny Creek contain detectable levels of lead and 0.3 to 1 percent zinc. Surficial material is rich in siderite, which may occur with sulfide minerals but it is those minerals that weather to give the iron staining (Mayfield and others, 1979) that is typical of these deposits in the Brooks Range. The mineralized area has geochemically anomalous zinc and lead concentrations south of the deposit and anomalous zinc north of the deposit (Mayfield and others, 1979).

Tract Delination for Sedimentary exhalative Zinc-Lead

The primary criterion for tract delineation was the presence of permissible rocks, particularly the abundance of black shales. Other units were included if they are part of the same stratigraphic sequence known to host deposits of this type elsewhere in the Brooks Range (for example, the Lisburne Group). Most of the tracts only cover areas of Devonian rocks; only Upper Devonian Rocks (the Endicott Group) have been identified in known mineral deposits; however, Mississippian age rocks appear to be particularly favorable, especially those found in the Brooks Range thrust sequence. Ten tracts have been delineated.

Subjective Estimate of number of undiscovered Sedimentary Hosted Zinc-Lead

Participants in the mineral resource assessment estimate that there is a 90 percent chance of 1 or more undiscovered deposit, a 50 percent chance of 3 or more undiscovered deposits, and a 10 percent chance of 5 or more undiscovered deposits of this deposit type in the Wiseman quadrangle. Track rank in order of decreasing probability of containing undiscovered deposits are: SEDX-I, SEDX-IIa; SEDX-IIc and SEDX-IVa; SEDX-IIb and SEDX-IV(a,b); SEDX-VI; and SEDX-III.

Description of Tracts for Sedimentary Exhalative Zinc-Lead

Tract No.: SEDX-I

a) Geographic description: This is a large elongated tract extending from northwest of Wild Lake to near the northeast corner of the quadrangle (pl. 2).
b) Permissive rocks and structures: The rocks within this tract are basement rocks of the Doonerak Fenster, largely of black siltstone and phyllite, which exhibit low greenschist- and prehnite-pumpellyite-grade metamorphism. Also included are minor quartzitic graywacke; red, green, and purple phyllites;

green chert; and siliceous metatuff. Dolomite and thin limestone lenses are found locally. Numerous mafic sills are present but unmapped. All of these rocks are suspected to be Cambrian to Silurian. A small amount of probable Devonian calcareous phyllite and thin dark limestone are found along the southwest margin of the tract. Some andesitic to basaltic volcaniclastic rocks containing local tuffaceous phyllite, gabbro, and diabase are scattered throughout the tract.
Known mineralization: This tract contains no described mineral occurrences. An area of scattered copper mineralization is found along the southwest edge of the tract; a barite vein occurs near the northwest edge of the tract (pl. 3).
d) Geochemistry: All of the tract is located in geochemical subdivision V. Anomalous geochemical area 1 intersects the tract twice: one area in the center of the tract and a second between the Tinayguk River and the North Fork of the Koyukuk River. Copper, zinc, barium, gold, silver, arsenic, and molybdenum are anomalous; lead, cobalt, nickel, chrome, antimony, bismuth, mercury, tin and tungsten less so.

Anomalous geochemical area 2, will not be considered because it includes only a very small area within this tract.

Tract No.: SEDX-IIa

a) Geographic description: This large tract extends across the northern part of the quadrangle with a branch extending southwest from the Allen River to the John River (pl. 2).
b) Permissive rocks and structures: Black slate, phyllites, and minor fossiliferous limestone of the Upper Devonian Hunt Fork Shale make up most of the bedrock in this tract. The upper part locally contains lithic wacke and the basal part quartz-chert clastic rocks. Also included is a small quartz and chert pebble conglomerate along the southern boundary in the west-central part of the tract. The Kanayut Conglomerate and Noatuk Sandstone crop out in the northeast part of the tract. Skajit Limestone is locally present, particularly between Allen River and John River.
c) Known mineralization: The tract has only two described occurrences, both along the John River in the northwest part of the tract. Both occurrences are described as quartz veins with galena. Seven occurrences are present outside the tract along the southeast edge of leg of the tract between the Allen River and John River. (See tract SHB-I for a description and discussion of these occurrences.)
d) Geochemistry: About 90 percent of the tract lies within subdivision VI and 10 percent of the tract is in subdivision IV. Three geochemical anomalous areas are intersected by the tract in subdivision VI. None of the geochemical anomalous areas in subdivision IV intersect the tract. A summary of the geochemical anomalous areas applicable to this tract follows:
Subdivision No. VI

Anomalous geochemical area no. 1 is in the northwest corner of the tract.
Anomalous elements: lead, zinc, silver, bismuth, tin
Locally anomalous: copper, cobalt, chrome

Anomalous geochemical area no. 2 is mostly all within the tract.
Anomalous elements: lead, zinc, silver, arsenic
Locally anomalous: none identified

Anomalous geochemical area no. 3 is mostly all within the tract.
Anomalous elements: lead, gold, silver, bismuth, tungsten
Locally anomalous: zinc, antimony, mercury, molybdenum

Tract No.: SDEDX-IIb

a) Geographic description: Tract is separated into two parts and forms a long narrow strip running across the quadrangle from its east edge to its west edge across the Hammond and headwaters of the Glacier River, the junctions of Clear Creek and Tinayguk River with the North Fork of the Koyukuk River,south of Wild Lake and across the Allen and John Rivers (pl. 2).
b) Permissive rocks and structures: Tract is delineated based on the presence of the Hunt Fork Shale (see description in tract SEDX-IIa). Also included locally are quartz and chert pebble conglomerate, siliceous clastic rocks, chloritic and carbonate rocks and Skajit Limestone.
c) Known mineralization: Identified mineralized occurrences in the tract are near Wild Lake. The main occurrences are southeast of Wild Lake, along the border with tract CHB-III, where a general area of undescribed copper mineralization 3 km long contains three described sites. One occurrence is described as sphalerite and pyrite in a coarse grain dolomite layers hosted by marble. Although this is atypical, about 35 percent of the deposits of this type are hosted by carbonate rocks (see Geologic Setting). Abundant manganese (much less than 0.5 percent) may indicate that this occurrence forms part of a manganese halo, which can be present around this deposit type. The third occurrence is described as a quartz vein with bornite. Quartz veins are part of the feeder zone and this occurrence is compatible with the deposit type; the presence of bornite is atypical of the ideal model.

Disseminated chalcopyrite and tetrahedrite with anomalous silver, copper, and molybdenum occur in greenschist in an area of low grade copper and lead mineralization. A scoriaceous ferricrete occurrence, rich in iron, manganese, arsenic and copper and a poorly described copper occurrence and area of copper mineralization are indentified in the western part of the tract.

Basins with gold placers intersect parts of the tract. This includes most of the basin for Birch Creek and Agnes Creek and parts of the basins for Jay Creek, Lake Creek and Crevice Creek.
d) Geochemistry: About 90 percent of the tract is in subdivision IV and 10 percent of the tract is in subdivision III The tract includes part of geochemically anomalous area 5, subdivision IV, along the west side of Michigan Creek. Gold, silver, arsenic, antimony, and bismuth are anomalous; lead is less commonly so. Geochemically anomalous area 4, subdivision III, intersects the tract along both sides of the Allen River. Copper, lead, zinc, gold, silver, antimony and tungsten are anomalous; barium and cobalt are less commonly so.
f) Comments: See also section on bedded barite.

Tract No.: SEDX-IIc

a) Geographic description: This tract is broken into five parts. SEDX IIc(1) is about 40 km long and stretches from the west edge of the quadrangle across Mettenpherg Creek and Malamute Fork John River, almost to the John River. SEDX-IIc(2) includes a triangular area north of Timber Creek and east of the John River. SEDX-IIc(3), the largest runs from east of Michigan Creek to the Middle Fork of the Koyukuk River. SEDX-IIc(4) runs from Bedrock Creek to the west bank of the John River. SEDX-IIc(5) the smallest, includes a triangular area east of the Middle Fork of the Koyukuk River and that extends to the east edge of the quadrangle (pl. 2).

b) Permissive rocks and structures: This tract is delineated on the presence of the Hunt Fork Schist, which consists of Upper Devonian (?) black quartz schist and biotite-garnet-quartz schist and is probably a stratigraphic equivalent of the Hunt Fork Shale used to delineate other tracts of the SEDX-II series. Also present in small amounts quartz- and chert-pebble conglomerate; black slate, phyllite, and limestone; and Proterozoic or lower Paleozoic schist.
c) Known mineralization: No mineral occurrences are found within the tract. Only two occurrences adjacent to the tract have features that might be associated with this deposit type. One is adjacent to SEDX-IIc(1) and consists of chalcopyrite associated with a small gossan overles a chloritic quartz schist. The other occurrence is adjacent SEDX-IIc(3) and consists of chalcopyrite and chrysocolla in a quartz-gypsum vein in mica schist.
d) Geochemistry: All parts of the tract are found in subdivision II. SEDX-IIc(1) intersects geochemically anomalous area 7. Copper, arsenic, and tungsten are anomalous; zinc, lead, cobalt, and niobium are less commonly so. The middle of SEDX-IIc(3) intersects geochemically anomalous area 2. Copper, zinc, arsenic, antimony, molybdenum and tungsten are anomalous; barium, cobalt and tin are less commonly so.

Tract No.: SEDX-III

a) Geographic description: The small and crudely rectangular tract is near the north edge of the quadrangle between the Tinayguk River and John Rivers (pl. 2).
b) Permissive rocks and structures: The tract contains Carboniferous through Upper Triassic sedimentary rocks, the same map unit used to delineate tract CHB-I, which is described later. However, the mix of lithologies in CHB-I was dominated by those with carbonate rocks; in contrast to this tract where the mix is dominated by shale and silt. In addition, the amount of carbonate rocks present in and the small size of this tract probably insures that, if a carbonate-hosted deposit were found in the tract, it would not likely be consistent with the grade and tonnage model used to describe carbonate-hosted deposit of the type found in the CHB series of tracts. The rocks in this tract that contain significant shale include: (1) the Shublik and Otuk formations which consist of Middle and Upper Triassic black shale, siltstone and limestone; (2) the Siksikpuk formation which consists of Permian black, red, and green shales and siltstone as well as buff-colored calcareous siltstone; and (3) the Lower Mississippian Kayak Shale, which consists of black shales and minor limestone. Other rocks in this tract that contribute minor shale include the Mississippian and locally Pennsylvania Lisburne Group, which consists of grey cherty limestone with black chert and shale, and the lower Mississippian Kekiktuk Conglomerate.
c) Known mineralization: Two undescribed barite occurrences are found in the tract.
d) Geochemistry: The tract is totally within subdivision VI. The tract does not intersect any geochemically anomalous areas.
e) Comments: The tract is also permissive for bedded barite deposits (see section on that deposit type).

Tract No.: SEDX-IVa

a) Geographic description: The tract is centered near Crag Peak west of the John River. The tract has five legs; three extend to the west edge of the quadrangle, the other two extend northeast toward the Allen River (pl. 2).

b) Permissive rocks and structures: Delineation based on Middle to Upper Devonian or possibly older black slate, phyllite and limestone. About half of the rocks is made up of fine-grained black clastic rocks. Also present are partly calcareous, chloritic, and siliceous metasiltstone, sandstone, phyllites, and conglomerates and calcareous chloritic wacke.
c) Known mineralization: Three identified occurrences are generally located in the southeast part of the tract. One occurrence near the boundary with tract CHB-II, is hosted by Skajit Limestone and includes copper-sulfide minerals and malachite. A second described occurrence has azurite, malachite, and chalcocite in a vein hosted by metamorphosed sedimentary rocks including slate. Analysis of a sample from this occurrence gave high concentrations of copper and silver. Veins of this kind may be present as feeder zones for this deposit type. The third occurrence is described as containing copper. Basins with gold placers are not identified.
d) Geochemistry: A small area of the tract is in subdivision III and the rest of the tract is in subdivision IV. The tract is intersects, wholly or partly, several geochemically anomalous areas in both subdivisions. A summary of these areas follows:
Subdivision III
Anomalous geochemical area 3 intersects a small area in the southeast corner of the tract.
Anomalous elements: copper, lead, zinc, gold, silver, antimony, arsenic tungsten
Less commonly anomalous: barium, cobalt
Subdivision IV
Anomalous geochemical area intersects part of the northern leg of the three legs extend to the west edge of the quadrangle.
Anomalous elements: lead, zinc, silver, arsenic, bismuth, molybdenum
Less commonly anomalous: barium, nickel
Anomalous geochemical area 2 intersects parts of both the south and middle legs of the three legs that extend to the west edge of the quadrangle.
Anomalous elements: lead, zinc, silver, arsenic, bismuth, tungsten
Occasionally anomalous: copper, cobalt
Anomalous geochemical area 3 intersects parts of both legs that extend northeast toward the Allen River.
Anomalous elements: copper, zinc, silver
Less commonly anomalous: silver, bismuth
e) Comments: The tract is also permissive for bedded barite.

Tract No.: SEDX-IVb

a) Geographic description: The tract divided into three parts: SEDX-IVb(1) is elongated, extending southwest from the east border of the quadrangle to near the junction of the Tinayguk River and the North Fork of the Koyukuk River; SEDX-IVb(2) south of SEDX-IVb(1), is a small, elongated area extending from the east border of the quadrangle to the west side of Glacier River; SEDX-IVb(3), the largest part, as well as most irregular in shape, extends from the east border of the quadrangle across Glacier Creek nearly to the east bank of the North Fork of the Koyukuk River (pl. 2).
b) Permissive rocks and structures: SEDX-IVb(1) and SEDX-IVb(3) consist of rocks tentatively correlated with the Cambrian to Silurian black siltstone and phyllite unit in the Doonerak Fenster. About one-quarter of SEDX-IVb(1) includes the Hunt Fork Shale plus the black slate, phyllite and limestone unit used to delineate tract SEDX-IVa. SEDX-IVb(2) is similar. Small amounts of calcareous chloritic wacke are also included.

c) Known mineralization: Mineralized occurrences in this tract are predominantly in SEDX-IV(3) (pl. 2). One occurrence in western SEDX-IV(1), consists of galena in a quartz vein. The four occurrences and deposits in SEDX-IV(3) and immediately east consist of simple stibnite mineraliization in quartz veins with associated gold and silver. The sites are consistent with the descriptive model for the simple stibnite deposit type (see) and represent a style of mineralization not known to be affiliated with the sedimentary exhalative zinc-lead deposit type. One occurrence consists of copper and zinc sulfide stains in quartz-vein float.

Stream basins and areas with gold placers in the tract include nearly all of the basins for Nolan and Vermont Creeks. Basins or areas with gold placers partly in the tract include Hammond River, Washington Creek and Mascot Creek.

d) Geochemistry: The tract is wholly included in subdivision IV. Anomalous geochemical area 7, intersects SEDX-IVb(3) of the tract in an area west of Glacier River. Copper, lead, silver, arsenic and bismuth are anomalous. Anomalous geochemical area 6 intersects the eastern half of SEDX-IVb(3). Copper, lead, gold, silver, arsenic, antimony, bismuth, tin and tungsten are anomalous; cobalt, nickel and mercury are less commonly so.

e) Comments: Tract is permissive for bedded barite deposit type (see).

Tract No.: SEDX-V

a) Geographic description: This large tract crosses the southern part of the quadrangle from west to east, crossing Mettenperg Creek, John River, and North Forks and Middle Fork of the Koyukuk River, and Middle Fork Koyukuk River (pl. 2).

b) Permissive rocks and structures: The tract contains many map units; about half the area consists of metamorphosed shales. The units contributing significant amounts of metamorphosed shale are widely exposed Proterozic or Lower Paleozoic schist as well as black slate, phyllite, and limestone. Igneous rocks are generally more aboundant in the west part of the tract. The Ambler metavolcanic rocks also include interbedded black quartzite schist. Other rocks included in the tract are metabasite.

c) Known mineralization: Identified sites with known mineralization are few. Two sites occur within the tract and one is just to the west. One occurrence is in the central part and one is in the eastern part of the tract. Only one occurrence exhibits a depositional style (disseminated) and host (black schist) that are is potentially consistent with the main mineralized bodies for this deposit type. The barium concentration at one site is also a favorable indicator. Veins and stockworks are also present and may represent feeder zones. Generally, the minerals identified are not particularly consistent with those expected in the ideal model.

Stream basins are typically devoid of gold placers. Only in the extreme east end of the tract are gold placers currently recognized, including most of the basin of Clara Gulch and Porcupine Creek-Quartz Creek. Basins with gold placers partly in the tract, include Minnie Creek, Mytle Creek-Slate Creek, Twelve Mile Creek and the poorly documented placers of Bourbon Creek.

d) Geochemistry: The tract is wholly in subdivision II. The tract intersects, wholley or partly, six of the seven geochemically anomalous areas in this subdivision. A summary of these areas follows:

Subdivision II

Anomalous geochemical area 1 intersects several parts of the tract in the east.

Anomalous elements: copper, lead, zinc, gold, silver, arsenic, antimony, tungsten
Less commonly anomalous: barium, nickel, molybdenum
Anomalous geochemical area 2 intersects one part of the tract.
Anomalous elements: copper, zinc, arsenic, antimony, molybdenum, tungsten
Less commonly anomalous: barium, cobalt, tin
Anomalous geochemical area 3 is contained wholley within the tract.
Anomalous elements: copper, zinc, gold, silver
Less commonly anomalous: lead, arsenic
Anomalous geochemical area 4 intersects parts of two areas of the tract.
Anomalous elements: copper, lead, zinc, gold, tungsten
Less commonly anomalous: barium, cobalt, chromium, silver, gold, antimony
Anomalous geochemical area 5 is contained wholley within the tract.
Anomalous elements: lead, zinc, silver, arsenic, molybdenum, tungsten
less commonly anomalous: copper, cobalt
Anomalous geochemical area 6 intersects part of the tract.
Anomalous elements: copper, zinc, gold, silver, tin
Less commonly anomalous: lead, barium, cobalt, bismuth, antimony, tungsten

e) Comments: The tract is also permissible for bedded barite.

Tract No.: SEDX-VI

a) Geographic description: The tract consists of two parts: SEDX-VI(1) extends along both sides of the Malamute Fork of the Alatna River and eastward to a point between the Malamute Fork of the John River and John River. SEDX-VI(2) extends from a point on the east side of Timber Creek, as a long strip, crossing the Wild River, North Fork of the Koyukuk River and Middle Fork Koyukuk River to the east edge of the quadrangle (pl. 2).
b) Permissive rocks and structures: The tract is delineated on the presences of a Proterozoic to Paleozoic calcareous schist unit. Over half the rocks in the tract are believed to have been derived from black shale.
c) Known mineralization: No mineralized occurrences are currently recognized in this tract. One occurrence, just outside the southeast edge of SEDX-VI(1), consists of disseminated chalcopyrite and azurite hosted by a greenschist. SEDX-VI(2) intersects parts of stream basins or areas with gold placers. This includes Twelve Mile Creek and Myrtle and Slate Creeks.
d) Geochemistry: The tract parallels and includes parts of subdivisions II and subdivisions I. The tract intersects a small part of two geochemically anomalous areas in subdivision I. Geochemically anomalous area 5 intersects a bit of the south edge of SEDX-VI(1) and contains anomalous copper and zinc; barium is locally anomalous. Geochemically anomalous area 3 intersects a small area of SEDX-VI(2) and contains anomalous zinc, lead, barium, and silver; gold molybdenum and tungsten are less commonly anomalous.
e) Comments: The tract is also permissible for bedded barite.

Tract No. SEDX-VII

a) Geographic description: The tract consits of three parts along the north edge of the Wiseman quadrangle. Two tracts are imbedded in the central part: SEDX-III, and CHB-I. The tract is bound on the south by SEDX-IIa.
b) Permissive rocks and structures: The tract is delineated on the presence of the Upper Devonian and Lower Mississippian (?) Kanayut Conglomerate. In

this case, the Noatak sandstone has been included (Dillon and others, 1986). The Kanayut Conglomerate does not fit particularly well to the descriptive model for the deposit type. However, this unit has been identified with mineralization of possible this deposit type at Story Creek (see previously). Two occurrences in this unit north of the quadrangle in the Killik River quadrangle may be feeder veins which are found in this deposit type (Duttweiler, 1987).

c) Known mineralization: No described occurrences are identified in this tract. Barite occurrences are identified in the adjacent tract CHB-I.

d) Geochemistry: The tract is included in subdivision VI. The tract intersects small parts of two geochemically anomalous areas 1 and 2. Area 1 is anomalous for Zn, Ag, and Bi and less commonly for Cu, Pb, Co and W. Ares 2 is anomalous for Pb, Zn, Ag, As, and Bi and less commonly for Cu.

d) Comment: The tract is permissible for bedded barite (see).

SEDIMENT-HOSTED COPPER (30B)

Introduction

Sedimentary-hosted copper deposits are one of at least 16 deposit types found predominantly in clastic sediments (Cox and Singer, 1986). Sediment-hosted copper deposits are stratiform and disseminated copper-sulfide deposits found in red-bed sequences (Cox, 1986c). Copper is the primary commodity; byproduct includes silver and cobalt (Mosier and others, 1986).

Geologic Setting

The following summary of the geologic setting for sediment-hosted copper deposits is taken from Cox (1986c) unless otherwise noted. This deposit type usually occurs in green or gray shales, siltstones, and sandstones of red-bed sequences. Thin carbonate and evaporite beds may be present and thinly laminated silty dolomite are locally present. Sedimentary rocks are usually highly permeable and may contain algal-mat structures, mudcracks, and crossbedding. Sabkhas may be present. Deposits seem to develop in basins on platforms (Smirnov and others, 1983), intracontinental rifts, and passive continental margins that were near a paleoequator at the time of formation. Deposits are either Middle Proterozoic or Permian to Lower Mesozoic. Associated deposits are typically evaporites--halite, sylvanite, gypsum, and anhydrite. Other deposit types include sandstone uranium, basalt copper, and Kipushi copper-lead-zinc.

Deposit properties

The following summary of deposit properties is taken from Cox (1986c) unless noted otherwise. Deposits of this type may be finely disseminated, stratabound, or stratiform. Deposits are thought to form at the interface between oxidized and reduced sediments where such items as fossil wood, algal mats, pyritic sediments and abundant biogenic sulfur may play a controlling role.

Ore minerals include chalcocite (as well as other copper sulfide minerals) and pyrite; other minerals that may be present include bornite and native silver all of which in some deposits form a core ore zone surrounded by chalcopyrite, which in turn is surround by galena and sphalerite. Copper minerals commonly form clusters around carbonate fragments. A few deposits of this type may contain cobalt-bearing pyrite, carrollite ($Cu(Co,Ni)_2S_4$), and germanium minerals.

Alteration is usually is green, white or grey whereas unaltered beds are red or purple, if the area is regionally metamorphosed like parts of the Wiseman quadrangle. Deposits exposed to weathering may be totally leached; secondary chalcocite may be present at depth.

Grade and Tonnage Model

The grade and tonnage model for sediment-hosted copper deposits was developed from 57 deposits (Mosier and others, 1986). In some cases, these deposits are likely to be districts (Russia); in other cases, deposit sizes are approximate due to inadequate reporting or unknown extent of mineralization between mines (Zambia, Zaire). No significant correlation exists between grades and tonnage. Slightly more than 20 percent of the 57 deposits used for the grade and tonnage model have reported silver grades; slightly less than 20 percent reported cobalt grades. Ore deposit grades and tonnage are summarized in table 7 (Mosier and others, 1986).

Table 7. Estimate of percentage of sediment-hosted copper deposits which equal or exceed a given grade or tonnage. Floor values are approximate lowest value given for each variable in the grade and tonnage model (Mosier and others, 1986). [--, grade not available, not reported.]

Variable		Percentage		
	Floor	90	50	10
Tonnes (10^6)	.1	1.5	22.	330.
Copper (percent)	.56	1.0	2.1	4.5
Siver (g/tonne)	1.0	---	---	23.
Cobalt (percent)	0.16	---	---	0.24

Identified sediment-hosted copper deposits in the Brooks Range

No deposit of this type is current recognized in the Brooks Range.

Tract delineation for sediment-hosted copper deposit

Two primary tracts are delineated as permissive for this deposit types (pl. 2).

Subjective Estimate of Number of Undiscovered Deposits for Sediment-hosted copper

Participants in the mineral resource assessment estimated that there is a 50 percent chance of 2 or more undiscovered deposits, and a 10 percent chance of 4 or more undiscovered deposits of this deposit type in the quadrangle. Both tracts are equally likely of containing undiscovered deposits.

Description of tracts for sediment-hosted copper deposits

Tract No.: SHB-I

a) Geographic description: This is a horse-shoe shaped tract with the a broad central area and two long tappered prongs running along the northwest and southeast edges of the Doonerak Fenster (pl. 2).
b) Permissive rocks and structures: The dominant rock units in this tract consists of nearly equal parts of: (1) chloritic clastic rocks; (2) sandstones, conglomerates and quartzite; and (3) shale and siltstone of

possibly Middle Devonian age. Other units are much less extensive but may be locally important. This includes black shales and siltstones and calcareous Skajit Limestone which overlies the shales and siltstones.

c) Known mineralization: This tract contains the largest number of reported occurrences of sulfide minerals, primarily copper-sulfide minerals, in the Wiseman quadrangle. Most of the occurrences are found in two areas--along the west margin of the tract and in the eastern quarter of the tract (pls. 2).

The largest exposed bedrock occurrence of sulfide mineralization in the quadrangle occurs along the west margin of the tract where stratiform copper sulfide minerals intermittently crop out along strike for about 25 km. The stratiform sulfide bodies occur in a mineralized horizon which can be as thick as 1.5 m and usually are continuous for 6 or 10 m. Mineralization appears to have been controlled by a change in rock permeablility. Descriptions of the mineralized horizon commonly identify the host as being a clastic sedimentary rock with various grades of metamorphism. On only one location is the host described as a carbonate, one with reefoid features. At all other occurrences mineralization is described as below the carbonate or does not specify a carbonate association. The horizon lies stratigraphically below the Skajit Limestone. In four places the mineralized clastic rocks are in placers separated from the carbonate rocks by a thrust fault. At one site, mineralization occurs in a facies change from clastics to carbonates. The hosting rock has also been described at two sites each as conglomerate; calcareous schist; and a metasandstone, metasiltstone, and chloritic schist. Two locations also have copper mineralization in quartz veins. Copper sulfide minerals are common and include four sites with bornite, two with cuprite, two with covellite, and two with chalcopyrite. Malachite is common and associated with almost all occurrences as compared to azurite, which has been reported only at one location. Four sites have unspecified copper sulfide minerals. Other sulfides are not commonly reported. Galena has been reported near the northern end of the horizon at two sites and at one location at the southern end of the horizon. Sphalerite has been reported at three locations in the northern end. At one site, sphalerite is associated with abundant hematite. A crude zonation is suggested by this incomplete data set. Copper sulfide minerals clearly are dominant at seven locations in the central section of the horizon. In the northern section, copper is joined by lead and zinc and by just zinc only at the extreme north end of the horizon. At one location in the southern part of the horizon, copper is also joined by lead. This pattern is consistent with zoning in the sediment-host copper deposit type.

Chemical analysis of various samples collected along the horizon usually show between 0.5 and 2 percent copper. The median value is about 0.15 percent copper. This is less than the floor value for copper grade present in the grade and tonnage model for sediment-host copper deposits (table 7). Molybdenum was found at concentrations between 10 and 100 ppm in samples from three sites. These higher concentrations tend to be at either the north end or south end of the mineralized horizon. Several other elements were detected in significant amounts (Dillon and others, 1981b), including arsenic, boron, bismuth,iron, antimony, tin, tungsten, and vanadium and are described at the individual sites. Antimony at greater than 100 ppm was found at the north end of the horizon and may be related to the zoning noted previously. Silver, which is produced from about 20 percent of the sediment-hosted copper deposits used in construction of the grade and tonnage model, was detected at only one site and at a concentration of 10 ppm. This tract is not in a geochemically anomalous area (see next section). Lack of geochemical anomalies may be due to high pH values of surface water because of the presence of the Skajit Limestone, about the mineralized horizon. Pyrite is also absent in the mineralized horizon which typically creates acid conditions that increase geochemical mobility of metals. No gold placers are present downstream from the mineralized horizon.

Other copper-mineralized areas that have a stratigraphic and structural setting similar to that along the tract's western boundary include two undescribed areas along the southern boundary southwest of Wild Lake. Here the Skajit Limestone lies above the unit hosting the mineralization. Two described occurrences are also found in this part of the tract. One is described as a copper-sulfide-bearing quartz vein in dolomite; a grab sample yielded 0.21 percent copper. The other location is copper-sulfide minerals hosted by phyllite and siltstone. No gold placers occur downstream from the mineralized areas nor are they part of a geochemical anomalous area (see geochemistry section which follows).

Six other mineral occurrences within the tract are predominantly east of and adjacent to Wild Lake (pl. 2). Two sites have copper mineralization in schist. One site, which contains 1 percent copper, also contains antimony (1.0 percent), zinc (0.1 percent), and silver (31 ppm). Four other sites have sulfide minerals in quartz veins. Two quartz veins are spatially associated with the stratiform copper horizon along the west boundary of the tract and may be associated with stratiform copper mineralization elsewhere in the tract. Quartz veins may contain bornite, tetrahedrite, or galena and are enriched in copper (0.24-0.27 percent), silver (3.1-13 ppm), and gold (0.4-6.5 ppm). One site contain 68 ppm lead. An undescribed area with copper occurrences is east of Wild Lake; two sites described as copper-bearing are also present. Gold placering takes place in or adjacent to most of these occurrences. These include the Lake Creek, Spring Creek, Sirr Creek, and Surprise Creek Placers. Occurrences east of Wild Lake are included in a geochemically anomalous area (see next section).

An area of undescribed copper occurrences is found along and crossing the northeast tract boundary in the central part of Sirr Mountains. The occurrences parallel a fault zone where siliceous clastic rocks are thrust over black calcareous phyllites and thin dark limestone, which are not included in the tract.

d) <u>Geochemistry</u>: About 75 percent of the tract is located in subdivision IV. About 20 percent in subdivision III, and the remaining 5 percent in subdivision VI. Two geochemically anomalous area are present, one in subdivision IV and one is subdivision VI.

Anomalous geochemistry area 4, subdivision IV, lies wholly within this tract and includes an area east of Wild Lake. Gold. silver, arsenic, antimony, and bismuth are anomalous; lead is less commonly so.

A very small part of the tract intersects anomalous geochemical area 3, subdivision VI. Lead, zinc, silver, arsenic and bismuth are anomalous.

e) <u>Comments</u>: The lithologies in the tract do not strongly conform to the types identified in the ideal deposit description for sediment-hosted copper. However, the type and style of mineralization observed in the tract suggest that assignment to this deposit type is appropriate.

<u>Tract No.:</u> SHB-II

a) <u>Geographic description</u>: The long tract trends from east to west almost

completely across the quadrangle, expanding to a broad area in the east.
b) Permissive rocks and structures: The dominant sedimentary rock units in this tract are: Upper or Middle Devonian green and gray phyllite and dolomite; chloritic, calcareous metasandstone and marble and carbonate-clast conglomerate. Also present are Devonian (and possibly older) marble, dolomite, and conglomerate with minor quartz, and graphitic and calcareous schist of the Skajit Limestone.
c) Known mineralization: Of the six mineral occurrences in and adjacent to this tract, three may possibly be of the type associated with or indicative of sediment-hosted copper. Two occurrences east of the John River, involve copper-sulfide mineralization of chlorite or quartz schist. A sample from one of these occurrences contains malachite, azurite, chalcopyrite, and sphalerite and yielded 0.5 percent copper, 200 ppm nickel, and 320 ppm zinc. A sample of chalcopyrite and malachite material from another site yielded 300 ppm cobalt, 0.2 percent copper, 200m ppm lead, 0.1 percent vanadium, and 320 ppm zirconium. Sediment-hosted copper deposits may produce cobalt (table 7); zinc, lead, and vanadium can also be considered to be favorable geochemical indicators (Cox, 1986). An undescribed lead occurrence and gold placers are found in the same stream basin. These occurrences are also part of a geochemically anomalous area (see next section).

Malachite, azurite, galena, and possible bornite occur in a quartz-vein stockwork in dolomite adjacent to green schist west of the Malamute Fork of the John River. One sample yielded 0.15 percent copper, 0.1 percent antimony, and 500 ppm zinc. Mineralogy and geochemistry suggest that the occurrence has some features similar to the outer zone of a sediment hosted copper deposit, ignoring the depositional style. No gold placers or geochemical anomalous areas are associated with this occurrence.
d) Geochemistry: About 60 percent of the tract is located in subdivision IV. The remaining 40 percent of the tract is located in subdivision III.

Anomalous geochemical area 4, subdivision III, crosses the tract from north to south as a strip about 6 km wide on the east side of the John River. Copper, lead, zinc, gold, silver, antimony, arsenic, and bismuth are anomalous; cobalt, tin and tungsten less so. The presence of anomalous copper, silver, lead, zinc, and cobalt are favorable geochemical indicators for this deposit type (Cox, 1986c). Antimony may be an important local geochemical indicator for mineralization associated with the outer zones of sediment-hosted copper deposits.

Anomalous geochemical area 5, subdivision III, is wholly contained in this tract in an small area between the John and Wild Rivers. Copper, lead, arsenic and tungsten are anomalous; cobalt and tin less so. Copper, lead and cobalt are favorable geochemical indicators for sediment-hosted copper (Cox, 1986c).

Anomalous geochemical area 6, subdivision III, wholly contained in this tract in a small area east of the Wild River. Gold, silver, and bismuth are anomalous; lead less so. Silver and lead are favorable geochemical indicators for this deposit type (Cox, 1986c).

Anomalous geochemical area 5, subdivision IV, is almost completely contained in this tract and is located along both sides of upper Michigan Creek. Lead, gold, silver, bismuth and tungsten are anomalous; zinc and arsenic less so. Lead, silver and zinc are favorable geochemical signals for this deposit type (Cox, 1986c).
e) Comments: The tract lacks the number of mineralized occurrences found in the tract SHB-I, but several of the mineral occurrences are encouraging. Also, it is large and has several geochemically anomalous areas. In both this

and the highly mineralized tract SHB-I, the host rocks do not fit the idea model very well.

CARBONATE-HOSTED BASE-METAL DEPOSITS (lead (zinc)) (32A, 32B)

Introduction

Carbonate-hosted base-metal deposits are addressed in Cox and Singer (1986) using two descriptive models (Southeast Missouri lead-zinc (32a), and Appalachian zinc (32b)), which are considered as end members of a continuum of carbonate-hosted stratabound deposits with variable grades of lead and (or) zinc (Mosier and Briskey, 1986). Southeast Missouri lead-zinc deposits and Appalachian zinc deposits are two of at least six recognized deposit-types hosted by carbonate rocks which do not have an associated igneous rocks nearby (Cox and Singer, 1986). Southeast Missouri lead-zinc deposits are stratabound, replacement, and open-space filling bodies of galena, shalerite, and chalcopyrite in carbonate rocks (Briskey, 1986c). Lead and zinc are the primary commodities and silver is a byproduct (Mosier and Briskey, 1986). Appalachian zinc deposits are stratabound, replacement and open-space filling bodies of sphalerite with minor galena in carbonate rocks (Briskey, 1986a). Zinc is the primary commodity with silver and lead are common byproducts. Because the two descriptive models have combined grade and tonnage model (Mosier and Briskey, 1986), tracts delineated for the Wiseman quadrangle are consistent with either descriptive models.

Geologic Setting

The Southeast Missouri lead-zinc deposit occurs in carbonate rocks associated with reefs in shallow-water adjacent to paleogeographic highs (Briskey, 1968c). Clastic basin rocks may occur along one margin of the deposits. The hosting rocks are usually dolomite but may also include sandstone, conglomerate and calcareous shales (Briskey, 1986c).

Appalachian zinc deposits occur in limestones, which commonly are micritic and in dolostones, which commonly are highly porous and exhibit subtidal, intratidal, and supratidal textures (Briskey, 1986a). For both deposit types, thick stratigraphic sections of carbonate rocks seem to be more favorable (Smirnov and others, 1983). Deposits of these types are quite widespread, and the "only sure lead" to discovery are their carbonate host-rock (Laznicka, 1985). Briskey (1986a,c) identified stable cratonic platforms as the favorable tectonic setting for the Southeast Missouri lead-zinc deposit-type and the stable continential shelf as the favorable tectonic setting for the Appalachian zinc deposit type. Although Laznicka (1985) suggested that orogenic areas are also favorable for the Appalachian deposit type, this may be due to his inclusion of a different set of deposits for this deposit type.

Southeast Missouri lead-zinc deposits tend to be hosted by calcarenites; features that may be present include tidalites, stromatolites, finger reefs, reef breccias, slump breccia, oolites, cross bedding, and micrites (Briskey, 1986c). The deposit-type has been found in Cambrian to Lower Ordovician rocks. The Appalachian zinc deposit type appears to be common in the same time interval but can also be found from the Proterozoic to the Triassic (Briskey, 1986a,c). Deposits associated with the southeast Missouri deposit-type include Precambrian volcanic-hosted magnetite and Cambrian age barite-lead deposits (Briskey, 1986c); those associated with the Appalachian deposit type include stratiform barite-fluorite-sphalerite deposits hosted by carbonate rocks (Briskey, 1986a).

Deposit Properties

Both deposit types assume many forms based on the wide range and types of depositional sites that are suitable. Deposits are crudely stratiform and lenticular and may extend "from hundreds of meters to a few kilometers" along strike and "up to 800 - 1,000 meters along dip" (Smirnov and others, 1983). Deposits may occur either as open-space fillings (partly dependent on porosity) and (or) as replacements (partly dependent on host reactivity). Deposits and districts exhibit a variety of local features; the only two that are persistent and well developed for all areas are dolomitization presumably associated with mineralization, and brecciation resulting from solution collapse (Laznicka, 1985).

Ore minerals commonly found in Southeast Missouri lead-zinc deposit include galena, sphalerite, chalcopyrite, pyrite, and marcasite; minor minerals include siegenite, bornite, tennantite, barite, bravoite, digenite, covellite, and arsenopyrite, among others (Briskey, 1968c). Deposits more like the Appalachian zinc deposit type have many fewer ore minerals. Sphalerite is dominant with lesser amounts of pyrite, marcasite, and local galena (Briskey, 1986a). Gangue minerals can include minor barite, fluorite, gypsum, and anhydrite (Briskey, 1986a).

Grade and Tonnage Model

The grade and tonnage model for carbonate-hosted base metal deposits is based on one developed by Mosier and Briskey (1986). Participants in the mineral resource assessment used a tonnage cutoff of 500,000 tonnes for undiscovered deposits of this type in the Wiseman quadrangle. This is less than the million tonnes used as the cutoff in Mosier and Briskey (1986) model. In addition, Mosier and Briskey (1986) excluded small districts from the grade and tonnage model, these are more likely the type of district that can be expected in the Wiseman quadrangle. Many of the deposits in the grade and tonnage model used by Mosier and Briskey (1986) represent districts (i.e. Central Missouri, Kentucky-Illinois, Central Tennessee), each is substantially larger than the total area of the Wiseman quadrangle of which less than half the area can be considered permissible for this deposit type (pl. 2). It is unlikely that a large district can exist in the quadrangle without having been discovered already. Therefore, the model was modified using data from 42 deposits in order to be more appropriate for this assessment. In the modified grade and tonnage model, silver is inversely correlated with tonnage ($r = -0.64$, $n = 15$). The modified model has smaller tonnages but slightly higher zinc, lead, and silver grades (table 8). Just under 90 percent of the deposits have reported lead grades, contrast to about 80 percent of the deposits in the Mosier and Briskey (1986) model. Silver is less frequently reported in the deposits used in the modified model, down from 50 percent to 40 percent. Other infrequently reported commodities in these deposits include copper, gold, cadium, and vanadium. Nonmetallic minerals which may be recovered include barite, witherite, and fluorite.

Table 8. Estimate of percentage of 42 carbonate hosted base metal desposits (includes both Southeast Missouri lead-zinc, Appalachian zinc deposits) equal or exceed a given grade and tonnage (Mosier and Briskey, 1986). Tonnage modified to conform to procedures and assumptions used in this assessment (see text). Floor values are approximate lowest value given for each variable in the grade and tonnage model; tonnage value set by definition. [--, grade not reported, unavailable.]

Variable	Percentage			
	Floor	90	50	10
Tonnes (10^6)	0.5	2.4	16.	120.
Zinc (percent)	1.0	2.4	5.7	12.
Lead (percent)	0.08	---	1.5	5.8
Ag (g/tonne)	0.4	---	---	25.

Identified carbonate-hosted base-metal deposits in the Brooks Range

To the best of our knowledge, no deposit of this type is currently recognized in the Brooks Range.

Tract delination for carbonate-hosted base metal deposits

The primary criterion used for tract delineation was the presence of significant amounts of carbonate rocks. Four tracts were delineated.

Subjective estimate of undiscovered carbonate-hosted base-metal deposits

Participants in the mineral resource assessment estimate that there is a 50 percent chance of one or more undiscovered deposits and a 10 percent chance of three or more undiscovered carbonate-hosted base-metal deposits in the Wiseman quadrangle. Tract ranks in order of decreasing probability of containing undiscovered deposits are: CHB-IV, CHB-II, CHB-III, and CHB-I.

Description of tracts for carbonate-hosted base-metal deposits

Tract No.: CHB-I

a) Geographic description: The crudely rectangular tract is along the northern boundary of the quadrangle, on both the north and south sides of the upper end of the Tinayguk River (pl. 2).
b) Permissive rocks and structures: Limestone comprises about three fourths of the rocks in this tract. Most of these limestones are part of the Lisburne Group which also may include chert and shale. The map unit used for delineation, Carboniferous to Upper Triassic sedimentary rocks, also includes varying amounts of limestone and dolomite. These include: the Shublik and Otuk formations with black shale, siltstone, and limestone; the Kayuk Shale with black shale and minor amounts of limestone; and the Siksikpuk formation, a unit of black, red, and green shales and siltstone.
c) Known mineralization: There are no identified mineralized occurrences in the tract.
d) Geochemistry: The tract is wholly included in subdivision IV. No geochemically anomalous areas include this tract.
e) Comments: The mix of rock types in this tract is also permissible for hosting sedimentary-hosted, exhalative zinc-lead deposits. Some mapped units

in this tract host deposits of this type elsewhere in the Brooks Range. Bedded barite deposits, associated with this deposit type, may be present as well.

Tract No.: CHB-II

a) Geographic description: This small, irregularly-shaped tract is in the northwest quadrant of the quadrangle between the Allen and the John Rivers (pl. 2).
b) Permissive rocks and structures: The tract is delineated based on the presence of the Skajit Limestone, which consists of Devonian and possibly older marble, dolomite, and carbonate conglomerate interbedded with minor amounts of quatzite and graphitic and calcareous schist. Also included in the tract is a small amount of black calcareous phyllite, chloritic and carbonaceous rocks and metabasite.
c) Known mineralization: There are no identified mineralized occurrences in the tract.
d) Geochemistry: The tract is totally within subdivision IV. Copper, zinc and silver are anomalous (predominantly in panned concentrates); arsenic and bismuth less commonly so (panned concentrates) (Cathrall and others, 1987, table 6). Copper, zinc and silver are part of the regional geochemical signature for the Southeast Missouri lead-zinc deposit type; zinc is also applicable as well to Appalachian zinc deposit type (Briskey, 1986a,c).

Tract No.: CHB-III

a) Geographic description: This large, irregularly-shaped tract extends from an area along and northeast of Sixtymile Creek, and crosses both the John and Allen Rivers, to a point south of Wild Lake (pl. 2).
b) Permissive rocks and structures: The tract is delineated on the presence of the Skajit Limestone (see description for tract CHB-II). Also included in this tract are a small amount of metabasite, particularly south of Wild Lake; quartz and chert pebble conglomerate, which is copper bearing, especially along the northeast edge of the tract; and Hunt Fork Shale.
c) Known mineralization: Only one mineralized occurrence is reported within the tract. Seven are found on the edges (usually just outside the tract); this is particularly true for a general area of copper mineralization along the northeast border and usually in tract SHB-I (Plate 2) Most of these occurrences are in clastic sedimentary rocks stratigraphically below the Skajit Limestone. The contact between the host rock and Skajit Limestone can be intrepreted as either a thrust fault or a facies change. One site, however, is an exception, with mineralization in reefoid Skajit Limestone above the contact. One of three occurrences in a copper mineralized area south of Wild Lake was described as replacement layers and veins bearing sphalerite and pyrite in coarse grain dolomite in marble. A sample collected from the site is enriched in lead, zinc, manganese and magnesium. One occurrence found just northwest of the tract includes sulfides and malachite in the Skajit Limestone. Within the same area, but along the northwest tract boundary, is a mineralized occurrence with azurite, malachite, and chalcocite veins in clastic sediments below marble. A sample collected here is enriched in lead, copper and silver. The occurrence in the west- central part of the tract contains 1 percent disseminated arsenopyrite or galena with chalcopyrite and pyrite. Analysis of a sample gave high levels of lead, nickel, chromium

and arsenic. An area of undescribed copper mineralization occurs along the west border of the tract.

d) Geochemistry: The tract is largely in subdivision III, a small segment of the eastern part of the tract is in subdivision IV. Anomalous geochemical area 3, subdivision III, includes the northwest part of the tract between Sixtymile Creek and John River. Copper, lead, zinc, gold, silver, antimony, arsenic and tungsten, are anomalous; barium and cobalt less commonly so. Anomalous geochemical area 4, subdivision III, includes areas along both sides of the Allen River. Copper, lead, silver, gold, antimony, arsenic, and bismuth are anomalous; cobalt, tin and tungsten less commonly so. No geochemically anomalous areas as are present in as the tract located in subdivision IV.

f) Comments: Although mineralization is rare in the interior of the tract, mineralization extending into the base of the Skajit Limestone at the tract boundaries, and the presence of dolomite associated with stratiform sulfide minerals, suggest the style of mineralization appropriate for the deposit type.

Tract No.: CHB-IV

a) Geographic description: The large, irregularly-shaped tract extends generally from Sixtymile Creek, across Mettenpherg Creek, to the west edge of the quadrangle (pl. 2).

b) Permissive rocks and structures: The tract is delineated on the presence of the Skajit Limestone and Proterozoic banded schist, which includes interlayered coarse quartz-mica schist, quartzite, calcareous schist, marble, graphitic phyllite, and metabasite. The joint occurrence of the two units distinguishes this tract from tract CHB-III. About three-fourths of the rocks in the tract are calcareous. Several small outcrops of Proterozoic (?) granitic gneiss are also included in the tract. Larger outcrop of gneiss embedded in this tract have been excluded. Also included in the tract are small amounts of Proterozoic(?) metabasite, and Ambler metavolcanic rocks.

c) Known mineralization: Nearly all mineralized occurrences in this tract are associated with the banded-schist, not the Skajit Limestone. Of the thirteen occurrences described only one occurrence explicitly identifies carbonate as a host. Two occurrences appear to be a skarn, another a tactite; five are hosted by schist, four by granitic-related rocks, and one by quartzite. Three occurrences appear to be sites of tin mineralization. Some sites contain minerals appropriate for carbonate-hosted deposits: two with chalcopyrite, one with bornite, three with sphalerite, three with galena, one with arsenopyrite and two with pyrite. These minerals tend to be disseminated at five localities, at lithological changes at one and lenticular at one. In only one occurrence is the mineralization describe as massive and hosted by a quartzite layer that is interbedded with marble. Several areas of undescribed mineralizations are present including an iron-copper mineralized zone which appears to be predominantly hosted by the Skajit Limestone along the north edge of the tract. Three other mineralized areas are in the north-central part of the tract, usually in the banded-schist. The Skajit Limestone is also a host to lead-silver mineralization. One other site contains lead,silver, and copper.

d) Geochemistry: The tract is included wholly in subdivision III and includes large parts of two geochemically anomalous areas and a small part of a third. Anomalous geochemical area 1, is found in the northwest part of the tract. Lead, zinc, silver, arsenic, bismuth, tin and tungsten are anomalous in stream-sediment samples; copper, barium, and cobalt are less commonly so. Anomalous geochemical area 2 is found in the southeast part of the tract. Lead, gold, silver, antimony, arsenic, tungsten and tin are anomalous in stream-sediment samples; copper, zinc, and bismuth are less commonly so. Anomalous geochemical area is found in a small leg of the tract extending to the northeast. Copper, lead, zinc, gold, silver, antimony, arsenic, and tungsten are anomalous in stream-sediment samples; barium and cobalt are less commonly so.

e) Comments: Only one of the thirteen mineralized occurrences suggests the style of mineralization (massive, and adjacent to carbonate rocks) for carbonate-hosted base-metal deposit-types. The broad area of iron mineralization in the Skajit Limestone along the north edge of the tract might be interpreted as iron-sulfide mineralization found up section from Southeast Missouri lead-zinc deposit types (Briskey, 1986c). Occurrences in the banded schist are not totally consistent in deposition style, mineralogy or geochemistry with those expected in these deposit types. The lack of reported brecciation at any of the occurrences is discouraging. Geochemistry of stream-sediment samples is best matched for anomalous area 1 where lead, zinc, silver and cobalt are anomalous.

BEDDED BARITE DEPOSITS (31B)

Intoduction

Bedded barite deposits are one of at least 16 deposit types found predominantly in clastic sedimentary rocks as are described in Cox and Singer (1986). Bedded barite deposits consist of stratiform barite hosted by dark-colored chert and calcareous rocks (Orris, 1986a). Barite is the primary commodity; no byproduct is identified (Orris, 1986b).

Geologic Setting

Bedded barite deposits are thought to form near the sea floor where barium is supplied by hydrothermal fluids and sulfate is supplied by sea water (Harben and Bates, 1984). Most of these deposits occur in the same geologic setting as sedimentary exhalaltive zinc-lead deposits. Bedded barite deposits associated with Japanese Kuroko deposits (Harben and Bates, 1984) seem too small to be included with those used to construct the grade and tonnage model (G.J. Orris, oral commun., 1986; Orris, 1986b). Bedded barite occurs with about 25 percent of sedimentary exhalative zinc-lead deposits (G.J. Orris, personal commun., 1986). Such bedded barite deposits generally are either laterally peripheral to or capping the base metal ore body (Briskey, 1986b).

Deposit Properties

Bedded barite deposits are stratiform and may be as thick as 15 m (Harben and Bates, 1984). Ore can be massive, laminated, or lenticular and may exhibit a variety of primary sedimentary structures (Orris, 1986a). Associated barite rosettes and nodules can be associated and may be found in weathered outcrops of deposits. Some replacement is reflected by small country-rock inclusions (Orris, 1986a). Sericitic alteration may be weakly to moderately developed (particularly evident in Nevadan deposits); secondary barite veining may be present also (Orris, 1986a).

Barite is the principal ore mineral; witherite, pyrite, galena, and sphalerite may occur locally (Orris, 1986a). Barium is the best geochemical exploration guide. Those geochemical guides associated with sedimentary exhalative zinc-lead deposits are useful when searching for joint occurrences.

Grade and Tonnage Model

The grade and tonnage model for the bedded barite deposit type was developed from 25 deposits, which occur both with and without sedimentary exhalative zinc-lead deposits (Orris, 1986b). Grade and tonnage of bedded barite deposits associated with sedimentary exhalative zinc-lead deposits are indistinguishable from bedded barite deposits not associated with them (G.J. Orris, oral commun., 1986). No significant correlation is present between barite grade and tonnage summarized in table 9 from (Orris, 1986b)

Table 9. Estimate of percentage of bedded barite deposits which equal or exceed a given grade or tonnage (Orris, 1986b). Floor values are approximately lowest values given for each variable in the grade and tonnage model (Orris, 1986b).

Variable		Percentage		
	Floor	90	50	10
Tonnes (10^6)	.025	0.12	1.8	28.
Barite (percent)	50.	64.	88.	96.

Bedded barite deposit in the Brooks Range

Bedded barite is recognized in the Brooks Range, either as isolated stratiform deposits or associated with sedimentary exhalative zinc-lead deposits. Significant amounts of barite are reported at the sedimentary exhalative zinc-lead Red Dog deposit; barite lenses thicker than 46 m cap the base-metal ore. Barite reoccurs throughout the section above the deposit (McMichael and others, 1984). Other zinc-lead deposits have associated barite, but it is unclear whether the barite is economic. Barite has been reported at Lik[1] (Pratt, 1984) and Drenchwater Creek (Lange and others, 1985) in the western Brooks Range. Lenses and pods of bedded barite, as much as 10 m thick cropping out for 1,600 m, are hosted by Mississippian(?) dolomite at Lik (Bundtzen and Henning, 1978).

Two possible bedded barite deposits have been identified in the central and eastern Brooks Range. Massive barite lenses, beds and nodules, some as much as 6 m thick and 30 m, long have been found northwest of the Sheenjak River in the Coleen quadrangle (Bundtzen and Henning, 1978; Brosgė and Reiser, 1969). The host rocks include chert, shale, and intrusive rocks and may be equivalent to rocks in the Angayucham terrane in the Wiseman quadrangle. Barite nodules and layers have been reported in the Siksikpuk Formation in Atigun Canyon, Phillip Smith Mountains quadrangle, which is adjacent to the pipeline corridor in the central Brooks Range. The barite is hosted by sideritic shale of the Permian and Lower Traissic Sadlerochit Group (Bundtzen and Henning, 1978; Paris, 1977; Menzie and others, 1985). Rocks belonging to this group crop out in the northern edge of the Wiseman quadrangle. Menzie and others, (1985) described the barite outcrop as a zone 5 m thick containing an estimated 10 to 15 percent barite. They report the host rock as sediments.

1. The deposit at Lik was initially called Wulik in the older literature.

The Nimiuktuk barite deposit was found in the Misheguk quadrangle in 1978 (Mayfield and others, 1979). At the surface is a 40 m by 60 m area covered with barite cobbles and boulders (Mayfield and others, 1979). Barnes and othes (1982) used gravity measurements to estimate that the deposit contains 1.5 million tonnes of "high-grade ore." The specific gravity of seven barite ore samples varied from 4.36 to 4.40, average was 4.37 (Barnes and others, 1982). The deposit is believed to be in the lowest of the five to seven thrust sequences which make up the western Brooks Range (Tailleur and Brosgè, 1970; Ellersiech and others, 1979). There are no bedrock exposures are at some distance from the deposit. Upper Mississippian balck chert and shale and lower Cretaceous shale and wacke are 500 m northeast of the deposit and Upper Mississippian volcanics and Lower Mississippian sandy limestone are 600 m southwest of the deposit (Mayfield and others, 1979).

Tract Delineation for Bedded Barite

Tracts delineated for sedimentary exhalative zinc-lead deposits (Tracts SEDX-I to SEDX-VI) and mixed sedimentary deposit types (M-1 to M-2) are permissible for bedded barite deposits. The primary criterion used to delineate the tracts was the presence of appropriate host rocks for sedimentary exhalative zinc-lead deposits, because bedded barite deposits can be intimately associated with sedimentary exhalative zinc-lead deposits. In such a setting there is a 0.25 probability that a bedded barite deposit is present. The same rocks and, therefore, the same tracts are permissible for those bedded barite deposits not associated with other deposits.

Subjective Estimate of Undiscovered Deposits

A subjective estimate of the number of undiscovered bedded barite deposits was not made. However, the number of bedded barite deposits can be estimated using the probability of 0.25 that an associated bedded barite deposit will be present with a sedimentary hosted zinc-lead deposit and the subjective estimate of the number of these deposits.

MISCELLANEOUS TRACTS FOR PREVIOUSLY IDENTIFIED DEPOSIT TYPES

Introduction

Two tracts contain a mix of sedimentary rocks were delineated and permissible for several deposit types. Two or more deposit types from the following are usually involved: sedimentary hosted zinc-lead, sedimentary hosted copper, and carbonate-hosted base-metal deposit types. Each type has been described previously. Bedded barite deposits association with sedimentary hosted zinc-lead deposit types may be present. Subjective estimates of number of undiscovered deposits is not provided for these tracts.The description of the tracts and deposit types that are permissible follows:

Tract No.: M-1

a) Geographic description: This tract extends from the east edge of the quadrangle, across both the Hammond and the Glacier Rivers to a point east of the junction of Tinayguk and North Fork of the Koyukuk Rivers (pl. 2).
b) Permissive rocks and structures: The dominant rocks consist of black slate, phyllite and limestones of Middle or Upper Devonian or possibly older

age. These rocks are black, calcareous, phyllitic siltstone, slate and quartzite with lenses of brown dolomite and black calcareous phyllite and schist with interbedded limestone. Also included in the tract is a small area with black calcareous phyllite and thin dark limestone. Although the descriptions suggest that carbonate rocks are a minor component, as much as a one-third of the rocks in this tract may be limestone and other carbonate rocks.
c) Known mineralization: No significant mineral occurrence is recognized in the tract.
d) Geochemistry: The tract is totally within subdivision VI. The tract does not intersect any geochemical anomalous areas.
e) Comments: The tract contains rocks which are permissible for the occurrence of sedimentary hosted zinc-lead deposits and carbonate-hosted base-metal deposits.

Tract No.: M-2

a) Geographic description: The tract is in two parts. M-2a extends from the North Fork of the Koyukuk River, to a point south of its junction with Glacier River, across the junction of Wild River with Michigan Creek, to a point about midway between Wild and John Rivers. M-2b is a triangular area along and predominantly west of the Middle Fork of the Koyukuk River (pl. 2).
b) Permissiver rocks and structures: The dominant rocks in both parts of the tract are Proterozoic or Paleozoic calcareous schist with layers of marble. Interbedded and locally found in significant amounts are coarse mica schist and paragneiss with lenses and bands of black, graphitic schist and rare layers of marble and calcareous schist. About one-third of the rocks in the tract are carbonate rocks.
c) Known mineralization: No significant mineral occurrence is recognized in M-2a. One described occurrence is recognized in M-2b. It consists of bornite-bearing veinlets with detectable levels of copper and zinc, and hosted by dolomite and limestone.

Stream basin with gold placers are more numerous in M-2b than in M-2a. M-2a includes, however, a part of the basin for the poorly documented gold placers of Bourbon Creek. M-2b includes nearly all the basin for Emma Creek and Kelley Gulch and parts of the basins for Minnie Creek, and Porcupine Creek-Quartz Creek.
d) Geochemistry: The tract is totally within subdivision II. M-2a includes a large part of anomalous geochemical area 4 and much of the smaller anomalous geochemical area 5; M-2b includes much of anomalous geochemical area 1. These are described as follows:

Subdivision No. II

Anomalous geochemical area 1 over laps with most of M-2a.
Anomalous elements: copper, lead, zinc, gold, silver, arsenic, antimony
Less commonly anomalous: barium, nickel, molybdenum

Anomalous geochemical area 4 includes a large of the central area of M-2a.
Anomalous elements: copper, lead, zinc, gold, tungsten
Less commonly anomalous: barium, cobalt, chromium, silver, arsenic, antimony

Anomalous geochemical area 5 includes a small area in the west end of M-2a.
Anomalous elements: lead, zinc, silver, antimony, molybdenum, tungsten
Less commonly anomalous: copper, cobalt

f) Comments: The tract contains rocks with are permissible for the occurrence of sedimentary hosted zinc-lead deposits and carbonate-hosted base-metal deposits

SKARNS

Introduction

Skarns are "coarse-grained Ca-Fe-Mg-Mn silicates formed by replacement of carbonate-bearing rocks accompanying regional or contract metamorphism" (Einaudi and others, 1981). Skarns are formed by the introduction of silica, aluminum, iron and manganese into carbonate rocks. Typical skarn minerals include iron-garnets, iron-pyroxenes, and epidote. Skarns resulting from regional metamorphism are not known to host metals of economic interest (D.P. Cox, 1986, oral commun.); those resulting from contact metamorphism may do so. This does not preclude mineralized skarns from occurring in areas of regional metamorphism. However, these skarns represent contact metasomatism either prior to or after the regional event.

Copper skarns and zinc-lead skarns are two of at least five deposit types found in calcareous rocks near the contact with porphyroaphanitic (including felsic, mafic, and alkalic) intrusions (Cox and Singer, 1986). Among these five types are skarns related to porphyry copper which are similar in depositional style to the type of copper skarns considered here. These two types of copper skarns have different grade and tonnage models. The median tonnage for copper skarns related to porphyry copper deposits is two orders of magnitude larger than for copper skarns not associated with porphyry copper deposits. Grades of the commodities differ as well (Singer, 1986c; Jones and Menzie, 1986).

Copper skarns consist of chalcopyrite hosted by contact metasomatic calc-silicate rocks (Cox and Theodore, 1986). These skarns are typically associated with barren intrusions. Copper is the primary commodity; silver and gold are possible byproduct commodities (Jones and Menzie, 1986).

Zinc-lead skarns consist of sphalerite and galena hosted by calc-silicate rocks formed by contact metasomatism (Cox, 1986d). Zinc and, in most cases, lead are the primary commodities; silver, copper, and gold are possible byproduct commodities (Mosier, 1986).

Geologic Setting

The following description of geologic setting for copper skarns is taken mostly from Cox and Theodore (1986); is essentially identical to that for zinc-lead skarns (Cox, 1986d). These skarn deposit types form in miogeosynclinal sedimentary rocks intruded by felsic plutons. Continental margins during late orogenic magmatism appear to be particularly favorable. The composition of the intruding igneous rocks associated with these two skarn types is quite variable; tonalite to monzogranite intrusives may be present for copper skarns and granodiorite to granite, diorite and syenite for zinc-lead skarns. The host rocks are either carbonate or calcareous clastic rocks. Rocks of Mesozoic age are commonly identified with these skarn types, but deposits may be expected in rocks of any age. Associated deposit types include polymetallic replacements and iron skarns. Copper skarns and zinc-lead skarns may be associated with each other as well.

The discription of tin skarns is taken from Reed and Cox (1986) unless noted otherwise. Tin skarns form in carbonate terrains intruded by leucocratic biotite and (or) muscovite granite which commonly exhibit specialized phases. Felsic dikes may also be found. Einaudi and others (1981) suggest that the associated with tin skarns granites have "no generally applicable distinctive criteria." They also suggest if this is a common element among these granites, it is the presences of iron, rhubidium, lithium, tin, beryllium, tungsten, and molybdenum, relatively reduced nature, low sulfur and ores of high oxide content. In addition, Reed and Cox (1986) also include lead, boron, nobium, cesium, uranium, thorium, hafnium, tantalum and most rhenium as being enriched. They note that these granites are depleted in nickle, copper, chromium, cobalt, vanadium, scandium, strontium, lanthanum and barium. These granites have SiO_2 greater than 73 percent, K_2O greater than 4 percent and depleted in CaO, TiO_2 MgO, and total iron. Granite emplacement is pastorogenic. Carbonate rocks hosting deposits are mainly Mesozoic but rocks of all ages are involved. Associated deposit types include tungsten skarn, tin gneissen, and quartz-cassiterite-sulfide veins. Also associated at greater distances are intrusive-carbonate contact tin replacement and fissure lodes.

Deposit Properties

The following description of deposit properties for Cu skarns is taken mostly from Cox and Theodore (1986). Copper skarn deposits are irregular to tabular bodies consisting of chalcopyrite and pyrite. Hematite, magnetite, bornite, and pyrrhotite may also be present. Deposits occur along, or adjacent to, the contacts of intrusions which may have a wide range of compositions and textures. For this purpose of the assessment, deposits within 500 m of the contact were considered. Alteration in carbonate rocks around the intrusion associated with the copper skarns may occur in three zones: an outer zone of marble, an intermediate zone of wollastonite, and an inner zone of garnet-pyroxene immediately adjacent to the intrusion. Most of of the copper mineralization is found in the garnet-pyroxene zone although all zones may be involved. The intrusion may be altered to pyroxene-epidote and usually does not host mineralization. Actinolite, chlorite, and clays may also be present, the result of retrograde metamorphism. Deposits are coarse-grained, with interstitial sulfides. Copper skarn deposits weather to form iron-rich gossans which contain copper carbonates and silicates. The geochemical signal for this deposit type may include an inner zone of copper-gold-silver followed by gold-silver, followed by enriched gold with lesser silver surrounded by an outer halo of lead-zinc-silver. Other possible geochemical signatures for this deposit type include cobalt, arsenic, antimony and bismuth. Copper skarns associated with porphyry Cu but have a different grade and tonnage model. These Cu skarns are not addressed here, since, by definition, only those with barren intrusions are considered[1].

The following description of deposit properties for zinc-lead skarns is taken from Cox (1986d). Zinc-lead skarns consist of sphalerite and galena at,

1. At least one Cu porphyry deposit is suspected to be present in the Chandalar quadrangle (DeYoung, 1978). Some skarns therein should be cataloged as members of the Cu skarn deposit type associated with Cu porphyry. However no porphyry Cu deposits are expect in the Wiseman quadrangle and therefore we have treated the Cu deposits in a fashion consistent with a deposit type associated with barren intrusions.

or adjacent to, intrusions in carbonate-bearing rocks. Other minerals may include pyrrhotite, pyrite, magnetite, chalcopyrite, bornite, arsenopyrite, scheelite, bismuthinite, stannite, and fluorite. Deposits may be found several kilometers from the intrusion or fail to exhibit any association with an intrusion (Einaudi and others, 1981) It is suspected that zinc-lead skarns unrelated to obvious intrusion represent from 30 to possibly less than 10 percent of all zinc-lead skarns. For this, only zinc-lead skarns within 500 m of a mapped intrusive contact were considered. Zinc-lead skarns are less likely to exhibit metamorphic aureoles, but there is a greater likelihood of structural or lithological control on deposition than for copper skarns (Einaudi and others, 1981). Zinc-lead skarns tend to be more manganese-rich; they contain manganese-hedenbergite plus andradite, grossularite, spessartine, bustamite, and rhodonite. Retrograde minerals may include manganese-actinolite, ilvaite, chlorite, dannemorite, and rhodochrosite. Gossans developed on these skarns exhibit strong manganese-oxide stains. Anomalous elements useful in geochemical exploration may include zinc, lead, manganese, copper, cobalt, gold, silver, arsenic, tungsten, tin, fluorine, and possible beryllium. Copper skarns may be associated. Zinc-lead skarns are less common than copper skarns.

The description of deposit properties for tin skarns is taken from Reed and Cox (1986) unless noted otherwise. Tin skarn bodies may be concordant--sheet-like and lenticular--or cross-cutting as pipes or veins (Smirnov and others, 1983). Deposits may develop as far as 300 m from the intrusive contact and apparently are controlled by intrusive related fractures. Tin is often in silicates and difficult to extract using standard metallurgical techniques. The includes tin-garnets (grossularite or andradite, up to 5.8 percent SnO_2), tin amphibole (up to 3 percent SnO_2), sphene, malayaite, epidote, and ilvaite (Laznicka, 1985; Kwak, 1987). Late stage stockwork of veinlets and veins may develop and cut both skarn and associated host rocks. Vein minerals include fluorite, quartz, tourmaline, axinite, and datolite (Laznicka, 1985). Greisenization may develop near granite margins and in cusps. Weathered deposits may generate tin placers. Anomalous elements useful in geochemical exploration may include tin, tungsten, iron, beryllium, zinc, lead, copper, silver, lithium, rubidium, cesium, rhenium and boron.

Grade and Tonnage Models

The grade and tonnage model for copper skarns was developed from 64 deposits and a few districts (Jones and Menzie, 1986) associated with barren stocks, using the classification criteria of Einaudi and others (1981). No correlation is found between grades or between tonnage and grades. The grade and tonnage model was tested to determine whether it was appropiate for the eight copper skarn deposits found in the Brooks Range (see next section Newberry, 1986a). Brooks Range copper skarns have statistically different grades and tonnages (t-test, variance not assumed to be equal). The test was run using MINITAB, (Ryan and others, 1976). The copper and silver grades and tonnage for Brooks Range skarn deposits are statistically undistinguishable from those use in the grade and tonnage model developed by Jones and Menzie (1986). However, nearly all Brooks Range skarns deposits have reported silver grades in contrast to only about 25 percent of those found in the Jones and Menzie (1986) model. The silver grades have been adjusted to conform to the likelihood that all undiscovered copper skarns in the Brooks Range will have a silver grade. Gold grades are not reported for the Brooks range deposits, but they are found in 30 percent of the deposits used in the model (Jones and Menzie, 1986). This may be do to an analytical cutoff, because the reported gold grades in the grade and tonnage model are quite low. The gold grades are unmodified for use in this assessment. Both grades (with adjustment in silver grade) and tonnages are given in table 10.

Table 10. Estimate of percentage of copper skarns which equal or exceed a given grade or tonnage (Jones and Menzie, 1986) with modifications as described in text. Floor values are approximately lowest values used for each variable in the grade and tonnage model. [--, grade not available, unreported.]

Variable	Percentage			
	Floor	90	50	10
Tonnes (10^6)	0.005	0.034	0.56	9.2
Copper (percent)	0.32	0.7	1.7	4.0
Silver (g/tonne)	1.0	6.0	32.	95.
Gold (g/tonne)	.04	---	---	2.8

The grade and tonnage model for zinc-lead skarns was developed from 34 deposits (Mosier, 1986). Zinc and lead grades are significantly correlated (r=0.66, n=30) and zinc and copper grades are significantly correlated (r=0.61, n=17). Information on skarns of this type in the Brooks Range is too incomplete to justify modifications of the grade and tonnage model (Mosier, 1986). About 90 percent of the deposits used therein reports lead grades; slightly fewer than 70 percent of the deposits have reported copper grades and slightly more than 20 percent of the deposits have reported gold grades. Grades and tonnage are summarized in table 11 (Mosier, 1986).

Table 11. Estimate of percentage of zinc-lead skarn deposits which equal or exceed a given grade or tonnage (Mosier, 1986). Floor values are approximate lowest value given for each variable in the grade and tonnage model (Mosier, 1986b).

Variable	Percentage			
	Floor	90	50	10
Tonnes (10^6)	.09	0.16	1.4	12.
Zinc (percent)	2.4	2.7	5.9	13.
Lead (percent)	.87	.87	2.8	7.6
Silver (g/tonne)	15.	---	58.	290.
Copper (percent)	.09	---	0.09	1.3
Gold (g/tonne)	0.06	---	---	0.46

The grade and tonnage model for tin skarn deposits was developed from four deposits (Menzie and Reed, 1986). This is a very small sampling of deposits of this type and likely strongly size biased (i.e. contains just the largest deposits), particularly for tonnage. Tin grades are likely less sized biased. Menzie and Reed (1986) suggest that potential by-products from tin skarns include tungsten, fluorine, beryllium, zinc, and gold. Grades and tonnage are summarized in table 12 (Menzie and Reed, 1986).

Table 12. Estimate of percentage of tin skarn deposits which equal or exceed a given grade or tonnage (Menzie and Reed, 1986). Floor values are not given do to the small sample size.

Variable	Percentage 90	50	10
Tonnes (10^6)	1.6	9.4	58.
Tin (percent)	0.13	0.31	0.76

Identified skarns in the Brooks Range

Skarns with and without significant economic mineralization have been compiled for Alaska (Newberry, 1986a). Barren skarns are recognized by their small tonnage, low grades, or both. Based on reported base-metal grades, four types of skarn occurrences are recognized and used in this assessment for the Brooks Range. They are (1) barren skarns, (2) copper skarns, (3) tin skarns, and (4) zinc-lead skarns. Gold is also found in skarns, with and without economic grades of copper, lead, zinc, and iron (Orris and others, 1987). Nearly all skarn occurrences and deposits for the Brooks Range in Newberry's compilation (1986a) are in the Chandalar and Survey Pass quadrangles, respectively located east and west of the Wiseman quadrangle.

Two kinds of skarns are prominent in the Brooks Range, based on Newberry and others, (1986); they are tin and copper skarns. Also described are several occurrences that match the description for zinc-lead skarns; one of these may be a deposit. Comparison of the tin grades for proposed Brooks Range tin skarns (Newberry, 1986a) with those tin skarns used by Menzie and Reed (1986) suggest that the Brooks Range tin skarn are below deposit grade. Fifteen skarn occurrences are identified in the Chandalar quadrangle and 18 in the Survey Pass quadrangle. The resolution of occurrences as defined by Newberry (1986a) is at a finer scale than used for developing the grade and tonnage model (Jones and Menzie, 1986). They identify districts among the types of copper skarn deposits used. DeYoung (1978) describes copper skarn deposits in the Chandalar quadrangle in which several occurrence defined by Newberry (1986a) are combined. Adjacent skarn bodies will be treated as part of the same occurrence or deposit if within 0.5 kilometers. In conformance with this rule, the following copper skarns deposits are recognized in Chandalar: Hurricane-Luna, Eva-Venus-Victor, Evelyn Lee, Pilgrim, and Deimos. In the Survey Pass quadrangle, three copper skarn deposits are recognized: Arrigetch Creek East, East Contact (Saddle Creek), and North Reed River. The single zinc-lead skarn, named Io, is in the Chandalar quadrangle.

The following summaries are taken from Newberry (1986a) unless noted otherwise. References to other published sources for specific occurrences can also be found in Newberry's (1986a) compilation. Tonnages of these deposits have been estimated by using the midrange of maximum and minimum estimated tonnage, adjusted to conform to reported deposit geometry. Also included in the compilation, at various degrees of completeness are reported assay values; host characteristics and chemistry; intrusive rocks characteristics including lithology, alteration, texture, and mafic and accessory minerals; morphology; composition (including normative minerals); skarn minerals; paragenesis; assemblage; zoning; and skarn ore minerals (and composition thereof).

Mineralized skarns in the Survey Pass quadrangle are associated with granodiorite and alkali granite intrusions. Most of the exposures are found in two adjacent areas that have an approximate area of 140 km^2. This is batholithic in scale (greater than km^2). In contrast, the mineralized skarns in the Chandalar quadrangle are associated with granodiorite dikes and stocks that have an approximate area of 52 km^2. In addition, 11 km^2 of calc-silicate hornfels are shown adjacent to these intrusions. Similar rocks are either not present or not mapped in the Survey Pass quadrangle.

The Skajit Limestone is the only host identified for occurrences and deposits in the Chandalar quadrangle. In the Survey Pass quadrangle, two others units are identified: a Devonian gray phyllite which locally has limestone beds up to 20 m thick; and a low- to medium-grade schist and gneiss interlayered with orange-weathering marble (Nelson and Grybeck, 1980). However, all but one of these deposits are identified as being hosted by the Skajit Limestone in Newberry (1986a). Deposit descriptions follow:
(1) The Hurricane-Luna deposit (also Hurricane-Diane-Luna deposit) was described as an active prospect by DeYoung (1978, no. 33). The deposit is estimated to contain 250,000 tonnes at 1.7 percent copper and 104 g/tonne silver. The deposit is hosted by the Devonian Skajit Limestone. At this location, the Skajit is estimated to be 20 percent limestone and 5 percent dolomite; the balance is shale, intermediate volcanic rocks and marl. The deposit consists of magnetite, pyrite, chalcopyrite, and sphalerite with skarn minerals such as garnet, epidote, and actinolite; some ore bodies have pyroxene as well. The skarn is associated with a granodiorite intrusion. Alteration of the intrusion is sericitic and propylitic.
(2) The Eva-Venus-Victor deposit was described as an active prospect by DeYoung (1978, no. 72). The deposit is estimated to contain 1,500,000 tonnes with 1.65 percent copper and 11 g/tonne silver. Mineralization is associated with a porphyry copper deposit in granodiorite. The deposit is hosted by the Skajit Limestone with the same lithologic profile as at Hurricane-Luna. Ore minerals consist of pyrite and chalcopyrite, joined by skarn minerals garnet, epidote and actinolite. Also found locally are chlorite, pyroxene, quartz, and serpentine. Alteration of the intrusion is generally sericitic, but locally, propylitic and potassic alteration occurs and some endoskarn is present.
(3) The Evelyn Lee deposit is described as an active prospect by DeYoung (1978, no. 24). The deposit is estimated to contain 1,200,000 tonnes with 1.0 percent copper and 30 g/tonne silver. Mineralization is in an isolated tactite body at least 100 m long and about 10 m wide (DeYoung, 1978). The deposit is hosted by the Skajit Limestone with the same lithologic profile as given previously. Ore minerals include magnetite, pyrite, chalcopyrite, bornite, chalcocite, and tetrahedrite associated with skarn minerals garnet, pyroxene, epidote, actinolite, chlorite, sphene, and quartz. The skarn is associated with a granodiorite. Alteration to the intrusion is sericitic and propylitic; some endoskarn is also present.
(4) The Pilgram deposit was described, along with location Cindy, Mike, and Vicki, as an active prospect (DeYoung, 1978, no. 17). The deposit is estimated to contain 5,900 tonnes with 3.0 percent copper and 17 g/tonne silver. The deposit is hosted by the Skajit Limestone with the same lithologic profile as given previously. Ore minerals include pyrite, chalcopyrite, and sphalerite associated with skarn minerals garnet, epidote, and actinolite. The skarn is associated with a granodiorite. Alteration to the intrusion is sericitic and propylitic.

(5) The Deimos deposit is estimated to contain 79,00 tonnes with 1.9 percent copper and 60 g/tonne silver. The deposit is hosted by the Skajit Limestone with the same lithologic profile as given previously. Ore minerals include magnetite, pyrite, and chalcopyrite associated with skarn minerals garnet, epidote, actinolite, and chlorite. The skarn is associated with a granodiorite. Alteration to the intrusive is sericitic and propylitic.

Three copper skarn deposits in the Survey Pass quadrangle are described next. Description from Newberry (1986a) unless noted otherwise.

(6) The Arrigetch Creek East deposit which is described by Nelson and Grybeck (1980, no. 33) as several tactite bodies, some as much as 700 m long and 70 m thick, at a granite-carbonate contact. The deposit is estimated to contain 450 tonnes with 2.0 percent copper and 1 g/tonne silver. The deposit is hosted by the Skajit Limestone with shale with the balance consisting of black shale, graywacke, marl, and intermediate to mafic volcanic rocks. Ore minerals include magnetite, chalcopyrite, cassiterite, and fluorite associated with skarn minerals garnet, pyroxene, hornblende, biotite, axinite, and quartz. The skarn is associated with an intrusion estimated to be 90 percent granodiorite and 10 percent alkali granite. Alteration to the intrusion is sericitic.

(7) The East Contact (Skaddle Creek) deposit is estimated to contain 1,200,000 tonnes with 1.0 percent copper and 6.5 g/tonne silver. The deposit is hosted by the Skajit Limestone and has the same lithologic profile as for the Arrigetch Creek East deposit. Ore minerals include magnetite, pyrite, pyrrhotite, chalcopyrite, and sphalerite associated with skarn minerals garnet, actinolite, and hornblende. The skarn is associated with an intrusion estimated to be 90 percent granodiorite and 10 percent alkali granite. Alteration to the intrusion is sericitic.

(8) The North Reed River deposit is estimated to contain 230 tonnes with 0.6 percent copper and 4 g/tonne silver. The deposit is hosted by a unit estimated to be 10 percent limestone. More than half of the unit is shale with the balance consisting of marl, graywacke, and mafic volcanic rocks. The only identified ore minerals is pyrite with the skarn minerals hornblende and biotite. The associated intrusions are estimated to be 80 percent granodiorite and 20 percent alkali granite. Alteration to the intrusion is sericitic.

The occurrence identified as a possible zinc-lead skarn deposit, the Io, is the Chandalar quadrangle. It is estimated to contain 47,000 tonnes with 12.6 percent lead[1], 8.5 percent zinc[1], 0.04 percent copper and 83 g/tonne silver. This deposit is too small to be described by the grade and tonnage model for this deposit type. The lead grade is probably too high. Identified ore minerals include magnetite, pyrite, chalcopyrite, sphalerite, and galena associated with skarn minerals such as garnet, epidote, actinolite, and chlorite. The deposit is hosted by the Skajit Limestone estimated to be made up of 20 percent limestone, 5 percent dolomite, and 15 percent marl. The balance is shale and intermediate volcanic rocks. The associated intrusion is granodiorite. The alteration to the intrusion is sericitic.

Several other small occurrences for copper skarns and zinc-lead skarns are listed for Chandalar quadrangle (DeYoung, 1978; Newberry, 1986a) and for the Survey Pass quadrangle (Nelson and Grybeck, 1980; Newberry, 1986a).

1. This value is either the maximum or the only one available and may not be a representative grade for the deposit.

Tin bearing skarns are formed in the Survey Pass 1^{o} by 3^{o} quadrangle which is adjacent to the Wiseman quadrangle to the west. Known skarns are small--usually much less than 100,000 short tons (Newberry and others, 1986). Tin tonnages are smaller than those used in the grade-tonnage model by Menzie and Reed (1986). Comparison of the tin grades for proposed Brooks Ranges tin skarns (0.1 to 0.25 percent) (Newberry, 1986a) with those tin skarns used by Menzie and Reed (1986) suggest that the Brooks Range tin skarns are below mineral deposit grade. Einaudi and others (1981) also suggested tin gades for tin skarns to be in the same range as Menzie and Reed (1986).

Tin skarn occurrences are found around the Arrigetch Peacks and Mt. Igikpak plutons in Survey Pass (Grybeck and Nelson, 1981; Newberry and others, 1986). Six of these 24 skarns had maximum tin concentrations exceeding 1000 ppm (0.1 percent) in grab samples (Newberry and other, 1986). The minerals they describe in these highest tin bearing skarns include biotie, horn blende, pyroxene, epidote and magnetite. Newberry and others (1986) suggest that tin skarns are unlikely to be found since (1) erosion has proceeded to a depth to remove the pluton roof and (2) retrograde alteration is not in evidence which release tin from garnet and magnetite for reconcentration.

Tract delineation for copper skarns and zinc-lead skarns and tin skarns

Tracts were not delineated in the Wiseman quadrangle for skarns copper and zinc-lead deposits. One tract which was permissible for carbonate host base metal (CHB-IV) was also determined to be permissible for tin skarn. Otherwise, we considered all contact zones (as much as 1 km wide) between carbonate rocks and intrusives, particularly granitic ones, as permissive for the occurrence of skarns. Devonian granitic intrusions appear to be localized in or along the boundary of tracts delineated for Kuroko massive sulfides and may be part of the plutonic package represented by bimodal volcanism of the Ambler volcanics. Granitic intrusives are primarily in tract KMS-Ia(1), KMS(4); and tract KMS-III(4). In the latter tract, a tactite and skarn is also recogized. Skarn and tactites are also recognized in the Wiseman quadrangle in the absence of associated intrusion. These include an occurrence in tract KMS-III(2), and an occurrence northeast of Wild Lake in an area not recognized as associated with major intrusion or volcanic activity.

Description of Tract for Tin Skarn

Tract No.: CHB-IV

a) Geographic description: See tract description under corbonate-hosted base-metal deposits.

b) Permissive rocks and structures: One of the three units delineated ispermissinve for tin skarns. The Devonian Skajit Limestone is included but probably should be excluded by explorations in target areas, since it is younger than the plutonism which is believed to be Proterozoic. The Proterozoic banded schist together with Proterozoic (?) granite gneiss are the lemits which make this tract permissive for tin skarns. The schist includes interlayered coarse quartz-mica schist, quartzite, calcareous schist, marble, graphitic phyllite, and metabasite. Smalll outcrops of Proterozoic (?) granitic gneiss are also included in the tract. The gneiss includes blastophyritic, foliated, coarse-grained, biotie granite orthogneiss. Large outcrops of the granitic gneiss embedded in the tract have been excluded.

c) Known mineralization: Esssentially all mineralized occurrences (Bliss and others, 1988) in this tract are associated with the Proterozozic banded schist, not the Skajit Limestone. Occurrences also tend to be peripheral to a large Proterozoic (?) granitic gneiss body centrally located in the tract (plate 2).

Alll but one of the thirteen described mineral occurrences (Bliss and others, 1988) in the tract are associated with the Proterozoic banded schist or metagranites, not the Skajit Limestone. Eight of the occurrences are perpheral to a large Proterozoic (?) granitic gneiss body central to the tract but not included in the tract (plate 2). Three occurrences are described as having cassiterite or migmatite. One occurrence was described as containing disseminated cassiterite in a orthogneiss adject to country rocks. The highest content (0.1 percent) was found in an occurrence described as a coarse-grained garnet-epidote skarn with copper oxides and sphalerite. Other occurrence involve base metals, one which was described as a tactite.
d)Geochemistry: See tract description under carbonate-hosted mase-metal deposits.
e)Comment: The geochemistry of anomalous area 1 is particularly well located for identification of tin skarns. Of the ten elements noted, as either anomalous or less commonly so, six (lead, zinc, silver, tin, tugnsten, and copper) are given in the descriptive model (Reed and Cox, 1986) as a geochemical signature for this deposit type.

The descriptions of a number of the tin occurrences identify magmatic rocks as host. This may suggest that tin veins (Reed, 1986) or tin gneissen deposits may need to be considered permissible in all outcrops of the Proterozoic (?) granitic gneiss.

Estimate of number of undiscovered deposits

Participants in the mineral resource assessment did not subjectively estimate the number of undiscovered skarn deposits. Several other methods were used:

(1) A modification of Newberry's (1986b) distance along contact rule that a skarn occurrence can be expected for approximately each 4.8 km of intrusive-carbonate contact. When aggregating occurrences so as we have in this report, one copper skarn deposit is expected for each 145 km of intrusive contact based on observed deposits and intrusive contacts in the Chandalar quadrangle (where there is one deposit per 150 km of contact) and in the Survey Pass quadrangles (where there is one deposit per 130 km of contact). The number of zinc-lead skarn deposits, based on the Chandalar quadranle only, is one deposit per 770 km of contact. Contacts between Devonian and Devonian(?) granitic gneisses and all other rocks measured on the 1:250,000 scale geologic map for the Wiseman quadrangle (Dillon and others, 1986) total about 21 km. Even assuming that all the intrusions are hosted by favorably to the development of rock skarns, no undiscovered copper skarn deposits or zinc-lead skarn deposits are expected, using this rule.

(2) Area of contact hornfels and tactite. In the adjacent Chandalar quadrangle, 11 km^2 of calc-silicate hornfels are associated with intrusions. The quadrangle also contains five identified copper skarns. Assuming that all copper skarns that are present have been found, one copper skarn is expected for each 2.2 km^2 of hornfels. Using similar assumptions for zinc-lead skarns, there are 11 km^2 for each deposit. Only 0.44 km^2 of contact skarn and tactite are present in the Wiseman quadrangle, as measured on Dillon and others (1986). This suggests that no copper skarn deposits or zinc-lead skarn deposits can be expected.

(3) Area of exposed intrusions. The intrusions considered to be appropriate in the Wiseman quadrangle are more similar in size to those in the Chandalar quadrangle than those in the Survey Pass quadrangle. The Chandalar quadrangle has 52 km^2 of exposed intrusive rock; it also contains eight copper skarn deposits. This suggests that for each copper skarn there are 6.5 km^2 of exposed intrusive rocks for each zinc-lead skarn there are at least 52 km^2 of exposed intrusive rock. In the Wiseman quadrangle, only 0.5 km^2 of intrusive rock is exposed. This suggests no undiscovered copper skarn deposits or zinc-lead deposits can be expected.

These last two methods of obtaining estimates may have a low bias because mineralized skarns may be present where the associated intrusion has yet to be exposed by erosion. The estimates made by the first method may have a high bias because all copper skarn deposits recognized to date in the Brooks Range have been found in the Skajit Limestone, which is not part of the intrusive contacts measured in the Wiseman quadrangle. Based on these estimates, finding an undiscovered copper skarn deposit or a zinc-lead skarn deposit in the Wiseman quadrangle seems unlikely.

SIMPLE ANTIMONY DEPOSIT (27D)

Introduction

Simple antimony deposits are one of at least four deposit types usually found in older clastic rocks that occur with subaerial felsic-mafic extrusive rocks (Cox and Singer, 1986). Deposits are dominantly quartz and stibnite occurring as veins, pods, or disseminated grains in or adjacent to brecciated or shear zones; deposition is thought to occur at shallow to intermediate depths (Bliss and Orris, 1986a). Antimony is the primary commodity; byproduct commodites include gold and silver (Bliss and Orris, 1986b).

Geologic Setting

The following summary of the geologic setting for simple antimony deposits is taken from Bliss and Orris (1986a). This deposit type can be found in any orogenic area and has been identified in rocks of Paleozoic to Tertiary age. Faults and shear zones are commonly recognized features of the depositional environment. Deposits occur in a wide range of rock types. However, in more than half the cases, the deposits are hosted by limestone, shale (commonly calcareous), sandstone or quartzite. Other rocks that may host simple antimony deposits include slate, rhyolitic flows and tuffs, argillite, granodiorite, granite, phyllite, siltstone, quartz-mica and chloritic schists, gneiss, quartz porphyry, chert, diabase, conglomerate, andesite, gabbro, diorite, and basalt. This deposit type can be associated with many other deposit types including complex base-metal deposits with antimony and base metals that also may contain cinnabar, silver, gold, and scheelite—they are mined primarily for lead, gold, silver, zinc, and tungsten; low sulfide gold-quartz veins; epithermal gold and gold-silver deposits; hot-springs gold; carbonate-hosted gold; tin-tungsten veins; hot-springs and disseminated mercury; gold-silver placers; and in some localities polymetallic veins and tungsten skarns. The range of different deposit types that can be found with simple antimony deposits suggest that the deposit type is equifinal—several different types of mineralizing system may be equally likely.

Deposit Properties

The following description of deposit properties for simple antimony deposits is taken from Bliss and Orris (1986a). Deposits contain stibnite and quartz, commonly accompanied by pyrite and calcite. Other minor sulfides, commonly less than 1 percent of the deposit, may include arsenopyrite, sphalerite, tetrahedrite, chalcopyrite, scheelite, and free gold. Other infrequently found sulfides include native antimony, marcasite, malachite, azurite, calaverite, berthierite, and argentite. Infrequently observed gangue minerals include: limonite, chalcedony, opal (usually identified as beta cristobalite), siderite, fluorite, barite, and graphite. Deposits are found in fissures and shear zones with breccia; some as replacement in associated host rocks; occasionally as open-space filling in porous sedimentary rocks.

Deposits assume several forms. Vein deposits with stibnite pods, lenses, or kidneys are common; stibnite streaks, grains, and bladed aggregates in shear or breccia zones are also observed. Some deposits are disseminated in which stibnite streaks or grains occur in the host rocks with or without stibnite vein deposits. Deposits are considered to be either members of the vein or disseminated deposit types for the purposes of grade and tonnage modeling. Alteration of simple antimony deposits includes silicification, sericitization, and argillization. Occasionally chloritization and serpentization are observed when deposits are hosted by mafic or ultramafic rocks.

Deposits develop soils that are enriched in antimony. Yellow to reddish kermesite and white cerrantite or stibicontie (antimony-oxide minerals) may be useful in exploration. Useful geochemical indicators from simple antimony deposits may include one or more of: antimony, iron, arsenic, gold, and silver; in some places mercury, tungsten, lead, and zinc may be useful.

Grade and Tonnage Model

Two grade and tonnage models for simple antimony deposits were developed, one for vein-dominated simple antimony deposits and a second for disseminated deposits. In the case of vein-type deposits, the model was developed from data, mostly derived from hand-sorted ore. There is no significant correlation between grades and tonnage or among grades. Between 10 and 20 percent of the 81 deposits used for the grade and tonnage model have reported silver and gold grades. At least 30 percent and possibly more of the deposits are suspected of containing gold and (or) silver. Grades and ore deposit tonnage are summarized in table 13 for simple antimony deposits dominated by veins (Bliss and Orris, 1986c). At least 15 percent of the simple antimony veins are accompanied by disseminated antimony mineralization but disseminated deposits are also present without accompanying vein deposits. Their grade and tonnage model summarized in table 14 (Bliss and Orris, 1986b).

Table 13. Estimate of percentage of vein-type simple antimony deposits which equal or exceed a given grade or tonnage (Bliss and Orris, 1986c). Floor values are approximately the lowest value given for each variable in the grade and tonnage model (Bliss and Orris, 1986c). [---, grade not available, not reported]

Variable	Floor	Percentage 90	50	10
Tonnes	1.0	6.7	180	4900
Antimony (percent)	8.0	18.	35.	66.
Silver (g/tonne)	16.	---	---	16.
Gold (g/tonne)	0.3	---	---	1.3

Table 14. Estimate of percentage of disseminated simple antimony deposits which equal or exceed a given grade or tonnage (Bliss and Orris, 1986b). Floor values are approximately the lowest value given for each variable in the grade and tonnage model (Bliss and Orris, 1986b). (---, grade not available, not reported]

Variable	Floor	Percentage 90	50	10
Tonnes (10^3)	5.	7.8	88.	990.
Antimony (percent)	1.0	1.8	3.6	7.0

Identified Simple Antimony Deposits in the Brooks Range

Several simple antimony deposits have been identified in the Brooks Range in the Wiseman quadrangle (Ebbley and Wright, 1948) and one deposit in the Chandalar quadrangle (Dillon, 1982). No other simple antimony deposits are currently identified in the Brooks Range. Deposits may be part of the mineralizing systems involving the porphyry copper deposits, several copper skarns, and possibly a zinc-lead skarns in the adjacent Chanadalar quadrangle. This association is an uncommon event, as it has not been commonly reported elsewhere.

All the simple antimony deposits are near Smith Dome-Midnight Dome in the Wiseman quadrangle. The deposit in the Chandalar quadrangle is found near Sukakpak Mountain (Dillon, 1982, no. 21), which is about 22 km northeast of the Smith Dome-Midnight Dome area. All the simple antimony deposits in the Wiseman quadrangle are hosted by schists. The Sukakpak deposit is hosted by marble and schist at a fault contact between the two (Dillon, 1982). All except the Sukakpak deposit which also has cinnabar and tetrahedrite contain stibnite with no other sulfides identified. Analysis of a sample from the Sukakpak deposit also gave significant molybdenum (as much as 1.7 percent, Dillon, 1982). Reported antimony ore grades for deposits in the Wiseman quadrangle are compatible with grades used in the grade and tonnage model. The ore grade is quite likely that for material that has been previously hand sorted, as is the the case for most deposits used for the grade and tonnage model (Bliss and Orris, 1986c). Analyses of samples collected from these deposits a much lower values--from 60 ppm to greater than 1 percent antimony. Analyses are also available for the host rocks of some of these vein deposits. In general, veins tend to be slightly enriched in antimony over the country rocks. At some deposits the surrounding schist appear to have more antimony then the vein material. Gold concentrations in these deposits is quite low (0.01 ppm), only one sample has a significant amount (9.2 ppm).

All known simple antimony deposits are located in stream basins with gold placers. Those in the Wiseman quadrangle are in the Nolan Creek basin which contains the largest placer (in terms of contained gold) known in the Brooks Range. Sukakpak deposit is also associated with a gold placer deposit (Discovery Creek) of unknown extent (Dillon, 1982). Stibnite is present in panned concentrates for Nolan and, Vermount Creeks, and is highly likely but not reported in placers of Union Gulch and parts of the area for Hammond River placers. Other gold placers with stibnite reported in concentrates include Crevice and Lake Creeks.

Tract Delineation

Tracts have not been delineated for the simple antimony deposit type in the Wiseman quadrangle. Previous analysis of simple antimony deposits identified elsewhere in the world during the preparation of the descriptive model (Bliss and Orris, 1986a) suggests that a wide range of geological situation are involved and a set of generally applicable factors can not be identified. Inspection of the geological environment in the Chandalar and Wiseman quadrangles suggest three guidelines that can be used in exploration. They are:

(1) Known simple antimony deposits are located in stream basins with gold placers. If all simple antimony deposits are associated with gold placer deposits in the Wiseman quadrangle, all basins with gold placers must be considered as possible host for antimony deposits (pl. 3).

(2) The Sukakpak deposit in the Chandalar quadrangle appears to be a distal component of a mineralizing system associated with plutonic rocks having at least one porphyry copper deposit, several copper skarn deposits, one zinc-lead skarn deposit, and at least one simple antimony deposit (DeYoung, 1978; Newberry, 1986a; Dillon, 1982). The plutonic rocks have been interpreted as a plunging to the southwest such that plutonic rocks which are part of this igneous complex should be present in the Wiseman quadrangle beneath the area along, or east of, the Middle Fork of the Koyukuk River. A small outcrop of granitic gneiss and associated tactite along the west side of the Middle Fork of the Koyukuk River may represent these plutonic rocks. If the identified simple antimony deposits in Wiseman quadrangle are part of the same mineralizing system, undiscovered deposits are likely to occur at similar distances from plutonic rocks, exposed and buried, as observed in both the Chandalar and Wiseman quadrangles. Using this criterion, undiscovered simple antimony deposits may be more likely in the the eastern part of the Wiseman quadrangle, above and adjacent to the buried plutonic rocks that are part of the same plutonic system as that in the Chandalar quadrangle. Other buried plutonic rocks in the Wiseman quadrangle may also have undiscovered distal simple antimony deposits.

(3) All identified simple antimony deposits are found in a 10 km wide zone which extends S 54° W from the Chandalar quadrangle into the Wiseman quadrangle. The zone has the bearing of and includes a tract in the Chandlar quadrangle (DeYoung, 1978), that contains nearly all its copper

skarn deposits and occurrences as well as the Sukakpak simple antimony deposit (Dillon, 1982) in the extreme southwest end of the tract. A southwest extension of the zone into the Wiseman quadrangle includes all the identified simple antimony deposits in the Wiseman quadrangle. Using this criterion, undiscovered simple antimony deposits are likely to be found in this zone between the identified deposits in the Wiseman quadrangle and the boundary with the Chandalar quadrangle. Other undiscovered deposits may occur along a possible extension of the zone southwest of the identified deposits in the Wiseman quadrangle.

These guidelines provide some rules which may be locally applicable; they are not exhaustive but may provide some assistance to those exploring for undiscovered simple antimony deposits in the Wiseman quadrangle.

Subjective Estimate of Number of Undiscovered Deposits

Participants in the mineral resource assessment estimated that there is a 90 percent chance of two or more undiscovered deposits, a 50 percent chance of five or more undiscovered deposits and a 10 percent chance of eight or more undiscovered simple antimony deposits in the Wiseman quadrangle. There is a probability of 0.15 that the simple antimony deposit will have an associated disseminated simple antimony deposit, based on deposits in the grade and tonnage model (Bliss and Orris, 1986b). As noted in the discussion of identified deposits, several have antimony in the adjacent country rocks.

LOW-SULFIDE AU-QUARTZ VEIN (36A)

Introduction

Low-sulfide gold-quartz vein deposits are one of at least four deposit types found predominantly in eugeosynclinal rocks which have been regionally metamorphosed (Cox and Singer, 1986). Low sulfide gold-quartz vein deposits are massive quartz veins bearing gold and hosted by metamorphosed volcanic and volcanic sedimentary rocks (Berger, 1986).

Geologic Setting

The following summary of the geologic setting for low-sulfide gold-quartz veins deposits is taken from Berger (1986). This deposit type occurs in greenstone belts associated with later granitic batholiths. Host rocks are quite diverse and may include regionally metamorphosed volcanic rocks, graywacke, chert, shale, and quartzite and commonly has alpine gabbro and serpentine. These Precambrian to Tertiary age rocks are part of continental-margin mobile belts, and accreted margins. Veins are localized in faults and joints and probably develop after metamorphism; they may be found locally in granites. Associated deposit types include gold placers (some with platinum group elements), Kuroko massive sulfide deposits, and Homestake-type gold deposits.

Deposit Properties

The following summary of the deposit properties for low-sulfide gold-quartz veins deposits is taken from Berger (1986). This deposit type is usually found as quartz veins with ribbon texture and some open-space fillings in many places disruputed by subsequent movement. Some deposits occur as saddle reefs concordant with the host. Deposits are found in high-angle fault zones, some regional in extent; other deposits are found in joints. Serpentine-metasediment contacts are a favorable local setting for the occurrence of low-sulfide gold-quartz vein deposits. Some disseminated gold is found in country rocks adjacent to veins.

The common minerals in these deposits are quartz with native gold, pyrite, galena, sphalerite, chalcopyrite, arsenopyrite and occasional pyrrhotite. Locally observed are telluride minerals, scheelite, bismuth, tetrahedrite, stibnite, molybdenite, and fluorite. Mineralized quartz may be grayish or bluish due in part to disseminated fine-grained sulfide minerals.

Alteration can be extensive. It may include quartz and siderite and (or) ankerite with albite; veins can have carbonate haloes. Mineralization adjacent to ultramafic rocks can give chromium mica, dolomite, talc, and siderite. Some granitic hosts have sericitic alteration and disseminated arsenopyrite and rutile.

Gold is the best guide to weathered deposits. Other geochemical indicators include arsenic, which is the best general indicator element, but silver, lead, zinc and copper may be useful as well.

Grade and Tonnage Model

The grade and tonnage model for low-sulfide gold-quartz vein deposits was developed from 313 deposits (Bliss, 1986). Deposits were defined to include adjacent mines within 1.6 km and containing more than 99 tonnes of ore. Gold grade is inversely correlated with tonnage ($r = -0.30$) and positively correlated with silver grade ($r = 0.45$, $n=39$). Slightly more than 10 percent of the deposits reported silver grades. Grades and tonnage are summarized in table 15 (Bliss, 1986).

Table 15. Estimate of percentage of low-sulfide gold-quartz vein deposits which equal or exceed a given grade or tonnage (Bliss, 1986). Floor values are approximately the lowest value given for each variable in the grade and tonnage model (Bliss, 1986). [---, grades not present, not reported]

Variable	Percentage			
	Floor	90	50	10
Tonnes (10^6)	0.0001	0.001	0.03	0.91
Gold (g/tonne)	2.5	6.0	16.	43.
Silver (g/tonne)	0.4	---	---	2.5

Identified Low Sulfide Gold-Quartz veins in the Brooks Range

Only two deposits compatiable with this deposit description are known in the Brooks Range. The Mikado (DeYoung, 1978, no. 48) and the Little Squaw-Summit (DeYoung, 1978, no. 42), are located in the Chandalar quadrangle 9 to 11 km east of Chandalar Lake. The deposits are associated with several gold occurrences (DeYoung, 1978, nos. 8, 23, 36, 68, and 81) as well as with several gold placers (DeYoung, 1978, nos. 7, 9, 43, and 70). Both low-sulfide gold-quartz deposits are hosted by rock of upper greenschist facies. Deposition was apparently controlled by parallel, nothwest-trending, high-angle faults (Lamal, 1983). Spacing between the faults is about 1 to 1.5

km. Deposits and some occurrences have two generations of quartz vein material: an early, barren, white, milky quartz, coarsely crystalline with minor sulfide minerals and gold, and the main stage quartz with minor sulfide minerals and gold (Lamal, 1983). The main stage quartz is fine grained, white, vuggy, and contains arsenopyrite, galena, sphalerite, stibnite, and pyrite. Free gold is usually as flakes in the quartz; some gold is also adjacent to galena or arsenopyrite. Less commonly, gold is associated with sphalerite or stibnite (Lamal, 1983). Mineralization and fault movement were contemporaneous, as evident from smeared sulfide minerals and fault gouge.

The Mikado is both the larger (at least 11,000 tonnes) and richer (75 g/tonne gold) of the two deposits. Two generations of quartz are present at the Mikado. Also present is an earlier generation of quartz pods and lenses similar to quartz segregations found in the hosting graphitic schist. The Mikado is on a 40-ft-wide fault zone with normal displacement of 500 ft down on the southwest side (Lamal, 1983; Chipp, 1970). The highly incompetent schist host rock, has contributed to the complexity of the vein system.

The Little Squaw-Summit deposit is located on a fault, with a bearing of N 80° W and dip 75-80° N, between schist and schist-phyllite. This mine also has two generations of quartz. Iron staining and scorodite are present and graphite and arsenopyrite are smeared along quartz banding. Gold is found as blebs in the quartz and in vugs. Fluid inclusions in these deposits suggests that mineralization occurred between 160-330° C. Gold mineralization is commonly found in quartz which probably formed at 275° C and at pressures of 825 bars. Boiling is thought to have occurred during quartz crystallization (Lamal, 1983). This is comparable to, or slighty cooler than, temperatures of $320^{\circ} \pm 60^{\circ}$ C found in the gold lode deposits of the Sierra Nevada foothills (Bohlke and Kistler, 1986).

The gold grades and gold fineness from the Mikado and the Little Squaw-Summit deposits are similar to those found in other low-sulfide gold-quartz deposits. Although the Little Squaw-Summit and Mikado deposits have higher gold grades (49 g/tonne and 75 g/tonne, respectively) than many low-sulfide gold-quartz vein deposits, the difference is not significant. Twenty samples collected from the Mikado deposit, the Little Squaw-Summit deposit, and the occurrences on St. Mary's Creek (Mosier and Lewis, 1986) have gold fineness between 700 and 927; the mean fineness is 815. These values are not statistically different from the fineness of 153 samples of gold delivered to the U.S. Mint in San Francisco from low-sulfide gold-quartz vein deposits in California (i.e. in the Sierra Nevada foothills and the Klamath Mountains) which varied from 700 to 927 in fineness; the mean fineness was 803 (Leach, 1899).

Tract Delineation

Although tracts have not been delineated for this deposit type, in the Wiseman quadrangle, some general guidelines follow that will assist in identifying areas which may contain these deposits.

(1) Most deposits of this type are associated with gold placer deposits and occur in rocks metamorphised to greenschist facies; higher-grade metamorphic rocks appear unfavorable for this deposit type. All rocks in the quadrangle with this metamorphic grade may be considered permissible. Although the presence of gold placers may be favorable for low-sulfide gold-quartz deposits, their absence is not unfavorable,

because extensive glaciation may have removed associated placers. The deposits may not yet outcrop sufficiently to develop placers.

(2) Low-sulfide gold-quartz deposits develop within 20 km to less commonly, 40 km of associated plutonic complexes, usually batholithic in size (greater than 100 km^2). The presence of two deposits southeast of the plutonic rocks in the Chandalar quadrangle, assuming they are correctly classified with this deposit type, suggests that deposits may be present near small exposures of plutons in this area. These deposits are numerous in some areas (Sierra Nevada foothills, California; Nova Scotia; Victoria, Australia) which appears not to be the case in the Chandalar quadrangle. The worldwide median density of deposits for areas in which these deposits occur is 4.3×10^{-3} deposits/km^2. Assuming that deposits in the Wiseman quadrangle are associated with the plutonic complex exposed in the Chandalar quadrangle and that deposits must occur within 40 km of that plutonic complex, about 140 km^2 of area along the east edge of the Wiseman quadrangle would be included. The area is east of a line from the headwaters of Clara Creek to Vermont Dome, then east to Jenner Creek Lake along the east edge of the quadrangle. The area also meets the metamorphic grade condition noted previously. Using median deposit density, 1 deposit might be expected in this triangle area of the Wiseman quadrangle.

Subjective Estimate of the Number of Undiscovered Deposits

Participants in the mineral resource assessment estimated that there is a 50 percent chance of one or more undiscovered deposits and 10 percent chance of two or more undiscovered deposit of this type in the Wiseman quadrangle. These estimates are similar to the one from using the worldwide median deposit density values used above.

GOLD PLACERS (39a)

Introduction

Gold placers are the only deposit-type that has contributed significantly to the metal production from the Wiseman quadrangle. The most productive placers are in the Koyukuk Mining District which is, wholly or partly, in the Wiseman quadrangle.

An initial grade and tonnage model of gold placers was developed by Orris and Bliss (1986) to provide an idea of what the gold grades and volumes in an undiscovered placer might be. A placer deposit as defined by them and used in this assessment, includes placers less than 1.6 km apart, and, in most cases, includes only data on past production. Gold placer data were collected from deposits so defined throughout the world (Orris and Bliss, 1985). Subsequent analyses of these data suggest that gold grade and deposit volume are more dependent on the mining method than on traditional placers classifications (Tertiary, bench, glacial-fluvial)(Bliss and others, 1987). Alluvial plain and fan placers found along mountain-valley boundaries, however, appear different from all other types with significantly lower gold grades and larger volumes.

Geologic Setting

Gold placers may develop in a wide range of geologic and climatic settings. Gold placers, along with other types of placer deposits, share the property that economic minerals are both resistent to decomposition and are usually denser than the accompanying rocks (Lindgren, 1933). If gold placers are to form, a suitable bedrock source must be present. Lode deposits containing gold are one type of bedrock source and may include vein-type deposits such as low sulfide gold-quartz vein, porphyry copper, copper skarn, and polymetallic replacement deposits (Yeend, 1986). Areas without obvious gold-bearing lodes can also develop gold placers. Wojcik (1984) notes that 17 worldwide placer gold districts contain slate, phyllite, or schist which are thought to have been initially gold-enriched shale. However, the gold in shale is in pyrite or other sulfides or very fine grain, less than 50 micrometers (less than 270 mesh), (Wojcik, 1984). Gold of this grain size cannot be effectively concentrated by surface processes; Boyle (1979) suggested it will either be directly dispered or dissolved. However, if the shale is metamorphosed, gold changes both location and grain size; this increases the chance that gold placers may subsequently develop (Wojcik, 1984). The gold within sulfide minerals forms grains in microfractures and some gold migrates to quartz veinlets. Gold grain size increases with metamorphism to a size that can be concentrated by weathering and erosion.

Given a suitable source rock, gold placers may develop during physical and chemical weathering to form residual (eluvial) deposits. Gold in these deposits may eventually be transported into streams where alluvial gold placers may develop. The steps in gold-placer development can be very complex and may involve special climatic controls such as a tropical climate, multiple episodes of weathering, erosion, and deposition, and interaction with groundwater (Wojcik, 1984). Alluvial gold deposits tend to be associated with white quartz clasts (Yeend, 1986). Placers that develop in high-energy fluvial environments typically form where stream gradients flatten at sites of flow-velocity reduction related to stream meanders, water falls, rapids, boulders, and vegetative mats (Yeend, 1986). Most gold placers are Cenozoic (Yeend, 1986); the ancient gold placers of the Witwatersrand, South Africa, are an important exception. Gold placers are associated with other placer deposits including black sands (magnetite, ilmenite, chromite) and yellow sands (zircon, monazite)(Yeend, 1986).

Deposit Properties

Gold placers contain native gold in numerous forms including gold dust (less than 0.1 - 2 mm), small scales, crystals, wires, leaves, tufts, and nuggets. Gold may be spongy, mossy, filiform, or dendritic (Boyle, 1979). Extremely finely divided gold, gold flour, is particularly difficult to recover during mining. Nuggets can be quite large (2516 troy ounces, Victoria, Australia), particularly in residual deposits (Boyle, 1979); rarely nuggets are equidimensional (Yeend, 1986). Gold in placers may be attached to other minerals including quartz, magnetite, or ilmenite (Yeend, 1986). Other minerals and alloys may be present in gold-placer deposits; the following breakdown from Boyle (1979) gives minerals in two general specific-gravity (S.G.) classes:

Specific Gravity	Minerals

From low to medium: quartz (S.G.=2.65), muscovite, amphiboles, pyroxenes, tourmaline, garnet, diamond, chromite, rutile, barite, chorundum, manganese-oxide minerals, limonite, and zircon (S.G.=4.5).

From medium to high: monazite (S.G.=5), magnetite, ilmenite, cassiterite, wolframite, scheelite, cinnabar, and platinum (S.G.=22).

Platinum is rarely pure and several alloys may be present including platinum-iron alloys, and osmium-iridium alloys (Yeend, 1986). Boyle (1979) identifies the following minerals in gold placers; this list is not exhaustive:

native silver (rare)	emeralds	pyrite
allanite	epidote	realgar
apatite	feldspars	rubies
arquerite (silver -murcury amalgam)	galena	sapphires
native arsenic (rare)	garnet	sperrylite
native bismuth	hematite	sphene
boulangerite	native mercury	spinel
carbonate minerals	jamesonite	tantalite-columbite
chalcopyrite	kyanite	topaz
cinnabar	molybdenite	native zinc
native copper	native lead	

Distribution of gold in a placer can be complex; however concentration tend to increase toward the gravel base (Yeend, 1986). Gold grades in drift mines, which usually work the gravel base, are high (see next section). Other types of traps operate in streams that collect gold include natural riffle, rock fracture, and bedding plane, and other bedrock features which cross the stream channel (Yeend, 1986). The best geochemical signature in exploring for gold placers is gold. Generally nuggets contain less silver downstream. Other elements that may be useful include silver, arsenic, mercury, antimony, copper, iron, and sulfur, as is the presence of heavy minerals (Yeend, 1986).

Gold Grade and Volume Models

The development of a grade and volume model for gold placers has been complicated by the overwhelming importance of mining methods in defining both grades and volumes; several mining methods are commonly applied to the same types of gold placer. The grade and tonnage model developed by Orris and Bliss (1986) aggregated placer grade and tonnage data without regard to mining method but excluded placer types cataloged as desert placers, pre-Tertiary or Tertiary placers, beach placers, residual placers, eluvial placers, and gravel-plain placers. Placers worked exclusively just by drift mining were excluded as they have very high gold grades clearly not compatable with placers worked by other methods. However, the grade and tonnage model of gold placers developed by Orris and Bliss (1986) is likely adequate for many mineral resource assessments. Alternatively, in areas with a previous history of gold placer mining, particularly dominated by small-volume mining methods, where data on gold production from this mining is available, another method for assessment can be used (Bliss and others, 1987) which focuses on the mining-life cycle of gold placers. As part of this modification, new grade and volume models using groupings by mining techniques was developed. In this method, gold placer deposits are classified into two groups: small-volume mining including panning, using a rocker, drift mining, sluicing, and drywashing; and large-volume mining including dredging, draglining, and hydraulicking. Small-volume mining can be further divided into surface methods and subsurface, or drift mining, methods. Some gold placers have been worked with a mix of large- and small-volume methods where neither was dominant. When recognized, these placers have been deleted from the data used. For this assessment, small-volume surface mining methods include those placers working less than 1,000,000 m^3 of material. Large-volume mining includes those placers that worked at least 100,000 m^3 and had gold grades between 0.1 and 1.0 g/m^3. Although volumes of material worked by the two clases of mining methods overlap, the lower grades of large-volume mining preclude using small-volume methods. The 50 placer deposits used to construct the grade-volume model for small-volume surface mining have volumes that are statistically indistinguishable from the 27 placer deposits used to construct a grade-volume model for drift mines (table 16). The 80 placer deposits used to construct a grade-volume model for large-volume mining have volumes two to three orders of magnitude larger than either small-volume surface mining or drift mining (table 16). Nearly all placers that have undergone large-volume mining were initially worked by small-volume mining methods. Gold grades are highest for drift mining, lowest for large-volume mining methods, and intermediate for small-volume surface mining methods (table 17).

Table 16--Estimate of percentage of placers which will equal or exceed a given volume (m^3) (Bliss and others, 1987).

Mining Method (volumes)	Percentage 90	50	10
Drift mining (m^3) (n=27)	130	4,200	300,000
Small-volume surface methods (m^3) (n=50)	450	48,000	410,000
Large-volume methods (m^3) (n=80)	400,000	4,400,000	45,000,000

Table 17--Estimate of percentage of placers which will equal or exceed a given gold grade (g/m^3) (Bliss and others, 1987).

Mining Method (gold grades)	Percentage 90	50	10
Drift mining (g/m^3) (n=27)	11.	19.	62.
Small-volume surface methods (g/m^3) (n=50)	.58	4.2	22.
Large-volume methods (g/m^3) (n=80)	.17	.30	.68

The mix of mining methods may account for the significant correlation (at the 1 percent level) between gold grade and volume and for small-volume surface mining methods ($r = -.43$) and large-volume mining methods ($r = -.39$), respectively. Drift mining has a small but marginally significant negative correlation (at the 5 percent level) between gold grade and volume ($r = -.37$).

Tracts delineated (for gold placers)

Three tracts are delineated for gold placers in the Wiseman quadrangle; tracts represent areas where gold placers are more likely to occur, assuming that the correct criteria for delineation have been used (pl. 3). Stream basins or areas with significant gold production are outlined on and description in Bliss and others (1988). All gold placers with significant surface enrichment are probably included. However, buried placer deposits may have been overlooked. Reed (1988) noted that buried gravels produced by fluvial aggradation are common in many streams in the quadrangle. Glaciation, which has significantly modified the surface (Hamilton, 1978), usually destroys gold placers; however, it can locally bury them by crossing stream valleys containing deposits at an oblique angle. For example, lacustrine silt buries the lower end of the Nolan Creek Placer and appears to have been deposited in a lake on the margin of a glacier in the valley of the Middle Fork of the Koyukuk River (Maddren, 1913).

Some placers may not be worked because of several factors: lack of water, large boulders, too much water leading to flooding in drift mining or other factors not specifically identified (accessibility, etc.)

Bourbon Creek Placer is not within any delineated tract (pl. 3). The placer is isolated from other deposits and occurs in an area which generally does not appear geologically favorable. Possible explanations are that the placer location may be in error, the report of extensive mining may be invalid, or the placer may result from other geologic conditions (e.g. the weathering of a lode deposit) not used in the delineation criteria. It is important to remember that gold placers may result from combinations of several factors; these can include several different types of weathering and erosional regimes over a variety of bedrock conditions.

Subjective estimate of undiscovered gold placers

There are 25 gold placer deposits identified in the Wiseman quadrangle for the purposes of this resource assessment. Three have been either exhausted or have some history of large-volume mining. Subjective estimates of the number of undiscovered gold placers suggest that there is a 90 percent chance that there are two or more deposits, a 50 percent chance of four or more deposits and a 10 percent chance of six or more deposits. Undiscovered gold placers are expected to have gold grades and volumes compatible with the values given in tables 15 and 16.

Description of tracts for gold placers

Tract No.: PLC-I

Tract PLC-I is the largest of the three placer tracts delineated in the Wiseman quadrangle (pl. 3). The tract boundaries are roughly parallel to the regional geologic fabric and include rocks which are slightly metamorphosed (phyllitic to green schist). Though quartz veins are most often cited as the source of placer gold, other vein-types suggested are quartz-carbonate, quartz-tourmaline, stibnite with or without quartz, and quartz-sulfide (Orris and Bliss, 1985).

Quartz veins are the possible source of gold in four of the 17 streams with gold placers (Birch Creek, Mascot Creek, Lake Creek, and Rye-Jay Creeks). Other basins for which gold sources are not given but which are adjacent to one of these four basins include: Kay Creek, Agnes Creek, Spring Creek, Surprise Creek, and the somewhat distant Sirr Creek. Stibnite-quartz veins are the proposed source of placer gold for Nolan Creek and may be a contributor at Rye Creek-Jay Creek. Basins associated with Nolan Creek, for which stibnite-quartz veins may be the source of placer gold, include Hammond River, Union Gulch, Vermont Creek and, possibly, Washington Creek. Colorado Creek, near the west edge of the quadrangle, has an undefined gold source. The gold source for Crevice Creek is thought to be mineralization associated with the Skajit Limestone.

Placer productivity in tract PLC-I generally declines from east to west. While tract delineation is based on rough metamorphic grade, other factors may be important. Tract A cross-cuts several tracts (pl. 1, 2) for other deposit types, which may have generated gold placers during weathering.

Claim-staking for placers or likely placers in PLC-I accounted for 60 percent of the activity in the Wiseman quadrangle in 1980 (U.S. Bureau of Mines, 1980). Claim-staking for placers between January 1980 and December 1982, was estimated to have decreased to 33 percent of all staking activity in the quadrangle (Alaska Division of Geological & Geophysical Surveys Mining-Claim Location Map, 1982).

Tract No.: PLC-II

PLC-II is located on both sides of the Middle Fork of the Koyukuk River, along the east edge of the quadrangle (pl. 3). The tract extends from Minnie Creek in the north to Cathedral Mountains in the south. Unlike PLC-I, PLC-II cuts across the geologic fabric and is not related to metamorphic grade. Six basins or areas are identified in PLC-II. Myrtle Creek and Slate Creek Placer is partly located in the Chandalar quadrangle to the east. Two placer deposits, Emma Creek, and Myrtle Creek and Slate Creeks account for 95 percent of the recorded gold production in the tract. In both areas, many quartz veins are reported in the stream basins; these are thought to be the source of the gold. The quartz veins may be associated with shallowly eroded plutons exposed within and just east of the tract in the Chandalar quadrangle (Brosgè and Reiser, 1964; 1972; Dillon and others, 1986). We suggest that modern sediments of the Middle Fork of the Koyukuk River do not have gold grades which are consistent with the grade models for placers. Claim staking for placers or likely placers in PLC-II accounted for 13 percent of the staking activity in the Wiseman quadrangle in 1980 (U.S. Bureau of Mines, 1980.) Claim staking for placers between January 1980 and December 1982 was estimated to have increased to 20 percent of all staking activity in the quadrangle (Alaska Division of Geological & Geophysical Surveys Mining-Claim Location Map, 1982).

Tract No: PLC-III

PLC-III includes areas adjacent to the Middle Fork and South Fork of the Koyukuk River in the southeast corner of the quadrangle. Most of the area is a glacial outwash plain, predominantly drift of the Itkillik glaciation (Hamilton, 1978). Orientation of morainal ridges suggests, that most drift and outwash material was derived from glaciers passing through the valley of the Middle Fork of the Koyukuk River in PCL-III. Gold placers tend to be in two groups, those along the Middle Fork (Mailbox Creek, Tramway Bar-Chapman Creek placers, and Hamil Bar placer) and those along the South Fork of the Koyukuk River (Eagle Cliff, Grubstake Bar-Hanshaw Bar placers, and Smally Creek Placer). The gold is probably reworked from placers in PLC-I and PLC-II and from Cretaceous conglomerates (Dillon and others, 1986).

Claim staking for placers or likely placers in PLC-III accounted for about 18 percent of the staking activity in the Wiseman quadrangle in 1980 (U.S. Bureau of Mines, 1980). Claim staking for placers between January 1980 and December 1982 increased to 41 percent of all staking activity in the quadrangle (Alaska Division of Geological & Geophysical Surveys Mining-Claim Location Map, 1982).

Placer staking activity beyond of PLC-I, PLC-II, and PLC-III

Claim staking for placers or likely placers beyond delineated tracts generally took place near the south boundary of PLC-I and accounted for about 10 percent of the staking activity in the Wiseman quadrangle in 1980 (U.S. Bureau of Mines, 1980). Streams with activity include East Creek (T. 29 N., R. 16 W.); Fall Creek (plus tributaries) (T. 28 N., T. 29 N.; R. 16 W.); an unnamed creek draining west of Ipnek Mountain into Michigan Creek (T. 26 N., T. 29 N.; R. 16 W.), and one unnamed creek draining north into Michigan Creek (T. 28 N., T. 29 N.; R. 17 W.); Suckik Creek (T. 26 N., T. 27 N.; R. 19 W.), at the junction of North Fork Koyukuk River and Glacier River (T. 29 N., R. 14 W.); Horse Creek (T. 29 N., R. 14 W.); and LaSalle Creek (T. 30 N.; R. 13 W., R. 14 W.). Claim staking between January 1980 and December 1982 beyond delineated tracts decreased to 6 percent of the all staking activity in the Wiseman quadrangle (Alaska Division of Geological & Geophysical Surveys Mining-Claim Location Map, 1982). Activity continued on Suckik Creek and there was new activity at two locations on Wild River (T. 27 N., T. 28 N., R. 18 W.; T. 28 N., R. 17 W.), and on Michigan Creek (T. 29 N., R. 30 W.).

General scheme for working gold placers

We will assess additional gold production from gold placers in the Wiseman quadrangle using a general life-cycle scheme of working gold placers as developed by Bliss and others (1987). The history of gold placer mining suggests a general pattern which is useful for mineral resource assessment. All placers are initially worked by small-volume methods; either surface mining or drift mining can be dominant. Analysis of data from Australia with better than normal reporting suggests that the ratio between the number of drift mines and small-volume surface mines is on the order of 3 to 5 indicating that drift mining comprises about 38 percent of all small-volume mining in Australia. A review of Wiseman placer data suggests that the ratio between the number of drift mines and surface mines is about 1 to 8, or that, drift mining constituted about 10 percent of all small-volume mining in the Wiseman quadrangle. Small-volume mining may exhaust the ore or can lead to subsequent large-volume mining. The typical odds against subsequent large-volume mining are 4 to 1. Historical data from placers in the Wiseman quadrangle suggest that the odds against subsequent large-volume mining are more like 5 to 1. At Mascot Creek, large-volume mining has essentially exhausted the deposit. Large-volume mining probably began on Washington Creek since a dredge and other equipment on Mascot Creek were to be moved there. Large-volume mining appears to have been operational (draglines) on Mytle Creek-Slate Creek although reported grade and volume data is more typical of small-volume mining. Additional gold production from these three deposits will not be addressed because they are essentially exhausted or have already entered the large-volume production phase. Additional gold will likely be gained but an objective assessment method is unavailable. The gold produced during small-volume mining can be used to give an approximate estimate of gold production from large volume mining. This general scheme for working gold placers is useful in the systematic evaluation of future gold production of both discovered and predicted gold placers.

Prospectors search for the gold-rich gravels easily worked by small-volume methods. Favorably located placer deposits with sufficient reserves, under suitable economic conditions will be worked with large-volume mining.

The proportion of a gold-placer deposit that can be worked by large-volume metholds is difficult to estimate because many placers worked only by the small-volume methods are not reported in the literature. We have already indicated that the odds against a placer being suitable for large-volume mining are 4 to 1. If a placer deposit is suitable for large volume-mining (LVM) and the amount of gold produced from small-volume mining (SVM) is reported, an approximate estimate of the remaining gold ($\log_{10}$ kg) can be made using the following relationship:

$$\log_{10}(\mathrm{Gold}_{LVM}) = 1.76 + 0.46 * \log_{10}(\mathrm{Gold}_{SVM})$$

This empirical relationship was developed using data from both small-volume surface and drift mining and subsequent large-volume mining (Bliss and others, 1987).

The grade-volume model and the equation are applicable to all placer types except alluvial-plain and fan-placers that develop when large volumes of gold-bearing material are deposited by rivers or streams descending from mountains into a valley or plain. Only a few of these gold placers have grade-volume data, but available data suggest they are world class in size. Statistically, they have slightly lower gold grades (table 19).

Predicted Additional Gold for Future Production from Gold Placers

Method of Computer Simulation: What gold remains in discovered and undiscovered gold placers in the Wiseman quadrangle? Computer simulation can provide an estimate using the sequence of events and associated probabilites of the mining life-cycle model of gold placers (Bliss and others, 1987). Also needed is the number of gold placers with small-volume mining, the gold produced from each, and and an estimate of the number of undiscovered placers. Simulation addresses the effects of uncertainty in the number of undiscovered placers, from variability in gold production from small-volume mining, and the variability associated with with the estimate gold-production from large-volume mining based on the equation developed previously. Specifically, such uncertainties can be appraised using a Monte Carlo simulation (Harbaugh and Bonham-Carter, 1970). Two kinds of future production can be predicted; production from small-volume mining of undiscovered placers, and production of large-volume and smal volume mining from both discovered and undiscovered gold placers. Simulation was conducted in MINITAB, a statistical software package (Ryan, and others, 1976) in which one thousand iterations were run.

Predicted Gold Production from Future Small-Volume Mining of Gold Placers:

Much of the past gold production in the Wiseman quadrangle has been from small-volume mining. With improved mining technology, accessibility, and economics, small-volume mining will continue to be important. In this precedure, prediction of additional gold production from small-volume mining can be made for undiscovered placers only. Available techniques do not show prediction of additional production by continued small-volume mining of discovered placers, but the amount of gold produced this way can be expected to be small when compared to past gold production. Subjective estimates of the number of undiscovered placers is approximated with the binomial distribution with the parameters: n=26, p=.17. The parameter n is the number of independent Bernoulli trials and p is the probability of success (Hastings and Peacock, 1975). Also needed is the probability that small-volume mining will be by drift mining (p=0.10). This probability may be low because undiscovered placers are likely to be buried; on the other hand, it may be high because drift-mining is currently unpopular and surface mining may be used despite cover. Gold production ($\log_{10}$kg) from small-volume surface mining (mean=1.73, standard deviation=0.902) and drift mining (mean=1.96, standard deviation=1.18) was assumed to be appropriate for undiscovered gold placers. The results of simulation suggests that there are 3 chances in 4 of 290 kg or more of gold, a 50 percent chance of 850 kg or more of gold, and a 10 percent chance of 2,100 kg or more of gold produced from undiscovered gold placers in the quadrangle.

Predicted Gold Production from Future Large-Volume Mining: Large-volume mining, as defined here, has likely occurred in two gold placer deposits in the Wiseman quadrangle; one other deposit is essentially exhausted. The remaining 22 known placer deposits plus predicted undiscovered placers are sites for future large-volume mining if the general life-cycle is followed. Some of these gold placers will be amenable to large-volume mining (p = 0.20). Calculation of future large-volume production is possible, using the equation and previous small-volume production data. Gold production from placers (Table 17) includes four which lack small-volume production data; consequently, their production was simulated. This information, along with estimated gold production from undiscovered placers, was used in the simulation to predict subsequent gold production from large-volume mining. The results of simulation suggest that there are 3 chances in 4 of 0.90 tonnes or more gold, a 50 percent chance of 1.9 tonnes or more gold, and 1 chance in

4 of 3.1 tonnes or more gold being produced from subsequent large-volume mining of gold placers.

Table 18. Estimate of placer production from the Wiseman quadrangle[1].

NAME	Gold (kg)[2]	NAME	Gold (kg)
Birch Creek	38.	Mytle Creek and Slate Creek	270.
Clara Gulch	6.9	Nolan	2000.
Crevice Creek	3.8	Porcupine Creek-Quartz Creek	11.
Eagle Cliff	.12	Rye Creek-Jay Creek	110.
Emma Creek	240.	Spring Creek	137.
Grubstake-Hanshaw	6.	Tramway Bar-Chapman Creek	72.
Hammond River	1800.	Twelve Mille Creek	11.5
Kelley Gulch	.75	Union Gulch	1.75
Lake Creek	39.	Vermont Creek	12.7
Mascot Creek[3]	27.	Washington Creek[3]	7.5
Minnie Creek	2.3		

1. Production data was unavailable for four placer deposits; therefore, four contained gold values were selected at random from distributions describing gold from small-volume surface workings and drift mines (p= .11) to insure that each iteration contained 22 identified placer deposits with production.
2. 1 kg = 1,000 g; 1,000 kg = 1 metric ton or tonne.
3. Significant gold production of unknown amount from these placers is likely and may include both small-volume and large-volume mining.

Total Future Gold Production from Gold Placers: Total median gold production from both small-volume and large-volume mining is predicted to be around 2,750 kg. About 76 percent of the predicted production is from large-volume mining of discovered and undiscovered placers. Reported production (table 18) is 4,800 kg. Predicted gold production is just over one-half of previously reported gold production. This is somewhat less, but probably comparable to the estimates of DeYoung (1978) that additional gold production from gold placers in the adjacent Chandalar quadrangle would be equal to or less than previously reported production (2,000 to 3,000 kg gold). This estimate of future gold production in Wiseman quadrangle is based on a mining life cycle of most gold placers and probably gives estimates accurate to within an order of magnitude.

Alluvial plain and fan gold placer-types

Aluvial plain- and fan-gold placers differ from all other types in terms of gold grades and volumes. Because only a small number of placers of this kind are currently recognized, we can only guess what the typical size and grades might be (table 18).

Table 19. Preliminary estimates of minimum, median, and maximum of contained gold, volume, and gold grades for 10 alluvial-plain and fan-gold placers.

Variable	Minimum	Median	Maximum
Contained gold (mt)	2.2	18	480
Ore (m^3) (10^6)	7.9	110	760
Gold Grade (g/m^3)	0.089	0.20	0.63

In the Wiseman quadrangle, Cretaceous clastic rocks including conglomerates crop out along the southern edge of the quadrangle. These rocks were deposited during the initial unroofing of the Brooks Range in the early Cretaceous (Dillon and Smiley, 1985; Dillon and others, 1986) and may be one possible source of gold in placers in PLC-III. These rocks were deposited by streams draining the early Brooks Range; this situation is favorable for development of alluvial-plain and fan-placers. If the bedrock source for such placers was similar to modern placers in PLC-II and PLC-III, Cretaceous rocks in and adjacent to PLC-III may be most favorable. However, all occurrences of Cretaceous conglomerates can be considered as permissible placer hosts. If an alluvial plain or fan gold placer is present, it is most likely buried and not amenable for working by dredges. Deposits used for constructing table 19 were all worked by dredges. Grades may need to be substantially higher to permit other types of mining. In any case, large uncertainty is involved as to whether such a deposit is present; however, if one were found to be amenable for exploitation, a large return on investment is possible.

REFERENCES CITED

Barnes, D.F., Mayfield, C.F., Morin, R.L., and Brynn, Sean, 1982, Gravity measurements useful in the preliminary evaluation of Nimiuktuk barite deposit, Alaska: Economic Geology, v. 77, p. 185-189.

Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, model 36a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 239.

Bliss, J.D., 1986, Grade and tonnage of low-sulfide Au-quartz vein deposits, model 36a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 239-243.

Bliss, J.D., and Orris, G.J., 1986a, Descriptive model of simple Sb deposits, model 27d, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 183-184.

-----1986b, Grade and tonnage model of disseminated simple Sb deposits, model 27d, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p 187-188.

-----1986c, Grade and tonnage model of simple Sb deposits, model 27d, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 184-186.

Bliss, J.D., Orris, G.J., and Menzie, W.D., 1987, Changes in grade, volume, and contained gold during the mining life-cycle of gold placer deposits: Canadian Mining and Metallurgical Bulletin, v. 80, no. 903, p.75-80.

Bliss, J.D., Brosgè, W.P., Dillon, J.T., Cathrall, J.B., and Dutro, J.T., Jr., 1988, Maps and descriptions of lode and placer deposits, prospects, and occurrences in the Wiseman 1° by 3° quadrangle, Alaska: U.S. Geological Survey Open-File Report 88- , 2 maps, 1:250,000, 54 p.

Bohlke, J.K. and Kestler, R.W., 1986, Rb-Sr, K-Ar, and stable isotopes evidence for ages and sources of fluid components of gold-bearing quartz veins in the northern Sierra foothills metamorphic belt, California: Economics Geology, v. 81, p. 296-322.

Boyle, R.W., 1979, The geochemistry of gold and its deposits: Geological Survey of Canada Bulletin 280, 584 p.

Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, model 32b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 222-223.

-----1986b, Descriptive model of sedimentary exhalative Zn-Pb, model 31a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 211-213.

-----1986c, Descriptive model of Southeast Misssouri Pb-Zn, model 32a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 220-223.

Brosgè, W.P., and Reiser, H.N., 1964, Geologic map and section of the Chandalar quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigation Map I-375, 1 sheet, 1:250,000.

-----1970, Chemical analysis of rock and soil samples from the Chandalar and eastern Wiseman quadrangles, Alaska: U.S. Geological Survey Open-File Report 70-39 (Sequence No. 1368), 8 p.

-----1972, Geochemical reconnaissance in the Wiseman and Chandalar districts and adjacent region, southern Brooks Range, Alaska: U.S. Geological Survey Professional Paper 709, 21p.

Brosgè, W.P., Reiser, H.N., Dutro, J.T., Jr., and Detterman, R.L., 1981, Organic geochemistry data for Mesozoic and Paleozoic shales, central and eastern Brooks Range, Alaska: U.S. Geological Survey Open-File Report 81-551, 18 p.

Bundtzen, T.K., and Henning, M.W., 1978, Barite in Alaska: Alaska Division of Geology and Geophysical Surveys, Mines and Geology Bulletin, v. 27, no. 4, p. 1-4.

Cathrall, J.B. 1982, Evidence from stream-sediment geochemical and biogeochemical data, mineral occurrences, and Landsat images for potential mineralized target areas in the Brooks Ranges, Alaska, in Coonrad, W.L., ed., The United States Geological Survey in Alaska: accomplishments during

1980: U.S. Geological Survey Circular 844, p. 41.

Cathrall, J.B., Dillon, J.T., and Chazin, Barbara, 1984, Maps of anomalous trace metals in rocks and stream-sediment pebbles of the Wiseman $1^{\circ} \times 3^{\circ}$ quadrangle, Brooks Range, Alaska: U.S. Geological Survey Open-File Report 84-161-B, 44 p. 2 sheets, scale 1:250,000

Cathrall, J.B., Dillon, J.T., Hoffman, J.D., Brosge, W.P., and Bliss, J.D., 1987, Geochemical maps and evaluation of stream-sediment geochamical data of the Wiseman $1^{\circ} \times 3^{\circ}$ quadrangle, Brooks Range, Alaska: U.S. Geological Survey Open-File Report 87-12, 67 p., 2 sheets, scale 1:250,000.

Churkin, Michael, Jr., Mayfield, C.F., Thesbald, P.K., Barton, Harlan, Nokleberg, W.J., Winkler, G.R., and Huie, Carl, 1978, Geological and geochemical appraisal of metallic mineral resources, southern National Petroleum Reserve in Alaska: U.S. Geological Survey Open-File Report 78-70-A, 85p.

Cox, D.P., 1986a, Descriptive model of Besshi massive sulfide, model 24b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 136.

-----1986b, Descriptive model of porphyry Cu, skarn related deposits, model 18a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 82.

-----1986c, Descriptive model of sediment-hosted Cu, model 30b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 205.

-----1986d, Descriptive model of Zn-Pb skarns, model 18c, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 90.

Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposits models: U.S. Geological Survey Bulletin 1693, 379 p.

Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, model 18b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 86.

DeYoung, J.H., 1978, Mineral resource map of the Chandalar quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-878-B, 2 sheets, scale 1:250,000.

Dillon, J.T., 1982, Source of lode- and placer-Au deposits of Chandalar and upper Koyukuk districts, Alaska: Alaska Division of Geology and Geophysical Surveys Open-File Report 158, 22 p.

Dillon, J.T., Brosgé, W.P., and Dutro, J.T., Jr., 1986, Generalized geologic map of the Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report 86-219, 1 sheet, scale 1:250,000.

Dillon, J.T., Cathrall, J.B., and Moorman, M.A., 1981a, Geochemical reconnaissance of the southwest Wiseman quadrangle--summary of data on pan-concentrate and stream-sediment samples: Alaska Division of Geological and Geophysical Surveys Open-File Report 133A, 176 p.

Dillon, J.T., Moorman, M.A., and Lueck, L., 1981b, Geochemical reconnaissance of the southwest Wiseman quadrangle--summary of data on rock samples: Alaska Division of Geological and Geophysical Surveys Open-File Report 133B, 164 p.

Dillon, J.T., and Smiley, C.J., 1985, Clastics from the early Cretaceous Brooks Range orogen in Albian to Cenomanian molasse deposits of the Northern Koyukuk Basin, Alaska [abs.]: Geological Society of American Abstracts with Programs, v. 17, no. 6, p. 279.

Dutro, J.T., Jr., 1952, Stratigraphy and paleontology of the Nolatak and associated formations, Brooks Range, Alaska: U.S. Geological Survey, Geological Investigations of Naval Petroleum Reserve No. 4, Special Report 33, 144 p.

Duttweiler, K.A., 1987, Use of factor analysis in locating base metal mineralization in the Killik River quadrangle, Alaska, in Hamilton, T.D., and Galloway, J.P., eds., Geologic studies in Alaska by the U.S. Geological Survey Circular 998, p. 27-30.

Ebbley, Norman, Jr., and Wright, W.S., 1948, Antimony deposits in Alaska: U.S. Bureau of Mines Report of Investigation 4173, 41 p.

Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits: Economic Geology, 75th Anniversary Volume, p. 317-391.

Ellersieck, Inyo, Mayfield, C.F., Tailleur, I.L., and Curtis, S.M., 1979, Thrust sequences in Misheguk Mountain quadrangle, Brooks Range, Alaska, in Johnson, K.M., and Williams, J.R., eds., The United States Geological Survey in Alaska: Accomplishments during 1978: U.S. Geological Survey Circular 804-B, p. B8.

Fox, J.S., 1984, Besshi-type volcanogenic sulfide deposits--a review: Canadian Insititute of Mining and Metallurgy Bulletin, v. 77, No. 864, p. 57-68.

Goodfellow, W.D., 1983, Stream sediment and water geochemistry of the Howard's Pass (XY) Zn-Pb deposit and Nor Zn-Pb-Ba occurrence, Selwyn Basin, Yukon and Northwest Territories: Geological Survey of Canada Open File 845, 25 p., 21 sheets, scale 1:1000,000.

Giegerich, H.M., 1986, Progress report on Cominco's Red Dog project in Alaska, second largest zinc deposit ever discovered: Mining Engineering, v. 38, no. 12, p. 1097-1101.

Grybeck, D.J., and Nelson, S.W., 1981, Mineral deposit map of the Survey Pass Quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Study Map MF-1176-F, 1 sheet, scale 1:250,000.

Hadjistavrinou, Y., and Constantinou, G., 1982, Cyprus, in Dunning, F.W., Mykura, W., and Slater, D., eds., Mineral deposits of Europe, volume 2: Southeast Europe: The Institute of Mining and Metallurgy and the Mineralogical Society, London, p. 255-277.

Hamilton, T.D., 1978, Surficial geologic map of the Wiseman quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1122, scale 1:250,000.

Hastings, N.A.J., and Peacock, J.B., 1975, Statistical distributions: London, Butterworth & Co., 130 p.

Harbaugh, J.W., and Bonham-Carter, Graeme, 1970, Computer simulation in geology: New York, John Wiley & Sons, 575 p.

Harben, P.W., and Bates, R.L., 1984, Geology of the nonmetallics: New York, Metal Bulletin, Inc., 392 p.

Hitzman, M.W., Proffett, J.M., Jr., Schmidt, J.M., and Smith, T.E., 1986, Geology and mineralization of the Ambler district, northwestern Alaska: Economic Geology, v. 81, no. 7, p. 1592-1618.

Hutchinson, C.S., 1982, Economic deposits and their tectonic setting: New York, John Wiley & Sons, 865 p.

Joesting, H.R., 1943, Supplement to Pamphlet No. 1—strategic mineral occurrences in interior Alaska: Alaska Department of Mines Pamplet no. 2, 28 p.

Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, model 18b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 86-89.

Kouda, Ryoichi, and Koide, Hitoshi, 1978, Ring structure, resurgent caldron, and ore deposits in the Hokuroku volcanic feild, northern Akita, Japan: Mining Geology (Japan), v. 23, p. 233-244.

Lamal, K.K., 1983, Genesis of gold depoists at the Little Squaw Mine, Chandalar Mining District, Alaska: Alaska Division of Geology and Goephysical Survey unpublished report, 35 p.

Lange, I.M., Nokleberg, W.J., Plahuta, J.T., Krouse, H.R., and Doe, B.R., 1985, Geologic setting, petrology, and geochemistry of stratiform sphalerite-galena-barite deposits, Red Dog Creek and Drenchwater Creek Areas, Northwestern Brooks Range, Alaska: Economic Geology, v. 80, p. 1846-1926.

Laznicka, Peter, 1985, Phanerozoic environments, associations and deposits, v. 1, pts A & B, of Empirical Metallogeny, Depositional Environment, Lithologic Associations and Metallic Ores: Amsterdam, Elsevier, 1785 p.

Leach, F.A., 1899, Fineness of California Gold: San Francisco, California, Miners' Association and the American Institute of Mining Engineers, p. 173-187.

Lindgren, Waldemar, 1933, Mineral deposits: New York, McGraw-Hill Book Company, 930 p.

Los Alamos National Laboratory, 1981, Uranium hydrogeochemical and stream-sediment reconnasisance of the Wiseman NTMS quadrangle, Alaska: U.S. Department of Energy, Grand Junction Office, Report GJBX 257(81), 97 p.

Maddren, A.G., 1913, The Koyukuk-Chandalar region, Alaska: U.S. Geological Survey Bulletin 532, 119 p.

Marshall, Robert, 1933, Artic Village: New York, The Literary Guild, 399 p.

Mayfield, C.F., Curtis, S.M., Ellersieck, I.R., and Tailleur, I.L, 1979, Reconnaissance geology of the Ginny Creek zinc-lead-silver and Nimiuktuk barite deposits, northwestern Brooks Range, Alaska: U.S. Geological Survey Open-File Report 79-1092, 20 p., 2 sheets, scale 1:63,360.

Mayfield, C.F., and Grybeck, D.J., 1978, Mineral occurrences and resources map of the Ambler River quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-120I, 1 sheet, scale 1:250,000.

McMichael, Ray, Plahuta, J.T., Young, L.E., Modene, J.S., and Moore, D.W., 1984, Geology of the Red Dog lead-zinc deposit, Delong Mountains, Alaska, in Cordilleran Geology and Mineral Exploration: Status and Future Trends Symposium: Geological Society of Canada, Cordilleran Section, Vancouver, British Columbia, February 20-21, 1984, p. 25-26.

Menzie, W.D., and Mosier, D.L., 1985, Grade, tonnage and lithologic data for sedimentary-hosted submarine exhalative Zn-Pb and sandstone-hosted Pb-Zn deposits: U.S. Geological Survey Open-File Report 85-206, 17 p.

-----1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, model 31a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 212-215.

Menzie, W.D., and Reed, B.L., 1986, Grade and tonnage model of Sn skarn deposits, model 14b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 58-60.

Menzie, W.D., Reiser, H.N., Brosgé, W.P., and Detterman, R.L., 1985, Map showing destribution of mineral resources (excepting oil and gas) in the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-897-C, 1 sheet, scale 1:250,000.

Moore, D.W., Young, L.E., Modene, J.S., and Plahuta, J.T., 1986, Geologic setting and genesis of the Red Dog zinc-lead-silver deposit, Western Brooks Range, Alaska: Economic Geology, v. 81, no. 7, p. 1696-1729.

Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarns deposits, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 90-93.

Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of Southeast Missouri Pb-Zn and Appalachian Zn deposits, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 224-226.

Mosier, D.L., Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of sediment-hosted Cu, model 30b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 206-208.

Mosier, D.L., Singer, D.A. and Salem, B.B., 1983, Geologic and grade-tonnage information on copper-zinc-lead massive sulfide deposits: U.S. Geological Survey Open-File Report 83-89, 78 p.

Mosier, E.L., and Lewis, J.S., 1986, Analytical results, geochemical signatures, and sample locatlity map of lode gold, placer gold, and heavy-mineral concentrates from the Koyukuk-Chandalar mining district, Alaska: U.S. Geological Survey Open-File Report 86-345, 172 p.

Nelson, S.W., and Grybeck, Donald, 1980, Geologic map of the Survey Pass quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1176-A, scale 1:250,000.

Newberry, R.J., 1986a, Compilation of data on Alaska skarns: Alaska Division of Geological & Geophysical Surveys, PDF 86-21, 835 p.

Newberry, R.J., 1986b, Quantification of the DGGS Rockval scheme for appraisals of skarn deposits: Final Report: Alaska Division of Geological & Geophysical Surveys unpublished report, 39 p.

Newberry, R.J., Dillon, J.T., and Adams, D.D., 1986, Regional metamorphosed, calc-silicate-hosted deposits of the Brooks Range, Northern Alaska: Economic Geology, v. 81, no. 7, p. 1728-1752.

Nokleberg, W.J., Bundtzen, T.k., Berg, H.C., Brew, D.A. Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metal-liferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.

Nokleberg, W.J., and Winkler, G.R., 1982, Stratiform zinc-lead deposits in the Drenchwater Creek Area, Howard Pass quadrangle, northwestern Brooks Range, Alaska: U.S. Geological Survey Professional Paper 1209, 22 p., 2 sheets, scale 1:20,000.

O'Leary, R.M., Hoffman, J.D., Sutley, S.J., and Lewis, J.S., 1984, Analytical results and sample locatity maps of stream-sediment, heavy-;mineral-concentrate, pebble, and rock samples from the Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report 84-161-A, 400 p., 3 sheets, scale 1:250,000.

Orris, G.J., 1986a, Descriptive model of bedded barite in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 216.

-----1986b, Grade and tonnage of bedded barite in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 216-218.

Orris, G.J., and Bliss, J.D., 1985, Geologic and grade-volume data on 330 Au placer deposits: U.S. Geological Survey Open-File Report 85-213, 172 p.

-----1986, Grade and tonnage model of placer Au-PGE, model 39a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 261-264.

Orris, G.J., Bliss, L.D. Hammarstrom, J.M., and Theodore, T.G., 1987, Description and grades and tonnages of gold-bearing skarns: U.S. Geological Survey Open-File REport 87-273, 50 p.

Paris, Chester, 1977, Models of barite deposition with reference to the barite-occurrence of Atigun Canyon, central Brooks Range, Alaska: Fairbanks, University of Alaska Special Paper, 45 p.

Reed, I. McK., 1938, Upper Koyukuk region, Alaska: Alaska Department of Mines Unpublished Report, 169 p.

Reed, B.L.,1986 Descriptive model of Sn gneisen deposits, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1963, p. 70-71.

-----1986, Descriptive model of Sn veins, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1963, p. 59, 67.

Reed, B.L., and Cox, D.P., 1986, Descriptive model of Sn skarn deposits, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p.

Pratt, Fred, 1984, Massive Red Dog ore deposit could see production by 1988: Canadian Mining Journal, v. 105, no. 11, p. 28-30.

Ryan, T.A., Jr., Joiner, B.L., and Ryan, B.F., 1976, MINITAB—student handbook: Boston, Duxbury Press, 341 p.

Schmidt, J.M., 1986, Stratigraphic setting and mineralogy of the Artic volcanogenic massive sulfide prospect, Ambler District, Alaska: Economic Geology, v. 31, no. 7, p. 1619-1643.

Singer, D.A., 1975, Mineral resource models and the Alaska mineral resource assesment program, in Vogely, W.A., ed., Mineral Material Modeling: Washington, D.C., John Hopkins University Press, p. 370-382.

-----1986a, Descriptive model of Cyprus massive sulfides, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 131, 133.

-----1986b, Descriptive model of Kuroko massive sulfide, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 189, 194.

-----1986c, Descriptive model of porphyry Cu, skarn related deposits, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 82.

-----1986d, Grades and tonnage model of Besshi massive sulfides, model 24b, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 136-138.

Singer, D.A., and Mosier, D.L., 1986a, Grade and tonnage model of Cyprus massive sulfide, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Gological Bulletin 1693, p. 131-132.

-----1986b, Grade and tonnage model of Kuroko massive sulfide, model 28a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 190-197.

Smirnov, V.I., Ginzburg, A.I., Grigoriev, V.M., and Yakovlev, G.F., 1983, Studies of mineral deposits: Moscow, USSR, Mir Publications, 288 p.

Smith, S.S., and Mertie, J.B., Jr., 1930, Geology and mineral resources of northwestern Alaska: U.S. Geological Survey Bulletin 815, 351 p.

Tailleur, I.L, 1970, Lead, zinc, and barite-bearing samples from the western Brooks Range, Alaska, with a section on petrography and mineralogy, by G.D. Eberlein and Ray Wehr: U.S. Geological Survey Open-File Report 445, 16 p.

Tailleur, I.L., Ellersieck, I.F., and Mayfield, C.F. 1977, Mineral resources of the western Brooks Range, in Blean, K.M., ed., The United States Geological Survey in Alaska: Accomplishments during 1976: U.S. Geological Survey Circular 751-B, p. B24-B25.

Tailleur, I.L., and Brosgé, W.P., 1970, Tectonic history of Nothern Alaska, in Adkinson, W.L., and Brosge, W.P., eds., Proceedings of the Geological Seminar on the North Slope of Alaska: Tulsa, Oklahoma, American Association of Petroleum Geologists, Pacific Section, p. E1-E19.

U.S. Bureau of Mines, 1980, Claim staking in the Wiseman 1° by 3°: U.S. Bureau of Mines Open-File 20-73, 1:250,000.

Wojcik, J.R., 1984, Geologic factors described for large global gold placer deposits: Mining Engineer, v. 36, no. 11, p. 1528-1530.

Wiltse, M.A., 1975, Geology of the Arctic Camp prospect, Ambler River quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Report 60, 41p.

Yeend, W.E., 1986, Descriptive model of placer Au-PGE, model 39a, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 261, 263.

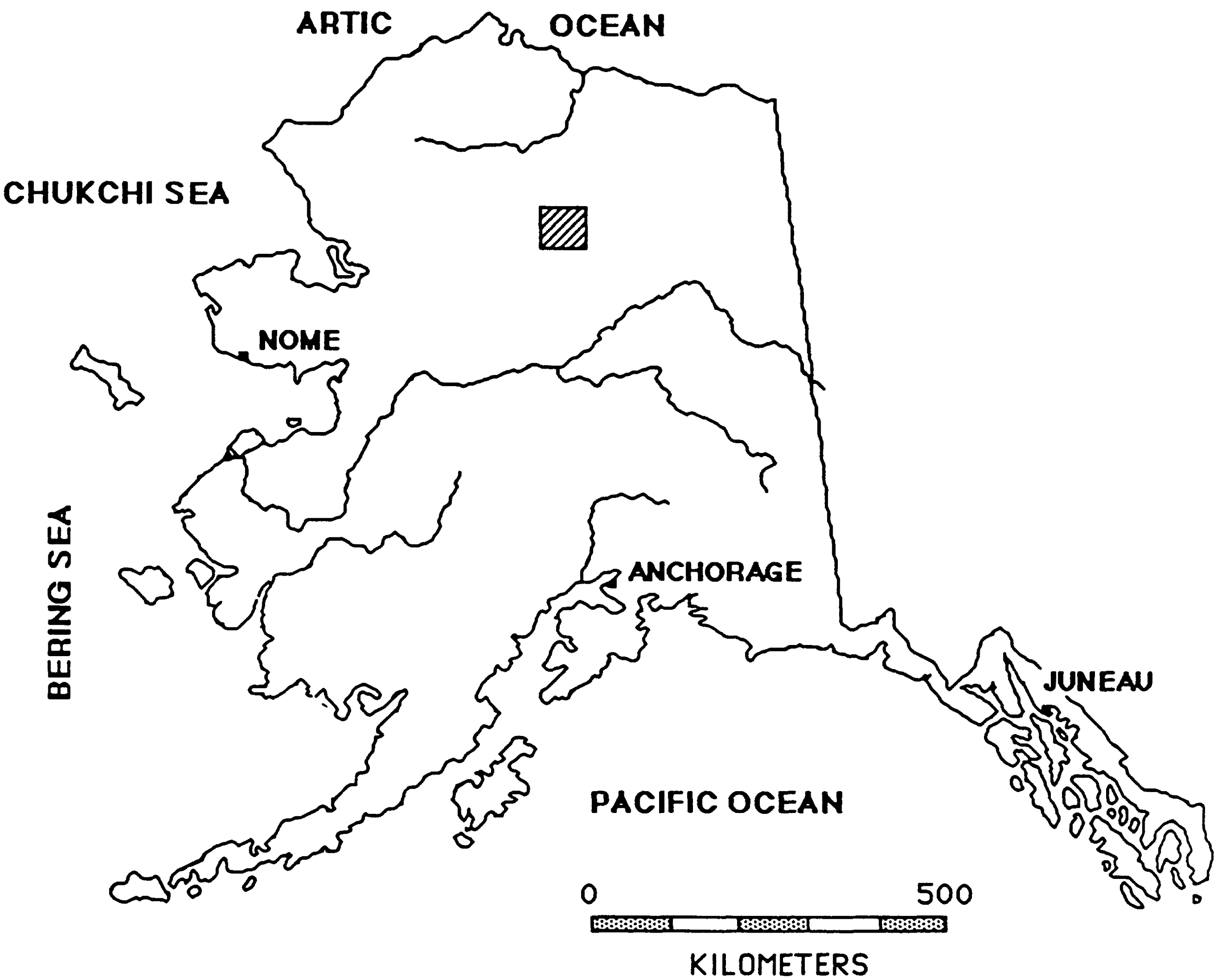

Figure 1. Alaska, showing approximate location of the Wiseman 1° by 3° quadrangle, Brooks Range.

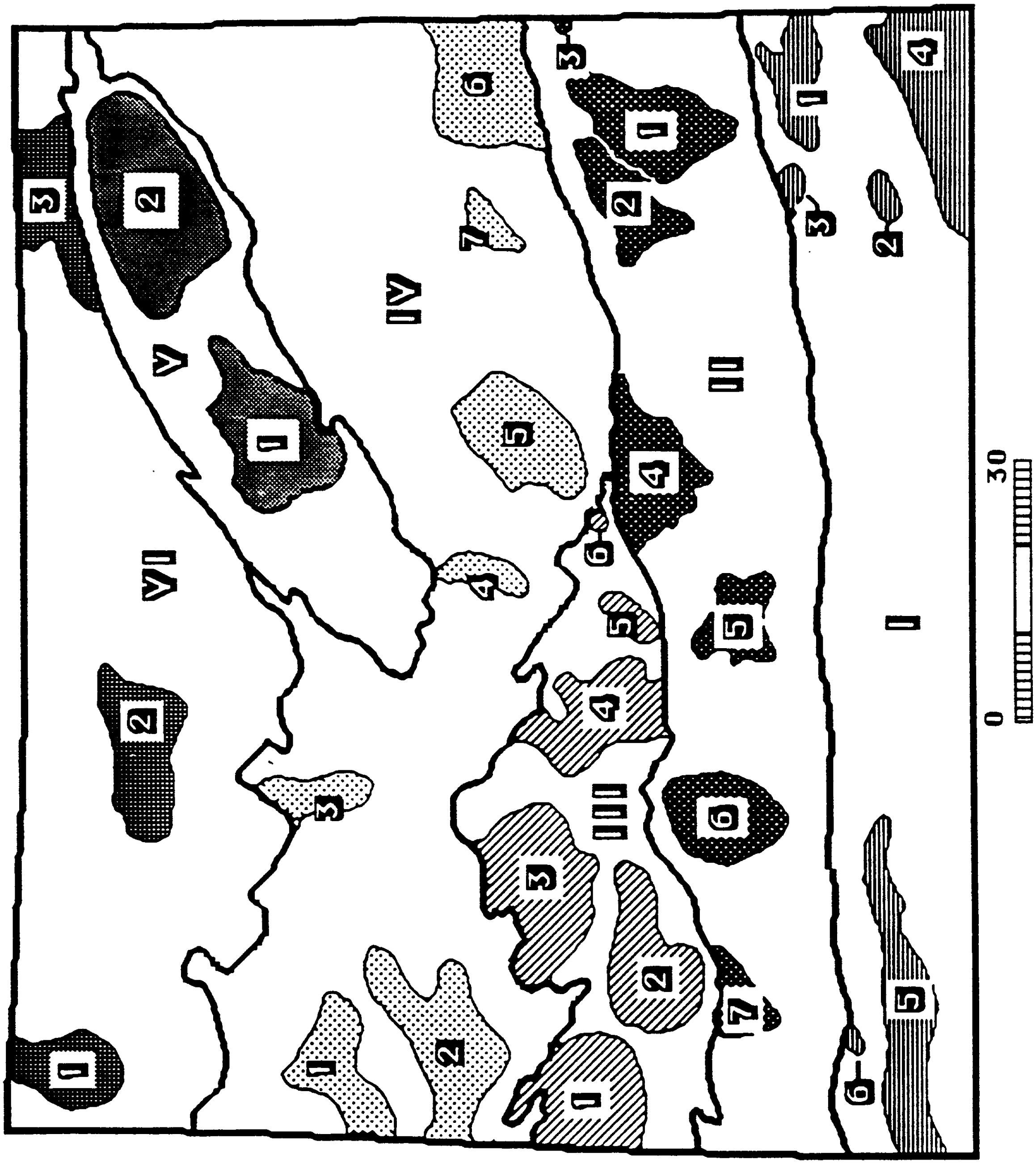

Figure 2. Wiseman 1° by 3° quadrangle, showing six geochemical lithologic subdivisions (I to VI), and geochemical anomalous areas (1,2, 3,...) within each (modified after Cathrall and others, 1987).