UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Quantitative mineral resource assessment of undiscovered mineral deposits for selected mineral deposit types in the Chugach National Forest, Alaska

by

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SUMMARY

Estimates of undiscovered metal endowment of the Chugach National Forest (CNF), Alaska at the 90th, 50th, and 10th percentile by planning unit, by commodity, deposit type, and for the entire forest (in thousand metric tons of metal (except Fe in tonnes); for Au, Ag in thousand of grams unless indicated otherwise) (Au veins=metamorphic Au-quartz veins; Besshi=Besshi massive sulfides; Cyprus=Cyprus massive sulfides; massive sulfides=Besshi plus Cyprus; OP volc. Mn=Olympic-Peninsula-type volcanogenic Mn):

PLANNING UNIT	COMMODITY	DEPOSIT TYPE	PERCENTILES 90	50	10
Big Island-Gravina					
	Au	Au veins	22	210	820
		Gold placers	7.6	130	680
		Cyprus	-	-	2,600
		Besshi	-	-	770
	Ag	Au veins	3.0	33	140
		Cyprus	-	-	22,000
		Besshi	-	-	24,000
	Cu	Cyprus	-	-	150
		Besshi	-	0.25	66
	Pb	Cyprus	-	-	-
	Zn	Cyprus	-	-	12
		Besshi	-	-	-
	Mn	OP volc. Mn	-	4.2	150
	Fe	OP volc. Mn	-	1.5	210
Kenai Peninsula	Au	Au veins	45	510	1,600
		Cyprus	-	-	1,900
		Besshi	-	-	900
	Ag	Au veins	6.6	86	280
		Cyprus	-	-	21,000
	Cu	Cyprus	-	-	140
		Besshi	-	0.24	76
	Pb	Cyprus	-	-	-
	Zn	Cyprus	-	-	10
		Besshi	-	-	34
	Ag	Besshi	-	-	29,000
College Fiord	Au	Au veins	36	370	1,200
		Gold placers	8.6	130	670
		Cyprus	-	-	1,800
		Besshi	-	-	890
		Polymetallic veins	-	36	1,800

	Ag	Au veins	5.4	58	220
		Cyprus	-	-	17,000
		Besshi	-	-	28,000
		Polymetallic veins	1,100.	47,000	500,000
	Cu	Cyprus	-	-	140
		Besshi	-	0.25	265
		Polymetallic veins	-	12	500
	Pb	Cyprus	-	-	-
		Polymetallic veins	130	6,700	62,000
	Zn	Cyprus	-	-	10
		Besshi	-	-	-
		Polymetallic veins	2.9	2,200	51,000
Nellie Juan	Au	Au veins	5.7	200	880
		Gold placers	6.5	130	690
		Cyprus	-	-	6,100
		Besshi	-	-	2,300
	Ag	Au veins	0.35	31	160
		Cyprus	-	-	96,000
		Besshi	-	-	62,000
	Cu	Cyprus	-	-	240
		Besshi	-	0.46	130
	Pb	Cyprus	-	-	-
	Zn	Cyprus	-	-	29
		Besshi	-	-	38
	Mn	OP volc. Mn	-	7.9	190
	Fe	OP volc. Mn	-	2.6	240
Copper River	Au	Au veins	25	210	840
		Cyprus	-	-	23,000
		Besshi	-	-	2,600
	Ag	Au veins	3.5	34	150
		Cyprus	-	-	100,000
		Besshi	-	-	70,000
	Cu	Cyprus	-	-	260
	Cu	Besshi	-	0.59	140
	Pb	Cyprus	-	-	-
	Zn	Cyprus	-	-	37
		Besshi	-	-	38
	Mn	OP volc. Mn	-	0.63	110
	Fe	OP volc. Mn	-	-	180

COMMODITY	DEPOSIT TYPE	PERCENTILES 90	50	10
Au	Au veins	980	2,000	3,900
	Gold placers	180	600	1,700
	massive sulfides	-	6,600	46,000
	Polymetallic veins	-	36	1,800
Ag	Au veins	160	340	670
	massive sulfides (10^6)	-	140	1,000
	Polymetallic veins	1,100	47,000	500,000
Cu	massive sulfides	45	360	12,000
	Polymetallic veins	-	12	500
Pb	massive sulfides	-	-	0.57
	Polymetallic veins	130	6,700	62,000
Zn	massive sulfides	-	59	420
	Polymetallic veins	2.9	2,200	51,000
Mn	OP volc. Mn	3.0	61	340
Fe	OP volc. Mn	-	70	420

The following summary is by commodity, planning unit, and deposit type:

COMMODITY	PLANNING UNIT	DEPOSIT TYPE	PERCENTILES 90	50	10
Au	Big Island-Gravina	Au veins	22	210	820
		Gold placers	7.6	130	680
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		massive sulfides	-	6,600	46,000
		Polymetallic veins	-	36	1,800
Ag	Big Island-Gravina	Au veins	3.0	33	140
		Cyprus	-	-	22,000
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		Besshi	-	-	29,000
	College Fiord	Au veins	5.4	58	220
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Cu	Big Island Gravina	Cyprus	-	-	150
		Besshi	-	0.25	66
	Kenai Peninsula	Cyprus	-	-	140
		Besshi	-	0.24	76
	College Fiord	Cyprus	-	-	140
		Besshi	-	0.25	265
		Polymetallic veins	-	12	500
	Nellie Juan	Cyprus	-	-	240
		Besshi	-	0.46	130
	Copper River	Cyprus	-	-	260
		Besshi	-	0.59	140
	CNF	massive sulfides	45	360	12,000
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Pb	Big Island Gravina	Cyprus	-	-	-
	Kenai Peninsula	Cyprus	-	-	-
	College Fiord	Cyprus	-	-	-
		Polymetallic veins	130	6,700	62,000
	Nellie Juan	Cyprus	-	-	-

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	CNF	OP volc. Mn	3.0	61	340
Fe	Big Island Gravina	OP volc. Mn	-	1.5	210
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	CNF	OP volc. Mn	-	70	420

INTRODUCTION

The Chugach National Forest (CNF), located in the Kenai-Chugach Mountains of south-central Alaska (fig. 1), is about 23,000 km^2 in area. The CNF has been the subject of several mineral resources evaluations by both the U.S. Geological Survey and the U.S. Bureau of Mines. More recently, these studies have been in response to the Wilderness Act (Public Law 88-577, September 3, 1964), the RARE II program (1979-1983) and the Alaska Mineral Resources Program (AMRAP). Early studies within the CNF include those by Brooks (1916), and Capps and Johnson (1915). Studies made during the 1950s include those by Moffit and Fellows (1950); Moffit (1954); and Mihelich and Wells, (1957). Resent studies include those by Dickinson and Morroe (1982); Tysdal and Case (1982), and Jansons and others (1984). Nelson and others (1984b) summary report on the mineral resource potential of the Chugach National Forest was of particular usefulness in this study.

The U.S. Geological Survey is responsible for estimating the endowment of undiscovered deposits; the U.S. Bureau of Mines is responsible for estimating the endowment of discovered but unworked deposits and additional reserves in discovered deposits. This report provides probabilistic estimates of undiscovered metal endowment in the the various planning units within the CNF.

METHOD

The methodology used in this study is based on the "three step method" developed by Singer (1984). The three step method was designed with the recognition that revisions are a common occurrence in mineral resource assessment and that a systematic method is needed that allows revisions to be made without invalidating other parts of the assessment process. Application of the three step methods allow metal endowment of undiscovered deposits to be estimated using Monte Carlo simulation. The steps in the method are the following:

1. Delineate areas according to types of deposits their geology will permit;
2. Estimate the amount of metal and some ore characteristics by means of grade-tonnage models; and,
3. Estimate the number of undiscovered deposits of each type within delineated tracts.

The steps are part of an iterative process all of which depends on the choice of a particular deposit type or model. While each step can be modified without invalidating the others, each must be executed using the same deposit type. Deposit models are those described in Cox and Singer (1986b). While these models identify geologic attributes shared by a group of deposits, the grade-tonnage models describe characteristics of the ore. These can be represented by a frequency distribution, commonly lognormal. Areas delineated are identified as permissible for a specific deposit type based on available geologic and other data. Delineation includes areas with permissible geology--mineral deposits of the type considered may or may not be present within the areas. Estimates of undiscovered deposits are made subjectively[1]. Several estimates of undiscovered deposits involved tracts which extend outside the CNF. They have been adjusted so that they are applicable to the CNF only.

Computer simulation combines the estimated number of undiscovered deposits with grade-tonnage models using Monte Carlo simulation to generate an estimate of the expected metal endowment. An example of this procedure is found in Drew and others (1986). The results of the simulation are reported as the median, upper and lower deciles of metal endowment and are given in the summary at the beginning of this report.

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[1]Subjective estimates of the number of undiscovered deposits were made at a meeting in Anchorage, August 29-31, 1988. Those in attendance included Bob Hoekzema, USBM, Steve Fechner, USBM, Barbara White, USBM, Tom Gunther, USBM, Dean Davidsen, USFS, Steve Nelson, USGS, and Jim Bliss, USGS.

GEOLOGIC SUMMARY

The geology of the Chugach National Forest is dominated by sedimentary rocks predominantly graywacke, siltstone, and slate. Traditionally, they have been divided into two units, the Valdez Group and the Orca Group (Schrader, 1900; Tysdal and Case, 1979; Winkler and Plafker, 1981; Nelson and others, 1984a). Both units have a slaty fabric. Nelson and others (1984a) reported that differences in lithology and types of ore deposits between the two units are not as pronounced as thought by previous investigators. The Orca Group (Paleocene to Eocene) is a complexly deformed flysch sequence containing tholeiitic pillowed flows. Dikes and sills of mafic composition occasionally intrude the mixed volcanic and sedimentary rocks. The Valdez Group (Upper Cretaceous) consist of enterbedded greywacke, siltstone, and mudstone. Pebble conglomerates are present but rare. Deposition by turbidite currents is currently suspected.

Intrusive rocks are usually associated with either an Eocene event or an Oligocene event. All events followed the accretion and deformation of both the Valdez and Orca Groups. The earlier intrusive event is dated as 50-53 million years in age using potassium-argon methods; the younger plutons are dated as 34-37 million years (Tysdal and Case, 1979; Winkler and Plafker, 1981; Nelson and others, 1984a). Compositionally, the earlier intrusive rocks includes biotite granite, hornblende-biotite granite, granodiorite, and tonalite. The later intrusive event includes mafic to felsic plutons (Goldfarb and others, 1986).

MINERAL DEPOSIT TYPES

Introduction

Tracts were delineated for six mineral deposit types. Models were developed or standard grade-tonnage models were used in the evaluation of all deposit types considered. Four deposit types are among the models compiled by Cox and Singer (1986b) and includes Au placers, Cyprus massive sulfides, Besshi massive sulfides, and polymetallic veins. The remaining two deposit types include Olympic-Peninsula-type volcanogenic Mn (Mosier and Page, 1988) and metamorphic Au-quartz veins. The latter, found in the Chugach National Forest, could not be successfully described with existing grade-tonnage models so one was developed and given herein.

The classification of the known massive sulfides in the Chugach National Forest is somewhat controversial. These deposits have been described by Holt (1942), Tysdal (1978), Janson and others (1984), Nelson and others (1984b) and Nokelberg and others (1987) and may be Cyprus massive sulfides or Cyprus massive sulfides plus Besshi massive sulfides. For the purposes of this assessment, both deposit types will be considered to be represented. The Besshi type deposits on a world average are considerably smaller in size then the Cyprus type deposits; the median deposit has 10 percent of the Cu, four percent of the Ag, six percent of the Au, and three percent of the Zn as compared to the median size Cyprus massive sulfide deposit.

Tract delineation was based on permissible geology and (or) mineral occurrence. Subjective estimates of the number of undiscovered deposits were made for massive sulfides without explicitly stating which of the two deposit types might be present. Therefore, the classification of an undiscovered massive sulfide deposit was made based on the ratio of identified Cyprus-type deposits to identified Besshi-type deposit in the CNF. This ratio is 3 to 4.

Besshi massive sulfides

Known Besshi massive sulfides of the world are found predominantly in marine sedimentary and extrusive rocks, including ophiolites. The deposits are stratiform bodies of Fe- and Cu-sulfides in thinly laminated sedimentary rocks and mafic to andesitic tuffs (Cox, 1986a). The primary commodity is Cu; by-products include Ag, Au, and Zn (Singer, 1986b). Deposits are believed to form near the sea floor as a result of hydrothermal activity. These deposits are rootless (D.A. Singer, oral communication, 1986), meaning they lack feeder veins, and therefore, are likely distal.

Besshi deposits are hosted by continentally derived clastic rocks, such as deltaic sandstone, hemipelagic mudstone, and siltstone (Fox, 1984). Some deposits may be associated with black shale, oxide facies of iron formation and red chert. Japanese deposits of this type occur in stratigraphic sections consisting of equal parts metasedimentary rocks and metamorphosed mafic volcanic rocks (Laznicka, 1985). Horizons with more volcanic rocks tend to contain more deposits. The type of tectonic setting permissive for this deposit type is unclear (Cox, 1986a). These deposits may occur in rift basins in island arcs or back arcs or even in spreading centers on or adjacent to continental slopes. Other types of mineral deposits associated with the Besshi massive sulfides are as yet undetermined.

The best studied Besshi deposits are in Japan. Those deposits 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 include magnetite, valleriite, galena, bornite, tetrahedrite, cobaltite, cubanite, stannite, and molydenite. Non-ore minerals include quartz, carbonate minerals, albite, white mica, chlorite, amphibole, and tourmaline. Deposits generally lack zoning. Some deposits are underlain by what has been interpreted as manganiferous exhalite (Fox, 1984). Some Japanese deposits have been found to extend down dip for at least 2,500 m. Deposits 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, sphalerite, and calcite (Cox, 1986a). The veins have been interpreted as the result of remoblization during metamorphism, not as footwall feeders (Laznicka, 1985). Gossans may develop during weathering. The geochemical expressions of theses deposits consist of Cu, Zn, Co, Ni, Cr, Au and Ag anomolies. The Cu/Ni ratio is approximately 0.8 (Cox, 1986a).

The grade-tonnage model for Besshi massive sulfides was developed using data for deposits in Japan with at least 10,000 tonnes combined production and reserves (Singer, 1986b). No correlation was found among the metal grades or between grade and tonnage. Thirty percent of the 44 deposits have Ag and (or) Au values; 15 percent have Zn values. The median deposit in the model contains 220,000 tonnes; the median Cu grade is 0.64 percent.

Tracts delineated for massive sulfides are based on the presence of permissible host rock and (or) known mineralization (fig. 2). The following properties (or districts) in or adjacent to the CNF are predominantly associated with sedimentary rocks (Nelson and others, 1984b) and are classified as Besshi massive sulfides: Midas, Beatson, Ellamar, Four-in-one, Scott Glacier, Duchess, and Schlosser.

Cyprus massive sulfides

Cyprus massive sulfides deposits consist of pyrite, chalcopyrite, and sphalerite hosted by pillow basalts (Singer, 1986a). Cu is the primary commodity; other commodities include Ag, Au, Pb, and Zn (Singer and Mosier, 1986). Deposits are associated with ophiolites and likely formed by submarine hot springs in or adjacent to an axial graben at either an oceanic or back-arc spreading ridge. Host rocks include dunite, harzburgite, gabbro, pillow basalts, and diabase dikes. Felsic volcanic rocks are rare, but, if present, are usually keratophyre. Some deposits are adjacent to steeply dipping faults. Regionally, Fe- and (or) Mn-rich cherts may be associated with some deposits (Hutchison, 1982); this includes some radiolarian cherts. Deposits are lenticular and concordant; mineralogically they are dominated by pyrite with lesser amounts of chalcopyrite and sphalerite (Laznicka, 1985). Maracasite and pyrrhotite may be present (Singer, 1986a); siliceous enrichment at the deposit base is only occasionally noted. Stockworks of pyrite and pyrrohotite veins may be found below these deposits and may extend for 700 m (Hadjistavrinou and Constantinou, 1982). Veins may contain Co, Au, and Ag. Those deposits hosted by basalts are associated with rocks which are silicified, chloritized, and argillized and have veins containing quartz and jasper (Laznicka, 1985). Weathered ore will contain limonite gossans (Singer, 1986a) and rock fragments with sulfide banding (Laznicka, 1985). Streams adjacent to weathered deposits may contain gold placers (Singer, 1986a).

The grade-tonnage model for Cyprus massive sulfides was developed from data for 49 world wide deposits underlain by mafic or ultramafic rocks. In addition, the host rock sequence must contain either pillow basalts or diabase dikes (Singer and Mosier, 1986). No correlation exists between the various metal grades or be between any given metal grade and tonnage. Thirty percent of the deposits contain Ag, Au, and Zn. About 10 percent contain Pb. The median deposit contains 1,600,000 tonnes; the median Cu grade is 1.7 percent.

Tracts delineated for Cyprus massive sulfides (fig. 2) are the same as for Besshi massive sulfides (see). The following properties (or districts) in the CNF are predominantly associated with volcanics (Nelson and others, 1984b) and are classified as Cyprus massive sulfides: Threeman, Rua Cove, Pandora Fidalgo, Cordova , Hemple, Copper Coin Galena Bay, Standard Copper, Ibeck, Reynolds-Alaska, Seattle-Alaska, Jonesy and Chisna.

Metamorphic Au-quartz veins

Metamorphic Au-quartz veins have characteristics which are consistent with the descriptive model for low-sulfide Au-quartz veins (Berger, 1986). However, a comparison of grade-tonnage data from these vein deposits in and adjacent to the CNF show that these deposits have about half the tonnages and half the Au grades as those for low-sulfide Au-quartz veins (Bliss, 1986). Metamorphic Au-quartz vein deposits are located along faults and joints without a "consistent association with igneous activity " (Goldfarb and others, 1986). Fluid inclusion data suggest these deposits were deposited by low salinity fluids generated by low-grade metamorphism (Goldfarb and others, 1986). In the case of the Valdez Group, this is dominantly medium greenschist facies. These deposits do not exhibit wall rock alteration (Goldfarb and others, 1986) which is a prominent feature of low-sulfide Au-quartz veins (Berger, 1986).

The grade-tonnage model (figs. 3-5) developed for this assessment contains data for 29 metamorphic Au-quartz vein deposits in and adjacent to the CNF. The deposit definition adopted the same spatial rules concerning proximity of workings as was used to develop the model for low-sulfide Au-quartz veins (i.e., properties within one mile of each other are aggregated). Data sources are from Jansons and others (1984) and the Survey computerized database on mineralized occurrences, prospects and mines (the Minerals Resources Data System (MRDS)). Examples of deposits of this type include Cameron-Johnson, Cliff-Sealy, Crown Point-Fall Creek and Granite-Snowball. Significant correlation is present between Ag and Au grades (n=21, r=0.77). The median deposit contains 32,000 tonnes; the median Au grade is 6.2 g/tonne and median Ag is 1.1 g/tonne. Tract delineation of metamorphic Au-quartz veins is based on permissible geology and (or) known mineralized occurrences (fig. 6).

Olympic-Peninsula type volcanogenic Mn

The Olympic-Peninsula type volcanogenic Mn deposit type is one of four types of volcanogenic Mn deposits identified by Mosier and Page (1988). Of the four, the Olympic Peninsula type is the smallest in terms of volume and tonnage although the Franciscan deposit type is within the same order of magnitude of size (Mosier and Page, 1988). In terms of contained Mn, the Olympic Peninsula is also one of the two smaller deposit type and, again, comparable to the contained Mn in the Franciscan type (Mosier and Page, 1988). The median length is 13.5 m, width is 4.7 m, and thickness is 3.9 m. This deposit type is easy to miss during exploration in areas covered by vegetation.

The grade-tonnage model based on data for 17 deposits is from Mosier and Page (1988). The median deposit contains 340 tonnes; the median Mn grade is 35 weight percent. Four deposits contained Fe; their mean grade is 6.5 percent Fe (Mosier and Page, 1988). No correlation exists between Mn grade and tonnage. Tract delineation was based on permissible geology (fig. 7) and Mn occurrences of which two have been identified. One is described by Kurtak (1982) and is located on Chenega Island; the other occurrence is on Hinchinbrook Island (Goodfellow and others, 1984).

Gold placers

Placers can occur even where significant lode deposits are not present. One type of source terrane without significant lode deposits which seems to be common is one that consists of slate, phyllite, and schist. This type of terrane has been recognized in 17 major placer districts of the world (Wojcik, 1984). These rocks are believed to have developed from Au-enriched shales in which the Au is in pyrite and other sulfides of less than 50 micrometers in size. Au that finely divided is not effectively concentrated by surface processes; thus Boyle (1979) has suggested this Au will either be dispersed or dissolved during erosion. However, if the shale is metamorphosed, Au changes both location and grain size so that concentration becomes possible during weathering and erosion. Au placers can also develop in the vicinity of a variety of lodes deposits including low-sulfide Au-quartz veins, porphyry Cu, Cu skarn, and polymetallic replacement deposits (Yeend, 1986).

Placer deposits have been classified into a number of types including Tertiary, bench, glacial-fluvial, and alluvial plain, among others. Orris and Bliss (1986) suggest that traditional Au placer type classifications do not define populations with unique grade-tonnage models. They have prepared a general model applicable to most placer types and placer deposits. The median placer deposit for the model used in this study contains 1,100,000 tonnes; the median Au grade is 0.2 g/tonne. Twenty five percent of the deposits contain Ag (Orris and Bliss, 1986).

Delineation of tracts for placer deposits are based on permissible geology and (or) presences of Au placer, and metamorphic Au-quartz veins which may also be a bedrock source of Au (fig. 6).

Polymetallic veins

Polymetallic veins is a widely found deposit type under a number of geologic situations. Cox (1986b) suggested that this deposit type is related to hypabyssal intrusive rocks in sedimentary and metamorphic terranes. Commodities include Ag and Pb; by-product commodities include Au, Cu, and Zn (Bliss and Cox, 1986). Deposits are thought to form near the surface in fractures and breccias within thermal aureole of clusters of intrusions which have compositions ranging from calcalkaline to alkaline, diorite to granodiorite, and monzonite to monzogranite. The deposit type as currently defined may be associated with porphyry Cu-Mo, porphyry Mo low F, and polymetallic replacement and placer Au. Bliss and Cox (1986) suggest that two subtypes are present--a base-metal polymetallic veins worked primarily for a base metal or metals and silver and a rarer gold-silver polymetallic veins worked primarily for precious metals with base metals in less than half of the deposits. The latter subtype does not have a grade and tonnage model and will not be considered here.

The grade-tonnage model was developed for 75 deposits predominantly from the Slocan Mining District, British Colombia, Canada. Properties within one kilometer were treated as working the same deposit. Thirty five percent of the deposits report Cu and 80 percent report Zn. Zinc grades are subject to considerable uncertainty because smelters have in the past penalized the producers for ore containing Zn which in turn caused mine operators to avoid Zn-bearing ore in their mining and milling. Seventy percent of the deposits report Au.

Tract delineation for polymetallic veins is based on the presence of intrusives and (or) occurrences. A single tract (fig. 8) is delineated in the College Fiord planning unit (fig. 1). No deposit is currently recognized in the unit or CNF based on the definition of a deposit used to construct the grade-tonnage model (100 tonne)(Bliss and Cox, 1986).

Other deposits type

Deposit types may be present in CNF for which data is insufficient for definition of deposit type, tract delineation, and (or) estimate of number of undiscovered deposits. These deposit types may be suggested (1) by associations they have with deposit types used to make estimates of metal endowment and (2) by the other evidence found in the description of occurrences and others types of geologic evidence. Polymetallic veins for which a tract is delineated have been found with a number of other deposits types. This includes porphyry Cu-Mo, porphyry Mo low F, polymetallic replacement and Au placers (Cox, 1986). Evidence for porphyry Cu-Mo or porphyry Mo is also suggested by an occurrence with disseminated pyrite and chalcopyrite associated with molybdenite in veins and disseminates in the Billings Glacier pluton (Nelson and others, 1984; Hoekzema and Sherman, 1981). This occurrence is NOT in the delineated tract for polymetallic veins.

Antimony occurs in at least four location in stibnite-bearing veins in the CNF (Johnson, 1914; 1915; Brook, 1916; Hoekzema and Sherman, 1981). The descriptive model for simple Sb deposits (Bliss and Orris, 1986a) and associated grade- tonnage models (Bliss and Orris, 1986b; 1986c) may be appropriate.

Anomolous levels of Cr, Co, and Ni in geochemical samples (Nelson and others, 1984b) may be from one or more deposit types associated with mafic and (or) ultramafic rocks (Cox and Singer, 1986a). Ba found in pan-concentrate geochemical samples (Nelson and others, 1984b) may be from Ba veins.

ESTIMATED NUMBER OF UNDISCOVERED DEPOSITS

In order to estimate the metal endowment of the BIG planning unit, a probabilistic estimate of the number of undiscovered deposits was made. Since the computer simulation uses standard grade-tonnage models, the deposit definition used for the estimation of the number of undiscovered deposits must also consider the minimum tonnage and other requirements and spatial the proximity rules used by the model builder. Undiscovered deposits may be found in three general situations:

1. undiscovered deposit adjacent to known deposits (but not extensions thereof) or in districts with known deposits,
2. undiscovered deposits which are manifest by mineralization at prospects and occurrences present at the surface, and
3. undiscovered deposits in areas with permissible geology but hidden by surface cover (ice, lakes, Quaternary fill, etc.) or located at depth.

Subjective estimates were adjusted using mineral deposit spatial models which are described for the Olympic-Peninsula-type volcanogenic Mn (Mosier and Page, 1988). The following subjective estimates of the numbers of undiscovered deposits were made by deposit type for each planning unit. For each deposit type, estimates were made of the largest number of undiscovered deposits that may be present with probabilities equal or greater than, respectively, 0.9, 0.5, and 0.1.

DEPOSIT TYPE	CNF PLANNING UNIT	Probability .90	.50	.10
Olympic-Peninsula-type volcanogenic Mn		0	9	24
	Big Island-Gravina	0	3	8(1)
	College Fiord	NT	NT	NT(2)
	Nellie Juan	0	4	10(1)
	Copper River	0	2	6(1)
Metamorphic Au-quartz veins		6	26	43
	Big Island-Gravina	0	2	6
	Kenai Peninsula	2	8	14
	College Fiord	2	6	10
	Nellie Juan	1	4	7
	Copper River	2	4	6
Au placers		3	6	9
	Big Island-Gravina	0	3	8
	Kenai Peninsula	0	0	0(3)
	College Fiord	1	2	3
	Nellie Juan	1	2	3
	Copper River	0	0	0
Massive sulfides(4)		5	7	12
	Big Island-Gravina	1	1	2
	Kenai Peninsula	1	1	2
	College Fiord	1	1	2
	Nellie Juan	1	2	3
	Copper River	1	2	3
	Outside	0	1	1(5)
Polymetallic veins		1	3	5
	College Fiord	1	3	5
Ag veins		1	3	6(6)

(1) Estimated number of undiscovered deposits made using deposit spatial models for the deposit type (Mosier and Page, 1988). (2) NT indicated that "No Tract" or part thereof was delineated in that particular planning unit. (3) All Au placers have been found; additional Au resources are extension of known mineral deposits. (4) Estimated of number of undiscovered massive sulfide deposits was made without distinguishing between two deposit types involved--Cyprus massive sulfides and Besshi massive sulfides. Selection of grade-tonnage model for undiscovered deposits is based on the ratio of Cyprus to Besshi type deposits in or adjacent to the CNF or 3:4 (also see text); subjective estimates have been redistributed from tracts used by the panel to CNF planning units based on the area of intersections. (5) One tract included 540 km^2 outside the north side of the CNF and a portion of the estimated number of undiscovered deposits have been assign to this area and **not** used in the assessment. (6) All of the Valdez group in all planning units is permissible; grade-tonnage model not available; metal endowment suspected to be small.

COMPUTER SIMULATION

The results of the computer simulation are in the summary at the front of this report. The grade-tonnage models used in this simulation are for the Besshi massive sulfide by Singer (1986); for the Cyprus massive sulfide by Singer and Mosier (1986), for Olympic-Peninsula-type volcanogenic Mn by Mosier and Page (1988), for metamorphic Au as developed and reported in this report, for gold placers by Orris and Bliss (1986) and for the polymetallic veins by Bliss and Cox (1986).

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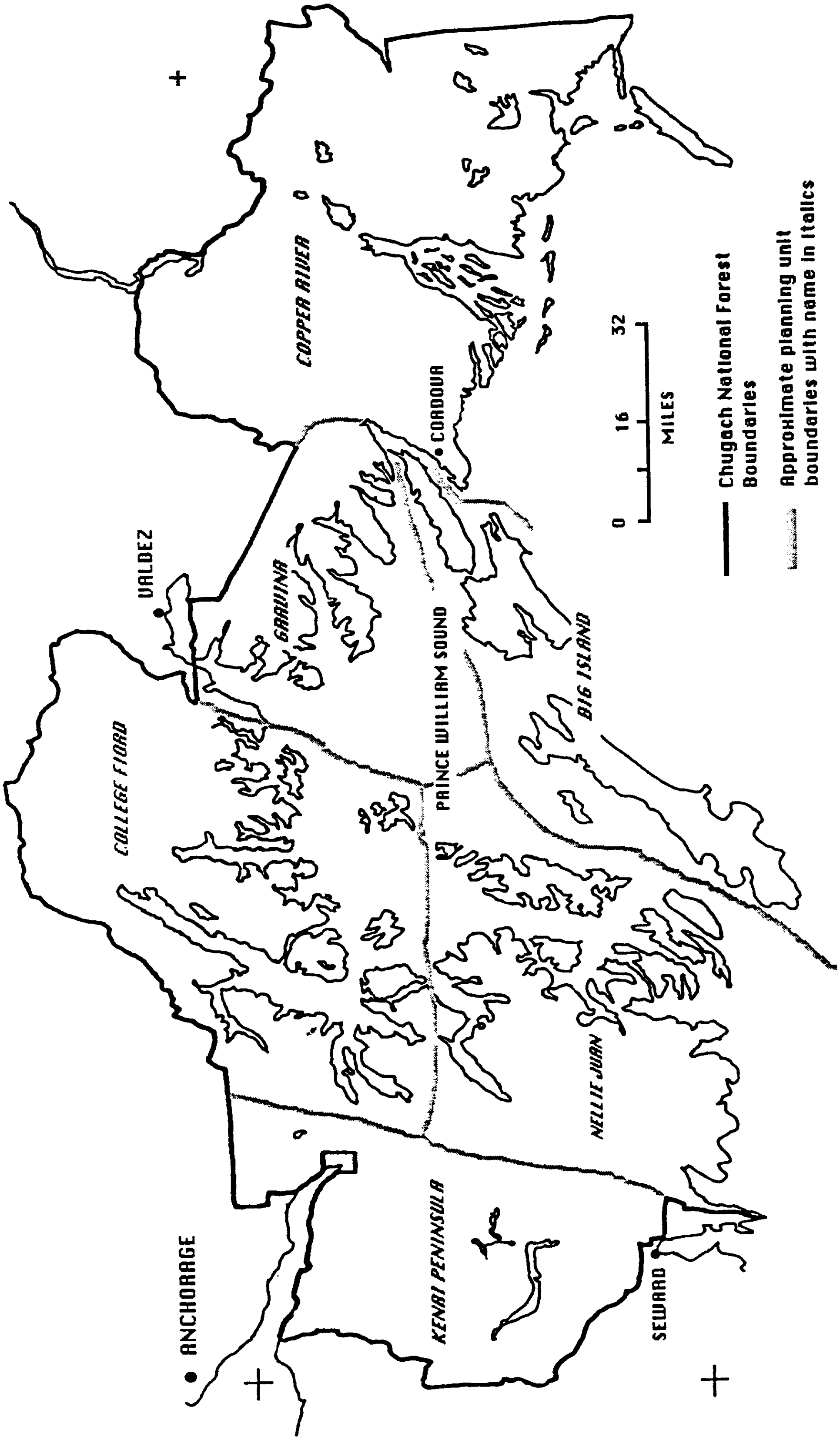
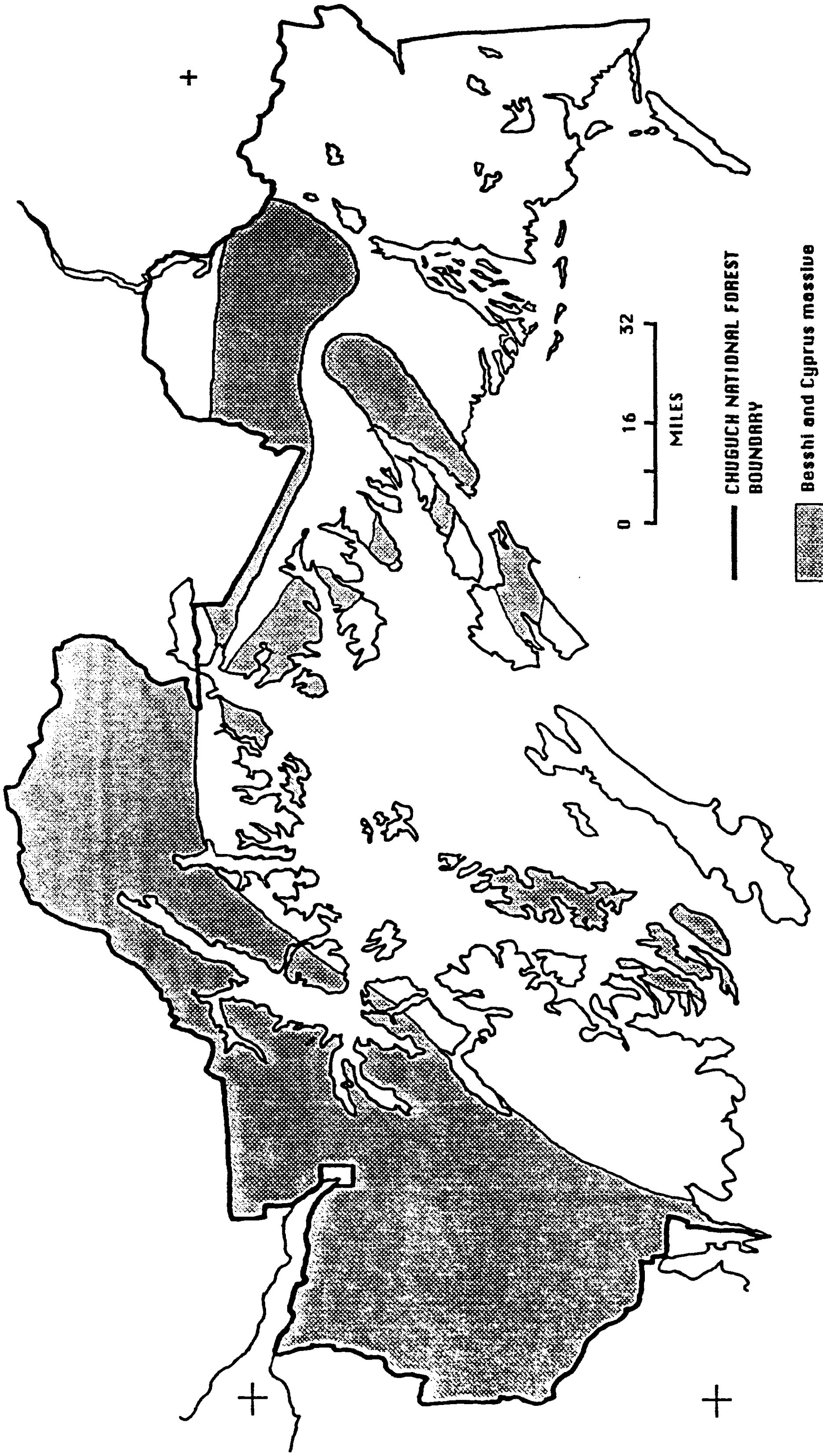

ANCHORAGE
KENAI PENINSULA
SEWARD
NELLIE JUAN
COLLEGE FIORD
PRINCE WILLIAM SOUND
BIG ISLAND
GRAVINA
VALDEZ
CORDOVA
COPPER RIVER
0
16
32
MILES
Chugach National Forest Boundaries
Approximate planning unit boundaries with name in italics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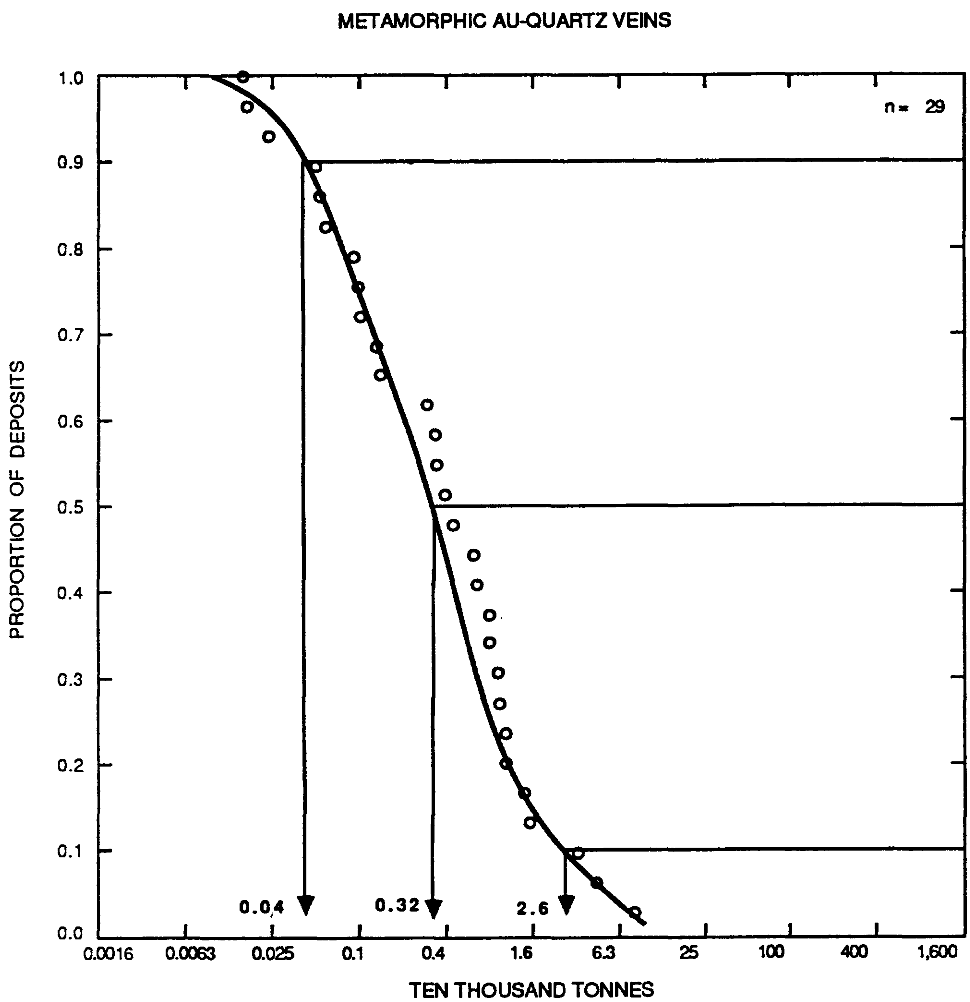
MILES
CHUGUCH NATIONAL FOREST
BOUNDARY
Besshi and Cyprus massive
sulfide tracts



METAMORPHIC AU-QUARTZ VEINS
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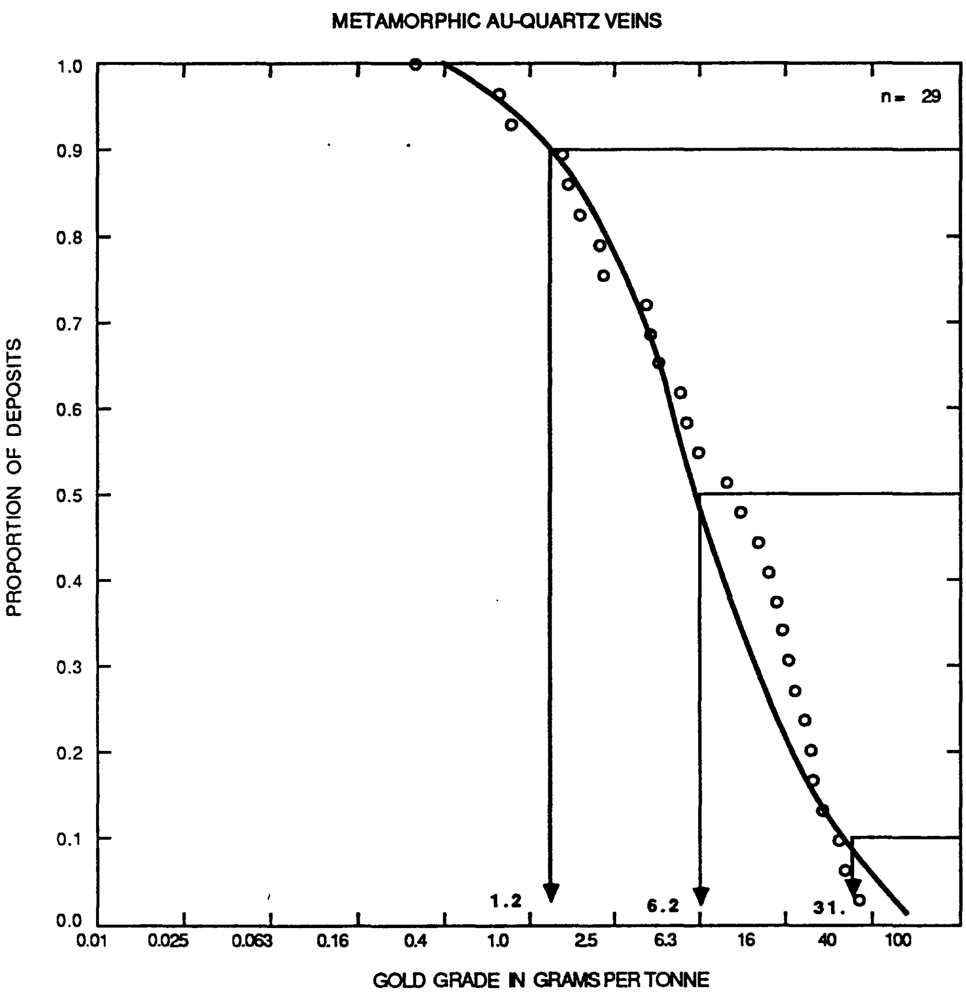
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.04
0.32
2.6
0.0016
0.0063
0.025
0.1
0.4
1.6
6.3
25
100
400
1,600
TEN THOUSAND TONNES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1.2
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0.063
0.16
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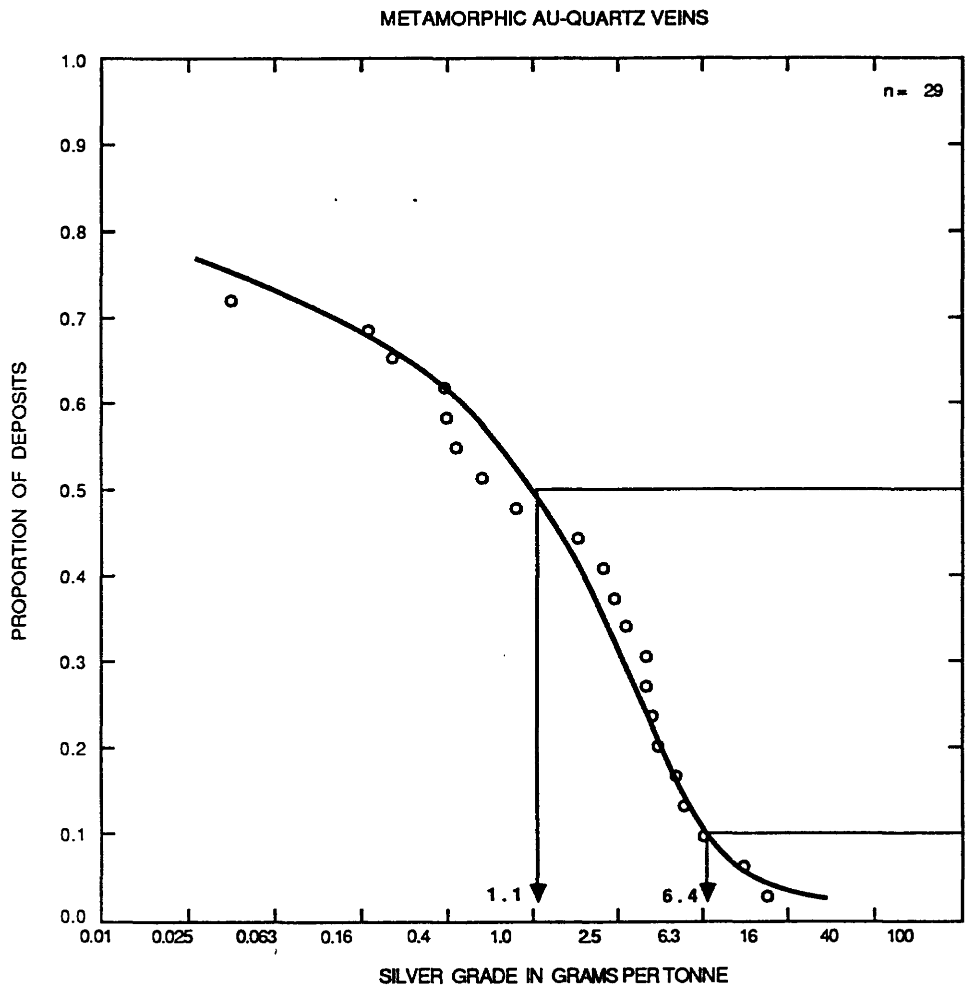
1.0
2.5
6.3
16
40
100
GOLD GRADE IN GRAMS PER TONNE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6.4
0.01
0.025
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0.4
1.0
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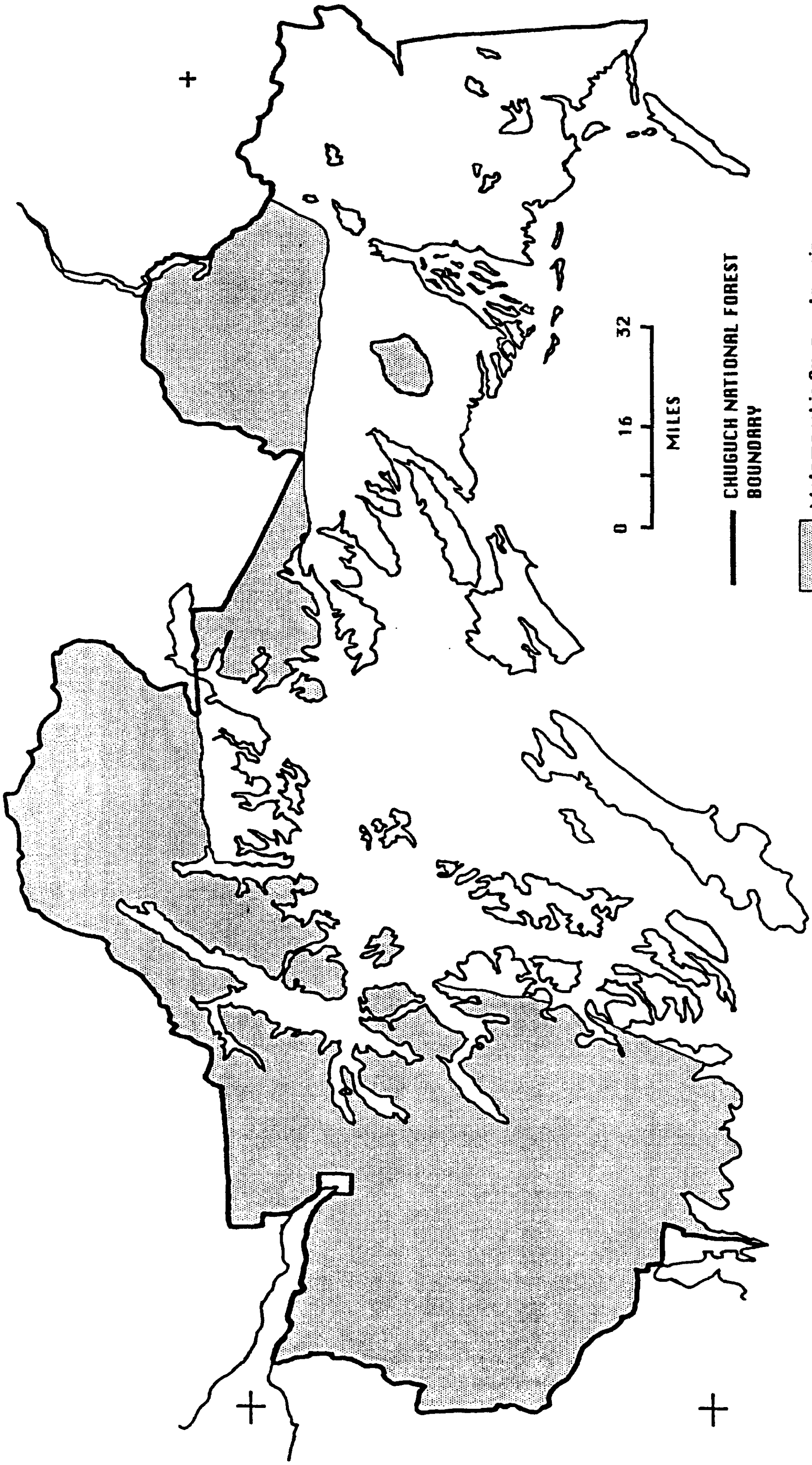
16
40
100
SILVER GRADE IN GRAMS PER TONNE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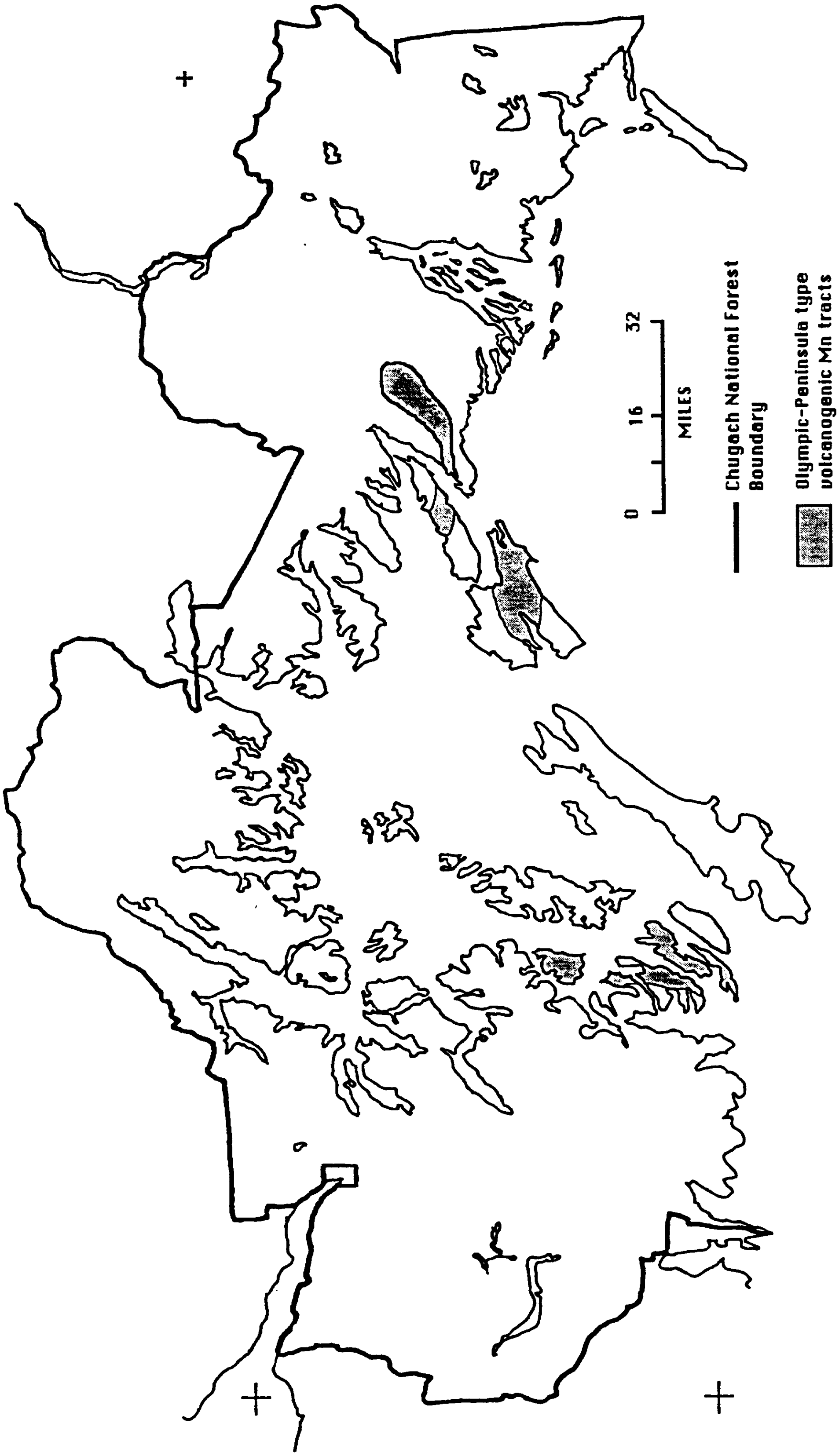
Metamorphic Au-quartz veins and Au placer tracts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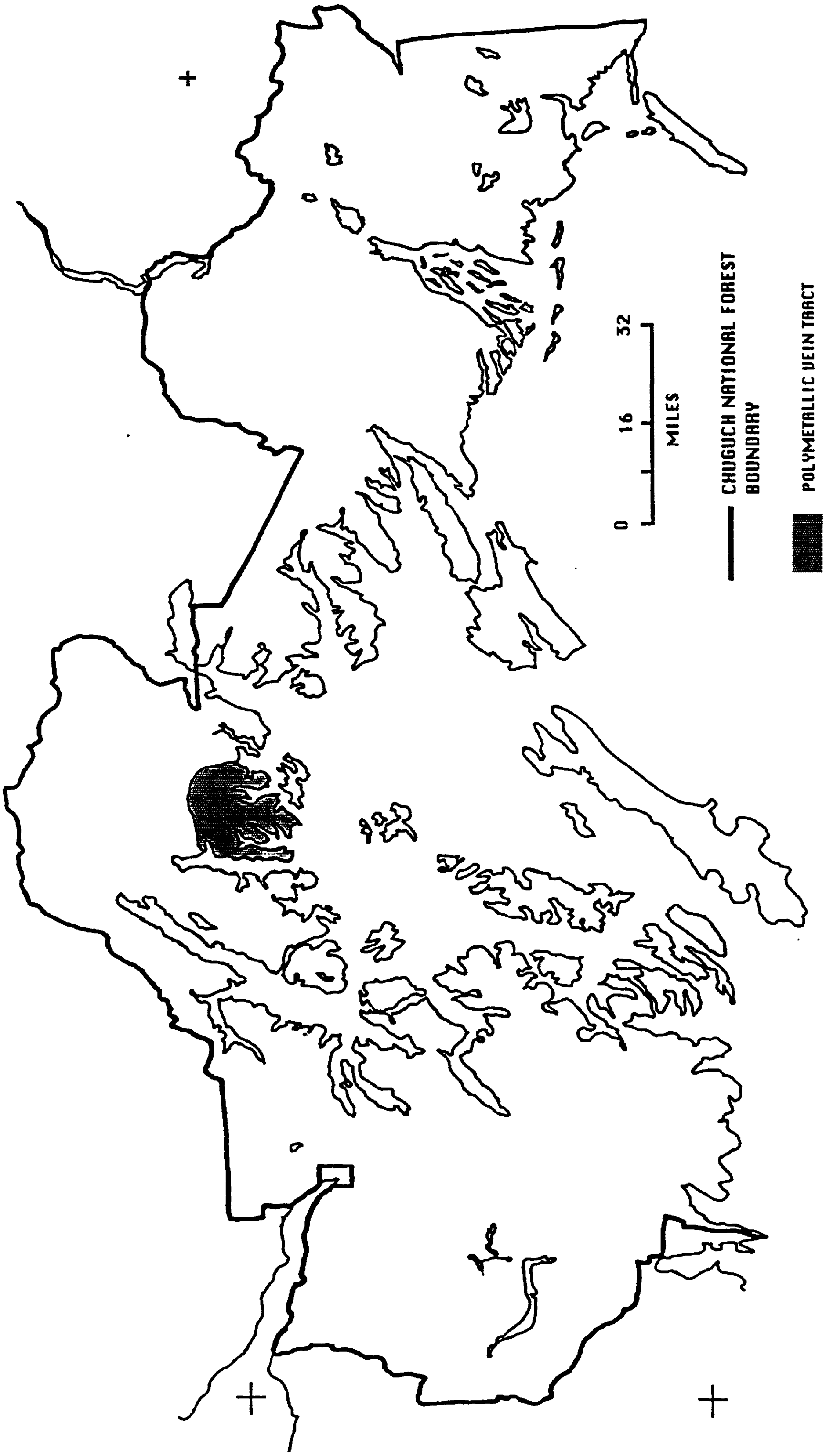
MILES
Chugach National Forest Boundary
Olympic-Peninsula type volcanogenic Mn tracts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MILES
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BOUNDARY
POLYMETALLIC VEIN TRACT