KNOWN AND POTENTIAL MINERAL RESOURCES
SEWARD PENINSULA, ALASKA

MIRL Report #18

by

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FORWARD

This report has been prepared under Contract No. DAW85-68-C-0117 for the Department of the Army Corps of Engineers. It is presented in two parts:

PART I: KNOWN MINERAL RESOURCES, PRODUCTION AND OCCURRENCES, SEWARD PENINSULA, ALASKA.

PART II: POTENTIAL MINERAL RESOURCES, SEWARD PENINSULA, ALASKA.

The study utilizes all available information pertaining to the resources of the Seward Peninsula in an attempt to present factual data as well as to predict by statistical means the resources yet to be found.

The contract was granted the 28th of June with the completion date the 15th of September.

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I. KNOWN MINERAL RESOURCES, PRODUCTION AND OCCURRENCES, SEWARD PENINSULA, ALASKA

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INTRODUCTION

The region comprises all of the Seward Peninsula including the Buckland River and its tributaries to the northeast and the Ungalik and Shaktolik Rivers and Egavik Creek and their tributaries to the southeast. The Seward Peninsula mining region consists, according to the Federal Bureau of Mine's classification (Ransome, 1954, p. 49) of seven districts namely: Council, Fairhaven, Kougarok, Koyuk, Nome, Port Clarence, and Serpentine. (See Figure 1, Index Map)

The Seward Peninsula is generally regarded as being one of the best mineralized areas in Alaska. (Anderson, 1968; Ballele, 1961) Geologically, the Seward Peninsula Province borders the Central Uplands and Plains Province. The large areas of Precabrian and Palezoic metamorphic rocks that cover the Peninsula are more closely related to those in adjacent Siberia than to those in Alaska. Mesozoic sedimentary rocks are less common than in the Central Uplands and Plains Province. Quaternary volcanic rocks occur in the central part of the Peninsula. Small masses of igneous intrusive rock, largely granitic, are scattered over much of the area.

Many mineral occurrences have been found in the Seward Peninsula mining region. These mineral commodities include: Gold, silver, platinum, tin, tungsten, beryllium, copper, lead, zinc, antimony, mercury, bismuth, molybdenum, manganese, arsenic, iron, mica, fluorite, graphite, uranium, and other radioactives. Gold, silver, and tin have been the minerals which have been developed and mined. There has been some production from base metal minerals, but this has been insignificant.

Recent exploration activity on the Peninsula and reports by the USGS and the

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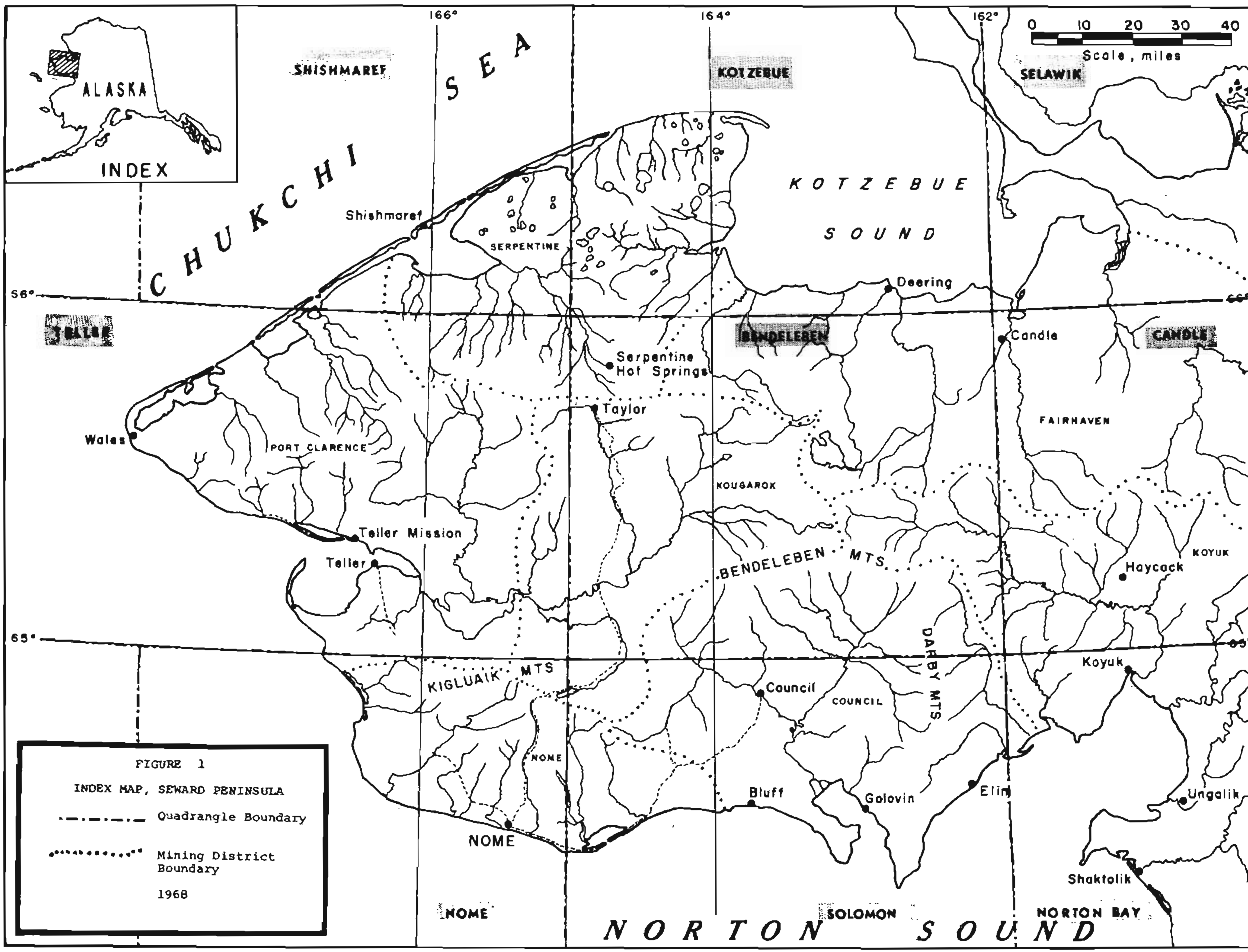


FIGURE 1

INDEX MAP, SEWARD PENINSULA

Division of Mines and Minerals (see Bibliography) indicate that there is good potential for the discovery of new reserves. A summary of the potential of the Seward Peninsula by Anderson (1968) is contained in the "Final Report - Mineral Resources of Northern Alaska" edited by Heiner, L. E., and Wolff, E. N. This report also gives a property by property discription of known occurrences and may be obtained from the Mineral Industry Research Laboratory of the University.

The information and data collected here is derived from many sources, which necessarily vary in reliability and completeness. Efforts are made, however, to reduce all the sources of information to a comparable basis and to give only those that appear to be well substantiated. Therefore, most of the data are extracted from the publications of the U. S. Geological Survey and the U. S. Bureau of Mines. Other sources which include unpublished works of the Territorial Division of Mines and Minerals, now the State Division of Mines and Minerals, are listed in the Bibliography.

MINERAL OCCURRENCES AND CLAIM ACTIVITY

Figures 2 through 5 indicate spatially the location of the more important mineral occurrences and indicates properties which have had recorded production. These maps were prepared from maps and publications of the U.S. Geological Survey. Figure 2 lists precious metals (gold-silver lode, platinum lode and gold placer distribution.) Figure 3 indicates the distribution of tin, tungsten, molybdenum, iron, and fluorite. Figure 4 shows the location of the base metals: copper, lead, and zinc. Figure 5 indicates the distribution of the more important antimony, mercury, and bismuth occurrences. More detailed data concerning these elements may be found in the section entitled, "Historical Review and Production Statistics."

The Division of Mines and Minerals' Mineral Kardex files were searched to obtain the number and type of mineral claims on the Peninsula. Table 1 indicates the number and type of patented mineral claims currently recorded. It shows that there are 36,885 acres patented. Table 2 summarizes information pertaining to active mineral claims and Table 3 summarizes information pertaining to inactive mineral claims. There are 305 active lode claims, 1351+ active placer claims, 765+ inactive lode claims, and 1725+ inactive placer claims. Data for these Tables are considered current as of June 1968. Data for inactive claims is extremely difficult to obtain as claims have been dropped, restaked or not cumulated on the Kardex summary.

Mineral claim information has been placed on Figures 6 through 8 to show spatial distribution of mining and exploration activity. This information was extracted from the Division of Mines and Minerals Kardex file.

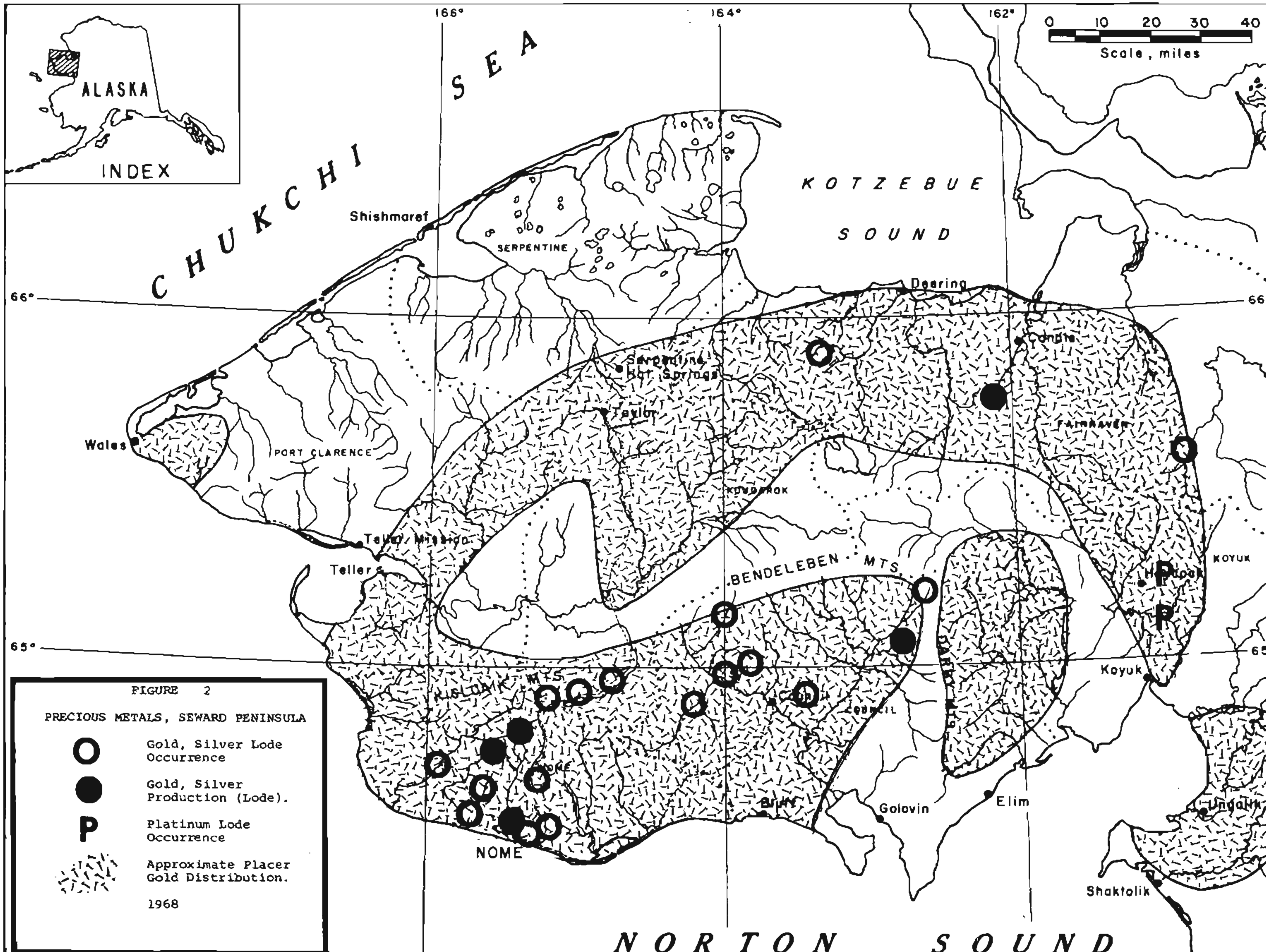


FIGURE 2

PRECIOUS METALS, SEWARD PENINSULA

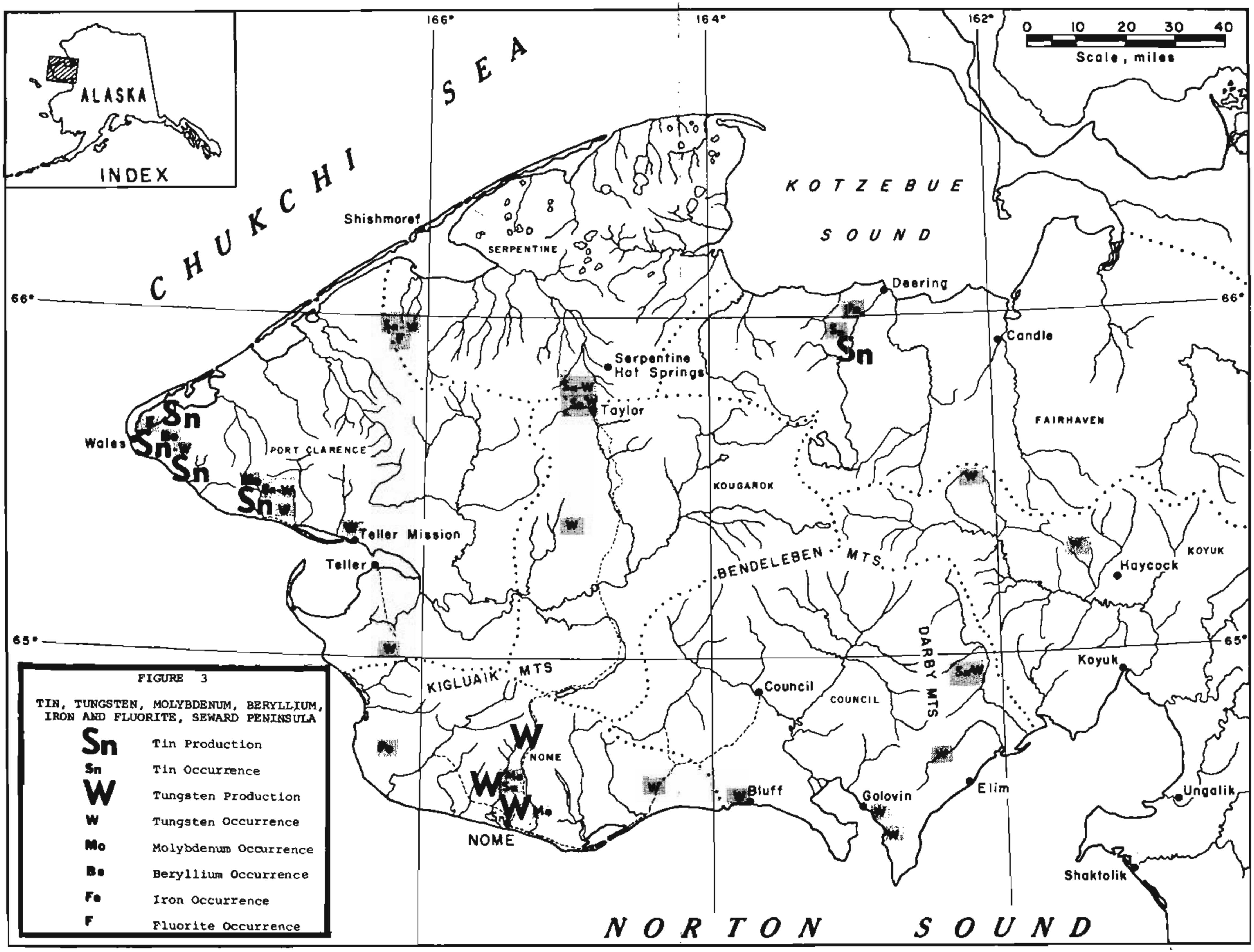


FIGURE 3

TIN, TUNGSTEN, MOLYBDENUM, BERYLLIUM, IRON AND FLUORITE, SEWARD PENINSULA

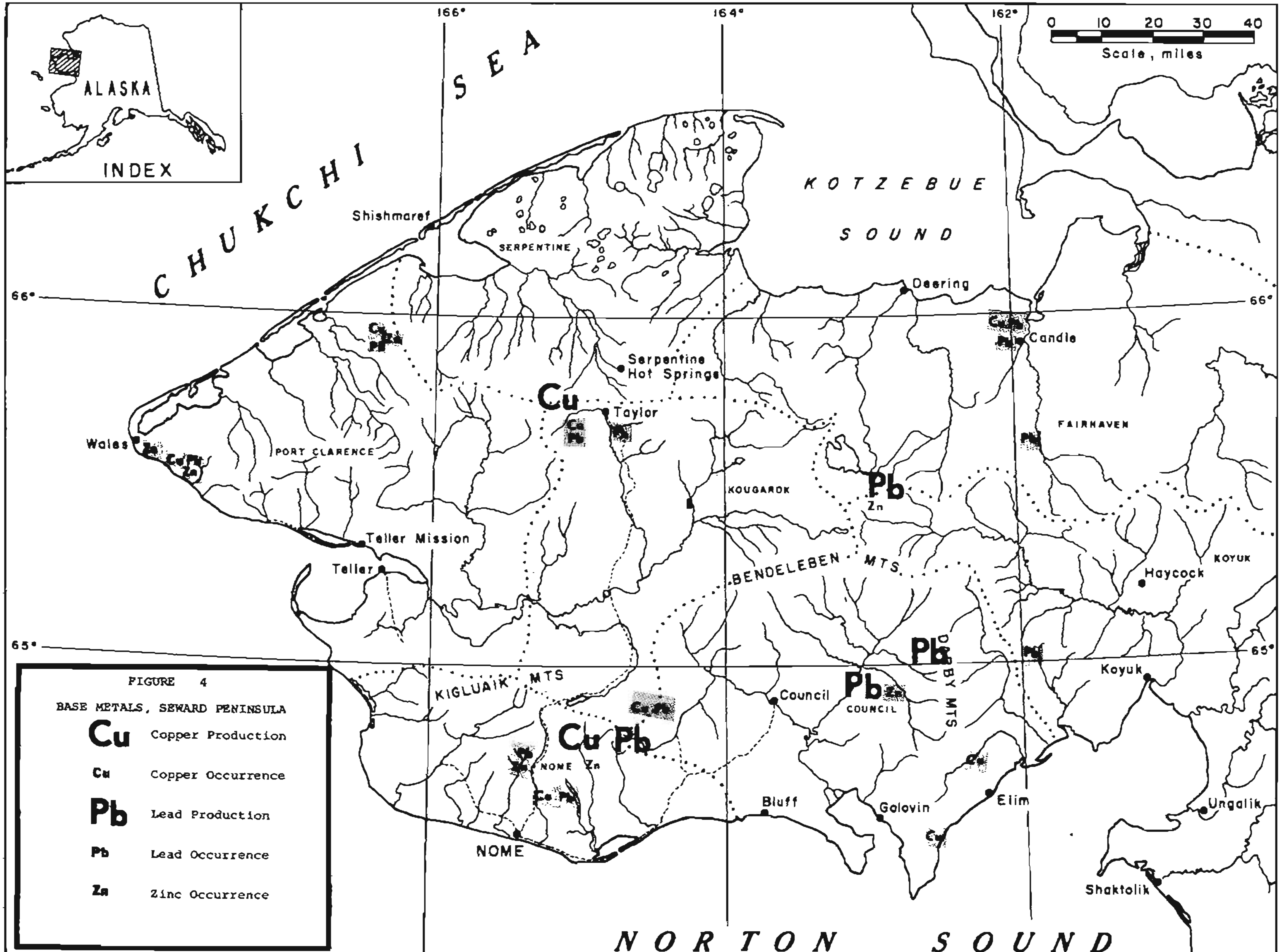


FIGURE 4

BASE METALS, SEWARD PENINSULA

Cu	Copper Production
Cu	Copper Occurrence
Pb	Lead Production
Pb	Lead Occurrence
Zn	Zinc Occurrence

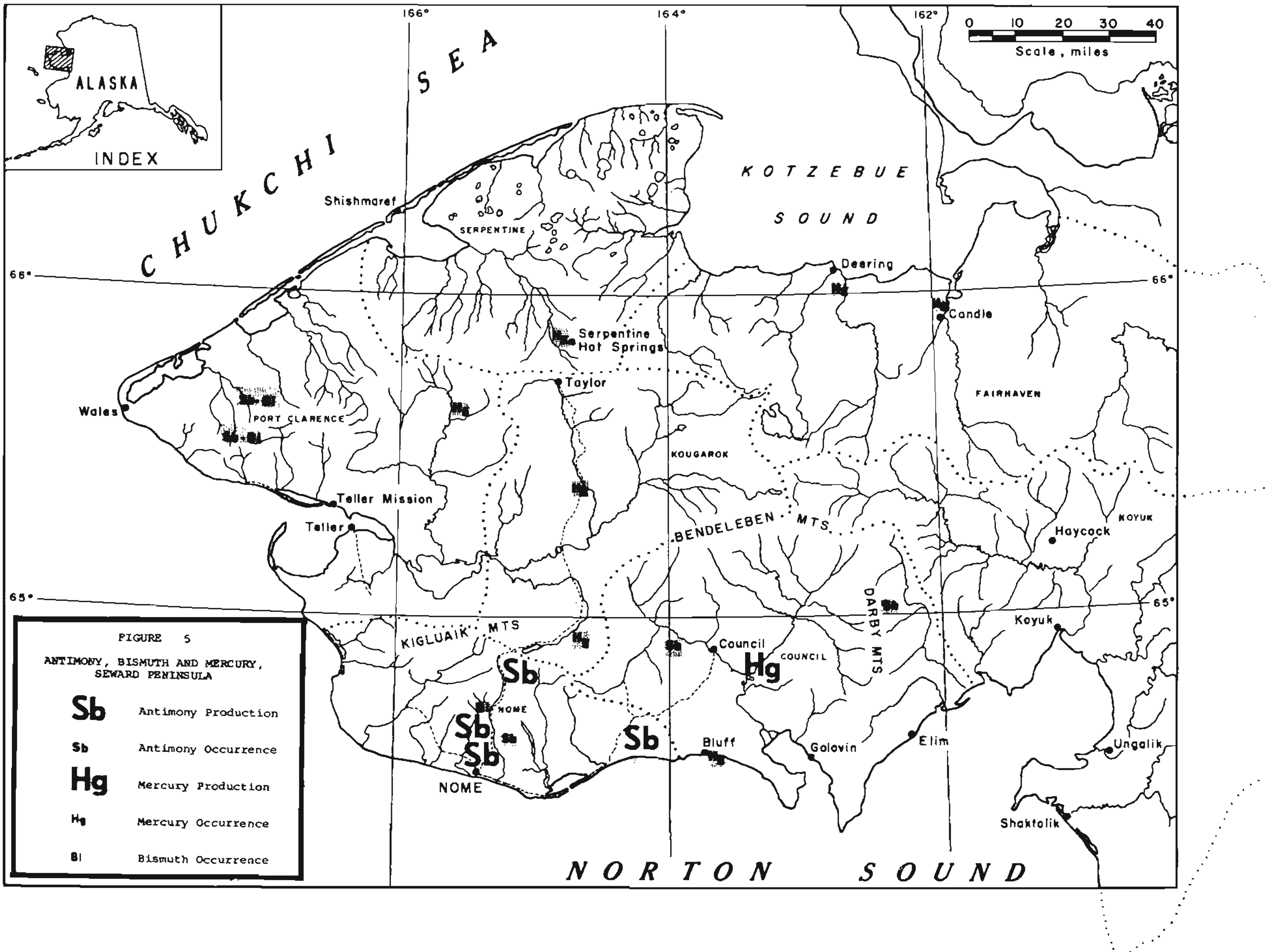


FIGURE 5

ANTIMONY, BISMUTH AND MERCURY, SEWARD PENINSULA

TABLE 1

PATENTED MINERAL CLAIMS-SEWARD PENINSULA, ALASKA
(Data Compiled from Division of Mines and Minerals Records)

Quadrangle	Area in Acres	# of Claim Groups	Commodity*	Lode or Placer
Bendeleben	1,899.49	1	Ag,Pb,Sb,Au,Sn	Lode
		8	Au	Placer
		5	Sn	Lode
		1	Cu	Lode
Candle	733.41	1	Au	Placer
Nome	29,132.46	1	Sb,As	Lode
		1	Sb	Lode
		1	Sb,Au,Ag	Lode
		1	Fe,Mn	Lode
		1	Fe	Lode
		71	Au	Placer
		1	Au,Sn	Placer
		2	Au,Sb,W	Placer
		4	Au,W	Placer
		1	Au,Sb	Placer
		1	Au,Bi	Placer
Solomon	2,426.31	14	Au	Placer
		1	Au,Hg,W	Placer
		1	Au,Ag,W,Sb	Lode
		1	Au	Lode
Norton Bay	559.59	2	Au	Placer
Teller	2,133.58	1	Sn,W,Mo,Pb,Zn	Lode
		1	Sn,Au,Ag,Cu	Lode
		1	Ag,Pb,Sb,Sn,W(?)	Lode
		1	Sn,W	Lode
		1	Sn	Lode
		1	Cu	Lode
		1	Au	Placer
		1	Sn,W	Placer

*Ag - Silver, Au - Gold, Pb - Lead, Sb - Antimony, Sn - Tin, Cu - Copper, As - Arsenic, Fe - Iron, Mn - Manganese, Zn - Zinc, W - Tungsten, Bi - Bismuth, Hg - Mercury, Mo - Molybdenum.

TABLE 2

ACTIVE MINERAL CLAIMS–SEWARD PENINSULA, ALASKA*

Quadrangle	Number	Commodities**	Number	Commodities**
Bendeleben	50	Pb, Ag, Au, Cu	379	Au, Sn, U
Shishmaref	None	-	None	-
Kotzebue	None	-	7	Au
Selawik	None	-	None	-
Teller	137	Au, Sn, Be, Fe, Pb Graphite, W, Mo, Zn	121	Au, Sn, W, Be
Candle	None	-	108+	Au, Pt
Nome	80	Au, Bi, Zn, Pb, Fe, Cu, Sb	339	Au, W, Bi, Sb, Pb, As, Cu
Solomon	38	Pb, As, Zn, Cu, Au	354	Au, W, Hg, As
Norton Bay	None	-	43	Au
Totals	305		1351+	

*Data compiles from the Division of Mines and Minerals Kardex files. Claims considered current if 1966 Assessment Work was filed. Patented claims included only if actually active. Counts for inactive claims approximate as records do not extend sufficiently into the past.

**Ag - Silver, As - Arsenic, Au - Gold, Be - Beryllium, Bi - Bismuth, Cu - Copper, Fe - Iron, Hg - Mercury, Mo - Molybdenum, Pb - Lead, Pt - Platinum, Sn - Tin, Sb - Antimony, U - Uranium, W - Tungsten, Zn - Zinc.

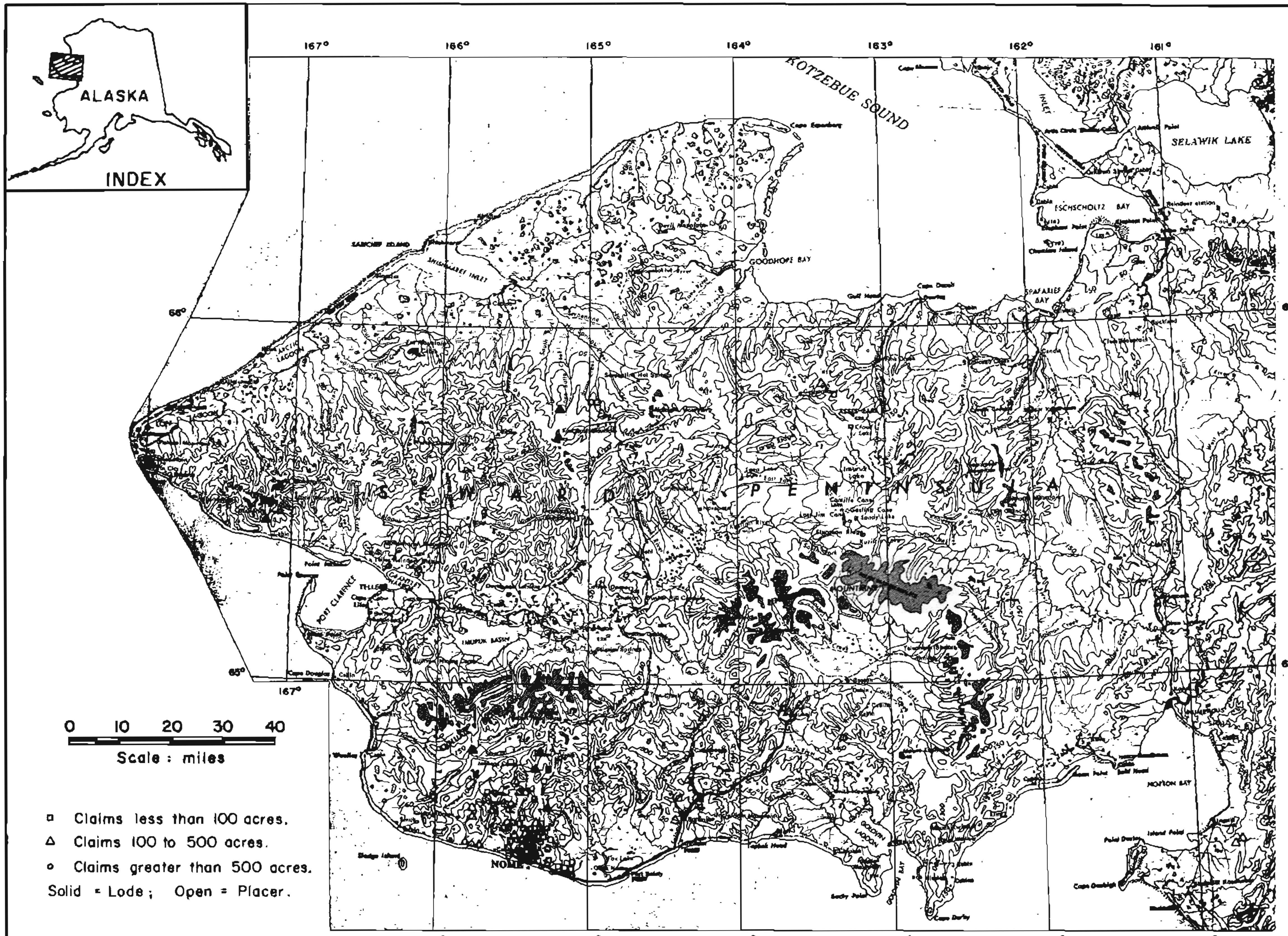
TABLE 3

INACTIVE MINERAL CLAIMS-SEWARD PENINSULA, ALASKA*

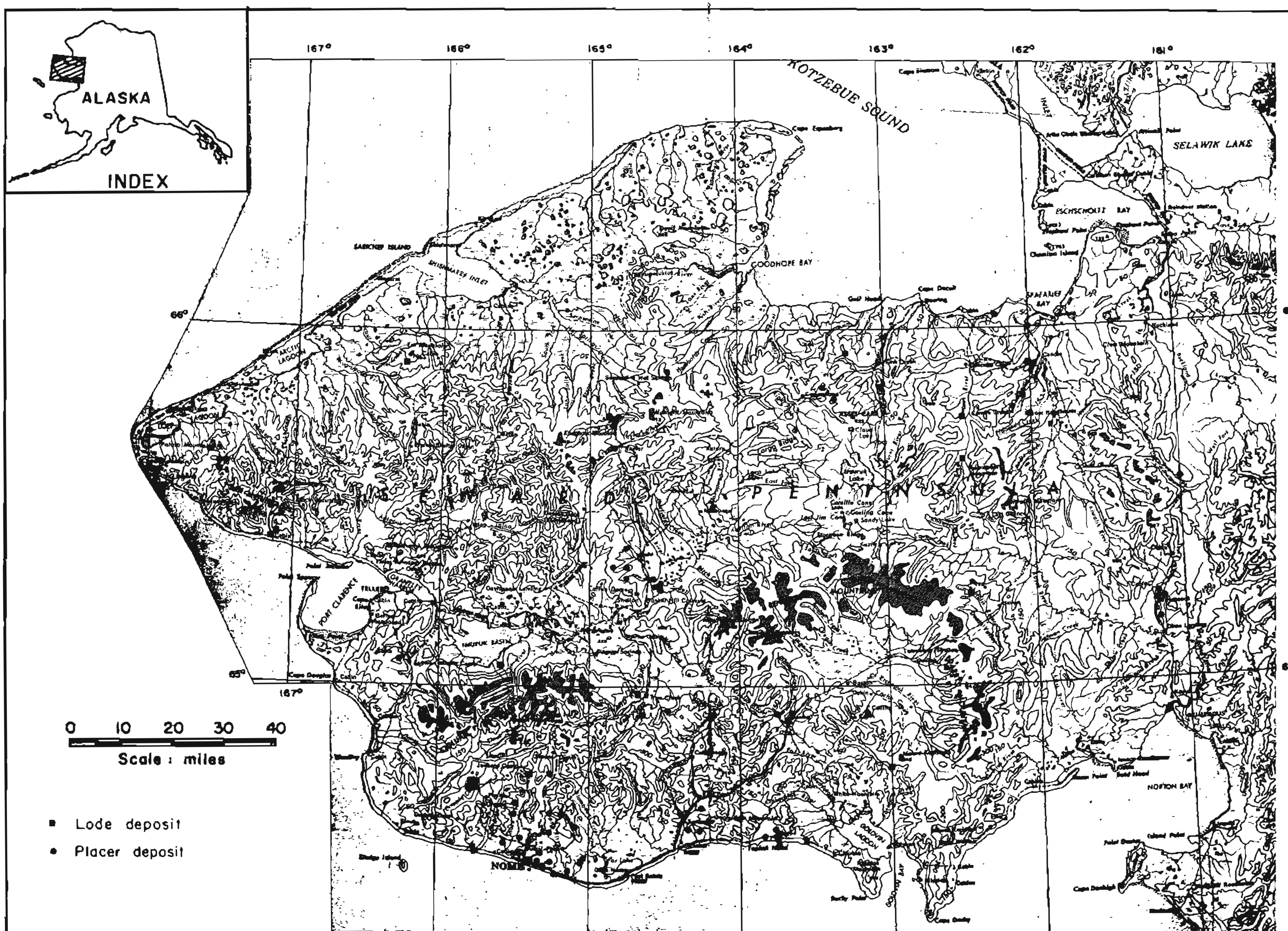
Quadrangle	Lode		Placer	
	Number	Commodities**	Number	Commodities**
Bendeleben	287	Ag, Pb, Mica, Sn, Cu, Hg, U, Au, Radioactive	399	Au, Sn
Shishmaref	None	-	None	-
Kotzebue	None	-	?	Au
Selawik	None	-	6	Au
Teller	258	Sn, Au, Ag, Cu, Radioactives, Graphite, F, W, Pb, Be, Bi, U, Zn, Sb,	186	Sn, Au, W, Hg
Candle	50	Au, U, Cu, Radioactive	129	Au, Radioactive, Pt, U
Nome	143	Hg, Sb, Au, Fe, Mn, W, Zn, A, Cu, Mo, Ag, Pb, Graphite	628	Au, W, Pt, Bi, Sn, Sb, Pb
Solomon	27	Sb, Au, Hg, Cu, Ag, As, Pb, Sn	340	Au, Hg, W, As
Norton Bay	?	Sb, Au	37	Au, Sb, W
Totals	765+		1725+	

*Data compiled from the Division of Mines and Minerals Kardex files. Claims considered current if 1966 Assessment Work was filed. Patented claims included only if actually active. Counts for inactive claims approximate as records do not extend sufficiently into the past.

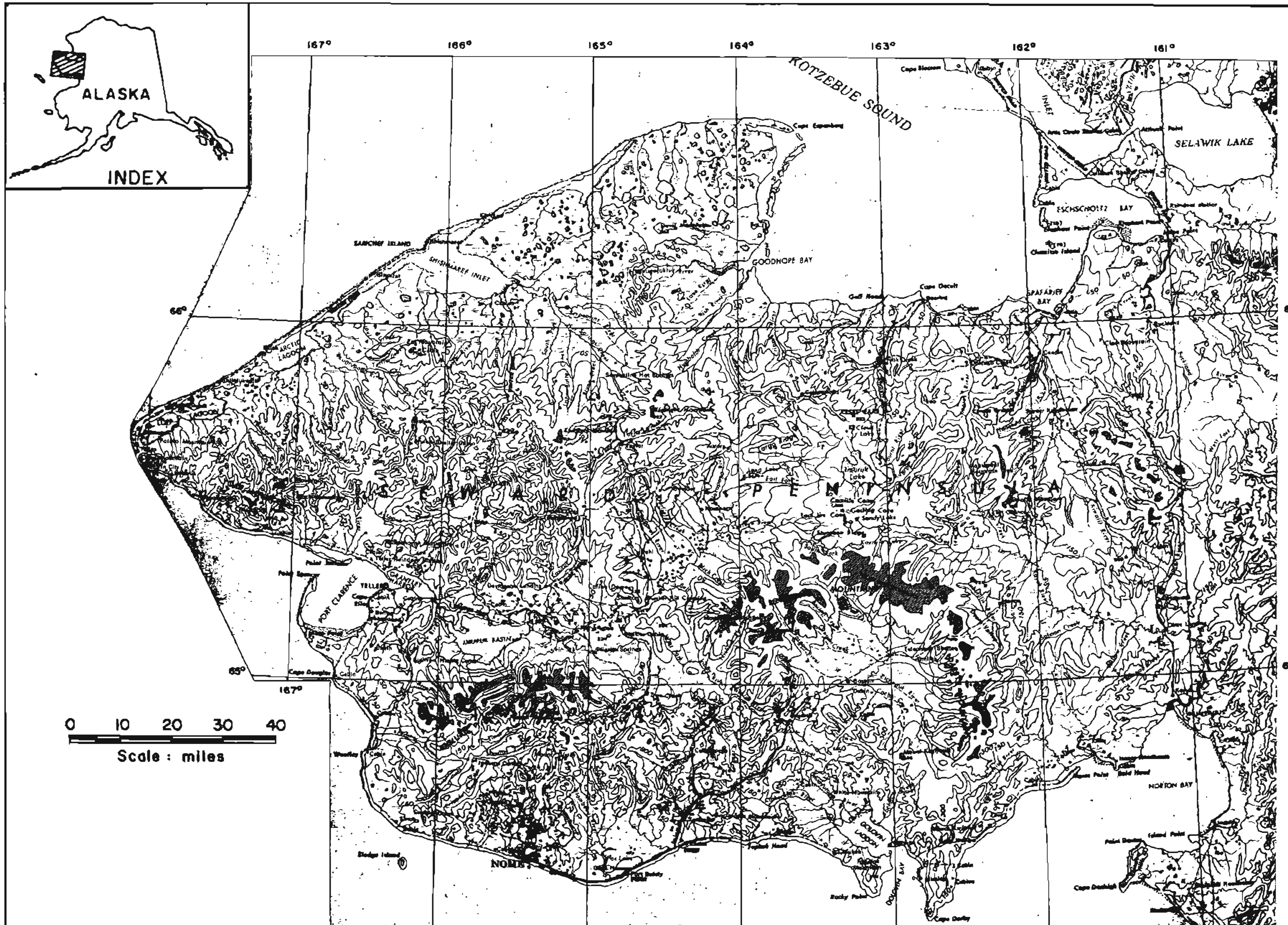
**Ag - Silver, As - Arsenic, Au - Gold, Be - Beryllium, Bi - Bismuth, Cu - Copper, F, - Fluorine, Fe - Iron, Hg - Mercury, Mo - Molybdenum, Mn - Manganese, Zn - Zinc, Pb - Lead, Pt - Platinum, Sn - Tin, Sb - Antimony, U - Uranium, W - Tungsten,



PATENTED MINERAL CLAIMS IN THE SEWARD PENINSULA REGION



ACTIVE MINERAL CLAIMS IN THE SEWARD PENINSULA REGION



SPATIAL DISTRIBUTION OF INACTIVE MINERAL CLAIMS IN THE SEWARD PENINSULA REGION

HISTORICAL REVIEW AND PRODUCTION STATISTICS

GOLD

Lode mining in the Seward Peninsula has never reached a very productive stage, and in the period prior to 1906 it was practically confined to one mine in the Solomon District, east of Nome. This deposit appears to have been discovered about 1900, but little active production took place until 1903, when a 20-stamp mill was built and considerable underground development was carried on. Smith (P. S., USGS B-433, p. 139, 1910) gave a general description of the property as a result of his studies there in 1907, but did not furnish any specific figures as to the amount of gold produced. Judging from the size of the excavation that had been made and the apparent tenor of the ore, it seems probable that the production for the 3 years, 1903-1905, inclusive, was approximately $100,000 and that figure has been adopted for use in Table 2 of USGS B-917-C, p. 187, 1942, by P. S. Smith, "Past Lode-Gold Production from Alaska."

The production of noteworthy amounts of lode gold from mines on the Seward Peninsula was rather closely restricted to the early years of mining; the principal producing mine, that of the Hurrah Quartz Mining Co., ceased operations in 1907 and was not again reopened for other than desultory work. In spite of the rather insignificant production of lode gold in later years there has always been a considerable amount of prospecting for lodes in progress, and many indications of lode mineralization have been reported in practically all parts of the Peninsula.

The many lode gold deposits which occur on the Seward Peninsula are mainly two types: (1) deposits of auriferous quartz veins and (2) deposits in which the gold occurs in sulfides disseminated in the country rock. The more common type of vein deposit is the filled fracture in shear zones. These zones, up to 50 feet in width, consist of numerous veins and stringers of quartz and calcite. Shear zone deposits are generally discontinuous along the strike, although some have been traced for several thousand feet. Most of the gold values are found in the associated sulfide minerals in which free gold is not common. The less common fissure vein deposits consist of veins and stringers of auriferous quartz and are generally more persistent along the strike than other types. In the fissure vein deposits a large proportion of the gold is free. The largest lode mine on the Peninsula is a fissure vein deposit.

The disseminated type deposit consists of blebs and stringers of auriferous quartz and sulfide minerals disseminated in wide zones in metamorphic rocks. The relatively small size and very low grade of these deposits is indicated by the absence of significant placers derived from them.

On the Seward Peninsula the gold-quartz vein at the Big Hurrah mine is the only one to have produced and the only one on which mining has been attempted in the past 10 years (USGS, 1964). Production from the Big Hurrah mine has amounted to 9,300 fine ounces; resource estimates are not available. A gold-quartz deposit near Bluff occurs as a stringer lode in slate, and resources are probably large but of low grade. Known resources of lode gold in mineable ore bodies on the Seward Peninsula probably do not exceed a few hundred thousand tons.

The production of lode gold in the Seward Peninsula started early in 1904. Between 1904 and 1952, a little over $1 million of lode gold was produced; this is less than one percent of the cumulative value of placer gold production during the same period. There has been no recorded production of lode gold since 1953. The record of lode gold production in the region could be listed as follows:

TABLE 4
LODE-GOLD PRODUCTION IN THE SEWARD PENINSULA, ALASKA

Year	Lode-Gold	Year	Lode-Gold	Year	Lode-Gold	Year	Lode-Gold
1904	$100,000	1919	$ 2,935	1938	$ 805	1948	$ 3,920
1906	50,000	1921	5,085	1939	1,260	1951	2,415
1907	30,000	1927	145	1940	1,435	1952	19,285
1912	240	1937	5,000	1941	595		
						Total	$1,123,120

Source: Smith, P. (1938), Malone, K. (1968).

Over $150 million (actual dollars) of placer-gold has been produced from the region between 1896 and 1967, ranking only after Fairbanks, in physical volume of cumulated production, having produced about 6.3 million troy ounces of placer-gold. The placers are more widespread than at Fairbanks, all parts of the Peninsula being represented. The ancient beach placers near Nome and the ancient stream channels extending inland from the southern shore have been the most productive. The chief placers, those at Nome, are mostly marine deposits, and although placer mining is almost shut down, there is much interest in off-shore beach placers.

The value of placer-gold produced on the Seward Peninsula during 1897-1967 is presented in Table 5. The cumulative value of placer gold has approached $150 million of which the Nome District has contributed about two-thirds of the value of production. Table 6 shows available production data of the physical volume of placer-gold produced during the period of 1930-1967.

Table 7 lists the cumulative value of placer precious metals produced in the Seward Peninsula, Alaska, by major creeks from 1900-1967. From Table 7, the significance of mining districts and creeks have been ranked according to the following classification:

I. Production greater than $10,000,000.
Nome Unit (Nome District).

II. Production greater than $1,000,000.
Candle Creek (Fairhaven District), Ophir Creek (Council), Solomon River (Nome), Little Anvil and Dry Creek (Nome), Melsing Creek (Council), Kougarok Creek (Kougarok-Nome), Inmachuck River (Fairhaven), and Niukluk River (Nome).

III. Production greater than $100,000.
Anvil Creek (Nome), Dime Creek (Koyuk), Ungalik River (Koyuk), Daniels (Nome), Gold Run Creek (Port Clarence), Shovel Creek (Nome), Sunset Creek (Port Clarence), Osborn Creek (Nome), Bangor Creek (Nome), Dahl Creek (Kougarok), Bourbon Creek (Nome), Dry Creek (Nome), Patterson Creek (Fairhaven), Monument Creek (Nome), Snake Creek (Nome), Spruce Creek (Nome), Wonde Creek (Nome), Coffee Creek (Kougarok), Grass Creek (Nome), and Glacier Creek (Fairhaven).

TABLE 5

VALUE OF PLACER GOLD PRODUCED IN SEWARD PENINSULA, BY DISTRICT

(a) 1897-1930

Year	Council	Fairhaven	Kougarok	Koyuk	Nome	Port Clarence	Solomon and Bluff	Total
1897	-	-	-	-	$ 15,000	-	-	$ 15,000
1898	-	-	-	-	75,000	-	-	75,000
1899	-	-	-	-	2,800,000	-	-	2,800,000
1900	$ 165,000	$ 200,000	$ 50,000	-	3,433,500	$ 76,500	$ 825,000	4,750,000
1901	600,000	50,000	40,000	-	3,320,000	-	120,000	4,130,000
1902	1,000,000	150,000	50,000	-	3,150,000	-	210,000	4,560,000
1903	1,000,000	200,000	75,000	-	2,900,000	-	290,000	4,465,000
1904	900,000	125,000	75,000	-	2,864,000	-	200,000	4,164,000
1905	500,000	300,000	400,000	-	3,400,000	-	200,000	4,800,000
1906	500,000	500,000	100,000	-	6,100,000	100,000	200,000	7,500,000
1907	500,000	600,000	100,000	-	5,550,000	50,000	200,000	7,000,000
1908	a	a	a	-	a	a	a	5,120,000
1909	a	a	a	-	a	a	a	4,290,000
1910	a	a	a	-	a	a	a	3,500,000
1911	a	a	a	-	a	a	a	3,100,000
1912	a	a	a	-	a	a	a	3,000,000
1913	a	a	a	-	a	a	a	2,500,000
1914	a	a	a	-	a	a	a	2,700,000
1915	680,000	250,000	140,000	-	1,500,000	75,000	255,000	2,900,000

TABLE 5 (Continued)

Year	Council	Fairhaven	Kougarok	Koyuk	Nome	Port Clarence	Solomon and Bluff	Total
1916	$ 670,500	$ 191,500	$ 111,000	-	$ 1,542,000	$ 91,500	$ 343,500	$ 2,950,000
1917	a	a	a	-	a	a	a	2,601,000
1918	307,000	113,000	50,000	$136,000	447,000	7,000	49,000	1,109,000
1919	225,500	81,000	39,500	89,000	698,000	3,000	124,000	1,360,000
1920	360,000	120,000	55,000	160,000	540,000	15,000	50,000	1,300,000
1921	420,000	120,000	45,000	152,000	585,000	8,000	120,000	1,450,000
1922	375,000	150,000	32,000	109,000	485,000	3,000	111,000	1,265,000
1923	360,000	107,000	50,000	59,000	598,000	7,000	89,000	1,270,000
1924	148,600	82,600	31,600	51,700	848,500	13,000	69,000	1,245,000
1925	46,700	111,500	47,300	44,900	740,200	12,000	85,900	1,088,500
1926	80,000	203,000	55,000	30,000	1,390,000	8,000	107,000	1,873,000
1927	87,000	143,000	28,000	24,000	953,000	17,000	113,000	1,365,000
1928	77,800	123,000	13,100	17,900	750,000	5,000	69,500	1,056,300
1929	60,000	126,000	16,000	25,000	1,442,000	4,000	25,000	1,698,000
1930	46,500	80,500	19,700	21,000	981,000	1,500	41,000	1,191,200
	2,700,000*	1,500,000*	600,000*	51,000*	20,600,000*	60,000*	1,300,000*	
Total	$11,809,000	$5,727,100	$2,223,200	$970,500	$67,707,200	$556,500	$5,196,900	$94,191,000

*Estimated additions for omissions (a).

TABLE 5 (Continued)

(b) 1931-1967

Year	Council	Fairhaven	Kougarok	Koyuk	Nome	Port Clarence	Serpentine	Total
1931	$ 5,643	$ 92,333	$ 6,428	$ 5,312	$ 843,729	$ 2,356	-	$ 955,800
1932	40,641	184,062	81,778	4,527	1,219,783	2,915	-	1,533,705
1933	10,710	264,776	17,074	4,038	1,065,085	3,169	-	1,364,853
1934	132,216	399,059	124,352	34,566	2,202,933	7,444	-	2,900,570
1935	49,770	149,100	99,400	24,850	2,087,715	74,550	-	2,485,315
1936	81,325	284,095	92,190	56,875	2,192,050	154,140	-	2,860,675
1937	938,630	301,000	445,410	70,000	2,326,870	40,740	-	4,122,650
1938	41,475	211,435	153,440	28,840	1,856,645	99,575	-	2,391,410
1939	73,045	555,310	102,865	13,965	1,809,640	114,065	-	2,668,890
1940	1,225	465,045	223,440	247,555	2,072,070	74,655	-	3,083,990
1941	10,990	564,060	310,765	226,975	2,720,550	39,550	-	3,872,890
1942	147,945	406,700	311,255	5,215	1,232,385	39,480	-	2,142,980
1943	28,735	351,085	129,640	245	47,810	105	-	557,620
1944	37,415	96,845	58,660	8,470	230,615	4,325	-	436,330
1945	44,730	367,920	107,100	17,395	80,185	4,830	$ 4,130	626,290
1946	66,675	351,925	121,765	10,815	222,040	37,135	4,725	815,080
1947	102,060	270,235	194,985	20,825	215,040	22,190	-	825,335
1948	153,265	341,460	103,775	75,565	483,035	10,815	4,480	1,172,395
1949	131,250	326,725	289,275	21,910	1,130,605	5,810	2,415	1,907,990

TABLE 5 (Continued)

Year	Council	Fairhaven	Kougarok	Koyuk	Nome	Port Clarence	Serpentine	Total
1950	$ 79,800	$ 252,770	$ 214,760	$ 48,440	$ 1,730,680	$ 1,295	$ 4,340	$ 2,332,085
1951	60,935	300,615	83,125	28,315	1,626,275	3,710	3,955	2,106,930
1952	36,820	189,840	19,950	22,400	1,341,130	3,605	1,820	1,615,565
1953	39,375	464,135	32,900	7,805	1,034,600	3,290	-	1,582,105
1954	20,825	227,115	31,500	8,575	741,195	1,225	-	1,030,435
1955	33,670	100,240	49,700	12,355	819,350	-	-	1,015,315
1956	33,985	80,360	21,315	2,310	842,030	-	-	980,000
1957	14,630	60,060	41,195	9,030	1,527,890	385	-	1,653,190
1958	9,310	63,455	47,320	21,805	1,168,720	2,450	-	1,313,060
1959	13,580	204,120	65,240	8,225	910,105	3,290	-	1,204,560
1960	13,825	172,655	54,880	9,660	1,366,015	5,845	-	1,622,880
1961	5,985	56,770	61,425	21,665	925,470	4,760	-	1,076,075
1962	16,555	70,945	60,270	14,630	840,035	8,155	-	1,010,590
1963	12,355	56,350	84,945	21,140	44,520	-	-	219,310
1964	14,350	61,810	37,345	5,215	23,065	6,405	-	148,190
1965	1,190	50,015	16,415	17,710	6,790	2,310	-	94,430
1966	2,730	42,805	70	-	1,435	1,015	-	48,055
1967	12,530	17,955	5,285	-	3,955	-	-	39,725
Total	$2,520,194	$8,455,185	$3,901,237	$1,137,223	$38,992,045	$785,590	$25,865	$55,817,268

Source: (a) U. S. Geological Survey, Bul. 857-B; (b) U. S. Bureau of Mines, Juneau, Alaska.

TABLE 6
QUANTITY OF PLACER GOLD PRODUCED IN SEWARD PENINSULA, BY DISTRICT
1931-1967

Year	Council	Fairhaven	Kougarok	Koyuk	Nome	Port Clarence	Serpentine	Total
1931	273 oz.	4,467 oz.	311 oz.	257 oz.	40,819 oz.	114 oz.	-	46,241 oz.
1932	1,966	8,904	3,965	219	59,007	141	-	74,193
1933	419	10,359	668	158	41,670	124	-	53,398
1934	3,783	11,418	3,558	989	63,031	213	-	82,992
1935	1,422	4,260	2,840	710	59,649	2,130	-	71,011
1936	2,321	8,117	2,634	1,625	62,630	4,404	-	81,731
1937	26,818	8,600	12,726	2,000	66,482	1,164	-	117,790
1938	1,185	6,041	4,384	824	53,047	2,845	-	68,326
1939	2,087	15,866	2,939	399	51,704	3,259	-	76,254
1940	35	13,287	6,384	7,073	59,202	2,133	-	88,114
1941	314	16,116	8,879	6,485	77,730	1,130	-	110,654
1942	4,227	11,620	8,893	149	35,211	1,128	-	61,228
1943	821	10,031	3,704	7	1,366	3	-	15,932
1944	1,069	2,767	1,676	242	6,589	121	-	12,464
1945	1,278	10,512	3,060	497	2,291	138	118 oz.	17,894
1946	1,905	10,055	3,479	309	6,344	1,061	135	23,288
1947	2,916	7,721	5,571	595	6,144	634	-	23,581
1948	4,379	9,756	2,965	2,159	13,801	309	128	33,497
1949	3,750	9,335	8,265	626	32,303	166	69	54,514
1950	2,280	7,222	6,136	1,384	49,448	37	124	66,631

TABLE 6 (Continued)

Year	Council	Fairhaven	Kougarok	Koyuk	Nome	Port Clarence	Serpentine	Total
1951	1,741 oz.	8,589 oz.	2,375 oz.	809 oz.	46,465 oz.	106 oz.	113 oz.	60,198 oz.
1952	1,052	5,424	570	640	38,318	103	52	46,159
1953	1,125	13,261	940	223	29,560	94	-	45,203
1954	595	6,489	900	245	21,177	35	-	29,441
1955	962	2,864	1,420	353	23,410	-	-	29,009
1956	971	2,296	609	66	24,058	-	-	28,000
1957	418	1,716	1,177	258	43,654	11	-	47,234
1958	266	1,813	1,352	623	33,392	70	-	37,516
1959	388	5,832	1,864	235	26,003	94	-	34,416
1960	395	4,933	1,568	276	39,029	167	-	46,368
1961	171	1,622	1,755	619	26,442	136	-	30,745
1962	473	2,027	1,722	418	24,001	233	-	28,874
1963	353	1,610	2,427	604	1,272	-	-	6,266
1964	410	1,766	1,067	149	659	183	-	4,234
1965	34	1,429	469	506	194	66	-	2,698
1966	78	1,223	2	-	41	29	-	1,373
1967	358	513	151	-	113	-	-	1,135
Total	73,038 oz.	249,861 oz.	113,396 oz.	32,731 oz.	1,166,256	22,581 oz.	739 oz.	1,658,602 oz.

Source: U.S. Bureau of Mines, Juneau, Alaska

TABLE 7

CUMULATIVE VALUE OF PLACER PRECIOUS METALS PRODUCED IN SEWARD PENINSULA, ALASKA
(By Major Creeks,* 1900-1967)**

Location	District	Cumulative $ Value	Production Period (Year)
Aggie Creek	Council-Bluff	$ 101,604	1910, 1930-33, 1942
Albion Creek	Council	86,987	1901, 1908-09, 1911, 1924-26, 1931, 1937
American Creek	Council	11,231	1920, 1922-24, 1935, 1936, 1938, 1940
Anvil Creek	Nome	953,456	1911, 1913-17, 1921, 1923-38
Arctic Creek	Nome	10,002	1918, 1920, 1922
Bangor Creek	Nome	439,067	1909-11, 1913, 1915-18, 1929, 1934
Bear Creek	Nome	196,003	1908, 1911, 1914-22, 1924-25, 1934, 1936, 1941-42
Beaver Creek	Nome	171,474	1908, 1940-42
Benson Creek	Kougarok	21,093	1920-22, 1927-28, 1931-34, 1937-39, 1941-42
Benson Gulch	Kougarok	19,503	1922, 1924, 1928-29, 1932, 1934-35, 1938-39
Bessie Bench	Nome	71,400	1906
Big Hurrah Creek	Nome	120,606	1912, 1916-24, 1933, 1935, 1937, 1939, 1940-41
Black Gulch	Kougarok	62,282	1937-38
Bonanza Creek	Koyuk	671,472	1917-18, 1922-23, 1933, 1936, 1938, 1939, 1940-41
Boulder Creek	Kougarok	82,503	1907-16, 1918, 1929, 1939-41
Bourbon Creek	Nome	454,000 (estimated)	1906-07, 1909-10, 1912, 1914-15, 1919, 1926, 1933

TABLE 7 (Continued)

Location	District	Cumulative $ Value	Production Period (Year)
Budd Creek	Port Clarence	$ 15,519	1917, 1919-20, 1938-39
Buster Creek	Nome	16,003	1910-18, 1922
Butte Creek	Nome	16,335	1914
Buzzard Creek	Nome	54,755	1938-39, 1941
Casa de Paga River	Council	81,634	1907, 1909, 1911-12, 1914-17, 1920-23, 1927-28, 1941.
Casa de Paga River	Nome	27,606	1935, 1937
Candle Creek	Fairhaven	5,404,750	1906-1946
Center Creek	Nome	185,000	1906, 1908, 1911-19
Coffee Creek	Kougarok	225,812	1908, 1924, 1928, 1936-37, 1940-43
Coyote Creek	Port Clarence	23,838	1919, 1924-29, 1931-32, 1939-40
Crooked Creek	Council	25,609	1907, 1909, 1933-36
Dahl Creek	Kougarok	314,836	1908-09, 1920-24, 1931-60
Daniel Creek and Eldorado Creek	Council	80,970	1901, 1941-42
Daniels Creek	Nome	531,789	1907-08, 1917, 1922, 1924-25, 1928-29, 1932
Dese Creek	Port Clarence	23,239	1918, 1934, 1936
Dexter Creek	Nome	173,950+	1912, 1914-22, 1928-29, 1933, 1936-37
Diamond	Nome	165,000	1906
Dick Creek	Port Clarence	32,027	1912-13, 1917-18, 1921-23, 1928
Dick Creek	Kougarok	159,480	1915, 1927-55
Dime Creek	Koyuk	817,003	1917-26, 1928-43

TABLE 7 (Continued)

Location	District	Cumulative $ Value	Production Period (Year)
Discovery Gulch	Fairhaven	$ 21,519	1927-28, 1930, 1934
Dry Creek	Nome	302,317+	1906-21, 1925, 1934-38, 1940
Elkhorn Creek	Council	58,045	1914-17
Flat Creek	Nome	41,051	1915-17
Glacier Creek	Fairhaven	145,243	1911-19, 1921-22, 1929, 1934-36, 1941
Gold Bottom Creek	Council	58,309	1910-12, 1921-22, 1924, 1929
Gold Run Creek	Port Clarence	526,193	1911, 1915-42
Goose Creek	Nome	12,011	1914, 1923
Grass Gulch	Nome	160,234	1908, 1916, 1919
Heath	Nome	20,000	1907, 1909
Hobson Creek	Nome	56,376	1909, 1912-15
Holyke Creek	Nome	47,951	1907-09, 1911, 1915-18
Ingloo	Port Clarence	40,692	1917, 1922-23, 1941-43
Inmachuck River	Fairhaven	1,060,766	1917-31, 1933-34, 1937-38, 1941-43
Independence	Nome	14,000	1906
Indian Creek	Kougarok	14,000	1911
Iron Creek	Nome	120,529	1917, 1921-22, 1927-28. 1935-37, 1939-41
Kougarok Creek	Kougarok-Nome	1,028,502	1907-26, 1930, 1934-42
Kogruk River	Fairhaven	39,988	1908, 1914-16, 1921-22, 1924-26, 1928-30, 1936, 1938
Last Chance Creek	Nome	30,000	1908-1918
Little Rock	Nome	152,558	1909, 1922-24, 1928, 1933

TABLE 7 (Continued)

Location	District	Cumulative $ Value	Production Period (Year)
Little Anvil and Dry Creek	Nome	$ 5,249,275	1907-09, 1912-14, 1916-20
Mabel Bench	Nome	40,000	1907
Margit Bench	Nome	24,800	1908
McDonald Creek	Nome	161,389	1907, 1912-16
Melsing Creek	Council	1,278,100	1908-09, 1912-17, 1919-24, 1933-38
Monument Creek	Nome	330,500	1918, 1928-30, 1932-34, 1936, 1938-39
Mosquito Claim	Nome	14,000	1906
Mud Creek	Nome	27,635	1942
Mystery Creek	Council-Bluff	113,413	1906, 1909-13
Newton Creek and Dog Creek	Nome	37,409	1909-10
Newton Gulch	Nome	136,187	1909, 1930-31
Newton Creek-Magit Claim	Nome	20,000	1908
Niukluk River	Nome	1,000,000 (estimated)	1935-44, 1946-48
Nome Beach	Nome	165,000 (estimated)	1908, 1914-15, 1917-18, 1920, 1922-23, 1928-29, 1931-32, 1935
Nome Unit	Nome	22,964,121	1923-42
Childbar Beach on Beach near Nome	Nome	18,578	1940
Ophir Creek	Council	2,760,000 (estimated)	1906-54
Oregon Creek	Nome	41,794	1913-17, 1919, 1940-41
Osborn Creek	Nome	500,071	1908-09, 1911-22, 1924, 1929-31, 1937
Otter Creek	Nome	101,124	1908, 1910-11, 1913, 1918

TABLE 7 (Continued)

Location	District	Cumulative $ Value	Production Period (Year)
Patterson Creek	Fairhaven	$ 371,018	1908-09, 1913-16, 1918-20, 1924-28, 1931, 1933
Quartz Creek	Kougarok	38,779	1912, 1922, 1932-35
Saturday Creek	Nome	54,110	1907-10, 1912, 1914
Shovel Creek	Nome	408,006	1912-15, 1917-21, 1923-27
Snake River	Nome	276,985	1908, 1913, 1915, 1917, 1921-24, 1935-36
Solomon River	Nome	2,424,797	1907, 1912-17, 1920-23, 1926-32, 1934-60
Solomon Creek	Nome	40,356	1916-19, 1926, 1932
Spruce Creek	Nome	297,773	1913-36
Sunset Creek	Port Clarence	480,611	1913-15, 1917, 1919-20, 1922-23, 1925, 1936-38, 1942
Sweepstake Creek	Koyuk	37,061	1917-18, 1920-23, 1926, 1928-42
Ungalik River	Koyuk	664,918	1938-41
Warm Creek	Council	51,219	1914, 1916-17
Wonder Bench	Nome	40,000	1906
Wonde Creek	Nome	262,344	1907-10, 1916-18
Wonder Gulch	Kougarok	36,290	1907, 1909-12, 1917-18, 1935, 1940

*Those Creeks produce more than $10,000 of the cumulated value or over 500 oz. of gold equivalent are listed in the table. (Serpentine District is excluded)

**Source data compiled from USBM and calculated by the Author.

SILVER

Silver has been found in numerous deposits in the region (Figure 2). Lode deposits of argentiferous galena occur at widely scattered localities on the Seward Peninsula. The silver-bearing galena deposits are small vein-type deposits in which silver values in crude ore do not exceed 20 ounces per ton (USGS, 1964, Congress Report, p. 116). Silver could be expected as a by-product, should a lead mine be developed. Deposits noted for their silver content alone are notably lacking. Silver production associated with placer-gold mining usually comprised 10% of the physical volume of gold mined. The recovery of silver as a by-groduct from placer-gold is shown in Table 8.

Between 1880 and 1890 about 300-400 short tons of silver-bearing lead ore containing 4 ounces of silver and 10 percent lead per ton were produced from deposits in the Omilak area on the Seward Peninsula. One shipment of 41 tons picked ore in 1889 reportedly contained 142 ounces of silver and 75 percent lead per ton. However, the estimated resources at these deposits are believed to be small to moderate (USGS, 1964, Congress, p. 118).

PLATINUM

The platinum and platinum-group metals occur as placer deposits in the Seward Peninsula. No lode deposits have been reported in the region. The bedrock sources of the platinum metals in most of the placers are unknown, but the region's few placers are closely associated with bodies of mafic and ultramafic intrusive rocks. Small amounts of platinum have been mined as a by-product of placer gold mining in the Seward Peninsula.

TIN, TUNSTEN

For a number of years, Alaska has been a small but consistent producer of tin, and in the course of the 66 years since tin minerals were discovered on the Seward Peninsula, it has shipped tin worth more than $3 million. Prior to the 1950's, the

TABLE 8
PLACER SILVER PRODUCTION IN SEWARD PENINSULA, BY DISTRICT
1931-1967

Year	Council (oz.)	Council (value)	Fairhaven (oz.)	Fairhaven (value)	Kougarok (oz.)	Kougarok (value)	Koyuk (oz.)	Koyuk (value)	Nome (oz.)	Nome (value)	Port Clarence (oz.)	Port Clarence (value)	Serpentine (oz.)	Serpentine (value)
1931*														
1932									5,743**	$1,619**				
1933	71	$ 25	145	$ 51	121	$ 42	26	$ 9	252	88	23	$ 8	-	-
1934	18	12	767	496	99	64	34	22	2,698	1,744	25	16	-	-
1935	114	82	432	310	125	89	31	22	4,850	3,486	172	123	-	-
1936*														
1937	5	4	1,775	1,377	497	386	67	53	7,955	6,171	187	145	-	-
1938	54	35	2,332	1,508	568	367	263	170	5,161	3,336	354	229	-	-
1939	159	108	2,013	1,366	320	217	33	23	4,940	3,353	413	280	-	-
1940	14	10	1,888	1,343	697	496	518	368	6,090	4,331	281	200	-	-
1941	5	4	2,402	1,708	1,041	740	393	279	7,266	5,166	144	102	15	$11
1942	310	220	1,741	1,238	1,112	791	16	11	3,697	2,629	181	129	-	-
1943	-	-	2	1	-	-	-	-	140	100	9	6	-	-
1944***														
1945	132	94	1,423	1,012	401	285	45	32	246	175	14	10	-	-
1946	208	188	1,515	1,371	393	356	32	29	722	653	106	96	11	10
1947	308	279	1,077	975	596	539	64	58	649	587	74	67	-	-
1948	471	426	1,322	1,196	324	293	220	199	1,564	1,416	33	30	12	11
1949	437	396	1,187	1,074	790	715	135	122	3,544	3,207	19	17	7	6
1950	244	221	809	732	611	553	238	215	5,501	4,979	3	3	11	10

TABLE 8 (Continued)

Year	Council (oz.)	Council (value)	Fairhaven (oz.)	Fairhaven (value)	Kougarok (oz.)	Kougarok (value)	Koyuk (oz.)	Koyuk (value)	Nome (oz.)	Nome (value)	Port Clarence (oz.)	Port Clarence (value)	Serpentine (oz.)	Serpentine (value)
1951	185	$ 167	1,004	$ 909	237	$ 215	123	$ 111	5,189	$ 4,696	8	$ 7	13	$12
1952	118	107	580	525	62	56	89	81	4,345	3,932	10	9	6	5
1953	114	103	1,702	1,540	92	83	24	22	3,306	2,992	5	5	-	-
1954	57	52	769	696	91	82	28	25	2,358	2,134	3	3	-	-
1955	95	86	410	371	115	104	61	55	2,602	2,355	-	-	-	-
1956	101	91	320	290	47	43	9	8	2,629	2,379	-	-	-	-
1957	42	38	255	231	101	91	19	17	4,870	4,408	1	1	-	-
1958	27	24	241	218	129	117	46	42	727	658	9	8	-	-
1959	40	36	753	681	191	173	28	25	2,920	2,643	13	12	-	-
1960	40	36	659	596	158	143	24	22	4,440	4,018	22	20	-	-
1961	18	17	196	181	168	155	48	44	3,036	2,807	18	17	-	-
1962	49	53	261	283	169	183	32	35	2,728	2,960	33	36	-	-
1963	38	49	206	263	232	297	45	58	134	171	-	-	-	-
1964	42	54	176	228	103	133	11	14	74	96	23	30	-	-
1965	3	4	160	207	41	53	40	52	21	27	9	12	-	-
1966	8	10	131	169	-	-	-	-	4	5	4	5	-	-
1967	38	59	60	93	15	23	-	-	14	22	-	-	-	-
Total	3,565	$3,090	28,713	$23,239	9,646	$7,884	2,742	$2,223	100,415	$79,343	2,196	$1,626	75	$65

*Total by districts or region total not available.
**Total for other districts and region total not available.
***Region total 1,379 ounces valued at $981, breakdown by districts not available.
Source: U.S. Bureau of Mines, Juneau, Alaska.

recorded value of production includes some tin from the Hot Springs and Yukon Region. Since the 1950's, the Lost River area of the Seward Peninsula has been the only producer in Alaska. Table 9 presents the cumulated production of tin in the State during the period of 1902-1967 indicating a production of over 4 million pounds, mainly from the Seward Peninsula.

Known Alaska tin resources (Figure 3) are not large, but they constitute the only significant tin resource known in the United States. The Seward Peninsula contains the only known lode tin deposits in Alaska; Lost River, Potato Mountain, and Ear Mountain. Cassiterite is the principal tin-bearing mineral in the lodes and placer deposits of the region. Tungsten, fluorite, and many other minerals are associated with lode tin in the western part of the Seward Peninsula.

It was also reported (Sainsbury, 1964, p. 50) that all inferred ore reserves at the Lost River mine of more than one percent combined tin and WO_3 are in the Cassiterite and the Ida Bell dikes. If the ore shoot continues from the mine's 195 foot level to the 365 foot level at a projected rake, it may contain as much as 80,000 tons of inferred ore that will average about 1.5 percent tin. However, no operation depending upon inferred ore should be undertaken until sufficient exploration and development is done to verify this tonnage estimate. The inferred ore in the extension to the east, according to Sainbury, (1964, p. 51) is approximately 430,000 tons.

Potential tin-tungsten resources in the Lost River Mine area are resources whose average assay value is below one percent tin or combined tin and tungstic oxide. Under favorable economic conditions and technological advance or in the event of strategic necessity, these tin-tungsten resources, together with other metal by-products, might be exploited. Currently residual tin is being mined on a small scale at Lost River. This operation is a placer mine in that surface rubble is pushed into a sluice box where the tin minerals are concentrated. The reserves could be listed as follows:

TABLE 9

TIN PRODUCTION IN SEWARD PENINSULA, ALASKA*

Year	Quantity	Value
1902-50 (Inclusive)	3,948,184 lbs.	$1,988,701
1951	15,456	197,163
1952	18,368	220,956
1953	10,976	105,917
1954	44,476	409,840
1955	19,264	182,284
1956-63	No Production	
1964	5,000	7,900
1965	15,600	27,768
1966	77,515	127,141
1967	11,200	20,000
Total	4,166,039 lbs.	$3,287,670

*Prior to 1953, the production figures include Hot Spring, Yukon River Region.

Sources: (1) Smith, P., USGS, B-933-A, 1940, P. 81.
(2) USBM, Minerals Yearbook, Annual Volumes.
(3) Malone, K., Personal Communication (1968).

Location	Tonnage	Grade
Cassiterite Dike	650,000 tons	0.4 % Sn +0.2% WO_3
Ida Bell Dike	840,000 tons	0.26% Sn +0.1% WO_3
Cupola Area*	3,000,000 tons	0.30% Sn

*Based on the weighted average of all available samples, because of the lack of assay and geologic data for large parts of this area, the estimate may be in error by as much as 50 percent.

Two estimated ore reserves for the Lost River Mine were presented by Sainsbury (1964, USGS, B-1129, p. 49). A cut-off grade of one percent tin or one percent combined tin and tungstic oxide was used in all calculations. In ore containing less than one percent tin, only tungsten-bearing material containing more than 0.2% WO_3 was considered. (See Table 10). All measured and indicated ore reserves containing at least one percent tin ore, combined tin and WO_3 at Lost River Mine are in the Cassiterite Dike. The grade of measured and indicated ore was computed by standard methods using weighed samples and longitudinal sections. The measured and indicated ore reserves are tabulated in Table 10 as follows:

TABLE 10

MEASURED AND INDICATED RESERVES IN LOST RIVER MINE, SEWARD PENINSULA, ALASKA (after Sainsbury, 1964)

Block	Short Tons	Sn %	Sn lbs.	WO_3 %	WO_3 lbs.
		Tin Ore Only			
1	100,000	1.47	2,940,000	0.15	
2	6,500	1.55	201,500	0.10	
3	6,000	1.20	144,000	0.10	
4	17,000	1.22	414,800	0	
5	11,000	1.12	246,400	0.20	
1	60,000	1.06	1,272,000	0.20	
Total or Average	200,500	1.30	5,200,000	0.125	
		Mixed Tin - Tungsten Ore			
A	14,000	0.85	244,800	0.83	239,000
F	20,000	1.16	474,000	0.69	276,000
H	71,000	0.63	984,600	0.53	752,600
Total Rounded or Average	105,000	0.76	1,600,000	0.60	1,250,000

Table 11 indicates recorded tin production in the Cape Mountain area. Table 12 indicates recorded tin production from Potato Mountain. These data were obtained from the USBM. Table 13 indicates total tungsten production in Alaska. This data is not broken down by property due to the confidential nature of the data.

COPPER

Numerous prospects in the Cape Nome, Council, and Kougarok districts on the Seward Peninsula contain copper minerals at or near contacts between marble and schist.

The Ward copper deposit was found near the head of the South Fork of the Serpentine River, between Quartz and Bismark Creeks and 3½ miles northwest of Kougarok Mountains. The first claim locations were made in 1904. The deposit yielded a small amount of copper in 1906 and 1907, and small shipments of ore were again made in 1913 and 1916, as follows:

Year	Tons	Copper Content, %	Value
1906	8	41	$1,200
1907	8	41	1,200
1913	14	30	1,400
1916	9.5	Not Available	981
			$4,781

No mining or development work has been done since 1916. The U.S. Bureau of Mines investigated the property in 1947 (R.I. 4110.)

LEAD

Deposits of silver-bearing galena in the Darby Mountains have been known since the earliest trading posts were established on the Seward Peninsula. The Omilak Mine was named in 1881 in the Fish River area and became the second producing lode mine in Alaska; the first was a small gold mine near Sitka. Production from the Omilak Mine was derived from shaft operations and from surface float; no ore was found in the adit. The principal underground workings were a 180-foot vertical shaft on the crest of a low ridge with two

TABLE 11

RECORDED TIN PRODUCTION, CAPE MOUNTAIN AREA, SEWARD PENINSULA, ALASKA*

	Lode		Placer		
Year	Tin, short tons	Dollar value	Tin, short tons	Dollar value	Remarks
1906	6.0	6,819	-	-	Bartels lode mine
1924	-	-	4.34	4,357	Goodwin Gulch
1925	-	-	9.75	11,290	Do
1926	-	-	7.05	9,165	Do
1927	-	-	14.48	31,516	Do
1928	-	-	38.83	38,830	Goodwin Gulch and Cape Creek
1929	-	-	36.65	32,985	Do
1930	-	-	10.87	8,718	Do
1931	-	-	3.66	1,464	Goodwin Gulch
1933	-	-	2.90	2,300	Goodwin Gulch (?)
1934	-	-	4.14	4,300	Do
1935	-	-	46.25	46,250	Goodwin Gulch and Cape Creek
1936	-	-	99.00	91,080	Do
1937	-	-	154.02	166,341	Do
1938	-	-	105.00	88,200	Cape Creek
1939	-	-	25.84	25,840	Cape Creek and Goodwin Gulch
1940	-	-	43.29	43,289	Cape Creek
1941	-	-	49.63	51,615	Do
Totals	6.0	6,819	655.70	657,540	

*Source: Mulligan, J. J. (1966) USBM, RI 6737, p. 8.

TABLE 12
PLACER TIN PRODUCTION
POTATO MT. AREA, SEWARD PENINSULA 1902-1953

Year	Tin (short ton)	Value ($)
1902	15	8,000
1903	25	14,000
1904	14	8,000
1905	6	4,000
1906	28	31,821
1907	22	16,752
1908	25	15,180
1909	11	7,638
1910	10	8,335
1911	61	51,798
1912	130	119,600
1913	48.5	42,780
1914	74	47,321
1915	100	77,300
1916	97	84,600
1917	85	104,553
1918	48	83,560
1919	36	47,182
1920	10.5	10,574
1937	5.95	6,426
1948	4.07	7,975
1949	32	64,984
1950	42	80,640
1951	52.5	134,400
1952	63.7	152,880
1953	55.3	106,176
Total	1,102.34	1,337,475

Source: Mulligan, J. J., USBM, RI 6587, 1965, P. 11.

TABLE 13

TUNGSTEN ORE AND CONCENTRATES SHIPPED FROM MINES IN ALASKA 1900-1967
(In Short Tons of 60% WO_3)

Year	Quantity
1900-1942	116
1943	10
1944	19
1945	-
1946	19
1947	13
1948	-
1949	-
1950	13
1951	10
1952	8
1953	3
1954-1967	No Production
Total	211

working levels and an adit on the south slope of the ridge driven about 500 feet to intersect the deposits at depth.

In 1889, a shipment of 41 tons of picked ore contained 75% lead and 142 ounces of silver per ton; total production for the decade 1880-1890 has been estimated at between 300 and 400 tons. The ore was transported overland, about 6 miles, to a landing on Omilak Creek; it was then floated, in shallow-draft boats, about 75 miles down the Fish River to Golovin and transferred to ocean-going vessels.

Mining was suspended in 1890, but sporadic attempts to resume operation continued until the early 1920's. The deposits were investigated by the Bureau of Mines during the 1953 and 1954 field seasons (Mulligan, J. J., USBM RI 6018, 1962, p. 44). In addition to diamond-drill sampling, the Bureau of Mines' investigation was supplemented by bulldozer trenching and by a reconnaissance of the general geology in the area with surveying and mapping.

The Foster prospect comprises a zonally arranged lead-silver-bearing gossan deposit. It was discovered at an early date; several trenches and pits appeared to be contemporaneous with the workings at the Omilak Mine, but no record of this early work could be found. In 1949, N. W. Foster and Associates of Nome, rediscovered the prospect and exposed the outcrop by bulldozer trenching. No production has been recorded, but several tons of hand-sorted ore were piled nearby (Mulligan, J. J., 1962, p. 7.)

ANTIMONY

Small antimony deposits have been found on the Seward Peninsula, stibnite being the dominant antimony mineral in the deposits. Most of the lodes are auriferous and many contain silver and base metals. Most of the antimony deposits were discovered while prospecting for gold. None of the deposits has been developed below the surface.

ARSENIC

Arsenopyrite is common in most of the tin deposits of the Seward Peninsula, particularly in the intrusive dikes at the Lost River Mine.

BERYLLIUM

Nearly all of Alaska's known lode deposits of beryllium occur in the Seward Peninsula. These are located in the Lost River area (Figure 3). According to Berg (1964, p. 97,) the beryllium deposits consist of replacement veins, pipes, and stringer lodes in limestone of Paleozoic age, in a zone 7 miles long and 2-3 miles wide. The limestone is faulted and intruded by dikes and stocks of granitic rock. The mineralized zones consist of the beryllium mineral chrysoberyl associated with fluorite, diaspore, and mica together with small amounts of hematite, sulfide minerals, manganese oxide, and other beryllium minerals. The beryllium content of bulk samples ranges from 0.11-0.54 percent Be (beryllium); high-grade nodules contain as much as 2.16% Be. Reported beryllium resources in the Lost River area indicate about 1,960,000 short tons of indicated and inferred material that contains 0.18-0.29% Be, and 50% CaF_2. Additional large indicated and inferred resources containing 0.04-0.07% Be and up to 0.3% tin also are probably present (Sainsbury, 1964.) The beryllium resources of the Western part of the Seward Peninsula are not only important to Alaska but also represent a substantial part of those for the entire United States. However, there has been no production yet from the Seward Peninsula deposits.

Geochemical reconnaissance indicates that additional beryllium deposits comparable to those now known in the Lost River Area may be found elsewhere on the Seward Peninsula, principally at Ear Mountain, Cape Mountain, and at other places near granite plutons on the western part of the region.

MOLYBDENUM

There are known occurrences of molybdenum minerals existing in the Seward Peninsula. Only a few deposits have been prospected in detail, and none has been worked commercially.

BISMUTH

The known bismuth deposits in the region are of minor importance and probably would not yield significant amounts of the metal. Vein deposits from which native bismuth and bismuthinite are reported, occur along Charley Creek about 25 miles north of Nome. The native bismuth and bismuthinite are commonly associated with sulfide minerals, graphite, and scheelite, in gold-quartz veins within igneous or metamorphic rocks. The veins are generally less than a foot thick and commonly are localized by joint or foliation planes.

URANIUM - RADIOACTIVE MINERALS

Uranium-bearing minerals are known to occur at Brooks Mountain on the Seward Peninsula. Numerous other radioactive deposits occur in the area; zeunerite, a secondary hydrous copper-uranium arsenate, is concentrated near the surface in granite adjacent to a contact with marble at the Foggy Day Prospect and the Tourmaline No. 2 claim.

MICA

Muscovite sheet mica of commerical importance has been found near granitic intrusive bodies on the Seward Peninsula and in the Bendeleben-Darby Mountains. There has been no mica production recorded so far. All of the reported mica deposits in the Bendeleben-Darby Mountains area are in pegmatites that are intrusive into a structually complex sequence of metamorphic schist and gneiss.

At Birch Creek, near the head of the Niukluk River, mica plates have been found that are over 6 inches in diameter. Large mica plates occur at Pargon Mountain near Fish River, where sheets of mica about 20 inches long by 14 inches wide have been found. Rock exposures are scarce and the pegmatite source of the mica is not exposed at the surface. This deposit was staked and float mica was used by local residents as early as 1901 (USGS, 1964, Pp. 139-140). Information is not available on which to base an estimate of the potential mica resources in the poorly exposed pegmatite deposits of the Seward Peninsula. Some trenching was carried out during 1943 at the Pargon Mountain mica deposit in the region.

GRAPHITE

The Seward Peninsula is the only area in Alaska that contains graphite deposits of potential economic importance. These are located in the Kigluaik Mountains in the vicinity of Imuruk Basin, and from which production has been recorded. Deposits contain graphite lenses in a series of schists and gneisses that make up a large part of the Kigluaik Mountains. According to the USGS (1964, p. 133), the lenses are associated with quartz-biotite-sillimanite schists that are in part garnetiferous. Locally there appears to be two or three series of graphite lenses which are parallel in strike and dip. Some of the graphite is segregated in beds or much-flattened lenticular masses that conform with schist cleavage and have a maximum thickness of 18 inches. Some schistose zones contain appreciable quantities of disseminated graphite. Sills and dikes of pegmatite cutting the schist also contain graphite. At one place about 8 inches of pure graphite is included between a pegmatite sill and overlying schist.

The size of the bodies is not apparent, but surface exposures indicate that some graphite lenses are at least 20 feet long, 30 feet deep, and a foot or more in thickness.

More exploration and development work are required to valuate the deposits in the area for potential utilization.

SUMMARY OF MINERAL RESERVES, RESOURCES AND CUMULATIVE PRODUCTION

As can be seen from the previous sections of this report, known reserves of ore on the Seward Peninsula are small. This is due mainly to two factors, lack of subsurface exploration of known occurrences and a minimum of exploration and geologic mapping by qualified and experienced personnel. To some extent the latter of the two factors is being alleviated by recent geological and geochemical investigations by both the Division of Mines and Minerals of the State of Alaska and the United States Geological Survey. Some subsurface work has been done by the United States Bureau of Mines and mining companies. At least one company is currently drilling on the Peninsula. The Division of Mines and Minerals has two Geological-Geochemical crews on the Peninsula this summer and the U. S. Geological Survey has several helicopter supported Geological-Geochemical programs on the Peninsula as well as off-shore investigations.

Regional characteristics,such as; climate, transportation, lack of harbor facilities, and high labor costs, have been restraints to the development of mineral resources on the Peninsula. Huber (1967), for instance, estimates that transportation costs alone to the Seward Peninsula would be 1.5 times that in Southeastern Alaska. (Includes lighterage.)

The previous sections have presented regional mineral occurrences and claim activity, a Historical Review and production statistics. Table 14 summarizes lode deposits on the Peninsula, by District. Most of this data is derived from published literature. That which has been obtained from other sources has been evaluated as to the reliability of the source.

Since a majority of this data has been derived from the USGS and USBM definitions of mineral reserve terms are in order. There are three categories of reserves commonly used by Federal agencies; measure, indicated, and inferred. These may be defined:

TABLE 14

SUMMARY OF LODE-DEPOSIT IN THE SEWARD PENINSULA, BY DISTRICT 1967

Location	Commodities	Ore Grade or Assay Data	Production, Activities and Remarks
A. Council District			
1. Omilak Mine	Pb,Ag,Sb	- 75% Pb and 142 oz. of Ag per ton. Out of 41 tons of picked ore in 1889. - Galena-rich material up to 71% Pb. Stibnite-rich material up to 32% Sb.	- 300-400 tons ore of 10% Pb and 4 oz. of Ag per ton shipped in 1880's. - Sample analysis by USBM in 1954.
2. Foster	Pb	A trace to 25.6% Pb, 7-7.6% Zn, 5.7-42.5% iron, and 0.02-14.9 oz. of Ag from diamond drilling sample.	Sample assayed by USBM in 1953-54.
3. Fish River	Hg,Pb-Ag	?	
4. Swede Creek	Hg	2.36% Hg in chip sample assayed.	
5. Daniels and Koyana Creek	Au	0.1-8.5 oz. of Au per ton.	
6. Bunker Hill	Au	Containing gold up to 3.9 oz. per ton.	Secondary iron and copper minerals.
7. Crooked Creek	Au	2 oz. Au per ton in quartz vein sample.	
8. Post Creek	Au	1.7 oz. gold per ton in an 8-ft. quartz vein.	
B. Fairhaven District			
1. Independence Mine (Imuruk Lake)	Pb,Ag,Au	The ore reportedly contained 30% Pb, 150 oz. Ag per ton and 0.1 oz. Au per ton.	+100 tons of ore mined by 1922.

TABLE 14 (Continued)

Location	Commodities	Ore Grade or Assay Data	Production, Activities and Remarks
B. Fairhaven District (Continued)			
2. Hannum and Harry Creeks	Pb,Ag	Analyses of 3 specimens showed as much as 0.73% Pb, 1.12 oz. of Ag per ton, and a trace of Au.	Oxidized (Deeply weathered) deposits were discovered in 1900's.
C. Kougarok District			
1. Wheeler Prospect (Pilgrim River)	Pb,Ag	Assayed 14-23% Pb and 14.5-20 oz. of Ag per ton.	Mined before 1922.
2. Sherrette Creek	Cu,Ag	Assayed 17.2-35.7% Cu, 7.6% Fe, and up to 5.2 oz. Ag per ton, and 1.8 oz. Au per ton.	The lode was worked for about 25 tons of ore before 1920.
D. Koyuk District			
1. Timber Creek	Ag	Picked samples assayed up to 70 oz. Ag per ton and 0.05 oz. Au per ton and had a high copper content.	Several prospect pits were dug about 1907. Minerals found too sparse.
E. Nome District			
1. Sophie Gulch	W		Several tons of scheelite concentrates were recovered by placer mining from 1916-1918.
2. California Lode	Au	Assayed about $50 a ton of gold plus Mo and W.	The ore was mined before 1916.
3. Waterfall Creek	Sb	Assayed +58% Sb plus Au and Ag.	2½ tons of high-grade stibnite ore was shipped before 1922.
4. Sliscovich Lode	Sb	Assays showed 36% Sb plus Au and Ag.	The ore was shipped in 1915.
5. Hed and Strand Load	Sb		106 tons of ore were shipped 1915-16.

TABLE 14 (Continued)

Location	Commodities	Ore Grade or Assay Data	Production, Activities and Remarks
E. Nome District (Continued)			
13. West Creek	Au	Ore tenor is unknown, but the wallrocks were reported to carry $8-10 a ton in gold.	
F. Port Clarence District			
1. Lost River	Be	Bulk samples range from 0.11-0.50% Be; high-grade nodules contain as much as 2.6% Be.	Beryllium resources estimated at 1,960,000 short tons of indicated and inferred material containing 0.18-0.02% Be and 50% fluorite. No production to date.
2. Lost River	Sn	Resources estimated in 1964 consist of 2,600 short tons of tin in measured and indicated material containing 1.3% Sn; 15,450 short tons of tin in inferred ore averaging about 1.0% sn; and 18,700 short tons of tin in inferred ore containing 0.2-0.75% Sn.	Lost River Mine yielded ore containing about 350 short tons of tin from 1904 through 1955.
3. Bessie-Maple Lode	Ag,W,Sb, and base metals	Samples assayed a trace to 0.03 oz. Au and 4.2-25.6 oz. Ag per ton, 0.5-9.1% Pb, 0.48-1.53% Cu, about 3% Zn, 0.30-1.6% Sn, up to 3.2% WO_3, and 3.8% Sb.	No workable ore has yet been found.
4. Wolframinte-Topaz Lode	W,Ag	An assay showed 22.9 oz. Ag per ton.	Exposed by surficial workings in the 1900's.
5. Cape Mountain	Sn	Samples contained as much as 32.9% Sn and traces of WO_3,but the most promising deposit averaged only about 7.24% Sn.	About 10 tons of concentrates containing 64% Sn were shipped in 1905.

TABLE 14 (Continued)

Location	Commodities	Ore Grade or Assay Data	Production, Activities and Remarks
E. Nome District (Continued)			
6. Rock Creek	Au	Concentrates of arsenopyrite and pyrite assayed $48-65 per ton Au.	The test showed 250 lbs. of concentrates per ton of mill heads and $6.25/ton in free gold. Work was done in 1920.
7. Anvil Creek, Dexter Creek	Au,Ag,Sb	Assays probably of selected materials, showed as much as $72/ton of Au, $28 of Ag, and some copper.	About 1,500 lbs. of stibnite was also mined on the Petersen and Lamoreaux property in 1900.
8. Breen Property	Sb	10% Sb.	About 14 tons float ore were shipped.
9. Copper Mountain	Cu,Pb	Samples from veins assayed 15% Cu, 20% Pb, with high Ag and low Au content.	
10. Rocky Mountain Creek	W	Vein sample contains about 3% sheelite by volume.	Vein 18 ft. long, ranges in thickness from 1½-2 in. found by USGS in 1944.
11. Monarch Claim	Fe	Samples contained 54.81% Fe, 1.06% Mn, 0.056% P, and a trace of S.	Reserves estimated that the residual high-grade material aggregates at least several hundred thousand tons.
12. Big Hurrah Mine	Au,W,Sb	- In some of the high grade ore, the gold formed masses an inch or more in maximum dimension, but most is said to have averaged less than $20 per ton in Au. - Samples of gold ore remaining in the bins of the mill in 1943 averaged 0.25% scheelite (high up to 10%).	- Discovered in 1900 and yielded at least 10,000 fine oz. gold in the ensuing 40 years. - Small amount of scheelite was also reported in quartz vein at the R. W. Silver mine on Tribly Creek. - 4 tons of stibnite ore were shipped in 1914.

TABLE 14 (Continued)

Location	Commodities	Ore Grade or Assay Data	Production, Activities and Remarks
F. Port Clarence District (Cont.)			
6. Brooks Mountain	Pb,Ag	Early assays showed as much as 34% Pb and 11 oz. Ag per ton. It also contained as much as 2.1% equivalent uranium in a few specimens examined by USGS in 1951.	Explored by shallow trenches and short shafts and adits, before 1918. No recorded production.
7. Ear Mountain	Sn,Cu	Assays average 0.2% Sn, 0.3% Cu. Some of the zone contains as much as 2% Sn and 3% Cu. (USBM, 1953-54)	Explored first for gold and then for tin and other metals. By 1915 few shallow shafts were dug. Assay showed up to 18.7% Sn and 4% Cu.
8. Potato Mountain	Sn	The richest lodes contain 1.10% Sn. Average grade estimated at 0.25% Sn maximum.(USBM, 1961)	Discovered about 1900 and explored until about 1920.
G. Serpentine District			
1. Ward Mine	Cu	Ore grade 35% copper in 1900's.	About 40 tons of ore were shipped from 1906-1918.

Source: Berg, H. C., and Cobb, E. H., Metalliferous Lode Deposits of Alaska. USGS Bull. 1246, 1967, p. 254.

"MEASURED reserves are those for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to be different from the computed tonnage or grade by more than 20 percent.

INDICATED reserves are those for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

INFERRED reserves are those for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or meaurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves should include a statement of the specific limits within which the inferred materials may lie."

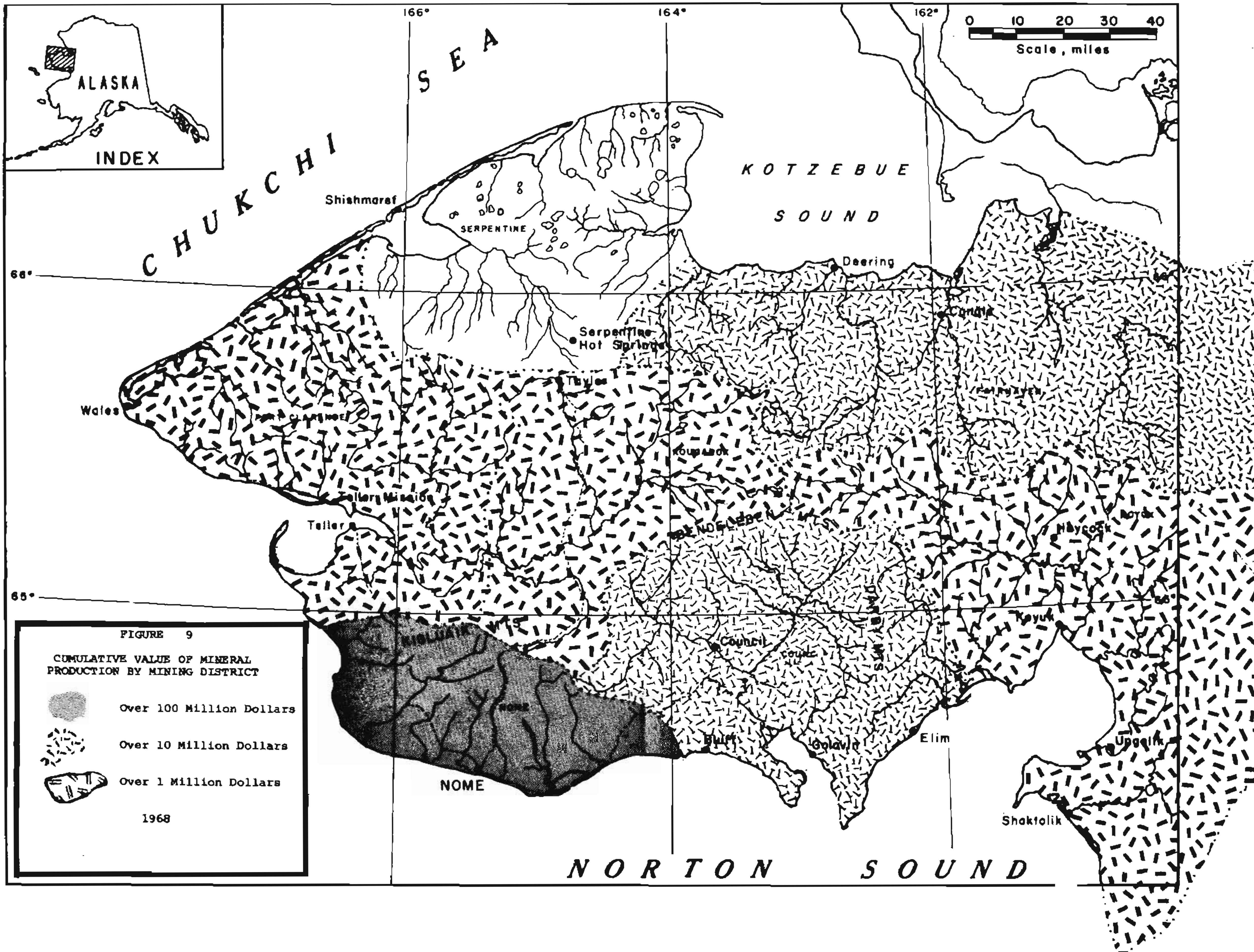
Table 15 summarizes the known reserves and resources and compares them to production data where available. Reserve data is again lacking. A great amount of money and effort will be required to explore and develop those properties known only as "mineral occurrences." Only after this is done can they be classified as reserves.

Figure 9 illustrates the cumulative value of mineral production on the Seward Peninsula by Mining District. Since 1896, there has been only one district, Nome, which has produced over $100 million. Two districts: Council and Fairhaven, produced over $10 million; three districts: Kougarok, Koyuk, and Port Clarence, produced over $1 million and one district: Serpentine, produced less than $1 million.

TABLE 15

SUMMARY OF MINERAL RESERVES, RESOURCES AND CUMULATIVE PRODUCTION
OF THE SEWARD PENINSULA, ALASKA 1968

Commodity	Reserves and Resources	Cumulative Production	Location
Antimony	?	+200 tons of high grade ore.	Nome District.
Beryllium	Indicated and inferred reserve: 2,000,000 tons of metal at 0.18-0.29% Be (plus large tonnage at 0.04-0.07% Be.)	No production.	Lost River.
Copper	?	40 tons of very high grade ore.	Ward Mine (Serpentine District)
Fluorite	1,900,000 tons of 40% CaF_2.	No production record.	Lost River.
Gold	?(+10 million oz. estimated.)	6.3 million oz.	Widely distributed.
Graphite	50 tons sorted material. 65,000 tons of 52% graphite. 300,000 tons of 10% graphite.	270 tons.	Kigluaik Mountain.
Iron	54.81% Fe, 1.06% Mn, 0.05% P, and a trace of S in several hundred thousand tons.	No production record.	Monarch Claim (Nome).
Lead	?	500 tons of high grade lead-silver ore.	Omilak Mine (Council District).
Silver	?(1 million oz. estimated.)	Several hundred thousand oz.	Widely distributed.
Tin	200,500 tons ore at 1.3% Sn,105,000 tons ore at 0.76% Sn and 0.60% WO_3. 3,000,000 tons of potential resources 0.30% Sn.	Over 1,500 tons of metal (estimated).	Lost River.
Tungsten	By-product in the tin mining (See above) 63,350 units (20 lbs.) WO_3 and indicated ore at 0.6%.	Over 100 tons of 60% WO_3.	Lost River.


ALASKA
INDEX
CHUKCHI SEA
KOTZEBUE SOUND
NORTON SOUND
166°
164°
162°
66°
65°
0 10 20 30 40
Scale, miles
Shishmaref
SERPENTINE
Serpentine Hot Springs
Deering
Candle
Wales
Teller
Council
Bluff
Golovin
Elim
Koyuk
Haycock
Ungalik
Shaktolik
NOME
FIGURE 9
CUMULATIVE VALUE OF MINERAL PRODUCTION BY MINING DISTRICT
Over 100 Million Dollars
Over 10 Million Dollars
Over 1 Million Dollars
1968

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ABBREVIATIONS

MF	-	Field Studies Map
MR	-	Mineral Resources Map
Prof. Paper	-	Professional Paper
Bull.	-	Bulletin
Circ.	-	Circular
R. I.	-	Report of Investigations
I. C.	-	Information Circular
PE	-	Property Examination
MI	-	Mineral Investigations
MR	-	Miscellaneous Report
OFR	-	Open-File Report
Spec. Pub.	-	Special Publication
Ann. Rept.	-	Annual Report

PART II

II. POTENTIAL MINERAL RESOURCES OF SEWARD PENINSULA, ALASKA AN EVALUATION BY GEOSTATISTICS AND COMPUTER SIMULATION

Dr. DeVerle P. Harris *

INTRODUCTION

PERSPECTIVE

Potential resources in this section are defined as those resources inferred to an area as a function of its general geological setting (or measures of mineral density) and the general economics of mineral exploration and exploitation. This definition is to be distinguished from potential reserves as estimated by rules of generalization from known mineral occurrences, which to a certain degree was covered in the previous section. As uncertain as is the estimation of potential reserves, the estimation of potential resources is even more elusive, for it requires consideration of probable occurrences of mineral deposits for which are known no direct evidences. Only indirect evidences are known, generally in the form of reconnaissance geology and economic characteristics of mineral deposits. The point to be emphasized here is that at best, estimation of potential mineral resources from reconnaissance information provides "ball park" figures. This is true for any study of this type, for it requires the ascribing of quantitative descriptions to events not known. It is for these reasons that a statistical approach combined with computer simulation was employed to generate the estimates of this study, for by

*Assisted by Azman Azis, James Chrow, and David Euresty this methodology estimates can be given in terms expressing the uncertainty of the factors entering the analysis. Estimates developed in this study are to be considered only as rough scientific guesses, and use of them should not be made without an appreciation of their nebulous nature.

SCOPE OF STUDY

The period of time allowed for this study was approximately two months. This served as a constraint in terms of data acquisition, completeness of the analytical framework (inclusion of all pertinent relationships), and the appraisal of special factors pertinent to the area of this study. Had it not been for the prior completion of part of the geostatistical work and the prior assembling in rough form of part of the data that were used in this analysis, it would not have been possible to perform this study in the length of time prescribed.

Two separate analyses were made: 1) Spatial Analysis, and 2) Geostatistical Analysis. Both of these related probability of occurrence of mineral deposits to economic factors to arrive at resource estimates; however, the spatial analysis was based upon the proposition of equal liklihood for the occurrence of deposits in each subarea (cell) of the Peninsula. On the other hand, the geostatistical analysis was based upon probabilities generated for each cell as a function of the cell's geology (Harris, 1968).

The resource appraisal in this section is based mainly upon the evaluation of the "bedrock" geology. Geologic features associated with placer deposits, such as alluvium, are treated simply as masking agents of the ultimate source of mineral values, the underlying bedrock. Naturally, there is a connection between primary mineral occurrence and placer deposits; however, there was not available an analytical framework by which to quantify this relationship and to evaluate the placer potential. It is left to the reader to link probable lode occurrences with placer occurrences. It is not clear whether as a general rule placer development and associated geologic features serve to decrease or increase the mineral potential of an area. On the one hand through secondary geologic processes, low grade mineralization which does not constitute an economic deposit might be concentrated into a placer-type deposit that is economic. On the other hand, development of extensive alluvium which may accompany placer formation serves to mask primary geologic features and to decrease the effectiveness of mineral exploration in discovering covered lode deposits. In either case, the mineral potential of the "bedrock" has a bearing in a resource appraisal, for it is from minerals in bedrock that the placers are formed.

The probabilities employed in the second analysis were computed by a multiple discriminant and classification model that was developed on a composite data base of cells from Utah, Arizona, New Mexico, and Alaska in a previous study (Harris, 1968). These probabilities are for a cell belonging to each of three classes of gross mineral value and are a function of the reconnaissance geology of the cell. Inasmuch as resources are in part a function of cost as well as geology, a quantitative estimate of resources for the Seward Peninsula requires a translation of gross value and probabilities to measures which relate to the physical characteristics of deposits and the economics of exploration and exploitation.

SPATIAL ANALYSIS

GENERAL

Spatial analysis implies consideration of the distribution of mineral criteria (mines, mining districts, deposits, value, etc.) as they relate only to area. This is to be distinguished from geostatistical analysis in which mineral criteria are related to an area indirectly through their relationship to the geology of the area. Thus, in spatial analysis each cell of an area is assumed to be equally endowed, the resources of the entire Study Area being a multiple of the resources of any one cell.

Although the appraisals resulting from the geostatistical analysis are the primary objectives of this study, a spatial analysis was performed to provide an additional estimate of the resources of Seward Peninsula. The utility of the spatial analysis is twofold: 1) it provides results that are not directly dependent upon a postulated relationship of geology to mineral occurrence and not subject directly to the bias that might result from selecting a Study Area of a somewhat different geologic environment than that of the statistical base, and 2) as the spatial analysis was based in part upon different economic data, it allows comparison of results of two quite different analyses, each serving as a check upon the order of magnitude of the other estimates.

GROSS MINERAL WEALTH

The Control Area (well explored area) in this study consists of approximately 154,800 square miles in Arizona, New Mexico, and Utah. Mineral density of the base and precious metals group only in the Control Area is about $220,000 per square mile. Density for the Utah part alone is about $299,000 per square mile and for New Mexico and Arizona collectively $172,000 per square mile. These density measurements were calculated by dividing total cumulative value of production plus estimated reserves by total surface area. Value of cumulative production was determined by summing annual production figures (weight) for each district and aggregating by the 1964 price vector: Au, $35.00/oz.; Ag, $1.30/oz.; Pb, $.14/lb.; Zn, $.13/lb.; Cu, $.30/lb. To this value figure was added the value of estimated reserves of producing districts. Production data for the Seward Peninsula are somewhat conflicting, depending upon the source; however as a general estimate, mineral density on the Peninsula is about $10,000/square mile, considerably below that of the Western United States.

An alternative and perhaps more enlightening comparison of mineral density derives from dividing the Control and Study Areas into cells (20 miles square subdivisions). Production values were alloted to these cells on the basis of their contained mining districts. While this procedure worked fairly well in the Control Area, in Alaska production data were often referenced to very large areas containing many cells, making allocation of value to the appropriate cell difficult. In some instances judgments were highly subjective and arbitrary. Table 16 shows a frequency count of cells of eight different value classes for the Control Area. In this same Table a relative frequency distribution has been constructed from the data on the 387 cells of the Control Area.

Employing the relative frequency distribution as a probability distribution, which is valid only when the number of observations is large, and utilizing the fact that only 52 cells were evaluated in the Study Area, column 5 of Table 16 was

TABLE 16

SPATIAL ANALYSIS - GROSS VALUE PER CELL

Value Class	Value	Frequency of Occurrence in Utah, Arizona, and New Mexico	Relative Frequency	Expected Occurrence in Seward
1	0 - $\$10^{4}$	265	.685	36
2	$\$10^{4}$ - $\$10^{5}$	24	.062	3
3	$\$10^{5}$ - $\$10^{6}$	30	.078	4
4	$\$10^{6}$ - $\$10^{7}$	30	.078	4
5	$\$10^{7}$ - $\$10^{8}$	22	.057	3
6	$\$10^{8}$ - $\$10^{9}$	6	.015	1
7	$\$10^{9}$ - $\$10^{10}$	9	.022	1
8	$\$10^{10}$ +	1	.003	0

constructed to show the expected occurrence in the Study Area of cells of the various value classes. The most interesting observation to be made from Table 16 is that on the basis of this spatial analysis there is expected to occur two cells of very large gross value, one in group seven ($100 million - $1 billion) and one in group eight ($1 billion – $10 billion). Mineral production information from Part I of this report indicates that there is no cell with known cumulative production even approaching that of value class eight. The implication of this is that there are yet to be exploited large resources in the Seward Peninsula, either in the form of unproven reserves in currently or previously active production areas or in the form of new deposits yet to be discovered.

Moderation is in order in evaluating this potential, for this inference is based purely upon the known intensity of mineral occurrence in the Control Area and does not reflect the greater exploration and exploitation costs and less favorable climatic conditions of the Seward Peninsula and their impact upon resources. The affect of costs upon the quantity of economic resources is the subject of the remainder of this section.

RESOURCES AND ECONOMICS

The relationship between mineral resources and mineral prices and production costs is an obvious one to the minerals professional and requires no exposition in principal; however, the manner of adjustment of measures of gross mineral wealth for pertinent economic factors in a regional resource analysis is not a trivial problem in practice, more because of data problems than conceptual problems.

Since cost figures relate to production units, it ultimately is necessary to shift from the more aggregative concept of the cell or area to the concept of a mine. Yet the mine as a production unit is not without problems, for more than one mine might be exploiting a single deposit (mineral occurrence), or what was once several mines with more recent technology might be one large mine. Nevertheless, lacking a better alternative, available data were analyzed for pertinent statistics to translate gross value to quantities and values of mineral resources in terms of mines.

Given a distribution of some mineral criteria, for example, number of mines per cell or value per mine, one can proceed to compute the expected values of these distributions and combine them as required to generate a single (deterministic) resource measure; however, because of the probabilistic nature inherent to the estimation of potential resources, computer simulation was employed so as to produce a distribution of results exhibiting explicitly the uncertainties in the evaluation.

COMPUTER SIMULATION MODEL

The major elements of the computer program for the simulation are shown in a schematic diagram in Figure 10. The first distribution to be tested in the simulation is that of the number of mines per cell. For each of the 387 cells in the Control Area the number of mines per cell was recorded and plotted to form the cumulative frequency distribution of Figure 11. The response from the Monte Carlo sampling of this distribution is the number of mines contained in the cell. The second distribution, value per mine, is then tested as many times as there are deposits so as to generate a value for each mine. Data on cumulative production per mine are

Figure 10. GENERALIZED SCHEMATIC DIAGRAM
SPATIAL ANALYSIS SIMULATOR

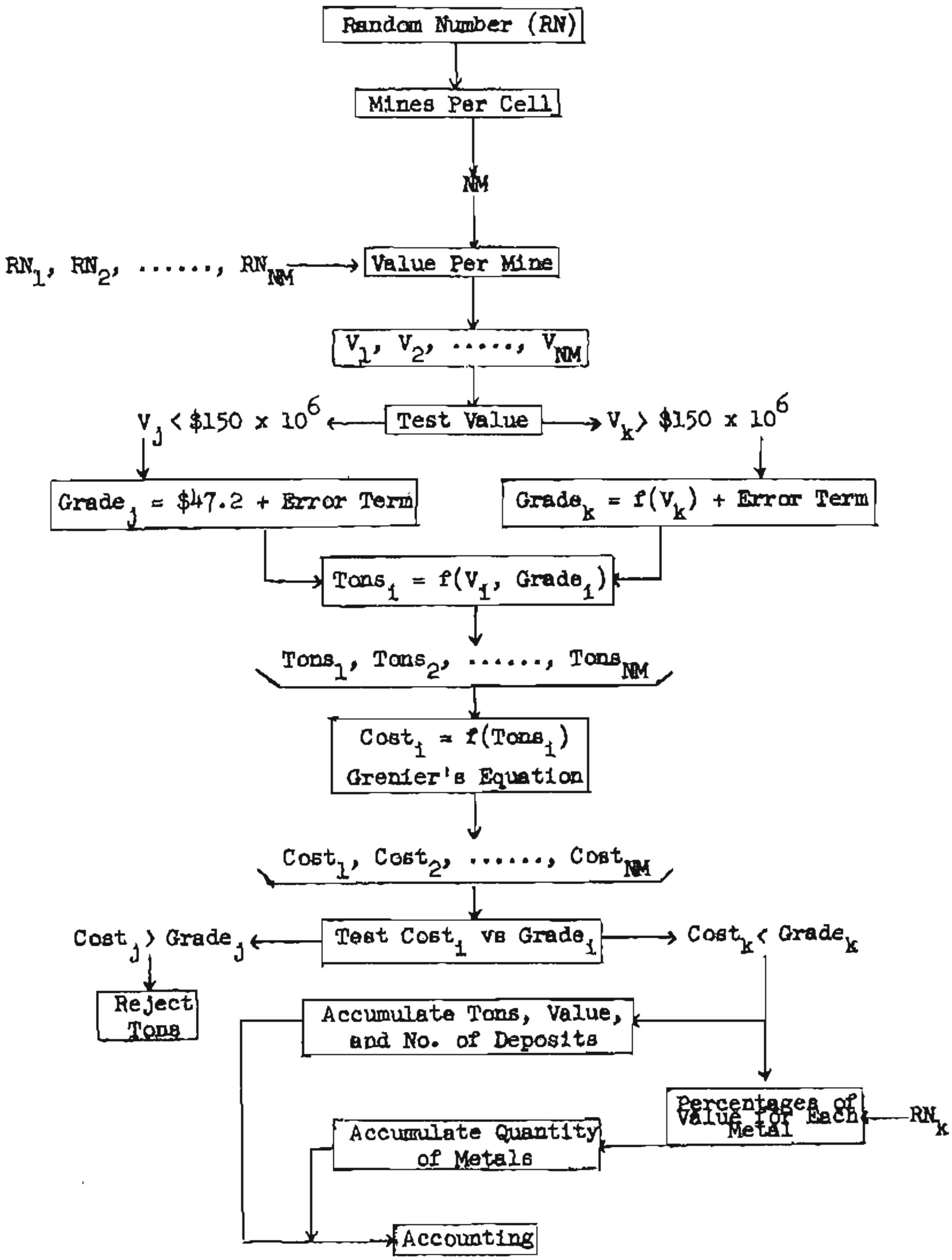
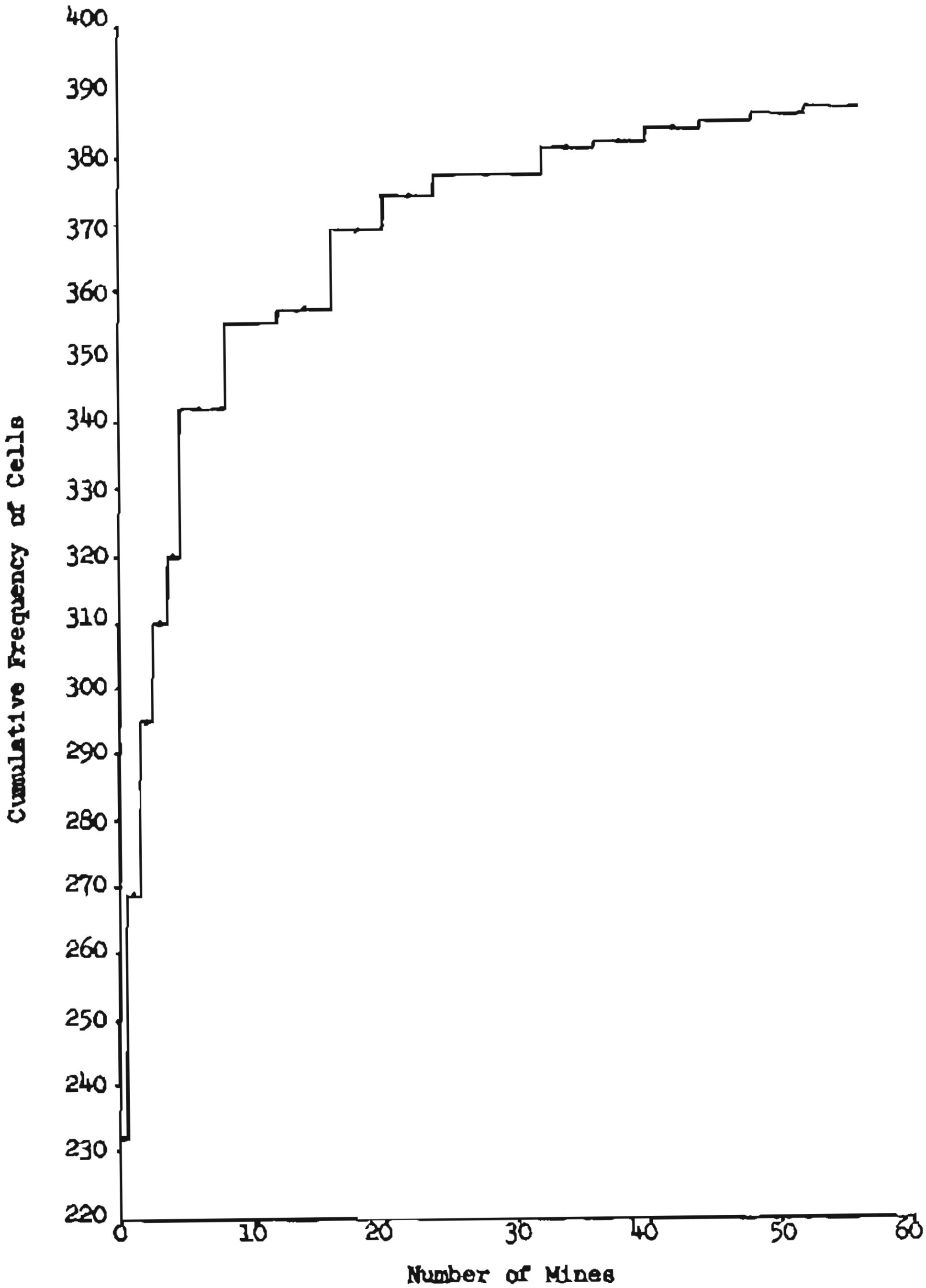


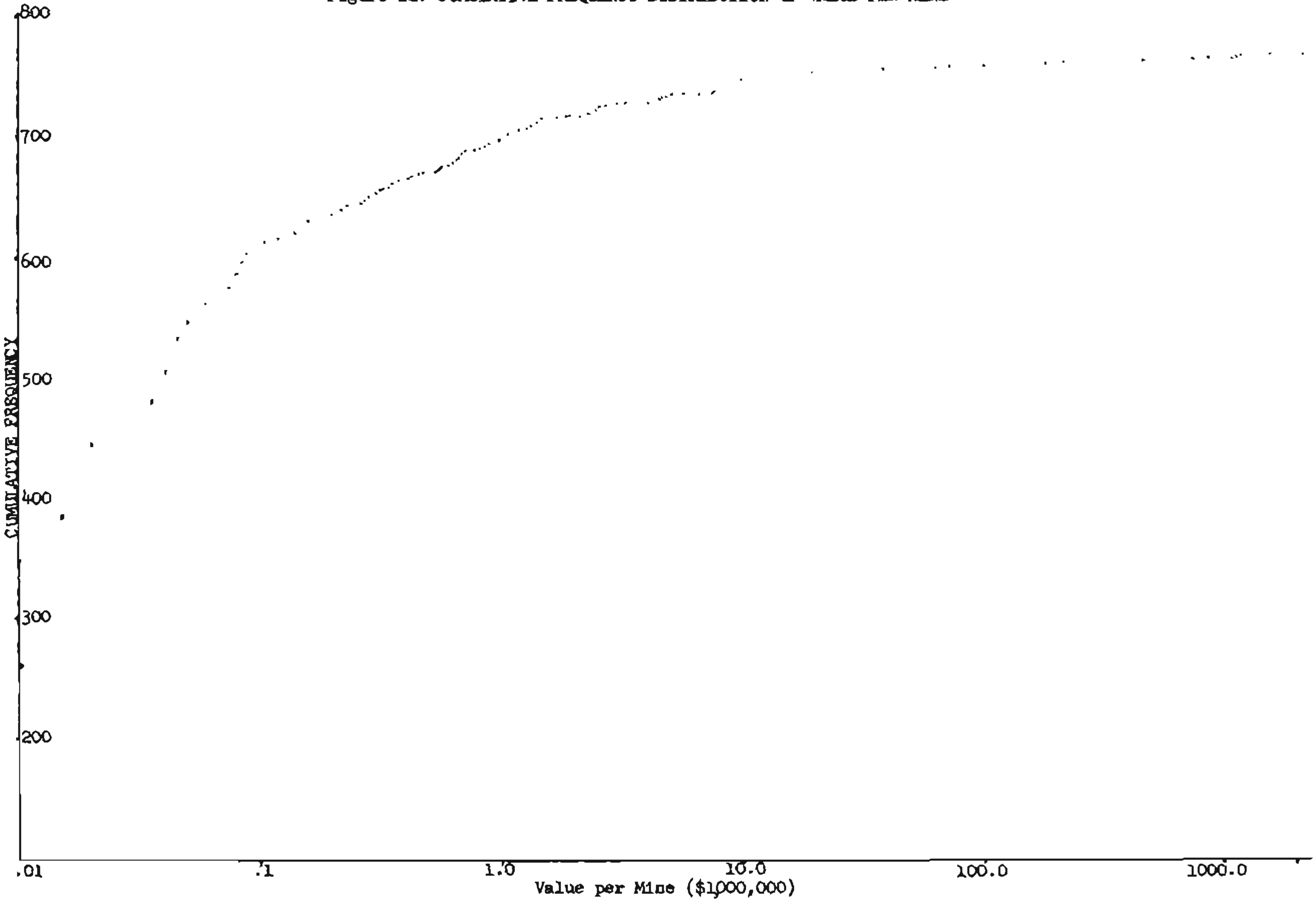
Figure 11. CUMULATIVE FREQUENCY DISTRIBUTION NUMBER OF MINES PER CELL



difficult to develop from annual production data, for the U. S. Bureau of Mines is not free to publish annual production statistics in a less aggregated form than the mining district. The cumulative frequency distribution of Figure 12 is based upon summarized data received from the U. S. Bureau of Mines on cumulative production statistics for 769 mines (personal communication, Scott Hazen, U. S. Bureau of Mines, 1968).

The introduction of grade into the simulation is required to transform the value per mine into tonnage per mine. Grade in dollars per ton reported in annual reports of mining companies was first examined as a source of data for the simulator; however, inasmuch as the objective here is to estimate potential resources, an area to be evaluated is considered for purposes of evaluation to be unexplored and unexploited. Therefore, these data were rejected because they would underestimate the grade of ore for a virgin area. For example, the grade of ore currently mined at Kennecott's open pit at Bingham, Utah, underestimates the grade of the total ore mined to date from that deposit, for the high-grade ore mined in the early history of the deposit if included in the computation of average grade for the deposit would cause the average grade to be above the current mining grade. The grade distribution finally selected for this analysis was constructed by recording for 43 mining districts in the Control Area the production in quantity terms of the base and precious metals and the production of ore over a period of at least 20 years (40 years for some districts) ending in 1957. For each mining district the quantities of metals produced were aggregated to a value by the following price vector: Au, $35.00; Ag, $1.55; Cu, $.38; Pb, $.14; and Zn, $.13. These values and tonnages of ore for each district were summed across the time period and combined to form an average

Figure 12. CUMULATIVE FREQUENCY DISTRIBUTION OF VALUE PER MINE

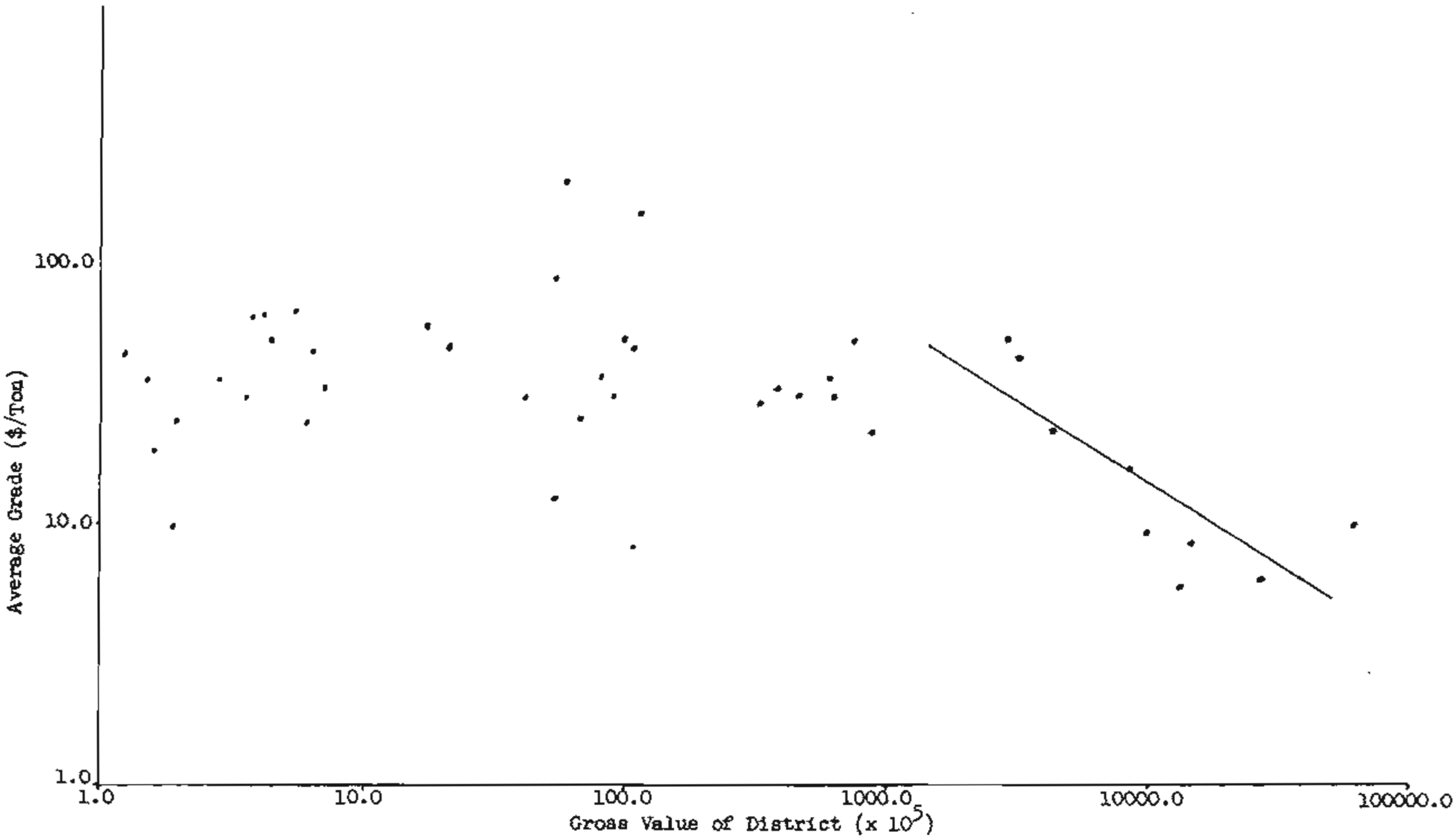


grade per mining district in dollars per ton. This average grade computed over a time series of 20-40 years was taken to represent the <u>total cumulative value</u> of the mining district. The total cumulative value of the mining district was computed by applying the price vector above to the total cumulative production of these five metals. Thus, for each district there exists an average grade computed over a period of 20-40 years and a total value computed over the life of the district. Figure 13 is a bivariate, log-log plot of average grade ($/ton) and total value of the district. For values less than $150,000,000 there appears to be no relationship between grade and total value; however, for values greater than this amount there appears to be a moderate relationship: log (Grade) = 6.89616 - 63775 10g (Value)

r = .79

Now, this bivariate plot is of the total value and average grade per mining district and not per mine as was desired for the analysis. Since data are not available on mines, an attempt was made to get from district data to mine measurements by dividing the district values by the number of mines per district, which gives a measure of the average value per mine per district. Data on the number of mines per district varies considerably from year to year, so an average for several years was computed and used to compute average value per mine. The resulting plot of average value per mine per district versus grade for mines less than $150,000,000 in total value also exhibited no obvious pattern and gave a mean nearly the same as for the district data. Critical examination of the pattern of the time series for number of mines per district for districts with greater than $150,000,000 does not for these districts make the use of an average number of mines very appealing. Production of

Figure 13. TOTAL VALUE OF SELECTED MINING DISTRICTS OF ARIZONA, NEW MEXICO, AND UTAH VS AVERAGE GRADE



these districts which once came from many small to moderately sized mines now is dominated in many cases by one very large mine, such as the open pit at Bingham, Utah, in the West Mountain District. Thus, the judgment was made that it was more correct to consider these very large districts as one mine. Furthermore, since there was little difference for the smaller valued districts between district grade or mine grade, district values and average grades were employed as a data base to generate the grade responses for all mines simulated. Thus, for mines with values less than $150,000,000 grade was determined by sampling from a normal population with a mean grade of $47.20 per ton and a standard deviation of $38.20 per ton. For the larger values a grade was computed from a regression equation. As a method of expressing the inherent error of this equation an error term was formed by multiplying the standard error of the equation by a deviate drawn from a normal distribution with a mean of zero and a standard error of one. This error term was added to the value computed by the equation:

1. For Value less than $150,000,000

   Grade $= \overline{G} + (Z)(S)$, where

   $\overline{G}$ = mean grade = 47.2

   S = standard error of grade ≈ 38.2

   Z = a standard normal deviate (determined by Monte Carlo Method)

2. For Value more than $150,000,000

   Grade $\approx 10^{G}$, where

   $G = \breve{G} + (Z)(S)$, and

   $\breve{G} \approx 6.89615 - .63775 \log(\text{value})$

$$S = .2299\sqrt{1 + \frac{1}{9} + \frac{[\log(\text{Value}) - 9.01947]^2}{1.5011}}$$

Z = a standard normal deviate

COST

Inasmuch as the spatial simulation is intended as a preliminary analysis (one as independent as possible from subsequent analysis) and for comparison purposes, a literature search was made for a set of data suitable for a very general treatment of production cost--a more explicit treatment is given in the geostatistical simulation. The cost relationship employed in this analysis is based upon a graph developed by Grenier (1964) in which he plots the boundary that separates the new mines developed in Quebec, Canada, that have proven economic from those that have proven uneconomic. This boundary defines cutoff grade (\$/ton) as a function of tonnage. The equation determined for this curve is as follows:

$$\text{Cutoff Grade} = 10^{[2.509544 - .221237 \log(\text{Tons})]}$$

This grade relationship is considered to treat implicitly production costs; that is, if for the tonnage developed by the simulator the average grade is greater than the cutoff grade given by this equation, then the deposit is considered economic.

This cost relationship is not considered to include exploration costs, for irrespective of the capital spent by the exploration firm upon discovery, successful development and exploitation of a newly discovered property is dependent only upon the production cost-grade relationship. In the long run, however, exploration costs must be considered in the appraisal of resource potential, for these costs ultimately must be covered by the operations of the mineral firm. If finding costs continually prove high in an area and are not offset by a larger production cost-grade differential, then capital resources will be diverted to other areas. In the short-run analysis this is not necessarily the case, for on any one venture, exploration costs might be charged against revenues from other operations. For the first simulations of the spatial model, exploration costs were completely ignored; therefore, these results can be considered as an inventory of resources that are economic if they were known. The cost relationship developed by Grenier pertains to Quebec, not the Seward Peninsula of Alaska. Mining costs in the Peninsula of course will be higher because of the overall higher level of costs in general (Lu, Heiner, and Wolff, 1968). In the case of mining, infrastructure development (roads, railroads, etc.), plays an important role in costs, for if there is no infrastructure link to the area of a deposit, capital for the construction of one must be charged against the resources of that area. Once such is constructed, it adds value to other resources in the area, creating a sequence of interactions in the investment-resource-development chain. Because of the difficulty in establishing satisfactory estimates of cost differentials, the costs from Grenier's relationship were varied (multiplied by a fraction greater than one) so as to observe the affect of several cost levels upon the resources of the area. The results of this analysis are shown in Table 17. The affect of production cost upon total tonnage of ore, average value per mine, and grade are shown in Figures 14 and 15; these relationships are expressed by the following equations:

$$\text{Tons} = 10^{(7.92658 + .39220M - 1.49693M^2)}$$

$$\text{Grade} = 23.798 + 2.987(M-1)M$$

$$\text{Val} = (-19.197 + 158.459M)10^6,$$

TABLE 17

SUMMARY OF SPATIAL SIMULATION*

Mean Statistics	Cost Conditions**			
	1.3G	1.75G	1.9G	2.0G
Ore (10^6 Tons)	(166.5)*** 152.6	(150.6) 142.4	(149.5) 135.9	(148.5) 129.2
Grade ($/Ton)	(19.5) 24.7	(19.56) 26.83	(22.06) 29.20	(22.63) 30.34
No. Economic Mines****	(7) 20	(5) 12	(5) 11	(4) 9
Av. Value/Mine ($\$10^6$)	109.12	183.17	203.33	221.29

*100 iterations on each of 52 cells
**Costs are in multiples of Grenier's equation
***Figures in parentheses are standard errors
****Figures rounded to nearest whole number

Figure 14. SPATIAL ANALYSIS: COST VS VALUE PER MINE AND AVERAGE GRADE

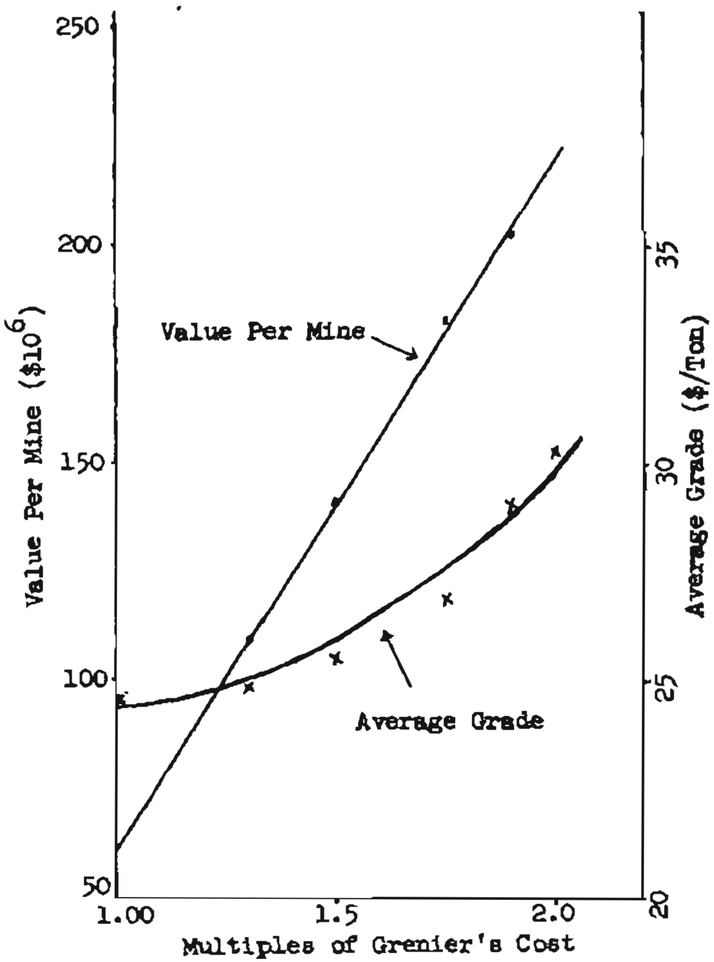
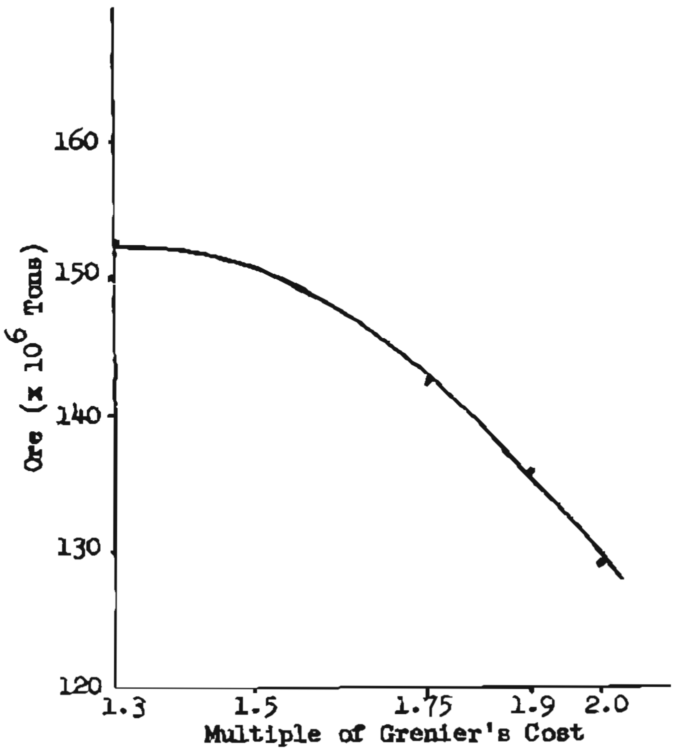


Figure 15. SPATIAL ANALYSIS:TONNAGE OF ORE VS COST



where, M = Multiple of Grenier's cost

Tons = Total tonnage of ore (Resources)

Grade = Average grade of ore in $/ton

Val = Gross value per mine for economic Mines

The quantities of the base and precious metals contained in the tonnages of ore were determined for each deposit in the simulator by Monte Carlo sampling on the distributions developed on the Control Area for the percentages of the total value comprised by each of the metals. These quantities based upon costs of 130% of Grenier's costs are shown in Table 22. Part I of this report indicates a considerably different pattern of metal production for the Seward Peninsula than for the Control Area: Au, 97.777%; Silver, .077%; Copper, .033%; and Tin, 2.143%. Since for the Control Area the value of base and precious metals production constitutes essentially the total metal production of the area, resource values can be considered as indicating the value of total metal resources. With this as a premise, it is logical to transform the value of the total tonnage of ore to quantities of metals more appropriate to the Seward Peninsula. Instead of using the percentages for Seward, percentages that apply to the entire State of Alaska were used, mainly because the bulk of Seward's production is from placer deposits and does not necessarily represent the potential of the bedrock (this same condition applies also to other areas in Alaska, but to a lesser degree for the State): Cu, 32%; Au, 65%; Ag, 1.5%; Pb, 3%; Tin, 2% (see Table 22).

Before leaving the SpatialAnalysis an attempt was made to test the affect of including some cost of exploration in the costs of the deposit, realizing of course that this is meaningful only in the long-run analysis of resources. Lacking a detailed simulation of the exploration process, which if done well in an economics and probability framework would require a large effort of itself, the method employed was to assume that all of the deposits would be found, for the distributions of the spatial model were based upon known occurrences in the Control Area. With this assumption, the problem is reduced to one of ascribing to the deposits the cost of the discovery. Brant (1968) indicates that the current level of expenditure in mineral exploration per year is approximately 4% of the gross value of mineral production. Thus, a cost of 4% of the gross value of the deposit was charged for exploration. This cost as well as the other costs were increased by 175% to allow for overall cost differentials for the Seward Peninsula. The results of this simulation are shown in Table 18.

GEOSTATISTICAL SIMULATION

GEOLOGY AND A PROBABILITY OCCURRENCE MODEL

The basic premise of this model is that the physical occurrence of economic mineral deposits is a function of earth processes that are reflected in geologic features. A corollary to this premise is that the probability of mineral occurrence in terms of gross value varies from area to area as the areas vary in their geology. Thus, given the function that relates geology to mineral wealth in terms of probabilities, a set of probabilities could be computed for a cell by evaluating the function on the geology of that cell.

As conceptually appealing as are these simple postulates, their application as a method of analysis is impeded by the lack of specification for the functional

TABLE 18

AFFECT OF EXPLORATION - SPATIAL ANALYSIS

Cost Conditions = 175% of Grenier's

Mean Statistics	No Exploration	Exploration
Ore (10^6 Tons)	(150.6) 142.4	(150.3) 138
Grade ($/Ton)	(19.56) 26.83	(22.05) 29.14
No. Economic Mines*	(5) 12	(5) 11
Av. Value/Mine	183.2	201.7

*Rounded to nearest whole number.

relationship. Nevertheless, seeking quantitative estimates of resources and yet desiring to employ regional geologic information, a compromise was adopted in which geology was treated as variables in a multivariate statistical model--as an approximation to the conceptual functional relationship. This approach was employed in a previous study of parts of Alaska (Harris, 1968), the results of which were published in M.I.R.L. Report No. 16, University of Alaska. Probabilities of 36 of the 52 cells of the Seward Peninsula were based upon that work; the probabilities of the remaining 16 cells could only be computed after the geologic information was assembled and processed in this study. Details on the multivariate analysis are given in the aforementioned M.I.R.L. Report. Suffice it here to state that some 22 geological measurements were made on each cell and constituted the basis for the computation of the probabilities employed in this analysis. The statistical bases defining the relationships were developed upon the geology of cells from Arizona, New Mexico, Utah, and parts of Alaska. The results of several discriminant analyses, each consisting of two functions, were combined to give probabilities, which can be interpreted as describing the occurrence of mineral wealth. The distinction in this study is made between the occurrence of mineral wealth and the current existence (as evidenced by cumulative production and reserves) of mineral wealth. By occurrence is meant the wealth that might exist if all of the geology of each cell were known and the area were thoroughly explored. This measure was generated by estimating statistically the covered (by alluvium, ice, water, etc.) geology and combining this with the known geology to evaluate the discriminant models. Thus, the probabilities describe what might exist in the bedrock, not necessarily what might be discovered.

Besides the usual problems of a statistical nature that relate to the assumptions of multivariate statistical models, the method of analysis employed is vulnerable to some degree to criticisms arising from geological concepts, such as geological and metallogenic provinces. That the general geological setting of the Seward Peninsula is somewhat different from that of Western U. S., which constituted the bulk of the statistical base, cannot be denied, and the possibility is admitted of biased results arising from this difference. It is not at all clear how large this bias might be, for at the aggregative regional level of analysis it might be that within "broad limits" the relationship of these geological measurements to mineral wealth is moderately stable, for example, the interaction of intrusives with other rock types and the presence of structural deformation, fractures, and faults as indicators of areas favorable to mineral occurrence. The assumption of this study is that the Seward Peninsula and the areas of the Control Area are within these "broad limits."

As indicated in Part I of this report, the suite of metals that occur on the Peninsula is quite varied and contains metals that are not common to the Western States, such as tin. The risk in inferring a similar distribution of metals for the two areas is greater than that of inferring similar mineral wealth. For, in the Control Area the base and precious metals production constitutes essentially the total metal production because of the dominance of these metals. Thus, it can be accepted as a rough approximation to a total metals resource model in terms of mineral wealth. It is conceivable that while a different metal suite might characterize two different areas, the amount of value based upon all metals that occurs in each area having similar geology also might be quite similar.

Finally, it is proposed that given the time and resources that a more suitable geostatistical base could be developed for the analysis of the Seward Peninsula; however, the alternative to the one available in the study is this spatial analysis previously described, and it is believed that the dangers of bias in geostatistical resource appraisals is less serious than assuming that geology is meaningless and basing conclusions completely upon spatial models of mineral density.

COMPUTER SIMULATION MODEL

The multivariate geostatistical analysis provides a set of three probabilities for each cell, probabilities for the cell belonging to each of three value classes: class 1, 0 - $\$10^4$; class 2, $\$10^4$ - $\$10^8$; and class 3, $\$10^8$ - $\$12 \times 10^9$. To employ this information in the analysis requires that the cumulative probabilities for a cell be sampled by Monte Carlo methods to determine to which class of mineral wealth the cell belongs. Once this is known, a cumulative frequency distribution of value per cell for the appropriate value class is tested to determine the total value for the cell--this is not necessary for a cell found to belong to value class 1, in which case it is assumed to possess zero mineral resources. Figures 16 and 18 show the distributions of value per cell for value classes 2 and 3. Once the total value for the cell is known, the distribution for the number of mines per cell for cells of that group is tested for the number of mines (see Figures 20 and 21). Given the value class to which the cell belongs and the number of mines it possesses, the distribution of value per mine for cells of that particular value class (Figures 17 and 19) is tested as many times as there are mines. This set of values is adjusted so that its total does not exceed the total for the cell. The same relationships as were employed in the spatial

Figure 16. CUMULATIVE FREQUENCY DISTRIBUTION
VALUE PER CELL--GROUP TWO CELLS

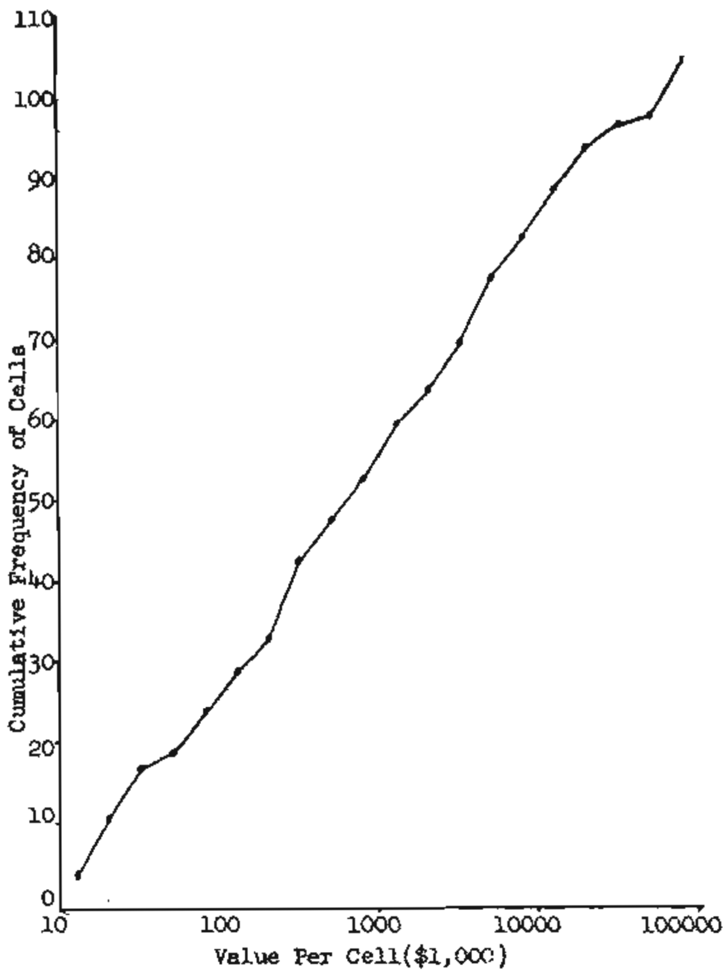


Figure 17. CUMULATIVE FREQUENCY DISTRIBUTION
AVERAGE VALUE PER MINE--GROUP TWO CELLS

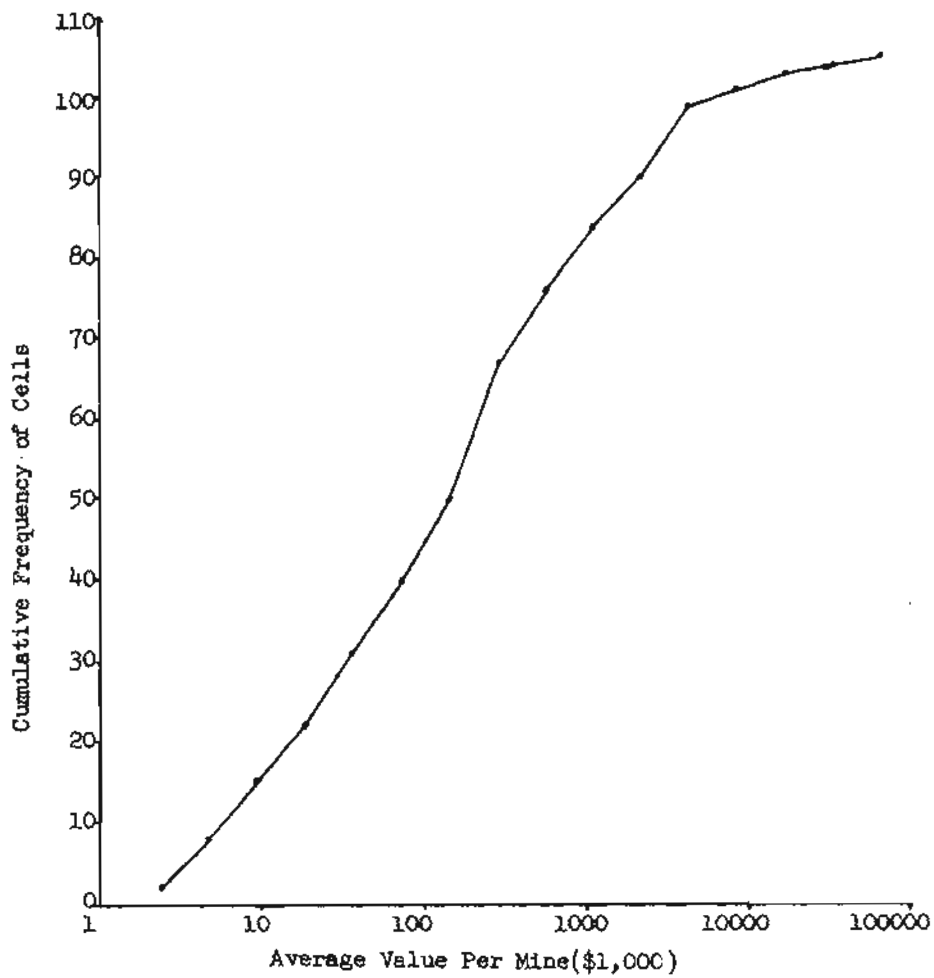


Figure 18. Cumulative Frequency Distribution
Value Per Cell--Group Three Cells

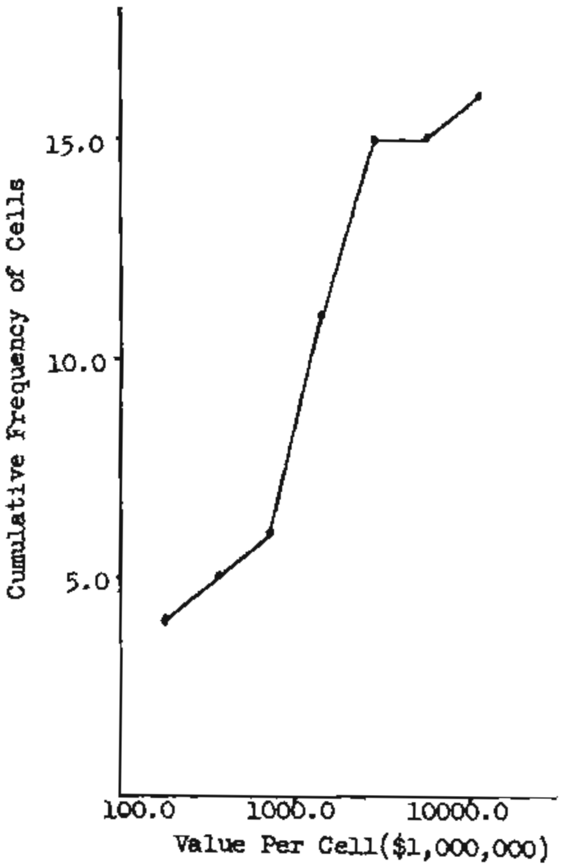


Figure 19. Cumulative Frequency Distribution
Average Value per Mine--Group Three Cells

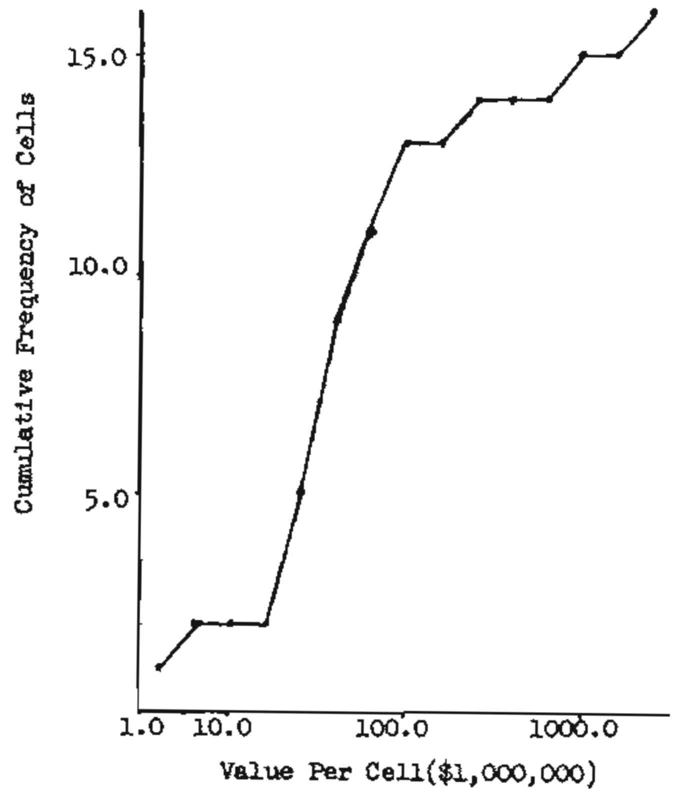


Figure 20. CUMULATIVE FREQUENCY DISTRIBUTION
NUMBER OF MINES PER CELL--GROUP TWO CELLS

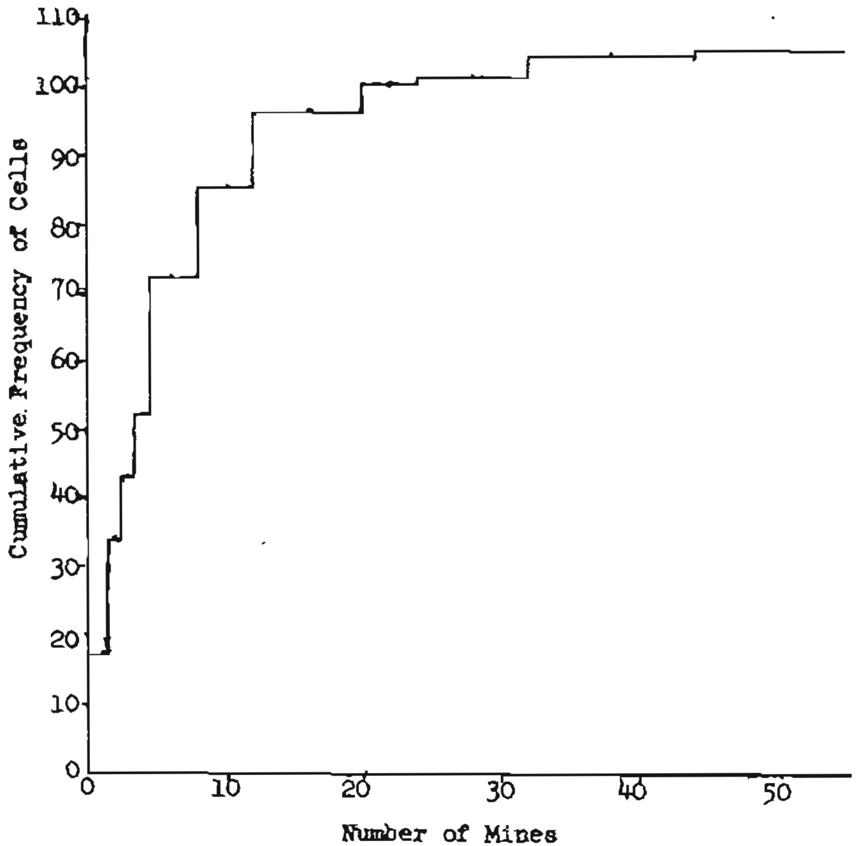
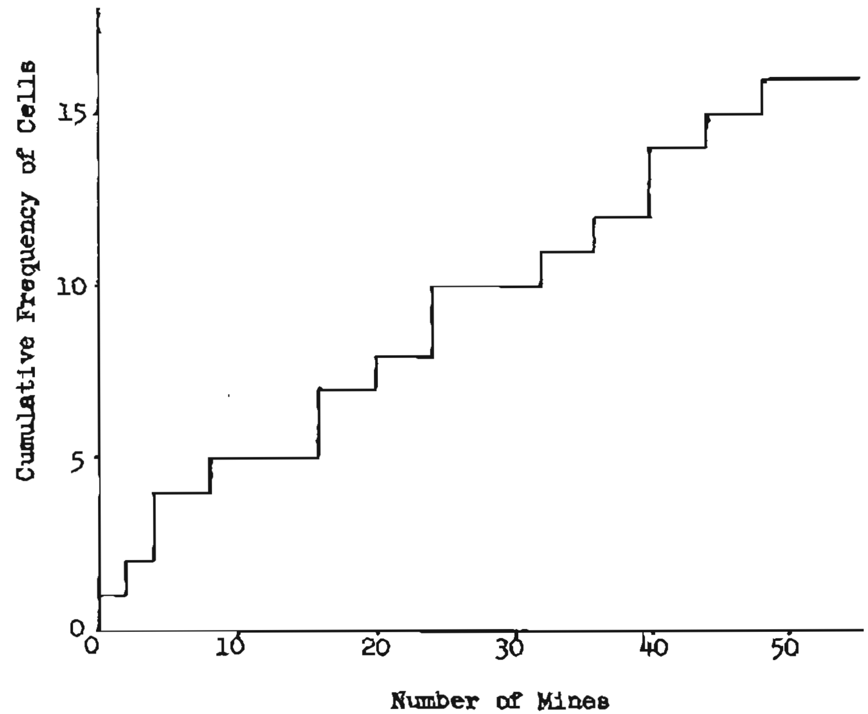


Figure 21. CUMULATIVE FREQUENCY DISTRIBUTION
NUMBER OF MINES PER CELL--GROUP THREE CELLS



simulator are tested for the grade associated with each of these values, and the grade and value are combined to give the tonnages for each of the deposits of the cell.

Instead of employing Grenier's relationship to determine the cutoff grade (cost) as was done in the spatial simulator, a separate analysis was made in which the major costs of mineral exploitation were treated explicitly. Data published in the Canadian Mining Manual (1958-1967) were analyzed for the relationships of operating cost, life of mine, and capital cost to preproduction reserves (in terms of tonnages of ore); bivariate plots and the mathematical relationships defined upon them are shown in Figures 22, 23, and 24. The equations for these relationships are as follows:

Operating Cost (OC)

$$\text{Log (OC)} = 3.21202 - 0.40139 \text{ Log (Tons)}$$

Standard Error Estimate = .19654

r = .77

Life of Mine (L)

$$\text{Log (L)} = -1.6175 + 0.3928 \text{ Log (Tons)}$$

Standard Error Estimate = .17568

r = .86

Capital (C)

$$\text{Log (C)} = 4.46165 + .32953 \text{ Log (Tons)}$$

Standard Error Estimate = 0.2619

$$SEE' = 0.2619 \sqrt{1.07 + \frac{[\text{Log (Tons)} - 6.12281]^2}{9.8}}$$

Figure 22. PRODUCTION COSTS VS PREPRODUCTION RESERVES

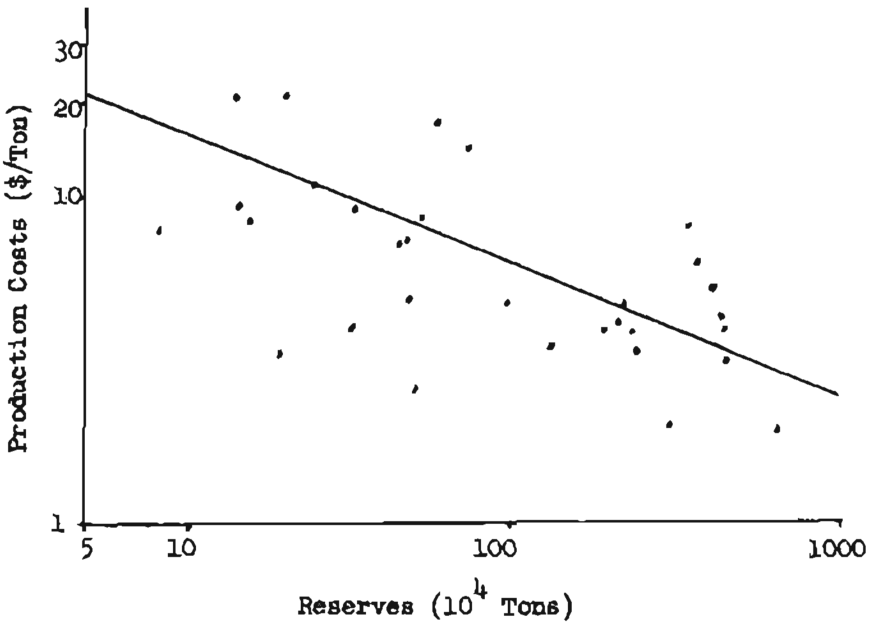


Figure 23. LIFE OF MINE VS PREPRODUCTION RESERVES

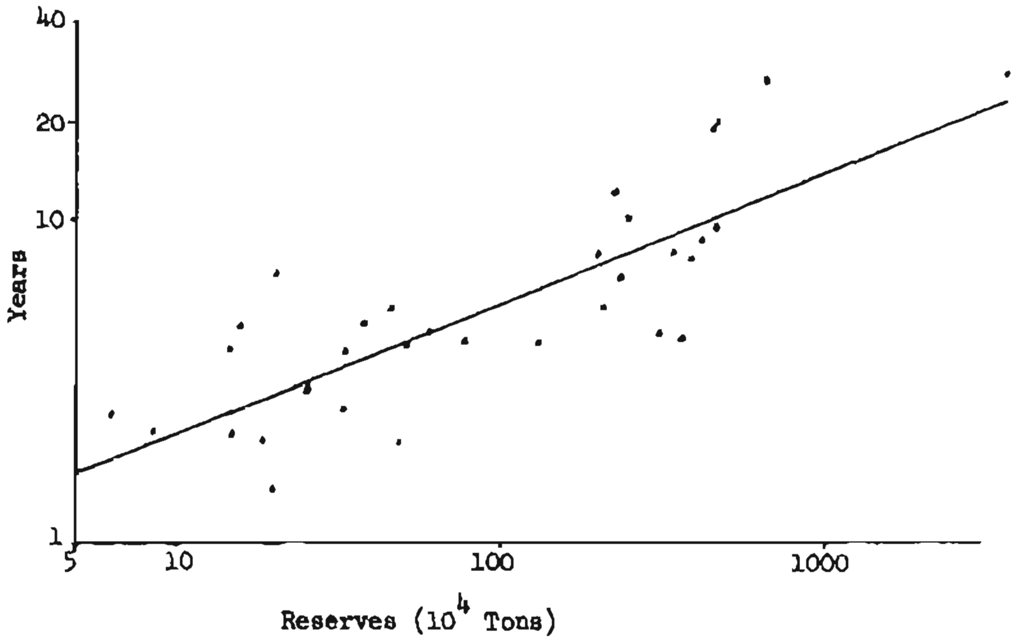
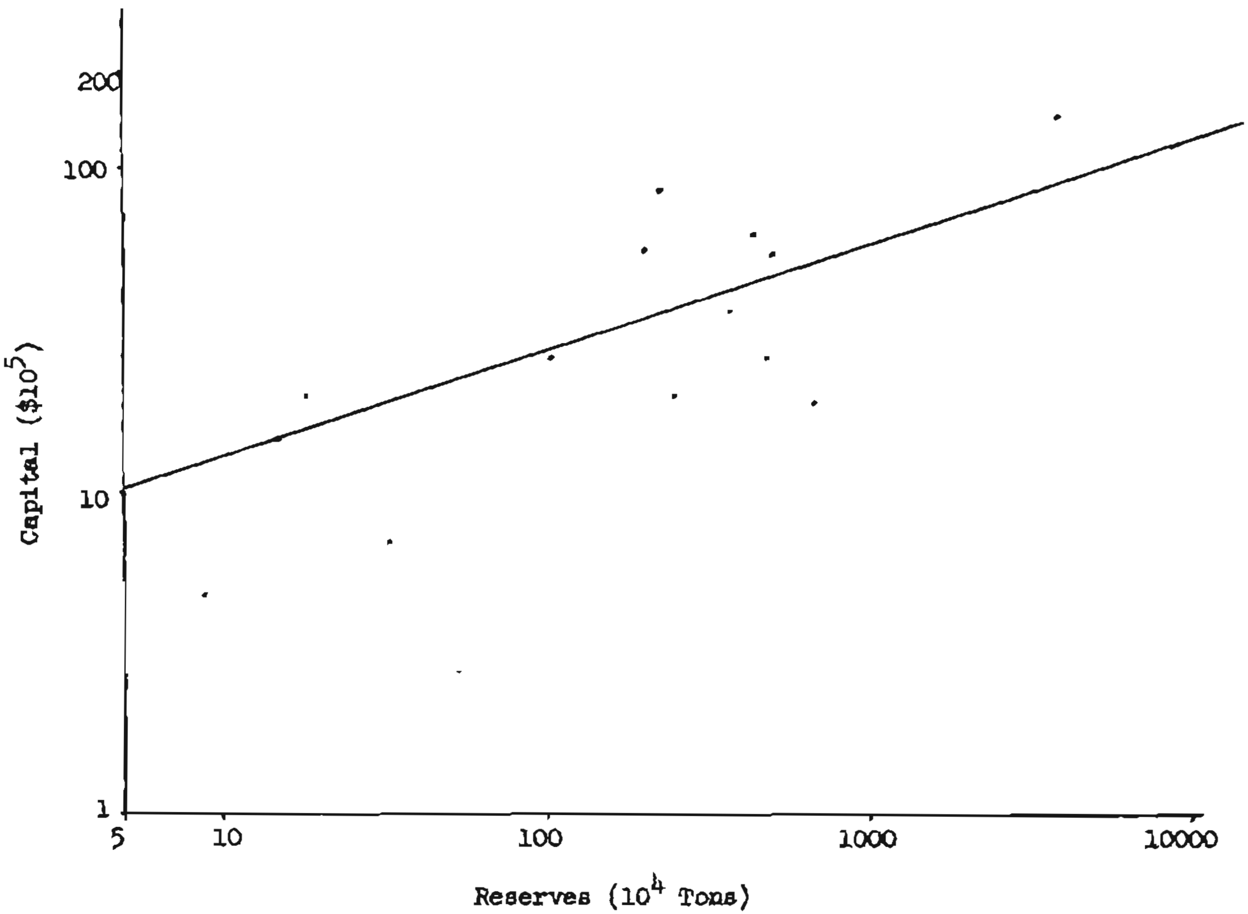


Figure 24. CAPITAL VS PREPRODUCTION RESERVES



$r \approx .69,$

where

$SEE' =$ Corrected standard error for small samples.

The errors of these equations are assumed for simplicity to be normally distributed. To generate operating cost, capital, or life of a mine the tonnage is substituted into the appropriate equation to give a mean value to which is added the error term. The error term is computed by sampling on a random normal distribution to obtain a normal deviate which is multiplied by the appropriate standard error.

For the computation of Federal income taxes, a depletion rate of 15% of gross value was allowed unless that amount exceeded 50% of net profit before taxes, in which case the latter amount was used. Depreciation charges were based upon straight line depreciation over the life of the mine. A Federal tax rate of 22% on the first $25,000 and 48% on the balance was levied on the tax base. State corporate tax was computed as 18% of the Federal corporate income tax plus a mining license tax of 7% of net income above $100,000, with an exemption for the first 3 1/2 years (Lu, Heiner, and Wolff, 1968).

Cost of capital was taken at 16%, thus the cash flows resulting from adding back the depletion and depreciation to the net profit after taxes was discounted at the rate of 16% to present value. The first set of runs purposefully excluded exploration costs so as to determine the "occurrence" of economic mineral resources not the discovery. Thus, the present value of the cash flows was tested against the initial capital investment generated by the above capital equation. If present value equaled or exceeded the capital charge, the deposit was economic and was added to economic mineral resources.

ANALYSIS

Occurrence

The geostatistical simulator as just outlined was run on each of the 52 cells of the Seward Peninsula for 200 large iterations (for each large iteration there can be as many small iterations as there are numbers of deposits within the cell). In order to observe the affect of different cost levels upon potential resources, operating costs and initial capital investment were increased by 30%, 75%, and 150%. The results of these simulations are summarized in Table 19. The affects of changes in the cost level on tonnage of ore and grade are exhibited in Figure 25 (see "General" grade and ore). Mathematical expressions for these relationships are as follows:

$$\text{Log (Tons)} = (2.89119 - 0.20614M)(6), \qquad R^2 = .996$$

$$\text{Grade} = 6.92963 + 7.16358M, \qquad R^2 = .991$$

where $M = (\text{Percent cost})/100$.

The results of the occurrence analysis (Table 19) should not be compared directly with those of the spatial analysis (Table 17), for the geostatistical simulation estimates the resources that exist in the Seward Peninsula, including equally the resources inferred to lie under covered areas, while the spatial analysis describes the resources that might be found under conditions similar to those of the Control Area. All other things being equal, the tonnages computed by the geostatistical simulation are larger.

TABLE 19

SUMMARY 1 OF OCCURRENCE STATISTICS
GEOSTATISTICAL SIMULATION

Mean Statistics	Cost Conditions*			
	1.0C	1.3C	1.75C	2.5C
Ore (10^6 Tons)	492.4	408.7	342.6	237.7
Grade ($/Ton)**	14.22	16.50	18.80	25.12
No. of Economic Mines***	69	63	54	41
Av. Value/Mine ($$10^6$)	101.5	107.0	119.4	148.1

*Multiples of costs generated in the simulation; these express overall cost differentials: Canada = 1.0C

**Weighted average grade

***Figures rounded to nearest whole number

Exploration

In order to make a comparison between geostatistical and spatial analyses and in order to have a measure more consistant with the long-term affect of exploration expenditures, the computation of cost was modified to include mineral exploration. The construction of a routine in this simulation that adequately represents the exploration activity is far beyond the scope of this study. A very simple and crude approach was adopted based upon the long-term statistic of approximately 4% of gross mineral production as an annual expenditure on mineral exploration and a 50% discovery rate (Brant, 1968).

Inasmuch as parts of the Seward Peninsula are quite heavily covered by quaternary deposits, the basic charge of 4% of gross value as an exploration charge for a deposit discovered in the simulator was modified to allow for the greater cover; a statistical survey of 380 cells of the Control Area indicated an average cover of 35.5%. More specifically, exploration was treated as follows:

1. Select a random number. If the number is greater than or equal to .5, the deposit was discovered.

2. If the deposit is discovered, exploration charges are computed according to the following equation:

$$\text{Expl} = [.04\,V + .0006\,(A - 35.5)\,V\tau]\;C/100.$$

where

V = Gross value of the mine

A = Percentage of cover

τ = 1 if $A = 35.5$, otherwise = 0

C = Cost condition as a percentage

TABLE 20

GEOSTATISTICAL SIMULATION - OCCURRENCE AND DISCOVERY
(Based Upon 130% Canadian Costs)

Mean Statistics	Occurrence	Exploration Discovery = 75%	Exploration Discovery = 50%
Ore (10^6 Tons)	408.7	103.7	66.0
Grade ($/Ton)*	16.50	41.84	42.93
No. of Economic Mines**	63	45	30
Av. Value/Mine ($\$10^6$)	107	97.5	94.9

*Weighted average grade
**Figures rounded to nearest whole number

3. The exploration charge determined in this manner was added to the capital charge and their sum was compared with the discounted cash flow to determine if the deposit was economic.

The result of treating exploration in this manner for the 130% cost condition is shown in Table 20. Notice that the tonnage of ore is now at 66.0 million tons at $42.93 per ton, giving thirty economic mines, as compared to 408.7 million tons at $16.50 per ton and 63 mines. Now some of the 33 mines deleted were done so because of the greater unit cost due to exploration expenditures; however, others of them would have been economic, but were missed in the process of search. The assumption is that the more obvious deposits would be discovered and that some of the 33 could be found by a more intensive exploration effort, which in the terms of this simulation would mean a greater exploration expenditure but a higher discovery rate. The relationship required for more insight to the optimum expenditure level is that between discovery rate and exploration expenditure. Obviously further research along these lines would be interesting and fruitful; however it is beyond the scope of this study.

The most striking feature of Table 20 is the great decrease (approximately 80%) in tonnage due to the exploration charge and the 50% discovery rate. If this treatment is anywhere close to being representative, this result underscores the long-term impact of mineral exploration in resource development and mineral supply. An additional simulation was made in which the same exploration cost relationship was used but the discovery rate was increased to 75%, the results of which also are listed in Table 20.

Special Conditions

Since the bulk of productive lode deposits on the Seward Peninsula are of the narrow vein type as contrasted to the very large low grade deposits that occur in the Control Area, a second series of simulations was made to examine the occurrence of mineral resources when an adjustment is made to approximate the absence of the large low grade deposits. This adjustment was to eliminate from the analysis all tonnage with a grade of $10.00 or less, for most of the open-pit production in the Control Area falls in this category. The results of varying the cost conditions with this new restriction on grade are shown in Table 21. Notice for comparison purposes that for the 130% cost condition that the tonnage is decreased from the 408.7 to 122.8 million tons, and the average grade is increased to $51.50. Figure 25 (see "Restricted" grade and ore) exhibits graphically the affect of the cost level on total ore and average grade. Mathematical expressions for these relationships for the restricted analysis are as follows:

$$\text{Log (Tons)} = (2.18554 - 0.07144M)(6), \qquad R^2 = .996$$

$$\text{Grade} = 44.46803 + 5.29281M, \qquad R^2 = .996,$$

where,

$$M = (\text{Percent cost})/100$$

As a check upon the cost relationship employed in the simulators, Grenier's implicit cost equation was substituted into the geostatistical model in place of the explicit cost analysis of the subroutine. Results of simulation with the two variations in the method of computing costs are as follows (175% cost condition):

TABLE 21

SUMMARY 2 OF OCCURRENCE STATISTICS

GEOSTATISTICAL SIMULATION - RESTRICTED GRADE*

Mean Statistics	Cost Conditions**			
	1.0C	1.3C	1.75C	2.5C
Ore (10^6 Tons)	130.4	122.8	115.8	101.4
Grade ($/Ton)***	49.80	51.50	53.41	57.83
No. of Economic Mines****	69	62	53	42
Av. Value/Mine ($$10^6$)	93	101.7	116.6	141.9

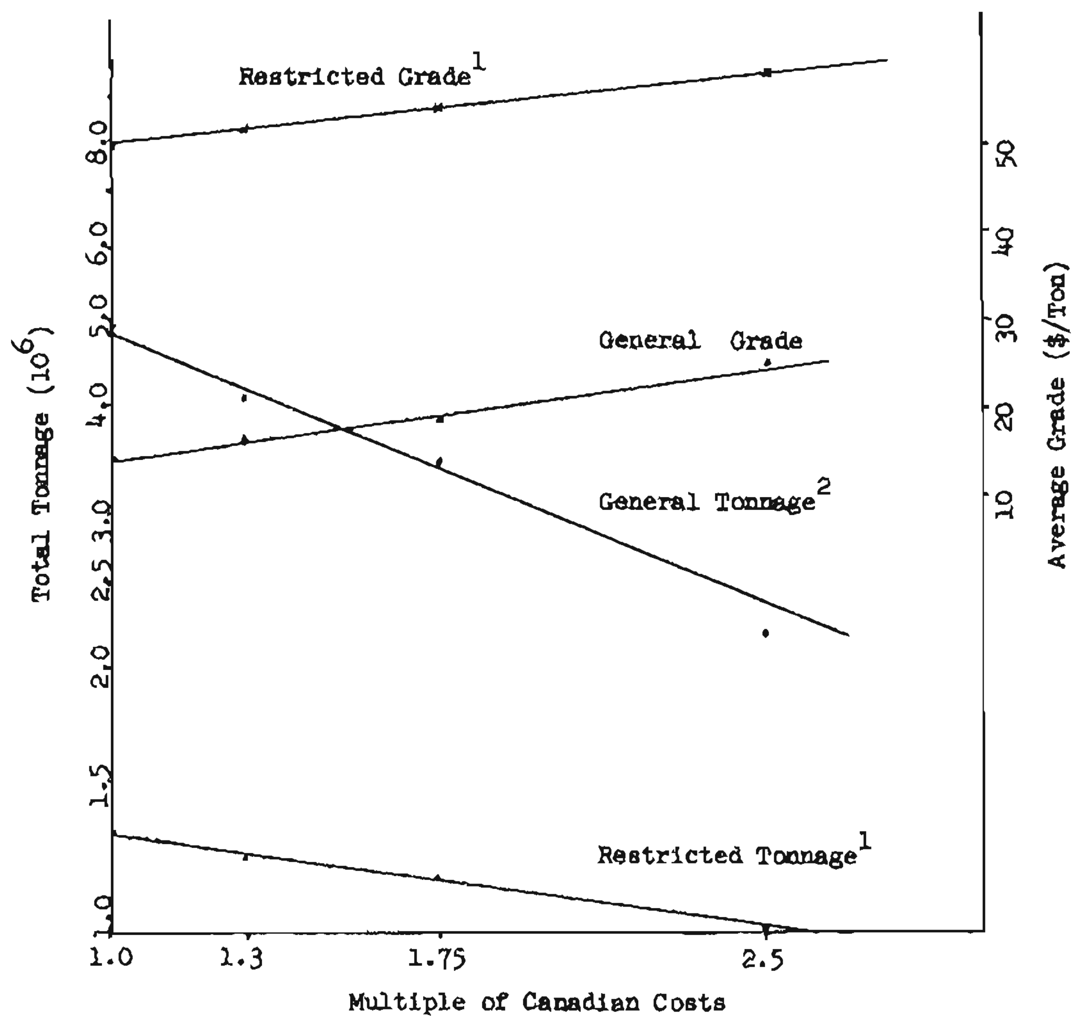
*Tonnages with Grade above $10/Ton

**Multiples of costs generated in the simulation; these express overall cost differential: Canada = 1.0

***Weighted average grade

****Figures rounded to nearest whole number

Figure 25. COST VS AVERAGE GRADE AND TOTAL TONNAGE



[1]Resources with grade less than or equal to $10/ton were not considered.

[2]All resources were considered.

	Grenier's Cost	Explicit Cost
Ore (10^6 Tons)	117.3	115.8
Grade ($/Ton)	56.36	53.41

Thus, at least for grades greater than $10.00 per ton, the two different cost treatments compare very well.

Geographic Distribution of Mineral Resources

The unit of reference in the geostatistical simulation is a specific cell. That is, for each cell a separate resource appraisal has been made. Figure 26 is a plot for each cell of the results of resource appraisals under the following conditions:

130% Canadian cost, occurrence (no exploration)
175% Canadian cost, occurrence
130% Canadian cost, occurrence, restricted grade
175% Canadian cost, occurrence, restricted grade
130% Canadian cost, exploration, 50% discovery rate

Each line of figures in a cell of Figure 26 corresponds to one of these analyses: reading from left to right, the data on a line within the cell consist of first, the mean tonnage of ore in millions of tons; second, the standard error of the tonnage estimate; and third, the weighted average grade in dollars per ton. In most cases the standard error of tonnage is usually considerably larger than the estimate, indicating that a wide range of tonnages were developed in the simulation. This serves as an indication of the uncertainty in the estimates of mineral resources.

The data for a cell can be employed to determine confidence limits on the tonnage estimate. For example, using the data of the richest cell in the exploration simulation (9.1 million tons, with a standard error of 25 million tons) a 95% confidence limit on the mean tonnage is computed as follows:

$$C.I._{95} = 9.1 - 1.96\,(25/\sqrt{199}) \leq \mu \leq 9.1 + 1.96\,(25/\sqrt{199})$$

Thus, the probability is 95% that the mean tonnage lies between 5,600,000 and 12,700,000 tons.

Examination of the tonnage and grade for the simulation that includes exploration reveals that approximately 50% of the 66 million tons of ore at $42.93 occurs in seven of the 52 cells, and 34% of the total occurs in three of the cells. Six of the seven cells lie in the fourth row of cells (counting from the southernmost tier), along the crest of the Bendeleben Mountains. The seventh cell joins the others to the northeast toward the Candle mining area. For the most part, this set of cells exhibits low mineral production. Figure 2 indicates that the production of precious metals lies to the north and south (except for the westernmost cell) of these cells. Most of this production derives from placer deposits, the bulk being from the Nome District. Small to moderate amounts of production occur in the cells immediately south and down drainage from this set, and may have derived some of their mineral values from them. The fact that most of the production has been from placer deposits does not detract from the inferred mineral potential of these cells, since this inference is based upon "bedrock" geology. Furthermore, as the Seward Peninsula is relatively unexplored by present standards, the fact that the proposed resources have not as yet been discovered does not obviate these estimates.

TABLE 22

METAL RESOURCES*

Metals	Geostatistical				Spatial	
	Based on Production of Control Area		Based on Production of Alaska		Based on Prod. of Control Area	Based on Prod. of Alaska
	No Exploration	Exploration**	No Exploration	Exploration**	(No Exploration)	(No Exploration)
Gold (10^5 oz.)	217.6	86.5	126.0	53.8	61.4	70.4
Silver (10^6 oz.)	688.	286.7	68.3	28.5	163.9	38.2
Copper (10^6 lbs.)	3156	1338	5733	2406	913.7	3204
Lead (10^6 lbs.)	8700	3763	168.6	70.8	2439	93.7
Zinc (10^6 lbs.)	5767	2409			1597	
Tin (10^6 lbs.)	--	--	14.16	5.9	--	7.9
Ore (10^6 Tons)	408.7	66	408.7	66	152.6	152.6
Grade ($/Ton)	16.50	42.93	16.50	42.93	24.7	24.7

*Costs = 130% of Canadian Costs

**Assuming 50% Discovery and from 4 to 8 percent of Gross Value (see text) as exploration cost

SUMMARY AND CONCLUSIONS

An evaluation of potential mineral resources can be no better than the economic and geological relationships that enter the analysis. This study does not treat in depth either of these factors and could be much improved upon by an extended and more detailed analysis. Consequently, these results are to be considered only as rough estimates.

Since costs figure so importantly into resource estimates, this study attempted to define quantitatively the relationships of grade and tonnage to the general cost level of the Seward Peninsula relative to the area upon which the operating and capital cost relationships were defined. Available data indicate a general cost level 150% higher in Nome than in Seattle, Washington (Lu, Heiner, and Wolff, 1968). Lacking specific figures on the cost level of the Peninsula relative to Canada, the 130% cost level was assumed to adequately express the qualitative judgment that costs are considerably greater in the Seward Peninsula than in Canada (Lu, Heiner, and Wolff, 1968).

The 130% cost level was examined in both the spatial and the geostatistical models. Whether this cost level accurately represents the comparitive costs of the two areas is not critical to results of this study, for any cost level can be substituted into the equations to give the tonnage and grade at that cost.

This study indicated the existence of over 408 million tons of ore at a $16.50 per ton average grade (at the 130% cost level). Consideration of the necessity for exploration in finding and developing mineral resources reduced this tonnage to an estimated 66 million tons at an average grade of $42.93.

Exploration costs for extensively covered cells may be somewhat overstated, as the 50% discovery ratio may be too severe when combined with the greater cost assigned to cells with extensive cover. This cost varied from 4% of gross value for cells with cover up to 35.5% to 7.9% of gross value for cells with 100% cover. The affect upon results of the overall analysis is believed to be small, for the average cover for cells of the Seward Peninsula is 40.5%, giving as the average exploration charge 4.3% of gross value. Furthermore, 4% is an average exploration cost; in the past it has been as high as 5%. So, although exploration costs for heavily covered cells may be high, the overall treatment compares reasonably well with industry statistics. In value terms the 66 million tons of ore amount to about 2.8 billion dollars of economic mineral resources in the Seward Peninsula. Production statistics indicate that approximately 200 million dollars of this potential has been produced, leaving a large residual of economic mineral resources yet to be developed.

The preliminary analysis of mineral density indicated an expectation of one cell with value between one and twelve billion dollars and one between 100 million and 1 billion dollars. Although the geostatistical simulation did not find a cell with value over 1 billion dollars, the total value of all cells (2.8 billion dollars) compares reasonably with the total of the inferred mineral density. Furthermore, the total value by geostatistical simulation differs from the total value by spatial simulation (no exploration) by about .6 billion dollars; however, the spatial value consisted of considerably larger tonnage at a correspondingly lower grade ($24). The geostatistical analysis seems more reasonable, however, for a consideration of all costs, including exploration, would serve to eliminate large tonnages of low grade ore from the economic resource base, causing the average grade of those resources found to be economic to increase.

As the analysis of this study was based on measures of geology, grade (dollars per ton), and tonnage, there is little in the form of an analytical framework by which to make meaningful estimates of quantities of metals associated with the estimated tonnages of ore. However, as a matter of interest of a speculative nature, assume for the moment that none of the 2.8 billion dollars of the estimated potential mineral resources had been found and that estimates of quantities of metals are to be based upon the distribution of metal production that characterizes the State of Alaska. With this as a premise, the estimated metal resources of the Seward Peninsula would be approximately 5 million ounces of gold, 29 million ounces of silver, 2.4 billion pounds of copper, 71 million pounds of lead, and 6 million pounds of tin (see Table 22). These metals would be produced from 66 million tons of ore at an average grade of approximately $43 per ton and by 30 mines having an average gross value per mine of approximately 95 million dollars.

Production of gold in the Seward Peninsula has already exceeded the 5 million ounce resource estimate; however, production of the other metals has been minor. Production records indicate that approximately 98% of the value of cumulative mineral production has been in gold. If all of the estimated mineral resources of the Seward Peninsula were to consist of metals in the same proportion as past production, then some 70 to 80 million ounces of gold would comprise the economic resources of this area. While this is not impossible, it is more likely that other metals in the future will constitute a larger share of total production than is indicated by historical production statistics.


66°
65°

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