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Mineral Resource Assessment of the Circle Quadrangle, Alaska

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Table of contents

Figure captions

Tables

Page

Appendices

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Introduction

This report, as part of the Alaska Mineral Resource Assessment Program (AMRAP), assesses, by tract and by deposit type, the metalliferous mineral resource potential of the Circle quadrangle, Alaska and briefly discusses the occurrence of selected non-metallic resources. The assessment is based upon investigations of the geology, geochemistry, and geophysics of the area. Specific investigations included: regional-scale (1:250,000) reconnaissance geologic mapping (Foster and others, 1983), potassium argon (Wilson and Shew, 1981) and uranium lead age determinations (Aleinikoff and others, in press), chemical analysis of mineralized and background rocks, chemical analysis of the minus-80-mesh fraction of stream sediment samples (Tripp and Crim, 1983), chemical analysis of and identification of selected minerals in nonmagnetic, heavy-mineral concentrate samples from stream sediments (Tripp and Houston, 1983, and Tripp, O'Leary, and Rizolli, 1983), interpretation of aeromagnetic data (Cady and Weber, 1983), interpretation of gravity data (Cady and Barnes, 1983), investigation of placer deposits (Yeend, 1982), and interpretation of Landsat images (S. L. Simpson, oral commun., 1982).

The Circle quadrangle has been an area of gold placer mining since the 1890's. During the period of fieldwork (1977-1982) for this report, the price of gold rose considerably. This led to increased placer mining. In addition, exploration for lode deposits in the quadrangle increased beginning in the early 1970's.

The first section of this report discusses the methods used in the assessment; a second section models types of ore deposits which may occur within the quadrangle. The third section discusses areas (tracts) which may contain particular types of deposits and gives the geological characteristics used to delineate these areas. In the final section of the report the extent to which characteristics of deposit types are present in individual tracts are summarized and estimates of the numbers of deposits that may occur in the tracts are given.

ACKNOWLEDGMENTS

The preparation of this report was facilitated by the efforts of a number of people. Discussions with Jeff Burton and Bob Schafer of MAPCO, Incorporated, and Cynthia T. Cunningham of HIM, Incorporated, were helpful in understanding the geology of particular parts of the quadrangle. James Barker of the U.S. Bureau of Mines provided information on mineral occurrences in the Circle quadrangle.

Jim Carson of Central, Alaska, assisted by providing information and contacts with local miners.

A large number of colleagues at the U.S. Geological Survey assisted in completing the report. Terry Keith provided petrographic and x-ray diffraction analysis of samples of altered rocks. Discussions with B. L. Reed and G. D. Eberlein about the geology of tin deposits and discussions with Jo Laird about contact metamorphic and plutonic rocks were particularly useful. James Bliss assisted with the statistical analysis of rock geochemical data and Gail Jones helped prepare the models of tin vein/greisen and tungsten skarn deposits. Florence Weber provided useful information about the general geology of the quadrangle and Cori Condon gave able assistance in preparing the map and table of mineral occurrences.

METHODOLOGY

This report follows the general methodology of the AMRAP program (Singer, 1975), which consists of (1) delineation of tracts as permissive for the occurrence of mineral deposits by type, (2) construction of statistical models of important characteristics, such as grade and tonnage of the types of deposit, and (3) estimation of the number of deposits likely to occur within delineated tracts.

As with other AMRAP studies, the methodology has been adjusted to be consistent with the types and amounts of information available. The deposit type models in the present report differ from previous AMRAP reports in that they include a description of geologic characteristics of the deposits along with a statistical model of deposit grades and tonnages. The descriptions are based upon compilations of geologic characteristics of individual deposits from throughout the world. The quality of the grade/tonnage models varies depending upon sample size and the degree of geological similarity of the deposits. This report contains descriptive models of tungsten skarn deposits, tin vein/greisen deposits, uranium deposits hosted by peraluminous granites, and lode gold deposits in metasedimentary terranes and shale-hosted lead-zinc deposits. Grade/tonnage models are presented for tungsten skarn deposits, tin vein/greisen deposits, and shale-hosted lead-zinc deposits. The tungsten skarn model is based upon figures that were formed by combining all occurrences related to an individual pluton to form a single grade and tonnage estimate. The tin vein/greisen model is a new model built with deposits from Europe, Australia, Asia, and North America; it must be regarded as preliminary because the deposits used to construct the model come from a number of settings within an overall vein/greisen environment. Nevertheless, the model should provide a guide to the importance of such deposits. No grade/tonnage models are available for the other two deposit types.

Several other adjustments in the method merit mention. In two cases stream sediment samples from drainages that contain particular rock units were geochemically anomalous for suites of elements. Because of a lack of good exposures of these units it was not possible to determine whether anomalies were caused by locally elevated background levels in the rock units, or by particular types of mineralization. The rock units were delineated and possible sources of the anomalies are enumerated. Finally, this report presents summary tables that relate the characteristics of individual tracts to the characteristics of the deposit types.

DESCRIPTIVE AND GRADE/TONNAGE MODELS OF DEPOSIT TYPES WHICH MAY OCCUR WITHIN THE CIRCLE QUADRANGLE

The Circle quadrangle in this report is divided into three areas (fig. 1): the largest is a complexly deformed, regionally metamorphosed terrane of mostly quartzitic and pelitic rocks south of the Tintina fault zone; the second is the area north of the Tintina fault zone which consists mostly of folded Proterozoic(?) and(or) Paleozoic sedimentary rocks which are only very slightly metamorphosed. These sedimentary rocks are in probable thrust contact with mafic igneous rocks and associated chert of late Paleozoic and early Mesozoic age (Circle Volcanics). Minor clastic deposits of probable Tertiary age occur in topographically low areas just north of the southern margin of the Tintina fault zone. The third area consists of the northwestern part of the quadrangle and is comprised largely of folded and slightly metamorphosed Precambrian(?) and(or) Paleozoic sedimentary rocks, Mesozoic clastic rocks, and tuffs and tuffaceous sedimentary rocks of Paleozoic and(or) Mesozoic age.

The area south of the Tintina fault zone and the northwestern part of the quadrangle are intruded by granitic plutons which post-date regional metamorphism and associated deformation. The intrusions are composite and dominantly of peraluminous biotite granite. All three parts of the quadrangle have minor mafic and ultramafic rocks. The ultramafic rocks are probably mostly in fault contact with adjacent rocks.

The geologic setting of the Circle quadrangle, especially the presence of post-orogenic plutons intruded into regionally metamorphosed rocks, is similar to regions, such as eastern Australia, southwestern England, northern New England, and southeastern Canada, that contain tin vein/greisen deposits, tungsten skarn deposits, lode gold deposits with associated placers, and uranium deposits hosted by peraluminous granites. The presence of very small bodies of ultramafic rocks would permit the occurrence of chromite, nickel, and asbestos deposits although supporting geologic and geochemical evidence for such deposits has not been found within the quadrangle. Finally, in many places in the northern Cordillera, Paleozoic clastic and carbonate rocks host stratiform lead-zinc deposits. Models of these deposits are presented below.

TIN VEIN/GREISEN DEPOSIT MODEL

Permissive rock types: Greisen tin deposits are associated with composite, greisenized granitic plutons, which commonly have a well established differentiation sequence. The stanniferous phase is generally the youngest and most differentiated phase of the magmatic sequence, occurring in the cupola of the pluton. The granitic rock is most commonly peraluminous (that is the weight percent $(Al_2O_3/(CaO+NA_2O+K_2O))\geq 1$ (Clark, 1981)) and generally is a biotite- or two-mica-granite. These granites normally contain at least 70 percent (by weight) SiO_2, are enriched in K_2O relative to Na_2O $(K_2O/Na_2O)\geq 1.2$, and are depleted in Fe_2O_3.

Taylor (1979) and Strong (1981) characterized tin deposits by the depth of emplacement of the intrusives. Deposits in the following two plutonic environments may occur in the Circle quadrangle:

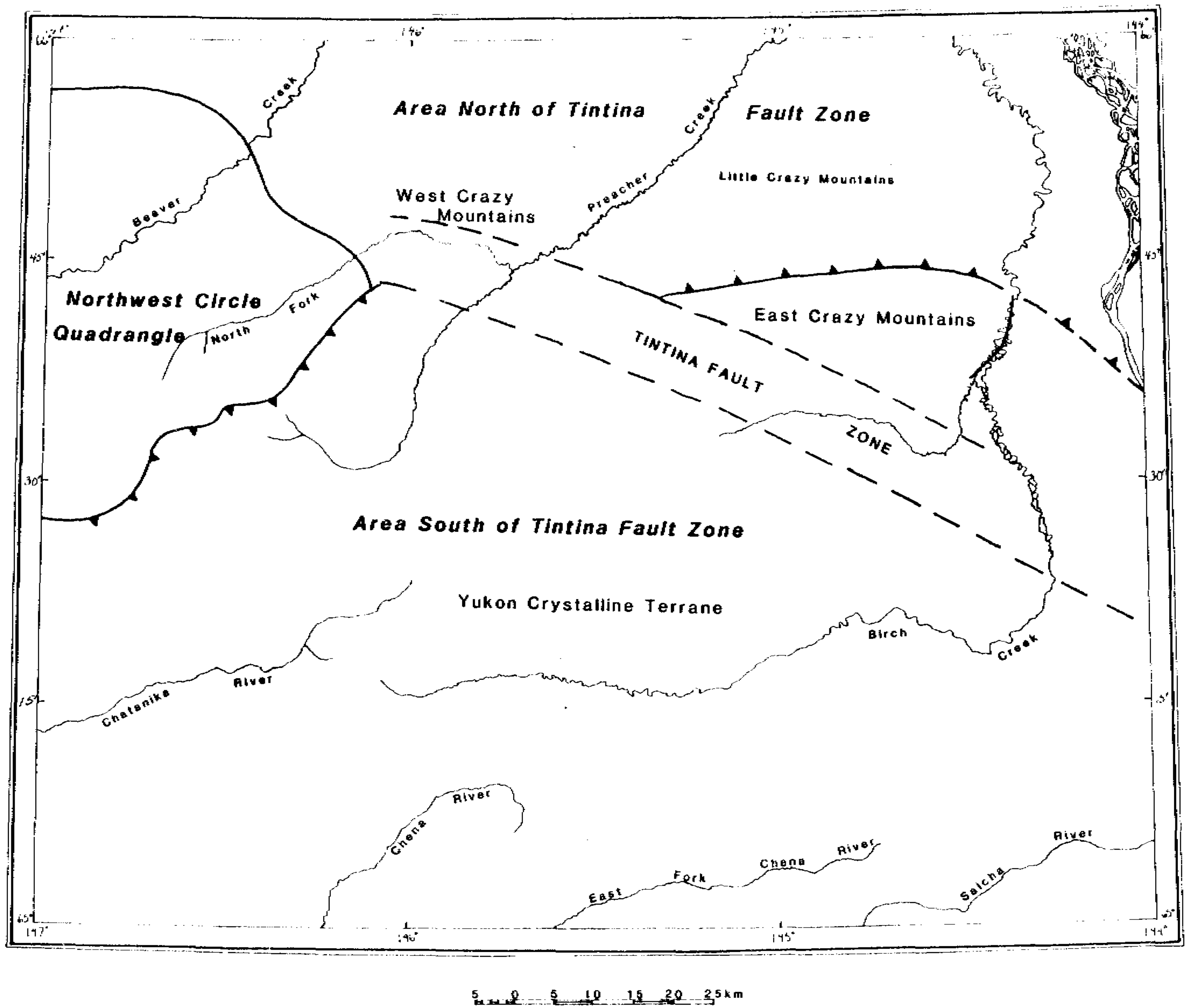


Figure 1. Map showing parts of the Circle quadrangle.

1. Deposits of entirely plutonic character in which cassiterite occurs in the sheet-like greisenized apical phase of the pluton emplaced at a depth of approximately 4-8 km (Blue Tier batholith, Tasmania, Australia, Erzgebirge, German Democratic Republic (G.D.R.), and Czechoslovakia).

2. Deposits of an environment transitional between plutonic and deep volcanic, in which the tin occurs in small stocklike bodies, commonly associated with regional structures which reflect a buried batholith (Chukotka, U.S.S.R.), and as dilational quartz vein systems.

In the transitional environment, tin deposits may also occur in the country rock. For instance, mineralized country rock may be associated with dikes and sills just above the cupolas.

Ore mineralogy: In deposits of the plutonic and transitional environment, quartz-cassiterite veins and stockworks in which cassiterite is generally the only economic ore mineral are commonly accompanied by any of the following: fluorite, pyrite, chalcopyrite, arsenopyrite, wolframite, and molybdenite. Topaz, tourmaline, galena, and sphalerite are also common. Accessory minerals may include muscovite, chlorite, hematite, stannite, pyrrhotite, scheelite, bismuthinite, and carbonates.

Controls on mineralization: The contacts of granite or dikes with country rock and occurrence of faults and fractures are important factors related to the localization of cassiterite. Cassiterite commonly occurs in sheetlike bodies in greisenized late-stage leucogranite at the apex of the pluton or in fissure veins, stockwork, open spaces adjacent to faults, or in pipes formed by intersecting structures in granites or adjacent country rock.

Geochemical zoning: Generalized vertical zoning consists of tin minerals, perhaps with molybdenum minerals, in the "emanative center" followed by tungsten and bismuth with copper, and lead and zinc farthest out from the center. The tin zone generally plunges at an angle less than that of the local slope of the granite contact (Garnett, 1966). However, numerous periods of jointing tend to mask vertical zoning (Dumler, 1978).

In the Miao Chang region, mineralization extends about 1,000 m vertically. Tourmaline occurs below chlorite which is followed by rocks with higher sulfide mineral content in the upper zones. Chalcopyrite gives way to cassiterite with depth (Taylor, 1979).

Greisenized rock: High temperature fluids, rich in fluorine and chlorine that emanate from a granitic magma are thought to leach plagioclase and primary mafic minerals and replace them with quartz and mica, commonly accompanied by topaz, fluorite, tourmaline, feldspar, and ore minerals (Scherba, 1970). The resulting greisen may replace the country rock adjacent to the granitic body as well as the granite. Greisens develop most extensively in quartzites, shales and their metamorphic equivalents (Reed, 1982).

Grade/tonnage model: Figure 2 presents a preliminary grade/tonnage model of tin vein/greisen deposits which is based upon 23 deposits from around the world. It should be regarded as preliminary, because of the small number of

Variable	Number of deposits in the model	90%	50%	10%
tonnes $\times 10^6$	23	.66	4.5	30.5
percent Sn	23	.15	.47	1.40

correlation of tonnage and Sn grade = -.30

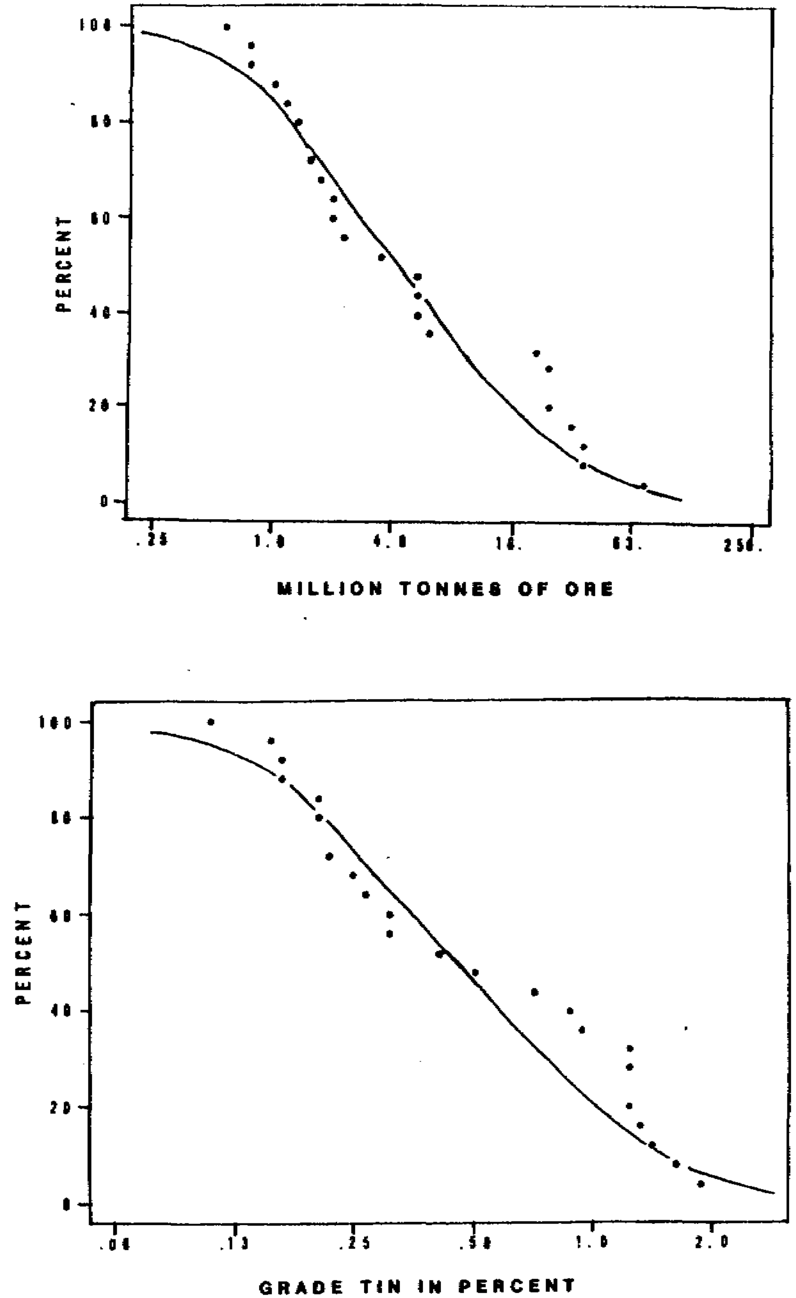


Figure 2. Grade/tonnage model of tin vein/greisen deposits (percent of deposits that equal or exceed a given tonnage or grade).

deposits upon which it is based and because the deposits in the sample come from a number of settings within the vein/greisen environment.

TUNGSTEN SKARN DEPOSIT MODEL

This descriptive model is based upon the recent, comprehensive review of skarn deposits by Einaudi, Meinert, and Newberry (1981), and upon descriptions of individual deposits, especially those in the western United States.

Host rocks: Scheelite occurs in contact metamorphosed carbonate rocks adjacent to felsic intrusives. The ore zones of these deposits may follow the intrusive--skarn contact or the bedding of the metasomatized marble depending upon a number of factors such as purity of the carbonate host and the presence of overlying or intercalated shales.

Associated intrusive rocks: Contact metasomatism and tungsten mineralization are associated with intrusions of relatively unfractured, calc-alkaline granitic bodies, which may be batholith or stock size, or dikes and sills. The plutons are commonly coarse-grained, porphyritic, and have compositions from granodiorite to alaskite (Einaudi, Meinert, and Newberry, 1981).

Altered rocks: The intrusive rocks generally show no alteration effects other than the occurrence of quartz-feldspar myrmekite. However garnet, pyroxene, and scheelite skarn in carbonate rocks adjacent to felsic plutons is a common characteristic of tungsten skarn deposits. The kind of garnet and/or pyroxene present depends upon the types of country rock and depth of the pluton. Skarns which contain hedenbergetic pyroxene, almandine-rich garnet, biotite and hornblende form adjacent to plutons emplaced at great depth or in carbonaceous country rocks. Plutons emplaced at shallow depths or in hematitic or non-carbonaceous country rocks form skarn which contain andraditic garnet and epidote. Large tungsten skarns form in deep plutonic environments (Einaudi, Meinert, and Newberry, 1981). The Circle quadrangle may contain both types of skarns.

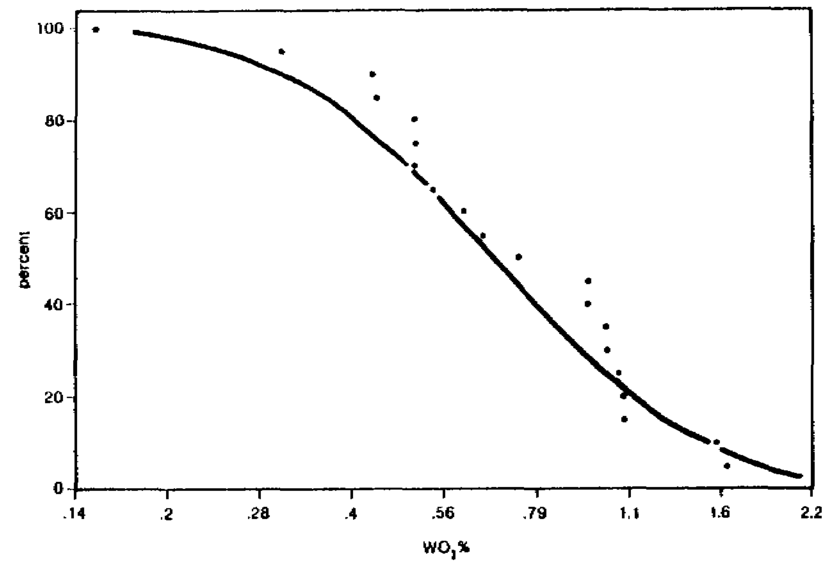
Ore mineralogy: The mineralogy of tungsten skarn deposits may include high-molybdenum and low-molybdenum scheelite and sulfides, particularly chalcopyrite, molybdenite, pyrite and pyrrhotite. The sulfide minerals may be zoned; sphalerite is often distal to chalcopyrite (Einaudi, Meinert, and Newberry, 1981).

Controls on mineralization: The contact between the favorable limestone beds and the intrusive body is the major ore control of skarn tungsten deposits. The disseminated scheelite generally occurs parallel to the intrusive contact or as ore shoots within the skarn zones. Ore shoots may extend away from the intrusive contact along original bedding planes of the limestone, or adjacent to dikes or sills.

Grade/tonnage model: Figure 3 presents a grade/tonnage model of tungsten skarn deposits. The model is based upon data from 20 districts in the North American Cordillera.

Variable	Number of deposits in the model	90%	50%	10%
tonnes $x10^6$	20	.05	.8	14.
percent WO_3	20	.3	.7	1.4

Correlation of tonnage and WO_3 grade = -.17



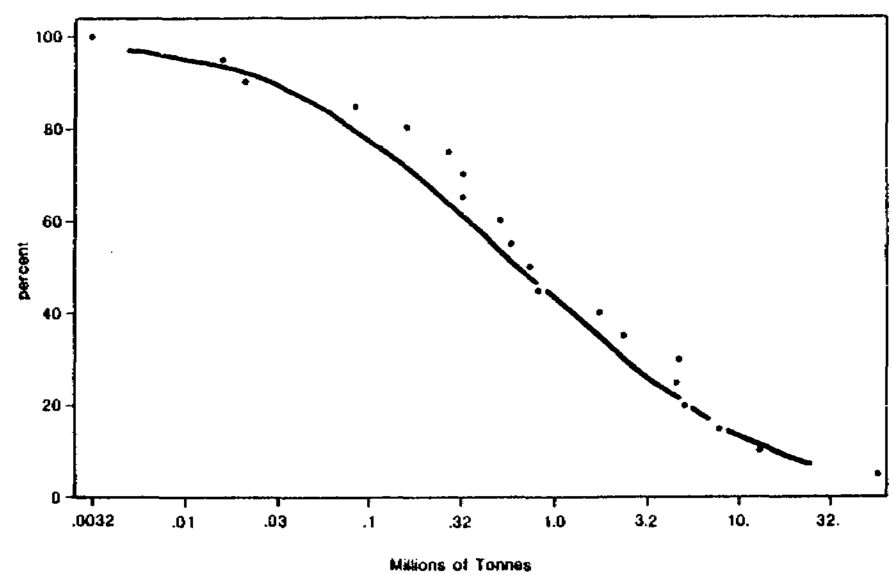


Figure 3. Grade/tonnage model of tungsten skarn deposits (percent of deposits that equal or exceed a given tonnage or grade).

URANIUM DEPOSITS HOSTED BY PERALUMINOUS GRANITES

This model is based upon recent literature on uranium deposits in peraluminous granites, including reports by Chatterjee and Muecke (1982), Darnley (1982), and Strong (1981).

Permissive rock types: The deposits are associated with late-tectonic to post-tectonic peraluminous granites. The granites are thought to result both from anatexis (Leroy, 1978) and from differentiation of biotite granite melts (Chatterjee and Muecke, 1982). In the latter case the deposits are associated with the most differentiated, generally last, phase of the biotite granite suite.

Altered rocks: Hydrothermally altered rocks commonly occur in narrow zones adjacent to uranium-bearing veins and shear zones. Types of altered rocks adjacent to these deposits include granites with secondary muscovite, clay minerals or sericite replacing feldspars, secondary albite, phosphates or hematite, and greisen.

Mineralogy: The uranium minerals in the deposits include autinite, meta-autinite, torbernite, and pitchblende. Other minerals include calcite, quartz, hematite, pyrite, chalcopyrite, apatite, lithium-bearing mica, albite, fluorapatite and barite.

Ore controls: The main controls are petrologic (late, highly differentiated phases of biotite granite plutons) and structural (shear zones and pipes formed at intersecting fractures in the granites). Chatterjee and Muecke (1982) conclude that the South Mountain batholith, Nova Scotia, was rapidly uplifted shortly after it was emplaced, and that uranium minerals were deposited by hydrothermal solutions in shear zones related to the uplift.

Geochemical characteristics: These deposits and the late plutonic rocks associated with them are enriched in uranium, but depleted in thorium relative to plutons associated with tin mineralization . Late stage intrusives associated with the deposits are enriched relative to earlier intrusive phases in F, Be, Li, Rb, Cs, Ta, Sn, and U, and are depleted in Sr, Ba, REE, Sc, Zr, and Hf (Chatterjee and Muecke, 1982).

Grade/tonnage information: Deposits occur as veins, pipes, and disseminated deposits and tend to have small tonnages of ore compared to other types of uranium deposits.

LODE GOLD DEPOSITS IN METASEDIMENTARY ROCKS

This model is based upon a classification and descriptions of deposits by Boyle (1979). The deposits are mainly gold-bearing quartz veins, breccias and saddle reefs but may also include disseminated deposits in chemically favorable rocks adjacent to veins and breccias.

Host and associated rocks: Deposits of this type are mostly hosted by metamorphosed clastic sedimentary rocks. These rocks are always folded and in most cases have undergone extensive and complex deformation. The lodes occur in areas where the metasedimentary rocks have been intruded by granites. However, the lodes rarely occur in granite, and it is debatable whether the granites bear any genetic relationship to the lodes (Boyle, 1979).

Altered rocks: Boyle (1979) states that the wall rocks of the lodes show only minimal effects of hyrothermal alteration. He reports that rocks adjacent to lodes may contain local, thin zones of chlorite, sericite, carbonate, or tourmaline. Pyrite and arsenopyrite may be disseminated in adjacent wall rocks.

Ore and gangue mineralogy: The primary ore minerals of these deposits are native gold with a low silver content, auriferous pyrite, and auriferous arsenopyrite. Galena, chalcopyrite, sphalerite, pyrrhotite, and molybdenite are common sulfides. Tungsten, bismuth minerals and stibnite are locally present; sulfosalts are rarely present. Gangue minerals include ribbon quartz, feldspar, micas, and chlorite; calcite and ankerite are commonly present, but only in small amounts.

Ore controls: The main controls on these deposits are structural; the deposits occur in faults, fractures, and in fold noses in anticlinal structures. The composition of rock units will affect the development of zones of dilation during folding. The composition of the host unit may also affect ore deposition; high grade lodes are developed in zones of dilation in carbonaceous rocks in some districts (Boyle, 1979).

Geochemistry: Boyle (1979) reports that the best pathfinder elements for detecting these deposits are Cu, Ag, Mg, Ca, Zn, Cd, B, Si, Pb, As, Sb, S, W, Mn, and Fe.

Examples: The following districts may be regarded as belonging to this type of deposit: Cariboo district, British Columbia; Meguma Group deposits, Nova Scotias, and the Bendigo-Ballarat districts, Australia.

Grade/tonnage information: Extensive data on the grades and tonnages of these deposits were not available for analysis. Boyle (1979) reports grades from 0.15 oz Au/ton to 1.5 oz Au/ton for some deposits. The gold generally had a fineness greater than 800. Most production from deposits around the world was from relatively high grade lodes; lower grade material may exist in lodes or disseminated in favorable locations adjacent to lodes.

SHALE-HOSTED LEAD-ZINC DEPOSITS

The classification of stratiform and stratabound lead-zinc deposits has changed rapidly in recent years. This model, based primarily upon Large (1979) but supplemented by the findings of other workers, is empirical and descriptive. It covers deposits which have been described by some authors as "sedimentary exhalative."

Tectonic environment: The tectonic environment in which this type of deposit forms is one of extensional faulting within or at the margin of a continent. Deposits occur along major lineaments and normal faults. Faulting is contemporaneous with sedimentation and ore formation (Large, 1979).

Host and associated rock types: The deposits occur most commonly in tuffaceous sediments and black shales, but siltstones and sandstones, detrital dolostones, and micritic limestones may also host deposits. Chemical sediments particularly chert or exhalite, gypsum, and halite commonly are spatially associated with the deposits. Though igneous rocks are not generally directly related to the deposits, potassium rich volcanic and subvolcanic rocks may be spatially or stratigraphically associated with them (Large, 1979).

Sedimentary features: Deposits occur within marine sediments that were deposited in organic rich, oxygen-poor environments (Carne, 1979). The host sediments commonly contain diagenetic pyrite. The deposits in many places are hosted by units that are characterized by rapid facies changes; sedimentary facies with some deposits include shallow marine, delta front, continental rise, and pelagic and abyssal shales and cherts. In most deposits, ore occurs preferentially in finer grained sediments (Large, 1979).

Altered rocks: Hydrothermally altered rocks are a feature common to many of these deposits. Altered rocks are commonly, but not always, confined to footwall units and are especially well developed near cross-cutting, or stringer, zones which are copper bearing (Large, 1979). The types of altered rock which have been identified in deposits of this type include: silicified, dolomitized, silica-dolomitized, tourmalinized, chloritized, and sericitized rocks.

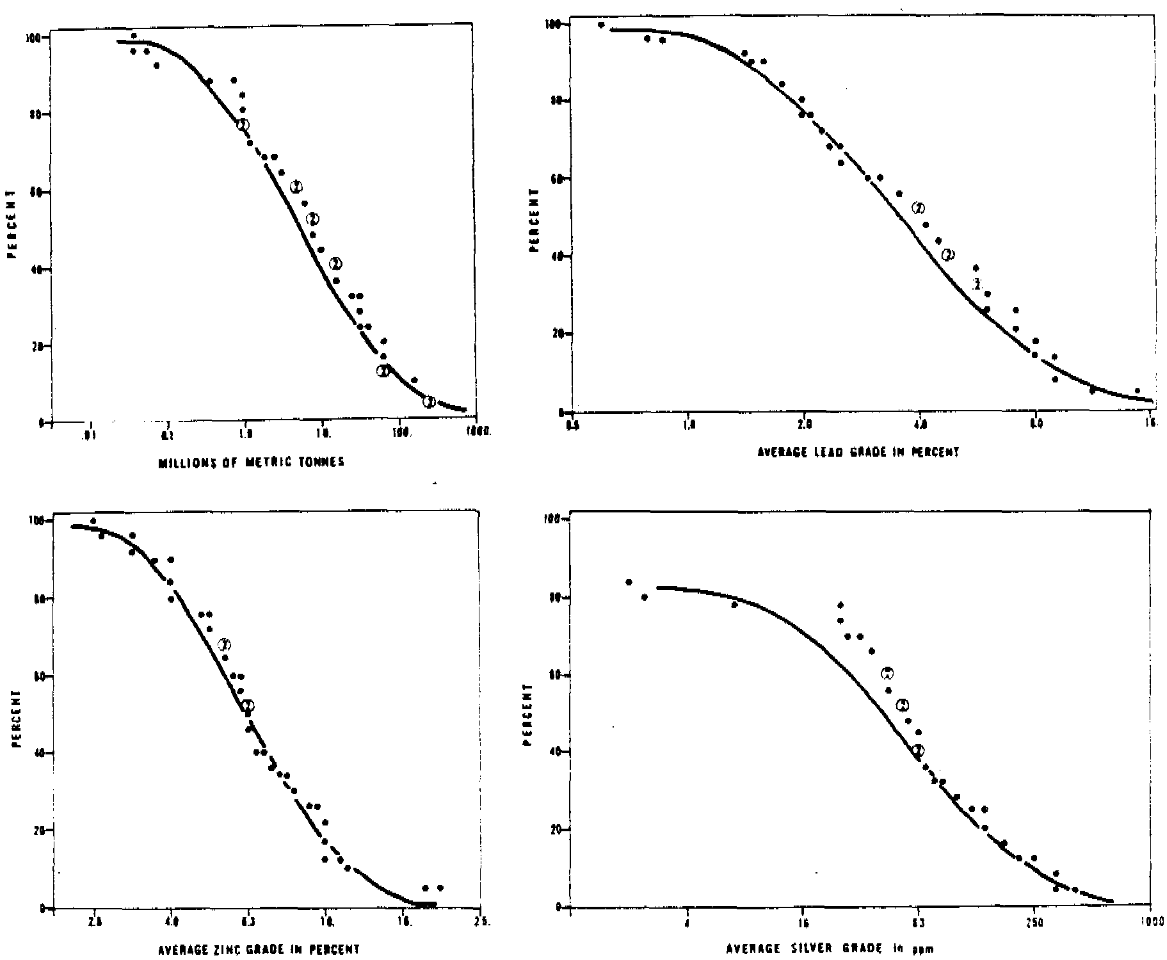
Ore and gangue minerals: The major ore minerals that occur in these deposits are: sphalerite, galena, and, to a lesser extent, chalcopyrite. Ore minerals that occur in lesser amounts and in only some deposits are: arsenopyrite, tetrahedrite-tennanite, bornite, chalcocite, and cassiterite. Common gangue minerals include pyrite, pyrrhotite, marcasite, magnetite, barite, calcite, dolomite, fluorite, and quartz.

Ore textures and mineral zonation: Three ore textures are commonly mentioned in reports on these deposits: finely laminated ores, massive ores, and stringers of copper ore in brecciated and altered footwall rocks.

A feature common to some of these deposits is mineral zonation. The four zones most commonly identified are: a stringer copper, an iron core, a lead-zinc (or sulfide), and a barite zone. The stringer copper zone, if present, in most cases occurs stratigraphically beneath the central portions of the deposit. A central core of iron minerals, often pyrrhotite, is present in some deposits. The lead-zinc zone is the ore; commonly the ratio of lead to zinc decreases outward from the center of the deposits (Large, 1979). A barite zone may occur lateral to, or stratigraphically above, the sulfide zone. Other zones have been identified in individual deposits.

Associated deposits: Shale-hosted lead-zinc deposits are, in some cases, associated with other types of deposits that are spatially distinct from the lead-zinc deposits. The two most common types of associated deposits are small copper vein deposits (Ireland) and stratiform barite deposits (Selwyn Basin, northern Yukon and northwest Brooks Range, Alaska). In addition, deposits may occur over a large stratigraphic range within a basin; for example, deposits in the Selwyn Basin occur in Lower Cambrian, Lower Silurian, and Upper Devonian rocks (Carne and Cathro, 1982).

Grade/tonnage model: Figure 4 presents a grade/tonnage model for shale-hosted lead-zinc deposits. The model is based upon 36 deposits from around the world.



Variable	number of deposits in the model	90%	50%	10%
tonnes $x10^6$	36	.11	5.5	286.
percent lead	36	1.	3.5	12.
percent zinc	36	2.8	6.3	14.
ppm silver	30	Ø	42.	240

Correlations of:

tonnage and lead grade = -.10
tonnage and zinc grade = .16
tonnage and silver grade = -.33
lead grade and zinc grade = .60
lead grade and silver grade = .71
zinc grade and silver grade = .43

Figure 4. Grade/tonnage model of shale-hosted lead-zinc deposits (percent of deposits that equal or exceed a given tonnage or grade).

CHARACTERISTICS OF TRACTS, TYPES OF DEPOSITS THEY MAY CONTAIN, DISCUSSION OF PLACERS AND SELECTED COMMODITIES

This section of the report summarizes the geologic characteristics used to delineate tracts and identifies the types of deposits that they may contain. In addition it discusses placer deposits and several commodities that may occur within the quadrangle, but did not lend themselves to delineation of tracts or representation by deposit models.

Tract I

Types of deposits that may occur within the tract:

1. Tin vein/greisen deposits

2. Uranium deposits hosted by peraluminous granites

Permissive rocks

The tract contains plutonic rocks, felsic dikes, fractured or contact metamorphosed country rocks and intensely altered granite and dike rocks which are similar to rocks which host or are associated with tin and uranium deposits.

Plutonic rocks: The pluton at Lime Peak is composite and composed primarily of peraluminous, biotite granite. At the summit of Lime Peak, at least three phases of biotite granite can be recognized on the basis of texture (Foster and others, 1983): a medium-grained, equigranular granite, porphyritic granite with a medium-grained groundmass, and a medium fine-grained, equigranular granite.

Dikes and hypabyssal rocks: The granites of the Lime Peak pluton and the adjacent country rocks are cut by felsic dikes which commonly have porphyritic texture with phenocrysts of dark gray smoky quartz and/or potassium feldspar, and less commonly plagioclase feldspar. In thin-section, these dikes have a fine-grained groundmass composed of intergrowths of quartz, feldspar, and light-green mica. Some samples contain exsolution textures. The intergrowths and exsolution textures indicate that some dikes have been hydrothermally altered and recrystallized (Keith, personal commun., 1983).

Country rocks: The country rocks adjacent to the Lime Peak pluton have been locally hornfelsed and are cut by boxworks of thin quartz veins and small breccia zones. The veins and breccias are commonly iron-stained.

Intensely altered rocks: Areas of iron and manganese stained rocks with granitoid textures occur adjacent to felsic dikes and at sharp breaks in slope that may indicate the location of small faults. These areas are especially abundant in the southeastern portion of the pluton. Although these rocks are dark colored, examination of thin sections indicates that most are hydrothermally altered granites and felsic dikes. Quartz, sericite replacing feldspar, and chlorite replacing mafic minerals are present in these rocks in varying amounts depending upon the degree of alteration. Fluorite occurs in veinlets or vugs in some samples and needles of green tourmaline, radially intergrown with colorless fluorite and quartz, occur in the vugs of an altered dike (Keith, personal commun., 1983).

Low temperature, probably hydrothermal alteration of feldspars to mixed-layer clays (Keith, personal commun., 1983) occurs in some granites adjacent to more intensely altered rocks and in the vicinity of felsic dikes. In one case, the altered feldspars were colored pink and in another, blue green; 5R 714 and 5BG 612 respectively on the rock color chart (Goddard and others, 1948).

Known occurrences (appendices 1 and 2)

Lime Peak area was staked about 1977 and exploration, including limited drilling, continued until 1981.

Stream-sediment geochemistry and heavy-mineral concentrate mineralogy

Analyses of 22 minus-80-mesh stream sediment samples (table 1) from this tract showed anomalous values for the elements Be, La, Mo, Pb, Sn, Th, U, and Zn. This suite of elements is consistent for both uranium and tin deposits, although the presence of both U and Th anomalies is more suggestive of tin deposits. In addition, the combined suite of minerals found in heavy-mineral concentrates (table 2) of the 22 stream sediment samples also indicates such potential. Minerals identified in the concentrates include allanite(?), arsenopyrite, cassiterite, cyrtolite, fluorite, galena, monazite, scheelite, sphalerite, and uranothorite.

Rock geochemistry

Analysis of samples of 29 intensely altered granites and felsic dikes, 15 granites, 25 felsic dikes, 9 hornfelses, 16 veins and 9 mafic dikes also indicates that the tract may contain tin deposits. The distribution of tin in granites (median (m) = 7 ppm, upper quartile (uq) = 10 ppm), felsic dikes (m = 15 ppm, uq = 30 ppm, maximum = 1000 ppm) and intensely altered rocks (m = 100 ppm, uq = 300 ppm, maximum = greater than 1000 ppm) indicates that tin was enriched in later formed parts of the pluton and in hydrothermal fluids which could form tin deposits. The intensely altered rocks are also enriched in zinc (m = 500 ppm, uq = 1000), molybdenum (uq = 5 ppm, maximum = 100 ppm) and silver (m = .7 ppm, uq = 1.5 ppm, maximum = 10 ppm).

Tract II

Types of deposits that may occur within the tract:

1. Tin vein/greisen deposits

2. Uranium deposits hosted by peraluminous granites

3. Lode gold deposits in metasedimentary terranes

Permissive rocks

The tract contains plutonic rocks, felsic dikes, and fractured or contact metamorphosed country rocks which are similar to rocks which host or are associated with uranium and tin deposits. In addition, quartz veins, quartz-healed breccias, and iron-stained quartzites may contain small lode gold deposits.

Table 1. Number of samples from delineated tracts and number of times that indicated elements reached anomalous levels in stream sediment and heavy mineral concentrate samples (1)

		Elements (2)																
		Stream Sediments													Heavy Mineral Concentrates			
Tract	Number of samples	Ag	Au	Ba	Be	Cu	La	Mo	Pb	Sn	Th	U	W	Zn	Au	Mo	Sn	W
I	22	6	2	0	21	10	11	1	12	3	10	12	0	17	0	6	16	0
II	36	0	0	0	20	1	3	0	0	7	3	23	3	0	0	0	15	5
III	30	1	2	0	0	7	1	1	0	0	2	0	3	0	1	2	1	15
IV	96	12	15	0	4	17	3	0	3	3	2	2	1	1	12	3	24	14
V	22	2	0	0	10	2	3	0	5	0	0	17	1	0	0	0	3	2
VI	151	5	1	35	18	18	29	0	4	2	3	10	5	7	0	0	8	36
VII	36	7	2	26	0	3	0	3	0	0	0	0	2	14	0	0	0	3
VIII	20	15	0	15	2	12	2	14	1	0	0	0	0	1	0	10	3	0

(1) Definition of geochemical anomalies (approximately upper 5-10 percent of samples from the entire quadrangle) in ppm

Stream sediments: Ag $\geq$ .7, Au $\geq$ .1, Be detected at $\geq$ 5, Cu $\geq$ 50, Mo $\geq$ 7, Pb $\geq$ 100, Sn $\geq$ 50, Th detected at 100, U $\geq$ 4, W $\geq$ 50, Zn $\geq$ 170

Heavy mineral concentrates: Au detected at 20, Mo $\geq$ 10, Sn $\geq$ 1000, W $\geq$ 500

(2) Element determined by six-step semiquantitative emission spectrographic methods except for Au, U, Th, and Zn for stream sediment samples which were determined by atomic absorption methods.

Table 2. Frequencies that minerals were identified in heavy mineral concentrate samples from streams that drain delineated tracts

Tract	Number of samples	Cassiterite	Scheelite	Fluorite	Sulfides py, gal, sph	Crytolite	Monazite	Uranothorite	Powellite	Gold
I	22	20	10	4	2 6 3	2	16	12	0	0
II	35	20	24	1	aspy=2 cpy=2 1 1 1	0	8	4	0	2
III	30	13	24	0	aspy=6 cpy=1 0 5 0	0	3	0	1	2
IV	92	43	62	0	aspy=16 cpy=5 stibnite=8 1 9 1	0	18	6	0	32
V	22	12	20	0	0	0	2	1	1	0
VI	150	34	135	0	aspy=4 cpy=1 6 0 2	0	24	7	0	1
VII	36	1	18	0	cpy=7 11 2 2	0	8	1	0	4
VIII	20	9	3	0	cpy=7 1 1 5	litharge=1 0	9	0	0	0

Abbreviations: py (pyrite), gal (galena), sph (sphalerite), aspy (arsenopyrite), cpy (chalcopyrite), stibnite

Plutonic rocks: The largest bodies of granite in the tract belong to the Mount Prindle and Quartz Creek plutons. Several smaller bodies of hornblende granite, mainly to the southeast of the main part of the Mount Prindle pluton probably belong to a separate body. The Mount Prindle pluton is composed primarily of biotite granite that was emplaced during two major intrusive events. The granites of both events vary texturally, but are very similar mineralogically, consisting primarily of potassium feldspar, quartz, plagioclase, and biotite with minor and accessory minerals which include muscovite, tourmaline, and topaz. Most granitic rocks are somewhat altered with the feldspars incipiently to completely altered to clay minerals and sericite. Commonly biotite is partly to completely altered to chlorite. Some altered plagioclase in granitic rocks of the early intrusive phase has a pink color (Holm, 1973).

Felsic dikes: The granites and adjacent country rocks are cut by many aplite, pegmatite, quartz porphyry, and felsite dikes. Holm (1973) reports that some aplites grade into complex pegmatites composed of quartz, muscovite, biotite, potassium feldspar, and tourmaline. He also states that in the Hope Creek drainage, pegmatites and a nearby biotite granite contain an unusual green mineral of the illite group.

Country rocks: Locally the country rocks have been hornfelsed adjacent to plutons and in roof pendents that overlie the Mount Prindle pluton. Quartzites adjacent to the pluton contain small quartz veins, breccias, and iron-stained zones. Breccias occur adjacent to small felsic dikes (Holm, 1973, p. 31-32). Iron-stained zones of brecciated quartz are found within the Nome Creek fault zone in T7N,R6E,S9. East of VABM Hope the metamorphic rocks are cut by many felsic dikes, which are commonly altered and associated with iron-stained breccias.

Known occurrences

Parts of the Mount Prindle pluton were staked in 1977 and were actively explored during the years just before and after 1977. Green fluorite occurs in breccia on the south side of the Mount Prindle pluton in the drainage of Hope Creek (T7N,R6E,S34), and Holm (1973) reports that fluorite also occurs in float on the east side of the Mount Prindle pluton in Fluorite Creek (T7N,R6E). Barker and Clautice (1977) report a series of radioactive springs on the southwest side of the Mount Prindle pluton (T7N,R5E,S25).

Stream sediment geochemistry and heavy mineral concentrate mineralogy

Analyses of 36 minus-80-mesh stream sediment samples (table 1) show anomalous values for the elements Be, La, Sn, Th, and U. Whereas these values are consistent with both uranium and tin deposits, the predominance of U anomalies over Th in stream sediment samples is more suggestive of U deposits. In addition, 35 heavy-mineral concentrate samples collected from streams draining this tract target potentially mineralized areas, as the mineral suite (table 2) included allanite(?), arsenopyrite, cassiterite, chalcopyrite, fluorite, galena, gold, monazite, scheelite, sphalerite, and thorite.

Rock geochemistry

Semiquantitative spectrographic analysis of 10 granite, 20 felsic dike, 18 hornfels, 5 vein, quartz breccia or iron-stained quartzite, 26 quartzite or schist and 3 marble grab samples indicates that the samples of granite and hornfels are enriched in both tin and boron. The median amount of tin in the granite samples is 20 ppm and a quarter of the samples contained at least 40 ppm. The median amount of tin in samples of hornfels is 15 ppm, a quarter contain at least 30 ppm and one sample contained 200 ppm. The median of amount of boron in the granites is 200 ppm, and it is 150 ppm in the hornfels. A quarter of the granite samples contain at least 500 ppm boron and there is 300 ppm or more in one fourth of the hornfels samples. While the felsic dikes are also enriched in tin, one half of the samples contain at least 15 ppm and a quarter of the samples contain 30 ppm, they are not enriched relative to the granites and hornfelses. This may indicate that tin did not concentrate in late phases of the igneous rocks or in hydrothermal fluids.

Tract III

Types of deposits that may occur within the tract:

1. Tin vein/greisen deposits

2. Tungsten skarn deposits

3. Lode gold deposits in metasedimentary terranes

Permissive rocks

The tract contains plutonic rocks, felsic dikes and fractured or contact metamorphosed country rocks that are similar to rocks which host or are associated with tin deposits. The country rock adjacent to the pluton may host tungsten skarn deposits. Lode gold deposits may occur in fractures in the country rock or adjacent to felsic dikes.

Plutonic rocks: Granitic rocks outcrop over a very small portion (2 sq km) of the tract. However, the distribution of contact metamorphosed rocks and the configuration of an aeromagnetic anomaly suggests that granite underlies more of the tract than is indicated by its area of outcrop (Burack and others, 1983). The granite is composite; both coarse-grained, equigranular, biotite granite and porphyritic biotite granite with a fine-grained groundmass are exposed.

Felsic dikes and hypabyssal rocks: Felsic dike and hypabyssal rocks are especially abundant near Table Mountain, southwest of the granite, and in the southwest part of the tract. Most of the dike and hypabyssal rocks in these two areas are aphanitic or less commonly porphyritic with an aphanitic groundmass and have a high color index. Some have orange brown streaks or bands, some of which are formed by specks of limonite after pyrite(?) and fluorite has been identified in one dike.

Country rocks: For a considerable distance northeast and southwest of the pluton, the country rocks have been hornfelsed; calc-silicate rocks may have undergone metasomatism from fluids emanating from the nearby granitic pluton, or the sequence of mineral assemblages observed could be the result of thermal metamorphism of compositionally distinct layers (Burack and others, 1983). Quartzites contain veins, breccias, and iron-stained quartzites. Thin quartz veins with arsenopyrite selvages were observed parallel to the foliation of quartzites; the veins and silicified breccia occur near an altered hypabyssal dike.

Known occurrences

Five blocks of lode claims are known to have been staked within the tract (appendix 2). These claims were all staked after 1968 and three of the claim blocks were active as recently as 1981. Many streams in the tract have been staked for placer deposits; the only streams with known production of gold are located in the southwest end of the tract (appendix 1).

Stream sediment geochemistry and heavy-mineral concentrate mineralogy

Analyses of 30 minus-80-mesh stream sediment samples (table 1) show anomalous values for the elements Ag, Au, Cu, La, Mo, Ni, Th, and W. Mineralogical data of 30 samples of stream concentrates (table 2) is indicative of probable mineralization in areas of this tract. Minerals of interest include allanite, arsenopyrite, cassiterite, chalcopyrite, galena, gold, monazite, powellite, and scheelite.

Rock geochemistry

Analysis of 4 granite, 18 felsic dike and hypabyssal, 4 hornfels, 5 vein, breccia and iron-stained quartzite, 3 mafic dike, 9 quartzite, and 8 marble samples indicate that the tract may contain tin, tungsten and gold deposits. The distribution of tin in the granites (median (m) = 15 ppm, upper quartile (uq) = 50 ppm) and dikes (m = 50 ppm, uq = 70 ppm) indicates that tin was enriched in later formed parts of the pluton. Samples of country rock, especially marbles contained tungsten. Two samples of black quartzite located near silicified breccia and an altered felsic dike contain unusually large amounts of gold (140 and 40 ppm). Finally felsic dikes and country rocks at two localities near the pluton contained unusually large amounts of beryllium. Three samples of dikes contain 700, 1000 and 1500 ppm; two samples of hornfels contain 700 and 1500 ppm, two samples of quartzite contained 1000 ppm and two other quartzite samples contain 200 and 300 ppm beryllium.

Tract IV

Types of deposits that may occur within the tract:

1. Tin vein/greisen deposits
2. Uranium deposits hosted by peraluminous granites
3. Lode gold deposits in metasedimentary terranes

Permissive rocks

The plutonic rocks, felsic dikes and fractured or contact metamorphosed country rocks of this tract are similar to rocks which host or are associated with tin and uranium deposits. The tract may contain lode gold deposits in quartz veins, breccias, silicified zones in the country rocks and adjacent to felsic dikes.

Plutonic rocks: The pluton near Circle Hot Springs is multiphase and composed mostly of biotite granite with minor biotite-hornblende granite and some biotite granite with minor white mica, especially in granites of the eastern part of the tract (Foster and others, 1983). Granite outcrops in the eastern part of the tract generally occur at elevations less than 3000 ft. In the western part of the tract, which is mainly above 3000 ft, granite outcrops are fewer and smaller in area. Because dikes occur in the western part of the tract and because granite is present in topographic lows, it is likely that granite underlies most of the tract but is below 3000 ft above sea level.

Felsic dike and hypabyssal rocks: Felsic dikes cut the granites and country rocks at many places in the tract. The dikes contain quartz, feldspar, and biotite and have textures that range from porphyritic to aplitic to pegmatitic. At occurrence 37 (table 2), a series of arsenopyrite-bearing, intensely altered felsic dikes(?) intrude the country rock either parallel to, or at a low angle to, foliation of the country rocks. In addition to being intensely altered, the dikes(?) have been sheared.

Country rocks: The country rocks in the tract belong to the quartzite and quartzitic schist (PzpЄq) unit and the mafic schist (PzpЄm) unit (Foster and others, 1983). Quartzites and schists of the PzpЄq unit locally are hornfelsed near contacts with the pluton, and at many places in the tract quartz veins cut the metamorphic rocks. Many of the veins are thin, one-eighth to one inch thick, with limonite pseudomorphs in them or in adjacent metamorphic rock. The veins occur individually, or as intersecting stockworks. Some veins are offset but are not folded, whereas others are folded indicating there has been more than one period of vein formation. One vein contained arsenopyrite(?) and was coated with a yellow stain. Veins from occurrence 37 have abundant, large fluid inclusions which contain, at room temperatures, three phases: water, liquid carbon dioxide and vapor (mostly carbon dioxide). At the same location, iron-stained quartz pods, which appear to occur along the margins of sheared, altered felsic dikes(?), contain large fluid inclusions which, at room temperatures, contain water, liquid carbon dioxide, vapor and crystals of salt(?). The presence of salt indicates that the fluids trapped in the inclusions were capable of carrying metals in solution; Boyle (1979) noted that carbon dioxide-bearing fluid inclusions are closely associated with gold. At several locations in the tract (T8N,R12E,S24; T7N,R14E,S8; T7N,R14E,S18; T7NR14E,S10 and T7N,R14E,S12) small zones (less than .65 sq km) were noted in which quartzites did not break with foliation and which contained minor breccia, limonite and arsenopyrite(?). These zones may represent areas in which rocks have been contact metamorphosed, or more probably areas of hydrothermal alteration (redistribution of silica(?)). Some breccias are probably related to regional deformation of the metamorphic rocks, but others were probably formed in conjunction with the intrusion of the pluton, or with post-intrusive faulting.

Known occurrences

The tract contains many claims and most of the streams in the tract have been mined for placer gold (appendix 1). A few lode claims (appendix 2) have been staked but none are known to have any recent significant activity.

Stream-sediment geochemistry and heavy-concentrate mineralogy

Analyses of 96 minus-80-mesh stream sediment samples (table 1) show anomalous values for the elements Ag, Au, Be, Cu, La, Pb, Sn, Th, U, W, and Zn. Mineralogical data of 92 samples of stream concentrates (table 2) are typical of results from a large gold placer area; minerals noted include allanite(?), arsenopyrite, cassiterite, chalcopyrite, galena, gold, monazite, scheelite, sphalerite, stibnite and its alteration products, and thorite.

Rock geochemistry

Analyses of 18 granite, 28 felsic dike, 4 mafic dike, 1 hornfels, 23 vein, breccia, and iron-stained quartzite, 77 quartzite and quartzitic schist unit (Pzp€q), and 44 mafic schist unit (Pzp€m) samples show important differences in element concentrations among rock types; individual elements are also zoned within the tract. Gold was detected in approximately 25 percent of the samples of veins, breccias and iron-stained quartzites, 20 percent of the samples of felsic dikes and 10 percent of the samples of the quartzite unit (Pzp€q). Gold was detected in only one sample of the mafic schist unit (Pzp€m), and was not detected in the samples of granite. Arsenic was detected in 30 percent of the veins, breccias and iron-stained quartzites and in 25 percent of the felsic dikes. Approximately one half of the felsic dike and vein, breccia and iron-stained quartzite samples contained silver and more than half of the samples of the quartzite unit contain detectable silver. Tin was detected, in amounts of 50 ppm or less, in half of the granite and 25 percent of the felsic dike samples. Rock geochemical data for individual elements are spatially zoned within the tract. The proportion of rock samples that contain detectable gold and arsenic is larger in the western part of the tract where metamorphic rocks are the primary exposed rock types than in the eastern part of the tract, where granitic rocks are the primary exposed type of rock. In contrast silver and tin were detected in a larger proportion of samples from the eastern part of the tract than from the western part. The distribution of gold by rock type and by its location suggests that gold occurs in small fracture zones, veins and associated with felsic dikes, that developed and were emplaced above the Circle pluton.

Tract V

Types of deposits that may occur within the tract:

1. Uranium deposits hosted by peraluminous granites

Permissive rocks

The tract contains plutonic rocks, felsic dikes and fractured and contact metamorphosed country rocks which are similar to rocks which host or are associated with uranium deposits.

Map No.	Name	Township and Range)	Development Category	Resource	Description	Reference
39	Eagle Creek	T7N,R11E	M	Au	Gold discovered in 1895. Since 1901 much profitable mining has been done on this stream from the mouth to near the heads of Mastodon and Miller forks. Mining reported nearly every year through 1981. Production through 1906 about 29,000 fine oz. Bedrock mainly quartzitic schist (Paleozoic and(or) Precambrian) cut by numerous quartz veins. Schistosity strikes N 60° E; dips 30°-4-° NW. Pay streak 150-200 ft wide extended down Mastodon Fork and Eagle Creek in present stream gravels 5-20 ft thick and overlain by 2-15 ft of muck. Gold in gravel and upper few feet of bedrock; coarse-grained and intergrown with considerable quartz. Most of the gravels in the main creek has been mined. Far gravels bordering Eagle Creek carry coarse gold and were being prospected in 1980. Fineness about 883 gold, 108 silver, with overall general increase downstream. Grade is about highest reported for Mammoth and Deadwood Creeks area	Brooks, 1907, p. 197; Spurr, 1898, p. 293, 354-355; Eberlein and others, 1977, p. 20; ADGS
40	Easley Creek	T8N,R14E	P		Bedrock is porphyritic granite which weathers to tors. Years of known activity: 1979 and 1980	ADGS
41	East Albert Creek	T9N,R14E	P		Thick silt cover here. Years of known activity 1980 and 1981. Several km to the northwest on Little Albert Creek gold was panned from Tertiary(?) gravels	ADGS
42	East Great Unknown Creek	T6N,R12E	P		Years of known activity: 1974 and 1976-1981	ADGS
43	Elliott Creek	T3N,R4E	P		Activity in 1981	ADGS
44	Faith Creek	T6N,R7E	M	Au	First reported finding of placer gold in 1906. Upper part of valley prospected in 1909. Other years of known activity include 1937-1940, 1953-1959, 1975-1977, and 1980-1982. Most of activity has been near mouth of Deep Creek, but claims were also active near mouth of Faith Creek 1975-1981 and on a south flowing tributary 2 km above the mouth in 1976-1977. Ninety percent of the clasts in creek are quartz-mica schist, quartzite, and quartz. (See also Deep Creek)	Eberlein and others, 1977, p. 20; ADGS
45	Fish Creek	T7N,R11E	P		Years of known activity: 1972-1981	ADGS
46	Flat Creek	T5N,R5E	P		Years of known activity: 1980 and 1981	ADGS
47	Frozen Creek	T5N,R7E	P		Years of known activity: 1953-1964, 1980-1981	ADGS
48	Fryingpan Creek	T6N,R11E	P	Au	Good values reported by prospectors during winter 1909-1910 in hole about 20 ft deep. More recent activity in 1974-1981. Schist (Paleozoic and (or) Precambrian) bedrock; 4-5 ft of pay gravel beneath 15 ft of overburden. No record of any production	Eberlein and others, 1977, p. 20; ADGS