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THE LITHOGEOCHEMISTRY OF THE KENO HILL DISTRICT, YUKON TERRITORY

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Abstract

The lithogeochemistry of the Keno Hill district, Yukon is discussed in terms of the analytical data for Cu, Pb, Zn, Ni, Co, As, Sb, Mo, W, U, Sn, Ag, F and Ba on 381 rock samples and limonite precipitates from springs. In addition, analytical data for the major constitutents of the principal rock types in the district are given.

The limonite precipitates vary greatly in their metal content, enrichments being marked in Zn, Cu, Pb, Ni, As, Sb, Mo, and F in a number of samples. The trace element content of the limonite precipitates commonly reflects the type of mineralization present in the rocks from which their parent springs issue.

Certain quartz vein samples analyzed are remarkably high in Sn, and the skarn samples report high contents of W and locally high contents of F.

The granitic rocks have high median values for Pb, As, W, U, Sn, F, and Ba, and certain of the porphyries contain significantly high contents of copper and other metals. The greenstones have high median values for Cu, Zn, Ni and Co and some samples are mineralized with chalcopyrite.

The various sedimentary rocks range widely in their metal content with relatively high concentrations of the metals in the vicinity of mineralization. Sites from which samples report medium to high metal values should be thoroughly prospected. The Ordovician-Silurian slate samples are exceptionally high in Ba which may indicate the possible presence of barium deposits in these and associated rocks.

Résumé

On étudie la géochimie des roches du district de Keno Hill, au Yukon, d'après les données analytiques relatives au Cu, Pb, Zn, Ni, Co, As, Sb, Mo, W, U, Sn, Ag, F et Ba portant sur 381 échantillons de roche et sur des précipités de limonite déposés par des sources. En outre, on présente des données analytiques portant sur les constituants essentiels des principaux types de roches du district.

Les précipités de limonite ont un contenu métallique très variable, et présentent des enrichissements notables en Zn, Cu, Pb, Ni, As, Sb, Mo et F, dans un certain nombre d'échantillons. Le contenu des précipités de limonite en oligo-éléments concorde généralement avec le type de minéralisation qu'ont subi les roches qui traversent les sources.

Certains des échantillons de veines quartzeuses analysés ont une concentration remarquablement élevée en Sn, et les échantillons de skarns, une concentration élevée en W, et parfois en F.

Les roches granitiques, présentent des concentrations moyennes élevées en Pb, As, W, U, Sn, F et Ba, et certains porphyrés sont enrichis en cuivre et autres métaux. Les roches vertes ont des concentrations moyennes élevées en Cu, Zn, Ni, et Co et certains échantillons sont minéralisés en chalcopyrite.

Les diverses roches sédimentaires ont un contenu métallique très variable, et a proximité des zones de minéralisation, leur teneur en métaux est relativement élevée. Le travail de prospection doit être effectué méticuleusement dans les sites où les échantillons présentent des teneurs moyennes à élevées en métaux. Les échantillons de schiste ardoisier de l'Ordovicien et du Silurien ont une teneur exceptionnellement élevée en Ba, ce qui indique peut-être la présence de gisements de barium dans les ardoises et les roches qui leur sont associées.

INTRODUCTION

During the summer of 1964 the Geological Survey of Canada carried out their first helicopter-supported, integrated, reconnaissance stream and spring sediment, surface and groundwater, heavy mineral, and rock geochemical survey over some 1900 square miles centred on Keno Hill, Yukon. The results of the water and stream sediment analyses have been published (Gleeson et al., 1965-1968) as have also those pertaining to the surface and groundwaters (Gleeson and Boyle, 1976) and the heavy minerals including gold (Boyle and Gleeson, 1972; Gleeson and Boyle, in press). Early lithogeochemical work in the district was described by Boyle (1965).

The present paper deals with the geochemistry of rock samples and limonite precipitates collected throughout the district in 1964.

Location

The Keno Hill district is in central Yukon some 220 miles due north of Whitehorse. The district is served by an all-weather road from Whitehorse and by Northward Airlines scheduled flights from Whitehorse and Dawson. The three villages in the district, Keno Hill, Elsa, and Calumet, can be reached by an all-weather road from Mayo the principal communications centre in the central Yukon.

Topography, glaciation, permafrost and climate

The Keno Hill district lies within the northeastern part of the Yukon Plateau, and the terrain is mountainous with elevations ranging from 6852 feet (Mt. Patterson) to 2300 feet (Keno Ladue-McQuesten River Valley).

Many of the mountains have steep slopes (Mount Haldane, Mount Hinton) and are traversed by numerous gulches that cut deeply into the rock strata. Keno Hill and Galena Hill, the sites of the principal mineral deposits, have more gentle slopes but here and there are cut by steep gulches and cirques. Below an elevation of 4500 feet the slopes of the mountains and hills are covered with thick deposits of till, soil, rock debris, muck, and muskeg, in which conifers, birch, aspen, Arctic black birch and other vegetation grow abundantly. Above this elevation the soil is thin, outcrops are more numerous, the ground is covered with local rock float, the terrain is treeless, and the vegetation is limited to alpine species and grassy meadows.

The lower slopes of the mountains and hills were severely glaciated during Pleistocene time by ice sheets that spread from the east across the entire area. Glacial till, gravel, and other debris form a series of benches on the slopes of the hills and floor of the valleys. The deposits are generally 5 to 20 feet thick, but in some areas, as on the southern slopes of Keno Hill facing Lightning Creek and north of Christal Lake, they are 30 to 50 feet thick or more.

The Keno Hill district is in the region of permanently frozen ground. The permafrost is irregularly distributed and its occurrence is dependent upon the elevation, hillside exposure, depth of overburden, amount of vegetative cover, and presence of flowing underground and surface water. It is generally present at high elevations and on slopes with a northern exposure. Thus, on Keno Hill, mine workings on the top of the hill and on the northern slope encountered permafrost some 400 feet below the surface. On the northern slopes of Sourdough Hill and Galena Hill a similar situation prevails, and frost and ice lenses have been found at depths of 250 feet or more in the mine workings. On the lower, southern slope of Keno Hill, however, the workings of the Onek and Mount Keno mines show little evidence of permafrost. In places where surface and underground waters are flowing frost-free windows and strips are present. These provide access and egress for waters that are oxidizing the lodes.

The climaté of central Yukon is rigorous. The mean annual temperature at Mayo is 26°F (-3.3°C), the average minimum temperature is 14°F (-10°C) and the average maximum 37°F (2.8°C). Temperatures as low as -80°F (-62°C) and as high as 90°F (32.2°C) have been recorded. The winters are long and cold with only a few hours of daylight each day, and the summers are short and warm with nearly continuous daylight.

The average annual precipitation at Mayo is 11.23 inches. The rainfall in the Keno Hill district during the spring and summer is moderate with occasional torrential downpours. The snowfall is moderate and usually commences in mid-September or early October. Most of the snow has melted by the end of May, but local patches and small snowfields remain in sheltered places on northern slopes until late August.

GENERAL GEOLOGY

The general geology of the Keno Hill district was described first by Keele in 1905 and later by Cairnes (1916) and Bostock (1947). The geology of Mayo area, Davidson Mountains, Beaver River area, and Keno Hill was described by Cockfield (1919, 1921a,b, 1922, 1924a,b, 1925) and the geology of Galena Hill was outlined by Stockwell in 1926. McTaggart (1950, 1960) described the geology of both Keno Hill and Galena Hill, and Kindle (1955, 1962) provided a description of the geology of the area comprising Mayo Lake, Galena Hill, and Keno Hill. More recent work in the Keno Hill district is described in the Bulletin by Boyle (1965) dealing with the lead-zinc-silver deposits of the Keno Hill-Galena Hill area, in the short note on the Mount Haldane and Dublin Gulch map-area by Poole (1965), and in the Memoirs by Green (1971, 1972) which cover the geology of Mayo Lake, Scougale Creek, McQuesten Lake, Nash Creek, and Larsen Creek map-areas.

The consolidated rocks underlying the Keno Hill district are mainly sedimentary in origin. Originally many of these rocks were considered to belong to the Yukon Group and to be of Precambrian or Paleozoic age. Later work by Green (1971, 1972), however, suggested that the sedimentary sequences are greatly interrupted by thrust faults and that some of the rocks, particularly the Keno Hill Quartzite and Lower Schist (Central Quartzite and Lower Schist formations respectively of Boyle, 1965) are of Mesozoic age, probably Lower Cretaceous and Jurassic respectively.

The Table of Formations is essentially that proposed by Green (1971) with some modifications. The quartz-feldspar porphyry has been included in the Cretaceous period since some of the vein and lode deposits cut these rocks on Keno Hill, and the mineralization is considered by the writers to be of late Cretaceous age. The rocks in the Eagle Ridge-Haggart Dome-Lynx Dome area, which are included in the Grit Division by Green, are considered by us to belong to units 1 and 2. In this respect we have followed Poole (1965).

The folding pattern of the sedimentary rocks is intricate and cannot be considered in any detail here. On Keno Hill and Galena Hill the rocks dip southeast and appear to form the southern limb of a large open anticline whose axis follows the South McQuesten River Valley in the western part of the area. Further details are given by Green (1971, 1972) for other parts of the district.

The fault pattern is, likewise, complicated on Keno Hill and Galena Hill, the sites of the economic orebodies of the district. There are two principal fault systems; a northeast-striking system of vein faults which, together with numerous subsidiaries, contains all the orebodies, and a north-northeast to northwest-trending series of faults which cut the orebodies and are barren. Faulting in the other parts of the district are described by Green (1971, 1972).

ROCK TYPES

Figure 1 shows the distribution of the various rock types in the Keno Hill district.

The principal sedimentary rocks in the area are shale, argillite, quartzite, phyllite, slate, schist, dolomite, and limestone. The intrusive rocks comprise greenstone (metagabbro, metadiorite, and metadiabase), quartz-feldspar porphyry, granite, granodiorite, and a few dykes of biotite lamprophyre.

Most of the sediments and greenstones fall into the greenschist or sericite facies. Next to granitic masses, skarn and hornfels are developed.

Shales, slate, and chert

The shales, slate, and chert are restricted to the rocks of (Unit 4) of Ordovician to Silurian age in the Beaver River and Eagle Creek areas. Most of the shales and slates are black due to abundant carbonaceous material, thinly banded, and interbedded with black chert and locally with dark grey quartzite. The shales and chert exhibit little evidence of metamorphism and are not foliated.

TABLE OF FORMATIONS[1]

Era	Period or epoch	Name or unit	Lithology
Cenozoic	Recent	12	Soils, stream deposits, talus, rock fragments transported by solifluction
	Pleistocene	12	Till, gravel, sand, and silt
		Unconformity	
Mesozoic	Cretaceous	11	Quartz-feldspar porphyry
		Not in contact	
	Cretaceous	10	Quartz monzonite, quartz diorite, granodiorite, granite
		Intrusive contact	
	Cretaceous	9	Greenstone (altered diorite, gabbro, and diabase)
		Intrusive contact	
	Lower Cretaceous (?)	8 Keno Hill Quartzite	Massive thick bedded quartzite, thin bedded quartzite, phyllite, graphitic phyllite, and minor limestone
		Conformable contact	
	Jurassic (?)	7 Lower Schist division	Graphitic phyllite, phyllitic quartzite, thin bedded quartzite, graphitic schist, and minor limestone
		Conformable contact (?)	
	Triassic	6	Platy, black limy shale and limestone; thin bands of grey- to buff-weathering limestone
		Unconformity	
Paleozoic	Ordovician to Silurian	5	Massive dolomite, minor limestone
		Unconformity	
		4	Black shale and chert, phyllite, slate, dark grey quartzite
		Probable unconformity	
Precambrian	Proterozoic	3 Grit division	Gritty quartzite, varicoloured phyllite and argillite, graphitic phyllite, minor limestone and chert
		Not in contact, relationship unknown	
		2	Thin bedded, phyllitic quartzite, quartz-mica schist, graphitic schist, and grit
		Conformable contact (?)	
		1 Upper Schist division	Quartz-mica schist, phyllitic and thin bedded quartzites, phyllite, graphitic phyllite, and minor limestone
			Orange-weathering platy dolomite

[1] Modified from Green (1971)

Carbonate rocks

Dolomite and minor limestone characterize unit 5. These rocks are of Ordovician to Silurian age and their description as paraphrased from Green (1971) is as follows:

Unit 5 consists of a thin lower zone composed of limestone conglomerate, fine grained buff weathering limestone and dolomite, and intraformational conglomerate, overlain by a great thickness of light grey dolomite with minor limestone.

The lower conglomerate contains rounded pebbles and cobbles in a matrix of fine grained grey limestone. The fragments in the conglomerate are up to 1 foot in diameter but most are less than 1 inch. They consist predominantly of limestone although a few pebbles of phyllite were observed. No fragments of the gritty quartzite of unit 3 were recognized. The intraformational conglomerate is separated from the lower conglomerate by buff-weathering, light grey, fine grained limestone and dolomite. The former consists of slab-like pieces of cream coloured dolomitic limestone up to 1 foot long and 1 inch thick in a matrix of similar material.

The remainder of unit 5 consists mainly of grey to white weathering light buff, cream, and grey dolomite. Most outcrops are massive and the rocks shows little evidence of bedding. The grain size of the dolomite ranges from about 0.1 to 1.0 mm. Much of the dolomite contains some quartz, and a few bands are as much as 70 per cent quartz. Most of the quartz occurs as angular grains up to 0.1 mm across which may have formed by the recrystallization of chert. The quartz grains commonly form subrounded blebs up to 3 mm in diameter and in a few cases, where the quartz content of the rock is high, the dolomite occurs in similar blebs. One band showing well-developed oolitic structure was observed. Interbedded with the lighter dolomite are small amounts of dark grey and black dolomite.

Limestones and dolomites are common as lenses and pods in a number of other units including a small area of Proterozoic orange weathering dolomite north of Kathleen Lake and limestone and dolomite in units 1, 2 and 3. Those in the central quartzite and upper schist formations of Boyle (1965) (Keno Hill Quartzite and Upper Schist division respectively of Green, 1971) are typical of the limestone lenses, pods, boudins, and beds in the argillite, phyllite, slate, schist, and quartzite map-units of the district. These limestones occur principally in irregular layers, lenses, and boudins in the schist and phyllite formations and as a few beds up to a foot or more thick interbedded with quartzites and phyllites in the quartzite formations. Most limestone beds and lenses are highly contorted and fractured and are in places seamed by numerous ramifying veinlets and irregular lenses of later white to buff carbonates.

In hand specimens the fresh limestones are grey to black; some varieties are banded with greyish layers alternating with irregular lens-like layers of white to buff carbonate. Some specimens exhibit a schistose appearance due to the presence of much sericite. Most bodies weather buff, but a few, particularly the black varieties, weather either greyish or black.

Under the microscope the normal limestones are seen to contain carbonate minerals with minor amounts of quartz and sericite. Accessory minerals include leucoxene, pyrite, and limonite. Siliceous varieties contain more quartz and sericite. The grey limestones are fine grained with a slight schistose texture and are composed of relatively clear carbonate minerals. Banded and mottled varieties contain grey bands of relatively fine grained carbonate alternating with bands containing coarser grained clear carbonate and quartz. The black limestones are nearly opaque to transmitted light. They have a microcrystalline groundmass in which is set much carbonaceous matter in wisps, bands, whorls, and irregular patches. Some black varieties have a brecciated appearance and consist of irregular fragments of dense black microcrystalline limestone intersected by patches, veinlets, and ramifying areas of relatively clear fine grained carbonate containing some quartz.

There is no indication of any original sedimentary features such as well-marked laminae, oolites, fossils, or concretions in any of the limestone beds or lenses seen by the writers.

Analyses of samples of two varieties of carbonate rocks from the Keno Hill-Galena Hill area are given in Table 1.[1]

Argillites, phyllites, slates, and schists

Of this group of rocks, schists are the most abundant, followed by phyllites and argillites; slates have a limited local occurrence.

The argillites occur in beds ranging in thickness from a few inches to 10 feet or more and are generally interbedded with the various types of schists, phyllites, and quartzites. All varieties of argillite exhibit a poorly developed cleavage approximately parallel with the bedding. In many occurrences they are crumpled, fractured, or crushed and contain numerous carbonate and quartz stringers.

In hand specimens most argillites are grey, but some are dense black and contain abundant carbonaceous matter and pyrite.

In thin sections the grey argillites are seen to contain white mica (sericite) and/or brown mica (biotite), microcrystalline quartz and leucoxene, chlorite, isotropic colloidal material, and pyrite. Some contain a little carbonate. Accessory minerals are tourmaline, zircon, and rutile. The texture is commonly banded, with layers containing essentially sericite, leucoxene, and a little quartz alternating with layers containing quartz, carbonate, and subordinate sericite and/or biotite. In most sections the small irregular masses of pyrite are strung out along particular bands.

The black argillites are composed mainly of layers of carbonaceous material containing much fine grained pyrite and minor amounts of carbonate minerals, quartz, and sericite. These generally alternate with layers containing quartz, sericite, carbonate minerals, some carbonaceous material, and a little pyrite.

Mineralogically, the phyllites are essentially the same as the argillites. They are, however, a little coarser grained and exhibit a silky sheen on cleavage surfaces. Most are greyish or buff; some are black and contain abundant carbonaceous material and pyrite. In the field many of the phyllites are warped, dragged, or crushed, and such rocks generally contain numerous stringers of quartz and carbonate. Boudins of quartz may also occur in these rocks but are rarely as abundant as in the schists.

The slates generally occur in highly disturbed zones, particularly on the noses of small folds. In most occurrences the slaty cleavage is not well developed. Mineralogically, the slates are similar to the argillites and phyllites.

There is little evidence of residual clastic grains in any of the argillites, slates, and phyllites. Most of these rocks are also remarkably devoid of original sedimentary features such as grain gradation, crossbedding, concretions, etc. Some argillites and phyllites, however, exhibit fine laminations.

The varieties of schist found in the area include graphitic schist, quartz-sericite schist, and chlorite schist. All are highly foliated and locally exhibit wrinkle lineations, many small drag-folds, and innumerable crenulations. Most contain an abundance of stringers, irregular masses, and bulbous lenses (boudins) of white quartz in small fractures, between schist layers, in dragged and crenulated zones, and along bedding planes.

[1] Tables 1-8 in Appendix, Tables 9 and 10 in pocket.

The graphitic schists weather easily to a crumbly mass of small black schistose fragments and hence only rarely form good outcrops. In drill-cores and underground exposures they occur in beds ranging from a fraction of an inch to a few feet in thickness and are everywhere intercalated with phyllites, slates or thin and thick bedded quartzites. In hand specimens they are black or greyish black, and exhibit well-developed schist planes that possess a dull to bright sheen when wet.

Under the microscope the principal mineral constituents are dense opaque carbonaceous matter (graphite), quartz, sericite, carbonate minerals, feldspar, chlorite, isotropic colloidal material, and numerous metacrysts of pyrite. The accessory minerals, where identifiable, are tourmaline, rutile and zircon. The texture is schistose with interlaced laminae, strands, and wisps of graphite and sericite enclosing elongated micro-lenses containing quartz, carbonate minerals, sericite, and minor feldspar. The pyrite metacrysts, mostly cubes or distorted cubes, tend to be concentrated in the quartz micro-lenses or in the wavy and crumpled zones of the graphite laminae. In some sections microcrystalline pyrite is strung out along the graphitic laminae. Micro-boudins of quartz, many containing cubes of pyrite, are common in nearly all sections.

The quartz-sericite schists also weather easily and form few prominent outcrops. All occurrences exhibit a marked schistosity and where dragged, creunulated, or crushed contain numerous stringers, masses and boudins of white quartz. In hand specimens they are greenish or mottled greenish yellow and have a silvery lustre when wet.

In thin sections, the quartz-sericite schists are seen to consist essentially of quartz and sericite with subordinate amounts of carbonate minerals and leucoxene. The leucoxene consists of a felted aggregate of rutile needles and is invariably concentrated in swirling masses in the laminae of sericite. The main accessories are apatite, zircon, and tourmaline, and a few pyrite metacrysts are also present in most sections. The texture is schistose with laminae, shreds, and wisps of sericite and leucoxene enclosing irregular elongated lenses and bands composed principally of quartz with some shreds of sericite and a few cubes of pyrite.

Analyses of samples of argillite, slate, graphitic schist, and graphitic phyllite and quartz-sericite schist from the Keno Hill – Galena Hill area are given in Tables 2 and 3.

Quartzites

Quartzites occur throughout the sedimentary sequence, but commonly are concentrated in well-defined bands in the various formations. Units 8 (Keno Hill Quartzite) and 7 (Lower Schist division) contain the bulk of the quartzites with smaller amounts in units 3, 2 and 1. Both thick and thin bedded varieties are present. The thick bedded variety is particularly characteristic of the Keno Hill quartzite where beds ranging from 3 to 25 feet in thickness are present; thin bedded varieties occur in beds from an inch to a foot or more thick in many of the formations. Both varieties are interbedded with assemblages of schist, argillite, and phyllite. All thick bedded quartzites are well jointed and yield large blocks during weathering and frost action. The thin bedded varieties are generally contorted, warped, and locally drag-folded. Stringers, irregular veinlets, and small lenses of quartz are abundant in both varieties.

In hand specimens the fresh quartzites are white to grey to black, and have a gneissoid to schistose appearance. Some are very fine grained and resemble recrystallized cherts. On weathered surfaces most of the quartzites are buff, but others are grey or white.

Thin sections show that the quartzites consist essentially of quartz, with minor amounts of white mica (sericite) and locally, carbonate minerals. Calcareous varieties contain up to 30 per cent carbonate minerals. The black quartzites contain much carbonaceous material. Accessory minerals in all varieties include irregular patches and specks of leucoxene, tourmaline, zircon, apatite, and pyrite. The pyrite occurs mainly as cubes, distorted cubes, and crystal groups.

Most of the quartzites are fine grained, the cherty variety being very fine grained. Typical specimens have a gneissoid to schistose mosaic texture with the quartz grains showing a pronounced elongation. Most of the sericite flakes and wisps and the carbonaceous material occur at the border of the quartz grains, and both exhibit parallelism. Some varieties of white quartzite are banded, with relatively pure quartz laminae alternating with laminae of quartz and sericite or quartz, sericite, and carbonate minerals.

Some of the quartzites exhibit crossbedding, bedding laminations, and other original depositional features, and a few show faint overgrowths of silica on the quartz grains. These were undoubtedly originally fine grained orthoquartzites. Other quartzites, especially the nearly pure white cherty varieties as well as some fine grained grey varieties, exhibit no observable original clastic features but have a banding similar to certain recrystallized cherts. These appear to have originated mainly by the precipitation of silica from the water of the basin in which they were laid down.

Analyses of samples of various types of quartzites from the Keno Hill – Galena Hill area are given in Table 6.

Gritty quartzites constitute a large proportion of the Grit Division (unit 3) outlined by Green (1971). The description of these quartzites as paraphrased from Green is as follows:

The gritty quartzites occur in bands ranging from a few feet to several hundred feet thick, commonly separated by chloritic phyllite. The quartzites are massive and do not show any trace of original structure. The colour of fresh surfaces ranges from green to grey to very light buff, and the weathered surfaces from brown to almost white. Many fracture surfaces show dark manganese stain. The gritty quartzites are composed of coarse quartz grains, and less commonly, plagioclase feldspar in a matrix of fine grained quartz and sericite. The coarse grains are commonly 2 mm of less in diameter and may form from 10 to 80 per cent of the rock. Within an individual bed of gritty quartzite, the coarse grains are commonly about the same diameter but the size and the amount present may vary widely between beds. Some of the rocks are quartz-pebble conglomerates, with pebbles up to 10 mm in diameter forming much of the rock. The coarse grains are generally grey but some beds are characterized by distinctive pale blue and less commonly, black grains. The gritty quartzites commonly contain a small amount of iron-bearing carbonate which is frequently altered to limonite.

Viewed in thin section, the gritty quartzites consist of coarse grains of quartz and minor feldspar, both potash feldspar and plagioclase, in a matrix of fine grained quartz and sericite. The rocks have recrystallized to the extent that the quartz grains now have sutured boundaries, but in some the outlines of well rounded grains are still visible. Generally, the coarse quartz grains or pebbles are elongated and may be in the form of augen with the major axis as much as four times the minor axis. The gritty quartzites contain minor amounts of detrital heavy minerals.

Gritty quartzites also occur in some quantity in unit 2 and locally in unit 1.

Skarn

Skarns are developed in the vicinity of granitic masses at several places in the area, but they are generally so poorly exposed that an accurate idea of their nature is difficult to obtain. Indeed most of the remarks made here are based on information derived from a study of the skarn rocks in the contact zone southeast and east of the Dublin Gulch stock.

The skarns occur as irregular bodies, boudins, beds, and in discontinuous lenses that appear to have resulted mainly from the contact metamorphism of limestone. Some bodies may have been derived from calcareous schist and calcareous quartzite.

The rocks are green or greenish brown, coarse to medium grained, and mostly massive, dense, and hard. Some bodies show a faint banding and others are slightly schistose in appearance.

In thin sections the skarns exhibit a wide variety in quantity and types of minerals. The predominant minerals are diopside, fibrous amphibole, scapolite, quartz, carbonate minerals, plagioclase and epidote. In some bodies these minerals are coarse grained, and euhedral to subhedral. In others they are fine grained, highly intergrown, and irregular. Accessory minerals include sphene and apatite. Scheelite, as subhedral to anhedral crystals, occurs in many of the bodies. This mineral is generally diseminated through the groundmass but commonly occurs in the carbonate or quartz rich parts. Many of the scheelite crystals are poikilitic and enclose particles of carbonate, quartz, and other minerals. Pyrrhotite is abundant in a few beds and lenses of skarn. It occurs as ramifying patches and blebs in the fine grained groundmass. Where pyrrhotite is present in quantity, the lenses carry up to 0.10 ounce gold/ton.

Analyses of samples of typical skarn from the Keno Hill district are given in Table 8.

Greenstones

The greenstones are schistose, greyish green to dark green rocks that occur in conformable elongated lenses and sills, principally in the schistose formations and to a lesser extent in the quartzite formations. The greenstones weather differentially compared with the schists and quartzites and form prominent precipices and knobs. In most occurrences they are jointed and present a slabby appearance. In some bodies narrow shear zones, joints, and irregular fractures contain small lenses and masses of quartz, epidote, and calcite.

Investigations in the district have shown that ore shoots are localized in some vein faults where greenstone forms one or both walls, and that they terminate when the vein faults pass into schist. This feature makes an understanding of the geometry of the greenstone bodies imperative in attempting to assess the extent and continuity of the ore shoots.

Blackadar (1951) described the form of the greenstone bodies and discussed their origin. He suggested that the greenstone lenses are (1) remnants of a highly faulted series of pipe-like intrusions or (2) are due to shearing of tabular bodies with consequent formation of boudins; he favoured the first hypothesis. Green (1971) has also described these bodies in great detail and has suggested a number of possible origins for them. He noted that the greenstones were originally intrusive and were emplaced before and possibly during the development of foliation in the enclosing sedimentary rocks. The discontinuous nature of the greenstones in the more schistose rocks is considered to be due to the original shape of the intrusions rather than late deformation and the production of boudins. Green conceded, however, that the shape of many of the greenstone bodies may have been modified considerably by later deformation.

Field and underground investigations by Boyle (1965) in the Keno Hill – Galena Hill area showed that most greenstone bodies occur in the lower schist formation and in the schist members of the central (Keno Hill) quartzite formation. In the schist members the bodies are lens-like and discontinuous both along the strike and down the dip, but appear to follow certain definite horizons. Where greenstone occurs in quartzite, as on the northern slope of Sourdough Hill and on parts of Galena Hill, the bodies are fairly continuous and appear to be sills. In both schist and quartzite the greenstone lenses and sills are cut by numerous shear zones and are highly sheared at their contacts with both quartzite and schist. This suggests that the discontinuous lens-like bodies of greenstone along specific horizons were once sills that were fractured and sheared, both along and oblique to their contacts. The sills were thus disrupted into separate entities which were compressed and sheared into lens-like bodies (boudins). The details of the process by which boudins are formed have been outlined by Cloos (1946) and De Sitter (1958), who also gave several references. Once formed the boudins were further cut and displaced by an extensive series of bedding plane faults, low-angle thrust faults, shear zones, vein faults, and cross-faults. The fact that most of the greenstone bodies (competent rocks) in the schists (incompetent rocks) show well-developed boundinage strongly supports the boudinage hypothesis. In the quartzites where the competency of the two rocks (greenstone and quartzite) is nearly the same, surface and underground mapping suggest that the greenstone bodies are faulted sills.

In thin sections the greenstones present considerable variety both in mineral composition and texture. All are highly altered, and it is rare to find bodies with any original minerals. Remnants of original textures are, however, preserved in most bodies.

The principal minerals now present in the greenstones are hornblende, actinolite, saussurite (zoisite, epidote, albite sericite, carbonate), plagioclase (oligoclase to andesine), chlorite, stilpnomelane, biotite, white mica (sericite), leucoxene, and carbonate minerals. Quartz, potash feldspar, ilmenite, magnetite, limonite, and apatite are common minor constituents, and pyrite is present in some bodies. All these minerals are not necessarily found in any one greenstone mass.

The texture of most of the larger greenstone bodies is diabasic with amphibole in various degrees of alteration as large lath-like crystals. In a few sections pyroxene (augite?) is present. Most of the feldspars are so highly saussuritized that their precise original composition is impossible to decipher. Original magnetite and ilmenite crystals are rimmed or pervaded by leucoxene and limonite. Apatite occurs in small euhedral crystals. Chlorite is generally present, commonly in considerable amounts, and biotite, sericite, quartz, and carbonate minerals are found in some bodies. Some of the quartz may be primary, but most appears to have originated from alteration processes.

Smaller greenstone bodies and the borders of the large lenses have a schistose texture. In these the amphibole, saussurite, carbonates and other minerals are fine grained, highly intergrown and drawn out into bands, streaks, and elongated lenses and trains.

A few greenstone bodies have a pseudo-porphyritic texture due to the presence of large, irregular, commonly somewhat angular, masses of leucoxene and/or saussurite set in a fine grained, felted groundmass of amphibole, feldspar, chlorite, carbonates, and saussurite.

Analyses of typical samples of greenstone from the Keno Hill – Galena Hill area are given in Table 4.

Granitic rocks

The granitic masses appear to be intrusive into the various formations, and, as mentioned previously, have produced a certain degree of metamorphism in the sediments. The most characteristic of the metasediments are the skarn rocks.

The granitic bodies range in composition from granodiorite and quartz monzonite to quartz diorite. Most are medium to fine grained and equigranular; a few have porphyritic and aplitic phases. Associated pegmatite bodies occur locally.

The northwest contact zone of the granitic body between Dublin Gulch and Lynx Creek is marked by numerous apophyses and granite dykes. In places these are cut by veins containing arsenopyrite, pyrite, and gold. Within the granite mass proper, and near its contacts, small stockworks of quartz veins carrying crystals of scheelite, and locally wolframite, occur sporadically. These and other occurrences are described in greater detail below.

The granitic rocks are grey to dark grey on fresh surfaces and commonly weather to a light or dark grey, or buff. The Dublin Gulch bodies are deeply weathered and decomposed in places to depths of 10 feet or more.

The principal mineral constituents of the granite masses are quartz, plagioclase (oligoclase to andesine), potash feldspar, biotite, muscovite, and hornblende. The plagioclase may be zoned, and the cores are commonly altered to saussurite and sericite. The biotite generally shows an alteration to chlorite, and in some thin sections the hornblende is seen to be similarly affected. Pyroxene is common in some of the Dublin Gulch bodies and is generally accompanied by some carbonate. The common accessory minerals in most of the granitic bodies are sphene, apatite, epidote, allanite, pyrite, and magnetite.

Analyses of composite samples of granitic rocks from the Keno Hill district are given in Table 7.

Quartz-feldspar porphyry

The quartz-feldspar porphyries occur as poorly exposed sills on the north and northeastern slopes of Keno Hill, on the south and western slopes of Galena Hill, and on the southern slope of Mount Haldane, as well as at other scattered points throughout the district. They cut the greenstones and are, therefore, younger than these rocks. In a few places the porphyries are cut and offset by the siderite veins, and hence were completely consolidated bodies before the veins were formed. The age relationships of the porphyries and various granitic bodies are unknown.

Most of the porphyries are light coloured rocks; some are grey and others are speckled with plates of biotite. On weathered surfaces they are buff.

Thin sections reveal a well-developed porphyritic texture in most specimens. The phenocrysts of quartz, feldspar, biotite, and chlorite are set in a fine to medium grained groundmass of quartz, plagioclase, myrmekite, muscovite, and chlorite. Accessory minerals include apatite, sphene, epidote, carbonate, magnetite, hematite, zircon and pyrite. The quartz crystals are generally clear and many are fractured. The feldspar crystals are zoned with calcic cores (andesine) and sodic rims (albite-oligoclase). The cores are commonly saussuritized. The biotite usually contains oriented rutile needles or patches of leucoxene or sphene and is more or less altered to chlorite. Pyrite is relatively abundant in some bodies.

A few of the bodies on Galena Hill are fine grained and equigranular with only a few random phenocrysts of quartz. They contains much sericite, myrmekite, some carbonate, quartz, altered feldspar, leucoxene, epidote, and zoisite and appear to represent altered fine grained granites or rhyolites.

An analysis of quartz-feldspar-porphyry from the Keno Hill district is given in Table 7.

Lamprophyre

The lamprophyres are light to dark brownish grey rocks that occur as a few discontinuous sills and dykes in the schist and quartzite formations. Their relationships to the granitic rocks and greenstone bodies are unknown as they are not found near or cutting one another. They are cut and altered by the siderite-sphalerite-galena lodes and hence are older than these bodies.

Most of the lamprophyres are the porphyritic biotite variety. The biotite, now highly altered to chlorite containing remarkable gridworks of rutile needles, is set in a fine to medium grained matrix composed essentially of carbonate minerals, chlorite, quartz, and white mica. The principal accessory minerals in the matrix are pyrrhotite, pyrite, marcasite, apatite, and rutile. Some of the lamprophyres contain rounded fragments of quartzite.

An analysis of a composite sample of biotite-lamprophyre from Galena Hill is given in Table 5.

MINERAL DEPOSITS AND OCCURRENCES

Six types of mineral deposits and occurrences are represented in the Keno Hill district: (1) cassiterite-tourmaline impregnation zones in the Dublin Gulch area, (2) scheelite-bearing skarn lenses and zones near the contact of granitic rocks in the Dublin Gulch area, (3) quartz-wolframite and quartz-scheelite stringers in granites and sediments in the Dublin Gulch area, (4) quartz-pyrite-arsenopyrite-gold lenses in vein faults, (5) siderite-galena-sphalerite-freibergite-pyrite-chalcopyrite lodes in vein faults, and (6) gold and scheelite placers. Paragenetically the tin and tungsten deposits (1-3) are the oldest and were followed consecutively by the gold-quartz lenses and the siderite lodes (4-5). The siderite lodes and gold placers constitute the economic deposits of the area, yielding silver, lead, zinc, cadmium, and gold.

The most favourable host rocks for the occurrence of the lodes and veins are thick bedded quartzites and greenstones. Structurally, the principal lodes are localized in three sites: (1) at the junction of two or more vein faults, (2) at the junction of a vein fault and subsidiary fracture, and (3) in quartzites or greenstones at or near the sites where vein faults pass upward from these rocks into schists or thin bedded quartzites. In physiochemical terms these three sites were dilatant zones into which the constituents of the ore and gangue minerals were drawn.

The cassiterite impregnation zones have a vein-like nature and consist essentially of highly brecciated rock impregnated with microscopic green tourmaline, quartz, microcrystalline cassiterite, and chlorite. Small crystals and masses of pyrite are common and locally some chalcopyrite is present. The principal elements enriched in the deposits include Si, Fe, Mg, Sn, W, Nb, Cu, Sc, As, Bi, B, and S.

The quartz-wolframite and quartz-scheelite veins and stringers contain enrichments of Si, W, Sn, Fe, Mn, and Sc. The scheelite-bearing skarns are composed essentially of diopside, fibrous amphibole, scapolite, quartz, carbonate minerals, plagioclase, epidote, sphene, apatite, and scheelite.

The scheelite occurs as subhedral to anhedral crystals and grains disseminated through a groundmass of the above minerals and is commonly concentrated in the carbonate- or quartz-rich parts of the skarn. Excluding gangue elements those principally enriched include W, Ca, Ti, and Mo.

The early quartz-pyrite-arsenopyrite veins contain essentially milky quartz, pyrite, arsenopyrite, boulangerite, jamesonite, bournonite, and minor amounts of galena and sphalerite. Most of these veins are slightly auriferous and argentiferous. The principal elements concentrated are Si, S, Fe, As, Sb, Pb, Cu, Zn, Au, and Ag.

The siderite lodes are composed essentially of siderite, quartz, sphalerite, galena, pyrite, chalcopyrite, and freibergite. Less common are barite, pyrrhotite, boulangerite, jamesonite, stephanite, and polybasite. Ag, Pb, Zn, and Cd are greatly enriched in these lodes; other minor to major enrichments include Fe, Mn, Ca, Mg, Si, Cu, As, Sb, Ba, CO_2, B, and S.

The siderite and quartz lodes are oxidized to depths ranging from 20 to 600 feet. Much of the oxidation appears to have taken place in late Tertiary time, but oxidation processes are still active in some deposits. In the oxidized zones the primary pyrite and siderite are altered to limonite and wad; arsenopyrite to limonite and scorodite; sphalerite and chalcopyrite to limonite, azurite, and malachite; and freibergite, boulangerite, and jamesonite to bindheimite, beudantite, malachite, native silver, and other secondary minerals. Oxidation of the siderite lodes has led to a marked enrichment of lead and silver and a strong depletion of zinc and cadmium.

In some siderite lodes the oxidation zones grade through a zone of reduction ranging from 2 to 20 feet in depth; in others the oxidation zones grade imperceptibly into the hypogene zones. The principal economic minerals formed in the zones of reduction are pyrargyrite and native silver.

Further details concerning the various types of mineral deposits in the Keno Hill district may be found in Boyle (1965) and Green (1971, 1972).

LIMONITE PRECIPITATES

Iron- and manganese-bearing springs are widespread throughout the Keno Hill district. These springs are marked by an abundance of iron and manganese (limonite and wad) precipitates at their orifices and on rocks and gravel in the stream bottoms. In some streams characteristic limonitic conglomerates are developed; these consist essentially of rock fragments, sand, gravel, soil, and organic fragments cemented by limonite and/or wad. The metals in the limonitic precipitates and conglomerates are derived mainly from the groundwater system which pervades the rocks of the district below the permafrost zone. The geochemistry of these groundwaters is dealt with in detail by Gleeson and Boyle (1976) and the geochemistry of the limonite and wad precipitates is discussed by Boyle (1965). In the present paper no distinction between iron and manganese precipitates is made since in nearly all cases both are inextricably intermixed. All, including the limonitic conglomerates, are referred to simply as limonite precipitates.

Iron springs in an area should be regarded by prospectors as favourable indicators of mineralization. It need hardly by pointed out that in many parts of the world iron springs and limonitic precipitates carrying copper, zinc, and other metals have drawn attention to an area in which deposits were later discovered.

FIELD AND LABORATORY PROCEDURE

While sampling the drainage systems of the area the crews, where convenient, obtained rock samples from nearby outcrops and precipitates from springs. A total of 381 samples were collected. The rock samples were as fresh as could be obtained from the outcrops.

The samples were crushed and pulverized to minus 100 mesh and analyzed for Cu, Pb, Zn, Ni, Co, As, Sb, Mo, W, U, Sn, Ag, F, and Ba. The extraction techniques for Cu, Pb, Zn, Ni,Co, and Sb involved fusion with potassium bisulphate; for As the extraction consisted of fusion with potassium hydroxide, and for Mo and W fusion was carried out using a mixture of sodium carbonate, potassium nitrate, and sodium chloride. Cu, Pb, Zn (Gilbert, 1959), Ni (Stanton and Coope, 1958), Co (Almond, 1953), Sb (Stanton and McDonald, 1962), and W and Mo (North, 1956) were determined colorimetrically. As was determined by the Gutzeit method (Lynch and Mikailov, 1963). Ag was determined by atomic absorption spectrophotometry after digestion with hot solutions of concentration HNO_3 and HCl. F (fluoride) was analyzed using a specific ion electrode technique after fusion of the sample with Na_2CO_3 and KNO_3. Sn and Ba were analyzed by X-ray fluorescence, and a delayed neutron activation technique was used for the determination of U (Boulanger et al., 1975).

Detection limits for each element were as follows:

Cu	– 4 ppm	Mo	– 1 ppm
Pb	– 5 ppm	W	– 4 ppm
Zn	– 10 ppm	U	– 0.1 ppm
Ni	– 5 ppm	Sn	– 1 ppm
Co	– 5 ppm	Ag	– 0.1 ppm
As	– 2 ppm	F	– 20 ppm
Sb	– 1 ppm	Ba	– 10 ppm

Values below the detection limit for Cu, Pb, Zn, Ni, Co, As, Sb, Mo, and W have been recorded as half of the detection limit. For Sn and Ag the notation ND (not detected) has been used to indicate values below the detection limits.

RESULTS OF THE INVESTIGATION

All analytical results are tabulated in Table 9. Sample locations are shown on Figure 1.

For the purpose of discussion the analytical values have been grouped according to rock type; a summary showing the range and median values for each of the 14 rock groups is presented in Table 10.

Limonite precipitates

The metal content of the limonite precipitates varies widely. The most abundant metals in the precipitates are: Zn, Ni, Co, As, Sb, Mo, F, and Ba.

Copper:

1. High copper contents in excess of 40 ppm occur in 17 of the 60 limonite precipitates. The highest values (160 and 180 ppm) are present in samples 242 and 243b from Parent Creek. The former is also enriched in As (44 ppm), Sb (9 ppm), and Ag (1.8 ppm).

2. Another significant high copper value (140 ppm) is present in sample 224 from a precipitate in Thunder Gulch; Ni (35 ppm), As (56 ppm), Sb (14 ppm), Mo (4 ppm), and U (3.6 ppm) are also enriched in this sample. The rocks underlying the area are quartzites (Keno Hill Quartzite) containing sills of greenstone and cut by a northwest trending fault. The high contents of Mo and U suggest the presence of granitic rocks.

3. Samples 83c and 88b, north of McQuesten Lake, contain 120 and 116 ppm Cu respectively. Zn (240 and 600 ppm respectively) and Ba (1678 and 3333 ppm respectively) are also above normal and sample 83c has 90 ppm As. Geologically these two sites are underlain by phyllitic rocks of the Lower Schist division.

4. Copper enrichments (64-80 ppm) are present in samples 75b, 76a, and 79, also north of McQuesten Lake. High contents of Pb (45-65 ppm), Zn (210-1300 ppm), Ni (30-50 ppm), As (10-14 ppm), and Ba (1019-1658 ppm) are also present in limonite precipitates from this area. In addition, one sample (76a) contains above normal contents of Mo (7 ppm) and F (6650 ppm) and a white precipitate (sample 78), identified as alunite, contained 1700 ppm Cu, 45 ppm Pb, 190 ppm Zn, 160 ppm Ni, 25 ppm Co, 14, ppm As, and 4.2 ppm U. Phyllitic rocks of the Lower Schist division and sills of greenstone underlie the above sample sites.

Lead:

1. The background for lead in the limonite precipitates is less than the detection limit (5 ppm), and there are only 10 samples containing greater than 10 ppm. The highest value (120 ppm) is present in sample 233 and is accompanied by an abnormally high Sb content (14 ppm). This sample came from the head of a tributary of Granite Creek which is underlain by massive quartzite of the Keno Hill Quartzite. Follow-up work by United Keno Hill Mines on stream sediment anomalies located by the Geological Survey resulted in the discovery of Pb-Zn-Ag-Au veins in this area (Findlay 1969).

2. Sample 278 in the eastern part of the district contains 50 ppm Pb in addition to high contents of Cu (44 ppm), Zn (220 ppm), As (20 ppm), U (11.9 ppm), Sn (11 ppm), F (1000 ppm), and Ba (5121 ppm). The Keno Hill Quartzite underlies the area; however the high values in U, Sn and F suggest that granitic intrusions may be present locally. The Mayo Lake granodiorite batholith occurs some 5 miles to the southwest.

3. The high lead contents (45-65 ppm) in samples 75, 76, 78 and 79 have been commented on above.

Zinc:

1. Zinc is abundant in the limonite precipitates, 19 of the 60 samples analyzed contained in excess of 300 ppm Zn. The maximum value (1800 ppm) is present in sample 75a, 7 miles north of McQuesten Lake and is accompanied by high contents of Ni (195 ppm), Co (180 ppm), and As (36 ppm). Phyllites of the Lower Schist division and greenstone sills underlie the area. The high Ni-Co contents suggest that the source of the metals may be the greenstones.

2. Contents in excess of 900 ppm Zn occur in the eastern part of the area in samples 14, 15a, and 15b. Associated with the latter samples are high contents of As (48 ppm), Sb (24 ppm), and Mo (13 ppm). The source of the metals may be the graphitic phyllites which predominate in this area.

3. The zinc content of sample 46 near Scougale Lakes is 1700 ppm and associated with it is 150 ppm Ni, 14 ppm Mo, and 7.9 ppm U. Phyllite of the Grit division underlies the sample site.

4. Sample 92, east-southeast of McQuesten Lake, contains 950 ppm Zn, 375 ppm Ni, 190 ppm Co, 65 ppm As, and 1558 ppm Ba. Greenstone sills and phyllitic rocks underlie this part of the area; the high Ni-Co contents indicate that the spring which gives rise to the limonite precipitate probable derives its metal from the greenstones.

5. A limonite precipitate sample (115) at the north end of Hanson Lakes contains 650 ppm Zn and 1330 ppm F. The area is drift covered, the nearest outcrops east of the sample site consist of phyllite of the Lower Schist division.

6. High Zn (240-950 ppm), Ni (40-90 ppm), and As (14-220 ppm) contents are present in samples 117, 118, and 119a in the northwest part of the district. Massive quartzites of the Keno Hill Quartzite and gabbro sills occur in this area.

7. Sample 230, 9.5 miles east of Keno Hill, contains 900 ppm Zn and 90 ppm Ni, 48 ppm As, 12 ppm Mo, 15.6 ppm U, and 1945 ppm Ba. Quartzite with greenstone sills comprise the bedrock in this area. Mineralization in the greenstones may account for the high Zn, Ni, and As contents; however, the high Mo-U values also suggest an affiliation with granitic rocks. The Mayo Lake granodiorite batholith outcrops 2.5 miles east of this sample point.

8. Zinc enrichments (560 and 480 ppm) also occur in samples 280 and 292 in the southeast sector of the area. Both of these samples are high in Ni (220 and 165 ppm) which suggests that the mineralization related to these precipitates is probably associated with the greenstones.

Nickel:

1. Eighteen of the limonite precipitates contain in excess of 40 ppm Ni. Most of the samples containing high Ni contents are from areas where mafic sills (greenstones) occur, and the nickel is probably derived from mineralization in these greenstones.

2. Sample 152, west of Potato Hills, contains 95 ppm Ni and 240 ppm Zn, 95 ppm Co, 104 ppm As, 30 ppm Sb, and 4.1 ppm U. Lead-arsenic-antimony-bearing veins occur in the Dublin Gulch and Secret Creek areas south of this anomaly, and hence the high contents in Zn, As, and Sb may indicate that similar mineralization may be near the sample site.

3. Samples 207, 209, and 211 from the Beauvette Hill area, northeast of Keno Hill contain above normal amounts of Ni (40-90 ppm). Precipitate from sample site 211 is also abnormally high in As (24 ppm), U (4.1 ppm), Ag (1.2 ppm), F (1270 ppm), and Ba (1851 ppm). Lower Schist phyllites and greenstone sills outcrop in this area.

Cobalt:

Most of the cobalt values are less than the detection limit. There are however, four values in excess of 95 ppm (samples 75a, 92, 119b, and 152); all of these are associated with Zn and Ni anomalies.

Arsenic:

1. Abnormally high concentrations of arsenic are common in the limonite precipitates being frequently associated with high values in one or more metals such as Zn, Ni, and Sb. Those associated with Zn and Ni have been mentioned above and are not discussed further.

2. The highest As value (1800 ppm) is present in sample 174 (6 miles west of Hanson Lakes); two nearby samples, 176a and 176b, also contain above normal contents of As (65 and 36 ppm). Above average values in Mo of 5 ppm (sample 174) and 3 ppm (sample 176b), and an abnormally high U content (5.7 ppm) in the latter sample indicates that the source of these metals may be the nearby granitic intrusions.

3. Sample 189a, southwest of Galena Hill, contains 40 ppm As and 4 ppm Sb, 7 ppm Mo, 10 ppm Sn, and 9216 ppm Ba. The area is underlain by schists which are cut by a northwest trending fault.

4. A series of high As values are present in samples (148a, c, and f) from a large limonite precipitate deposit in a tributary of Christie Creek in the western part of the area. Sample 148c is also high in Zn (360 ppm), Ni (65 ppm), and Ag (1.8 ppm). The rock from which the spring at this site is issuing is a massive quartzite. In the pond formed around the spring, samples of yellow precipitate (148d) and green precipitate (148e) were taken. The former contained 150 ppm As and 8 ppm Sb; the latter 500 ppm As, 24 ppm Sb, and 4 ppm Mo.

5. Sample 17 in the eastern part of the area contains 60 ppm As in addition to 44 ppm Cu, 18 ppm Mo, and 1340 ppm F. These elements may derive from the enclosing phyllites which in places are pyritiferous and graphitic.

Antimony:

About 85 per cent of the Sb values are less than 2 ppm, and there are 5 samples in excess of 9 ppm Sb. All of these enrichments have been discussed above relative to other anomalous metals.

Molybdenum:

Molybdenum contents in excess of 13 ppm occur in samples 15b, 17, 46, and 88a. Geologically all these locations are underlain by phyllite, and the source of the Mo may be the graphitic phases of the phyllite.

Tungsten:

Tungsten contents in excess of the detection limit were not found in the limonite precipitates.

Uranium:

The median value for U in the limonite precipitates is 2 ppm. Most of the samples having U in excess of 4 ppm have been discussed above. Others with high levels include sample 71d (4.7 ppm) and sample 104 (7.1 ppm); quartzite is present at both locations and at the former site it contains 6.7 ppm U.

Tin:

There are 2 samples with contents of 10 ppm Sn or more (189a, 278). Both of these are high in Ba (9216 and 5121 ppm) and F (970 and 1000 ppm). Sample 278 is also high in U (11.9 ppm) and Pb (50 ppm).

Silver:

Most of the samples contain non-detectable amounts of Ag. There are several samples with contents in excess of 1 ppm, and these have been discussed above in relation to other metals.

Fluorine:

The fluorine content of the limonite precipitates varies from 140 to 6650 ppm with a median value of 550 ppm. Values in excess of 1000 ppm occur in samples 14, 15b, 17, 58, 64, 76a, 104, 110, 115, 176a, 207, 211, and 278. These samples are also high in one or more of the metals discussed above. The source of fluorine is apparently related to the phyllites and granitic rocks.

Barium:

Seventeen samples have contents in excess of 1500 ppm Ba. Most of these samples are associated with enrichments in other metals that have been described above. The maximum value of barium is 13392 ppm in sample 135. This sample is in an area underlain by Ordovician-Silurian slates in the northwest corner of the study area. Heavy mineral samples from the alluvium in this area are also high in Ba (Gleeson and Boyle, in press). The source of the Ba is probably the slates of the Eagle Creek syncline.

The other significant Ba enrichments have been discussed above in relation to other metals.

Quartz veins

Quartz veins are common throughout the district, and some are associated with a variety of enriched metal contents.

Quartz veins in the Dublin Gulch area (samples 157a, 158b, 162, 167) contain high contents of Pb, Zn, As, Sb, Mo, W, U, and Ag. This reflects the type of mineralization known to be associated with these veins.

In the eastern part of the district, enrichments occur in quartz vein samples 5 and 166 in one or more of the following elements: Cu, Zn, Ni, As, U, and Ba. Sample 63d, near Mt. Patterson, is high in Zn (380 ppm), Ni (105 ppm), Co (40 ppm), and As (48 ppm). Sample 186b, from a quartz vein on North Star Creek on Mount Haldane is enriched in Pb (45 ppm), Zn (340 ppm), Ni (45 ppm), As (70 ppm), and Sn (2115 ppm).

Five quartz veins were sampled from Thunder Gulch, the most interesting results being in samples 217 and 218. In the former, Cu (140 ppm) and W (240 ppm) are high and in the latter Pb (115 ppm), As (36 ppm), and Ag (6.1 ppm) are enriched. Quartz veins are probably the source of the placer gold which has been mined near the mouth of Thunder Gulch.

A quartz vein (sample 235) from an occurrence on Duncan Creek south of Keno Hill contains 130 ppm Cu, 750 ppm Pb, 800 ppm As, 1980 ppm Sn, and 3.1 ppm Ag. Heavy mineral samples from Duncan Creek (Gleeson and Boyle, in press) are enriched in tin, the provenance of the metal probably being quartz veins.

Skarn

Two samples of skarn were analyzed from the region. One (sample 173) came from a site east of Dublin Gulch that is known to contain scheelite. This sample gave 40 ppm Pb, 12 ppm Mo, and 4600 ppm W. The second sample (1a) came from a dolomite band in the eastern part of the district; it contained 35 ppm Pb, 12 ppm Mo, 768 ppm W, and 150 600 ppm F. Additional field work is required to determine the significance of these results.

Porphyry

Five samples of quartz porphyry and quartz-feldspar porphyry were analyzed from the district, the most important results from each of the samples being:

Sample 159a – 16 ppm Mo, 16 ppm W, 1978 ppm Ba

159 – 150 ppm As, 9 ppm Sb

184 – 560 ppm As, 5 ppm U, 9 ppm Sn, 1699 ppm Ba

186c – 520 ppm Zn, 4.6 ppm U, 13 ppm Sn, 3914 ppm Ba

253b – 700 ppm Cu

The first two samples are from the Dublin Gulch area where Mo, W, As, and Sb mineralization is known. The next two are from North Star Creek, where sample 186c came from the vicinity of a known Pb-Zn-Ag showing. The last sample (253b) (north of Mayo Lake) is interesting because of its high copper content, and because a nearby quartzite sample (252) contains 400 ppm Cu. Additional field work should be carried out to determine the significance of these results.

Granite

All four granite samples analyzed came from the Dublin Gulch area. The results show that uranium tends to be relatively high (4.1-7.6 ppm) in these rocks. Three samples (156, 157b, and 158a) contain high contents of W (20-112 ppm). In places, as in sample 158a, Mo (16 ppm), F (1500 ppm), and Ba (2168 ppm) are high; in sample 157b, Pb (140 ppm), As (16 ppm), and Sb (6 ppm) are above normal.

Granodiorite

The granodiorite tends to be relatively high in U (3-12.7 ppm), F (210-2500 ppm), and Ba (1076-3442 ppm), and Pb enrichments (25-50 ppm) are present in samples 168, 185, 297, and 299. Two granodiorite samples (161, 164) from the Dublin Gulch area are high in As (16 and 60 ppm), and one (161) contains 36 ppm W. Relative to the porphyries and granite the As and Sn contents of granodiorite are significantly lower; the former rock types have median values of 6 and 4 ppm for As and 5 and 7 ppm for Sn respectively, and the medians of the latter are 1 ppm As and 2 ppm Sn (Table 10). Conversely, F is generally higher in the granodiorite (median 950 ppm) than in either the granite (median 500 ppm) or porphyries (median 220 ppm).

Quartz-sericite schist

This rock type is particularly abundant in the Upper Schist division. In this division little distinguishes the rock except its relatively high median values for Zn (70 ppm) and Sn (5 ppm).

The highest metal values (145 ppm Pb, 2200 ppm Zn, 40 ppm Ni, 10 ppm Co, 560 ppm As, 1100 ppm Sb, and 10 ppm Sn) in quartz-sericite schist come from sample 146a taken in the vicinity of the Lime Creek Pb-Sb occurrence. Other samples containing above normal amounts of metals are as follows:

Sample 147 – 32 ppm Cu, 70 ppm Ni, 10 ppm Co, 12 ppm As, 5 ppm Mo, 1430 ppm F

139 – 24 ppm Cu, 35 ppm Ni, 15 ppm Co, 1050 ppm F, 1407 ppm Ba

151 – 45 ppm Ni, 25 ppm Co, 9 ppm Sn, 1239 ppm Ba

163 – 20 ppm Co, 28 ppm As

180 – 40 ppm Pb, 60 ppm Ni, 40 ppm Co, 4 ppm Sb, 1400 ppm F, 2000 ppm Ba

188 – 36 ppm As, 7 ppm Sn, 2818 ppm Ba

191 – 30 ppm Pb, 15 ppm Mo

244 – 90 ppm Pb, 1113 ppm Ba

250 – 4.6 ppm U, 7 ppm Sn, 1070 ppm F, 1706 ppm Ba

262 – 6588 ppm Ba

287 – 160 ppm Zn, 240 ppm Ni, 10 ppm Co, 7 ppm Sn, 1634 ppm Ba

309 – 8 ppm Sn

316 – 4 ppm U, 1721 ppm Ba

Additional field work is required to determine the economic significance of these results.

Quartzite

1. Although quartzite is the most common host rock for the Pb-Zn-Ag deposits of the area, the trace element content of the 94 samples analyzed is generally quite low. Boyle (1965) has shown that marked increases in metal content occur only in the immediate vicinity of the veins. This is evident from the results of samples 186a, d, and f which were taken from the vicinity of a small Pb-Zn-Ag vein on Mount Haldane.

2. Cu, Zn, Ni, Co, U, and Ba are enriched in a group of quartzite samples (51, 52 and 54) north of Mt. Patterson.

3. A piece of sericitic quartzite float (sample 179) from Secret Creek in the western sector of the area contains 140 ppm Pb, 320 ppm Zn, and 30 ppm Sb. This float sample probably came from the Pb-As-Sb veins which are known upstream from the sample site.

4. Interesting contents of Zn (160 ppm), Ni (130 ppm), and U (5.6 ppm) occur in sample 228, 9 miles east of Keno Hill. A sample of gossan (sample 229) over a fracture zone in the quartzite at this site contains 1100 ppm Pb, 130 ppm Zn, 4 ppm Sb, 9 ppm Sn, and 4.1 ppm Ag.

5. A sample of quartzite (sample 231), about 2 miles east of Mount Hinton, contains 75 ppm Pb; Pb-Ag-Au veins have been found in this area by United Keno Hill Mines, Ltd.

6. Sample 252 contains 400 ppm Cu. This quartzite sample was taken from a site near porphyry sample 253b which contains 700 ppm Cu.

7. Sample 267, which comes from the vicinity of a Pb-Ag occurrence on Cobalt Hill, contains 120 ppm Pb, 40 ppm Ni, 36 ppm As, 10 ppm Sb, and 2143 ppm Ba. The quartzites from this area (samples 267, 275, 282, 284, 285) appear to be relatively enriched in barium, the content varying from 1078 to 9461 ppm.

8. It is evident that quartzites in the vicinity of the veins are enriched in the metals that constitute the veins. Additional field work is necessary to assist in interpreting the economic significance of the metal-rich quartzite samples noted above.

Phyllite

1. Phyllite was the second most common rock type sampled, a total of 76 samples being taken, mostly from the Lower Schist division. There is a wide range of trace elements in the phyllites, and median values for Zn (60 ppm), Ni (20 ppm), Sn (5 ppm), F (550 ppm), and Ba (1200 ppm) are relatively high.

2. Phyllites (samples 268b, 268c) in the vicinity of the Cobalt Hill Pb-Ag occurrence exhibit marked enrichments in Pb (65-1800 ppm), Zn (220 ppm), Ni (55 ppm), and As (56 ppm). Other phyllite samples exhibiting an enrichment in Pb include:

Sample 36 – 180 ppm Cu, 45 ppm Pb, 20 ppm As

91 – 60 ppm Pb, 150 ppm Zn, 50 ppm Ni, 26 ppm As, 8 ppm Sn, 1050 ppm F.

3. Maximum Zn values were found in phyllite samples from the Mt. Patterson area, they include:

Sample 63b – 360 ppm Zn, 95 ppm Ni, 25 ppm Co, 8 ppm As, 4.4 ppm U

53b – 230 ppm Zn, 88 ppm Cu, 55 ppm Ni, 20 ppm Co, 14 ppm As

4. Ni is relatively abundant in the phyllites, 23 samples containing in excess of 40 ppm. As contents greater than 12 ppm frequently accompany the Ni enrichments.

5. The background for Mo in the phyllites is less than the detection limit (1 ppm). Maximum contents are associated with graphitic phyllite e.g. sample 251 – 20 ppm Mo, and sample 3a – 17 ppm Mo.

6. There is an enrichment of U in the phyllites; the median value in 2.5 ppm, but contents in excess of 4 ppm occur in 13 of the 75 samples analyzed. The highest content (13.5 ppm) is present in sample 3a from the eastern part of the area, which is also high in Ni (80 ppm), Mo (17 ppm), and Ba (6757 ppm).

7. The background for Sn (5 ppm) in the phyllites is comparable to that in the granitic rocks. Samples containing greater than 12 ppm Sn include samples 283 (24 ppm), 194 (17 ppm) and 140 (12 ppm).

8. The background for F in the phyllites is relatively high (750 ppm); maximum values of 1500 ppm, 1270 ppm, 1100 ppm, and 1216 ppm are present in samples 2, 59, 101, and 283 respectively; Ba is also high in all these samples.

9. There is a definite enrichment of Ba in the phyllitic rocks. The median value is 1200 ppm and 24 of the samples contain more than 2500 ppm. Samples in the southwest corner of the district appear to be particularly high in Ba; they include samples 193 (5870 ppm), 194 (5967 ppm), 195 (6478 ppm), 323 (14 345 ppm), and 327 (8892 ppm). These phyllites were initially marine shales, and many of the trace elements found in them were probably incorporated at the time of their deposition. Bedded barite deposits in Devonian-Ordovician shales are common throughout the Selwyn Basin where they are frequently associated with Pb-Zn deposits. Similar barite deposits may be present in the phyllites of the Keno Hill district.

Greenstones

1. Geochemically, the greenstones are marked by high median values in Cu (60 ppm), Zn (110 ppm), Ni (70 ppm), and Co (10 ppm).

2. Maximum metal contents (2600 ppm Cu, 65 ppm Pb, 320 ppm Zn, 30 ppm Ni, 20 ppm Co, 1.2 ppm Ag, and 3087 ppm Ba) occur in sample 96b near Mount Cameron. At this sample site the greenstone is cut by a stringer of quartz which contains 1 to 2 per cent chalcopyrite and 2 per cent pyrite.

3. A sample of greenstone (221b), from Thunder Gulch contains about 1 per cent disseminated chalcopyrite and 2 per cent pyrite-pyrrhotite. This sample analyzed 850 ppm Cu, 170 ppm Zn, 90 ppm Ni, 60 ppm Co, and 1 ppm Ag.

4. Several other samples (21, 63a, 177b) contain in excess of 300 ppm Cu. In addition samples 23, 112, 220, and 307 have greater than 125 ppm Ni, and samples 49, 62, 63a, and 259 have greater than 22 ppm As. Samples 63c, 106, and 155 contain more than 4.7 ppm U, and sample 132 has 11 ppm Sn. Ba in excess of 2500 ppm is present in samples 22b, 23, 106, and 213.

Limestone

The trace element content of the limestones is low. Only samples 3b (230 ppm Zn, 50 ppm Ni, 1383 ppm Ba) and 89 (35 ppm Pb, 130 ppm Zn, 55 ppm Ni, 6 ppm Mo, 1135 ppm Ba) contain significant quantities of metals.

Dolomite

Of the 4 dolomite samples analyzed, 2 of them (33 and 34) are high in Cu, and one (35) contains 28 ppm As. All of these samples come from the Ordovician-Silurian massive white dolomites in the northeast part of the district.

Slate

Five samples of Ordovician-Silurian slate were analyzed, and the results show some enrichment in Cu (median-20 ppm), Ni (median-45 ppm), F (median-720 ppm), and Ba (median-5500 ppm). All of the slate samples came from the northwest part of the district and form part of the Eagle Creek syncline. These results indicate that the slates are probably the source of the Ba found in the heavy mineral concentrates from this area (Gleeson and Boyle, in press). Bedded barite deposits similar to those found in the Selwyn Basin (Blusson, 1976) may occur in the slates of the Eagle Creek Syncline.

Grit

Only 2 grit samples were analyzed. Above average contents of Cu (52 ppm), Ni (150 ppm), and Ba (697 ppm) occur in sample 142.

SUMMARY AND CONCLUSIONS

Geochemical analysis for Cu, Pb, Zn, Ni, Co, As, Sb, Mo, W, U, Sn, Ag, F, and Ba are reported for 381 rock samples obtained from an area of some 1900 square miles centred on Keno Hill, Yukon Territory. The results show a wide range of metal values for the various rock types. Limonite precipitates in particular vary greatly in their metal content, enrichments in Zn, Cu, Pb, Ni, As, Sb, Mo, and F being marked in a number of samples. The trace element content of the limonite precipitates commonly reflects the type of mineralization present in the rocks from which their parent springs issue.

The highest median values in the quartz veins are those for Cu, Pb, As, and Sn. Two of the quartz veins (samples 186b and 235) containing Pb-Zn-Ag-As mineralization are enriched in Sn (2115 and 1980 ppm respectively).

Both the skarn samples that were analyzed contained significant amounts of W. Sample 1a (768 ppm W) is also high in F (150 600 ppm), a feature which suggests that additional work should be done in the area.

The granitic rocks have relatively high median values for Pb, As, W, U, Sn, F, and Ba. A sample of porphyry (253b) in the area north of the west end of Mayo Lake contains 700 ppm Cu. Additional work is warranted in this area.

The quartz-sericite schist samples have relatively high median values for Zn (70 ppm), Sn (5 ppm), and Ba (750 ppm). Quartz-sericite schist from sample sites 180, 191, and 244 are enriched in Pb. These sample sites should receive further study.

The quartzites are not generally enriched in any of the metals analyzed in this survey. However, enrichment does occur in the immediate vicinity of the Pb-Zn-Ag veins. In Allen Creek a sample of gossan (sample 229) over a fracture zone in quartzite contains 1100 ppm Pb, 130 ppm Zn, 4 ppm Sb, 9 ppm Sn, and 4.1 ppm Ag. This zone and surrounding area definitely warrants follow-up work.

The greenstones have high median values for Cu, Zn, Ni and Co, and two (samples 22b, 96b) are mineralized with chalcopyrite.

The trace element content of the limestones and dolomites sampled in the district is generally low.

The Ordovician-Silurian slate samples are marked by high Ba contents. In addition, the high median values for Cu, Ni, and F indicate a general enrichment of these elements in the slates.

Analyses of all rock samples and limonite precipitates are listed in Table 9. Use of these data together with those obtained from the stream sediment, hydrogeochemical, and heavy mineral surveys reported earlier (Gleeson et al, 1965-1968) (Boyle and Gleeson, 1972) (Gleeson and Boyle, 1976) (Gleeson and Boyle, in press) should give a better understanding of the geochemistry and metallogeny of the Keno Hill district and as a consequence a more accurate evaluation of the future mineral potential of the district.

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APPENDIX

Table 1

Analyses of composite samples of limestone, Keno Hill-Galena Hill area

Constituent	A-730[1] %	A-731 %
SiO_2	17.96	1.35
Al_2O_3	0.00	0.00
Fe_2O_3	0.27	0.36
FeO	0.32	1.74
CaO	44.50	30.26
MgO	0.72	19.66
Na_2O	0.17	0.06
K_2O	0.04	0.01
H_2O+	0.13	0.13
H_2O-	0.00	0.01
TiO_2	0.03	0.03
P_2O_5	0.05	0.02
MnO	0.38	0.36
CO_2	35.55	45.70
S	0.02	0.01
C	0.12	0.53
Total	100.26	100.19
Less O ≡ S	0.00	0.00
Net total	100.26	100.19
Powder density	2.725	2.882

[1] Analyst: K.G. Hoops.

This and subsequent sample numbers in the following tables refer to samples described in Boyle (1965).

A-730 Banded white to grey crystalline limestone

A-731 Black brecciated limestone

Table 2

Analyses of composite samples of argillite, slate graphitic schist, and graphitic phyllite, Keno Hill-Galena Hill area

Constituent	A-464 %	A-619 %	A-697 %
SiO_2	66.9	65.7	63.6
Al_2O_3	16.7	12.2	15.5
Fe_2O_3	2.1	1.4	1.7
FeO	1.79[1]	1.93[1]	2.44[1]
CaO	1.3	2.3	2.4
MgO	1.7	1.1	1.5
Na_2O	0.2	1.1	0.7
K_2O	2.7	2.3	2.7
H_2O (total)	2.7	3.49	2.82
TiO_2	0.9	0.7	0.8
P_2O_5	0.2	0.4	0.4
MnO	0.3	0.2	0.0
CO_2	2.25	4.66	2.05
S	0.72	0.56	1.18
C	1.37	1.00	1.34
Total	101.8	99.0	99.1
Less O ≡ S	0.3	0.2	0.5
Total	101.5	98.8	98.6
Powder density	2.755	2.763	2.798
Analysts	G. Bender	K.G. Hoops	K.G. Hoops

[1] Values uncertain because of the presence of large amounts of carbon

A-464 Graphitic schist and phyllite, Sourdough Hill-composite sample

A-619 Graphitic schist, phyllite, argillite, and slate, Keno Hill-composite sample

A-697 Graphitic schist, argillite, phyllite, and slate, Galena Hill-composite sample

Table 3

Analysis of composite sample of quartz-sericite schist, Galena Hill

Constituent	A-692 %
SiO_2	80.8
Al_2O_3	7.5
Fe_2O_3	0.8
FeO	2.33
CaO	1.4
MgO	1.2
Na_2O	0.3
K_2O	1.3
H_2O(total)	1.91
TiO_2	0.4
P_2O_5	0.0
MnO	0.0
CO_2	0.51
S	0.21
C	–
Total	98.7
Less O ≡ S	0.1
Total	98.6
Powder density	2.717

Analyst: K.G. Hoops

A-692 Quartz-sericite schist

Table 4

Analyses of composite samples of greenstone, Keno Hill-Galena Hill area

Constituent	A-621 %	A-691 %
SiO_2	49.7	46.3
Al_2O_3	15.3	13.8
Fe_2O_3	2.6	0.8
FeO	8.07	10.12
CaO	9.3	12.9
MgO	6.3	4.5
Na_2O	2.2	1.7
K_2O	0.2	0.2
H_2O (total)	2.90	4.05
TiO_2	1.7	1.7
P_2O_5	0.2	0.2
MnO	0.0	0.1
CO_2	0.31	2.56
S	0.03	0.14
C	-	-
Total	98.8	99.1
Less O ≡ S	0.0	0.1
Total	98.8	99.0
Powder density	3.032	2.975

Analyst: K.G. Hoops

A-621 Composite sample greenstone lenses, Keno Hill

A-691 Composite sample greensone lenses, Galena Hill

Table 5

Analysis of composite sample of biotite-lamprophyre, Galena Hill

Constituent	A-693 %
SiO_2	51.1
Al_2O_3	12.6
Fe_2O_3	0.5
FeO	6.07
CaO	7.4
MgO	6.2
Na_2O	2.1
K_2O	2.2
H_2O (total)	3.23
TiO_2	0.8
P_2O_5	0.4
MnO	0.1
CO_2	5.84
S	0.30
C	-
Total	98.8
Less O ≡ S	0.1
Net total	98.7
Powder density	2.787

Analyst: K.G. Hoops

A-693 Biotite-lamprophyre

Table 6

Analysis of composite samples of quartzite, Keno Hill-Galena Hill area

Constituent	A-698 %	A-622 %	A-620 %	A-694 %	A-463 %	A-695 %
SiO_2	88.9	88.2	66.9	97.4	75.8	81.5
Al_2O_3	1.5	2.1	8.4	0.6	1.9	1.1
Fe_2O_3	0.2	0.3	0.8	0.0	0.4	0.2
FeO	1.05	1.10	1.72	0.34	0.46	0.74
CaO	3.2	1.5	7.7	0.9	10.3	7.4
MgO	0.0	1.1	0.8	0.0	0.9	0.3
Na_2O	0.2	0.4	1.1	0.1	0.1	0.0
K_2O	0.2	0.3	1.6	0.1	0.3	0.2
H_2O (total)	0.71	0.56	0.9	0.15	0.44	0.32
TiO_2	0.2	0.2	0.5	0.1	0.2	0.1
P_2O_5	0.1	0.1	0.2	0.0	0.2	0.1
MnO	0.1	0.1	0.1	0.0	0.0	0.0
CO_2	2.94	2.94	7.97	0.00	8.42	7.24
S	0.10	0.17	0.52	0.02	0.25	0.00
C	-	0.09	0.29	-	-	-
Total	99.4	98.7	99.5	99.7	99.7	99.2
Less O ≡ S	0.0	0.1	0.2	0.0	0.1	0.0
Total	99.4	98.6	99.3	99.7	99.6	99.2
Powder density	2.668	2.690	2.726	2.684	2.701	2.670
Analysts	K.G. Hoops	K.G. Hoops	K.G. Hoops	K.G. Hoops	G. Bender	K.G. Hoops

A-698 Composite of all samples of thick and thin bedded quartzite Keno Hill-Galena Hill

A-622 Composite of medium and thick bedded grey quartzite, Keno Hill-Galena Hill

A-620 Composite of thin-bedded quartz and phyllite, Keno Hill-Galena Hill

A-694 Composite of white cherty quartzite, Galena Hill

A-463 Composite of calcareous quartzite, Sourdough Hill

A-695 Composite of calcareous quartzite, Galena Hill

Table 7

Analyses of composite samples of granitic rocks, Keno Hill district

Constituent	A-703 %	A-702 %	A-699 %	A-701 %	A-700 %	A-696 %
SiO_2	66.2	70.1	61.3	68.8	64.9	67.0
Al_2O_3	16.7	15.5	16.6	16.5	16.5	16.7
Fe_2O_3	0.3	0.3	0.3	0.5	0.8	0.6
FeO	2.91	2.36	3.59	1.50	2.82	2.31
CaO	3.0	2.6	7.0	2.9	3.6	1.9
MgO	2.0	1.2	2.5	1.2	1.2	0.7
Na_2O	2.5	2.5	2.6	2.9	3.0	3.6
K_2O	4.6	3.3	3.4	4.5	4.1	2.9
H_2O (total)	0.80	0.80	0.56	0.50	0.57	1.50
TiO_2	0.5	0.4	0.5	0.3	0.7	0.3
P_2O_5	0.2	0.1	0.2	0.1	0.4	0.0
MnO	0.0	0.0	0.0	0.0	0.1	0.0
CO_2	0.06	0.00	0.10	0.00	0.00	1.07
S	0.01	0.00	0.02	0.02	0.01	0.01
C	-	-	-	-	-	-
Total	99.8	99.2	98.7	99.7	98.7	98.6
Powder density	2.684	2.679	2.750	2.678	2.717	2.789

Analyst: K.G. Hoops

A-703 Granodiorite composite, Dublin Gulch area

A-702 Granodiorite stock west of Hanson Lakes

A-699 Quartz diorite-monzonite-aplite. Marginal facies of batholith north of Mayo Lake

A-701 Granodiorite-quartz monzonite phase. Batholith north of Mayo Lake

A-700 Porphyritic quartz monzonite from core of batholith north of Mayo Lake

A-696 Quartz-feldspar porphyry Galena Hill-Mount Haldane

Table 8

Analyses of typical skarn, Keno Hill district

Constituent	A-735 %	A-733 %	A-734 %	A-732 %
SiO_2	55.56	59.98	41.45	37.01
Al_2O_3	0.52	6.21	9.53	10.07
Fe_2O_3	0.06	0.67	1.77	21.17
FeO	5.74	11.28	12.47	not obtainable
CaO	21.19	15.64	19.65	13.00
MgO	7.09	0.48	1.41	1.78
Na_2O	0.09	1.21	0.64	0.39
K_2O	0.01	0.14	0.15	0.08
H_2O+	0.13	0.48	0.63	0.19
H_2O-	0.09	0.28	0.15	0.29
TiO_2	0.06	0.17	0.35	0.27
P_2O_5	0.08	0.04	0.14	0.12
MnO	0.12	0.31	0.49	0.24
CO_2	6.88	2.86	2.72	0.52
S	NF	NF	0.38	7.44
C	0.03	0.05	0.11	0.15
WO_3	2.43	0.00	7.80	11.58
Total	100.08	99.80	99.84	not obtainable
Less O ≡ S	0.00	0.00	0.14	2.79
Net total	100.08	99.80	99.70	-
Powder density	3.000	2.942	3.365	3.574

NF = not found

Analysts: J.A. Maxwell and S. Courville.

A-735 Scheelite skarn, Ray Gulch; Dublin Gulch area

A-733 Skarn, Ray Gulch, Dublin Gulch area

A-734 Dense greenish scheelite skarn, Cement Creek (Castnor Creek) (24 km southwest of Mount Haldane)

A-732 Sulphide-scheelite skarn, Cement Creek (Castnor Creek) (24 km southwest of Mount Haldane)