A URANINITE OCCURRENCE AT HAZELTON, BRITISH COLUMBIA

by

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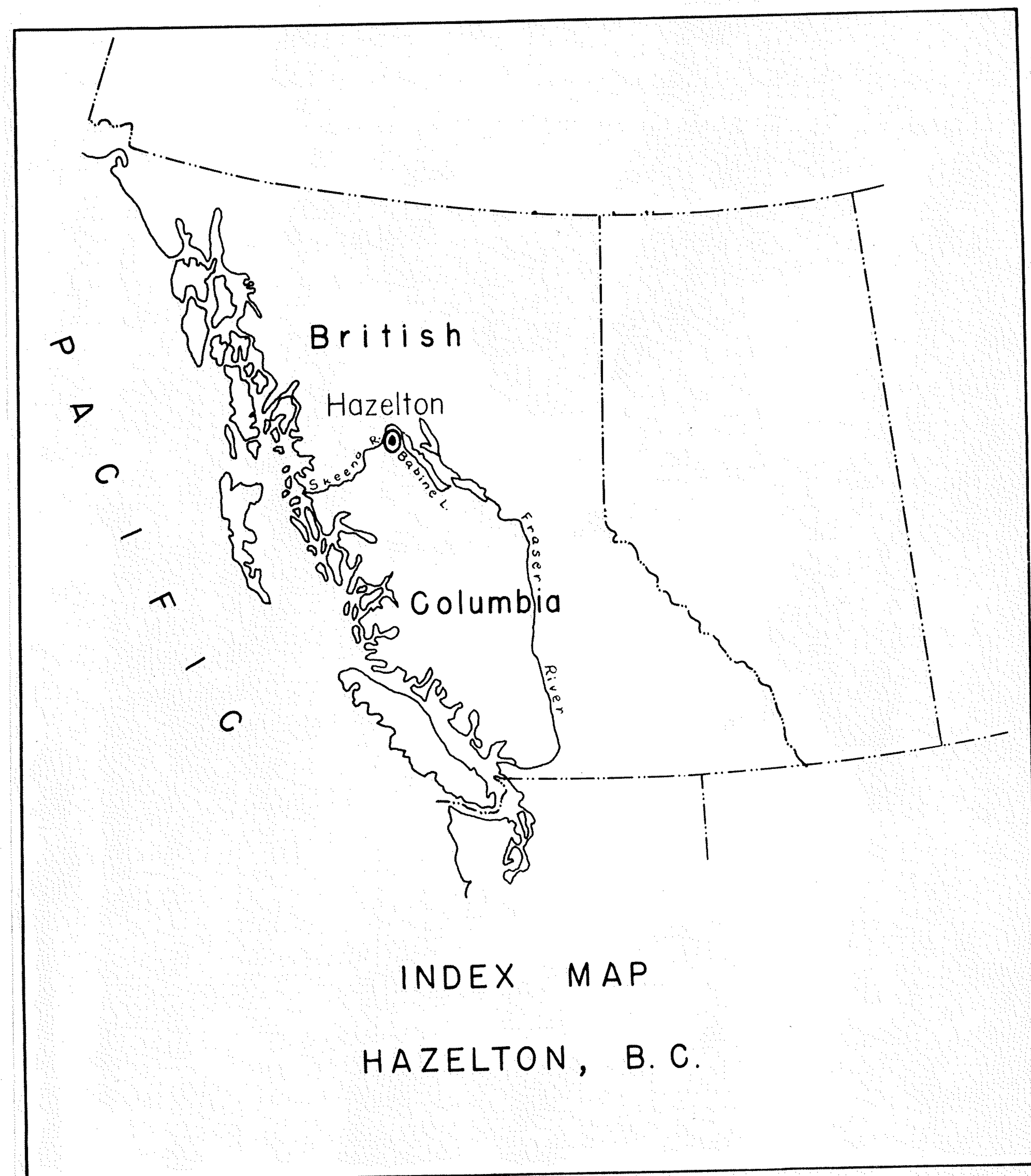
British
Columbia
Hazelton
Skeena R.
Babine L.
Fraser River
PACIFIC
INDEX MAP
HAZELTON, B.C.

FIGURE 1

ACKNOWLEDGMENTS

The writer wishes to thank Mr. James Mackee, president of Victoria Securities Ltd. of Vancouver, British Columbia, for making this study possible, Mr. Martin Jasper, mining engineer for the company, for his many helpful suggestions and assistance while in the field, and Professor G. E. Goodspeed of the University of Washington Geology Department for his aid in preparation of the manuscript and suggestion of the problem.

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ABSTRACT

The Victoria property lies on the contact between the Rocher Deboule granodiorite batholith and Upper Jurassic sediments of the Hazelton group. Three of the four veins within the property are entirely within the granodiorite; the other is along the contact zone between sediments and granodiorite. All are similarly mineralized, hornblende, orthoclase, quartz, calcite, scapolite, orthite, apatite, sphene, chlorite and a little biotite comprising the gangue, and complex gold-bearing sulfarsenides, molybdenite and uraninite, the ore. The mineral assemblage indicates a hypothermal origin for the deposit.

Uraninite formed after molybdenite in the later stages of mineralization, followed by a little quartz and carbonate. It is very erratic in its distribution and only on a microscopic scale can any definite structural control of deposition be seen. It forms tiny crystals, usually less than 0.1 millimeters in diameter and occurs principally in disseminated form in the hornblende, molybdenite, orthite, orthoclase and arsenopyrite. Of these minerals, hornblende and molybdenite are most closely associated with the uraninite. Pleochroic halos, hematite alteration products and red and pink coloration of feldspars are among the alteration effects produced by the uraninite.

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CHAPTER I

INTRODUCTION

The Victoria Property

<u>Location</u>. The Victoria property lies on the northwest slope of the Rocher Deboule Mountain at a point approximately five miles south of Hazelton, British Columbia. It may be reached by a pack horse trail three miles long leading from Comeau's ranch at the foot of the mountain, two miles east of Carnaby on the Canadian National Railway.

<u>Description</u>. Three parallel veins outcrop on the property, which lies just west of a sharp, north-south trending ridge in the Rocher Deboule granodiorite. The veins strike roughly east and west and dip between forty and sixty degrees north. They will be referred to as Number 1, Number 2, and Number 3 veins, from north to south. Near the Number 1 or northernmost vein is a cross vein which strikes to the northwest and dips fifty degrees northeast.

Only the Number 1 vein has been worked for its ore. Four adits have been driven along this vein at elevations of 5250, 5500, 5730 and 5900 feet. An open cut and several prospect pits follow the vein over the top of the ridge. These pits are at elevations between 6100 and 6200 feet. Another adit, whose portal is ninety feet northwest of the 5250 foot level adit portal and at an elevation of 5170 feet, intersects an apparently barren shear zone which is probably the underground projection of the cross vein. This adit and the adit at 5900 feet were both extended in 1950.

The Number 2 vein, a little less than 1000 feet to the south, is mineralized similarly to the Number 1 vein. A series of outcrops and prospect pits trace the vein for more than 1000 feet horizontally. The Number 3 vein, 750 feet farther to the southwest, has not been traced for any great distance along its strike. Mineralogically, it is similar to veins 1 and 2.

History of mining and development. Development of the property began in 1916, following completion of the Canadian National Railway, which provided a means of shipping ores from the vicinity of Hazelton. Between 1918 and 1941, sixty-four tons of hand sorted ore were shipped. An analysis of the metallic content of the ore is given in Table 1, taken from Black's report (1948, p. 81). Samples submitted by Black (1948, p. 82) to the Department of Mines of British Columbia led to the identification of uranium in the ore; recent activity has been concerned with exploration to determine the possibility of an economic deposit of uranium on the property.

Table 1

ORE SHIPPED BETWEEN 1918 AND 1941

Year	Tons	Gold (oz/ton)	Silver (oz/ton)	Arsenic (%)	Molybdenum (%)	Cobalt (%)	Zinc (%)
1918	26.6	1.24	*	8.98	0.96	1.18	*
1926	22.0	4.65	*	42.3	*	4.6	*
1940	7.7	2.18	0.2	6.6	*	2.6	Nil
1941	7.3	2.02	0.2	6.1	*	1.4	0.6

*Not available

Statement of the Problem

The main object of this work has been to determine what conditions, structural, mineralogical and physical, have led to the deposition of uraninite in the veins of the property. Toward this end, the following features, believed by the writer to be of significance, have been studied in the literature, field and laboratory:

1. The geology of the Hazelton mining district and the distribution and zoning of ore deposits within the district.

2. The geologic features of the Victoria property, including the composition and spatial relationships of country rock, dikes and vein material, the presence of faults and shear zones and the succession of ore and gangue minerals.

3. The form, mode of deposition and associations of the uraninite. Post-depositional effects produced by the uraninite, such as the formation of alteration products and pleochroic halos, have also been observed and will be described

in this paper. The importance of these effects lies in their possible usefulness as guides to uranium ore.

The study was made at the request of Mr. James Mackee, president of Victoria Securities Ltd. of Vancouver, British Columbia. Its purpose was to provide as much detailed information as possible on uranium deposition at a location where, owing to the fact that the presence of this element was not known until 1948, it had not been intensively studied. The writer has attempted to enlarge upon the information obtained by Black (1948) and Stevenson (1949) in their investigations of the property.

The Present Investigation

In this study, all available literature was consulted; approximately one and one-half months were spent in field work on the property and three months in laboratory work at the University of Washington.

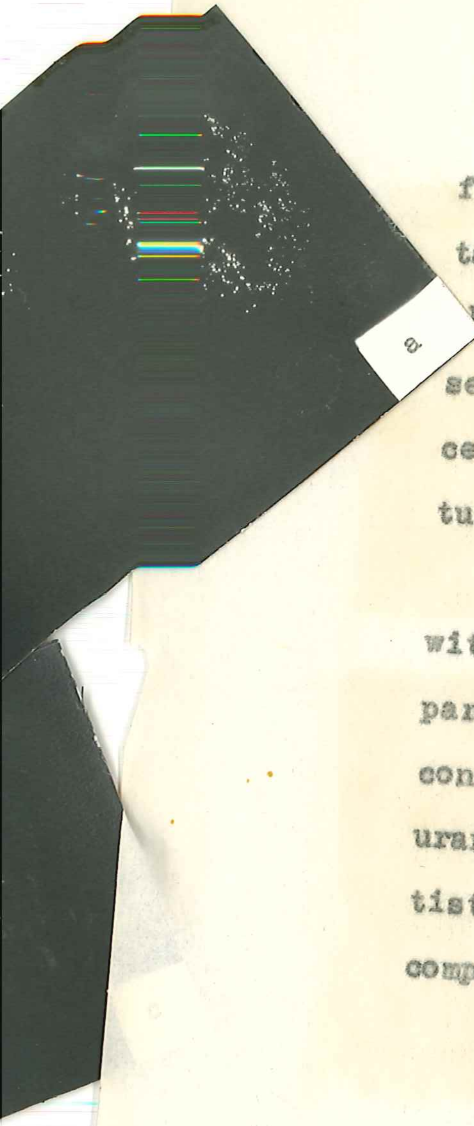
Literature consulted. The literature consulted was of two types: that dealing with the general and economic geology of the region, and that dealing with the Victoria Securities property. Particularly valuable in the latter were the results of investigations by Galloway (1916, 1917 and 1918), Black (1948) and Stevenson (1949) which appeared in Annual Reports to the Minister of Mines, British Columbia, and the reports by O'Neill (1919) and Kindle (1940) in Geological Survey of

Canada memoirs. Armstrong's work (1944, 1946) was frequently consulted in connection with the general geology.

Field work. Field work consisted of the following procedures: 1. Mapping of the veins, dikes, lithologic contacts and faults, using a map constructed by Mr. Martin Jasper, mining engineer for the company, as a base map. 2. Geiger-Mueller counter surveys of the two main adits on Number 1 vein, with readings taken at five foot intervals along the vein (Figure 29). 3. Collection of specimens of vein material from as many radioactive locations as possible. Continuous samples across the full width of the vein were taken wherever possible. Sample locations are shown in Figure 6.

Laboratory work and methods. Approximately 200 thin sections were made from the specimens collected. Of these, 120 are from the Number 1 vein and the rest from Number 2. In addition, six polished sections were made from specimens of sulfides, known, by the method described below, to contain uraninite.

In order to identify the uraninite in the thin sections, an adaption of a method described by Yagoda (1946) for localizing radioactive minerals in polished sections was employed. Before mounting the cover glass, each section was placed on a photographic plate so that the emulsion and section were in direct contact. For uniformity of results, an exposure time of 100 hours was used. A sharp, clear pattern of uraninite distribution was obtained in all plates exposed to uraninite-bearing



formation of a turbidity in that part of the emulsion in contact with the mounting medium (Lakeside No. 70), the rest of the emulsion remaining clear and outlining the shape of the section. In Figure 2, b, c and d were made with contrast process orthochromatic film and a with another type of film. The turbid zones in the former can be readily distinguished.

The thin and polished sections were used in conjunction with the exposed plates in order to establish the identity and paragenesis of the minerals and to study the associations, controlling microstructures and alteration effects of the uraninite. The large number of sections made possible a statistical treatment of uraninite associations (Table 7) and a comparison of the mineralogy of veins 1 and 2 (Table 3).

CHAPTER II

ECONOMIC GEOLOGY OF THE HAZELTON DISTRICT

General Geology

Introduction. The Hazelton district is underlain by a series of sedimentary rocks intruded by granodiorite and diorite masses with associated ore bodies. The relationships of sediments and intrusions may be seen in Figure 5, which is based on a preliminary map of the area by Armstrong (1944). The geology is by Armstrong and Gray (1938) and Kindle (1938, 1939).

Sedimentary rocks. The sedimentary and volcanic series, of Jurassic and Lower Cretaceous age, is known as the Hazelton group. The geographical extent, lithology, age and stratigraphic subdivision is discussed by Armstrong (1946, p. 9) as follows:

> The Hazelton group is widespread from Portland Canal to Prince George, and comprises a conformable succession, possibly 10,000 feet thick, of interbedded greywacke, argillite, conglomerate, tuff, breccia, andesite, and basalt. In most places the volcanic rocks occur as lens-shaped masses up to many miles long and thousands of feet thick that are roughly conformable with overlying and underlying sedimentary rocks.
>
> On the basis of contained fossil shells and plants the rocks of the Hazelton group range in age from pre-Middle Jurassic to Lower Cretaceous, and include what have been called Hazelton group and Skeena formation or

series (Armstrong, 1944b). The shell collections that have been identified are from beds of two ages: (1) Middle Jurassic, and (2) Upper Jurassic or possible very early Lower Cretaceous. No fossil plants have been found in the Middle Jurassic beds, which are mainly marine; however, plants have been collected from many localities in the younger beds, which consist of interbedded continental and marine strata. The plants represent two distinct flora, correlated provisionally with the Kootenay and Lower Blairmore of Alberta, and are, presumably, of Lower Cretaceous age. However, marine shells of Upper Jurassic or, possibly, very early Lower Cretaceous age were collected on Hudson Bay Mountain from a bed 300 feet stratigraphically above coal measures containing fossil plants identified as of Lower Blairmore age, so that, until further paleontological investigations have been made, it is not possible to indicate how much of the Hazelton group is Lower Cretaceous.

The Hazelton group has been subdivided in places, but over much of its outcrop area it contains few fossils of diagnostic value, and the limits of the group are not known.

Crystalline rocks. The intrusive bodies vary from dioritic to granodioritic in composition and range from less than one to more than thirty square miles in area. They form the cores of most of the higher peaks in the area, where alpine glaciation has carved a rough, jagged topography (Figure 4).

Several writers suggest that these bodies are related to the Coast Range batholith. Armstrong (1946, p. 12) summarizes information pertaining to the Coast Range batholith and related intrusions:

> The dominant geological feature of the Coast Range is its great composite batholith and numerous related intrusions. . . . The rocks of the main batholiths are dominantly granodiorites and quartz diorites. . . . Most of the satellitic intrusions are of granodiorite and quartz monzonite, but a few more basic bodies have

> been recorded. The Premier, Big Missouri, Hidden Creek (Anyox), Dolly Varden, Red Rose, Silver Standard, Duthie, Rocher Deboule, and Polaris-Taku orebodies, and innumerable smaller mineral deposits, occur in or near the Coast Range batholith and related intrusions. . . . Along the Canadian National Railway from Terrace to Smithers, Jurassic and probable Lower Cretaceous strata of the Hazelton group have been invaded by the (Coast Range) batholith and by related intrusions (Kindle, 1937a, p. 6, 1937b, p. 7; Armstrong, 1944b and 1944c) . . . . It is evident . . . that various phases of the Coast Range batholith and related intrusions range in age from Upper Jurassic to Upper Cretaceous and possibly later, and that a large part was intruded in Lower Cretaceous or later times.

Orebodies. Of the orebodies listed in the above quotation, the Red Rose, Silver Standard and Rocher Deboule all are within the limits of the Hazelton district. The relationship of these and other mineral deposits to the intrusives may be seen in Figure 3.

Structure. Regarding the structure in the Hazelton area, Armstrong (1946, p. 14) states:

> In the Hazelton-Smithers region the main valleys appear to lie along major fault zones (Armstrong, 1944c), and each individual mountain range or massif, as for example Rocher Deboule Range, which is 250 square miles in area, may represent a fault block. Much of the folding in this region is asymmetrical, and in places overturned folds have developed into overthrust faults.

The system of faults cutting the Rocher Deboule Range, which lies south of the Skeena and Bulkley Rivers, may be seen in Figure 5. The general trend of the faults is north and south. An exception is the small east-west trending fault in the northwest part of the range.

Ore Deposits

Distribution. Approximately forty ore deposits exist within a thirty mile radius of Hazelton, all but four being within a fifteen mile radius. Half of the deposits lie north of the Bulkley River on Glen, Four Mile, and Nine Mile Mountains; the rest are south of the Bulkley River on the slopes of Rocher Deboule Mountain.

Geology and age. Nearly all of the deposits are definitely associated with the intrusive masses scattered throughout the district. An apparent exception is the highly productive Silver Standard mine whose veins are in fissures in the quartzite of Glen Mountain (Kindle, 1940, p. 28). Even here, two small stocks of porphyritic granodiorite which intrude the quartzite indicate the presence of a larger, deep seated intrusion. The usual site of ore deposition is in fissures near the contacts of the intrusive masses. Most notable examples of this are at the west contact of the Rocher Deboule granodiorite and on the entire perimeter of the granodiorite of Nine Mile Mountain.

Because the deposits are associated with masses intrusive into Lower Cretaceous sediments, they may be considered to be of post-Lower Cretaceous age. It is not possible to fix the age with more precision since the relationship of the intrusions to scattered small deposits of Upper Cretaceous sediments is not certain (Armstrong, 1944).

Zoning. A definite temperature zoning is exhibited by the mineral deposits of the Hazelton district. On the basis of mineral assemblages considered to indicate temperatures corresponding to those of the epithermal, leptothermal, mesothermal and hypothermal zones (McKinstry, 1948, p. 380; Bateman 1950, pp. 40-43) the following diagram has been prepared, in which all deposits classifiable according to temperature of

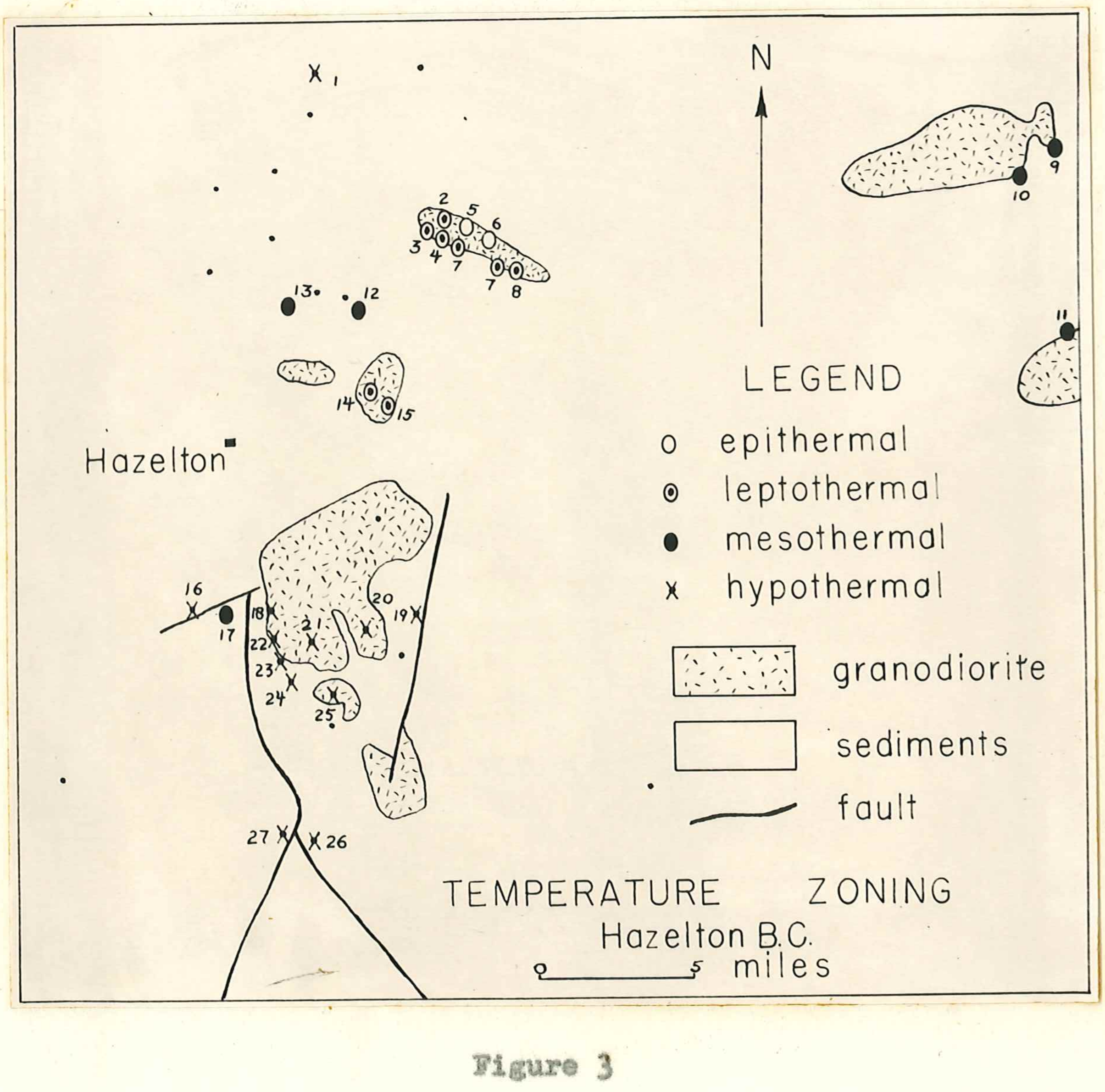


Figure 3

formation are represented by the symbols given in the legend. Those whose mineral assemblages do not indicate a definite temperature zone are represented by the small dots without numbers.

The mining properties indicated by the numbers in Figure 3 are as follows:

> 1. Fortune Hill claim; 2. Barber Bill group; 3. Silver Cup group; 4. Pole Star claim. 5. Sunrise group; 6. Lead King group; 7. Slocan group; 8. Silver Pick group; 9. O. K. group; 10. True Fissure group; 11. Higgins property; 12. American Boy group; 13. Silver Standard mine; 14. Erie group; 15. Comet group; 16. Golden Wonder group; 17. Cap or Comeau group; 18. Victoria Securities property; 19. Lone Star claim; 20. Black Prince group; 21. Highland Boy group; 22. Rocher Deboule mine; 23. Great Ohio group; 24. Spaulding property; 25. Red Rose group; 26. Brian Boru group; 27. Killarney group.

Table II lists the minerals used in making the classification. The number at the top of each vertical column represents the corresponding deposit in Figure 3. The mineral assemblages are taken from Kindle's report (1940).

From this information, the following conclusions may be drawn regarding zoning in the Hazelton area:

1. The highest temperature (or hypothermal) deposits are associated with the Rocher Deboule batholith. An exception is the Fortune Hill claim (number 1, Figure 3) in which pyrrhotite occurs. Among the minerals found near the Rocher Deboule batholith, which are not found elsewhere in the district, are molybdenite, pyrrhotite (with one exception), wolframite, magne-

Table 2

MINERAL ASSEMBLAGES PRESENT IN MINES OF THE HAZELTON DISTRICT

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Sphalerite	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x											x	x
Galena		x	x	x	x	x	x	x	x	x	x	x	x	x	x											x	x
Pyrite	x	x	x		x		x		x	x	x	x	x	x	x	x	x			x	x	x	x		x		x
Chalcopyrite	x									x	x	x				x	x	x		x	x	x	x	x	x	x	
Jamesonite		x	x		x	x	x	x						x	x												
Freibergite													x														
Tetrahedrite			x	x	x	x			x	x	x	x	x	x								x					
Cosalite					x	x																					
Arsenopyrite	x	x		x	x	x						x	x			x		x				x			x		
Argentite					x	x								x													
Safflorite																		x				x					
Molybdenite																		x		x		x					
Pyrrhotite	x															x			x			x			x	x	x
Wolframite																				x					x		
Magnetite																					x	x		x			
Uraninite																		x									
Chlorite																					x						
Quartz	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x		x		
Siderite	x													x	x		x										
Carbonate								x	x			x									x						x
Hornblende																		x			x	x	x		x		
Biotite																									x		

tite, uraninite, hornblende and biotite: all hypothermal minerals.

2. Nearly all of the lower temperature (epithermal to mesothermal) deposits are north of the Bulkley River. The Comeau group (number 19, Figure 3) appears to provide the only exception, with the assemblage: chalcopyrite, jamesonite, quartz and siderite. Most typical of the minerals in this area are sphalerite, galena, jamesonite and tetrahedrite, indicating lower temperature deposits than are found on the Rocher Deboule Mountain.

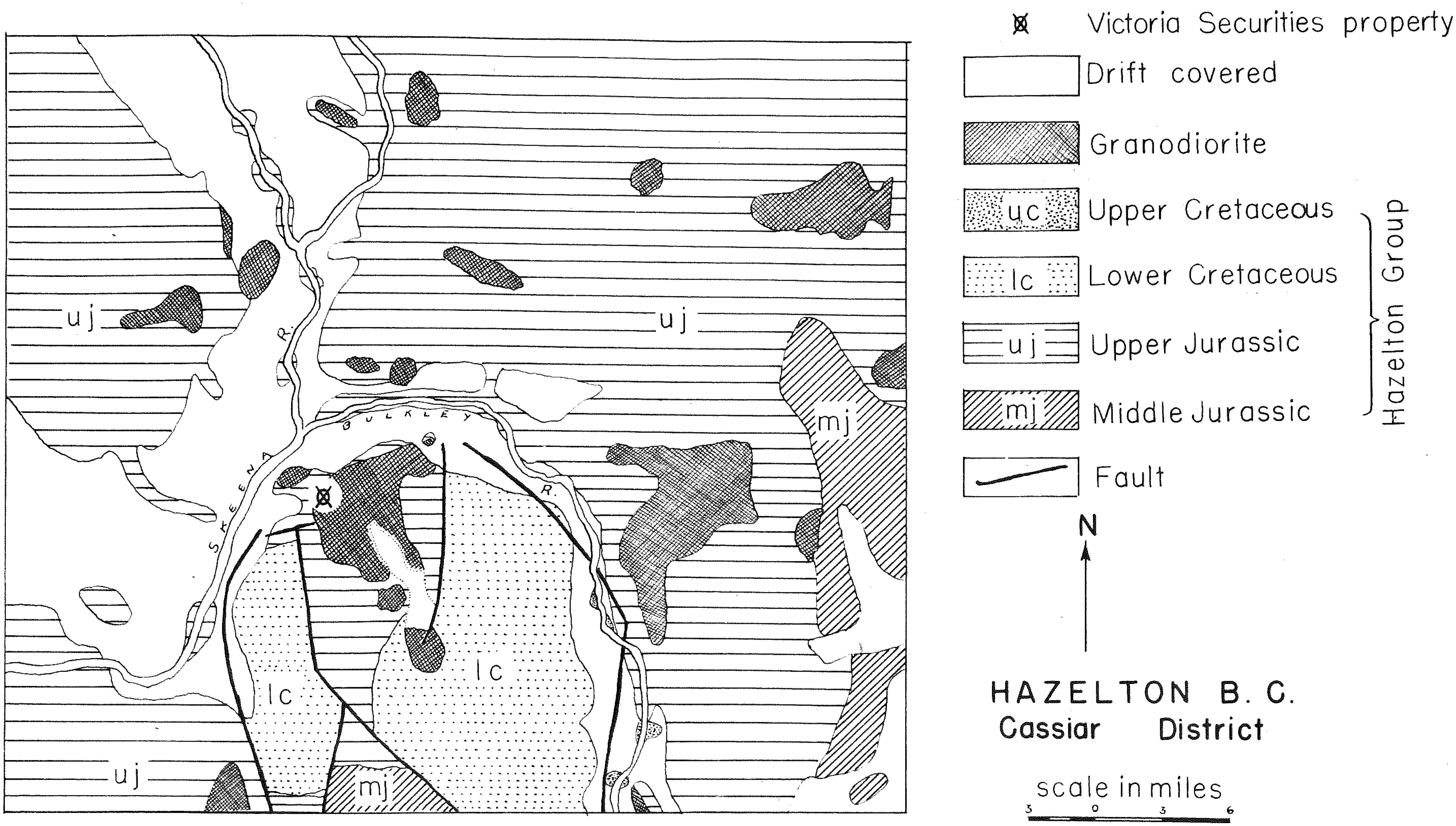
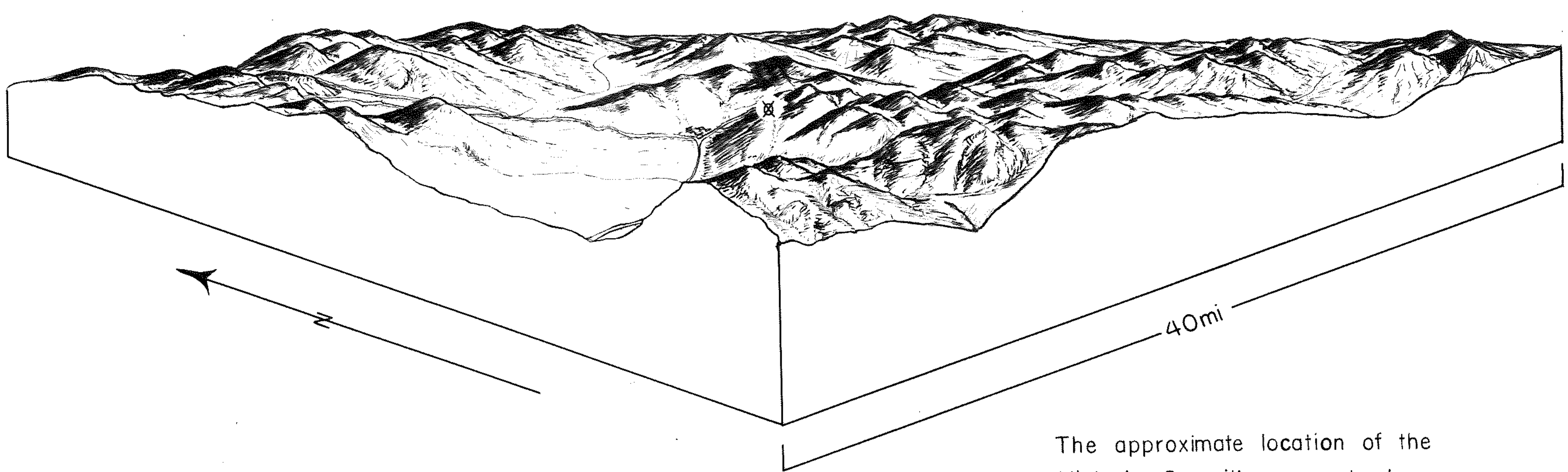


FIGURE 5
Modified after Armstrong, 1944



The approximate location of the Victoria Securities property is shown by the symbol ⊠.

HAZELTON

Cassiar District

B.C.

FIGURE 4

CHAPTER III

THE VICTORIA PROPERTY

Introduction

Geologic setting. As may be seen in Figures 3 and 5, the Victoria property lies on the contact of the Rocher Deboule granodiorite intrusion and Upper Jurassic sedimentary rocks of the Hazelton group. The contact here trends nearly north and south. The sediments strike in an easterly direction and dip to the north. According to Stevenson (1949, p. 85) they are predominantly quartz-biotite hornfels with a few limy beds up to six inches thick containing calcium garnet and diopside.

The proximity of the property and contact provides an example of the general rule that most of the mineral deposits on Rocher Deboule mountain are aligned along the contact, both in sediments and granodiorite. Mineralization in the veins of the Victoria property is confined primarily to the granodiorite. Where the faults containing the veins pass into the sediments, few traces of mineralization have been found.

Zoning and temperature classification. A rather definite regional pattern of temperature zoning exists in the

Hazelton district (see Figure 3 and Table 2). High temperature deposits form a cluster near the western margin of the Rocher Deboule batholith, and the Victoria property lies within this cluster. This, in addition to the presence of molybdenite, uraninite, hornblende, biotite and scapolite definitely indicates that it is a hypothermal deposit.

Geological Features of the Property

General. The sediments underlying the western part of the property and the granodiorite underlying the eastern part comprise the two major geologic units. Three dikes intrude the granodiorite: two of them follow the No. 1 and No. 2 veins; the other intersects the No. 1 vein at an angle of about forty-five degrees. Veins 1, 2 and 3 follow east-west striking faults in the granodiorite; the cross vein is in the contact zone between granodiorite and sediments (see Figure 6).

Sedimentary rocks. The composition and attitude of the sediments underlying the western part of the property have already been discussed under Geologic Setting.

Granodiorite. The composition of the granodiorite, as determined by thin section study of four specimens, is:

quartz	15%	
oligoclase-andesine	50%	
orthoclase	10%	
biotite	10%	±
hornblende	15%	
magnetite	-	

Except near the veins, where a considerable increase in hornblende gives it a darker appearance, the granodiorite is a fairly light, uniform gray with a medium grained, hypidiomorphic texture. Feldspar and quartz grains average approximately four millimeters in diameter. Feldspar crystals are euhedral to subhedral; anhedral quartz and biotite fill intergranular spaces. Some of the hornblende replaces earlier formed minerals. This is most noticeable near the veins.

Dikes. 1. A dark green, fine grained andesite dike composed of andesine and hornblende follows the Number 1 vein. It is sheared in many places by the faulting which controlled vein formation and is found in both the foot and hanging walls of the vein. Sub-parallel alignment of feldspar laths causes a distinct flow structure. Approximately eighteen inches wide and having very sharp contacts with the granodiorite, the dike may be traced on the surface the full length of the Number 1 vein.

2. Intersecting the Number 1 vein at a surface elevation of 5600 feet, striking northeast and dipping southeast, is a twelve foot thick light colored quartz-feldspar porphyry dike. Where it crosses the Number 1 vein, the northern part is offset twenty feet to the west. The dike is also found in the 5500 level adit 320 feet from the portal with approximately the same offset seen on the surface.

3. A third dike, the relationships of which are a little more complex than the two described, follows the Number 2 vein. It is composed of light green material containing

large phenocrysts of andesine partly altered to sericite. The matrix appears mainly to be composed of very fine grained hornblende. Best exposures are found at the easternmost part of the property, where the dike is over forty feet in thickness and lies in the foot wall of the vein. Several scattered exposures occur from twenty to one hundred feet into the hanging wall of the vein as it approaches the sediments to the west. The thinness of the dike in these exposures and their distance from the Number 2 vein suggests that the exposures might be those of one or more dikes of similar composition striking parallel to the dike exposed farther east.

The fact that the first and third dikes are consistently followed, and, in places, sheared by the pre-mineral faults of veins 1 and 2 indicates that they were probably zones of weakness which localized the faulting. That the direction of relative movement was to the west on the north side of the Number 1 vein is shown by the direction of offset of the second dike. The direction of relative movement of opposite sides of the Number 2 vein is not evident.

Faults. The faults on the property have already been discussed to some extent in connection with dikes. There are two major faults striking easterly and dipping between forty and sixty degrees north. These are the controlling structures for veins 1 and 2. In the Number 1 vein it is evident that shearing took place along the faults both before and after mineralization. The fissure caused by the earlier shearing is occupied by the vein and cuts across the andesite dike in a number of places. Later shearing has produced a gouge zone, in places nearly a foot thick, which contains fragments of vein material. The latest movement has resulted in a displacement of the hanging wall of the fault twenty feet to the west (see preceding paragraph). Slickensides seen in some of the adits show that the movement was not horizontal but had a dip component to the west of about forty degrees. Besides the two major faults there are a number of cross fractures and zones of brecciation which strike in a northerly direction. The two largest of these are the shear occupied by the cross vein and a brecciated zone about 210 feet from the portal in the 5500 level adit.

Veins. With the exception of the cross vein, which lies in the contact zone between granodiorite and sediments, all the veins are entirely within the granodiorite. They vary from a few inches to three feet in thickness and are mineralogically similar. The similarity in composition of veins 1 and 2, as determined by thin section study of 113 samples from Number 1 and fifty-seven samples from Number 2, is shown in Table 3. Each figure represents the ratio, expressed in per cent, of thin sections containing the mineral in the left column to the total number of thin sections from the location given at the top.

The apparent difference in the amount of molybdenite indicated by Table 3 is probably due to its very erratic dis-

Table 3

COMPARISON OF THE MINERAL CONTENT OF VEINS 1 AND 2

	No. 1 Vein (113 sections) (per cent)	No. 2 Vein (57 sections) (per cent)
Arsenopyrite	44.3	47.3
Molybdenite	17.7	1.7
Uraninite	31.9	38.6
Hornblende	77.0	73.6
Orthoclase	35.4	44.0
Plagioclase	18.6	17.5
Quartz	55.6	63.0
Calcite	28.3	22.8
Orthite	40.6	21.0
Scapolite	15.9	14.0
Sphene	5.3	8.8
Apatite	24.8	19.3
Sericite	12.4	19.3
Chlorite	15.0	31.6
Hematite	7.9	15.7
Amorphous SiO_2	--	5.3
Biotite	6.1	3.5
Muscovite	0.8	--

tribution in the veins rather than to any actual difference. Among the other minerals, there is fairly close agreement, and it may be assumed that veins 1 and 2 were formed under nearly identical physical and chemical conditions.

Hornblende is the predominant gangue mineral in all the veins. An indication that the formation of at least part of the hornblende resulted from alteration of the granodiorite is provided by the presence of a large number of hornblende-filled cracks up to half an inch thick in the granodiorite leading to the veins. For several inches on either side of these cracks, the granodiorite is leached of mafic material, suggesting that these areas are the source of the hornblende. Discontinuous lens-like bodies of orthoclase-quartz pegmatite, disseminated apatite, orthite, sphene and scapolite and veinlets of quartz and calcite all occur within the hornblende. In places the veins are entirely in altered granodiorite or in altered dike material. Arsenopyrite occurs both as solid veinlets up to an inch thick along cracks and as broad bands of disseminated crystals replacing hornblende. It is by far the most abundant metallic mineral. Molybdenite forms thin seams and a few solid pockets several inches in diameter, principally within the hornblende, and is much more restricted in distribution than arsenopyrite. Uraninite occurs most often as paper thin seams similar to those of molybdenite. Microscopic examination shows most of the seams to consist of numerous small euhedral crystals of uraninite disseminated in hornblende along narrow microfractures. Occasionally it is also found disseminated through zones more than a foot wide. The close association of uraninite and molybdenite will be discussed later.

Figure 6 shows a number of locations on veins 1 and 2 and the cross vein from which samples were taken. The following paragraphs describe briefly the vein at each of these locations. The minerals are listed in order of decreasing abundance.

1. The vein here is forty inches wide. The hanging wall is granodiorite; a one-foot gouge zone containing fragments of granodiorite and vein material forms the foot wall. The gangue is coarse grained hornblende, orthoclase-quartz

pegmatite, quartz and calcite veinlets, chlorite, apatite, biotite and orthite. The ore is arsenopyrite, uraninite and a little molybdenite. The pegmatite is in lens-like bodies several inches thick and approximately eighteen inches from the hanging wall contact. Most of the arsenopyrite and uraninite is in the same zone. A thin veinlet of molybdenite and uraninite occurs eight inches farther away from the hanging wall at the contact of the predominantly hornblende bearing zone and a zone containing considerable glassy quartz and calcite. This latter zone persists through the remaining distance to the gouge in the foot wall.

2. The granodiorite is brecciated and altered in a zone two feet in thickness. A smooth slickensided surface, below which is a zone of medium to coarse grained hornblende of an unknown thickness, forms the foot wall of the brecciated granodiorite. The plunge of the slickenside striations is forty northwest. The gangue is hornblende, orthite, apatite, quartz and sericite. The ore is arsenopyrite, molybdenite and uraninite. Alteration of the arsenopyrite has produced considerable hematite. The arsenopyrite forms a solid seam just below the slickensided surface; molybdenite and uraninite are in tiny veinlets in the same position.

3. The relationships here are the same as at location two and need not be further discussed.

4. Below the hanging wall of granodiorite is a zone, several inches thick, of highly altered, brecciated granodiorite

followed by six inches of gouge and eighteen inches of altered dike material. The dike contains a considerable amount of coarse grained hornblende, orthite, scapolite, sphene, apatite, quartz and calcite, all later than the dike material which consists primarily of fine grained andesine and hornblende. Traces of molybdenite and uraninite occur in microscopic pockets and in disseminated form.

5. Granodiorite forms both the foot and hanging walls of the vein, which is approximately twenty-four inches thick at the floor of the adit and narrows to less than a foot at the ceiling. The gangue is composed of hornblende, orthoclase-quartz pegmatite, orthite, chlorite, sericite, apatite, and a little calcite. Arsenopyrite and molybdenite are fairly abundant and some uraninite is disseminated in the hornblende. The vein at this point has a highly weathered appearance.

6. The granodiorite in the hanging wall contains a three inch band of hornblende which intersects the main part of the vein. The vein consists, from hanging to foot walls, of a two inch zone of quartz and altered granodiorite and twelve inches of dike material. Hornblende is the predominant gangue mineral, with considerable quartz and small amounts of calcite, scapolite, sphene, sericite and chlorite. A little uraninite is disseminated in the hornblende.

7. Two zones of dark green material join at this point. The hanging wall zone, six inches thick, is composed of very fine grained material which appears to be hornblende;

the foot wall zone, twelve inches thick, is composed of fine to medium grained hornblende, quartz, orthoclase, sericite, calcite, chlorite, scapolite, orthite, and disseminated uraninite and arsenopyrite. The granodiorite in the area of intersection has been partly altered to sericite, chlorite and kaolinite.

8. A twelve inch hanging wall zone of fine grained dike material composed of andesine and hornblende is separated by several inches of granodiorite from the vein, which is eighteen inches thick. The gangue is principally medium grained hornblende with much disseminated orthite and apatite and some sphene and chlorite. In the center of the vein is a lens of coarse grained quartz and calcite, three or four inches thick and several feet long. Molybdenite and uraninite are associated in veinlets in the hornblende; arsenopyrite is disseminated in the hornblende.

9. The dike, altered intensely to a mixture of quartz, calcite and sericite, is offset here by a shear zone of brecciated and altered granodiorite. The hanging wall of the shear has moved west with respect to the foot wall. Both arsenopyrite and uraninite occur in the altered granodiorite, in which a considerable amount of sericite, muscovite, quartz and a glassy green material has formed. The thickness of both the dike and the zone of altered granodiorite is about four feet.

10. A large amount of uraninite occurs disseminated in granodiorite surrounding the intersection of a five inch

vein composed of calcite, quartz and hematite in parallel bands, and a seam in the granodiorite, the marginal areas of which have been leached of mafics. The vein strikes sixty-eight degrees southeast and dips fifty-seven degrees north; the seam in the granodiorite is nearly vertical and strikes about thirty degrees north. The amount of uraninite decreases in proportion to the distance from the intersection in all directions, and it occurs only in the altered granodiorite. There is none in the vein or in a small pocket of hornblende in the hanging wall of the vein. The granodiorite close to the intersection is altered to a deep red color. The relationship of this vein to the Number 1 vein is not known. Its position and approximate parallelism show that it could be a narrow extension; however, the great difference in mineral composition does not tend to confirm this idea.

11. The zone is eighteen inches wide. Gangue minerals are hornblende, quartz, orthoclase, orthite, scapolite and sericite; ore minerals are arsenopyrite, molybdenite and a little uraninite. The surrounding granodiorite contains stringers of hornblende leading into the zone and is altered to a slight pink color. Four feet south, the zone narrows to several inches in thickness. It strikes eighty-four degrees northeast and dips seventy degrees north. Evidence that this zone is the western extension of vein Number 1 or that there is at least some connection seems more conclusive than for location 10.

12. The cross vein here is fifteen inches wide, strikes fifty-five degrees southeast and dips steeply northeast. A barren shear zone intersected by the 5170 foot level adit is probably its underground projection. Granodiorite forms the hanging wall of the vein and quartzite, the foot wall. The gangue consists of hornblende, lenses of orthoclase-quartz pegmatite, orthite, scapolite, apatite, sphene and chlorite. Arsenopyrite is the most abundant ore mineral, forming solid veinlets up to half an inch thick. The uraninite occurs in disseminated form and associated with molybdenite in narrow veinlets. The cross vein, so called because of its variation in strike from the main vein, might also, with 10 and 11, represent a feathering out of the main vein.

13. The vein, fifteen inches thick, lies along the hanging wall of the feldspar porphry dike. Hornblende, orthoclase-quartz pegmatite, considerable orthite and a little sphene and apatite comprise the gangue. Uraninite and arsenopyrite form veinlets, principally in the hornblende. This location is at the easternmost known extension of vein Number 2.

14. A number of small prospect pits along the hanging wall of the feldspar porphyry dike are similar mineralogically to location 13. Gangue minerals are hornblende, orthoclase, quartz, chlorite and scapolite. Arsenopyrite occurs in solid veinlets along seams and cracks; a small amount of uraninite is associated with hornblende. Hematite, derived from altera-

tion of arsenopyrite, replaces some of the gangue minerals.

15. Mineralization is in a zone about five feet wide within the feldspar porphyry dike. Cross brecciation appears to be the main control of mineralization. The gangue is composed of hornblende, chlorite, orthoclase-quartz pegmatite, orthite, calcite, sericite, apatite, scapolite, sphene and hematite. Arsenopyrite forms solid veinlets up to half an inch thick, and a little uraninite forms thin veinlets in the gangue material.

16. In the feldspar porphyry dike and granodiorite foot wall, west of the zone previously described (15), and within a distance of fifty feet, are a number of branching veins striking southeast and ranging in thickness from less than an inch to more than twelve inches. They consist principally of hornblende, with some orthoclase-quartz pegmatite, orthite, sphene, apatite and chlorite. Solid veinlets of arsenopyrite and thin veinlets of molybdenite and uraninite comprise the ore.

17. Clinging to the smooth surface of Number 2 fault, well exposed at this location, are several lins-like bodies of vein material, some of which reach a thickness of more than eighteen inches. Gangue minerals are hornblende, quartz, calcite, hematite, sericite, chlorite, apatite, orthite, scapolite, sphene, amorphous or colloidal silica and biotite. The ore minerals are arsenopyrite and uraninite. The uraninite occurs mainly in the hornblende and also as veinlets in the

amorphous silica, with which a considerable amount of hematite is associated.

The Ore

Gangue minerals. The gangue minerals, in their approximate order of abundance, are given in Table 3. The manner in which they occur has already been sufficiently discussed in the preceding section under Veins.

Ore minerals. The metallic elements for which the ore has been mined are gold, arsenic, cobalt, molybdenum and uranium. According to Table 1, small amounts of silver and zinc are also present. Uranium and molybdenum are contained in uraninite and molybdenite, respectively; the remaining elements occur in the arsenopyrite, which, as the following table shows, is of complex composition.

Table 4

ANALYSIS OF SAMPLE OF ARSENICAL ORE*

Silica and insoluble silicates		13.70%
Iron		17.98
Arsenic		55.53
Cobalt		4.40
Sulfur		4.00
Lime		2.07
Magnesia		0.90
	Total	95.58%
Gold	4.34 oz/ton	
Silver	3.60 oz/ton	
Specific gravity	5.66	

*O'Neill, 1919, p. 22

According to O'Neill (1919, p. 22), the cobalt-bearing minerals are safflorite and lollingite. Both occur within the arsenopyrite, which safflorite replaces. The age relationship of lollingite and arsenopyrite is uncertain. Gold occurs as small grains scattered through the arsenopyrite and safflorite, some of it occupying minute veinlets in the arsenopyrite. O'Neill (1919, pp. 44-54) gives a number of photomicrographs of polished sections of the ore which illustrate the above relationships.

Paragenesis. The paragenesis of the ore and gangue minerals, given in Table 5, is based on field observation and the study of approximately two hundred thin sections made from the same number of hand specimens. The specimens were taken from the seventeen locations shown in Figure 6.

Table 5

PARAGENESIS

Stages of Vein Formation	Evidence
1. Emplacement of granodiorite.	
2. Intrusion of granodiorite by dikes.	The cross cutting position of the vein with respect to the dike proves the earlier formation of the latter.
3. Faulting along dikes and adjacent granodiorite.	
4. Formation of hornblende.	Both in the field and in thin section, the host relationship of the hornblende to all other gangue and ore minerals is apparent.

Table 5 - Continued

Stages of Vein Formation	Evidence
5. Formation of orthoclase-quartz pegmatite.	The pegmatite forms lens-like bodies within the hornblende. Microscopically, orthoclase can be seen replacing hornblende along cleavage cracks and crystal boundaries.
6. Formation of orthite.	In several thin sections, orthite occurs in veinlets in orthoclase.
7. Formation of apatite.	In one thin section, apatite occurs in a veinlet in orthite.
8. Formation of scapolite.	There is no direct evidence for the age of the scapolite other than its very close association with apatite and orthite.
9. Formation of calcite and quartz.	Veinlets of calcite and quartz occur in all earlier minerals.
10. Microbrecciation.	Earlier minerals, including the quartz of stage 9, are sheared along zones parallel to the vein.
11. Formation of secondary hornblende, biotite, and some calcite.	These minerals form veinlets in shear zones of the quartz of stage 9.
12. Formation of arsenopyrite.	Forms veinlets within, and replaces all earlier minerals.
13. Formation of molybdenite.	Forms veinlets in arsenopyrite and other earlier minerals.
14. Formation of uraninite.	It is not definite whether uraninite formed before or after the molybdenite, with which it is practically contemporaneous. In several sections, uraninite crystals occur within molybdenite veinlets, apparently replacing the molybdenite.
15. Formation of hematite stains.	The hematite stains occur principally where arsenopyrite and uraninite are in contact, indicating the hematite is later.

Table 5 - Continued

Stages of Vein Formation	Evidence
16. Formation of calcite and quartz.	Minute veinlets containing both calcite and quartz cut through all earlier minerals, including pleochroic halos of several uraninite crystals.

Mine Workings

The outlines of the adits and prospect pits are shown in Figures 6 and 29. A summary of the main features of the adits on vein Number 1 is given below:

The 5900 foot level adit drifts on the vein throughout its 240 foot length. Some stoping has been done between 100 and 150 feet from the portal.

The 5730 foot level adit is a little over thirty feet in length and is a drift on the vein. No stoping has been done.

The 5500 foot level adit has been developed more extensively than any of the other adits. Caving and timbering prevent access to some of the stopes, but a description of them is given by Galloway (1918, p. 112) and other writers. At forty from the portal is a stope, thirty feet in length and forty feet upward; at three hundred feet a raise one hundred feet in length connects with a drift which runs eighty-four feet to the west; at 450 feet a winze goes down twenty-two feet. The remaining part of the adit drifts along the vein to the face, 715 feet from the portal.

The 5170 foot level adit crosscuts through the granodiorite for 210 feet, where it intersects a barren shear zone, along which it drifts approximately twenty-five feet.

The 5170 and 5900 level adits are the sites of most recent development, both having been lengthened in the summer of 1950.

CHAPTER IV

THE URANINITE

Identification

Both thorium and uranium minerals are radioactive and therefore cannot be distinguished by this property alone. Spectrochemical analysis has shown (Black, 1948, p. 82) that the radioactive mineral on the Victoria property is definitely a uranium-bearing mineral. Microscopic examination of the mineral in thin section shows that it occurs as black cubic, octahedral and rounded crystals (Figure 28) as well as in solid veinlets with no evident crystal form (Figure 19). Pleochroic halos surround the crystals where they occur in certain host minerals (Figure 23). On sufficient exposure, a photographic plate will be blackened in an area corresponding to the shape of the crystal (Figure 2). These properties coincide with those of uraninite, a mixture of UO_2 and UO_3 with varying amounts of lead, rare earths and thorium which crystallizes in the isometric system. Uraninite is found in both pegmatites and veins; it differs from pitchblende, of similar chemical composition, in that it occurs as crystals, rather than as botryoidal, amorphous masses.

Extent and Concentration

Persistence horizontally and in depth. Veins 1 and 2 have been traced for over 2200 feet and 1000 feet, respectively, through vertical distances of approximately 1000 feet. They vary in thickness from a few inches to several feet.

Figure 29 shows that the uraninite, insofar as radioactivity is an accurate indicator, is distributed rather erratically along vein number 1 at the 5500 and 5900 foot levels. A prospect pit at 6200 feet (Location 1, Figure 6) shows a high radioactive intensity, as do several other prospect pits at slightly lower elevations along the strike of the vein. The 5250 foot level adit contains only three or four isolated spots which are fairly radioactive. At the 5170 foot level, one very small, intensely radioactive area and another mildly radioactive area (Locations 10 and 11, Figure 6) are in small veins not known to be connected with the main vein. These are at the lowest elevation at which uraninite has been found. In vein number 1, therefore, the minimum horizontal and vertical extents in which uraninite is known to occur are 1600 and 1000 feet, respectively.

There are no mine workings in vein number 2, and persistence of the uraninite along the strike and dip is more difficult to determine, particularly since much of the outcrop is talus covered. Locations 13 to 17 (Figure 6) are all radioactive in varying degree, seventeen most intensely and thirteen next. The elevation of thirteen is 6200 feet. This indicates horizontal and vertical extents of approximately 1000 and 650 feet.

Concentration. The bar graph of Figure 29 shows only relative radioactive intensities and does not, except in a relative way, indicate the quantity of uraninite in the veins. The following table, taken from Black's report (1948, p. 82), shows the percentage of uraninite in a number of samples.

Table 6

EQUIVALENT PERCENTAGES OF U_3O_8 IN EIGHT REPRESENTATIVE SAMPLES

Location	Description	U_3O_8(%)
6150 open-cut	Moderate amount of sulfides	0.75
5900 level	Abundant sulfides	0.021
5500 level dump	Molybdenite, other sulfides	0.14
5500 level dump	Hornblende, some sulfides	0.56
5900 level	Hornblende, some sulfides	0.065
5250 level	Altered hornblende	0.02
5500 level dump	Altered wall rock	0.43
5900 level	Carbonate veinlets in hble.	0.18

From information in the above table, it may be assumed that the longest bars in Figure 29 represent ore with equivalent percentages of at least 0.06 per cent U_3O_8 and that the other bars represent ore with decreasing amounts, the minimum of which is probably close to 0.01 per cent U_3O_8. In analyses of thirty-six samples taken by Stevenson (1949, p. 87), the percentages of U_3O_8 varied from 0.001 to 0.75, with fifty-eight per cent of the samples above 0.01 per cent U_3O_8.

Appearance of the Uraninite

Aggregate forms. The aggregate forms taken by the uraninite include solid, barely visible veinlets (Figures 19 and 21); linear clusters of disseminated crystals which appear megascopically as veinlets (Figures 11, 12 and 18); zones of disseminated crystals without a definite pattern (Figures 13, 15 and 16); and solid, apparently isolated pockets (Figure 14). These are usually microscopic in size and cannot definitely be identified in the hand specimen, even where some of the veinlets are large enough to be visible, because of similar appearing veinlets of orthite and other dark minerals. The solid veinlets and pockets are rare as compared to the disseminated form.

Individual crystals. Except where the uraninite occurs in solid veinlets or pockets, its crystals are euhedral to subhedral in shape. Perfect cubes are sometimes seen, particularly in hornblende, in cases where the pleochroic halo is light enough to permit observation of the crystal (Figure 23). Octahedral and rounded forms seem to be more prevalent in the larger grains (Figures 27 and 28).

Grain size varies from less than 0.02 mm (Figure 23) to somewhat larger than 0.1 mm (Figure 28). An apparent relationship exists between grain size and the composition of the enclosing mineral. In fifty-seven uraninite-bearing thin sections, the diameter of the uraninite crystals was consistently close to 0.02 mm in hornblende (Figures 23 and 25), approximately 0.08 mm in orthite (Figure 26) and over 0.1 mm in feldspar (Figures 27 and 28).

Uraninite Deposition

Structural controls. The uranium-bearing ore solutions rose along channels provided by the east-west striking faults of veins 1, 2 and 3; the northeasterly striking fault of the cross vein; and smaller shears (Locations 10 and 11, Figure 6) which are possible extensions of the main, Number 1 fault. Specific structural features within these channels which controlled uraninite deposition appear to differ considerably from one another. At Location 10, an isolated pocket of uraninite, disseminated in altered granodiorite, occurs at the intersection of a narrow joint, near which the granodiorite has been leached of mafics, and a five inch vein composed of calcite, quartz and a hematite alteration product. All of the uraninite is within the altered granodiorite. In the 5500 level adit, uraninite forms numerous, isolated pockets along both narrow and wide portions of the vein. The most strongly radioactive area (Location 9, Figure 6) is one in which the andesite, highly altered to quartz and calcite, is offset by a two foot shear zone in the granodiorite. The uraninite occurs within the sheared and brecciated granodiorite; very little is in the altered dike material. Most of the uraninite in the 5900 foot level adit is distributed thinly along a smooth, slickensided fault surface (Locations 2 and 3, Figure 6). Within a distance of one or two feet along this surface, radioactive intensity passes through a very wide range of values, indicating the erratic, and apparently haphazard, distribution of the uraninite.

On a microscopic scale, uranium-bearing solutions were guided by a variety of structures; among them are: simple fractures cutting across two or more crystals or through massive, more or less homogeneous material (Figures 17, 19, 20, 21, 22 and 26); shear zones, either within a single mineral aggregate (Figures 11 and 14) or along the contact between aggregates of dissimilar minerals (Figures 8, 9, 12 and 18); cleavage cracks and crystal boundaries (Figures 16, 23 and 25); no apparent controlling structure (Figures 27 and 28). Often two or more of these structures are combined.

Mineralogical controls. Of approximately two hundred thin sections from the locations given in Figure 6, fifty-seven contained uraninite in appreciable quantity. Table 7 shows the composition of each of the fifty-seven thin sections as well as those minerals which act as hosts for the uraninite.

Hornblende, the most abundant gangue mineral, is also the most frequent host mineral for uraninite.

Molybdenite, not so abundant, usually is associated with uraninite where both occur in the same section. It also is more abundant in the uraninite-bearing sections than it is in the total number of sections made, occurring in only 12.4 per

Table 7*

HOST MINERALS FOR URANINITE IN 57 THIN SECTIONS

Arsenopyrite	x	x	x	x		x	x							x	x	x			x	x	x		x	x	x	x	x	x	x	x		x		x	x	x	x	⊗		x	⊗	⊗	x	⊗	x	x	x	⊗						x		x	x
Molybdenite	x																		x						⊗	x		⊗										⊗		x	⊗	⊗			⊗	⊗				⊗				⊗	⊗		
Hornblende	⊗	⊗	⊗		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗		⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗						⊗		x	x	⊗	x	⊗	x	⊗	⊗	⊗	⊗	x		
Feldspar	x	x		⊗															⊗	x	x	⊗	x	x			x		⊗	x	x	x		x	x	⊗																x	x			x	x
Quartz	x	x		x	x	x	x		x	x			x	x	x		x	x		x	x			x		x		x	x	x	x	x					x		x		x	x			x	x		x		x	x	x	x		x	x	x
Calcite					x	x	x		x	x			x				x												x	x	x	x	x	x	x		x																				
Orthite	x	x	x	x	x					x												x			x	x		x										x		⊗	x	⊗	⊗					⊗	x				x		x		
Scapolite			x						x	x									x						x																									x		x			x		
Sphene										x																																										x					
Apatite	x	x	x			x													x						x										x		x			x			x				x						x	x	x	x	
Sericite				x												x													x																							x				⊗	⊗
Chlorite				x		x	x							x	x	⊗															x				⊗	x							x														
Hematite	x		x				x	⊗																					x											x	x	x	x		x	x		x									
Amorph. SiO_2								⊗										⊗																																							
Biotite																	⊗																		x	x																					
Muscovite																																																								x	x

*<u>Explanation</u>: Table 7 gives the mineral compositions of the 57 thin sections, each being represented by a vertical column. The symbol "x" indicates that the section contains the corresponding mineral in the left-hand column; the symbol "⊗" means that it acts as a host mineral for uraninite.

From Table 7, the following data may be computed:

<u>Mineral</u>	Per Cent of Total Sections Containing the Mineral	Per Cent of the Sections Containing the Mineral in Which It Acts as a Host for Uraninite
Arsenopyrite	66.5	13.2
Molybdenite	24.6	71.5
Hornblende	84.2	83.5
Feldspar	36.8	23.8
Quartz	63.1	--
Calcite	28.1	--
Orthite	33.4	21.0
Scapolite	14.0	--
Sphene	3.5	--
Apatite	26.3	--
Sericite	10.5	33.3

From Table 7 - Continued.

Mineral	Per Cent of Total Sections Containing the Mineral	Per Cent of the Sections Containing the Mineral in Which It Acts as a Host for Uraninite
Chlorite	17.5	20.0
Hematite	21.0	8.3
Amorph. SiO_2	3.5	100.0
Biotite	5.3	33.3
Muscovite	3.5	--

cent of the latter. In four of the five cases in which hornblende does not act as a uraninite host mineral, molybdenite fulfills this function.

Feldspar, orthite, sericite, chlorite and biotite all contain uraninite fairly often. It should be noted, however, that biotite is relatively rare and the above figures have little meaning with respect to its role as a host mineral. This also applies to amorphous silica, which contains uraninite in both of its occurrences. Arsenopyrite and the hematitic alteration product derived from it also sometimes enclose uraninite.

Quartz, calcite, scapolite and apatite, which occur frequently, do not act as host minerals in any of the sections.

The above information does not conclusively prove that any one of the above minerals is chemically more susceptible to replacement by uraninite than any of the others. Since hornblende is the most abundant mineral in the veins, chance alone would make it the most frequent host, assuming that all the minerals were equally susceptible to replacement. Other confirmatory evidence is needed. This is supplied by observing instances in which two or more of the host minerals occur together, each having an equal opportunity for receiving the uranium-bearing solutions and causing precipitation. In nearly all such cases, the uraninite shows a marked preference for hornblende and, if present, molybdenite.

Physical controls. The hypothermal conditions under which most of the mineralization took place have already been discussed. Evidence that uraninite was immediately after molybdenite in order of deposition is provided by its very close association with that mineral in a number of thin sections (Figures 7-10), following the same microstructures and apparently replacing it. Since molybdenite is known to form predominantly under hypothermal and lower mesothermal conditions, it is reasonably safe to infer that uraninite formed at a stage of mineralization still fairly close to hypothermal conditions, rather than at a later, cooler stage.

Alteration Effects Produced by the Uraninite

Most striking of the alteration effects of the uraninite are the pleochroic halos surrounding crystals which occur in either hornblende or orthite. In hornblende (Figures 23 and 25), uraninite crystals tend to be small, often exhibiting perfect cubic crystal form, and the pleochroic halos very large in comparison. The reverse is true in orthite (Figure 26) where uraninite crystals are larger and the halos form a narrow, distinct ring around them. No halos were observed in any of the other host minerals.

Where uraninite is in close association with arsenopyrite, especially in hornblende, a red-brown stain, probably hematitic in composition, usually forms. This material is very mobile and permeates much of the surrounding rock through small fractures and other microstructures (Figure 24).

Feldspar, both in pegmatites within the veins and in granodiorite near the veins, is often altered pink, particularly near uranium-bearing zones. In one of the thin sections examined, a pink alteration product is formed in an orthoclase crystal near a few grains of uraninite; further away, in the same crystal, it is entirely absent. In several other sections with apparently the same pink alteration product, however, no uraninite is present, making definite conclusions as to the role of radioactivity with respect to the alteration impossible.

At Location 10 (Figure 6), radioactive intensity and red coloration of the granodiorite are in direct proportion to each other. Autoradiographs (Figure 2) show that specimens from the most deeply colored granodiorite contain the most uraninite. Microscopic examination shows that the redness is due to a large number of minute flecks of hematitic material in the altered granodiorite, principally within the feldspar (Figures 13 and 27).

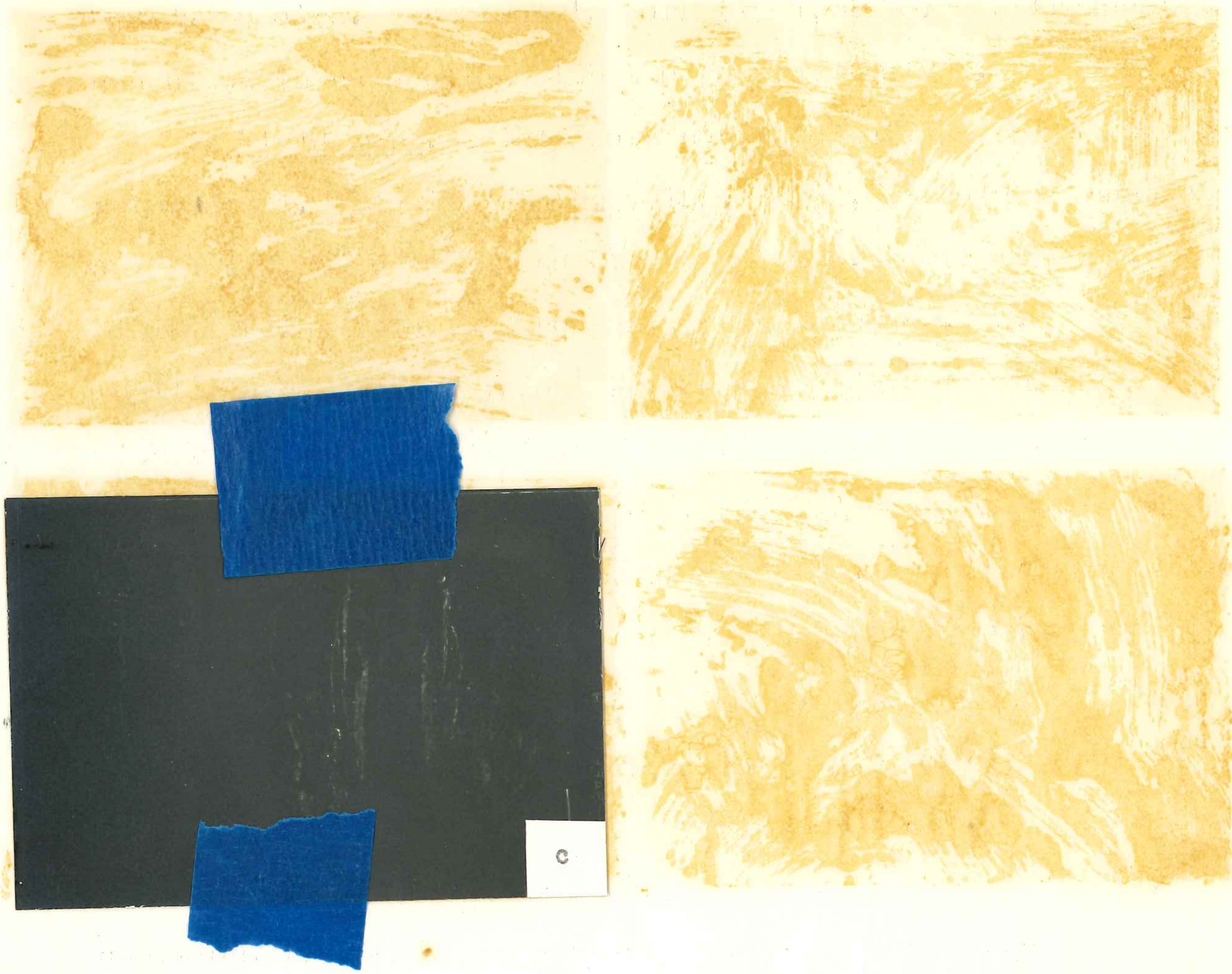


Figure 2

AUTORADIOGRAPHS OF URANINITE-BEARING THIN SECTIONS

sections. The uraninite could be identified in a section simply by superimposing the corresponding negative over it in the field of view of the microscope.

Initial difficulties in matching the section and negative were overcome by using high contrast process film and applying gentle pressure during exposure. This resulted in the

Figure 27
Uraninite in highly altered plagioclase cut by later quartz. The crystals average 0.1 mm. in diameter. Flecks of hematite color the feldspar red. X 60. Pl. light. Loc. 10. Section D-1.

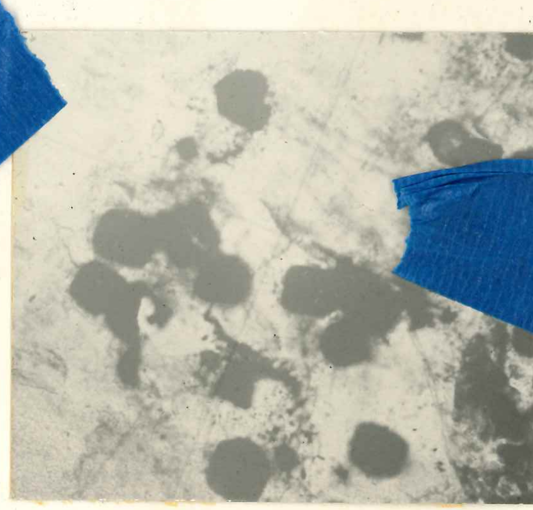


Figure 28
Crystals of uraninite in orthoclase. The uraninite crystals average 0.1 mm. in diameter. X 60. Plain light. Loc. 1. Section A-9.

Figure 7
Molybdenite (large grains) and uraninite in hornblende and apatite. The Uraninite occurs as small grains in molybdenite and hornblende. X 16. Plain light. Loc. 12. Section C-10.

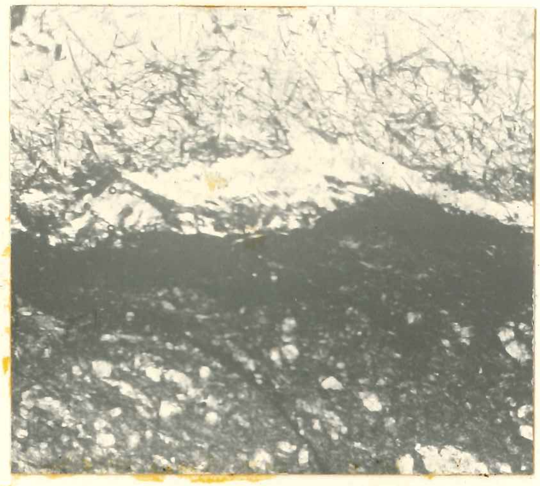


Figure 8
Veinlet of uraninite at contact between sheared hornblende-scapolite zone and coarse grained quartz with hornblende inclusions X 16. Pl. light. Loc. 3-4. Section B 6.4.

Figure 9
Veinlet of molybdenite and uraninite in hornblende, orthite and quartz, with halos along edges of the veinlet. X 16. Pl. light. Loc. 12. Section C-9

Figure 10
Molybdenite (large grains) and uraninite (small grains) disseminated in hornblende. X 60. Pl. light. Loc. 8. Section C-3.5.

Figure 11
Uraninite in hornblende shear. Actual crystals are much smaller than black spots, which are pleochroic halos. X 16. Pl. light. Loc. 1. Section A-6.

Figure 12
Uraninite veinlet in shear between orthoclase and hornblende. Pl. light. Loc. 13. Section M-4.

Figure 13
Uraninite in altered granodiorite with later quartz. The mottled appearance is caused by tiny flecks of red hematite. X 16. Pl. light. Loc. 10. Section D-1.

Figure 14
Pocket of uraninite in sheared horn blende. The surrounding hornblende is altered brown. X 16. Loc. 4. Section B-7.6.

Figure 19
Veinlets of uraninite in colloidal silica with a little crystalline quartz. X 16. Point near Loc. 17. Pl. light. Section J-5.

Figure 20
Uraninite and molybdenite veinlets in arsenopyrite. Uraninite (black) forms crystals along fractures in arsenopyrite. X 16. Polished sec. Loc. 2. Sec. B-1.

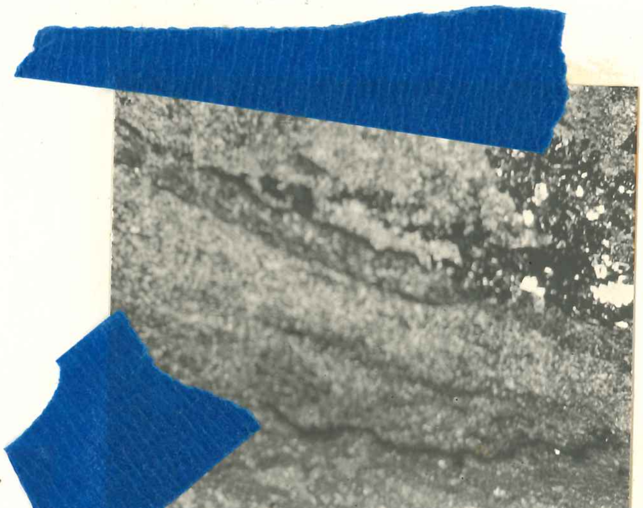


Figure 21
Veinlets of uraninite in fine grained mixture of hornblende, chlorite and quartz. X 16. Pl. light. Loc. 17. Section I-1.

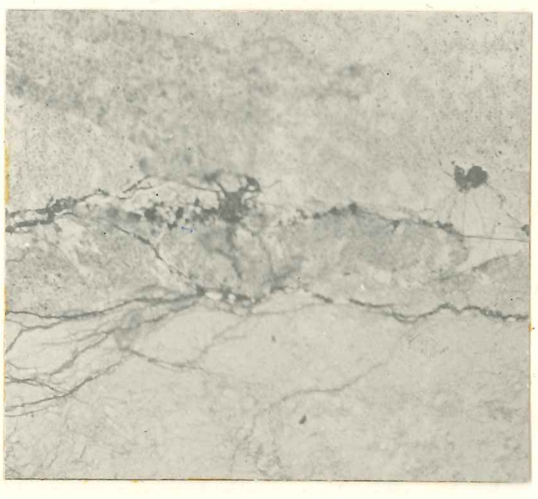


Figure 22
Uraninite crystals (slightly above center) between altered and unaltered orthoclase. Size of crystals 0.1 mm. X 16. Pl. light. Location 16. Section K-3.

Figure 23
Crystals of uraninite in hornblende. The pleochroic halos are 0.1 mm. and the crystals, 0.02 mm. in diameter. X 60. Plain light. Loc. 1. Sec. A-8.

Figure 24
Uraninite crystals with pleochroic halos. The hornblende is reddish-brown near the uraninite. X 60. Pl. light. Loc. 13. Section M-5.

Figure 25
Uraninite crystals in hornblende. The halos average less than 0.1 mm. in diameter. X 60. Pl. light. Loc. 1 Section A-5.

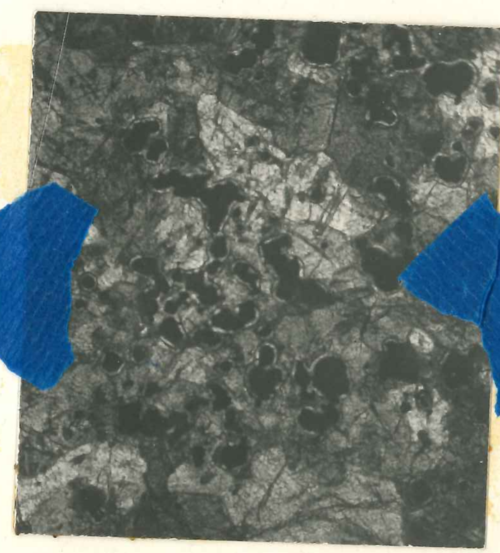


Figure 26
Uraninite in orthite. The halos are smaller than those in hornblende. The larger crystals are less than 0.1 mm. in diameter. X 60. Pl. light. Loc. 2. Sec. B-11

Figure 15
Clusters of uraninite in fine grained hornblende (black) and biotite (gray). Light mineral, with no uraninite, is calcite. X 16. Plain light. Loc. 17. Section J-2.

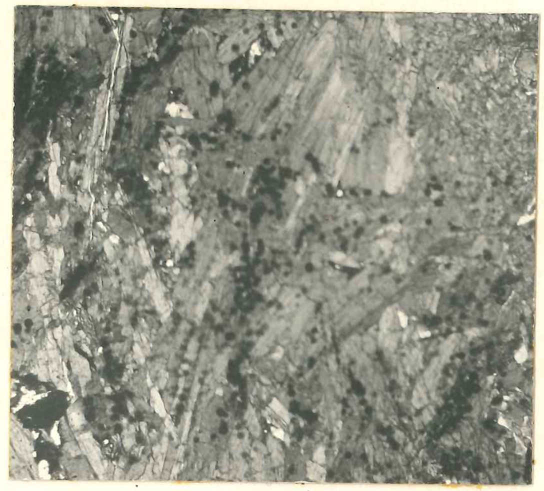


Figure 16
Uraninite crystals in hornblende along cleavage cracks and crystal boundaries. X 16. Pl. light. Location 1. Section A-4.

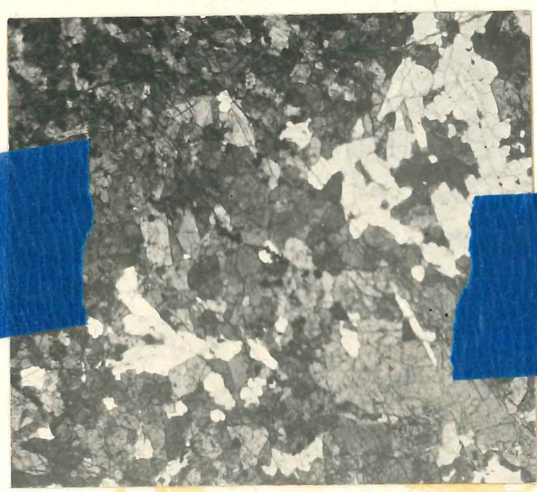


Figure 17
Uraninite crystals along minute fractures in orthite and apatite (center). X 16. Plain light. Loc. 2. Section B-1.1.

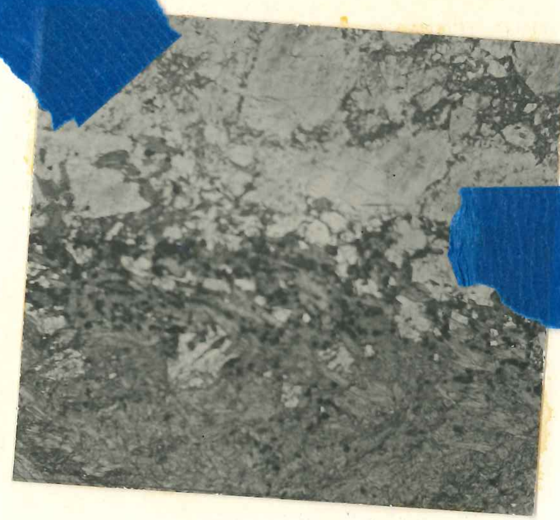


Figure 18
Uraninite crystals along sheared contact between hornblende and orthoclase. X 16. Plain light. Loc. 1. Section A-5.

CHAPTER V

SUMMARY AND CONCLUSIONS

Mineral deposits in the Hazelton district are associated with a number of granodioritic intrusions into Jurassic and Lower Cretaceous sediments of the Hazelton group. These deposits exhibit a definite regional pattern of temperature zoning. High temperature deposits form a cluster near the western margin of the Rocher Deboule batholith - largest of the intrusions in the area - and lower temperature deposits are near the smaller intrusions to the north.

The Victoria property is one of the group of hypothermal deposits, and its veins, which strike easterly, are entirely within the Rocher Deboule granodiorite, terminating rather abruptly at the sedimentary contact. In the same plane as the two principal veins are an andesite dike and a feldspar porphyry dike. These are sheared in many places by the pre-vein faulting, suggesting that they acted as zones of weakness along which faulting took place. The vein minerals, hornblende, orthoclase, quartz, orthite, scapolite, sphene, apatite, calcite, chlorite, complex sulfarsenides with gold, molybdenite and uraninite indicate definitely a hypothermal origin for the deposit. Hornblende is by far the most abundant of the gangue minerals and arsenopyrite, of the ore minerals. In order of deposition, most of the gangue minerals preceded the ore minerals; exceptions are later quartz and calcite. Of the ore minerals, arsenopyrite was deposited first, followed by molybdenite and uraninite. The latter two were apparently very close in paragenesis, occupying the same minute fractures, cleavage cracks and other microstructures.

Spectrochemical analysis of the radioactive mineral from the veins of the property has shown it to be uraninite, a dense, black mineral which crystallizes in the isometric system as the crystalline form of pitchblende. Approximately forty samples of ore containing uraninite varied from 0.003 to 0.75 equivalent per cent of U_3O_8, with more than half over 0.01 per cent. The uraninite crystals are very small, few exceeding 0.1 millimeters in diameter. They occur mainly as clusters, disseminated along linear zones principally in the hornblende, but often in other minerals. In rare cases, solid veinlets or pockets of uraninite occur.

Within the veins, the uraninite has a very erratic distribution, both vertically and horizontally, and evidence of definite structural control is lacking except on a microscopic scale. Minute fractures and shears, cleavage cracks and other microstructures can all be seen to have acted as ore solution channels.

During deposition, hornblende and molybdenite were most favorable host minerals for the uraninite; orthoclase, orthite, sericite, chlorite, biotite, amorphous silica and arsenopyrite often enclose it; quartz, calcite, scapolite and apatite, although fairly plentiful in the veins, rarely contain any uraninite. The close paragenetic relationship between molybdenite and uraninite during the later stages of mineralization suggest that temperature was still fairly high during deposition of the uraninite, since molybdenite is usually formed under hypothermal to mesothermal conditions.

Alteration effects produced by the uraninite vary according to the composition of the associated minerals. In both hornblende and orthite, pleochroic halos surround individual crystals of uraninite. Hematite stains often result from the close association of uraninite and arsenopyrite, particularly if both are enclosed by hornblende. Numerous minute flecks of a red hematitic alteration product in the granodiorite at one location are definitely caused by uraninite. Pink coloration of feldspar near uraninite-bearing zones also appears to have some relation to the uraninite, but this is not certain.

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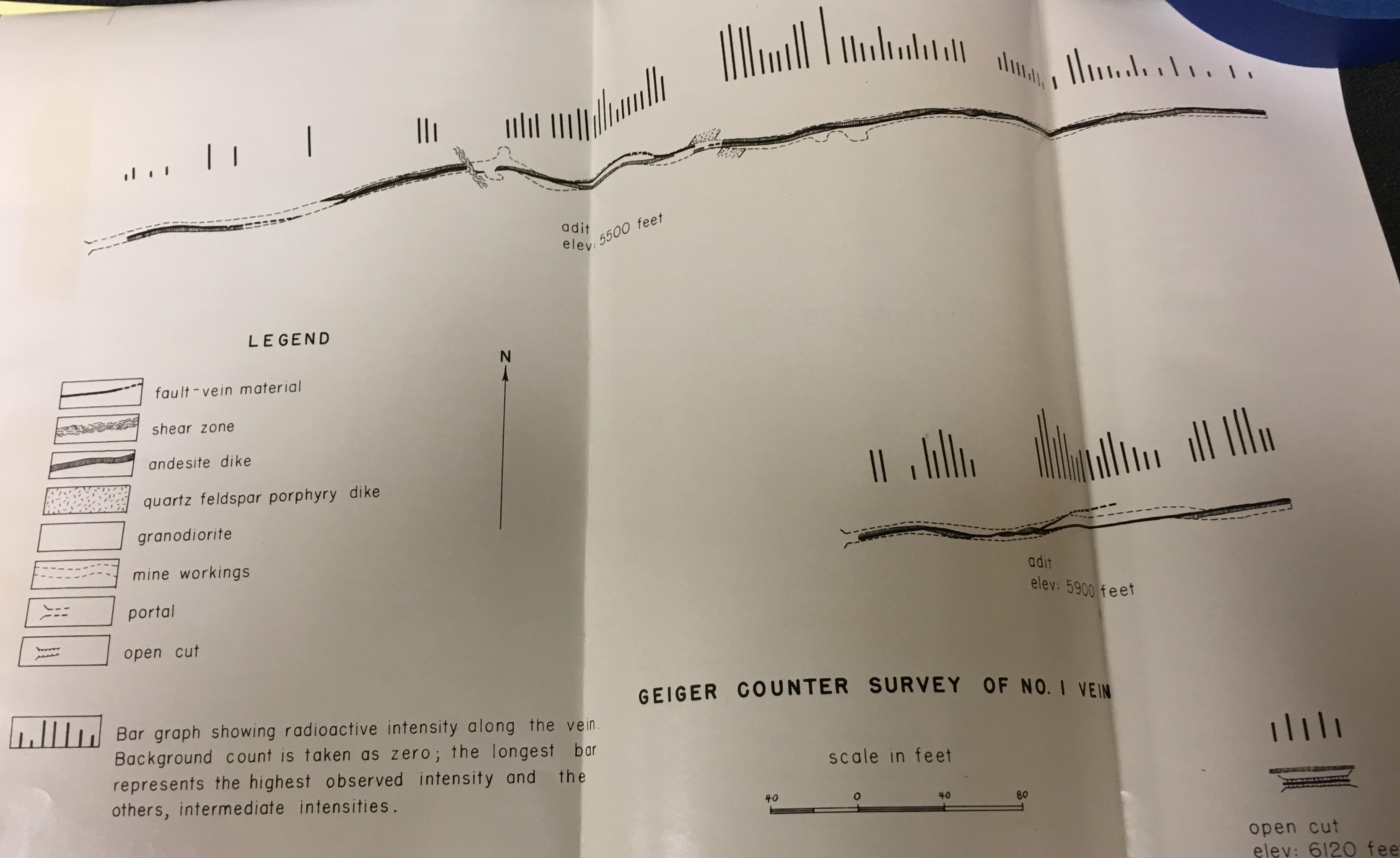
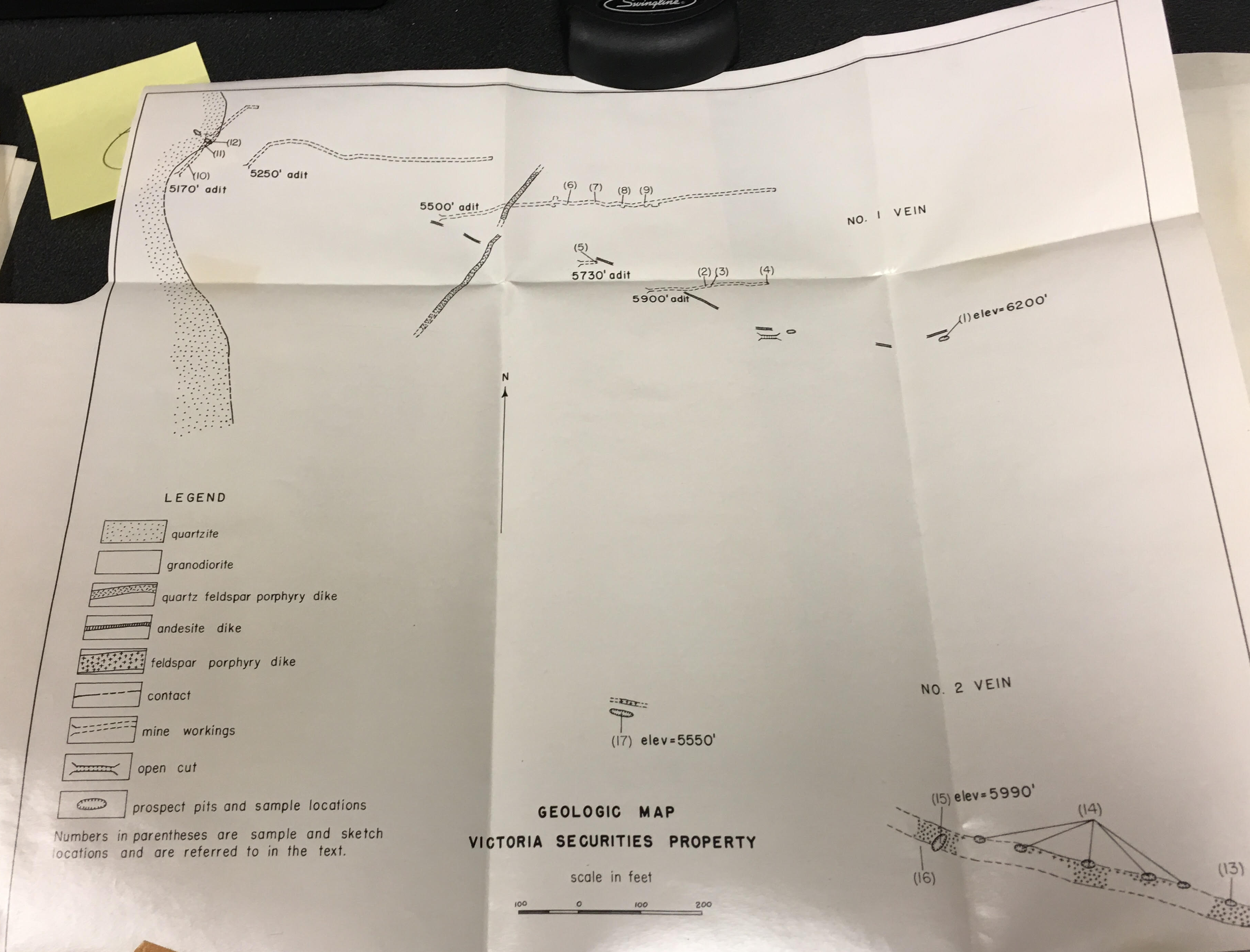


GEIGER COUNTER SURVEY OF NO. I VEIN



GEOLOGIC MAP
VICTORIA SECURITIES PROPERTY