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A PETROGRAPHIC DESCRIPTION OF THE WALL-ROCKS AND ALTERATION PRODUCTS ASSOCIATED WITH PITCHBLENDE-BEARING VEINS IN THE GOLDFIELDS REGION, SASKATCHEWAN

(Report and Figure)

By

K. R. Dawson

OTTAWA

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(Preliminary Account)

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A PETROGRAPHIC DESCRIPTION OF WALL-ROCKS AND ALTERATION PRODUCTS ASSOCIATED WITH PITCHBLENDE-BEARING VEINS IN THE GOLDFIELDS REGION, SASKATCHEWAN

INTRODUCTION

GENERAL STATEMENT

This investigation was undertaken to determine the nature of the wall-rock alteration associated with the pitchblende-bearing veins in the Goldfields-Martin Lake map-areas (Christie, 1949)[1], in an effort to establish additional criteria to aid in the search for that mineral.

The geology of this area has been capably described by Christie, and an interim report on the mineralogy has been published (Robinson, 1950). Field investigations were carried out during the 1950 field season when many mineralized zones were studied and collections made for laboratory study at the University of Toronto.

The present preliminary account deals with investigations made on specimens collected from the Ace Lake mine, the Martin Lake mine, and Tam prospect, all of Eldorado Mining and Refining (1944) Limited. It is expected that more complete data will be published when further laboratory and field work have been done.

ACKNOWLEDGMENTS

The co-operation of E. B. Gillanders, mine manager and manager of the Exploration Division, S. N. Kesten, E. E. N. Smith, R. Edie, and N. Grant, all of Eldorado Mining and Refining (1944) Limited, is gratefully acknowledged, as are also the advice and assistance of Professors W. W. Moorhouse and F. G. Smith, of the University of Toronto. S. C. Robinson very kindly collected specimen material for the writer. In addition, thanks are due to Mr. George Cumming, field assistant, and to all others who have contributed in any manner to the success of this project.

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[1]Names and dates in parentheses indicate references listed at the end of the report.

LABORATORY METHODS

Numerous thin sections have been cut from specimens of the altered wall-rocks for microscopic study. The specimens were obtained as part of a program intended to show the variations in texture and mineral content at measured distances from the pitchblende occurrences.

Many specific gravity determinations have been made on material obtained for this purpose, and, in addition, on material that has been sectioned. In the first case, the data will be used to complete the descriptions of the various host rocks, whereas in the second it will be used to indicate the nature of the density changes that have taken place in the rocks due to alteration. These data are compiled in a series of illustrative tables in the body of the report.

Several samples of fresh rock chips were collected for chemical analyses, which are expected to supply additional information regarding the chemical changes resulting from the hydrothermal alteration of the various wall-rocks.

Where the mineral constitutents are sufficiently coarse, rock specimens will be crushed and the minerals will be separated for other optical tests to establish their identity. In addition, mode counts are being made, using a technique recently adapted to thin section analysis (Chayes, 1949). These data will be prsented as modes or, if they illustrate the origin of the metamorphosed rocks, will be recalculated to approximate chemical compositions[1].

GEOLOGY OF THE REGION

GENERAL STATEMENT

The Goldfields region of northern Saskatchewan lies between latitudes 59°15' and 59°45' and longitudes 108°15' and 108°45', near the southern edge of the Precambrian Canadian Shield immediately north

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[1] In the report the terms 'recalculated chemical composition' and 'approximate chemical composition' indicate that the analysis in question has been calculated from mode counts and is, therefore, not a chemical analysis.

of Lake Athabasca.

The bedrock formations are entirely of Precambrian age and are obscured here and there by Pleistocene drift and Recent stream, lake, and swamp deposits. The Precambrian rocks can be subdivided into two major components, separated by a marked angular unconformity. These are the Tazin group and the Athabasca series. The former has been mapped as Archaean or Proterozoic (Christie, 1949), but shows marked similarities to the early Proterozoic formations described from the Nonacho and Great Slave Lakes (Henderson, 1948). The latter has been mapped as Proterozoic, and is restricted to structural basins in the vicinity of Beaverlodge Lake.

TABLE OF FORMATIONS

The following table of formations has been drawn up to illustrate conditions observed in the vicinity of the radioactive occurrences studied. The rocks that serve as wall-rocks to pitchblende veins in this area are marked by x, in parentheses.

Era		Formations and lithology
PROTEROZOIC		Diabase dykes (x)
	Athabasca series	Meta-basalt flows (x)
		Arkose and feldspathic sandstone (x)
		Conglomerate (x)
		Unconformity
ARCHAEAN OR PROTEROZOIC		Lamprophyre dykes
		Granite, oligoclase alaskite, and granite-gneiss; locally mylonitized (x)
		Oligoclasite[1], syenite-pegmatite (x)
		Meta-gabbro (x)
		Intrusive contact
	Tazin group	Greywacke; may be metamorphosed to paragneiss or mylonite (x)
		Greenstone; probably altered flows (x)
		Argillite; may be metamorphosed to chlorite or chlorite-muscovite schist and mylonite (x)
		Quartzite; may be metamorphosed to sericite schist (x)
		Conglomerate
		Dolomite, dolomitic quartzite, dolomitic argillite; may be metamorphosed to pyroxenite, amphibolite, and epidote amphibolite

[1] This name is applied to a group of rocks in which the dominant constituent is sodic oligoclase and the minor constituents are quartz, calcite, dolomite, chlorite, apatite, and sericite. The rocks range from coarse to fine grained. In most cases they are irregular in outline, as feldspathic replacement bodies in a variety of host rocks.

TAZIN GROUP

The Tazin group is dominantly a sedimentary series, but includes a few lava flows. It has been subjected to regional metamorphism that has altered the sediments to crystalline limestones, amphibolites, quartzite, argillite, and, in extreme cases, to a variety of banded paragneisses. The lavas in the occurrence studied have been altered to the greenschist facies. The group has been intruded by gabbro sills, gneissic granites, lamprophyre dykes, and a variety of red, acidic rocks ranging from oligoclasite to feldspar porphyry. All of these rocks, with the exception of the conglomerate and most paragneisses, carry pitchblende. In this report, the discussion of the distribution of the rocks will be limited to those that outcrop on the properties described.

Quartzite

The bulk of the Tazin quartzite outcrops south of the St. Louis fault, with the exception of scattered bands, such as on the Tam prospect, and in the paragneisses to the north. It is associated with amphibolites south and east of Beaverlodge Lake and west of Lodge Bay. The quartzite studied for this report outcrops on the Tam prospect, where it is interbedded with argillites and greenstones.

Amphibolite

Amphibolites have a wide distribution in the Goldfields region, as narrow bands within the paragneisses north of Beaverlodge Lake and as intrusive sills and flows associated with the quartzite in the southern part of the area. The rock studied for this report is an epidote amphibolite, and its known distribution is limited to the Ace Lake mine.

Chlorite Schist

Bands of chlorite schist are rare in the Goldfields region, and have only been found in the vicinity of the Crackingstone and St. Louis faults. The sinuous, narrow band that lies north of the St. Louis fault on the Ace Lake property is the only one discussed here. The rock separates the epidote amphibolite from the micaceous northern border of the oligoclasite lenses on that property.

Chlorite-muscovite Schist

The only known occurrence of chlorite-muscovite schist is in the vicinity of the St. Louis fault on the Ace Lake property, where it outcrops as a narrow, sinuous band along the north side of the red oligoclasite lenses. It is also known to outcrop as a band within the oligoclasite lens on the shore of Ace Lake.

Argillite

Argillite is limited in its distribution to a narrow band parallel with the St. Louis fault. It outcrops at the head of Ato Bay on the Tam prospect, on the Ace Lake property north of the St. Louis fault, and farther to the northeast on the Bolger prospect both north and south of the St. Louis fault. Specimens of the argillite have been studied from the Tam prospect and the Ace Lake property.

Oligoclasite

The name 'oligoclasite' is applied in this report to feldspathic replacement of a considerable variety of rock types. The process is very well illustrated in the Goldfields area, particularly around the north end of Beaverlodge Lake. Argillites, chlorite schists, granites, paragneisses, and mylonites have been hydrothermally replaced by red feldspar, which ranges in grain size from very fine to coarse. The rock has been studied on the Ace Lake property and the Tam prospect.

ATHABASCA SERIES

The Athabasca series is characterized by a limited variety of rock types, which include conglomerate, feldspathic sandstone or arkose, and meta-basalt flows. Radioactive veins have been discovered in all of these rocks, but to date have proved most significant in the meta-basalts west of Beaverlodge Lake. These rocks are restricted to structural basins and down-faulted blocks on the south sides of such faults as the Crackingstone and the St. Louis.

Feldspathic Sandstone

Feldspathic sandstone is as widely distributed as any of the Athabasca sedimentary rocks, outcropping as massive beds in the Martin Lake syncline, and elsewhere interbedded with the conglomerates. Specimen material used for this report has all been collected from the Martin Lake syncline, and, specifically, the Martin Lake mine.

Meta-basalt

The meta-basalts are massive and amygdaloidal flows, which outcrop in the Martin Lake syncline interbedded with the feldspathic sandstones. Specimen material has been collected for study from the flows, which outcrop on the Martin Lake mine property.

STRUCTURAL FEATURES

Rocks of the Tazin group were laid down in a conformable succession over an area of unknown dimensions. They were intruded by basic sills before, or after, a period of folding, and remnants of folds still persist. These can be seen around the south end of Beaverlodge Lake, along the north shore of Lake Athabasca, and to the north in the paragneisses. They have been deeply buried and probably intruded by granites.

During this period of deformation, and probably before granitization of the Tazin sediments, the rocks were mylonitized along well-defined zones. Such rocks outcrop along the Crackingstone fault north of Martin Lake, south of Sybil Lake, north of Verna Lake, and on the Donaldson prospect.

The Athabasca sedimentary rocks and associated lavas have been subjected to considerable erosion and mild folding since their deposition in structural basins around Martin and Fredette Lakes. Additional patches of the conglomerate and arkose have been preserved as down-faulted blocks along the south side of several late faults in the area.

The two major faults in the area are the St. Louis, which extends from Ato Bay northeasterly to Raggs Lake, and the Crackingstone, which parallels it, from the head of Black Bay to Anne Lake. The former shows a horizontal movement, estimated at 1,100 feet, of the northwest side towards the northeast (Christie, 1949, p. 15). No estimates are available on the Crackingstone fault. Clay gouge has been found in both of these faults and in others thought to be of the same age. Probably during the same period of deformation, the Martin Lake syncline subsided, causing the cross-faults, which have since been mineralized. At the same time, the Tazin rocks also underwent deform tion, resulting in faults and breccia zones. Schist zones are poorly developed but do occur near the late faults. Minor faults are particularly abundant in the area where the two main faults converge.

WALL-ROCK ALTERATION AT THE ACE LAKE MINE

GEOLOGY OF THE PROPERTY

(See Figure 1B)

The geology in the immediate vicinity of the Ace Lake inclined shaft is illustrated by the accompanying plan. Epidote amphibolite outcrops along the north side of the area, succeeded towards the south by chlorite schist, chlorite-muscovite schist, and oligoclasite. South of the St. Louis fault, which strikes north 65 degrees east and dips southeast at 45 degrees, a remnant of the Athabasca series, consisting of sandstone and conglomerate, has been preserved as a down-faulted block. The pitchblende veins have not been observed in these sedimentary rocks.

The epidote amphibolite outcrops along the north edge of the area mapped on the Ace Lake property. It forms the north wall of the chlorite schist zone and parallels the St. Louis fault zone except near the shore of Ace Lake where it bends to strike north 45 degrees east.

The chlorite schist forms an irregular sinuous band up to 40 feet wide, which outcrops south and west of the shaft between the oligoclasite and the epidote amphibolite. It strikes roughly parallel with the fault, and dips steeply south. It is bordered on the south by a narrow band of muscovite-chlorite schist, and conforms to the outline of the oligoclasite lenses in the foot-wall of the St. Louis fault. East of the shaft, a band of this muscovite-bearing schist is incorporated within the dense red oligoclasite. Underground, there appear to be all gradations between the schist and the oligoclasite.

The oligoclasite is believed to be of hydrothermal origin, consisting mainly of fine red oligoclase (An_{15}), which has replaced the schist in a lit-par-lit fashion. Elsewhere, the oligoclasite is believed to be a feldspathized mylonite, as in the small outcrop southwest of the shaft. It occurs as tabular bodies immediately beneath the St. Louis fault zone. Surface exposures indicate that these bodies are lenticular. The age of the Ace Lake oligoclasite is of critical interest in determining the alteration resulting from the ore solutions. Information on hand is still inconclusive.

PETROGRAPHY OF THE HOST ROCKS

Epidote Amphibolite

The following table gives the results of five specific gravity determinations for the epidote amphibolite:

Maximum density	Minimum density	Average density	Tests
3.114	3.003	3.063	5

The epidote amphibolite ranges from black to pale green, depending upon the amount of epidote present. The epidote fills veinlets that range in width from under $\frac{1}{16}$ to $\frac{1}{2}$ inch, and average $\frac{1}{8}$ inch, and that penetrate the rock parallel with the amphibole crystal lineation as well as across it.

Weathering reduces the colour of the rock to a bleached green, and also produces surface corrugations. The latter are commonly composed of epidote or quartz veinlets, many of which parallel the linear texture of the rock. The resulting appearance suggests sedimentary bedding, but there is no evidence of banding of any description on fresh surfaces.

Clastic deformation has produced joints and narrow breccia zones along which there rarely has been enough movement to rotate the fragments. In addition, the rock shows a well-developed linear texture, but is not schistose.

The following table of modes will serve to illustrate the mineral composition of the epidote amphibolite:

Mineral	Thin sections				
	G-24	A-24	A-43	A-45	G-22[1]
	%	%	%	%	%
Actinolite	54.6	59.0	38.6	51.6	21.2
Epidote-clinozoisite	14.2	14.6	39.5	33.6	66.1
Oligoclase	18.0	17.0	12.0	1.5	0.2
Quartz	10.7	1.5	6.8	1.5	4.8
Calcite	3.1	0.6	3.1	10.3	4.7
Hematite	-[2]	1.0	-	1.4	4.8
Sphene	-	6.9	-	-	-

Of the above modes, those obtained from sections G-24 and A-24 illustrate the composition of the epidote-free matrix, and the others represent rock containing varying numbers of epidote veinlets.

In order to determine the origin of the epidote amphibolite, two of the modes listed above have been recalculated to approximate chemical compositions. For the sake of comparison, two analyses of rocks believed to be analogous to those from which the epidote amphibolite was derived, and an analysis of gabbro, have been added.

[1] Thin section or specimen numbers.

[2] Dashes in modal or chemical analyses indicate that the constituent was not determined.

Oxide	I	II	III	IV	V
SiO_2	48.12	60.88	52.3	58.6	50.43
TiO_2	0.78	0.62	-	-	1.26
Al_2O_3	12.80	17.78	12.2	7.0	17.38
Fe_2O_3	1.60	1.94	5.2	8.7	3.43
FeO	3.25	4.07	4.4	-	6.45
MnO	0.09	-	-	-	0.12
MgO	2.55	3.53	5.8	8.4	5.45
CaO	10.77	2.77	16.8	12.6	9.52
Na_2O	0.60	2.65	1.1	1.8	2.78
K_2O	3.60	3.16	-	-	1.33
H_2O+	3.25	1.91)	1.4	1.1	1.42
H_2O-	1.70	0.13)			
P_2O_5	0.65	0.29	-	-	0.30
CO_2	9.19	-	1.2	1.2	0.14
SO_3	0.24	-	-	-	-
S	0.88	0.10	-	-	-
BaO	0.01	-	-	-	-
SrO	nil	-	-	-	-
C	0.24	1.70	-	-	-
	100.36	101.53	100.4	99.4	100.01

I. An analysis of an Ordovician marine calcareous shale; D. Schaaf analyst; Pettijohn, 1949, p. 285.

II. Knife Lake slate, Archean, Minn.; F. F. Grout analyst; average of three analyses; Pettijohn, 1949, p. 287.

III. Specimen A-43, epidote amphibolite, bearing a moderate number of epidote veinlets.

IV. Specimen G-24, epidote amphibolite, in which there are very few epidote veinlets.

V. Average of sixty-six olivine-free gabbros from the United States; Johannsen, vol. 3, 1937, p. 221.

It is apparent that there is a greater similarity between the calculated analyses for the epidote amphibolite and that of the calcareous marine shale than for that of the gabbro.

A simple calculation based upon the assumption that there has been no change in the lime and magnesia content of the rock provides some interesting figures. For example, thin section No. G-24 could have been derived from a shale containing 38.5 per cent dolomite and 1.4 per cent calcite.

The difference in value for alumina in analyses III and IV is due to the concentration of that oxide in the epidote. That oxide is commonly assumed to be stationary during the processes of metamorphism, but in this case appears to have been transported short distances to be concentrated in veinlets in the epidote amphibolite.

The rock is probably a product of the thermal metamorphism of a limy or dolomitic argillite, and is presently equivalent to the epidote amphibolite facies (Turner, 1948, p. 88).

The epidote amphibolite shows a granoblastic texture, with a pronounced fabric resulting from the orientation of the actinolite shreds. The grain size of the rock is uniformly fine, rarely exceeding 0.5 mm. The rock is holocrystalline, and the constituents, with the exception of some epidote and secondary albite, are anhedral. Veinlets of fine granular epidote, clinozoisite, oligoclase, and calcite cut the rock at all angles. Microscopic fracturing disrupts the linear fabric of the actinolite. Fragments of the matrix have been locally incorporated within the veinlets.

Actinolite is one of the major constituents. It occurs as elongated shreds, with the long axis of the grains twice the length of the short axis. The shreds form the linear fabric of the epidote amphibolite, which is so characteristic of that rock, and are locally sinuous where displaced by micro-faults. The other constituents occur either along the contacts among the shreds or are incorporated within them.

Epidote is not as abundant in the thin sections as clinozoisite despite the common occurrence of pale green veinlets. The veinlets contain mainly epidote individuals that show a pale green colour and higher birefringence than the colourless, disseminated, clinozoisite grains. Clinozoisite occurs in veinlets, but is more common as disseminations in the matrix of the rock. In the latter case, the grains may occur either along contacts of the actinolite shreds or else be incorporated in them.

Quartz and oligoclase are common felsic constituents, and owing to the common lack of twinning in the feldspar it has been difficult to distinguish between the two minerals. The vein oligoclase, on the other hand, is commonly twinned, either after the albite or carlsbad laws, and much of it is euhedral. The veinlets also carry specularite flakes and acicular inclusions of amphibole.

Calcite, like oligoclase, occurs both as ragged disseminated grains in the matrix and in late, crosscutting veinlets. The type shows twin lamellae, some of which may be bent, suggesting mild deformation.

The opaque minerals are accessory constituents. A sooty black mineral is disseminated in the matrix as small elongated aggregates paralleling the actinolite shreds. An occasional small grain of pyrite has been observed near the late veinlets. Specularite flakes are associated with albite and quartz in the late veinlets and adjoining parts of the thin sections.

Chlorite Schist

The following table is illustrative of the specific gravity of the chlorite schist:

Maximum density	Minimum density	Average density	Tests
2.846	2.746	2.796	3

The table below contains three modes that illustrate the mineralogical composition of the chlorite schist.

Minerals	Thin sections		
	A-49	A-42	A-36(2)
	%	%	%
Chlorite	40.0	48.0	44.5
Oligoclase	27.9	36.0	39.0
Quartz	8.3	-	-
Calcite	4.5	7.8	3.0
Epidote	5.5	5.9	10.5
Hematite	14.1[1]	2.4	3.0
White Mica[2]	-	-	-
Apatite[2]	-	-	-
Leucoxene[2]	-	-	-

[1] This section shows an abnormally high content of hematite owing to its concentration in a veinlet.

[2] The last three minerals occur in such small amounts that counts could not be made of them

The following table contains recalculated chemical compositions that illustrate the composition of the chlorite schist:

Oxides	A-49	A-42	A-36(2)
SiO_2	42.3	42.4	44.8
TiO_2	-	-	-
Al_2O_3	12.9	15.9	15.8
Fe_2O_3	16.5	5.0	7.7
FeO	-	-	-
MgO	14.5	17.4	16.1
CaO	3.6	5.6	3.9
Na_2O	3.3	4.3	4.6
K_2O	-	-	-
H_2O	5.3	6.3	6.0
CO_2	2.0	3.5	1.3
	100.4	100.4	100.2

A comparison of the above analyses with analyses I and II on p. 11 suggests that the chlorite schist is related in composition to a dolomitic shale. The rock is believed to have been an amphibolite that has been subjected to retrograde metamorphism and is now a member of the greenschist rather than the amphibolite facies.

Megascopically, the chlorite schist is a soft, pale green weathering rock. It is equally soft on fresh surfaces, which show a darker shade of green. Foliation is developed to varying degrees, ranging from an almost massive rock to a fissile schist with drag-folded folia.

Primary structures that might indicate the original nature of the rock have been erased by mineralogical changes and deformation. Aside from its calculated chemical composition, there is little evidence of the original nature of the rock.

Microscopically, the chlorite schist is holocrystalline, and is characterized by a linear texture resulting from the orientation of the chlorite shreds. Owing to the deformation undergone by the rock, the linear texture is crenulate, and the chlorite fluidal in its arrangement. The texture is further complicated by a variety of veinlets that crosscut it.

Pale green chlorite, with deep blue birefringence, is the major constituent, and is shown by optical tests to be penninite. All of the other mineral constituents occur among the shreds of chlorite or are included within them. The chlorite shreds themselves become coarsened where in contract with late veinlets.

The plagioclase, which is usually sodic oligoclase, An_{15}, rarely occurs in sufficient quantities to be classed as a major constituent. It rarely shows twinning, but its alteration to fine white mica makes its identification simpler than in the epidote amphibolite. Oligoclase occurs in late veinlets, and it is commonly stained by finely disseminated hematite granules[1]. The plagioclase in the matrix of the rock, on the other hand, carries inclusions of epidote, chlorite, and calcite, but no hematite. Twinning has been observed only in the feldspar of the veins.

Calcite fills veinlets, and is disseminated throughout the rock. The veinlets cross the schistosity at all angles, and commonly carry twinned calcite grains.

Epidote is common as a fine-grained, disseminated accessory mineral in the matrix of the rock. Occasionally, it appears as vein-like aggregates intimately mixed with fine shreds of white mica. The latter may be a retrograde product, due to the alteration of the epidote.

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[1] The term granule is applied in this report to grains of hematite 0.001 mm. or less in maximum diameter, which do not appear to be crystalline in outline. Many such grains show yellow birefringence, whereas others are opaque even under oil immersion lenses.

The opaque minerals are either disseminated in the matrix of the rock or form part of the filling of late veinlets. Disseminations of black iron oxide accompany the string-like aggregates of epidote granules and leucoxene that parallel the foliation. Pyrite occurs as an occasional clump of cubes near veinlets. Specularite flakes accompany oligoclase in the late veinlets and in some cases impregnate the adjoining rock.

Accessory apatite occurs as rounded grains scattered through the matrix of the schist.

Chlorite-muscovite Schist

The following table is illustrative of the specific gravity determinations that are characteristic of this rock:

Maximum density	Minimum density	Average density	Tests
2.742	2.693	2.719	6

The table of mineral compositions given below is not complete owing to the extreme fineness of some phases of the muscovite-bearing schists.

Minerals	Thin sections		
	A-46	29-11	29-6
	%	%	%
Chlorite	35.0	30.3	11.1
Oligoclase	22.8	31.3	30.2
Muscovite	38.0	19.6	31.8
Quartz	-	9.9	24.0
Black opaque minerals	0.3	3.5	2.8
Sphene	-	3.7	-
Calcite	3.8	0.7	-
Pyrite	-	0.7	-
Apatite	-	-	-
Zircon	-	-	-

Below are listed the recalculated chemical compositions derived from the modes in the preceding table.

Oxides	Thin sections		
	A-46	29-11	29-6
SiO_2	44.1	48.1	60.3
TiO_2	-	1.8	-
Al_2O_3	25.6	18.0	19.8
Fe_2O_3	0.3	6.3	5.1
FeO	-	6.7	2.6
MgO	12.6	5.7	2.2
CaO	2.3	1.7	-
Na_2O	2.7	3.4	3.3
K_2O	4.5	2.3	3.9
H_2O	6.3	4.3	2.9
CO_2	1.7	0.3	-
Fe	-	0.6	-
S	-	0.6	-
Totals	100.1	99.8	100.1

A comparison of these theoretical compositions with analyses I and II on page 11 suggests that the muscovite-chlorite schist has a closer relationship to the Archaean slate than to the calcareous shale. The schist is believed to be a member of the green schist facies.

At least two varieties of chlorite are represented, the coarse, blue-birefringent flakes of delessite and the green, vermicular variety in the late oligoclase-calcite veins. In the poorly foliated phase of the schist, fine scales of the mineral form matted aggregates and are disseminated through the matrix consisting of quartz and feldspar.

The oligoclase is usually anhedral and poorly twinned. It occurs as a fine mortar tailing away from coarser individuals that form augen 2 or 3 mm. long. In addition, fine angular grains join with quartz, chlorite, and disseminated hematite granules to form a fine matrix. The evidence of cataclastic deformation is abundantly supplied by the feldspar and ribbon quartz. The plagioclase, with the exception of that occurring in veinlets, is altered to fine shreds of white mica. The variety that forms the veinlets shows either albite or carlsbad twins, and it is commonly associated with comb quartz, calcite, specularite, and vermicular green chlorite.

Muscovite is represented in three, fairly distinct habits: as fine shreds on the older feldspar; as fine mats in the matrix of the rock; and as relatively coarse books, which may or may not be interleaved with chlorite, quartz, feldspar, black opaque granules, leucoxene, and sphene. It joins with the same assemblage of minerals to armour various types of augen and lenses. In the highly foliated schist, the proportion of coarse books is greater than in the less well-foliated variety.

Quartz is not everywhere a major constituent, but where it is, it forms sinuous ribbons that may envelop the feldspar augen. Elsewhere, it forms fine-grained mosaics in lenses and bands in the matrix. Occasionally, the albite individuals contain quartz inclusions. In the late veins, the quartz is commonly euhedral. Characteristically, it is clear of the red hematite granules that permeate the feldspar and the calcite. The inclusions detected to date form festoons, and are thought to be secondary in origin.

The accessory minerals include calcite, sphene, apatite, pyrite, hematite, and zircon. The calcite is generally confined to the late veins, but occasionally a few grains are disseminated through the matrix of the rock. Sphene occurs as euhedral grains, but more commonly as stringy aggregates parallel with the banding in the rock, in which case it is believed to have recrystallized from leucoxene, which accompanies it. Apatite is common as rounded individuals in the matrix. Pyrite occurs as rectangular spongy aggregates in all stages of replacement by green chlorite. Hematite granules occur as strings along the folia of the rock and as flakes within the late veins. Zircon grains are sparsely disseminated through the matrix.

Oligoclasite

Specific gravity determinations illustrative of this rock type are listed below;

Maximum density	Minimum density	Average density	Tests
2.702	2.620	2.662	5

The red oligoclasite generally consists mainly of sodic oligoclase and quartz, a composition reflected in the average value for its specific gravity above (quartz ranging from 2.600 to 2.660 and oligoclase from 2.62 to 2.65).

Listed below are three characteristic modes:

Minerals	Thin sections		
	G-2	G-3	A-41
	%	%	%
Oligoclase	76.0	58.0	53.0
Calcite	7.3	3.9	3.6
Chlorite	13.2	-	0.7
Quartz	0.6	25.2	47.7
Specularite	3.1	3.0	0.8
Sphene	-	1.9	-
Apatite	-	-	-
Muscovite	-	-	-
Pyrite	-	-	-

Of these three modes, the first two are of rocks that have replaced the muscovite-chlorite schist, and the last one represents a replacement of a leucocratic paragneiss.

Oxides	Thin sections			
	G-2	G-3	A-41	A-21
SiO_2	54.5	69.2	78.2	68.30
TiO_2	-	1.1	-	0.42
Al_2O_3	16.3	11.8	10.2	15.17
Fe_2O_3	5.7	6.0	1.6	3.90
FeO	2.9	-	0.2	1.92
MnO	-	-	-	-
MgO	2.6	-	0.1	0.40
CaO	4.1	3.1	2.0	1.56
Na_2O	8.7	7.2	6.3	5.55
K_2O	-	-	-	0.14
H_2O+	1.5	-	0.1	0.87
H_2O-				0.15
P_2O_5	-	-	-	0.08
CO_2	3.2	1.8	1.6	1.57
S	-	-	-	0.08
Totals	99.5	100.2	100.3	100.11

The first three columns represent recalculated chemical compositions derived from modes on the preceding page; the last is an actual chemical analysis by R. J. C. Fabry of the Geological Survey. The table illustrates a rock that is moderately high in silica, high in soda, low in potash, and high in alumina. The alkali ratio is the reverse of that found in most acidic and intermediate igneous rocks.

It is characteristic of the soda aplites and a few other rare rocks (Johannsen, 1937, vol. II, pp. 375-377).

Megascopically, the oligoclasite is very fine grained, so that it is rarely possible to detect individual grains in it. Occasionally, fine banding can be detected in the rock, such as on the small outcrop southwest of the Ace Lake shaft. This has led to the use of the term 'mylonite' for the rock, but there are phases, such as that occurring east of the shaft, in which there are few indications of banding. The rock is massive, and contains small feldspar phenocrysts, which can be detected in hand specimens. Elsewhere, the oligoclase has replaced the muscovite-chlorite schist in a lit-par-lit manner, and, in addition, has crossed the foliation of the schist at all angles as dense red veinlets. These features are more indicative of feldspathic replacement of the schist than of the extreme degree of clastic deformation that is implied in the term mylonite.

The oligoclasite has been subjected to deformation, as indicated by closely spaced discontinuous fractures and breccia zones. These are superimposed upon the rock in the sense that the reddening has no apparent spatial relationship to either. These features are particularly well shown where the rock adjoins the St. Louis fault, particularly in the foot-wall. In the immediate vicinity of the fault the oligoclasite has been replaced by a black chloritic rock containing remnants of bright red feldspar.

Microscopically, the oligoclasite ranges from massive to well banded depending upon the phase being examined. Locally, in the massive phase, small rounded feldspar fragments can be discerned in the sections, and most of these lie in a very fine feldspathic matrix with their long axes roughly parallel. The feldspars are lightly altered and usually show either bent twin lamellae, fracturing, or some other indication of deformation. The Ace Lake oligoclasite is believed to be a feldspathic replacement of either an altered argillite or a recrystallized mylonite. Replacement by an unaltered generation of sodic oligoclase is particularly well illustrated in the lens east of the shaft where the host rock, which was either an altered argillite or mylonite, has been replaced to varying degrees. This replacement by younger feldspar appears as bright red veinlets, which penetrate the chlorite-muscovite schist at all angles.

The red oligoclasite consists mainly of oligoclase (An_{15}), with chlorite, calcite, and quartz as minor constituents. Specularite, sphene, and apatite are the accessory minerals in the massive phase of the rock.

Oligoclase is the dominant mineral constituent, either as fine-grained, untwinned individuals in the matrix or else as rounded and deformed phenocrysts within the feldspathic matrix. In the oligoclasite lens west of the Ace Lake shaft, the plagioclase has been reduced to augen and tails of mortar interbanded with ribbon quartz. The feldspar shows light to moderate alteration to white mica and, in addition, a uniformly distributed cloud of red dust. The rock is veined with red feldspar, which usually occurs as well-formed individuals well twinned after either the albite or carlsbad laws. The alteration is generally lightest on the late veinlets.

Chlorite, which is delessite, the ferriferous variety of penninite, is disseminated as shreds in the feldspathic matrix of the rock and as coarser shreds in the late veinlets. In addition, vein calcite commonly carries vermicular green chlorite, which may be prochlorite.

Quartz is not particularly abundant in the oligoclasite east of the Ace Lake shaft, except as vein material. Southwest of the shaft, the rock carries more quartz both as a fine mosaic and in ribbon form, and carries more comb quartz veins than the oligoclasite to the east.

Sphene, muscovite, and apatite are the main accessory minerals. They occur as fine shreds or granules disseminated through the matrix.

The opaque minerals are limited to specularite and the occasional anhedron of pyrite, both of which occur near the late veinlets.

ALTERATION OF THE EPIDOTE AMPHIBOLITE

Megascopic Description

The epidote amphibolite is noticeably altered, as evidenced by the colour change, the appearance of chlorite, the disappearance of epidote veinlets, and the development of foliation or schistosity in the rock. The fresh amphibolite has a linear fabric due to the rod-like habit of the actinolite, and this directional property is inherited and amplified by the shreds of chlorite, which are equally well developed in two crystal directions. The folia may or may not be crenulated. The colour changes from the lustrous black to the dark dull green of the chloritic phase and finally to brick-red adjacent to the radioactive veins.

Microscopic Description

Textural changes in the epidote amphibolite are not great except for the development of schistosity. The chlorite shreds tend to form as sinuous plates, and in addition they are commonly larger than the actinolite shreds. These two features promote the development of the foliated nature of the rock. Veinlets and lenses of calcite increase in number in the more altered phase, which is softer than the fresh amphibolite.

The mafic minerals involved in this change are actinolite and chlorite, the latter being derived from the former by retrograde metamorphism. The chlorite, which is penninite, occurs in dense sinuous aggregates of fairly coarse shreds, and carries a fair proportion of the larger opaque granules, whereas the original actinolite was clear of opaque minerals.

The plagioclase, which is the second most abundant constituent, is clear and unaltered in the amphibolite but both coloured and altered in the chlorite schist. In addition, oligoclase occurs as a vein mineral, and as such its grains carry red hematite crusts, and fractures in them are filled by the same material. There are also spotty patches of hematite granules that have no apparent relationship to fractures within the feldspar individuals. The vein oligoclase is generally unaltered. The feldspar in the matrix of the rock, on the other hand, is altered to moderately dense mats of white mica.

Epidote and clinozoisite were dominant constituents in some of the thin sections of amphibolite examined; they occur either as disseminations or as vein fillings. In the chlorite schist, granules of these minerals are evenly distributed throughout the matrix and have only rarely been observed in aggregates that might suggest a veinlet. In some cases, these aggregates consist of fine white mica shreds in dense mats carrying ragged inclusions of epidote.

Quartz is an uncertain factor owing to the difficulty encountered in distinguishing it from the untwinned plagioclase in the matrix of the fresh amphibolite. It does form veins in both fresh and altered rocks, but in neither does it carry as many coloured granules as the plagioclase.

Calcite is a minor constituent of the amphibolite, but becomes quantitatively prominent in the chloritic phase. Part of the lime has been derived from the breakdown of the original amphibole. Calcite occurs as veins in the amphibolite and much more commonly in that form in the chlorite schist. It is disseminated as fine, ragged grains and as lenses along the folia. Colouring material is rarely abundant in the calcite, but more commonly forms crusts along cleavages and around the grains. Locally, the solutions appear to have attacked the calcite, as the perimeters are badly corroded and exhibit islands of calcite in a matrix of hematite granules.

Opaque minerals are relatively uncommon in the amphibolite, but become more abundant in the altered phases. In the former, they occur as opaque flakes at the edges of veinlets and rarely as disseminations in the matrix of the rock. In the chlorite schist, the opaque minerals are disseminated widely in the matrix and are common in veinlets. The finest granules, which are red under reflected light, occur most commonly in the feldspar and in the interstices of the fine matrix of the rock. The coarser granules are to be seen in the chlorite shreds, and opaque flakes are common in and near the late veinlets. The coarser grains are usually black and submetallic in lustre.

ALTERATION OF THE RED OLIGOCLASITE

Megascopic Description

The principal radioactive veins on the Ace Lake property are restricted to the red oligoclasite, and their emplacement has effected few visible changes in the rock. The latter is normally red and massive to finely banded, so that it is difficult or impossible to determine whether there has been significant silicification or hematitization as a result of vein formation. This is particularly true of the surface exposures. There is, however, evidence of brecciation of the rock and the filling of the interstices by the radioactive minerals and the accompanying gangue.

Microscopic Description

On the Ace Lake property, the alteration of the red oligoclasite has involved deformation, feldspathization, hematitization, and the main period of mineralization, which resulted in the deposition of the radioactive minerals in gangues of chlorite, calcite, and oligoclase. The origin of the rock is obscure, but it is believed to be a mylonite or argillite that had been partly recrystallized before being involved in the above sequence of events. It has subsequently been shattered, but the fragments, or most of them, do not appear to have been rotated, but have been recemented in much the same orientation as they held originally.

Oligoclase (An_{10}-A_{15}) occurs as vein fillings and as irregular lenses in the dense matrix of the rock. The grains are well twinned, and range from subhedral to euhedral in outline. They are little altered, and the grains are not deeply coloured by hematite granules. Oligoclase of this generation is veined by the later minerals of the pitchblende deposits. There are few indications of deformation in this oligoclase and no secondary white mica on the individual grains. Oligoclase of a slightly later generation, together with calcite, penninite, black opaque minerals, and some quartz, comprise the gangue of the radioactive veins.

Hematitization is the most colourful type of alteration affecting the oligoclasite. Hematite is lightly concentrated throughout the rock and concentrated in the vicinity of the late veinlets. With the exception of the occasional small grain, very little specularite is found more than an inch from the pitchblende. Under a medium-power magnification (80x) much of the rock is seen to consist of a dense orange aggregate in which an occasional fragment of twinned feldspar or clear quartz can be identified. At a higher magnification (800x), the dense, hematite-impregnated matrix of the rock resembles a boxwork, the walls of which consist of orange transluscent granules. Some of these granules show a yellow birefringence; others are opaque. The hematite encrusted grains are either quartz or clear oligoclase. The coarse-twinned fragments that could be identified as oligoclase carry these granules accumulated along cleavages or random fractures and as light to heavy disseminations. No geometric arrangement of the granules has been detected. The hematite commonly occurs in close association with white mica flakes. The remaining products of the hydrothermal solutions are the gangue and the ore minerals. The gangue consists of oligoclase, chlorite, calcite, and hematite.

In an attempt to identify the constituents of the dense hematitic phase of the red oligoclasite, material was selected and mounted for x-ray photography. According to E. J. Brooker, who took the photograph, the most prominent set of lines developed correspond with those of a sodic plagioclase and, in addition, there are some weak lines that might represent quartz. The film also shows darkening that might be attributed to hematite. Apparently, the dense matrix of the oligoclasite consists mainly of sodic plagioclase coated with fine hematite granules and associated with a small quantity of quartz.

CONCLUSIONS

1. The pitchblende veins at the Ace Lake mine are restricted to the foot-wall or north side of the St. Louis fault, where they fill fractures and breccia zones striking north 65 degrees east, approximately parallel with the fault zone.

2. The veins are best developed in the red oligoclasite.

3. The mineralogical changes in the epidote amphibolite consist of the alteration of the actinolite to chlorite and calcite, the partial removal of epidote, the addition of hematite, and the alteration of the plagioclase to white mica. In the extreme phase, the plagioclase becomes reddened by fine hematite granules.

4. The specific gravity of the epidote amphibolite is reduced as the result of the hydrothermal alteration to chlorite schist.

5. The mineralogical changes observed in the red aplite are limited to feldspathization, hematitization, and, finally, to ore mineralization, accompanied by chlorite and calcite gangue minerals.

6. The colour of the oligoclasite is due to fine red hematite granules coating grains of sodic plagioclase in the matrix of the rock. Larger feldspar individuals contain patches of these granules, which may or may not be concentrated in or near fractures.

WALL-ROCK ALTERATION AT THE MARTIN LAKE MINE

GEOLOGY OF THE PROPERTY

(See Figure 10)

The Martin Lake mine lies on the east limb of the Martin Lake syncline, between Martin Lake and Beaverlodge Lake. It is underlain by interbedded meta-basalts and feldspathic sandstones of the Athabasca series. Rocks of both types show reddening in the vicinity of pitchblende veins. Significant pitchblende mineralization is confined to the the lavas.

Structurally, this bedded sequence of flows and sedimentary rocks dips steeply west and strikes a few degrees east of north. It has undergone fracturing and faulting. There are two major systems of faults, those striking north 68 degrees east and those striking north 85 degrees east (Allen, 1950), and, in addition, a set of radiating faults (Christie, 1949 map) that cut the bedded sequence of the syncline. Gouge has not been observed in these faults where they occur on the Martin Lake property.

PETROGRAPHY OF THE HOST ROCKS

Meta-basalt

Below are listed a series of density determinations that illustrate the specific gravity of the meta-basalt:

Flow (See Fig.1C)	Maximum density	Minimum density	Average density	Tests
1	2.839	2.708	2.789	10
2	2.787	2.750	2.770	5
2[1]	2.828	2.727.	2.792	14
3[1]	2.832	2.743	2.785	11
			2.789	40

[1] Specimens for these tests were taken underground.

These lavas show a limited range of specific gravities, which does not fall within the ranges assigned to basalts, namely:

Daly[2] ---------------------------- 2.870-3.070

Johannsen[3] ---------------------- 2.87

Broderick[4])
) ---------------------- 2.861-2.993 (Keweenawan)
Cornwall[5])

[2] Daly, 1933, p. 47. Daly believes that lower values are due to the presence of glass.

[3] Johannsen, 1937, vol. III, p. 262.

[4] Broderick, 1925, pp. 503-558.

[5] Cornwall, 1951, p. 152.

(The data from references 4 and 5 have been combined in figures given above)

Microscopic examination of meta-basalt thin sections indicates the following mineralogical compositions:

Minerals	Thin sections		
	M-48	M-55	M-56
	%	%	%
Albite	44.9	45.4	42.0
Calcite	14.0	11.8	13.8
Hematite and magnetite	15.8	23.9	18.9
Chlorite	15.5	8.8	18.9
Quartz	8.8	10.2	6.4
Apatite	-	-	-
Sericite	-	-	-
Pyrite	-	-	-
Leucoxene	-	-	-
Serpentine	-	-	-
S.G.	2.805	2.809	2.786

The following table illustrates the chemical composition of the fresh meta-basalt near radioactive veins, and compares it with average compositions of andesites and basalts.

Oxides	I	II	III	IV
SiO_2	46.07	49.57	48.78	59.59
TiO_2	0.63	2.17	1.39	0.77
Al_2O_3	16.29	14.63	15.85	17.31
Fe_2O_3	9.14	2.85	5.37	3.33
FeO	4.26	8.24	6.34	3.13
MnO	0.01	0.15	0.29	0.18
MgO	4.53	7.84	6.03	2.75
CaO	4.64	10.23	8.91	5.80
Na_2O	5.48	2.58	3.18	3.58
K_2O	1.56	0.60	1.63	2.04
H_2O+	3.08	)		
		) 0.94	1.76	1.26
H_2O-	0.40	)		
P_2O_5	1.08	0.20	0.47	0.26
CO_2	3.30	0.10	-	-
S	0.04	-	-	-
BaO	-	0.01	-	-
Totals	100.51	100.11	100.00	100.00

I. Fresh meta-basalt taken from No. 2 flow at the Martin Lake mine, Goldfields, Saskatchewan; analyst, R. J. C. Fabry, Geological Survey of Canada.

II. An average of the analyses for 24 basalts (Johannsen, 1937, vol. III, p. 260).

III. An average for 161 basalts (Daly, 1933, p. 17).

IV. An average of the analyses for 87 andesites (Daly, 1933 p. 16).

It is apparent from the last table that the Martin Lake meta-basalt is more closely related to the average composition for fresh basalts than for andesites. In addition, the meta-basalt is abnormal in that it has low silica, lime, and magnesia, and high total iron, soda, water, and carbon dioxide. These observations support thin section evidence that the rock has been regionally metamorphosed to the greenschist facies (Turner, 1949, p. 93). There has probably been metasomatic addition of soda, water, and carbon dioxide, coupled with the thermal metamorphism of the original rock.

Megascopically, the meta-basalts are fine grained to aphanitic, and range in colour from green to black. In the zones of alteration associated with the pitchblende veins, the rock becomes a chocolate-brown or red. Feldspars can be detected on the surfaces of fresh material. The mafic constituents can be identified only with difficulty in hand specimens.

Weathering has produced a variety of characteristic features, such as grey to pale green surfaces, pits where calcite-filled amygdules were leached, and knots of mafic minerals. Generally, the fine feldspar laths resist weathering and stand out on the rock surface in contrast with the pits left by the weathered mafic constituents.

Primary structures, such as the chlorite- and calcite-filled amygdules, are common, and small pillows, brecciated tops, and, rarely, polygonal joints were observed.

Microscopically, these lavas show characteristics that classify them as meta-basalts. The textures range from diabasic to intersertal, with the plagioclase laths locally lending a porphyritic appearance to the rock. Pseudomorphs of chlorite, magnetite, and serpentine after pyroxene and olivine occur as phenocrysts in many of the sections examined. The grain size of the rock is usually uniform, and the interstices among the feldspar laths are either filled by mafic minerals or by dense aggregates of devitrified glass.

In the vicinity of the pitchblende veins, the plagioclase is generally albite (An_5-An_{10}), and is well crystallized in euhedral or subhedral laths. The individuals carry rounded patches of a white mica aggregate, which probably indicated that the original feldspar altered to white mica. The present feldspar is pseudomorphous after the original one, and is replacing the white mica aggregates. Both albite and carlsbad twins were observed. Red staining, resulting from fine hematite granules, is at a minimum on the fresh variety. Calcite, white mica, hematite, chlorite, and needles of apatite appear as inclusions within the feldspars.

Chlorite and serpentine are the dominant mafic constituents. The chlorite is delessite, a ferriferous variety of penninite (Winchell, 1947, p. 279). It is usually free of inclusions, except for an occasional grain of apatite, feldspar, or hematite. The hematite granules may occur in festoons, suggestive of the curving fractures so characteristic of olivine, or along comparatively straight lines suggestive of the cleavage of pyroxene. Under crossed nicols, the chlorite scales in the aggregates are arranged in patterns that also suggest cleavage or fractures. The serpentine is a brownish green, fine-grained, fibrous mineral, and does not show the bright blue interference colours of the chlorites. It may be pseudomorphous after the primary mafic constituents and may also be replacing the dense matrix of the rock. In some thin sections the interstitial patches of serpentine show colloform banding suggestive of the filling of cavities by hydrothermal solutions.

Calcite is a fairly common constituent, occurring either as disseminated ragged anhedra or as a vein mineral. Generally it replaces the dense matrix of the rock, but less commonly it may replace any of the other minerals present. In the fresh phase of the mata-basalt, the calcite is rarely stained by hematite granules.

Quartz occurs in two forms - as moderately coarse anhedra between crystals of other minerals, and as chalcedonic spherulites in chloritic aggregates. Owing to the abundant pseudomorphs of olivine and pyroxene, the quartz is believed to be of secondary origin.

The opaque minerals are usually magnetite and leucoxene, with an occasional grain of pyrite. The first two, together with chlorite and serpentine, form most of the pseudomorphs after olivine and pyroxene.

The accessory minerals are commonly sphene and apatite. The former occurs in poorly crystallized aggregates that might be confused with leucoxene. The apatite occurs as acicular grains in the interstitial patches of quartz, dense matrix, or chlorite. Some of the needles are as long as the feldspar individuals.

Feldspathic Sandstone

Seven specific gravity determinations illustrative of the Athabasca feldspathic sandstone are tabulated below:

Maximum density	Minimum density	Average density	Tests
2.685	2.605	2.651	7

These determinations were made using fresh material from surface exposures of the beds immediately above No. 3 flow (See Figure 1B).

Megascopically, the sandstone ranges from grey to pink depending upon the amount of hematite in it. The rock is sufficiently coarse grained to enable twin lamellae to be identified on fragments of plagioclase. Poikilitic patches of calcite can be detected, and specimens commonly effervesce with hydrochloric acid.

Weathering of the sandstone causes it to crumble readily to sand, indicating a paucity of cementing material. Such primary structures as crossbedding and grain gradation are poorly developed. Colour banding commonly serves to emphasize the bedding in the finer grained phases of the rock.

Microscopic measurements show that the arkose or feldspathic sandstone consists mainly of detrital grains that fall into the sand grade (Pettijohn, 1949, p. 13) between the diameters of 0.06 and 2 mm. with a small proportion of finer materials. Detrital or colloidal materials with diameters less than 0.06 mm. are usually conspicuously lacking.

The arkose is cemented by calcite, albite, and to a lesser degree by materials of the silt or clay grades. Minerals such as the feldspars and apatite that have low resistance to the abrasion caused by transportation are quite common in this rock. The detrital quartz and feldspar range in shape from angular to subangular. Secondary growth rims have been observed on the plagioclase grains but not on the quartz fragments.

The feldspathic sandstone consists of plagioclase, quartz, microcline, sphene, zircon, apatite, and iron oxides. Below is a partial mode of the constituents, as determined from one thin section:

Mineral	M-23
	%
Feldspar	43.7
Quartz	33.3
Calcite	20.5
Opaque minerals	2.6

The feldspar, which is the major constituent in most thin sections, includes both plagioclase and potash varieties. The former predominate, and the altered detrital grains are usually sodic oligoclase. They show light alteration to white mica, which is rarely sufficiently dense to hide the twin lamellae. The coarser mica shreds, in such alteration products, show pale yellow birefringence. Occasionally, however, larger flakes have formed, which show second order interference colours and clearly defined cleavages. In addition, the plagioclase shows a reddish coloration due to finely disseminated material, probably granules of hematite. In the fresher phase of the rock, the granules are not concentrated near the fractures or cleavages in the feldspars. Plagioclase fragments in several sections show rims of secondary material; The coloured and altered core remains, but with a corona of clear feldspar, which is usually optically continuous with the feldspar of the core. Occasionally, the rims are twinned. Potash feldspar (microcline) is recognized by its characteristic grating structure, and no secondary rims were observed around fragments of it. It is coloured in the same manner as the plagioclase, and is also lightly altered to white mica.

Quartz varies in amount, but rarely dominates over the feldspar. It is usually clear, with the exception of festoons of secondary inclusions. The fragments are angular to subangular; some are single crystals; others are fine mosaics not unlike those of the Tazin quartzite. Occasional coarser pieces of quartz mosaic were seen. No secondary rims were observed around the quartz fragments.

Calcite occurs both as veinlets and as disseminated ragged grains replacing the matrix and, commonly, the feldspar individuals. The coarser grains are commonly twinned, and may or may not be impregnated by hematite granules.

The accessory minerals are chlorite, white mica, zircon, sphene, apatite, and the opaque minerals. The chlorite, which shows deep blue interference colours, is probably penninite. It occurs as shreds in the fine matrix of the rock. White mica occurs both in the feldspar grains as an alteration product and as coarser flakes replacing the finer fractions of the matrix. Zircon has been observed as rounded fragments within quartz as well as in independent grains in the matrix of the rock. Sphene has been identified in one section. Apatite also occurs as rounded individuals disseminated through the rock. The opaque mineral is some form of hematite, either the earthy red or black metallic variety. It is associated with a minor amount of leucoxene or kaolinite.

ALTERATION OF THE META-BASALT

Megascopic Description

The alteration of the meta-basalt is most readily seen in the pronounced reddening that occurs in the walls of fractures carrying radioactive minerals. This is accompanied by silicification and carbonatization, the former being particularly noticeable where the flows are amygdaloidal, and the latter best observed in the walls of calcite-bearing veins. The first process hardens the meta-basalt and lessens the grain size. Carbonatization, on the other hand, softens the meta-basalt and, in conjunction with the production of red hematite, combines to produce a muddy red colour. Alongside calcite veins, the lavas are impregnated with calcite, crystals of which may be large enough to permit their detection by the unaided eye. Pink or white calcite veins are common in the ore zones; grey calcite-quartz veins are less frequent. The latter consist of grey, cherty quartz, calcite, and, rarely, albite. The wall-rock of such veins is commonly coloured a brighter red for a distance of a quarter of an inch from the vein.

Microscopic Description

The meta-basalt is most noticeably altered, through replacement by fine red hematite granules and calcite, where it forms the wall-rock of pitchblende-bearing veins. Locally, a little fine-grained quartz and albite have been added.

The red coloration of these rocks is due largely to hematitization, that is, to replacement by fine red granules of hematite. In addition, there is increased incidence of specularite flakes coupled with a quantitative decrease in the amount of chlorite present. In its granular form, hematite impregnates the albite in small patches, which may or may not be concentrated along cleavages or fractures. This form of hematite shows yellow birefringence in the finest granules, which are otherwise opaque. They show no marked preference for the vicinity of patches of secondary white mica in the feldspar. The hematite impregnates albite and chlorite and encrusts calcite. It is improbable that there has been a marked addition of iron because the meta-basalt carries magnetite and delessite (Winchell, 1947, p. 279), a ferriferous variety of penninite, both of which could supply the iron required for the hematite granules.

The replacement of the groundmass of the meta-basalt by calcite is most complete in the vicinity of the calcite veins. The fresh, dark green or black meta-basalt carries very little disseminated calcite, the bulk of the mineral present being confined to amygdules. The vein calcite is rarely heavily impregnated with hematite granules, and commonly shows well-developed twin lamellae. In its disseminated form, calcite may or may not show heavy hematite impregnation, and is more commonly crusted by a layer of the iron oxide. The calcite attacks and replaces the dense groundmass of the rock, the albite individuals, and the chlorite. It is one of the principal secondary minerals observed in the Athabasca lavas.

Silicification has affected the meta-basalt to only a minor degree. The process is best illustrated in the amygdaloidal flows and as cryptocrystalline vein matter. Interstitial patches of quartz and spherulites of chalcedonic quartz in chloritic aggregates also occur, but there is no reason to believe that the last two are related to ore mineralization.

Albitization is an uncommon type of hydrothermal alteration of the Athabasca flows, but it has been observed in one section of the many examined. It occurs in the form of a small albite-calcite vein unassociated with any changes in the adjoining rock.

A study of the optical properties of the chlorites was made in an attempt to determine if there is a progressive change in iron content in approaching the radioactive veins. No changes in optical properties were detected, as the mineral was found to be delessite in every case. However, there is commonly a quantitative decrease in the amount of the mineral present in the altered lava.

Similarly, the plagioclases were studied in an effort to determine what compositional changes appear on passing into a radioactive zone. In all cases the index of refraction is lower than that of the mounting balsam, and other optical tests have shown the feldspar to be albite or albite-oligoclase (An_{5-10}). Consequently, there has been no progressive change brought about in the plagioclase as the result of hydrothermal alteration processes.

Specific Gravity Data

The data listed below illustrate the specific gravities of the altered and fresh phases of the meta-basalt:

Source	Maximum density	Minimum density	Average density	Tests
1[2] sf[1]	2.839	2.708	2.789	10
2 sf	2.787	2.750	2.770	5
2 uf	2.828	2.727	2.792	14
3 uf	2.832	2.743	2.785	11
			2.789	40
1 sa	2.831	2.713	2.789	8
2 ua	2.828	2.715	2.782	17
3 ua	2.854	2.768	2.806	9
			2.787	34

[1] s = surface; u = underground; f = fresh;
a = altered.

[2] Flow numbers (See Figure 1C).

This table shows conclusively that the red alteration affecting the meta-basalts is not coupled with any detectable change in the specific gravity of that rock.

Chemical Data

The table below contains three analyses of the Athabasca meta-basalt from the Martin Lake mine.

Oxides	I	II	III
	%	%	%
SiO_2	46.07	47.97	40.93
TiO_2	0.63	1.16	1.37
Al_2O_3	16.29	16.41	15.94
Fe_2O_3	9.14	9.23	10.60
FeO	4.26	2.67	3.14
MnO	0.01	0.01	0.04
MgO	4.53	3.62	4.39
CaO	4.64	5.77	7.74
Na_2O	5.48	4.42	3.16
K_2O	1.56	1.54	1.69
H_2O+	3.08	2.34	3.15
H_2O-	0.40	0.76	0.31
P_2O_5	1.08	0.87	1.00
CO_2	3.30	3.10	6.10
S	0.04	0.16	0.03
Totals	100.51	100.04	99.59

Analyst, R. J. C. Fabry of the Geological Survey of Canada.

I. A specimen of No. 2 meta-basalt flow from the Martin Lake mine; 18 inches from pitchblende.

II. A specimen of No. 2 meta-basalt flow, Martin Lake mine; 12 inches from pitchblende.

III. A specimen of No. 2 meta-basalt flow from the Martin Lake mine; from the immediate vicinity of pitchblende.

As shown by the table, there has been no significant change in the content of silica, alumina, total iron, magnesia, and water that might be attributed to hydrothermal alteration. In every case but that of the iron, thin section observations support the chemical data. The marked reddening of the meta-basalt is misleading, as it suggests a considerable addition of hematite. This is not borne out by the analytical results, indicating that the colouring material has been derived by the oxidation of the ferriferous chlorite and magnetite present in the unaltered phase of the rock.

The table shows a marked increase in lime and carbon dioxide in the wall-rocks immediately adjacent to the pitchblende. This is apparent in hand specimens and to a lesser degree in thin sections.

There has been a marked decrease in the soda content of the altered meta-basalt, which normally has twice the soda carried by unaltered lavas. This is due to the replacement of the original albite by the fine-grained red colouring material.

ALTERATION OF THE ARKOSE

Megascopic Description

The alteration of the Athabasca arkose is a combined result of hematitization and carbonatization processes. The fresh rock is a sand colour, whereas the altered phase is chocolate-brown. Calcite can be detected with hydrochloric acid in both the fresh and altered phases. In addition, the reddened arkose shows a layer of brown sand on weathered surfaces, due to the leaching of the calcite, and on fresh surfaces poikilitic patches of calcite are visible.

Microscopic Description

Results of both hematitization and carbonatization are quite apparent in thin sections. The addition of calcite and albite to the rock preceded hematitization, and the sum-total of alteration has resulted in an apparent decrease in the amount of calcite because of the obscuring effect of the hematite granules. Calcite occurs both in veinlets and as disseminations, and hematite impregnation mainly involves the disseminated calcite.

Hematite, as fine red granules, appears in the fresh arkose nearly 3 feet from the radioactive veins. The only mineral that might supply the iron needed would be chlorite, which is a minor constituent. Consequently, the hematite is regarded as mainly a hydrothermal addition to this rock. The quantity of granules increases on approaching the veins, the granules replacing the matrix and locally forming spongy aggregates of the metallic oxide. The calcite and feldspar become crusted and mineralized along cleavages and fractures with granules of red hematite. Quartz remains relatively uncoloured, and the granules have been restricted to late fractures in it. In the matrix, the hematite has replaced the fine-grained material in addition to filling available fractures. Blades of specularite are not as abundant nor as large as those observed in the meta-basalt. Under reflected light the sections are uniformly red, except for angular clear feldspar and quartz fragments.

Specific Gravity Data

Below are listed the results of a group of density determinations, which characterize both altered and unaltered phases of the Athabasca arkose:

Phase	Maximum density	Minimum density	Average density	Tests
Red[1]	2.730	2.665	2.693	6
Fresh	2.685	2.570	2.614	9

[1]The altered phase of the arkose is either red or chocolate-brown.

It is apparent that there is an increase in density in passing from the fresh to the altered phase of the arkose. Specimens were collected for a limited distance along the strike of the arkose, which is at right angles to the veins, so there should be little variation in physical properties. The densities of the original constituents do not exceed 2.68, so the increase is due to both addition of hematite and a reduction in porosity.

CONCLUSIONS

1. Pitchblende veins occur in fractures striking north 68 degrees east and north 85 degrees east, with calcite rather than cherty quartz the dominant gangue mineral.

2. The mineralogical changes observed in the meta-basalts involve the reduction in amount of magnetite and some ferriferous chlorite to produce the granular red hematite and the addition of calcite to the wall-rocks of the veins. Only insignificant amounts of quartz and albite are added.

3. The chemical alteration of the meta-basalt is restricted to the addition of lime and carbon dioxide and the partial removal of the soda.

4. There has been no significant change in the density of the meta-basalt due to hydrothermal alteration.

5. The mineralogical changes observed in the alteration of the arkose are limited to the addition of calcite and hematite.

6. The density of the arkose has been slightly increased by the processes of alteration.

7. Reddening and carbonatization are characteristic of both the meta-basalt and the arkose, and both occur within 2 feet of the late fractures.

8. In some cases, the meta-basalt is hardened in the vicinity of these late fractures.

WALL-ROCK ALTERATION AT THE TAM PROSPECT

GEOLOGY OF THE PROPERTY

(<u>See</u> Figure 1D)

Owing to the limited distribution of the radioactive showings, the discussion of the geology of the Tam prospect will be restricted to the area in their immediate vicinity. No attempt is being made to cover the entire block of claims.

The radioactive veins outcrop in a black, finely laminated argillite and a fine white quartzite, and underground they have been encountered in a greenstone, which has been diamond drilled. These rocks dip at low angles to the east and northeast and strike in a north and northwesterly direction across the regional trend of the Tazin rocks. Drilling confirms this attitude, and indicates a conformable succession of argillites, quartzite, and greenstone. Drag-folds have been observed in the quartzite and argillite.

The bedded sequence has been disrupted by faulting, which has produced a series of tight fractures and, less commonly, narrow breccia zones. The evidence for movement is limited to slickensiding on the walls and the rotation of fragments in the breccia zones. Gouge has not been observed in any of these fractures, of which there are two sets, one striking north 40 to 60 degrees west and the other north 70 degrees east, both dipping vertically. Radioactive mineralization is chiefly effective in the faults striking northwesterly, particularly in zones of parallel fractures, whether brecciation has occurred there or not.

PETROGRAPHY OF THE HOST ROCKS

Quartzite

The following are specific gravity determinations on the Tam quartzite:

Maximum density	Minimum density	Average density	Tests
2.656	2.639	2.647	5

The density assigned to quartz ranges from 2.600 to 2.660 (Ford, 1926, p. 470). Cryptocrystalline varieties are as low as 2.600. The average value in the table falls within this range and thus provided additional evidence of the purity of the quartzite.

Megascopically, the quartzite is dense and of uniform grain size. It weathers a characteristic sugary white colour and, owing to its fine grain size, commonly exhibits conchoidal fracture. Bedding appears as alternating light and dark bands both on fresh and weathered surfaces.

The quartzite is commonly jointed in an irregular fashion and deformed sufficiently to promote the local development of breccia zones, usually without schistose foliation.

Microscopically, the quartzite is cryptocrystalline, and consists mainly of quartz. The original angularity of the grains has been masked by recrystallization, which has produced a general elongation of the grains so that they are commonly twice as long as wide. The same process masks the original bedding structures by obliterating evidence of variations in grain size. Grain gradation is, consequently, poorly developed, and the bedding is shown in part by lines of fine grains of some opaque mineral.

Argillite

(See Figure 1E)

Specific gravity determinations for the argillite at the Tam prospect are as follows:

Maximum density	Minimum density	Average density	Tests
2.776	2.700	2.723	17

The following table contains two analyses of the argillite and an average analysis for shales:

Oxides	I	II	III
SiO_2	68.39	61.84	58.10
TiO_2	0.53	0.52	0.65
Al_2O_3	13.20	17.42	15.40
Fe_2O_3	1.86	0.07	4.02
FeO	4.26	6.12	2.45
MnO	0.04	0.03	-
MgO	2.17	3.35	2.44
CaO	0.93	1.82	3.11
Na_2O	2.08	5.32	1.30
K_2O	2.10	0.90	3.24
H_2O+	3.03	2.41	5.00
H_2O-	0.08	0.30	
P_2O_5	0.12	0.20	0.17
CO_2	nil	nil	2.63
SO_3	-	-	0.64
S	0.12	0.04	-
C	0.23	0.24	0.80
Totals	99.14	100.28	99.95

I. T-4. A specimen of fresh argillite obtained 6 feet from the nearest radioactive vein. Analyst, R. J. C. Fabry of the Geological Survey of Canada.

II. T-30. A specimen of fresh argillite 10 feet from the nearest radioactive vein. Analyst, R. J. C. Fabry of the Geological Survey of Canada.

III. This analysis represents the average composition of shales (Pettijohn, 1949, p. 271).

These analyses indicate the similarities between the argillite and an average shale. With the exception of the alkalis, particularly the dominance of soda over potash, they are alike. The high soda to potash ratio may indicate that part of the material is fine pyroclastic dust or else that the rock has been enriched in soda by metasomatic addition of the oxide.

Megascopically, the argillite is cryptocrystalline and finely laminated. The bedding laminae are emphasized by colour banding, which can be detected both on fresh and weathered surfaces. The colour ranges from black to reddish grey. Occasional lenses of clear quartz lie parallel with the lamination. The weathered surface may or may not be corrugated, depending upon the presence of resistant laminae and quartz veinlets. Such surfaces are bleached to a pale green or pink.

The argillites have undergone considerable deformation, the effects of which have ranged from those productive of bedding cleavage to others responsible for irregular fracturing and breccia zones. The cleavage planes are commonly curved, and in addition may exhibit lineations plunging with the dip or parallel with the strike; the former are fine wrinkles on the surface whereas the latter are step-like plications. They are analogous to small folds in brittle beds that failed at the two flexure points instead of forming a continuous smooth curve. Joints cross the bedding at all angles. Brecciation is restricted to narrow zones along which there has commonly been sufficient movement to shatter the rock and to rotate the fragments from their original position.

Microscopically, the argillite consists of a small proportion of quartz grains in a dense matted aggregate of chlorite, sericite, and quartz. The quartz grains fall into the silt grade as they rarely exceed 0.02 mm. in maximum dimension. The matrix consists of materials that average less than 0.004 mm. in diameter, and, consequently, fall into the clay grade (Pettijohn, 1949, p. 13).

The coherence of the rock is due to a combination of two factors: the recrystallization of the detrital quartz and the recrystallization of the clay minerals to form the dense matted aggregate of chlorite and sericite that are the dominant constituents. The argillite has been veined by sodic oligoclase but shows no other evidence of metasomatism. Glass shards or other materials of igneous origin are conspicuously lacking, so there is no positive proof that such material is an important constituent of the rock.

Texturally, the argillite is characterized by delicate laminae locally disrupted by dispersed quartz grains or lenses of the same mineral. These may have been clastic grains that have been recrystallized sufficiently to remove the angular corners and to produce lenticular grains. Both grain gradation and mineralogical banding are common features; some laminae, for instance, consist essentially of fine quartz, whereas others consist mainly of chlorite and white mica. The bedding shows all stages of disruption from the occasional cross fracture to microscopic breccia zones.

Certain of the bedding laminae consist essentially of dense mats of scaly chlorite and white mica, chlorite and quartz, or quartz alone. The micaceous minerals become recrystallized to coarser aggregates in and near the late veinlets. The quartz shows a tendency to recrystallize into fine ribbons. Accessory zircon and apatite form rounded isolated grains. A white, opaque mineral, which is either leucoxene or kaolinite, occurs in lines of granules parallel with the bedding. Fine grains of red dust, probably hematite, are evenly distributed over the mafic laminae, and pyrite, in cubes and anhedral aggregates, is disseminated through the rock.

The argillite is veined by comb quartz, red oligoclase, epidote, and, to a lesser degree, calcite. Epidote veinlets are crossed by oligoclase veinlets, and at their intersections the epidote appears to have been attacked and white mica produced. This phenomena has been observed elsewhere, and in each case fine shreds of white mica contain residual scraps of epidote.

Meta-basalt

The meta-basalt does not outcrop within the area of the Tam prospect as outlined in Figure 1D, but is exposed to the north and is encountered at depth in drill-holes. The only radioactive vein known to occur in this rock has been found in a drill core.

Megascopically, the rock is dark green and fine grained. It is more granular in appearance than the argillite, and has a specific gravity of 2.775, which is greater than the average density of the latter. It is jointed to a similar degree to the argillite and quartzite. Primary structures, which might lend a clue to its origin, are lacking, and the rock is believed to have been igneous in origin.

Microscopic examination has shown the rock to have the following modal composition:

Minerals	20-17
Penninite	45.0
Oligoclase)) Quartz)	34.4
Pyrite	9.7
Calcite	10.7
Hematite	-
Sphene	-

The meta-basalt is holocrystalline, with an intersertal texture controlled by the feldspar laths. The principal constituents are sodic plagioclase, chlorite, and quartz, and the accessory minerals are hematite, pyrite, and sphene. The plagioclase, which is sodic oligoclase (An_{15}), occurs in lath-shaped individuals, which reach maximum dimensions of 0.9 by 0.2 mm. and average 0.5 by 0.2 mm. The grains are twinned after both the albite and carlsbad laws, the albite twinning tending to be patchy and discontinuous in single grains. Evidence of severe deformation is lacking in this rock, as the feldspars are only slightly fractured. They have been largely replaced along cleavages and fractures by chlorite and small grains of calcite.

The chlorite, which is probably penninite (Winchell, 1947, p. 279), is the green pleochroic variety characterized by bright blue birefringence. It occupies the angular interstices among the feldspar laths, and partly replaces the feldspars. Textures or patterns suggestive of pseudomorphous relationships have not been observed. The chlorite was observed to carry hematite granules in some thin sections, but not in such a manner as to suggest that the two minerals are pseudomorphous after either olivine or pyroxene.

Quartz occurs as a minor constituent among the feldspar grains, and is also one of the late minerals.

The opaque minerals are magnetite and/or specularite and pyrite. Pyrite occurs in irregular spongiform patches with chlorite. Neither hematite nor pyrite occur in euhedral outline.

ALTERATION OF THE ARGILLITE

Megascopic Description

(See Figure IE)

The alteration of the argillite at the Tam prospect is a result of deformation and metasomatic replacement. The host rock has been shattered sufficiently to produce narrow breccia zones that rarely exceed 3 feet in width. It is in such zones and immediately adjacent to them that the mineralized veins occur. The reddish colour characteristic of the altered argillite rarely extends more than a foot from the fractures containing the radioactive minerals. At the outer edges of the altered zones, the finely laminated argillite shows alternating red and black bands. Nearer the veins the coloration and the degree of brecciation increase to where, in the walls of the vein itself, the sedimentary structures have been destroyed, and argillite is transformed to a very fine-grained 'red oligoclasite'.

Microscopic Description

(See Line A-B, Figure IE)

At 8 feet from the pitchblende veins the argillite shows a minor development of breccia in which there has been little or no shearing. The sedimentary laminae are still well preserved, though lenses of well-crystallized sodic oligoclase are present as well as sharply walled veinlets of the same feldspar. The oligoclase is euhedral to subhedral in outline, and is usually twinned. It is not altered, nor is it highly coloured by hematite granules. Penninite is a minor constituent in these late veinlets and occurs as fine shreds in the sedimentary beds. Also, there is a higher content of both red earthy and metallic hematite than is normal in the unaltered argillite.

At 4 feet, the host rock is strongly brecciated, and the matrix of the fragments shows effects of recrystallization. Quartz rather than oligoclase has become the dominant vein mineral, and the feldspar is restricted to narrow lenses and veinlets. Calcite has been deposited in the central parts of the veins along with the radioactive minerals and hematite. The recrystallization of the matrix has proceeded to the point where it consists of a dense mat of chlorite, hematite granules, and patches of quartz and oligoclase.

At 1 foot from the radioactive minerals, the rock is completely recrystallized and replaced by a mixture of oligoclase, quartz, and granular hematite. It is fine grained, and retains a linear texture emphasized by quartz mosaic lenses. In addition to the minerals listed, the matrix contains disseminated, fine, green scales of chlorite. The rock is a breccia, and the linear texture is commonly disrupted by the rotation of the fragments. The breccia is veined by oligoclase, quartz, calcite, chlorite, and the ore minerals. The plagioclase is characteristically twinned in a patchy manner, and is not altered either in the matrix of the rock or in the veinlets. It is coloured by hematite, whereas the quartz remains colourless. The opaque minerals are limited to orange granules of hematite, a semi-opaque white mineral, and a black metallic mineral. The last two may be uranium-bearing.

Specific Gravity Data

Below is a table of determinations made on the fresh and altered phases of the argillite at the Tam prospect:

Maximum density	Minimum density	Average density	Tests
2.759	2.702	2.721	36
2.698	2.620	2.671	13

The first row of figures refer to the fresh argillite and the second to the altered phase. It is apparent from these figures that there is a detectable variation in the density of the two phases. This is due to a combination of two factors: increased porosity and mineralogical changes. The brecciated argillite is cemented by comb quartz, and even though apparently massive specimens were selected it is probable that some of them contained small vugs.

Mineralogical changes are due to hydrothermal alteration that has produced visible changes in the argillite. The major additions to the rock are quartz (S.G. 2.60-2.65), calcite (S.G. 2.72), and oligoclase (S.G. 2.63). In addition, there has been an insignificant increase in hematite (S.G. 5.1). Of these, the quartz and plagioclase dominate, and this is reflected in the reduced density shown by the altered phase of the argillite.

Chemical Data

The following are two chemical analyses of the fresh and altered phases of the argillite:

Oxides	T-1	T-4
SiO_2	65.76	68.39
TiO_2	0.31	0.53
Al_2O_3	12.04	13.20
Fe_2O_3	1.10	1.86
FeO	3.09	4.26
MnO	0.04	0.04
MgO	2.62	2.17
CaO	3.20	0.93
Na_2O	3.70	2.08
K_2O	0.54	2.10
H_2O+	1.67	3.03
H_2O-	0.11	0.08
P_2O_5	0.05	0.12
CO_2	4.12	nil
S	0.08	0.12
C	0.40	0.23
Totals	99.63	99.14
S.G.	2.657	2.729

Analyst, R. J. C. Fabry of the Geological Survey of Canada.

T-1. A specimen of brecciated and feldspathized argillite obtained from the wall of a radioactive vein.

T-4. A specimen of fresh argillite cut 6 feet from the nearest radioactive vein.

The silica variation is less than thin section studies seemed to indicate, and may be due to the replacement of the matrix of the rock by oligoclase, hematite, and calcite.

The total iron remains unchanged in the altered phase, which lends support to the premise that both the specularite flakes and the earthy red hematite granules have been derived from the original constituents of the argillite. Primary iron oxides and ferriferous penninite are the probable sources of much of the colouring material in the altered phase.

Lime shows a significant increase due to the relatively more abundant occurrence of calcite in the radioactive zones. Magnesia is more nearly constant, but may have gained slightly due to the alteration.

In the case of the alkalis, soda shows a considerable increase and potash a definite decrease in the altered argillite. The gain in soda is reflected in the increase in the amount of sodic plagioclase, which is characteristic of the walls of the radioactive veins.

The water content of the altered phase is lower than that of the fresh argillite, due mainly to the increased amounts of anhydrous minerals in the altered phase, namely, hematite, oligoclase, quartz, and calcite.

Carbon dioxide is higher in the altered argillite, due to the marked increase in calcite in passing into the wall-rock immediately adjacent to the vein.

The low sulphur is of interest as it indicates that the hydrothermal solutions were relatively poor in that element. Sulphides of any description are uncommon in the wall-rocks.

ALTERATION OF THE QUARTZITE

Megascopic Description

The alteration of the quartzite outcropping on the Tam prospect will be dealt with very briefly because few radioactive veins occur in it. It is a result of brecciation and reddening, the latter not as intense as that observed on other prospects in this region.

Microscopic Description

The altered phase of the quartzite is more highly shattered than the unaltered rock, resulting in an increased number of openings for the deposition of red oligoclase, chlorite, and quartz veinlets. Generally such veinlets have sharp matching walls, and the constituents rarely corrode them. The red colour is due to the increased amount of red hematite granules in the fractured matrix of the quartzite.

Chemical Data

The following analyses illustrate the chemical composition of the quartzite of the Tam prospect:

Oxides	T-29	T-28
SiO_2	95.55	95.51
TiO_2	0.03	0.07
Al_2O_3	2.26	1.86
Fe_2O_3	0.48	0.26
FeO	0.74	0.44
MnO	nil	nil
MgO	0.08	0.11
CaO	0.73	1.12
Na_2O	0.48	0.49
K_2O	0.17	0.23
H_2O+	0.12	0.21
H_2O-	0.18	0.15
P_2O_5	0.03	0.05
CO_2	nil	nil
S	nil	nil
Totals	100.85	100.56
S.G.	2.642	2.657

Analyst, R. J. C. Fabry of the Geological Survey of Canada.

T-29. A specimen of mildly reddened quartzite taken 3 feet from a radioactive fissure.

T-28. A specimen of reddened quartzite from the wall of a radioactive fissure.

It is apparent from these analyses that no significant chemical change is involved in the alteration of the quartzite. The constituents do show variations, but these are so small as to make their interpretation unreliable.

ALTERATION OF THE META-BASALT

Megascopic Description

The altered zone in the Tam meta-basalt is wider than those found in the other rocks on this prospect owing to the width of the zone of brecciation along the radioactive vein. The alteration is characterized by reddening, increased numbers of veinlets, silicification, and replacement of the chloritic matrix of the rock. The reddish colour first becomes noticeable due to the occurrence of red veinlets, which become increasingly abundant at the expense of the chloritic matrix of the rock. No significant increase in the yellow metallic sulphides was noted, and, in general, reddening and hardening of the meta-basalt are the most apparent changes.

Microscopic Description

At 3 feet from the zone of intense alteration some of the feldspar begins to show irregular patches of red granules. Calcite veinlets appear, but they are not coloured by red hematite granules. In addition, sodic oligoclase, relatively free of hematite, also fills late veinlets. The original texture of the rock is little changed except for the increased number of veinlets in the rock.

At a distance of 1 foot, red veinlets and patches become even more abundant in the rock. Among them remnants illustrative of the greenstone texture are still preserved. At high magnifications (360x) these dense aggregates are seen to be fine mosaics of feldspar impregnated with red granules, some of which are elongated but most of them round. Within each aggregate are lenses consisting of quartz, quartz and feldspar, and occasionally green shreds of chlorite. The quartz is usually colourless, whereas the feldspar is coloured by the red granules. In addition, the alteration is characterized by increased numbers of oligoclase veinlets with or without calcite cores. Some veinlets show a succession of mineral crusts with oligoclase nearest the walls and succeeded inwards by quartz and calcite. Specularite and the ore minerals fill late fractures in the centres of such veins.

In the vicinity of the radioactive minerals, the alteration has been sufficient to destroy all of the original textures and structures, leaving nothing but a dense aggregate of quartz and feldspar intersected by veinlets of the same minerals plus calcite, chlorite, and the ore minerals. The alteration is so intense that it is impossible to identify the original rock without tracing the transformation from altered to fresh material.

CONCLUSIONS

1. The radioactive minerals occur in a set of fractures and breccia zones striking north 40 to 60 degrees west and south 70 degrees west, with vertical dips.

2. The mineralogical changes brought about in the argillites are as follows: a reduction in the chlorite, white mica, and quartz content, and addition of oligoclase, calcite, and ore minerals. The chlorite originally present plus the original iron oxides have supplied the hematite that colours the altered phase.

3. The chemical changes include the reduction in the total silica present and an addition of soda, lime, carbon dioxide, and sulphur. Of these, lime and carbon dioxide increase the most.

4. The mineralogical changes in the quartzite are restricted to veining by reddened oligoclase, colourless quartz, and calcite. Minor amounts of granular hematite are added to lend the reddish colour to the altered rock.

5. Chemically, the alteration of the quartzite is insignificant.

6. The paragenesis of the mineralogical changes in the meta-basalt consist of the replacement of the rock by dense aggregates of oligoclase impregnated by hematite, and veining by clear oligoclase, comb quartz, calcite, and chlorite.

7. The best field guides to the location of radioactive showings in these rocks are radioactive anomalies, and careful study of the late faults and breccia zones, particularly where such structures are accompanied by reddening of the host rocks.

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