CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
BULLETIN 33

PETROLOGY AND RED COLORATION OF WALL-ROCKS, RADIOACTIVE DEPOSITS, GOLDFIELDS REGION, SASKATCHEWAN

By
K. R. Dawson

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1956

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Preface

The results of preliminary studies of the radioactive deposits about Goldfields, Lake Athabasca, suggested that a detailed knowledge of the characteristic features of the wall-rocks might assist greatly those prospecting the area and developing the radium deposits. With this purpose in view a detailed field and laboratory investigation of the wall-rocks of certain radioactive deposits was undertaken in the period 1949 to 1951 and the results of these studies are presented in this bulletin.

Suites of specimens of wall-rocks representative of deposits in the main formations of the camp were collected for detailed study under a petrographic microscope, specific gravity determinations, chemical analyses, X-ray spectrographic analyses for total iron, and alpha radiation counts. The results of all these studies and of the field investigations are presented in fourteen figures and eight tables. Brief descriptions of the main features of the study are presented, also red coloration so characteristic of the wall-rocks of some radioactive deposits is discussed the results of the investigation are summarized and interpreted.

GEORGE HANSON,
Director, Geological Survey of Canada

OTTAWA, March 25, 1955

PETROLOGY AND RED COLORATION OF WALL-ROCKS, RADIOACTIVE DEPOSITS, GOLDFIELDS REGION, SASKATCHEWAN

Introduction

LOCATION

The Goldfields region of northern Saskatchewan lies between latitudes 59°15′ and 59°45′ and longitudes 108°15′ and 108°45′. In this report Goldfields region includes the area immediately north of Lake Athabasca within a radius of 25 miles of Goldfields. The area is within but near the west margin of the Canadian Shield.

ACCESSIBILITY

The Beaverlodge airstrip, 5 miles north of the town of Goldfields and about the same distance east of Uranium City, is a point of call for Canadian Pacific Airlines flights from Edmonton, Alberta. In addition, aircraft can be chartered from either Fort Smith or Fort McMurray, both of which are scheduled stops for Canadian Pacific flights north from Edmonton. Heavy freight is carried into the area by the Northern Transportation Company, Limited, which operates a barge system from Waterways, Alberta.

ACKNOWLEDGMENTS

The co-operation of E. B. Gillanders, formerly manager of the Eldorado mine and manager of the Exploration Division of Eldorado Mining and Refining (1944), Limited, and that of the geological personnel and mining staff at the Beaverlodge camp of this company is gratefully acknowledged. The assistance of Gordon Moore and J. R. Macdonald, formerly of Technical Mine Consultants and their staff, of Dr. G. C. McCartney, Consulting Geologist for Nicholson Mines Limited, S. Oliver, Engineer for Orbit Uranium Mines Limited, and the late Emil Wally and John Nesbitt of Nesbitt-Labine Uranium Mines Limited, is much appreciated. The advice and assistance of Professors W. W. Moorhouse and F. G. Smith, of the Department of Geology, University of Toronto, are gratefully acknowledged. Dr. S. C. Robinson very kindly collected specimen material for the writer. In addition, thanks are due to George Cumming, survey assistant, and to all others who have contributed to the success of this project.

MINING HISTORY

The Goldfields region has long been of interest to mining people, having been prospected successively for iron, copper, and uranium (Alcock, 1936; Robinson, 1950)[1]. In 1921, interest was drawn to the area by the discovery of iron deposits on the Fish Hook Bay area, but these deposits did not prove to be ore grade. In 1930, a copper deposit was discovered on what is now the Nicholson property east of the town of Goldfields, but the deposit did not prove to be of economic size. In 1934, gold was discovered near Lodge Bay and subsequent development brought the Athona and Box mines into production. These continued in operation until 1942. Pitchblende was discovered on the Nicholson property in 1935, and later thucholite was identified in the underground workings of the Box mine.

The demand for uranium during the 1939-45 war brought about the re-examination of the Nicholson property in 1944 by officers of the Geological Survey and geologists of Eldorado Mining and Refining (1944) Limited. This awakened general interest in prospecting for radioactive minerals, especially when, in 1948, the Federal Government lifted the ban on prospecting for uranium-bearing minerals by the general public. Furthermore, the Saskatchewan Government, in March 1949, leased concessions covering unstaked ground within a radius of 20 miles of the north end of Beaverlodge Lake. Since that time the area has been carefully explored by the Crown Company and private companies, and the Crown Company has proceeded with an extensive development program (Lang, 1952), including the Martin Lake adit and shafts at the Eagle, Ace, and Ura deposits. A mill now (1954) in operation handles uranium ore from the Ace mine and other nearby properties. Three shafts were sunk by Nicholson Consolidated Mines Limited, and Nesbitt-Labine Uranium Mines Limited has sunk a shaft to explore underground a deposit on its Jam-Maj block of claims and is driving an adit to explore showings on the ABC claims. Rix Athabasca Uranium Mines Limited has driven an adit to explore the Leonard showing and is sinking a shaft on the Smitty showing. The deposits of some twenty other properties have been explored by diamond drill-holes. Scintillometer or Geiger surveys cover much of the Goldfields region and many anomalies have been explored by trenches and a few by diamond drill-holes.

GENERAL GEOLOGY

The bedrock formations of the Goldfields region are Precambrian in age. Pleistocene drift and Recent stream, lake, and swamp deposits here and there cover the bedrock. The Precambrian rocks are divided into three major components, two of which are separated by a major angular unconformity, and the third consists of intrusive rocks. The first two are the Tazin group and the Athabasca series respectively, the last includes the granitic rocks that intrude the Tazin group strata, and gabbroic rocks cutting members of the Athabasca series are the youngest known in the region.

The Tazin group wall-rocks studied include amphibolite, chert, and cherty dolomite, argillite, and subgreywacke. These have been subjected to metamorphism on a regional scale that has produced a wide range of metamorphic grades. Dynamic metamorphism, moreover, has produced bands of mylonite in chert, subgreywacke, and metamorphic rocks derived from them.

[1]Names and dates, or dates, in parentheses are those of References listed on page 8.

TABLE OF WALL-ROCKS DESCRIBED

Era	Formation	Lithology
Early or Late Precambrian		Gabbro
	Intrusive contact	
	Athabasca series	Meta-basalt Feldspathic sandstone Conglomerate
	Major unconformity	
		Alaskite, locally mylonitized Quartz gabbro
	Intrusive contact	
	Tazin group	Subgreywacke in part mylonitized Argillite Chert in part mylonitized Cherty dolomite Amphibolite

Amphibolite of certain bands has been studied near the adit on the Leonard showing (*see* Figure 1). The rock is black to green in colour and may or may not carry epidote veinlets. The grain size varies from fine to moderately coarse and although the amphibolite is foliated it is not schistose. The rock consists essentially of dark green hornblende, clinozoisite, untwinned plagioclase, quartz and biotite with accessory leucoxene, calcite, apatite, and black opaque materials.

Chert has been studied from the South Tam showing and cherty dolomite from the No. 4 zone at Nicholson Consolidated Mines Limited. The chert is massive to finely bedded due to alternating light and dark colour layers that are believed to be relicts of beds. Microcrystalline quartz is the principal constituent and accessory amounts of hematite or carbon dust are distributed in lines parallel with the beds. The cherty dolomite consists mainly of microcrystalline quartz with scattered aggregates of green diopside with or without accessory clinozoisite.

Tazin argillite is well exposed at the South Tam showing (*see* Figure 1) and is a black, fine-grained rock in which the beds are thin laminæ emphasized by differing shades of colour. The rock consists essentially of microcrystalline flakes of chlorite, and white mica, with quartz grains and accessory epidote, zircon, apatite, pyrite, and hematite. The laminæ are due largely to the concentration of one or more of the principal constituents in layers.

Massive, fine-grained, green subgreywacke occurs in the vicinity of the Eagle shaft (*see* Figure 1). This rock has a granular appearance and is characterized by having bright reflecting facets on fresh surfaces. Angular fragments of quartz and albite are common constituents together with a few slivers of altered slate in a matrix of fine-grained chlorite, sericite, quartz, and feldspar. Accessory amounts of disseminated calcite, pyrite, and hematite are also present.

Mylonites have been observed along the Black Bay fault and on the Emar claims, and these rocks have been studied from specimens collected at the Ace mine and the Lost mine vein on the Eagle claims (*see* Figure 1). Mylonites are red to black and medium grained to aphanitic. They consist essentially of oligoclase, quartz, sericite, and chlorite with accessory quantities of hematite and apatite. Mylonites and related rocks show megascopic and microscopic textures that support the hypothesis of their origin by dynamic metamorphism.

The post-Tazin intrusive rocks investigated in the course of this project include quartz gabbro and "granite". Of the two, the "granite" shows the greatest effects of metamorphism as all its mafic minerals are altered to chlorite and locally "granite" was reduced by dynamic metamorphism to a mylonite.

An alaskitic post-Tazin "granite" has been studied from the Eagle group of claims (*see* Figure 1) and is a pink, fine- to medium-grained rock, which in many exposures is characterized by ellipsoidal shaped aggregates of milky quartz.

Quartz gabbro which is well exposed on the Gil prospect (*see* Figure 1), is a coarse- to medium-grained type that weathers buff or grey. The rock consists mainly of hornblende, biotite, and untwinned feldspar, and with accessory apatite, ilmenite, and pyrite. The hornblende tends to occur as porphyroblasts in a fine-grained matrix.

The members of the Athabasca series studied include conglomerate, feldspathic sandstone, and meta-basalt. Generally speaking, these rocks show the greenschist facies of metamorphism but no evidence of mylonitization. The Athabasca conglomerate in the vicinity of the Ura showing southwest of the Fay shaft (*see* Figure 1) consists of detrital material ranging in size from moderately well-rounded cobbles (*see* Plate I A) to fine-grained angular material in the matrix. Fragments of argillite, chert, greywacke, feldspar, and quartz are commonly present. A fine-grained aggregate of dark green flakes of chlorite, and grains of quartz and feldspar form the matrix of the rock.

Feldspathic sandstone in surface outcrops that lie immediately above No. 2 flow on the RA claim (*see* Figure 1) is fine grained with a few scattered fragments of quartz and feldspar. The colour is pink to buff. Albite, microcline, quartz, and calcite are the principal minerals and accessories are hematite dust, chlorite, sericite, apatite, and zircon. Calcite is the cementing material with subordinate amounts of chlorite-sericite aggregate and authigenic albite.

Specimens of the Athabasca meta-basalt were collected from surface exposures and underground workings on the RA claim group (*see* Figure 1). These lavas are dark green to black types that form fine- to very fine-grained amygdaloidal or massive flows. Andesine, calcite, hematite, chlorite, and quartz are the principal minerals with accessory quantities of apatite, sericite, pyrite, and leucoxene. The thin sections show diabasic textures in which the primary interstitial mafic minerals have been replaced by fine-grained aggregates of chlorite and hematite dust.

The post-Athabasca gabbro has been observed at a number of localities but has been studied only from the Strike claims south of Mickey Lake and the Jam claims at the outlet of Cinch Lake This gabbro is characterized by a diabasic texture and is a fine- to very fine-grained rock that outcrops as dykes rarely exceeding 25 feet in width. The rock is black in colour and shows chilled borders and amygdule-like structures. The primary mafic silicates are replaced by chlorite-hematite aggregates, and the plagioclase by dense mats of sericite.

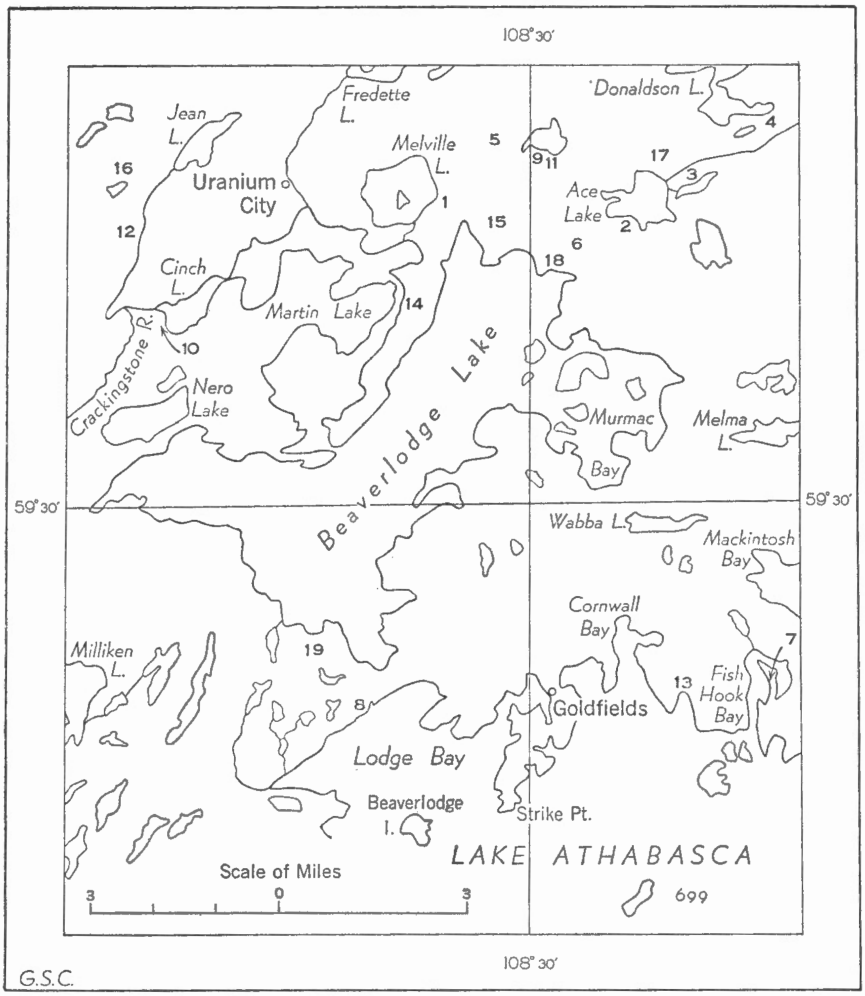

Figure 1. Index map showing location of radioactive deposits discussed or mentioned in this report: (1) ABC; (2) Ace mine; (3) Bolger; (4) Donaldson or Emar claims; (5) Eagle shaft; (6) Fay shaft; (7) Fish Hook Bay; (8) Gil; (9) Gully; (10) Jam; (11) Jam-Maj; (12) Leonard; (13) Nicholson No. 4 zone; (14) RA; (15) South Tam; (16) Smitty; (17) Strike; (18) Ura; (19) YY-1.

The St. Louis and Black Bay faults are major structures of the region and important radioactive deposits are distributed along the zones followed by these faults. East of Beaverlodge Lake, Athabasca series strata are preserved south of the St. Louis fault and at this locality they indicate that the post-Athabasca movement of the south side relative to the north is down at least 250 feet. The plane of the fault at the points determined dips about 50 degrees southeast. Mylonite and breccia, at points up to 100 feet wide, are present at many places along this fault. The Black Bay fault is north and northwest of Beaverlodge Lake and also strikes northeast and dips southeast at from 50 to 70 degrees with Athabasca series sediments on its southeast side. Large bodies of mylonite, breccia, and schist are present along the belt followed by this fault, and these and the mylonite along the St. Louis fault zone are interpreted as the result of compressional and shearing forces in pre-Athabasca time (Christie, 1953, p. 67).

GENERAL CHARACTER OF RADIOACTIVE DEPOSITS

According to Christie (1953, p. 81) the two main types of radioactive deposits known in the region are: (1) veins containing pitchblende; and (2) pegmatitic bodies containing uraninite. Most vein-type or pitchblende occurrences are in faults, shears, fractures, or fracture zones, or in their immediate vicinity. Most of the pitchblende deposits whose wall-rocks were studied follow fractures or a series of fractures striking roughly parallel with the St. Louis fault or in fractures subparallel with the Black Bay fault. On the Rix Athabasca concession a pegmatitic type of uraninite deposit occurs in relatively massive, moderately fine-grained red "granite" or gneiss. In a deposit south of Gatzke Lake tiny crystals of uraninite are present in the chloritic matrix and in the feldspathic gneiss, and, in one specimen, hydrothermal quartz containing uraninite grades into pegmatitic material (Christie, 1953, p. 81).

Most pitchblende deposits consist of narrow veins and stringers filling tension fractures or developed along breccia and fault zones. The pitchblende of some deposits is disseminated locally in the host rock. The gangue minerals include calcite, comb quartz, specular hematite, chlorite, dolomite, ankerite, and albite. In addition to pitchblende such veins contain small quantities of a great variety of metallic minerals, including pyrite, chalcopyrite, bornite, copper selenides, cobalt, nickel arsenides, arsenopyrite, sphalerite, galena, native silver, native gold, and others (Robinson, 1950). Some veins are banded, others contain vugs, and brecciated fragments of wall-rocks are plentiful in a few deposits. The veins appear to favour certain host rocks, as, on the RA group at Martin Lake, veins in meta-basalt are radioactive but when they pass into arkose are non-radioactive within a short distance from the basalt. The source of the materials to form the pitchblende veins of the region is unknown. Veins occur in the Athabasca series strata and also in gabbro dykes cutting certain members of this series, and those rocks are the youngest that have been recognized in the region.

RED ALTERATION

The outcrops of many radioactive deposits in the Goldfields region are strikingly red in colour and the wall-rocks of some deposits at depth also are red. Red staining of outcrops may have resulted in part from weathering but that at depth is best interpreted as an effect of the deposition of the veins. Ellsworth (1932) first described the red alteration products beside the pitchblende-bearing veins at Great Bear Lake. Kidd and Haycock (1935) described the same occurrence and drew attention to the red wall-rock alteration along the veins in the Eldorado mine as follows: "The alteration of these rocks (flows and argillites) consists in widespread feldspathization, either by recrystallization or by introduction of new material or both, together with formation of chlorite, carbonates, magnetite, garnet (probably grossularite), biotite, white mica, pyrite, and actinolite" (page 890). In 1946 Murphy (page 432) stated that at Eldorado "In both rocks and veins, the alteration has given rise to widespread discoloration by hematite and the obliteration of the original textures", and this author called the characteristic alteration product 'jasperoid'. He states (page 432) that "The rocks are then reduced to a dense, reddish 'jasperoid'. The exact nature of the alteration has not been determined, but quartz, hematite, magnetite, sericite, chlorite, and carbonate are obvious constituents".

There are marked similarities between the alteration products at the Eldorado mine and those in the wall-rocks of the pitchblende-bearing veins of the Goldfields region. The first description of the alteration products from this region (Christie and Kesten, 1949), however, indicated a greater variety of alteration products than have been described from the Eldorado mine. The authors state (page 20) "Fish Hook Bay prospect—hematite is almost invariably found in the vein and/or in the wall-rock", and (page 21) "Gil prospect—wherever pitchblende occurs, carbonate is stained a deep red brown, a colour due to hematite, which everywhere accompanies the mineral laying special emphasis on the association of hematite with pitchblende". At the Ace mine (page 24) "it (pitchblende) is disseminated thinly through a mass of red-altered rocks. This fine-grained, red, cherty-looking alteration product is a prominent feature of the property". This rock seems analogous to Murphy's 'jasperoid' at Great Bear Lake. It has since been described as due to feldspathization or silicification (Christie and Kesten, 1949; Conybeare, 1950).

Red coloration is not prominently developed in the uraninite-bearing pegmatites of the Goldfields region nor has it been observed in pegmatites from the United States (Page, 1950). Ellsworth (1932), however, has reported red coloration of radiocative pegmatites from numerous deposits in eastern Canada.

Reddening of the wall-rocks is not characteristic of many presently known radioactive deposits elsewhere in Canada or in other parts of the world. For example, the sedimentary type deposits of the Colorado Plateau (Fischer, 1950) do not show this feature, nor has it been described from the Katanga deposits (Thoreau and de Terdonck, 1933). Red coloration, however, has been observed in a vein described from the Cœur d'Alene district of Idaho (Thurlow and Wright, 1950), and according to Wolverton (1950) hematite, calcite, and chlorite form the radioactive occurrences at Theano Point, Ontario.

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Description of Altered Wall-Rocks

TAZIN GROUP AMPHIBOLITE

General Statement

The amphibolites of the region are interpreted as metamorphic products of a variety of rocks; some represent pillow lava, others basic intrusive rocks (Christie, 1953, pp. 18-20), and others may have formed by the recrystallization of shaly and limy sedimentary rocks (Dawson, 1951, pp. 9-12). Many of the amphibolites are cut by veinlets of epidote and quartz. All are regarded by most authors as older than the widespread granitic rocks.

At the Leonard deposit (*see* Figure 1) an amphibolite beside the radioactive veins was studied in some detail. There the amphibolite outcrops between sheets of "granite", some of which are pegmatitic. The foliation of the amphibolite strikes between north 20 and 35 degrees east and dips vertically. The radioactive minerals occur in veins within the amphibolite and they follow a series of sinuous fractures that strike west. The deposit has been explored for a length of 400 feet.

Petrography

The field criteria of hydrothermal alteration of the amphibolite include colour changes and variations in hardness. The colour changes from lustrous black to dull green in the proximity of radioactive veins, and locally becomes red. The amphibolite softens as the colour becomes green and hardens where reddened.

Thin sections were cut from specimens of the fresh and altered amphibolite for a systematic study of variations in texture, identification of minerals, and Rosiwal analyses. The Rosiwal analyses were made using a Leitz mechanical stage with a clicking mechanism set to click at 0.5 mm. intervals along the direction traversed and a laboratory counter capable of registering eight minerals. The counting traverses were spaced at from 1 to 2 mm. apart to give 500 to 800 counts for the standard thin section. The technique was adapted to this purpose by Chayes (1946).

Table I contains data from a suite of four thin sections collected to illustrate the character of the alteration of the amphibolite beside radioactive veins. The veins crosscut the strike of the beds and, consequently, the results from a study of these thin sections demonstrate the mineralogical effects of the alteration processes along the strike of the same layer.

At 24 inches from the vein, the amphibolite consists mainly of dark green hornblende, brownish green biotite, plagioclase, and quartz (*see* Figure 2 A). Little or no calcite is present, either as disseminations or as veins. The hornblende and biotite beside the few calcite veinlets present show incipient replacement by chlorite, and the plagioclase is more intensely altered to sericite than elsewhere.

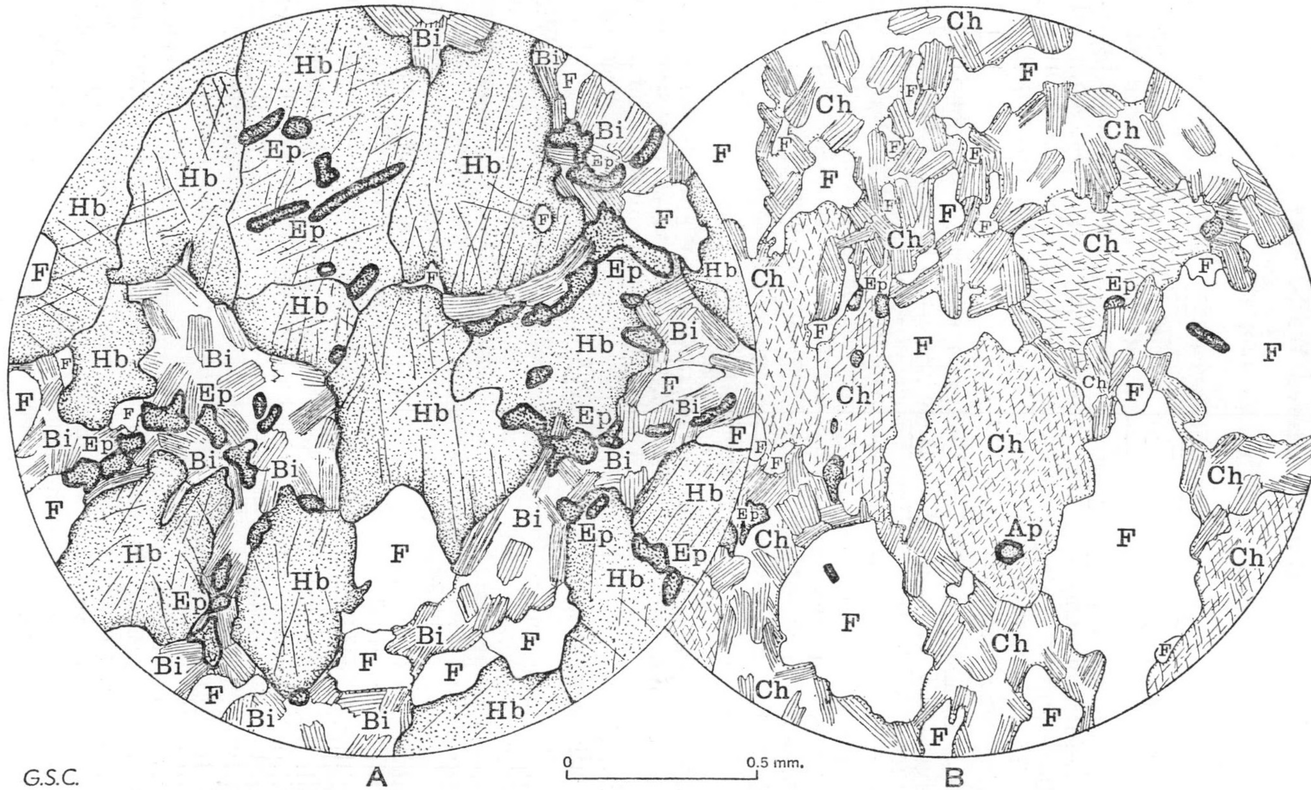


Figure 2. Camera-lucida drawings of altered and unaltered amphibolite, Leonard deposit.
A. Unaltered amphibolite: Hb, hornblende; Bi, biotite; F, quartz and untwinned plagioclase; Ep, epidote.
B. Altered amphibolite: Ch, fine-grained aggregates of chlorite after hornblende, and books of chlorite after biotite; F, minor epidote and untwinned plagioclase; Ap, apatite; stipple hematite dust.

TABLE I

Modes of Amphibolite, Leonard Deposit

—	Distance in inches from radioactive vein			
	2·0	6·0	10·0	24·0
	%	%	%	%
Chlorite	54·0	38·0	33·8	9·6
Biotite	—	26·0	17·6	8·6
Hornblende	—	—	—	47·2
Epidote	8·8	5·5	9·2	6·0
Plagioclase	27·0	20·2	22·6	20·8
Calcite	7·8	4·5	8·0	1·2
Quartz	1·8	5·0	8·0	6·0
Apatite	0·8	0·5	0·8	0·6
Sphene	—	—	—	—
Chalcedony	—	—	—	—
	100·2	99·7	100·0	100·0

Dashes in this and succeeding tables indicate that the mineral or constituent is present but the amount was not determined.

At 10 inches from the vein, the hornblende has been completely replaced by chlorite (penninite), the biotite partly replaced by chlorite and leucoxene, and the plagioclase by sericite. Quartz in disseminated grains exhibits no apparent change. Veinlets containing quartz and calcite become larger and more abundant than in the thin section 24 inches from the vein, also scattered calcite is quite widespread and the plagioclase grains are lightly stained by hematite dust.

At 6 inches from the vein, the replacement of both hornblende and biotite by chlorite has been completed. The plagioclase is clouded by sericite and no change has taken place in the disseminated quartz. Quartz-calcite veinlets and disseminated calcite grains are prominent features. Hematite dust is abundant.

Within 2 inches of the pitchblende-bearing vein there is a marked increase over that in the thin section 6 inches from the vein in the quantity of hematite dust staining the feldspar. Secondary albite has replaced some grains of the altered plagioclase. Hornblende and biotite have been completely replaced by chlorite (*see* Figure 2 B). The calcite content of the amphibolite reaches its maximum both as veinlets and as disseminated grains.

Figure 3 A illustrates graphically the progressive loss in the percentages by volume of hornblende and biotite and the gain in percentage of chlorite minerals in the amphibolite beside the Leonard radioactive veins. The data available indicate gain in percentages by volume of chlorite in the rock which can be correlated with the decrease of the combined biotite and hornblende. These two minerals combined reach a peak percentagewise between 15 and 5 feet from the vein and then decrease abruptly.

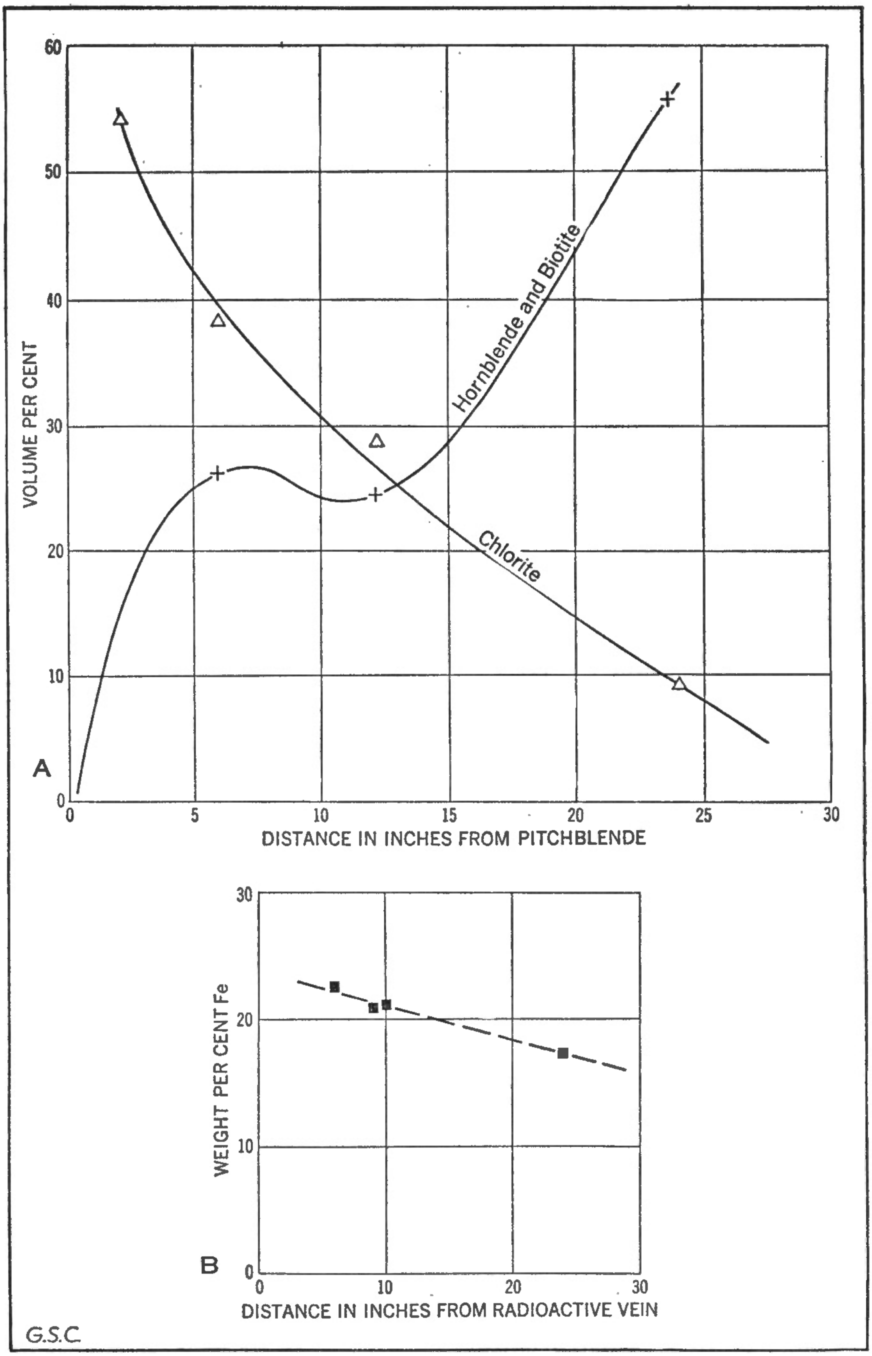


Figure 3. A. Graph to illustrate progressive decrease in the percentage of hornblende and biotite and increase in the percentage of chlorite as radioactive vein in amphibolite is approached, Leonard deposit.

B. Increase in percentage of total iron content of amphibolite as radioactive vein in amphibolite is approached, Leonard deposit.

X-ray Spectrograph, Radioactivity and Specific Gravity Tests

Specimens of amphibolite from the surface at the Leonard deposit were collected at measured distances from the veins and these were analysed in an X-ray spectrograph. The X-rays excite the elements present in the sample to give off a characteristic radiation for each and the strength of this radiation is proportional to the quantity of the element present. The results obtained for iron in the specimens studied are plotted on Figure 3 B and probably they are accurate within 10 per cent (Brooker, 1953) and thus indicate a progressive increase in the percentage of iron present in the amphibolite as the radioactive veins at the Leonard deposit are approached.

Four specimens of amphibolite from the Leonard deposit were cut and one surface of each was polished. In the Radioactive Laboratory of the Geological Survey a probe was placed on the polished surface and the alpha radiation was counted using an electronic counter for a period of 1 hour. The results are tabulated as follows:

Specimen No.	Distance in inches from radioactive vein	Alpha counts per hour over background
DD-3	6	19·9
DD-2	10	nil
DD-1	12	nil
DD-5	24	4·1

These results indicate a slight increase in the radioactivity of the amphibolite as the degree of alteration increases on approaching the vein.

The specific gravity of amphibolite collected from the outcrops of the Leonard deposit was determined on a triple beam balance from specimens weighing from 10 to 100 grams. The results are as follows:

Location	Distance in inches from radioactive vein	Specific gravity
Rix adit	24	3·05
Rix adit	0	2·80

Four possible explanations for specific gravity changes are: (1) metasomatism; (2) solution of constituent minerals; (3) brecciation; and (4) retrogressive metamorphism. In the amphibolite no evidence was noted to indicate volume changes by the solution of silicate or other minerals either by meteoric or by juvenile waters. Little evidence of brecciation of the amphibolite was noted in the study of the outcrops. Metasomatism combined with retrogressive metamorphism probably produced the reduction in specific gravity of the specimens studied and of these processes the study of thin sections indicates metasomatism as the important process associated with the deposition of the veins.

TAZIN GROUP DOLOMITIC CHERT AND CHERT

General Statement

Dolomitic chert from the walls of Nicholson No. 4 deposit, and chert from the South Tam, Bolger, and Gully deposits (*see* Figure 1) have been studied. In outcrop and specimens the cherts show a varying degree of brecciation and reddening. At Nicholson No. 4 deposit the breccia contains a few vugs large enough for a man to enter. Crackle breccia is the most widespread type, however, and this probably marks zones of shattering along which the movement has been insufficient to separate and to rotate the fragments. Brecciated chert at only a few places is as intensely reddened as mylonitized "granite".

Petrography

An examination of thin sections of brecciated chert shows that the rock is veined and cemented by quartz, calcite, hematite dust, chlorite, and rarely albite. Hematite dust also is disseminated throughout the rock in microfractures and along the intergranular boundaries of the quartz grains. The brecciated chert varies from white in the unaltered phase to red or bluish in the proximity of radioactive veins. Where studied, this coloration does not extend over 12 inches from the vein.

The pitchblende-bearing vein of Nicholson No. 4 deposit occurs in a wide zone of coarsely brecciated dolomitic chert. The fragments contain aggregates of pale green diopside crystals that have been partly altered to microscopic flakes of talc in a matrix of elongate quartz grains. Calcite and dolomite are both present in veinlets and the latter forms a dense, buff-coloured rock that has replaced parts of the brecciated chert. Both calcite and dolomite show varying degrees of reddening, and quartz and hematite combine to form microcrystalline aggregates.

Two chip samples of chert, one 36 inches from and the other at the contact of a radioactive vein, South Tam occurrence, were submitted for chemical analyses. The results, with calculations, are given in Table II. The unaltered chert is pink in colour.

In the altered chert the gains in magnesia, lime, soda, and potash over the quantities of these constituents in unaltered chert as indicated by the analyses probably went to form chlorite, calcite, and albite and the white mica in veinlets. Some of these minerals occur more prominently in the altered than in the unaltered chert. The large loss of total iron

TABLE II

Chemical Composition of Chert, South Tam Occurrence

—	I	II	III	IV
	%	%	%	%
SiO_2	95·55	95·51	−0·04	− 0·04
TiO_2	0·03	0·07	+0·04	+133·33
Al_2O_3	2·26	1·86	−0·40	− 17·70
Fe_2O_3	0·48	0·26	−0·22	− 45·83
FeO	0·74	0·44	−0·30	− 40·54
MnO	nil	nil	nil	nil
MgO	0·08	0·11	+0·03	+ 37·50
CaO	0·73	1·12	+0·39	+ 53·42
Na_2O	0·48	0·49	+0·01	+ 2·08
K_2O	0·17	0·23	+0·06	+ 35·29
H_2O+	0·12	0·21	+0·09	+ 75·00
H_2O-	0·18	0·15	−0·03	− 16·67
P_2O_5	0·03	0·05	+0·02	+ 66·67
CO_2	nil	nil		
S	nil	nil		
Totals	100·85	100·50	−0·35	
S.G.	2·64	2·64		

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

I. Mildly reddened chert taken 3 feet from a radioactive vein, South Tam occurrence.

II. Reddened chert from the immediate vicinity of this radioactive vein.

III. Gain or loss.

IV. Gain or loss in percentage of constituent present.

during the alteration, however, would not be expected as the chert of outcrops of the unaltered rock was not as deep red in colour as those of the altered rock adjoining the vein. The iron when in solution, however, may have been spread evenly and widely throughout parts of the chert undergoing alteration and the small amount that was redeposited could give a brighter red appearance than a larger percentage of iron, some in silicates and the balance as oxides localized in their distribution. X-ray fluorescent analyses were made of two samples of chert from the wall of a radioactive vein in chert at the north end of the YY-1 concession (*see* Figure 1), and the results of these show an increase of iron in chert from about 0.40 per cent at 36 inches from the vein, to 6 per cent adjacent to the vein. At the Bolger deposit where the zone of brecciation and reddening in the chert is irregular in shape and at least 100 feet wide, some quartz crystals contain one or more concentric bands of hematite dust and these are interpreted as the result of cyclic deposition of quartz and hematite upon each other. Small crystals of pyrite are abundant in the altered chert of this breccia, also veinlets, some of comb quartz and others of vermicular prochlorite (*see* Plate I A and B). Chlorite flakes and pyrite crystals join to give lenticular aggregates. During the growth of the radioactive veins in brecciated chert undoubtedly some minerals were dissolved and others formed, and the minerals of the wall-rocks probably were the chief source of iron of the hematite associated with the veins.

Specific Gravity of Chert

The specific gravity of red and grey to white chert was determined carefully. On the Bolger property the specific gravity of white chert 90 feet from a radioactive vein is 2·62; that of reddened chert 50 feet from a radioactive vein 2·56; that of translucent red chert 35 feet from a radioactive vein 2·64; that of reddened chert 2·5 feet from a radioactive vein 2·65; and that of grey chert from outside an altered zone 2·65. Reddened chert from near a radioactive fracture on the Fish Hook property has a specific gravity of 2·64 and that of bluish chert containing visible specularite from near a radioactive deposit on the YY-1 concession is 2·77. The results of the determination do not give significant variation in the specific gravity of chert wall-rocks unless enough iron has been added to form veinlets of hematite or visible grains of specularite.

TAZIN GROUP ARGILLITE

General Statement

The effects on wall-rocks of argillite during the deposition of certain of the South Tam radioactive veins (*see* Figures 1 and 4) have been studied in some detail. There the argillite is fractured to breccia zones commonly under 3 feet wide (*see* Plate I B and Figure 4). The colour of the argillite changes from black to red towards the veins and the number of red veinlets in the altered rock also increases, particularly in breccia zones. At some places the thin beds characteristic of the argillite are obscured.

Petrography

A study of thin sections of the argillitic wall-rocks of the South Tam veins (*see* Figure 4) indicates that alteration products do not extend more than 8 feet from the vein. At this distance the minerals are distributed in layers that probably represent thin beds and where these are slightly brecciated, veinlets and lenses of comb albite cut some fragments and cement others together. The albite grains vary from euhedral to subhedral and most crystals are well twinned (*see* Figure 5 A). It is unaltered although lightly stained by hematite dust. Penninite is an accessory mineral in the albite veinlets but this mineral is more abundent in the altered argillite than the veins. The veined argillite contains more earthy red hematite and specularite flakes than is characteristic of this rock outside of alteration zones.

At 4 feet from the radioactive vein the argillite is strongly brecciated and most of the albite is in thin lenses and veinlets. In the larger veins quartz, calcite, hematite, and chlorite are the gangue minerals. The argillite as a whole has been altered to a dense aggregate of chlorite, hematite dust, quartz, and albite.

At 1 foot from the radioactive vein the rock is completely recrystallized and replaced by microcrystalline aggregates of albite, quartz, and hematite dust. The only suggestion of bedding is the elongated aggregates of quartz mosaic, but the brecciated nature of the wall-rock is still visible. The altered rock is cut by veins carrying albite, quartz, calcite, chlorite, and the ore minerals. The albite shows checkerboard twinning,

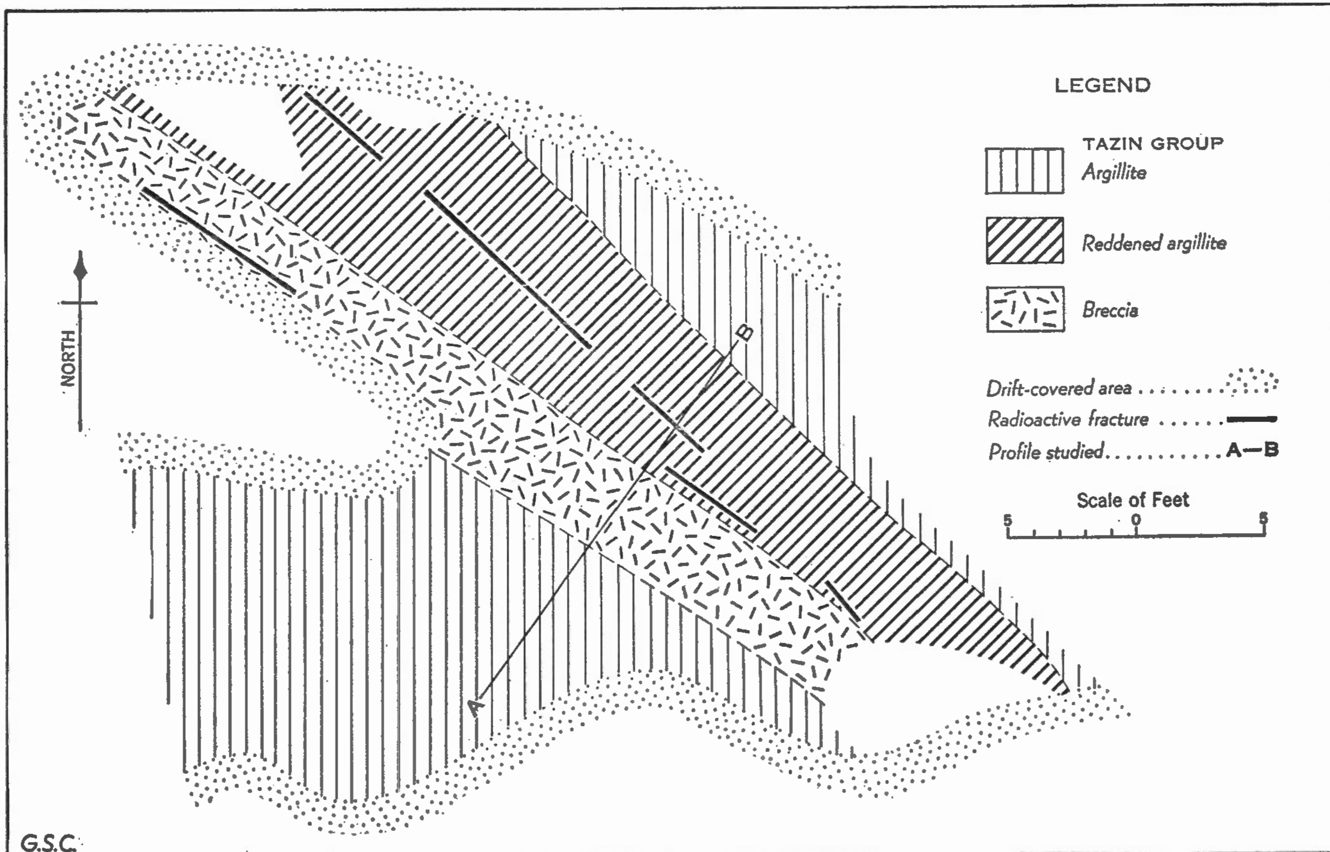


Figure 4. Geological sketch, South Tam occurrence.

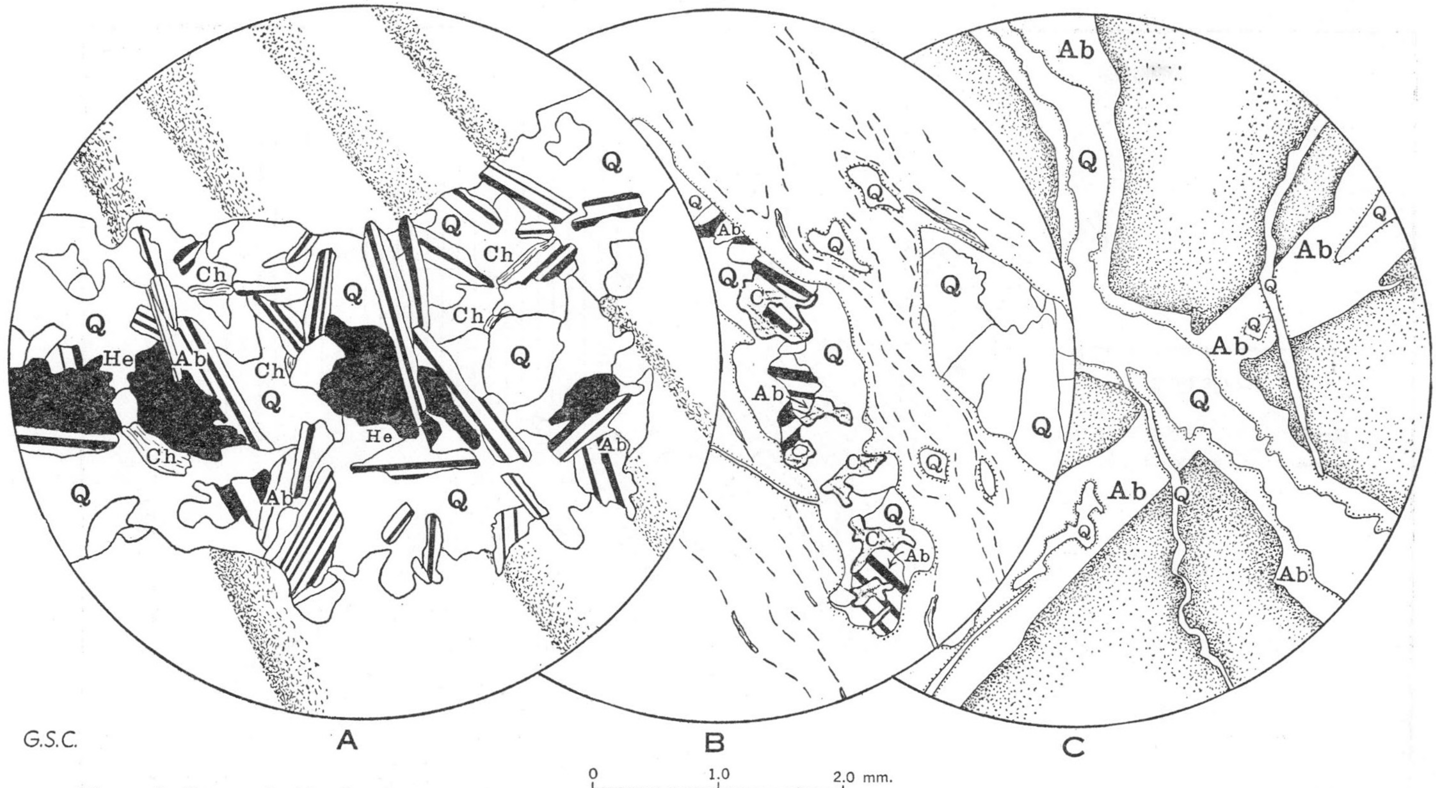


Figure 5. Camera-lucida drawings of albite veinlets.
A. In argillite: Ab, euhedral albite; He, hematite; Q, clear quartz.
B. Albite-calcite-quartz in lens parallel with foliation of gneiss: C, calcite; Ab, albite; Q, quartz.
C. In argillite: Ab, albite veinlet with discontinuous quartz core; Q, crosscutting quartz veinlet with albite along walls.

a maximum index lower than that of the Canada balsam, and the albite is not altered to white mica although lightly stained by hematite dust. The opaque minerals include hematite flakes and dust, a semi-opaque mineral, and a black metallic mineral. The last two may be radioactive.

Chemical Analyses

Two specimens of argillite were collected from the South Tam showing to illustrate the chemical effects of the alteration processes on that rock (*see* Table III). One analysis represents normal argillite, the second the altered phase. These indicate that there have been losses in silica, titania, alumina, total iron, potash, and total water, and gains in magnesia, lime, soda, and carbon dioxide. The cause of the loss of silica and alumina is not apparent in thin sections whereas the reduction in quantity of the mafic silicates supports the loss of total iron. The abundance of albite in the altered phase coupled with the absence or scarcity of hydrous silicates supports the loss of water. The gain of carbon dioxide and lime is reflected in the development of calcite and the gain in soda by the development of albite in the altered phase. The loss of potash may be the result of the increase in the content of albite.

TABLE III

Chemical Analyses of Argillite, South Tam Occurrence

—	I	II	III	IV	V
	%	%	%	%	%
SiO_2	68·39	65·76	63·78	−4·61	− 6·74
TiO_2	0·53	0·31	0·30	−0·23	− 43·40
Al_2O_3	13·20	12·84	12·45	−0·75	− 5·68
Fe_2O_3	1·86	1·10	1·06	−0·80	− 43·01
FeO	4·26	3·09	3·00	−1·26	− 29·58
MnO	0·04	0·04	0·04	nil	nil
MgO	2·17	2·62	2·54	+0·37	+ 17·05
CaO	0·93	3·20	3·10	+2·17	+233·33
Na_2O	2·08	3·70	3·59	+1·51	+ 72·60
K_2O	2·10	0·54	0·52	−1·58	− 75·24
H_2O+	3·03	1·67	1·62	−1·41	− 46·53
H_2O-	0·08	0·11	0·11	+0·03	+ 37·50
P_2O_5	0·12	0·05	0·05	−0·07	− 58·33
CO_2	nil	4·12	4·00	+4·00	+400·00
S	0·12	0·08	0·08	−0·04	− 33·33
C	0·23	0·40	0·39	+0·16	+ 69·57
Totals	99·14	99·63	—	2·51	
S.G.	2·73	2·66			

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

I. Unaltered argillite obtained 6 feet from the nearest radioactive vein, South Tam occurrence.

II. Altered argillite obtained from the immediate vicinity of radioactive vein.

The data in columns III, IV, and V are based upon the assumption that there has been no volume change in the wall-rocks. Column III gives analysis II recalculated to the same density as that of the unaltered rock. Column IV shows differences between analysis for the unaltered rock and the recalculated analysis for the altered rock. Column V contains the data from IV recalculated to percentages.

X-ray Spectrograph Analyses, Specific Gravity and Radioactivity

Three specimens of argillite from the South Tam deposit were analysed for total iron on the X-ray spectrograph. The results of these few analyses are given graphically (*see* Figure 6). These suggest that the total iron content increases and then decreases as the vein is approached. This decrease is confirmed by the chemical data given in Table III. The iron released from the silicate minerals of argillite and some other types of wall-rocks during alteration thus is a probable source of some of the abundant hematite and other iron-bearing minerals in certain wall-rocks and radioactive veins of the region.

Specific gravity determinations were made of a series of chips of unaltered and altered argillite from the South Tam occurrence. The average specific gravity of chips of fresh argillite from a point 1 foot from the radioactive vein is 2·72 and that of chips taken from beside the vein 2·67. This slight loss in density is a result of brecciation and the development of a suite of minerals with a lower specific gravity than those of the original rock.

A specimen of unaltered and one of altered argillite from the South Tam deposit were polished and tested in the Radioactivity Laboratory. The one of unaltered argillite taken 13 feet from a radioactive vein gave 16·9 alpha counts per hour above background and the one of reddened argillite 1 foot from the radioactive vein registered 32·1 alpha counts an hour above background. Reddened argillite at this locality is significantly more radioactive than unaltered argillite.

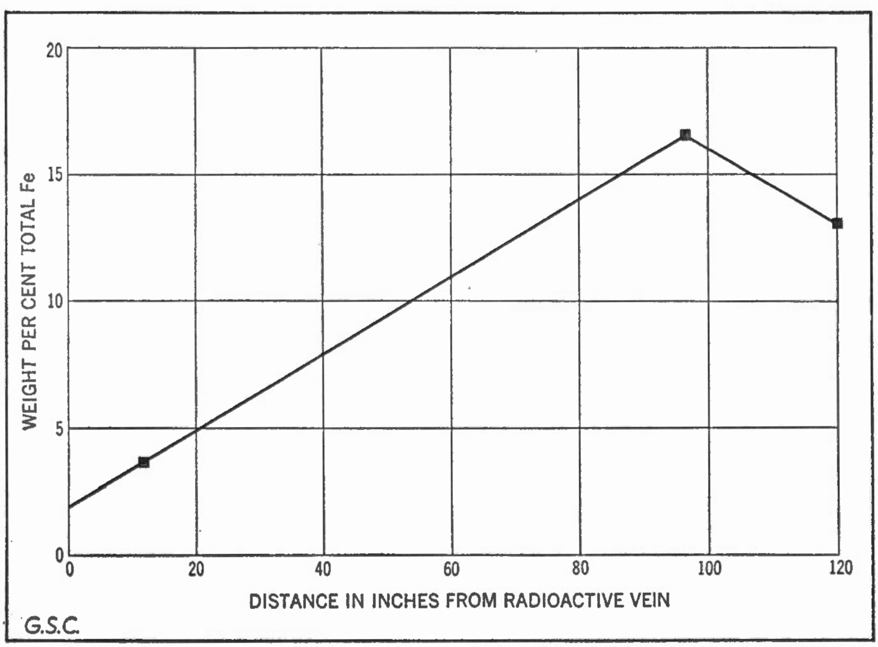


Figure 6. Graph to show change of total iron in argillite wall-rock of radioactive vein, South Tam deposit.

TAZIN GROUP SUBGREYWACKE

Petrography

Subgreywacke (Pettijohn, 1949) occurs at the Eagle mine (*see* Figure 1) and was studied in specimens of drill core and from the underground workings. The rock is a microbreccia consisting of angular fragments of quartz and feldspar with a few slivers of altered slate in a matrix of fine-grained chlorite, sericite, quartz, and feldspar. Classified on the basis of size, the constituents are chiefly of sand grade (quartz and feldspar from $\frac{1}{16}$ mm. to 2 mm. in diameter) and clay grade (represented by scaly aggregates of chlorite and sericite); silt grade is not important quantitatively.

In the walls of the radioactive veins at the Eagle mine subgreywacke changes in colour from dark green to an orange shade of red adjoining the vein. Such zones of change in colour are less than 5 feet wide and in them the rock is hard and the grain size is reduced from that of the nearby unaltered subgreywacke. Numerous veinlets carrying calcite, albite, quartz, and hematite are characteristic of the altered zone, and in places the walls of these veinlets become increasingly indistinct and the subgreywacke is completely replaced by a fine-grained mosaic of the vein minerals. Flakes of white mica present in the matrix of the unaltered subgreywacke are absent in altered phases and in the latter, chlorite is recrystallized to form fewer but larger flakes than in the unaltered rock. The grains of detrital quartz and feldspar also are recrystallized in the altered subgreywacke. A fine dust of hematite is present throughout the altered rock and this colours calcite and coats grains of siderite both in the veins and altered wall-rocks. The wider veinlets of calcite and albite contain flakes of specularite and this mineral is present along fracture planes in the altered subgreywacke. Most of the quartz occurs in veinlets, many of which cross albite veinlets as in Figure 5 C, but some quartz is well crystallized and this contains curved bands of inclusions. Pyrite and other sulphides are absent and only in a few of the specimens studied is the quartz stained by hematite. The unaltered subgreywacke has a specific gravity of 2·72 and the altered subgreywacke 2·69.

TAZIN GROUP MYLONITE

General Statement

All known mylonite is in formations older than the Athabasca series and mylonite is present at many localities along the St. Louis and the Black Bay faults. Mylonite occurs both in Tazin group strata and post-Tazin group intrusive rocks. The long axes of zones of mylonite at most points are parallel with the regional trends of the beds and the foliation of the country rock, consequently, cataclastic structures and textures of the mylonite are the principal evidence of movement along such zones.

Mylonite in the Tazin group rocks at the Ace mine has been studied in detail and mylonite also was noted in the area between Fredette Lake and the St. Louis fault, on the Emar group of claims and on the Strike and Bolger claims. The mylonite body exposed on the Emar group of claims strikes northeast except near Foot Bay where the strike is east and the dip south at approximately 45 degrees. On the Bolger property from

Verna Lake the mylonite zone strikes northeast and dips southeast. At the Ace and Eagle mines the mylonite bodies strike northeast and at the Ace mine the dip of the body is southeast from 45 to 55 degrees and thus parallels the dip of the St. Louis fault plane. The general strike of the mylonite bodies at the Ace mine, however, is more northeasterly than that of the St. Louis fault plane. Mylonite bodies near the Black Bay fault strike northerly and in general they parallel the plane of this fault. Some of the mylonite from near the Black Bay fault as recovered from drill cores from near Cinch Lake is chalky white, and this alteration product, as determined by X-ray powder tests, consists of quartz and white mica.

Petrography

The mylonite (oligoclasite) at the Ace mine (*see* Figure 7) consists of fine-grained reddened oligoclase (An_{10-15}) that shows optical anomalies, probably due to stress. The oligoclase of the larger grains is well twinned and some such grains are in part surrounded by flakes of penninite and sinuous grains of strained quartz. The origin of the rock is obscure.

The main veins carrying radioactive minerals cut this mylonite and these veins also contain oligoclase, calcite, penninite, opaque minerals, and some quartz. Light hematite stain is widespread but this mineral is particularly plentiful beside some radioactive veinlets. Only a little specularite is found more than 1 inch from veins. Under 800 magnification (Dawson, 1951, p. 27) the dense hematite-impregnated matrix surrounding the oligoclase grains resembles a boxwork, the walls of which consist of orange translucent granules. Some of the granules show a yellow birefringence; others are opaque. In twinned oligoclase similar granules follow cleavage or fracture planes. Much of the hematite occurs with white mica flakes. X-ray photographs of the dense hematitic matrix show a prominent set of lines corresponding to those of a sodic plagioclase and weak lines that might represent quartz. Darkening of the film probably is due to hematite. The walls of the radioactive veinlets cutting the oligoclase crystals and the hematite-stained matrix are sharp and many veinlets appear to follow microfractures.

In conclusion, the principal radioactive veins on the Ace property are restricted in distribution to red mylonite, a massive to finely banded rock. It is difficult to determine precisely the amount of the reddening that resulted from the addition of hematite during the deposition of the veins or if quartz and oligoclase have been added to form the dense matrix. The emplacement of the radioactive veins, however, appears to have effected few other visible changes in the mylonite.

POST-TAZIN GROUP ALASKITE

General Statement

The radioactive veins at the Lost mine veins on the Eagle property (*see* Figure 1) are in crushed and reddened alaskite that grades along and across the strike of the long axis of the bodies into black ultramylonite.

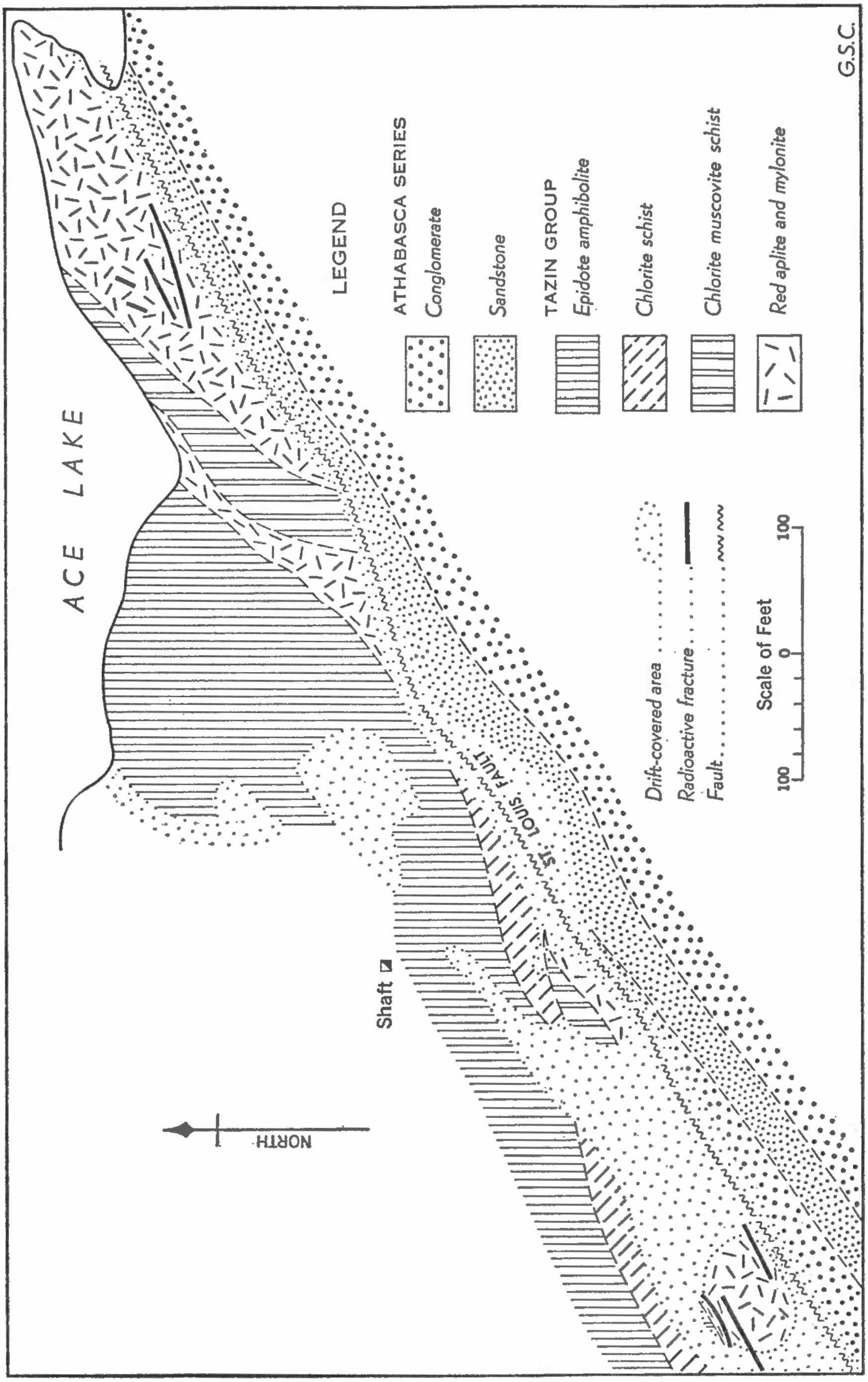


Figure 7. Geology, Ace mine shaft.

The black ultramylonite also contains radioactive veins, and one vein along the strike passes from red alaskite to black mylonite (*see* Figure 8). The alaskite is a foliated siliceous red rock consisting principally of quartz and feldspar without microcline or mafic minerals. The black ultramylonite is microcrystalline. Neither the alaskite nor the mylonite is known to show intrusive relations with the surrounding formations. These unusual rocks possibly are recrystallized chert to which materials have been added from a granitic magma.

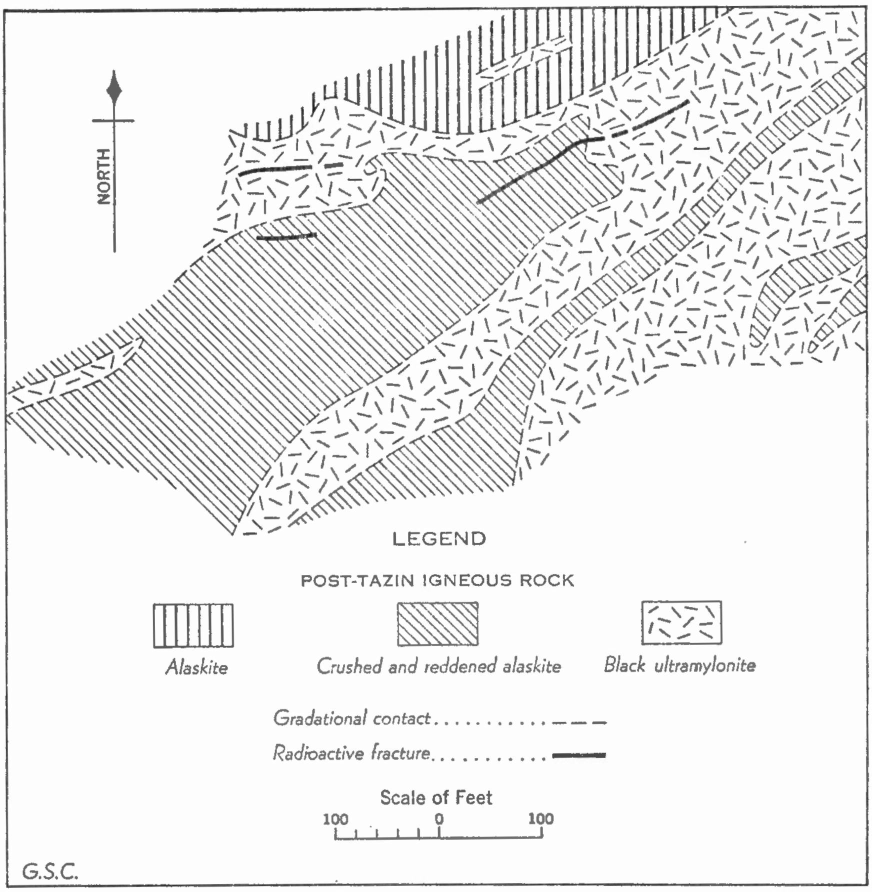


Figure 8. Geological sketch of Lost mine vein, Eagle claim group.

Petrography

Modes of alaskite at points from 1 foot to 14 feet from a radioactive vein are given in Table IV and the per cent gain by volume of hematite, carbonates, and quartz are plotted graphically in Figure 9 A.

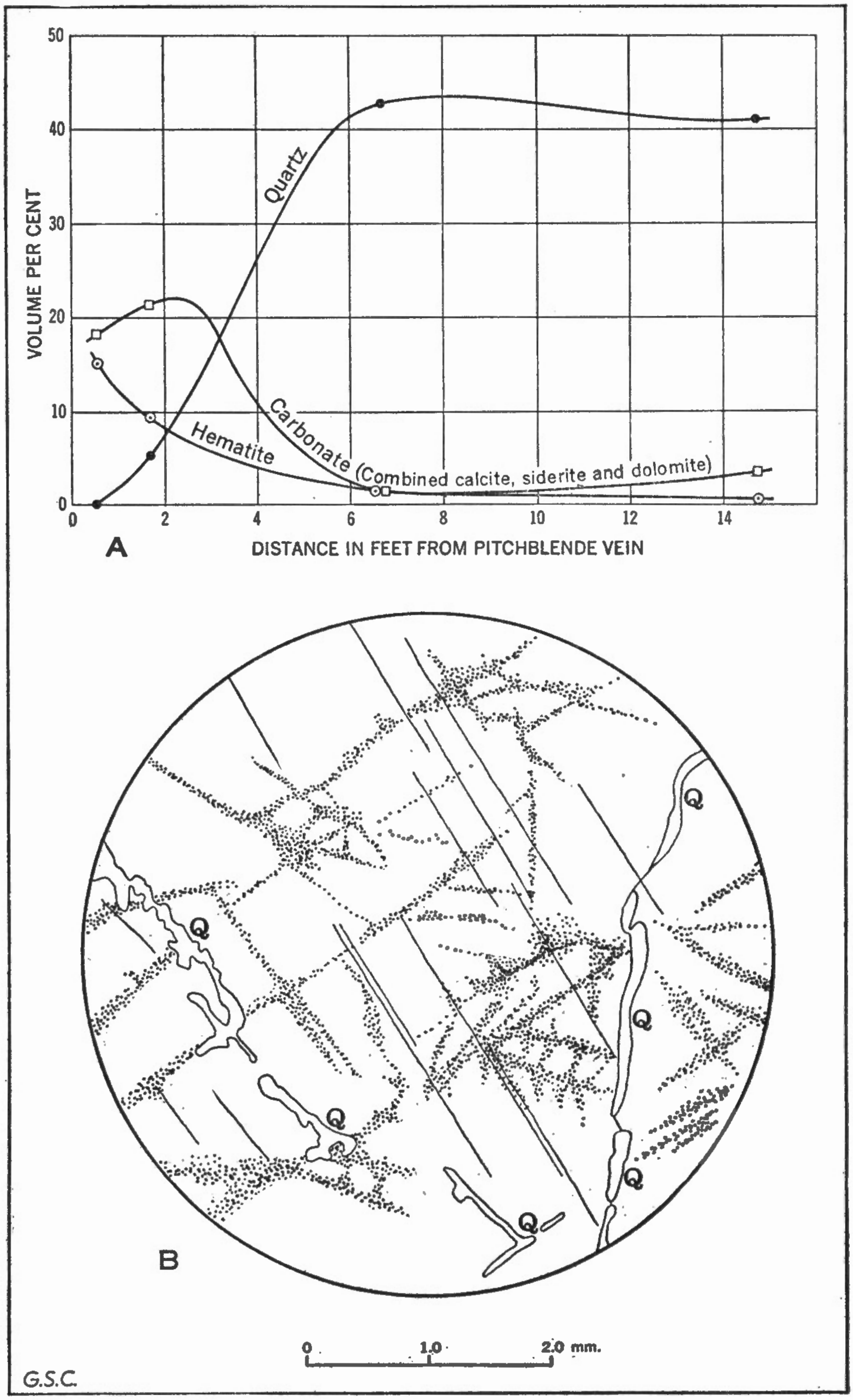


Figure 9. A. Graph to show per cent gain and loss by volume of minerals of alaskite.
B. Alteration of albite by quartz (Q) and hematite (stipple).

TABLE IV

Modes of Alaskite, Lost Mine Vein, Eagle Claim

—	Distance in feet from vein				
	1·0	2·7	3·7	6·7	14·5
	%	%	%	%	%
Albite	56·0	66·3	63·0	52·2	53·6
Calcite	19·2	17·0	21·8	1·6	3·8
Chlorite	9·0	0·3	0·4	1·0	0·4
Quartz	2·0	0·5	5·0	43·0	41·4
Hematite dust }	11·8	—	—		
Specularite }		} 14·5	{ 9·8	1·8 }	} 0·8
Kaolinite	—		—	—	
Siderite	2·0	1·5	—	—	—
Pyrite	—	—	—	—	—
Sericite	—	—	—	—	—
Apatite	—	—	—	0·4	

Alaskite close to the radioactive veins is noticeably redder than that away from the veins and also is cut by numerous veinlets. The albite contains abundant kaolin and at 7 feet from the radioactive vein veinlets of fresh albite cut the kaolin-bearing albite. Dusty hematite stains both the original albite of the rock and the vein albite. At 3 feet from the vein dolomite and siderite are abundant and they replace fine-grained albite. Hematite dust and flakes of specularite increase in quantity at 3 feet from the vein. Some chlorite and calcite are present and these minerals are gangue minerals of the adjoining radioactive veins. A noticeable feature of the change in the alaskite on approaching the Lost mine radioactive veins is the rapid and marked decrease in the quantity of quartz in the wall-rocks commencing at about 6 feet from the vein and the correspondingly smaller increases in the volume per cent of carbonates and hematite. The specific gravity decreases only slightly from 2·65 for the unaltered to 2·62 for the altered alaskite. The reddened alaskite or mylonite is much more radioactive than the normal type, for a specimen from beside a vein on the Eagle claim group returned 88·3 alpha counts per hour over the background, whereas alaskite 12 feet from the same vein registered only 1·8 alpha counts per hour over background.

POST-TAZIN GROUP QUARTZ GABBRO

General Statement

Quartz gabbro from the walls of the Gil deposit was studied as a representative of altered wall-rocks of veins in basic intrusive rocks that are younger than the Tazin group metamorphic types. The gabbro on the Gil property forms tabular sills up to 50 feet thick that strike east and dip gently south. The gabbro is medium to coarse grained and the sills contain lenses and irregular-outlined areas of gabbroic pegmatite and pink granophyre. The unaltered gabbro is black whereas the altered rock beside the deposit is red and the large grains and crystals of hornblende are represented by a fine-grained aggregate to give a uniformly fine-grained type.

Petrography

In Table V the per cent by volume of the minerals present in quartz gabbro from 1·2 to 8 feet from the Gil deposit is given. At 2·3 feet from the deposit hornblende and biotite are completely gone; the hornblende has changed to chlorite and dusty hematite, and the biotite to chlorite and leucoxene. Ilmenite also has changed to leucoxene and hematite. Some plagioclase contains fine-grained aggregates of sericite and epidote. The feldspar content, however, increases rapidly as the deposit is approached and the quartz content decreases. The changes in volume per cent of six minerals of the gabbro with distance from the deposit are indicated graphically in

TABLE V

Modes of Quartz Gabbro, Gil Deposit

—	Distance in feet from vein			
	8·0	2·3	1·6	1·2
	%	%	%	%
Hornblende	36·4			
Biotite	29·4			
Chlorite		54·6	40·4	37·4
Plagioclase	7·4	34·2	40·0	41·0
Quartz	23·2	5·4	3·8	4·6
Apatite	1·8	1·2	1·0	0·6
Ilmenite	1·4			
Hematite	—	—	11·8	14·4
Pyrite	0·5			
Leucoxene	—	4·6	3·0	2·0

Figure 10 A, and 10 B illustrates the decrease in specific gravity of the quartz gabbro. The slight decrease probably results from the change of ilmenite (S.G. 4·5–5·1) to leucoxene and hematite (S.G. 3·9–5·3) and the introduction of albite (S.G. 2·6) and calcite (S.G. 2·71) (Ford, 1926).

The quartz gabbro at 8 feet from the deposit consists of large ragged-outlined grains of hornblende (*see* Figure 11 A) that contain inclusions of biotite, untwinned plagioclase, and magnetite. The matrix is fine-grained quartz and untwinned plagioclase. At 2 feet from the vein (*see* Figure 11 B) all the biotite and the hornblende are altered to chlorite and hematite. Some leucoxene occurs along cleavage planes of chlorite. Calcite appears in small veinlets and scattered grains and at 1·6 feet from the deposit epidote and veinlets of quartz are present. Microcrystalline albite, lightly stained by hematite dust, replaces some of the chlorite and also the plagioclase of the quartz gabbro. Immediately adjacent to radioactive veins the silicate minerals have been in large part replaced by calcite and the texture of the quartz gabbro has been obscured. Specimens of this altered quartz gabbro from beside a vein are highly radioactive, giving 354·7 alpha counts per hour over background, whereas a specimen 4 inches from the vein gives only 15·6 alpha counts per hour over background.

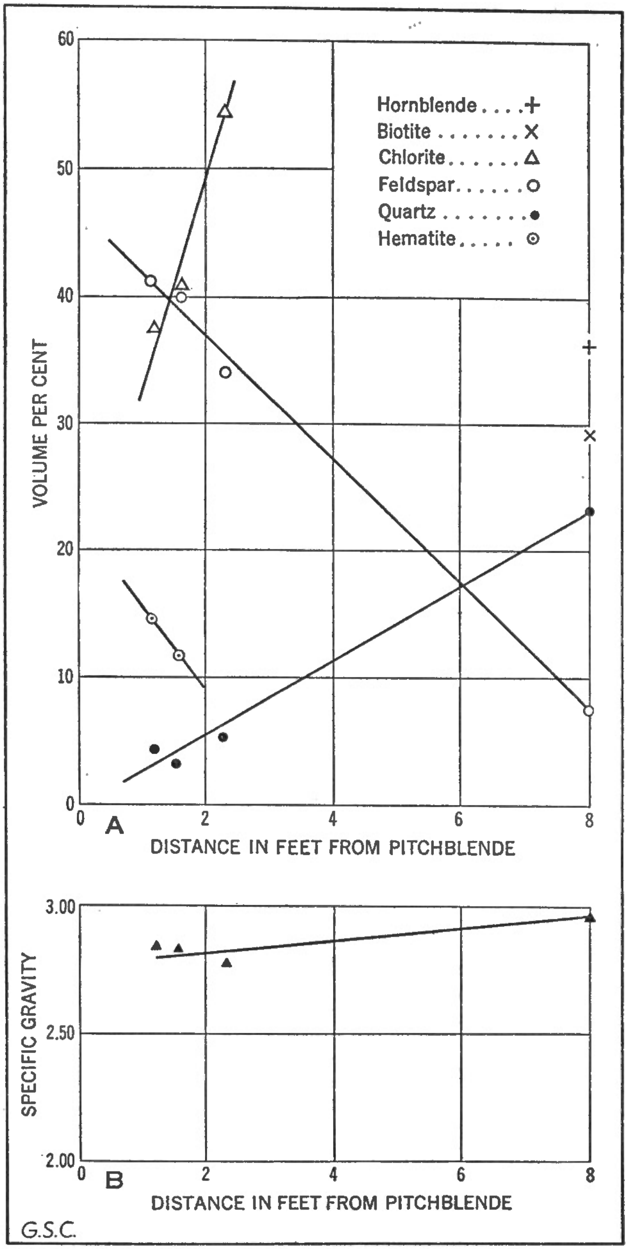


Figure 10. A. Graphical representation of changes in per cent by volume of minerals of quartz gabbro, Gil deposit.

B. Graph of change in specific gravity, quartz gabbro beside Gil deposit.

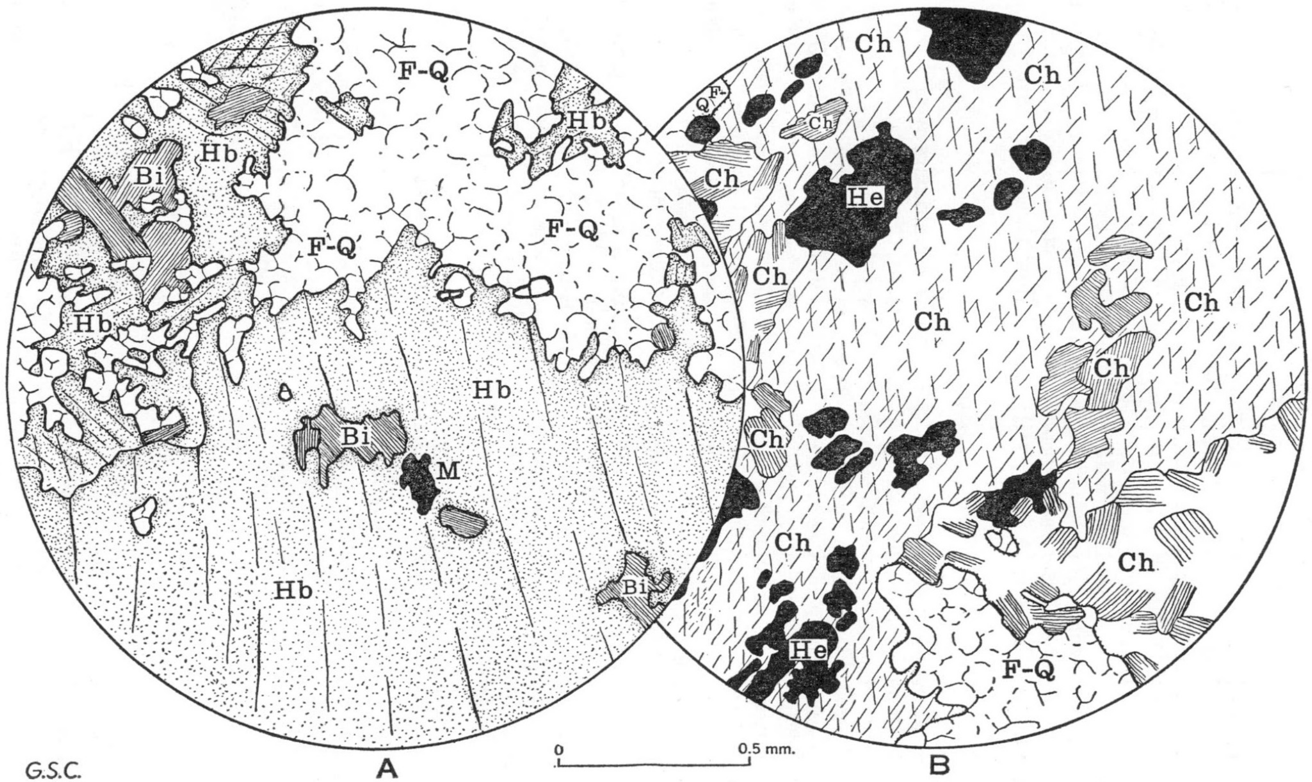


Figure 11. A. Camera-lucida drawing of quartz gabbro, Gil property: FQ, feldspar and quartz; Hb, hornblende; Bi, biotite; M, magnetite.

B. Camera-lucida drawing of altered quartz gabbro beside Gil deposit; FQ, feldspar and quartz; Ch, chlorite; He, hematite.

ATHABASCA SERIES CONGLOMERATE

General Statement

The Ura occurrence (*see* Figure 1) follows a northeast striking fracture (*see* Figure 12 A) in conglomerate and this structure is located south of the St. Louis fault. The fracture for a part of its length is bordered on both sides or one side only by a narrow sinuous zone of breccia and the rock of this and the unbrecciated conglomerate for distances as great as 4 inches from the breccia is altered. Unaltered and unbrecciated conglomerate grades through brecciated conglomerate into a dense red rock adjoining the radioactive veins. The radioactive minerals occur chiefly in calcite veins, containing some barite and pyrite, and follow the central fracture.

Petrography

Gangue minerals introduced into the altered conglomerate and conglomerate breccia include hematite, albite, quartz, barite, pyrite, and calcite. They occur in sharp-walled veinlets that cut matrix and pebbles alike (*see* Plate I A). These veinlets may extend 3 feet into the wall of the central vein. Some of the albite is in subhedral laths that are 0·05 mm. long. The albite of such laths is either coated or stained lightly by submicroscopic grains of red hematite. At some points albite crystals are present on the walls of quartz veins and at others this mineral forms veinlets that cross fractured quartz crystals. Near the centre of the zone of altered conglomerate and breccia a fine-grained mosaic of untwinned albite contains scattered albite grains showing checkerboard twinning.

Veinlets of milky quartz (*see* Plate I A) have a distribution similar to those of reddened albite. Quartz also cements the fragments of the breccia and in some places small cavities are lined by comb quartz. Fine-grained quartz is plentiful in the dense red rock. Some crystals of quartz contain numerous gas, liquid, or liquid gas inclusions and hematite dust arranged in layers parallel with terminal faces of the crystals.

ATHABASCA SERIES FELDSPATHIC SANDSTONE

General Statement

On the RA group of mineral claims (*see* Figure 1) radioactive veins pass from meta-basalt to feldspathic sandstone (*see* Figure 12 B). Most of the veins in meta-basalt strike southwest but the strike of these veins changes to nearly west in the sandstone. Towards the veins in sandstone the intensity of red coloration increases and poikiloblasts of calcite are characteristic.

Petrography

Red dust is prominent in all thin sections of specimens of feldspathic sandstone taken within 3 feet of radioactive veins but the quantity increases markedly from about 7 inches from the vein to the vein (*see* Figure 13 A). Beside the vein the sandstone becomes a spongiform aggregate of hematite carrying a few unaltered fragments of plagioclase, microcline, and quartz (*see* Plate III A and B). At 7 inches or more from the veins sodic oligoclase is the abundant feldspar of the sandstone and this mineral shows

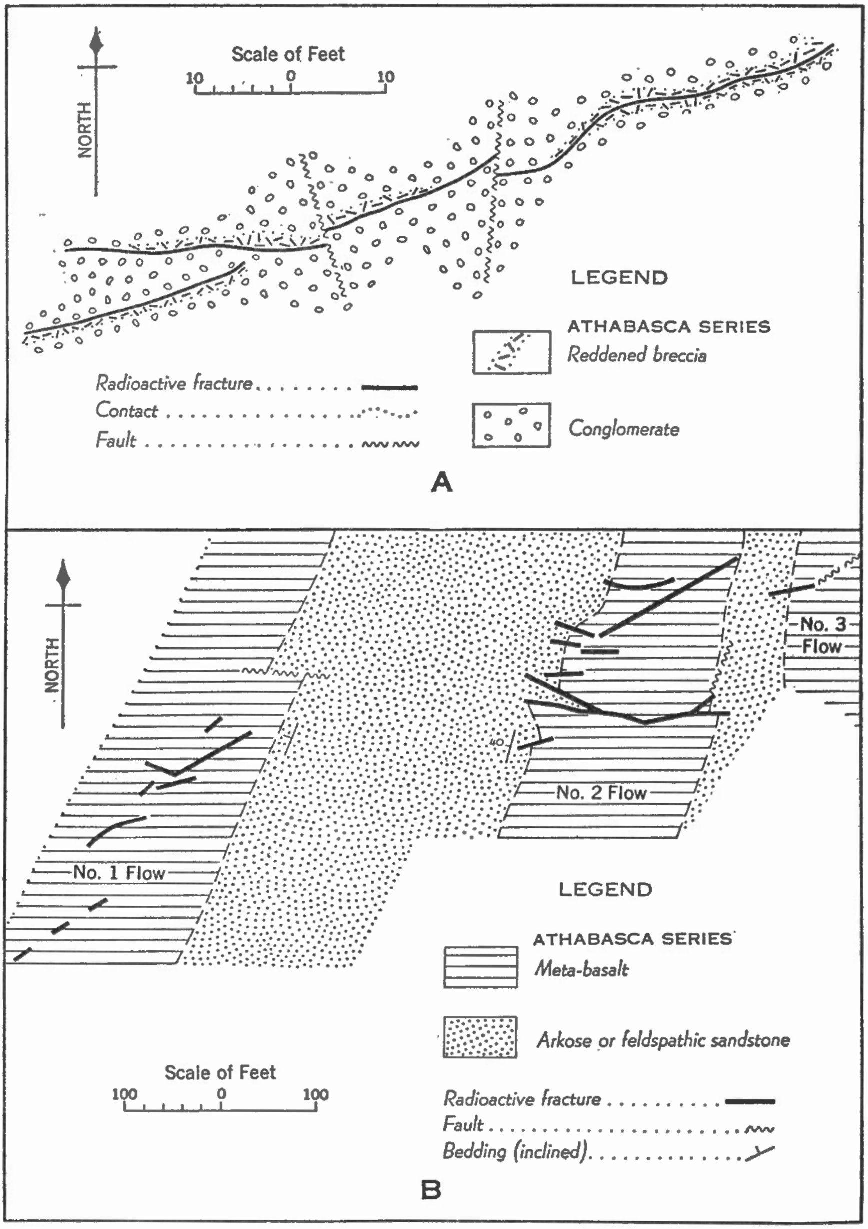


Figure 12. A. Geology of Ura deposit.
B. Geology of RA deposit.

light alteration to white mica. Some coloured and altered oligoclase fragments have a rim of clear feldspar and this in most fragments is optically continuous with the feldspar of the core. The microcline shows its characteristic grating structure, and no rims were observed around fragments of it. Quartz is not as plentiful as feldspar in most thin sections and it occurs as fragments of single crystals or of a fine quartz mosaic. Calcite occurs as veinlets, as ragged grains replacing the matrix and, commonly, the feldspar grains, and as a cement between the fragments. Many of the larger grains of calcite are twinned and may or may not be impregnated by hematite dust. The calcite cement is partly replaced by hematite. In general the amount of calcite is constant, but within 10 inches of one radioactive vein it decreases sharply. From there to the limit of observation, 5 feet, it is relatively uniform (*see* Figure 13 A).

The total iron of three specimens of feldspathic sandstone was determined by X-ray spectrographic analyses and these (*see* Figure 12 B) indicate that the total iron content is nearly constant to within 6 feet of the vein and from there on increases about 1 per cent at the vein. The specific gravity of unaltered feldspathic sandstone is 2·61 and that of the altered sandstone is 2·69.

ATHABASCA SERIES META-BASALT

General Statement

Specimens of meta-basalt from outcrops of Nos. 1, 2, and 3 flows on the RA group of mineral claims (*see* Figure 12 B) and from sub-surface workings along radioactive veins in these flows have been studied. The meta-basalt is not altered noticeably over 2 feet from the radioactive veins except where two fractures approach each other. The altered meta-basalt is strikingly red in colour.

Petrography

The meta-basalt consists of andesine in laths (*see* Figure 14 A) and flakes of specularite and grains of apatite in a dense matrix of chlorite flakes, hematite, and undeterminate material. In the altered meta-basalt only remnants of the andesine laths and the matrix remain in a fine-grained aggregate of hematite and calcite (*see* Figure 14 B). The chlorite (ferriferous penninite) and some specularite flakes produce dusty hematite, and andesine is in part altered to sericite. Hematite dust and flakes of specularite also are distributed in an irregular manner in andesine and calcite along grain boundaries and in microfractures. Pink or white calcite is abundant in the walls of radioactive veins. Quartz forms interstitial patches and radiating aggregates in the penninite. Veins of grey calcite and quartz are not known to be radioactive. Only a few veinlets of albite were noted.

Three samples of meta-basalt were collected from the adit to the Martin Lake radioactive deposit and the chemical analyses of these are presented in Table VI. These analyses show a loss of silica and soda and a gain in lime, potash, and carbon dioxide. They show, moreover, that the total iron content of the analysed materials did not change significantly. The behaviour of the ferric and ferrous oxides, magnesia, alumina, and phosphate shows no clear trend but does show some variation.

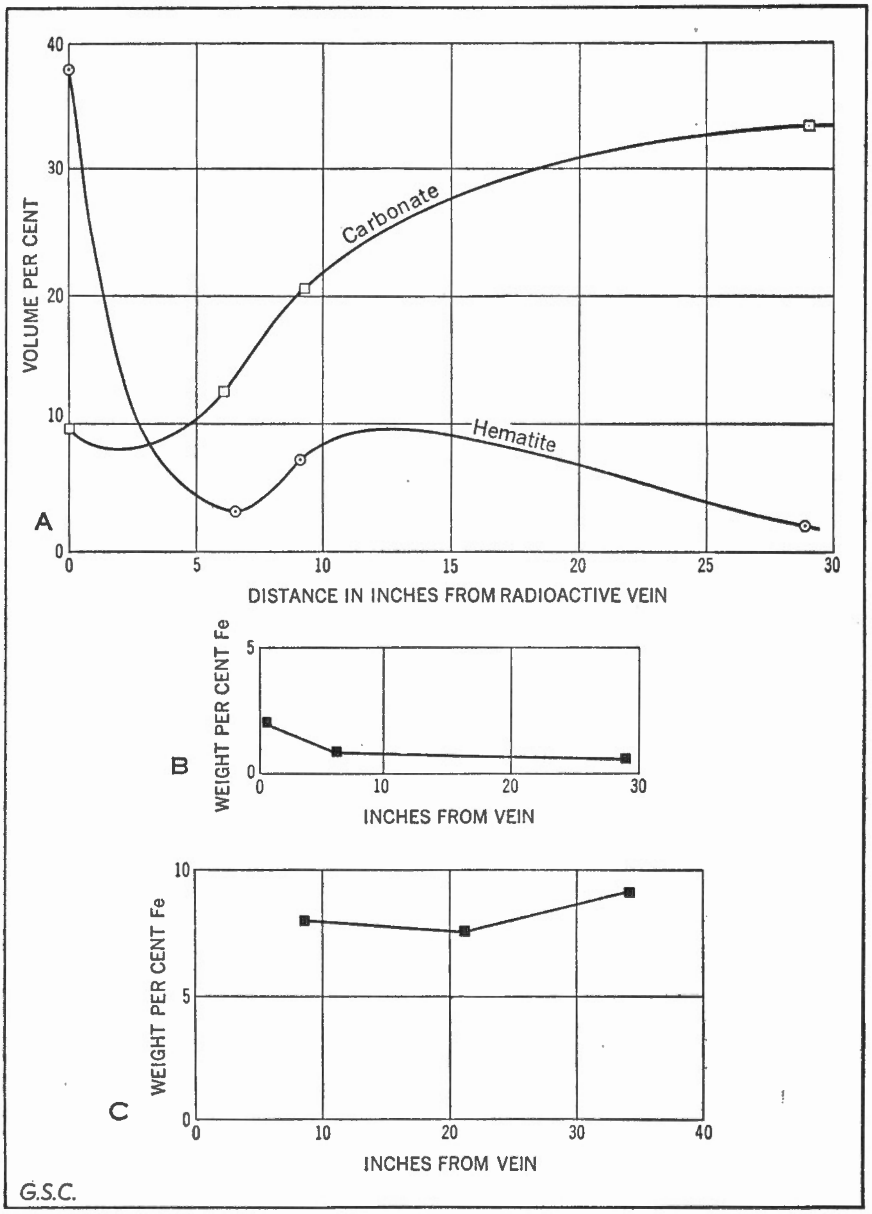


Figure 13. A. Graph to show gain and loss in volume per cent of hematite and carbonate, feldspathic sandstone beside a radioactive vein.
B. Graph to show gain in total iron near radioactive vein.
C. Loss and gain total iron in meta-basalt beside radioactive vein.

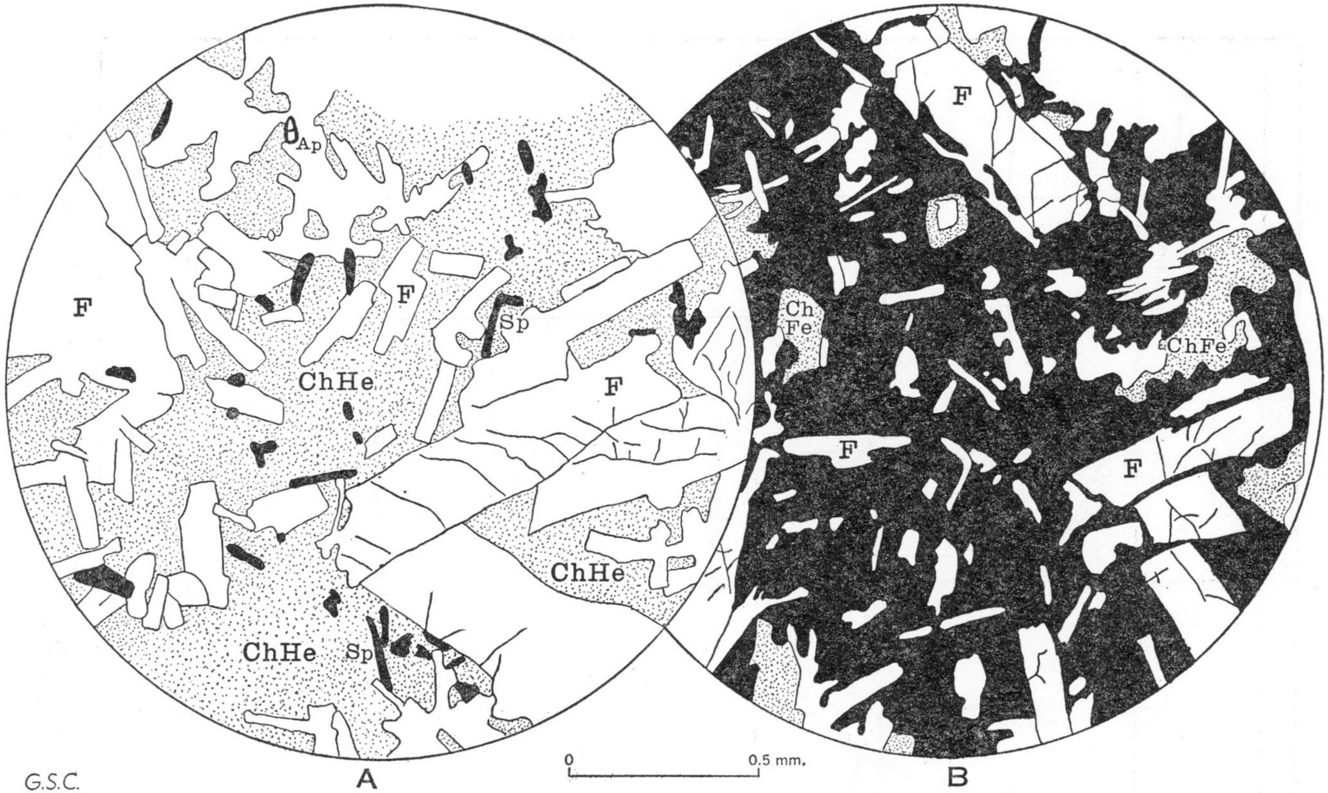


Figure 14. Camera-lucida drawings of meta-basalt.

A. Unaltered: F, andesine laths; Sp, specularite flakes; Ap, apatite; Ch He, chlorite flakes, hematite dust, and undeterminate material.

B. Altered: most of F, andesine laths and Ch Fe matrix gone to black, consisting of a fine-grained aggregate of hematite and calcite.

TABLE VI

Chemical Composition of Meta-basalt, No. 2 Flow, Martin Lake Adit, RA Claims

	I	II	III	IV	V	VI	VII	VIII	IX	X
	%	%	%	%	%	%	%	%	%	%
SiO_2	46·07	40·93	40·52	−5·55	− 12·05	47·97	40·93	40·52	−7·45	− 15·53
TiO_2	0·63	1·37	1·36	+0·73	+115·87	1·16	1·37	1·35	+0·19	+ 16·40
Al_2O_3	16·29	15·94	15·78	−0·51	− 3·13	16·41	15·94	15·78	−0·63	− 3·84
Fe_2O_3	9·14	10·60	10·49	+1·35	+ 14·77	9·23	10·60	10·49	+1·26	+ 13·65
FeO	4·26	3·14	3·11	−1·15	− 27·00	2·67	3·14	3·11	+0·44	+ 16·47
MnO	0·01	0·04	0·04	+0·03	+300·00	0·01	0·04	0·04	+0·03	+300·00
MgO	4·53	4·39	4·35	−0·18	− 3·97	3·62	4·39	4·35	+0·73	+ 20·17
CaO	4·64	7·74	7·66	+3·02	+ 65·09	5·77	7·74	7·66	+1·89	+ 32·76
Na_2O	5·48	3·16	3·13	−2·35	− 42·88	4·42	3·16	3·13	−1·29	− 29·19
K_2O	1·56	1·69	1·67	+0·11	+ 7·05	1·54	1·69	1·67	+0·13	+ 8·44
H_2O+	3·08	3·15	3·12	+0·04	+ 1·30	2·34	3·15	3·12	+0·78	+ 33·33
H_2O-	0·40	0·31	0·31	−0·09	− 22·50	0·76	0·31	0·31	−0·45	− 59·21
P_2O_5	1·08	1·00	0·99	−0·09	− 8·33	0·87	1·00	0·99	+0·12	+ 13·79
CO_2	3·30	6·10	6·03	+2·73	+ 82·73	3·10	6·10	6·04	+2·94	+ 94·84
S	0·04	0·03	0·03	−0·01	− 25·00	0·16	0·03	0·03	−0·13	− 81·25
Totals	100·51	99·59	99·59	−1·92	—	100·04	99·59	—	−1·44	
S.G.	2·79	2·77	—	—	—	2·80	2·77			

The specific gravity of meta-basalt is as follows:

Spec. gravity	Flow No.	No. meas.	Remarks
2·79	1	10	Fresh
2·79	2	14	"
2·79	3	11	"
2·78	1	8	Altered
2·78	2	17	"
2·81	3	9	"

The altered meta-basalt is highly radioactive, that from beside a calcite vein registering 301·3 alpha counts per hour above background; that 6 inches away from the vein 195·6 counts; that 20 inches from the vein 11·5 counts; and that 1 mile away nil counts. The total iron content as determined by X-ray spectrographic tests decreases from about 9 per cent at 34 feet from the vein to 7·5 per cent at 20·5 feet from the vein and then increases slightly towards the vein (*see* Figure 13 C). These results confirm those of the chemical analyses (*see* Table VI), showing that the total iron content did not change significantly in wall-rock alteration beside calcite veins.

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

I. Meta-basalt, 18 inches from radioactive vein.
II. Meta-basalt 6 inches from radioactive vein.
III. Analyses II calculated to same density as I.
IV. Gain or loss of constituent.
V. Gain or loss percentage of constituent present.
VI. Meta-basalt 12 inches from radioactive vein.
VII. Meta-basalt 6 inches from radioactive vein.
VIII. Analyses VII calculated to same density as VI.
IX. Gain or loss of constituent.
X. Gain or loss percentage of constituent present.

The meta-basalt beside such veins is altered at most points less than a foot on each side of the deposit.

POST-ATHABASCA SERIES GABBRO

General Statement

The specimens of post-Athabasca series gabbro studied are from the Jam claims at a point near the outlet of Cinch Lake, the FF-1 concession and the Strike group of claims (*see* Figure 1). At these localities the known veins are in tight fractures a few feet in length and bordered by lenses of breccia rarely exceeding 3 inches in width.

Petrography

The examination of thin sections of the altered gabbro shows little or no change in the minerals and texture of the rock. Albite is present and it, calcite, and quartz form veinlets. A few grains of calcite also are disseminated in the gabbro close to the veins. Hematite occurs in particles of microscopic size and probably was derived from magnetite and iron-bearing silicates. A few grains of pyrite are present.

Red Coloration

DESCRIPTION

The altered wall-rocks of many radioactive deposits of the Goldfields region are strikingly coloured and this feature has been emphasized in the general descriptions given in the preceding pages. The colour in different deposits is bright red, yellowish red, or brown and results from a concentration of hematite veinlets, iron oxide stain on minerals, and evenly disseminated red or yellow dust. In some cases the hematite veinlets increase in width and numbers as a radioactive vein is approached from the walls and accordingly the intensity of red coloration increases. Potash and plagioclase feldspars, carbonates, quartz, and barite are reddened. Of the feldspars, reddened albite probably is the most widespread and this mineral is especially plentiful in alaskite and mylonite. In these rocks the albite is an intense red, and in the wall-rocks of some deposits the intensity of red coloration increases noticeably close to the veins due to dusty red hematite that forms around the boundaries of white albite grains, and penetrates these along microfractures until the whole grain becomes an earthy red aggregate of hematite. Carbonates are from pink to dark red in colour and reddened carbonates are not so widespread in their occurrence as the feldspars. Quartz is rarely reddened and it does not show the colour intensity of either the feldspars or the carbonates.

Earthy red dust stains the wall-rocks of some radioactive deposits, particularly those in the Athabasca series feldspathic sandstone and basalt and Tazin group chert. In these rocks the red dust is distributed through the intergranular spaces and is not concentrated within a particular mineral. The staining material in the matrix, and where present within the grains is a yellowish red dust consisting of particles less than 0·001 mm. in diameter. These particles are translucent with yellow birefringence and they are not tabular nor do they show other plane geometric shapes. The particles have no detected preferred orientation and their distribution in abundance at grain boundaries and along microfractures is characteristic. These particles may be alpha hematite, as suggested by the results of differential thermal analysis (Forman, 1952).

The feldspars are characteristically red in some rocks, especially granite and pegmatite, and various explanations of this have been advanced. To check the idea that the red coloration may be the result of the presence of a larger than normal content of some element, the relative abundance of trace elements of feldspars from different regions was determined (*see* Table VII). Assuming iron a cause of the red coloration, the analyses indicate this varies in quantity 0·01 to 1·0 per cent and that the red feldspars, Nos. 16 to 20 inclusive, contain much more iron than white feldspars, Nos. 1 to 3 inclusive. Other trace elements that might influence the colour of the feldspar, as manganese and magnesium, are more plentiful in some red than in white feldspar.

TABLE VII

Trace Elements in Feldspar Determined by Spectrographic Analyses

No.	Elements detected											
	Ba	Be	Mn	Mg	Pb	Cr	Fe	Ca	V	Cu	Ti	Zr
1	—*	—	3	4	4	—	3	3	—	4	—	—
2	—	—	3	4	4	—	3	3	—	4	3	—
3	—	4	3	3	4	—	3	2	—	3	3	—
4	3	4	2	1	3	4	2	2	3	4	3	4
5	3	—	2	1	4	4	2	2	3	4	3	—
6	4	4	2	1	4	4	2	2	3	4	3	—
7	3	—	2	1	4	4	2	2	3	3	3	—
8	3	4	2	1	3	4	2	2	3	2	3	—
9	3	—	2	1	3	4	2	2	3	4	3	4
10	—	—	3	2	4	—	2	2	—	4	3	—
11	—	—	3	2	4	—	2	2	4	4	3	—
12	3	—	2	1	3	4	3	2	3	4	3	—
13	—	—	3	2	4	—	2	2	4	4	3	4?†
14	3	—	2	1	3	4	2	2	3	4	3	—
15	3	—	2	1	4	4	2	2	3	4	3	—
16	—	—	2	2	4	4	2	2	4	4	2	4?
17	—	—	3	2	4	4	2	2	4	4	2	4?
18	2	4	2	1	4	4	2	2	3	2	3	—
19	3	4	2	1	3	4	2	2	3	4	3	—
20	3	—	2	1	3	4	2	2	3	4	3	4

1. 1·00% — 10·0%.
2. 0·10% — 1·0%.
3. 0·01% — 0·1%.
4. 0·01% or less.

* Nil
† Possible trace

Explanation of Table VII

Feldspars from pegmatite dykes in the Grenville region.

1. Colourless microcline (dental spar) from a pegmatite, Buckingham, Quebec.
2. Pink-coloured microcline from a pegmatite, Buckingham, Quebec.
3. Colourless albite from Villeneuve, Quebec.

Feldspars from pegmatite in the Goldfields region.

4. White feldspar from a radioactive pegmatite on PP concession.
5. Pink feldspar from a non-radioactive pegmatite on PP concession.
6. Red feldspar from a pegmatite near the Leonard showing, DD-1 concession.
7. Red feldspar from a pegmatite exposed on CC-2 concession.
8. Brown feldspar from a pegmatite exposed on CC-1 concession.
9. Blue feldspar from a pegmatite exposed near the Leonard showing, DD-1 concession.

Feldspar from post-Tazin granite, Goldfields region and from a Precambrian granite, Great Slave Lake.

10. Red feldspar, Lodge Bay granite collected by A. M. Christie.
11. Red feldspar, MacIntosh Bay granite collected by A. M. Christie.
12. White feldspar granite exposed on CC-2 concession.
13. Red feldspar from granodiorite north of McKinley Lake, north of Taltheilei Narrows, Great Slave Lake, Northwest Territories. Collected by I. C. Brown.

Reddened feldspar from Tazin group, Goldfields region.

14. Red feldspar from augen in gneiss near Nesbitt Lake.

Feldspar from feldspathic mylonite, Goldfields region.

15. Red oligoclase from the Donaldson showing on the Emar claim group.

Feldspar from the walls of radioactive veins, Goldfields region.

16. Red oligoclase from post-Tazin granite, Eagle property, 300 feet from nearest known radioactive minerals.
17. Red oligoclase collected 3 feet from the nearest known radioactive minerals, Lost mine vein, Eagle property.
18. Red albite collected from a vein 1 foot from radioactive minerals, Fold Lake.
19. Red albite collected from beside radioactive minerals in a vein near Fold Lake.
20. Pink feldspar, from a radioactive vein exposed in the adit at the Leonard showing, DD-1 concession.

ORIGIN

The red dust and stain in the matrix and certain minerals of the wall-rocks at some radioactive deposits in Goldfields region could result from auto-oxidation, exsolution, alumina metasomatism, simultaneous breakdown and crystallization of mafic silicates, and the introduction of the red material by solutions from which the radioactive veins were deposited. Auto-oxidation was proposed by Ellsworth (1932) to explain the occurrence of hematite beside radioactive minerals in pegmatites. The uranium in these minerals gives off radon gas, alpha and beta particles, gamma rays, and nascent oxygen, under which circumstances ferrous iron might have become ferric iron and this combined with any nascent oxygen present to form hematite. This could happen in wall-rocks, as gabbro or basalt, where magnetite, hornblende, biotite, and chlorite were altered to supply ferrous iron, but such rocks and minerals as chert, alaskite, some mylonite, quartz, feldspar, and carbonates contain a limited supply of ferrous iron. Auto-oxidation furthermore is regarded as taking place at a fixed rate after the radioactive minerals were deposited and the formation of hematite and the staining of the wall-rocks are best interpreted as a result of alteration effected during the deposition of the veins containing the radioactive minerals.

Exsolution and alumina metasomatism apply especially to the feldspars. Both exsolution and alumina metasomatism require that the feldspar retain some iron in the alumina lattice positions at low temperatures. Faust (1936) states that orthoclase is the only iron-bearing feldspar known to occur naturally, and as albite or sodic oligoclase are the principal stained feldspars known in the Goldfields region, this process apparently is not applicable.

In certain wall-rocks most of the hematite probably resulted from the alteration of silicates in the rocks beside the veins. Some of this was trapped as microscopic inclusions in minerals, such as calcite, albite, quartz, that grew from the products of the alteration. Hematite inclusions without discernible crystallographic orientation in clear albite of veins crossing the altered rocks may be thus explained. Modal analyses of mafic unaltered and altered rocks adjoining radioactive veins indicate an increase in the hematite content of the altered rock that can be correlated with the decrease in the quantity of mafic silicates present as compared with that of the nearby unaltered rock. This probably is an important source of hematite. Chemical analyses, however, indicate that iron is added in some cases and removed in others and hematite locally intergrown with and staining gangue minerals of the veins suggests that the solutions from which the veins were deposited were capable of transporting iron and depositing hematite. Such solutions also were capable of penetrating microfractures and intergranular spaces of minerals of the wall-rocks and depositing hematite in these situations. Hematite was deposited in chert beside veins and also some was added to altered amphibolite and the movement of iron and the deposition of iron is supported at many radioactive deposits by the occurrence of hematite along fractures, and as encrustations on carbonate, quartz, and feldspar grains.

Summary and Interpretation

The investigation described in the foregoing sections of this report was limited in scope and conclusions, accordingly, are tentative. Most of the material for study was taken from surface exposures, as prior to 1952 underground development was limited to a few deposits and to less than 500 feet in depth. The wall-rocks of disseminated deposits have not been studied and all veins or series of veins investigated follow pre-vein fracture zones.

Retrogressive metamorphism and metasomatism characterize the alteration beside the radioactive veins studied in detail. Of the two, the effects of retrogressive metamorphism are dependent on the nature of the wall-rocks, chert, alaskite, and some mylonite being only slightly affected whereas amphibolites, basalts, and gabbro are strongly altered by this process. The products of metasomatism are distributed widely and the suite of minerals formed is quite uniform regardless of the nature of the wall-rock.

Table VIII is a summary of the wall-rocks studied and lists the minerals affected by retrogressive metamorphism and those formed by metasomatism; it includes changes in specific gravity and general comments.

The information compiled in this table indicates that under retrogressive metamorphism the chief minerals affected are plagioclase, hornblende, and biotite. Most of this localized retrogressive metamorphism is attributed to changes of temperature along the vein channels accompanied by the addition of water from the vein. The alteration of some wall-rocks, however, may have been facilitated by shearing that resulted in brecciation and fissuring. The products of retrogressive metamorphism from this cause are difficult to differentiate from those directly connected with the deposition of the radioactive deposits.

Hematite, calcite, and albite are the principal minerals formed by metasomatic processes from the products of retrogressive metamorphism;

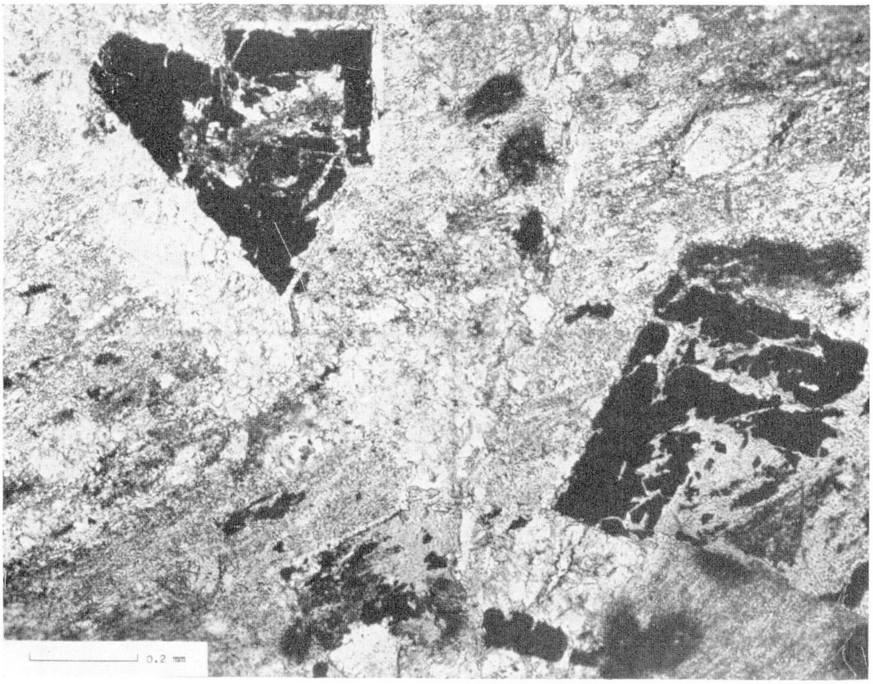
Table VIII

Summary Wall-rock Alteration by Processes and Remarks

—	Minerals affected by retrogressive metamorphism					Minerals formed by metasomatism								Specific gravity	Remarks
	Hornblende	Plagioclase	Diopside	Chlorite	Biotite	Hematite	Calcite	Albite	Radioactive minerals	Quartz	Pyrite	Barite	Chlorite		
Amphibolite	<	<			<	<	<	<	<					Reduced	Width 20 inches; biotite to chlorite and leucoxene; and hornblende to chlorite and hematite
Chert			<			<	<	<			<		<	No change	Width on Bolger 10 feet; Tam 6 inches; and YY-1 concession 20 inches
Argillite			<			<	<	<	<	<			<	No change	Width 8 feet; some recrystallization
Subgreywacke						<	<	<	<					No change	Width 5 feet
Mylonite		<				<	<	<	<	<			<		Width 12 inches; plagioclase to white mica (muscovite, kaolin, and pyrophyllite)
Quartz gabbro	<	<			<		<	<	<					Reduced	Width 6 inches
Alaskite		<				<	<	<	<				<		Width 6 feet
Conglomerate						<	<	<	<	<	<	<			Width 12 inches
Feldspathic sandstone						<	<							No change	Width 12 inches
Meta-basalt		<		<			<	<	<	<				No change	Width 12 inches
Gabbro		<	<			<	<								Width 6 inches; most of hematite derived from gabbro

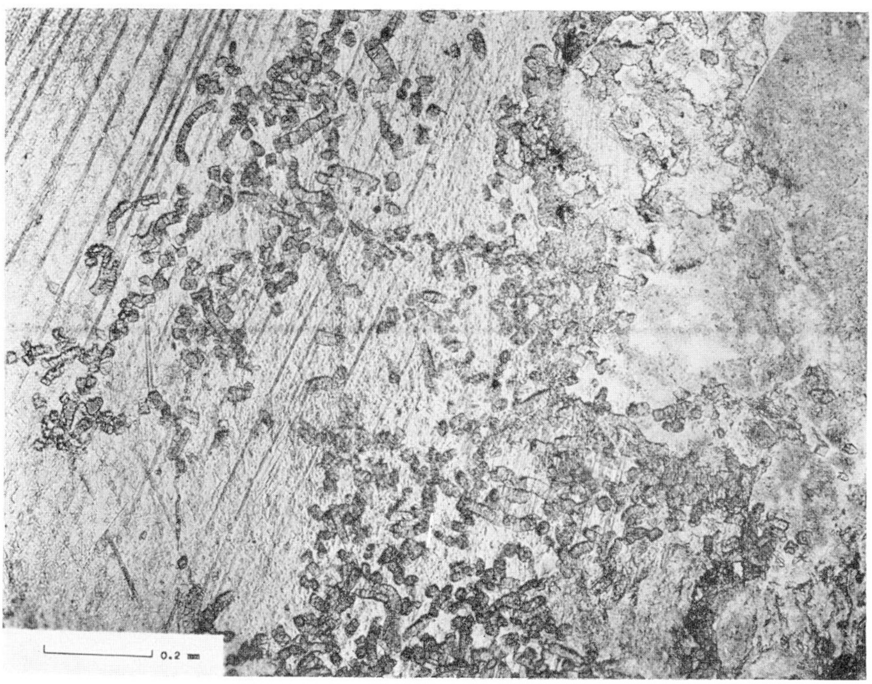
the unaltered minerals of the wall-rocks, and by the vein-forming agencies. To form these minerals the quantity of material added during vein formation to that on the wall-rock is difficult to establish and both sources may have contributed, especially so in the formation of albite and quartz. Pyrite, barite, chlorite, and radioactive minerals are sporadic in their distribution. Lime and carbon dioxide were transported by vein-forming solutions and calcite was deposited as an abundant gangue mineral and also in the altered wall-rocks as scattered grains and veinlets. The quantity of lime abstracted from the wall-rocks is unknown but beside almost all deposits some lime must have been added to form the abundant calcite. Albite forms veinlets at least of two ages and the occurrence of albite as small twinned crystals and fine grains in some wall-rocks suggests that soda, silica, and alumina were in solution at two periods in the history of some radioactive veins. Chlorite and white mica in argillite also have been replaced by albite, quartz, and calcite. The reddening of many wall-rocks by ferric iron oxide and the presence of red hematite as inclusions in some minerals formed by metasomatic processes indicate that iron was both in solution and in solid form during the period of alteration. Hematite also was carried by the vein solutions and deposited both after and contemporaneously with the gangue minerals. In some cases the iron forming the hematite was added and in others removed from the wall-rocks. The development of hydrated silicates as penninite and prochlorite in altered amphibolite, gabbro, and meta-basalt suggests that water penetrated these wall-rocks. At the South Tam occurrence, however, dehydration probably has occurred, and these two features suggest that the solutions from locality to locality had a different composition and character. In all cases the solutions produced characteristic suites of minerals, changes of texture, and a distinctive reddening of the wall-rocks.

PLATE I



104978

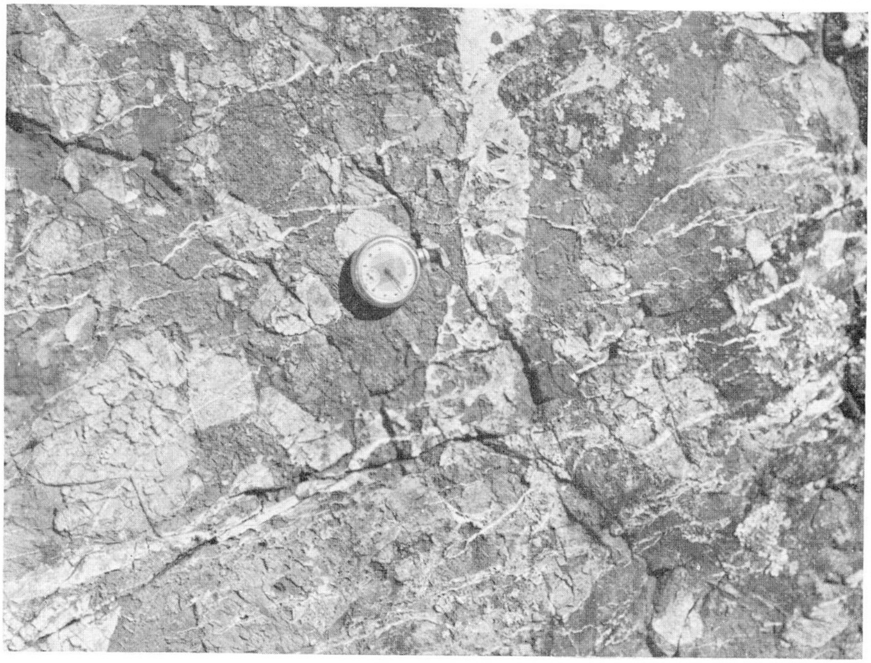
A. Chlorite replacing pyrite in Tazin schist, east orebody, Ace mine. Plane light.



104977

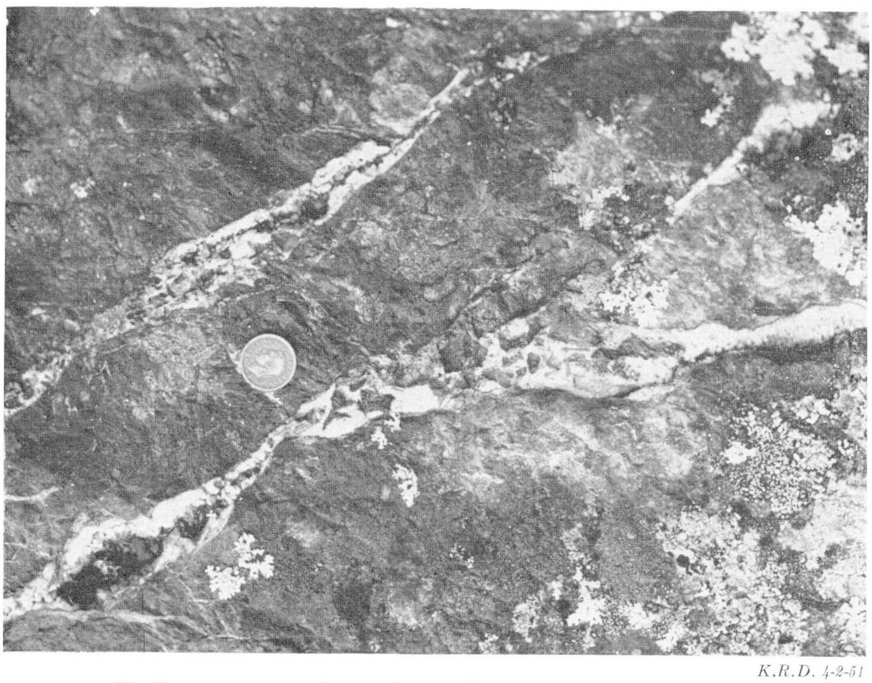
B. Prochlorite inclusions in calcite, east orebody, Ace mine. Plane light.

PLATE II



K.R.D. 3-5-51

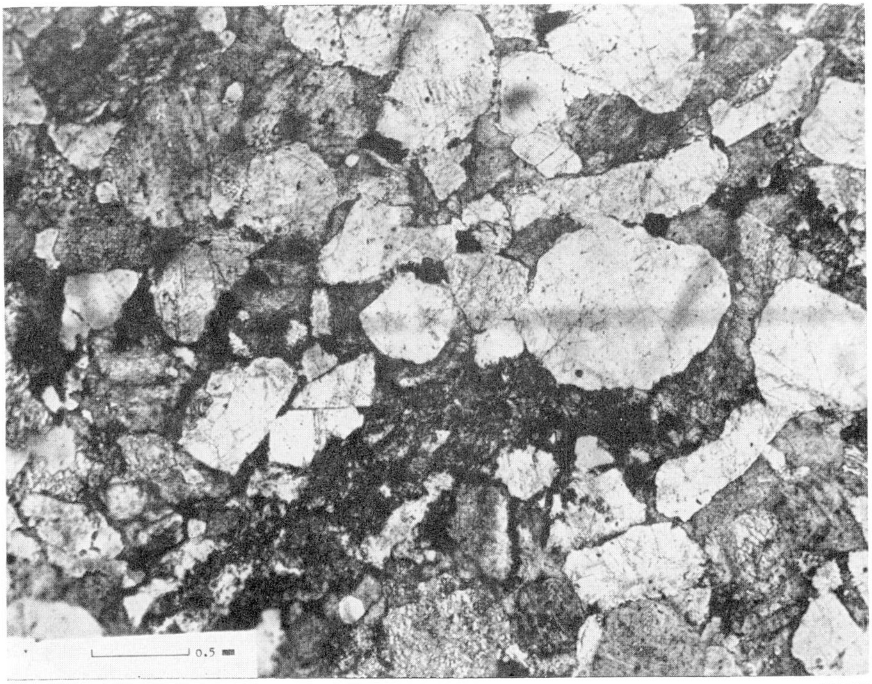
A. Conglomerate, Ura deposits. Quartz veinlets cross matrix and pebbles alike and quartz also cements the breccia zone at the right of the watch.



K.R.D. 4-2-51

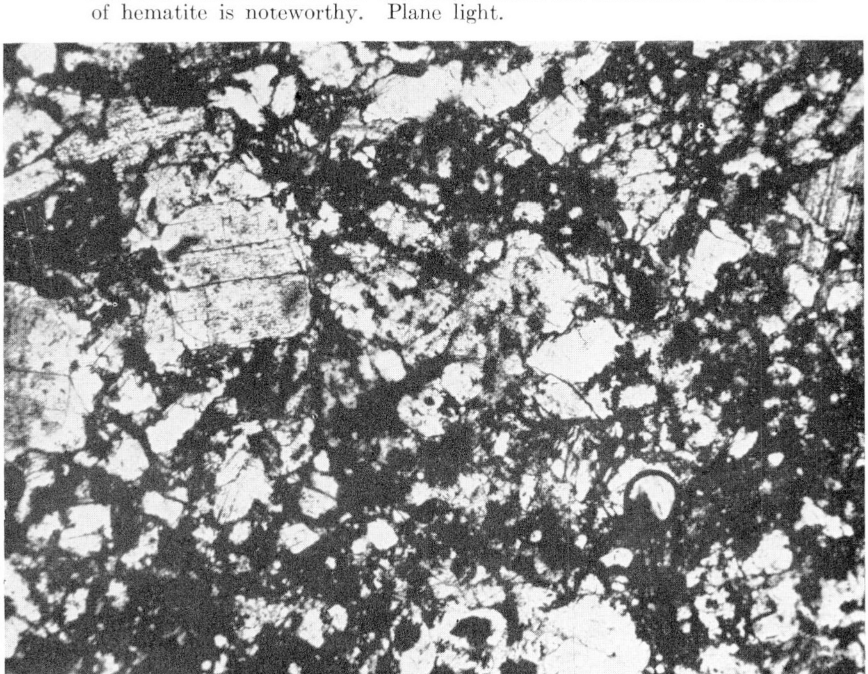
B. Vuggy quartz vein crossing argillite, South Tam occurrence.

PLATE III



104979

A. Photomicrograph of the unaltered Athabasca feldspathic sandstone from surface showing on the RA claims. The size and shape of the fragments and the distribution of the fine constituents are illustrated. The lack of hematite is noteworthy. Plane light.



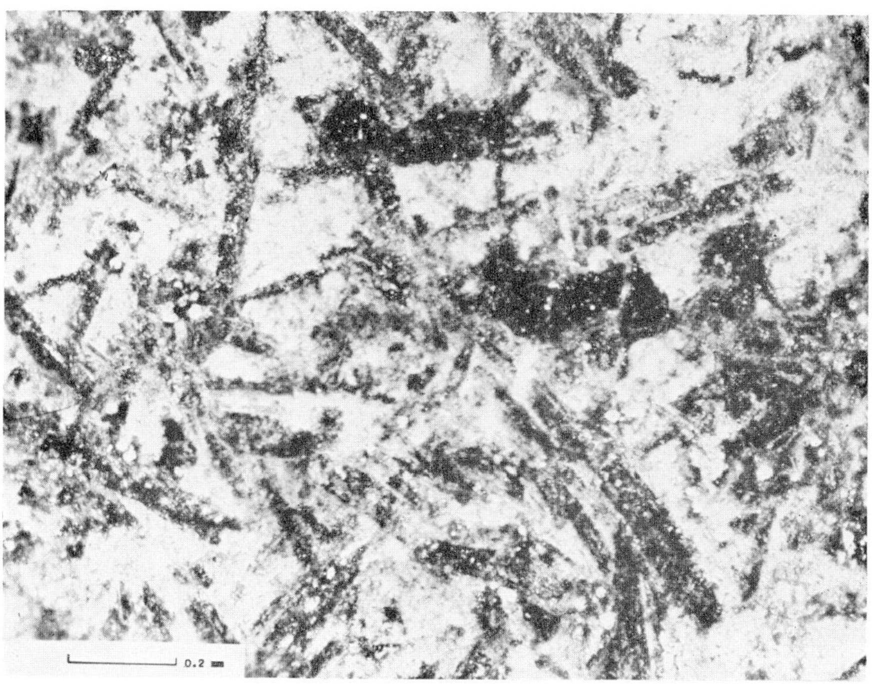
104975

B. The altered phase of the Athabasca feldspathic sandstone from the RA claims. The high content of hematite dust (black) is noteworthy. Plane light.

PLATE IV

104984½

A. Photomicrograph of altered meta-basalt, RA claim group. Black areas consist largely of hematite dust, white rectangular areas are feldspar laths, and light grey areas are aggregates of chlorite and calcite. Plane light.



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B. Photomicrograph of altered meta-basalt, RA claim group. White dusty material is hematite, black areas are andesine laths. Plane reflected light.