PETROLOGY OF THE RED RADIOACTIVE ZONES NORTH OF GOLDFIELDS, SASKATCHEWAN

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ABSTRACT

The red rocks that occur along faults and shear zones in the Precambrian granitic terrane north of Lake Athabaska are more radioactive than others in the area. They are mylonites ranging from protomylonite to ultramylonite, the latter generally forming anastomosing veinlets in the less intensely crushed types.

In the protomylonites the feldspar is deformed albite colored with hematite dust, especially along the cleavages; unstrained minerals fill the interstices. In the more intensely crushed types the hematite dust permeates most of the rock; the unstrained minerals present form scattered aggregates or may locally replace the mylonite completely.

The first of these late minerals is clear albite, which forms rims on the red albite relicts. Then follow, in variable order and with repetitions, clear subhedral quartz and albite, specularite, and penninite containing radioactive anatase grains. The latest veins contain also pitchblende, calcite, and specularite. Oxidation products of pitchblende are locally abundant in solution cavities.

The early iron and later radioactive elements were introduced probably by solutions that rose along the mylonite zones. The other elements were probably present before mylonization; and all the late minerals, excepting pitchblende and calcite, may be products of recrystallization.

The dusty hematite was probably not formed either by radioactive bombardment of ferrous minerals or by unmixing of iron-feldspars.

INTRODUCTION

During the summer of 1948, while engaged in exploration for uranium deposits in the Goldfields area (Fig. 1), the attention of the first author was drawn to certain linear zones of brick-red radioactive rock containing stringers of pitchblende. These zones lie along or close to the surface expressions of major faults. Although the degree of radioactivity is not uniform over the exposed portions of the zones, the lowest measurements obtained with Geiger-Mueller counters were two to three times higher than those obtained over the local soda-rich granites and granodiorites. The texture of this reddish rock varies from coarse to very fine grained. Megascopically it shows a marked resemblance to reddish cherty rock associated with the pitchblende deposits at Great Bear Lake. Kidd and Haycock (1935, p. 890) have mentioned these rocks and Murphy (1948, p. 266) states: "This so-called red alteration, undoubtedly related to the quartz-hematite period of mineralization, affects the quartzose rocks most severely, but where alteration is intense there is little selectivity. The exact nature of the alteration has not been determined, but quartz, hematite, magnetite, sericite, chlorite, and carbonate are obvious constituents." Christie and Kesten (1949*b*, p. 650) suggest that the red cherty alteration "may be due to silicification, the silica being accompanied by iron stain, or it may be due to introduction of fine-grained red-stained feldspar, or to both of these causes." No explanation for the red coloration is offered by James, Lang, Murphy, and Kesten (1950).

As no petrographic work has been carried out with these reddish rocks at Great Bear Lake, their genesis and possible relationship to the pitchblende mineralization is still open to question. The apparent similarity

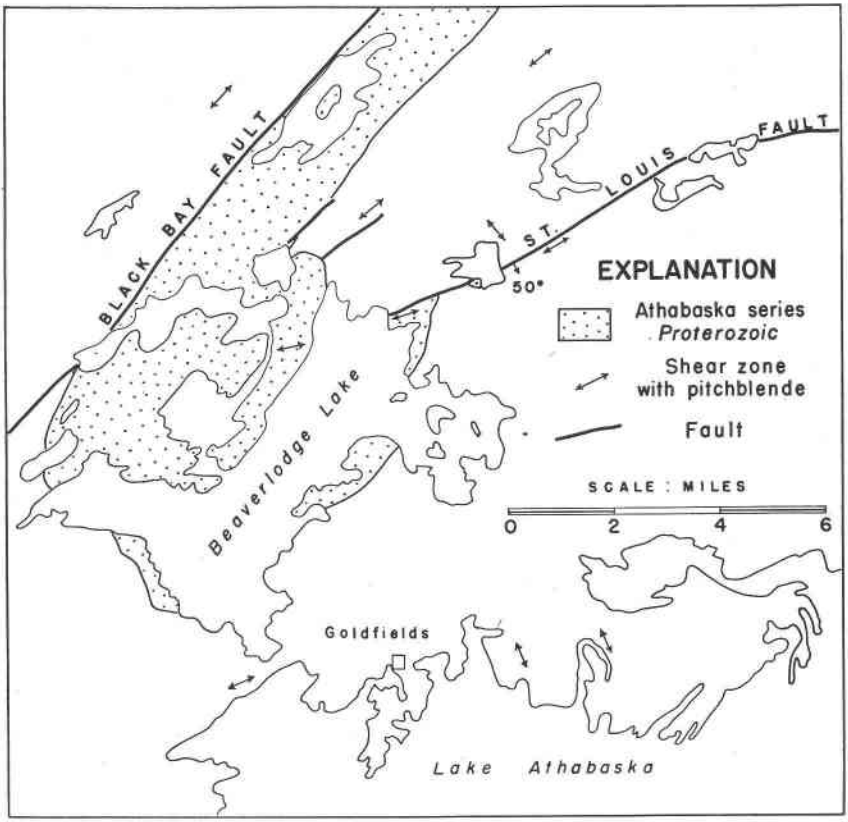


Fig. 1. Map of Goldfields area.

between these rocks and those forming pitchblende-mineralized linear zones in the Goldfields area suggests that the same genetic relationship between the rock and the pitchblende obtains in both the Great Bear Lake and Goldfields areas. For the purpose of determining the nature of this red radioactive rock and its probable genesis, the writers made a petrographic examination of about 80 thin sections, which included both coarse and fine-grained phases and the associated country rocks.

Structural Relationships

Within a few miles north of the townsite of Goldfields there are two major faults striking northeasterly. As shown on the maps accompanying reports by Christie and Kesten (1949*a*) and James and others (1950), the Black Bay fault can be traced for twelve miles and the St. Louis fault for seven. Along both faults are zones of red radioactive rocks.

Diamond drilling across the St. Louis fault has shown that the zone of movement is marked by a 100-foot width of sheared rock. Examination of core taken from this zone indicates that the rock has not everywhere been sheared with equal intensity, as minor zones, from a fraction of an inch to a few feet wide of reddish and cherty rock are separated by rock

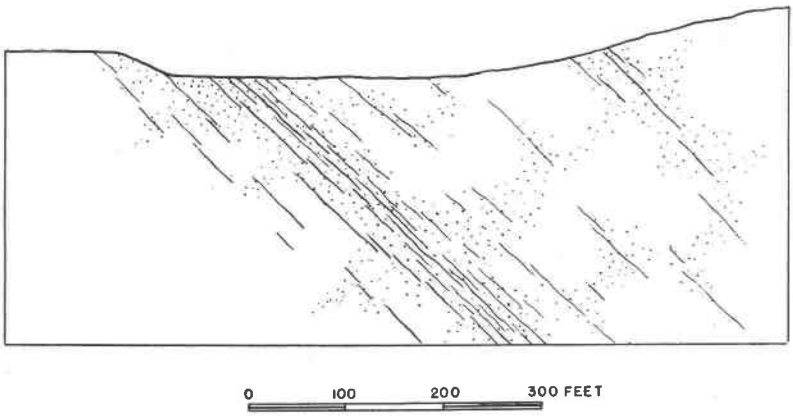


Fig. 2. Generalized section across St. Louis fault. Red rock is stippled.

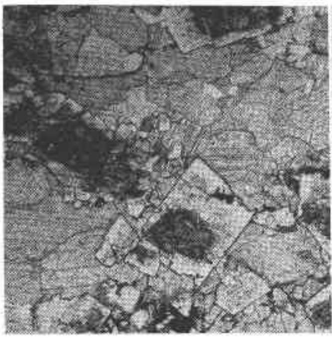
which usually is much coarser grained and shattered. Microscopic examination shows the cherty rock to be ultramylonite. Its vein-like character strongly suggests that it has been squeezed into fractures in the less-crushed rock.

The St. Louis fault closely follows the strike and dip of foliation in the country rock, and movement has taken place along numerous sub-parallel shears which are indistinguishable within the main zone. The generalized relationship of the linear zones of red rock, which in outcrop tend to follow the strike of the foliation and shearing, is shown in Fig. 2.

Petrology of the Red Rock

Coarse-grained varieties of this brick-red rock resemble breccia with the texture of building stucco. Close examination reveals, however, that the angular constituents are not rock fragments but subhedral feldspar crystals. These crystals, which are on the average a few millimeters wide, are loosely intergrown, and the interstices are filled with calcite, penninite, and quartz.

Under the microscope the feldspar crystals are seen to consist of fresh rims surrounding dark reddish and highly altered relicts (Fig. 3) with bent and broken twinning lamellae. Optical continuity between the relicts and rims suggest that the former have the same composition as the latter; that is approximately An_{10}. The relicts are colored with hematite dust, which has thoroughly permeated both fine and coarse-grained types of the red rock, and which is concentrated especially along microfractures and cleavages in shattered grains of feldspar (Fig. 4).



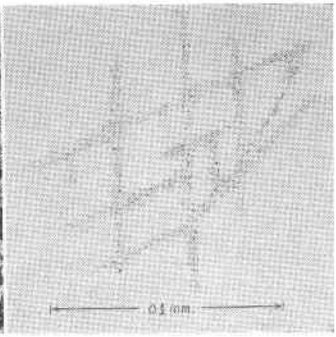


FIG. 3. Clear albite overgrowths on red albite relicts. Matrix of twinned calcite. Largest albite crystal is 0.4 mm. wide.

FIG. 4. Pattern of red alteration in feldspar porphyroclast. Camera lucida drawing.

The interstices are filled largely with twinned calcite, the lamellae of which are not bent. Variable amounts of penninite are also present in the interstices, and in places there is more penninite than calcite. Penninite also fills fractures and occurs as tiny flakes within the feldspar. These flakes, imbedded in a reddish matrix of dusty hematite and altered feldspar, are surrounded by bleached zones. It is inferred that the flakes of chlorite have chemically utilized the hematite during their growth. On the basis of this inference at least part of the chlorite has formed subsequent to the development of the dusty hematite impregnation.

Adhering to the surfaces of feldspar crystals and lining interstices filled with calcite, chlorite, and quartz are clusters of euhedral crystals of specularite. These crystals possess a platy and tabular habit and are approximately 0.05 mm. wide. A few convex forms with striated surfaces were observed. It was further observed that clusters of the crystals were sufficiently magnetic to adhere to the point of a magnetized needle. The possibility that the crystals might be pseudomorphs of magnetite after specularite was obviated by comparing their magnetic susceptibility with that of finely powdered magnetite. Also adhering to the surfaces of feldspar crystals, and projecting into the interstices are euhedral grains of quartz up to 1.0 mm. long. Larger anhedral and subhedral grains form aggregates in the interstices. None of the quartz grains show strain shadows.

Disseminated in the calcite are euhedral crystals of anatase from 0.05 mm. to 0.2 mm. in width. Very small grains form elongated clusters along cleavages in the flakes of penninite and these clusters are surrounded by very pronounced pleochroic halos.

Finer-grained varieties of the red rock contain much less calcite and chlorite. Under the microscope they show angular fragments of dark reddish feldspar surrounded by a fine-grained matrix impregnated with hematite dust. Within the matrix are aggregates of albite, chlorite, and specularite. The albite crystals are unaltered, have a composition within the range An_5 to An_{10} and are usually less than a millimeter wide.

The modes of this red rock could be determined only in the coarse-grained type. In general, where quartz is present there is more penninite than calcite. Also, where specularite is present in relative abundance it is usually associated with calcite. The approximate minimum and maximum percentages by volume of the various minerals are estimated as follows:

Albite	70%–80%
Calcite	10%–25%
Chlorite	1%–15%
Quartz	1%–10%
Specularite	1%– 5%
Anatase	trace

Recrystallization and Replacement of Mylonites

Along the St. Louis fault crushed granitic rocks are abundant. They are reddish from dusty hematite, and vary in texture from protomylonites (Fig. 5) through fine-grained and streaked mylonite (Fig. 6) to cherty-appearing ultramylonite. Apparently similar rocks were noted in southern Norway by Barth (1949, p. 177), who refers to granite having been "partly mylonitized and again compressed to a dense, red felsite."

Fairly evenly disseminated within the ultramylonite are rounded and amoeboid grains of albite usually less than 0.1 mm. wide. As these grains are unaltered they are considered to be the initial forms of porphyroblasts. Microcline grains of similar size are also present, and in one sample of mylonite microcline was observed to have replaced part of an augen of fine-grained quartzose-feldspathic material (Fig. 7). In places euhedral porphyroblasts, up to 10 mm. wide, of unaltered albite and microcline are so numerous that the mylonite has the appearance of a porphyry.

Whether the albite and microcline have resulted from the introduction of soda and potash into the mylonite, or from recrystallization only, is open to question. As the mylonites were originally alkali-rich granitic rocks, recrystallization alone could account for the porphyroblasts. The very high albite content of the red rock suggests, however,

FIG. 5. Protomylonite. Red feldspar porphyroclast 0.7 mm. wide in fine flow-textured groundmass of quartz and muscovite.

FIG. 6. Mylonite. Red feldspathic material with clear lenses and swirls of quartz. Transverse veinlets of quartz-calcite are 0.05 mm. wide.

that there has been local migration of soda. It is perhaps significant that this enrichment of soda should have occurred along the zones of most intense shearing. Wiman (1932, pp. 156–157) has expressed the view that a certain amount of soda derived from crushed granite will migrate along mylonite zones.

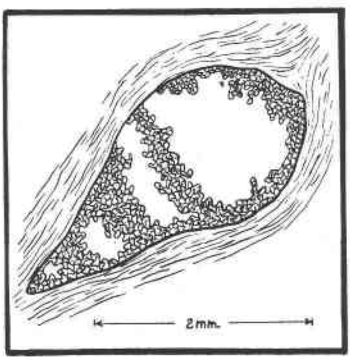


FIG. 7. Clear microcline porphyroblasts. Amoeboid forms replacing quartz-feldspar lens in mylonite.

Paragenesis of the Minerals

The paragenesis of the minerals in the red rock is by no means clear-cut. The earliest mineral to have developed within the mylonite is albite which, in addition to the amoeboid forms mentioned above, forms fresh rims around highly altered albite relicts. Later there crystallized, in variable order and with repetitions, quartz and albite, specularite, and penninite containing anatase grains. Cutting the red rock are stringers containing pitchblende, calcite, and specularite. Oxidation products of pitchblende are disseminated locally within the red rock.

A. M. Christie[1] made a petrographic examination of stringers within a pitchblende-mineralized zone in the area and found them to be of quartz, quartz-albite, albite, chlorite-albite, chlorite, carbonate, albite-carbonate-hematite, hematite, and pitchblende. He states: "A striking feature is the lack of shearing in these veinlets and the freshness of the quartz and albite. The quartz occurs in fresh-looking equidimensional grains as contrasted with the intensely sheared and fractured lamellar quartz of the wall rock. The vein albite is also fresh, the twinning clear. The vein quartz of the main vein is fractured but by clear-cut fractures parallel to the walls of the vein which cut the grains in a straight line. The vein quartz shows no appreciable straining or strain lamellae." And further, "In one interesting case a quartz veinlet is cut by an albite-carbonate-hematite (pitchblende?) veinlet, the latter being therefore the younger. The more complex vein is banded, the albite crystals lining the walls with the metallics, carbonate and chlorite in the centre. In this case the quartz veins must be older and the complex vein the younger with albite being deposited before the other associated minerals."

It is not known to what extent the stringers of albite, quartz, chlorite, calcite, and possibly hematite represent introduced minerals, or minerals dissolved from the wall rock and re-deposited along fractures. It does seem fairly certain, however, that pitchblende was introduced at a late stage.

The Red Coloration

There are at least three possible explanations for the presence of dusty red hematite in the feldspar porphyroclasts and the groundmass around them:

(1) The iron of the hematite was introduced by solutions or diffusion.

(2) The hematite was liberated from pre-existing iron-bearing minerals by radioactive bombardment.

(3) The hematite is an exsolution product of ferromicrocline and ferroalbite.

[1] Geological Survey of Canada, written communication.

The first of these explanations is believed to be the correct one. The iron for the hematite was probably introduced by solutions that rose along the mylonite zones before recrystallization began. Transport principally by solutions, not by diffusion, is suggested by the distribution of the red rock, which is indicated diagrammatically in Fig. 2, but without the actual intricacy of detail. In detail the limits of the red coloration are very irregular, as some foliae of the mylonites are red to a greater distance than are others. In general, the great irregularity in distribution of the red coloration suggests, though it does not prove, that the iron was distributed in solution along a network of fissures, mainly parallel to the foliation, instead of migrating as a continuous front through the unfissured rock. It is not possible to state whether it was these iron-bearing solutions or later ones that permitted recrystallization of the mylonites after the hematite was formed.

Concerning the second explanation, an examination of thin sections of pitchblende stringers in fine-grained red rock revealed no deepening of color close to the stringers, and it is therefore inferred that the brick-red color of this rock is not attributable to the proximity of pitchblende.

Frequently it has been observed that strongly radioactive minerals in pegmatite are surrounded by aureoles of reddened rock and that minute fractures radiate from the radioactive mineral. Walker and Parsons (1923, p. 26) wrote of such an occurrence: "A section of potash feldspar enclosing euxenite from Maberley, Ontario, was examined to see whether any trace of shattering could be observed. Although the shattering was not radial the feldspar was completely ruptured and the cleavages and fractures were filled with hematite, which gives a deep red colour to this feldspar in contrast to the pale colour which characterises most of the feldspar from this quarry." The hematite in this case appears to have been introduced subsequent to or during the period of fracturing. The cause of the observed fracturing around highly radioactive minerals such as euxenite, uraninite, and samarskite is not known; but it is inferred that oxidation of these minerals results in an increase of volume which produces shattering in the surrounding rock.

The third explanation, that the hematite is an exsolution product from ferric feldspars, is more probable than the second but is rejected also. Faust (1936, p. 762) has shown that iron-orthoclase definitely exists, that what is probably iron-microcline has been synthesized, and that iron-albite may exist, though its existence is doubtful. Andersen (1915) had given indirect proof of the existence of iron-plagioclase at high temperatures by showing that the hematite scales in aventurine feldspar were, at least in part, so oriented as to indicate exsolution as their origin.

The analogy between the red feldspars and aventurine feldspar is weakened when the following differences are noted:

(1) The hematite in the red feldspars forms dull-lustered granules under 0.005 mm. in diameter; but hematite scales in aventurine feldspar are transparent and shiny, and are from 0.2 to 3.0 mm. in diameter and 0.0001 to 0.0004 mm. thick.

(2) Exsolution of hematite from ferric feldspars results only from cooling, not from comminution, so far as is known. Mylonization, during which temperatures may locally rise to fusion point, might cause solution of iron in melted feldspar, which would then unmix upon cooling. But although some of the dusty hematite in the ultramylonite stringers may be of this origin, the hematite in the bent and evidently unfused feldspar relicts is not. Moreover, the hematite formed in the laboratory experiments by Faust (1936, p. 750) crystallized into translucent red and yellow flakes, as in aventurine feldspar, not dull-red granules.

Radioactivity of the Red Rock

The relatively high radioactivity of the red rock is no doubt due in large part to the contained uranium minerals. Even where these minerals are not apparent, however, the rock has a radioactivity two to three times that of the local granite. To what extent this radioactivity may be caused by accessory minerals or included gases is not known. It is an interesting fact that the anatase within penninite is surrounded by very dark pleochroic halos, and one which suggests that the anatase is radioactive.

It has been pointed out by Piggot and Merwin (1932), Morgan and Auer (1941), Keevil, Larsen, and Wank (1944), and Sahama (1945) that more than half the radioactivity of a granite is attributable to the accessory minerals zircon, apatite, allanite, epidote, sphene, monazite, and the micas. Osborne (1939, p. 934) quotes J. W. Waters (1909, 1910) as saying that within the Cornish granite, radium is concentrated in anatase and rutile; within the Dalbeattie granite, in allanite; and within the Mourne granite, chiefly in zircon and a titaniferous mineral. Osborne found that the radioactivity of a tonalite in southern California varies directly with the albite content. In view of Osborne's findings, the high albite content of the red rock may have some bearing on the radioactivity. According to Palache, Berman, and Frondel (1944) anatase is of hydrothermal origin. It is therefore possible that both sodium and titanium have been introduced.

Conclusions

Zones of deep-red rocks, shown by petrographic study to be mylonites, have been observed to be more radioactive than others in the Goldfields and Great Bear Lake areas of western Canada. For the Goldfields area, this relationship is considered a result of the following sequence of events, all of which took place in Precambrian time:

(1) Partial replacement of a bedded series by the minerals of albite granite.

(2) Mylonization during early movements along the St. Louis and related fault zones.

(3) Deposition of finely-divided hematite in feldspar porphyroclasts and groundmass, from solutions migrating along the mylonite zones.

(4) Widespread recrystallization of feldspar and quartz and introduction of calcite, penninite, specularite, and pitchblende.

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