

## **13. VEIN URANIUM**

### **13.1 Veins in shear zones**

### **13.2 Granitoid-associated veins**

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**V. Ruzicka**

### **INTRODUCTION**

Uranium vein deposits are concentrations of uranium minerals, such as pitchblende, coffinite, and brannerite, in fractures, shear zones, and stockworks. The uranium minerals are commonly accompanied by quartz and/or carbonate gangue. The mineralization is, as a rule, lithologically and structurally controlled. The vein deposits occur either (a) in shear or mylonite zones in various geological environments (veins in shear zones), or (b) within granitic or syenitic plutons or in rocks mantling granitic batholiths

(granitoid-associated veins). The host rocks are parts of metasedimentary, metavolcanic, or plutonic complexes. Classical veins in mylonite zones occur in the Beaverlodge area, Saskatchewan; classical veins in shear zones are those in the Bohemian Massif; classical granitoid-associated vein deposits are those of the Massif Central in France and the Gunnar property in Saskatchewan; typical peribatholithic veins occur in rocks mantling the Central Bohemian Pluton, in the Czech Republic.

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1996: Vein uranium; in *Geology of Canadian Mineral Deposit Types*, (ed.) O.R. Eckstrand, W.D. Sinclair, and R.I. Thorpe; Geological Survey of Canada, *Geology of Canada*, no. 8, p. 277 (also Geological Society of America, *The Geology of North America*, v. P-1).

## 13.1 VEINS IN SHEAR ZONES

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### IMPORTANCE

In Canada, uranium vein deposits in mylonite zones have been important sources of uranium in the past. The mines in the Beaverlodge area, Saskatchewan (Fig. 13.1-1), produced in excess of 25 000 t of uranium metal between 1950 and 1982 (Ward, 1984). They were the major producers of uranium in Canada before the uranium mines in the Elliot Lake area, Ontario, commenced operations in 1957. In Europe, mineralized shear zones which extend vertically for more than 1000 m have been exploited in the eastern and western parts of the Bohemian Massif, at Rožná - Olší and Zadní Chodov, the Czech Republic, respectively (Ruzicka, 1971, 1993).

### SIZE AND GRADE OF DEPOSITS

The vein deposits associated with mylonite or shear zones contain mineralization, as a rule, in lenses and in narrow veinlets. Individual orebodies consist of irregularly distributed lenses. The largest uranium vein deposits of this subtype in Canada were exploited in the Beaverlodge area in northern Saskatchewan (Tremblay, 1972). Numerous orebodies contained from a few tonnes to as much as several thousand tonnes of uranium metal. The mining grades (i.e., grades of ore diluted to mining width) were on average 0.2% U, and the maximum average grade was as great as 0.4% U. Metal tonnage and pertinent mining grades of individual orebodies mined by Eldorado Mines Limited in the Beaverlodge area are shown in Table 13.1-1 (see also Fig. 13.1-2 and Figure 13.1-3). The largest metal tonnage (in the 09 Fay orebody) was in excess of 8000 t of U in ore grading 0.25% U. The highest grade of ore was 0.42% U (the 38 Hab orebody, containing in excess of 500 t U; Ward, 1984).

The Rožná - Olší deposits produced in excess of 20 kt of uranium metal from ore containing on average several kilograms of uranium per tonne.

### GEOLOGICAL FEATURES

The characteristic geological features of Canadian uranium vein deposits associated with mylonite zones are best demonstrated by deposits in the Beaverlodge area, specifically the deposit exploited by the Ace, Fay, and Verna mines (Fig. 13.1-3). This deposit consists of numerous orebodies hosted by mylonitized feldspathic quartzite, brecciated and mylonitized granitic gneiss, altered argillite, and brecciated feldspar-carbonate rocks.

The host rocks are part of the Lower Proterozoic meta-sedimentary sequence of the Tazin Group, and to a lesser extent the Middle Proterozoic sedimentary and volcanic suite of the Martin Formation (Fig. 13.1-4). The rocks of the area have been deformed during at least two orogenies: Kenoran (about 2.6 Ga; Stockwell, 1982) and Hudsonian (about 1.7 Ga; Stockwell, 1982). During the Kenoran Orogeny, gneiss domes and uranium-bearing pegmatite dykes were formed. The Hudsonian Orogeny caused mylonitization of Tazin Group rocks and reactivation of major fault systems, such as the St. Louis, which provided the main structural control for the Ace-Fay-Verna deposit. Deposition of the rocks of the Martin Formation during the late stages of this orogeny was accompanied by volcanism.

Most of the orebodies are spatially related to the St. Louis Fault and to fracture systems associated with crossfaults, such as the Larum, South Radiore, and George Lake faults (Fig. 13.1-4). Stratigraphically the orebodies occur near the Tazin-Martin unconformity. The rocks in the footwall of the St. Louis Fault represent units of the Tazin domain and may form part of a subduction zone assemblage; the fault itself apparently represents a suture zone in the region.

The ore is epigenetic. The main episode of mineralization was associated with the Hudsonian Orogeny, but pitchblende was subsequently remobilized. Ward (1984) reported the results of a statistical analysis of a total of approximately 120 age determinations (U-Pb) on pitchblende from the Beaverlodge deposit. This analysis shows clustering of isotopic ages in three periods, namely at 1.8 to 1.7 Ga, which corresponds with Hudsonian events, at 1.1 to 0.9 Ga, which corresponds with Grenvillian events, and at about 0.2 Ga.

The mineralization exhibits vertical zoning (Ruzicka, 1989). The upper parts of the main orebodies consist essentially of pitchblende, whereas the lower (deeper) parts contain substantial amounts of brannerite. Locally the

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1996: Veins in shear zones; in *Geology of Canadian Mineral Deposit Types*, (ed.) O.R. Eckstrand, W.D. Sinclair, and R.I. Thorpe; Geological Survey of Canada, *Geology of Canada*, no. 8, p. 278-283 (also *Geological Society of America, The Geology of North America*, v. P-1).

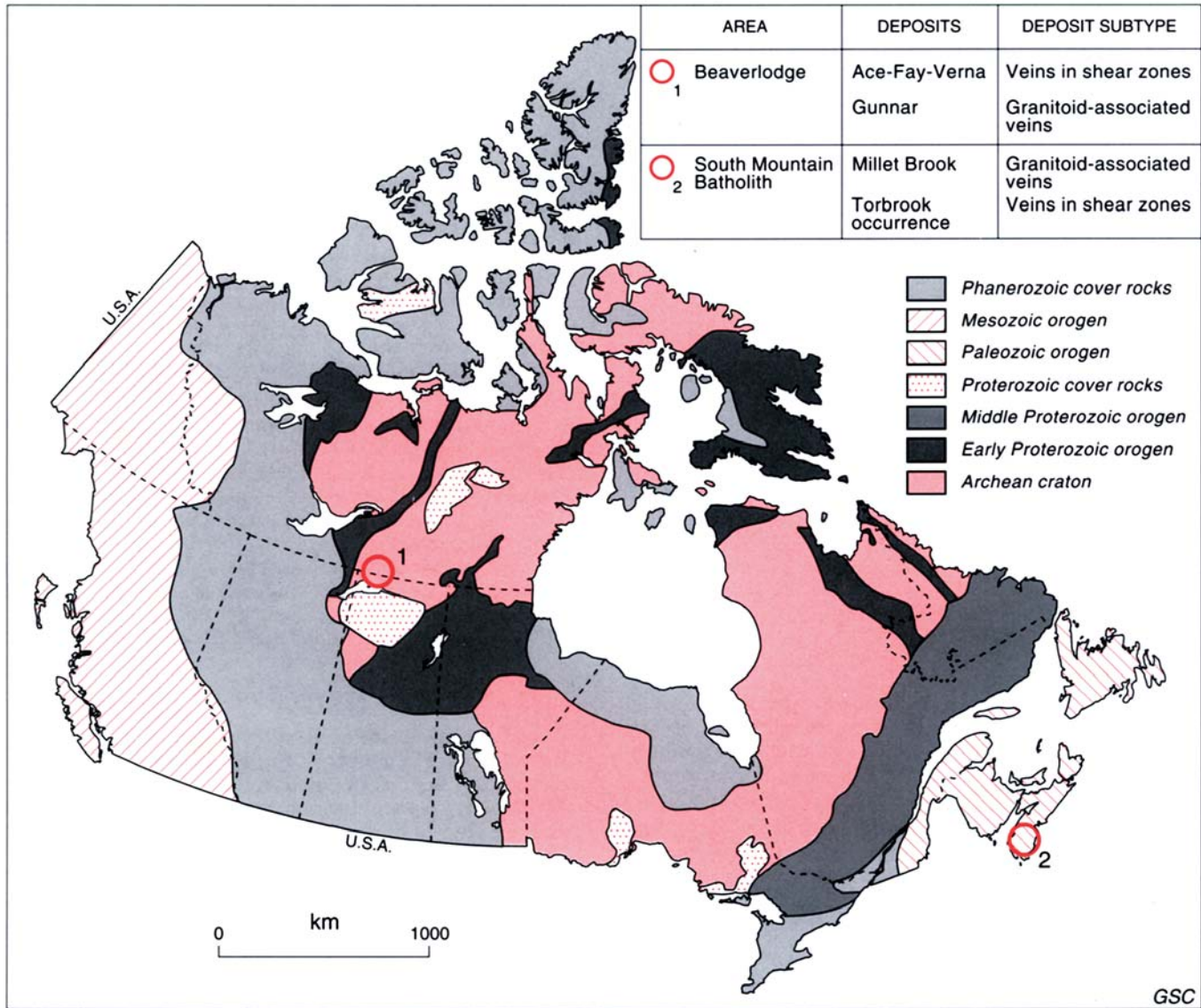


Figure 13.1-1. Distribution of vein uranium deposits in Canada.



**Table 13.1-1.** Tonnages of ores, their grades, and contained uranium metal in orebodies in mines of former Eldor Resources Limited Beaverlodge operations. (Cumulative production and reserves as of 1975.)

Symbol	Orebody	Ore (kt)	U (t)	Grade (U%)
1	01 Fay	1347	3033	0.23
2	04 Center	98	175	0.18
3	09 Fay	3247	8362	0.25
4	16 Center	274	615	0.23
5	38 Hab	128	532	0.42
6	39 Hab	55	130	0.24
7	43 West Fay	113	202	0.18
8	44 Verna	315	476	0.15
9	55 West Fay	151	244	0.16
10	64 Center	327	389	0.12
11	71 Verna	76	111	0.14
12	73 Verna	1355	2104	0.15
13	76 Verna	738	1436	0.2
14	79 Verna	893	1186	0.14
15	91 Zone	178	249	0.14
16	93 Verna	990	1762	0.18
17	Other (<100 t U each)	258	353	0.14

veins contain coffinite, uranoan carbon (thucholite), and secondary uranium minerals, such as metauranocircite, liebigite, and becquerelite, which are alteration products after pitchblende. Also, locally, sulphides of iron, copper, lead, and zinc, and selenides of lead, are present.

The principal gangue minerals in the Ace-Fay-Verna deposit are carbonates and the minor ones are quartz, chlorite, and albite. Sassano (1972) distinguished five generations of carbonates, four of calcite, and one of dolomite. The quartz gangue occurs in two generations: older comb quartz and a younger clear variety.

The main ore-forming mineral, pitchblende, occurs in a number of forms: euhedral (Robinson, 1955), botryoidal, massive, and sooty. The euhedral pitchblende, which is a

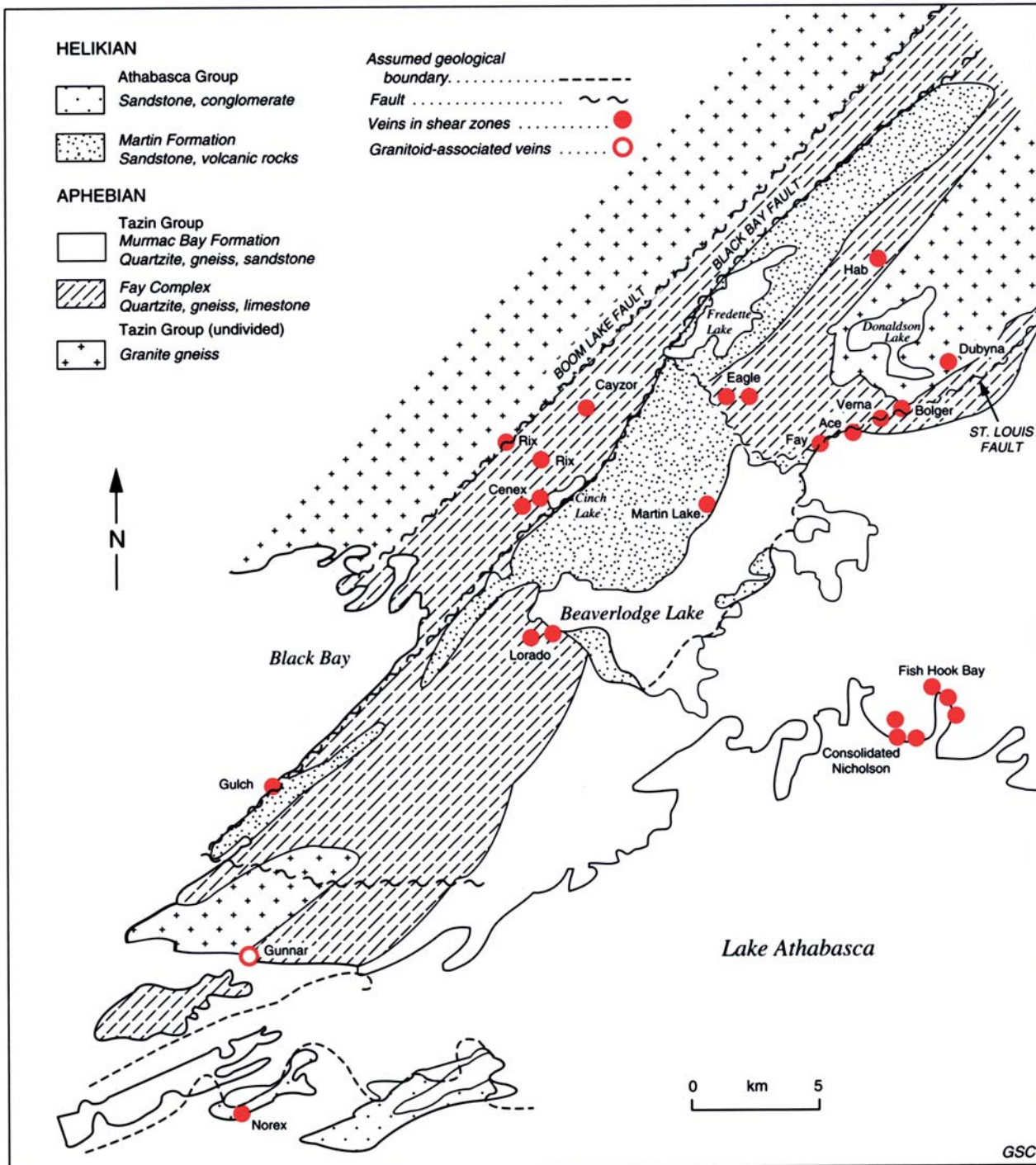
metastable form of pitchblende, may correspond to the euhedral alpha-triuranium-heptaoxide form in the Key Lake, Eagle Point, and Cigar Lake unconformity-associated uranium deposits (Dahlkamp and Tan, 1977; Ruzicka and Littlejohn, 1982; Ruzicka, 1984). The botryoidal pitchblende is locally cut by selenides. The massive pitchblende occurs as veins and breccia fragments. Sooty pitchblende represents a finely disseminated variety that has been derived from massive or botryoidal pitchblende by hydration shattering, as indicated by the preserved forms and structures.

Fluid inclusion studies of quartz and carbonate gangue minerals from the Ace-Fay-Verna deposit indicate (Sassano, 1972) that the mineralizing fluids were derived from pore fluids in the host rocks and that the exchange reactions took place initially at a temperature of 500°C, and that the temperature gradually dropped to 80°C. Oxygen isotopic studies show that no additional fluids were later introduced and that the system was essentially closed, i.e. that only redistribution and redeposition of uranium and associated metals took place during subsequent reactivation of the vein system. The presence of albite in the deposits indicates that sodic metasomatism occurred during the early stages of the mineralization process. Wall rocks adjacent to the orebodies are commonly hematitized, feldspathized, chloritized, and carbonatized. Oligoclase and quartz locally cement wall rock breccias.

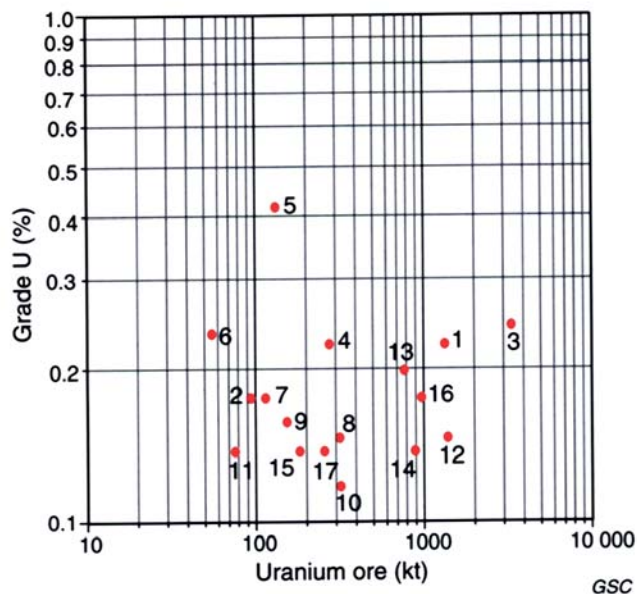
The pitchblende-coffinite mineralization of the Rožná Olší and Zadní Chodov deposits, in the Czech Republic, is associated with shear and fault zones containing chlorite, carbonate and, locally, graphite, quartz, and albite gangue. The mineralized zones of the Rožná – Olší deposits, several tens of kilometres long, are parts of the Labe Lineament fault system, which also contains several other smaller deposits. The Zadní Chodov deposit is spatially related to the Bohemian Quartz Lode, a major fault, which is part of a 60 km long regional fault system (Ruzicka, 1971).

## DEFINITIVE CHARACTERISTICS

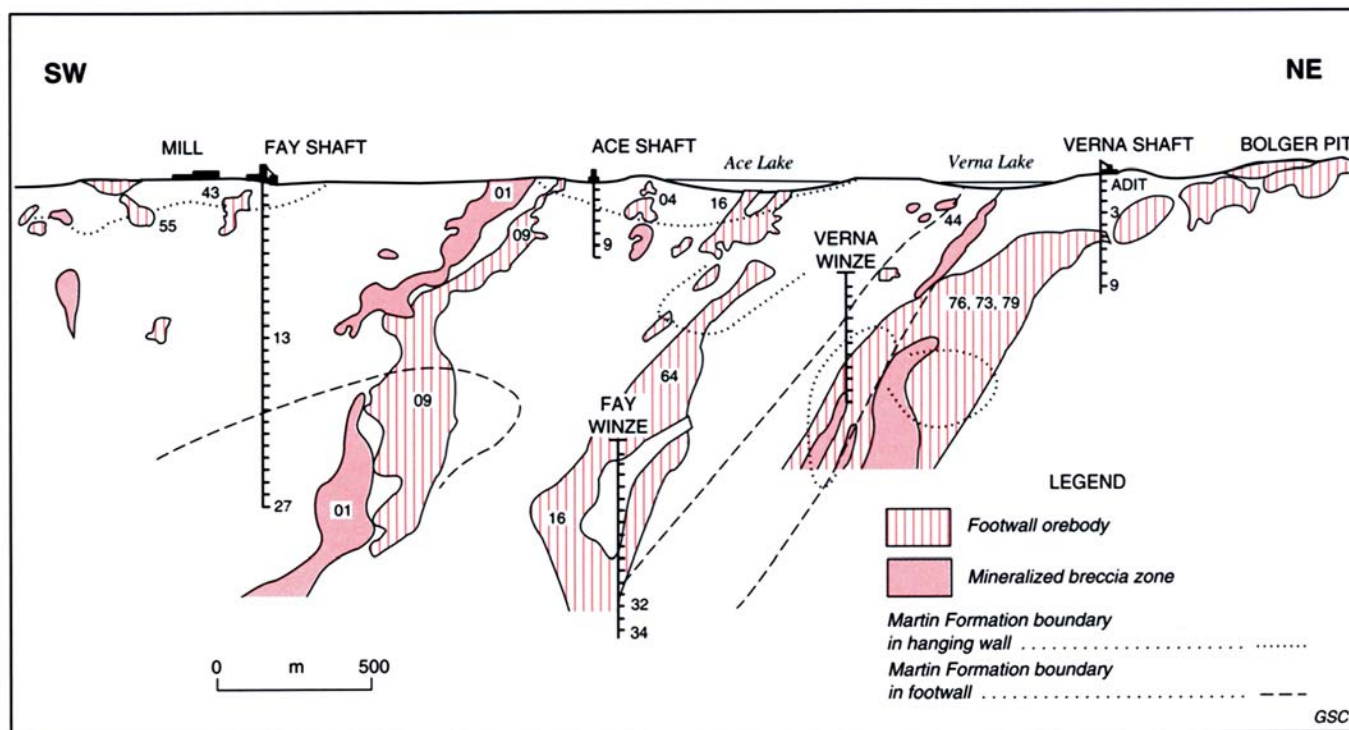
Vein deposits associated with mylonite zones in the Beaverlodge area are lithologically controlled by Apebian rocks of the Tazin Group and Helikian rocks of the Martin Formation. They are structurally controlled by major faults and apparently by the Apebian-Helikian unconformity. The principal ore-forming minerals are pitchblende, which is abundant in upper portions of the deposits, and brannerite, which is associated with pitchblende in the deeper portions. The deposits in the Bohemian Massif are lithologically controlled by Precambrian metasedimentary and metavolcanic mylonitized rocks as well as by younger granitoid intrusions, and structurally by major regional fault systems (Ruzicka, 1971, 1993).



**Figure 13.1-2.** Uranium vein deposits in the Beaverlodge area, Saskatchewan (modified after L.P. Tremblay, unpub. report, 1978).



**Figure 13.1-3.** Uranium metal/grade relationships of orebodies, Ace-Fay-Verna mining field, Beaverlodge area, Saskatchewan. Numbers correspond to deposits in Table 13.1-1.



**Figure 13.1-4.** Longitudinal section of the Ace-Fay-Verna deposit, Beaverlodge area, Saskatchewan (after unpublished documentation of the former operator, Eldor Resources, Limited, 1980). Red vertical line pattern indicates orebodies in the footwall of the St. Louis Fault. Red contoured areas indicate mineralized breccia zones. Rocks of the Martin Formation are shown by dashed (in the footwall of the St. Louis Fault) or dotted (in the hanging wall of the St. Louis Fault) lines. Numbers designate orebodies keyed to Table 13.1-1.



## GENETIC MODEL

In the Canadian Shield the vein deposits in shear and mylonite zones are part of a major metallogenic cycle, which started with introduction of uranium that was incorporated within granitoid plutons during the Kenoran Orogeny. Uranium and associated elements were further concentrated in sedimentary rocks of the Tazin Group, which were mylonitized and faulted during the Hudsonian Orogeny. The metals from the sediments were remobilized and redeposited by hydrothermal processes to form fracture fillings, stockworks, and disseminations in the host rocks. The mineralization was controlled lithologically and structurally. Sodic metasomatism (albitization) took part in the early stages of the mineralization process. Hematitization, chloritization, feldspathization, and carbonatization are the main types of alteration associated with the mineralization.

In the Bohemian Massif, the uranium in the original sedimentary and volcanic rocks has been mobilized by metamorphic, tectonic, and igneous events and redistributed in

mylonitic and fault zones (Ruzicka, 1971, 1993). The mineralization processes were accompanied by chloritization, carbonatization, and locally, by albitization of the host rocks.

## EXPLORATION GUIDES

Vein uranium deposits similar to those in the Beaverlodge area, Saskatchewan, should be sought in areas underlain by granitoid plutons of the Kenoran Orogeny containing elevated radionuclide contents. Aphebian metasedimentary and metavolcanic rocks should flank these granitoid bodies, and clastic sedimentary rocks should unconformably overlie the metasedimentary-metavolcanic sequence. The complex should be faulted, mylonitized, and subjected to retrograde metamorphism. Hematitization, feldspathization, and chloritization of wall rocks, adjacent to carbonate or quartz-carbonate veins would indicate that hydrothermal processes, a prerequisite for mineralization, were operative in the area.

# 13.2 GRANITOID-ASSOCIATED VEINS

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## INTRODUCTION

Granitoid-associated uranium-bearing veins are concentrations of uranium minerals that fill fractures within granitic or syenitic plutons (intragranitic veins) or in rocks mantling granitic batholiths (peribatholithic veins).

Intragranitic uranium veins are typically developed in highly differentiated granitic rocks, e.g., in two-mica leucocratic granites that were subjected to preceding alteration, such as albitization and desilicification (episyenitization). The deposits are spatially related to regional faults or lineaments. Their principal uranium minerals, pitchblende and coffinite, are commonly associated with sulphides and gangue minerals, such as carbonates, quartz, chalcedony, fluorite, and barite.

In Canada the best representatives of the intragranitic veins are the Gunnar deposit, which occurs on the north shore of Lake Athabasca, about 30 km southwest from the Ace-Fay-Verna deposit (Evoy, 1960; Gandhi, 1983), and the Millet Brook deposit in the South Mountain Batholith, Nova Scotia (Chatterjee and Strong, 1984). The host rocks of the Gunnar deposit are essentially 'episyenitic' in the terminology used for the altered granitoid plutons in France, pervasively albitized and carbonatized. The Millet Brook deposit occurs in sheared, metasomatically altered granitic rocks. Typical intragranitic vein deposits are associated with Hercynian granitoid plutons in France, Portugal, and China (Ruzicka, 1993).

Peribatholithic veins have been discovered in Canada in Cambro-Ordovician rocks of the Meguma Group and their analogues in Nova Scotia, in the proximity of their contacts with the South Mountain Batholith (e.g., occurrences at Torbrook, Lamb's Lake, and Inglisville along the southern margin of the Annapolis valley). The occurrences consist of massive pitchblende associated mainly with carbonate gangue in short tension fractures in pelitic and psammitic rocks. Important deposits of this type occur in Europe in the Bohemian Massif (e.g., the Příbram deposit, Czech Republic).

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1996: Granitoid-associated veins; in *Geology of Canadian Mineral Deposit Types*, (ed.) O.R. Eckstrand, W.D. Sinclair, and R.I. Thorpe; Geological Survey of Canada, *Geology of Canada*, no. 8, p. 283-285 (also *Geological Society of America, The Geology of North America*, v. P-1).

## IMPORTANCE AND SIZE OF DEPOSITS

In Canada uranium resources in granitoid-associated veins are much less significant than those in veins in shear zones. The Gunnar deposit yielded, during nine years of production, little more than 6000 t of uranium metal from ores grading 0.13% U (Evoy, 1960). The Millet Brook deposit contains dormant resources amounting to less than 500 t U (Chatterjee and Strong, 1984). In Europe, particularly in France and Portugal, however, intragranitic vein deposits represent a substantial source of uranium production. In China intragranitic vein deposits contain a major part of the country's uranium resources. The most important deposits occur in the Xiazhuang mining district, Guangdong Province, southern China.

Peribatholithic veins account for only a small amount of Canada's subeconomic uranium resources. However, the Příbram deposit, Czech Republic, produced in the period 1950 to 1990 in excess of 55 000 t of U from ores grading about 0.64% U (NUEXCO, 1990).

## GEOLOGICAL FEATURES

The Gunnar uranium deposit occurs in rocks of the Aphebian Tazin Group, at a contact between granite gneiss and syenite, which in turn are in contact with paragneiss. The pipe-like orebody consists of pitchblende and uranophane. The host rock, which originally had a granitic composition, is highly albitized, irregularly carbonatized, and locally silicified. The albitization of the granitic rock produced albite syenite and albite granite by complete or partial metasomatic replacement of the quartz, microcline, and perthite in the original rocks. Carbonate (calcite) was introduced during the subsequent uranium-bearing stage and replaced some albite and some remaining quartz in the albite granite, and in this way produced calcite syenite (Evoy, 1960).

The ore, consisting of pitchblende, coffinite, uranophane, and associated gangue minerals such as calcite, quartz, chlorite, and hematite, was formed from epigenetic hydrothermal solutions in the metasomatic syenite (or "sponge rock" of Lang et al., 1962). The mineralization process was succeeded by local kaolinization of the host rocks.

Metasomatic replacement of quartz and some other rock-forming minerals by sodic feldspars and micas, and subsequent carbonatization, is associated with some intragranitic vein deposits that are related to Phanerozoic Hercynian granites in France. This process, similar to that at the Gunnar deposit, has been called "episyenitization" by French geologists (Poty et al., 1974).

The Millet Brook deposit, Nova Scotia, occurs in alteration zones in granodiorite of the South Mountain Batholith. The alteration zones, as much as 30 m wide, were developed along fractures in four stages: potassic, sodic, ferruginous, and calcic, by replacement of quartz in the biotite granodiorite, which is 370 Ma old. The uranium-bearing solutions, which

produced the mineralization and alteration, were apparently derived from a leucomonzogranite body that intruded the granodiorite (Chatterjee and Strong, 1984).

In China some deposits, for example, Zhushanxia, Shijiaowei, and Xiwang, are associated with granitic rocks of the Yanshanian structural unit. The host granites were, however, emplaced during a preceding orogeny. The host rocks formed 185 to 135 Ma ago, but uranium was deposited 85 to 70 Ma ago (Li Tiangang and Huang Zhizhang, 1986; Du Letian, 1986; Chen Zuyi and Huang Shijie, 1986).

## CONCEPTUAL MODEL AND EXPLORATION GUIDES

Intragranitic vein uranium deposits occur, as a rule, in alteration zones which have developed along structures of high permeability in granitic bodies. Some of the fluids that caused the alteration (sodic, potassic, carbonatic) also introduced uranium mineralization into fractures or other open spaces, developed by dissolution of rock-forming minerals. Therefore, areas underlain by granitoid rocks that have been affected by sodic, potassic, or calcic metasomatic processes should be considered favourable for the occurrence of intragranitic vein uranium deposits.

Favourable environments for peribatholithic veins exist in areas containing sedimentary and metamorphic rocks that mantle granitic plutons, particularly those in which granitic bodies have intruded black shales. The black shales are considered by some authors (e.g., Ruzicka, 1971) not only as a metal source, but also as favourable host rocks.

## RELATED DEPOSIT TYPES

These vein uranium deposits (13.1 and 13.2) are similar in some features to other deposit types. They are closely similar in morphology and mineral composition, in particular, to some unconformity associated deposits (Tremblay, 1982). For example, the shapes and monometallic compositions of the orebodies of the Eagle Point deposit, Saskatchewan, which is associated with the unconformity underlying the Athabasca group rocks, strongly resemble those of the Ace, Fay, and Verna deposits. Furthermore, some of the vein deposits are, at least spatially, related to unconformities. For example, the Ace-Fay-Verna orebodies occur mainly below, but also just above, the unconformity underlying the Martin Formation rocks. The Proterozoic rocks of the Bohemian Massif host the veins of the Příbram deposit, which extend from the unconformity below the Cambrian rocks to a depth of more than 2000 m.

## ACKNOWLEDGMENT

Critical reading of the manuscript by R.I. Thorpe of the Geological Survey of Canada is gratefully acknowledged.



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