Mineralization, Mining, and Mineral Resources in the Beaver Creek Area of the Grenville Lowlands In St. Lawrence County, New York

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1279

MINERALIZATION, MINING, AND MINERAL RESOURCES IN THE
BEAVER CREEK AREA OF THE GRENVILLE LOWLANDS
IN ST. LAWRENCE COUNTY, NEW YORK

Cluster of sea-green fluorite cubes modified by octahedral faces (from the "Macomb locality," locality 98). This is one of several large specimens collected by George Kunz at a small fluorite mine in the town of Macomb in St. Lawrence County, N.Y., in 1888–89 and acquired by the New York State Museum (Kunz, 1889; New York State Museum, 1889, p. 64, and 1890, p. 30). The exact location of the mine has been essentially unknown since the report by Kunz. Robert Paul Rice, a local naturalist, showed the author a pit from which he collected fluorite. The locality closely matches the description by Kunz. The fluorite with calcite occurs in a westward-dipping gash vein, and other similar, but less spectacular, occurrences appear to be related to late (Paleozoic?) movement on a major fault in the Beaver Creek area. Photograph courtesy of the New York State Museum, William M. Kelly, Curator of Mineralogy, and Greg Troup, photographer.

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By C. Ervin Brown

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Beaver Creek Area of the Grenville Lowlands

In St. Lawrence County, New York

The following changes should be noted in Professional Paper 1279:

p. 3 Replace the caption for figure 1 with:

Figure 1.--Major faults and lineaments and distribution of Rossie-type veins in the vicinity of the Beaver Creek area.

p. 16 Add the following to the caption for figure 6:

Photograph is 2/3 of actual size of specimen.

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ILLUSTRATIONS

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MINERALIZATION, MINING, AND MINERAL RESOURCES IN THE BEAVER CREEK AREA OF THE GRENVILLE LOWLANDS IN ST. LAWRENCE COUNTY, NEW YORK

By C. ERVIN BROWN

ABSTRACT

The Beaver Creek area in western St. Lawrence County, N.Y., is in the Grenville lowlands, which are underlain by metasedimentary and metaigneous rocks of Proterozoic age. Since about 1812, mining has been an important part of the economy of the area. Iron, lead, zinc, pyrite, talc, graphite, feldspar, marble, garnet, and wollastonite have been mined in the Grenville lowlands, and the area is still an important source of zinc and talc for the United States.

The mineralization of the region can be categorized as taking place during four major geologic events in the following chronologic order:

1) Sedimentation and penecontemporaneous mineralization (>1,000 m.y. ago);

2) Recrystallization and remobilization caused by regional tectonism and metamorphism (1,000 m.y. ago);

3) Oxidation and hydrothermal alteration subjacent to the Proterozoic-Paleozoic unconformity (<1,000 to 500 m.y. ago);

4) Hydrothermal vein deposition along vertical fractures (<450 m.y. ago).

Identified mineral resources, numerous abandoned mines and prospects, and many occurrences of minerals that are economically or scientifically significant are in the Beaver Creek area. One hundred and one localities of mineral resource-related features that are located and described include abandoned lead, iron, graphite, pyrite, fluorite, and barite mines and prospects and many unusual mineral occurrences. Identified resources of high-purity marble, talc-tremolite schist, stratabound zinc and pyrite-pyrrhotite, galena, rutile, pegmatite, and peat are in the area.

A quartz, mica, feldspar granofels unit rich in magnesian tourmaline is found in the rock sequence southeast of Beaver Creek in association with other metasedimentary rocks rich in magnesium. Similar rocks at many places elsewhere in the world are associated with stratiform base-metal sulfide deposits that were formed as submarine exhalative deposits. On this basis, the presence of similar base-metal deposits is speculated here.

INTRODUCTION

Mineral deposits, old mines and prospects, and numerous mineral occurrences were located by the author while mapping the geology of the Beaver Creek area, an area of about 280 km^2 in western St. Lawrence County, N.Y. Rocks are metasedimentary and metaigneous rocks of the Grenville Complex. The purpose of this report is to highlight and appraise the mineral resources and to record locations of abandoned mines, prospects, and mineral occurrences where fine mineral specimens might be collected. The map (pl. 1) shows point locations and the principal minerals of interest. The mineral assemblage and evidence of mining activity at each numbered locality are listed and described on the map.

Indicated, inferred, and speculative mineral resources[1] of base metals, limestone, dolomite, talc, and peat that were recognized during my investigation and some from earlier studies are shown on the map (pl. 1) and discussed here. Lead, iron, pyrite, feldspar, garnet, fluorite, and graphite mining, and possibly barite prospecting, were done during the 19th and early 20th centuries in St. Lawrence County; numerous sites of such activities are located in the Beaver Creek area. Early mineralogists collected minerals in St. Lawrence County and referred to such many times in mineralogy texts, but with indefinite locations (Beck, 1842; Dana, 1914). Small prospect pits at some crystal localities described here probably date from this early mineral-collecting activity.

The geologic units that are outlined on the map (pl. 1) are selected for their resource potential. Unlabelled areas are undivided granites, amphibolites, gneisses, and marbles of little or unrecognized resource potential.

The southeastern part of the Richville quadrangle was mapped by H. M. Bannerman (1972) as part of his study of the Richville-Bigelow area. His geologic units are reinterpreted and correlated with the Beaver Creek area by the author in regard to their resource potential (see mapping index, pl. 1), and mines and mineral occurrences that are described in the geologic literature are shown. A small area of white, pure dolomitic marble (locality 95, pl. 1) was mapped and sampled by Prucha

[1]Resource terminology used in this report is that prescribed by the U.S. Bureau of Mines and the U.S. Geological Survey in U.S. Geological Survey Circular 831 (1980, p. 2, 3).

(1953) near the south edge of the map. His geologic units are also generalized and shown here.

ACKNOWLEDGMENTS

The author acknowledges the geologic assistance through consultation in the field and office provided by many colleagues, and particularly by Harold M. Bannerman (deceased), John S. Brown, David B. Dill, Yngvar Isachsen, Michael P. Foose, and Robert V. Guzowski. Special thanks are due John F. Slack for calling to my attention the possible economic significance of tourmaline-rich metasedimentary rocks, Eric Force for providing data on rutile in aplite, and to Deborah Dwornik who photographed numerous mineral specimens for this report. The author is particularly grateful to Robert Paul Rice, a resident from the southwest part of the area. Mr. Rice is a self-trained naturalist who is well acquainted with mineral localities in that area. In 1981, in a fortuitous meeting in the field, he called my attention to the features that I have included as localities 98 through 101. One of these, locality 98, is a much-cited fluorite occurrence described by Kunz in 1889. Its exact location has been essentially unknown since then.

GEOLOGIC SETTING

The Beaver Creek area is northwest of the Adirondack highlands in the northern part of the Grenville lowlands (Buddington and Leonard, 1962, p. 7) that is characterized by a low, but very hilly relief of about 60 m and a topographic grain that closely reflects the highly deformed crystalline bedrock. Valley floors are flat because of lacustrine clay that was deposited during the period of inundation that followed Pleistocene glaciation. After inundation, peat accumulated in many of the valleys. The lowlands are underlain mainly by metasedimentary rocks of the Grenville Complex, which here have a large carbonate component, and were intruded by igneous rocks ranging from granite to gabbro, which are now gneisses and amphibolites. To the north and south of the Beaver Creek area, rocks of the Grenville Complex are unconformably overlain by relatively undeformed sedimentary rocks of early Paleozoic age. In the Grenville lowland area, the overlying sedimentary cover has been breached by erosion along a broad arch known as the Frontenac axis that connects the Proterozoic rocks of the Adirondack highlands with the Canadian Shield to the northwest. Rocks of the Grenville lowlands are regionally metamorphosed mainly to the upper amphibolite facies. The border with granulite-facies rocks is about 20 km southeast of the Beaver Creek area, essentially at the highland-lowland boundary (New York State Museum and Science Service, 1971).

Rocks of the Grenville lowlands have been severely affected by deep-seated, ductile folding and faulting and igneous intrusion at least 1000 m.y. ago. Since then, renewed intermittent fault movement has caused mylonitization and brittle deformation along some of the old faults. The Beaver Creek area can be divided into northeast-trending panels or structural domains separated by faults or lineaments (fig. 1). From southeast to northwest, the bounding structures are 1) a fault zone now followed by the Oswegatchie River, 2) the Beaver Creek lineament, and 3) the Pleasant Lake fault that extends in this area from south of Pleasant Lake northeastward through Hickory and Mud Lakes. Each structural domain is characterized by its own structural style, stratigraphic sequence, and somewhat by its intrusives. The confidence level of the correlation of lithologic units from one domain to another ranges from positive to purely speculative. For instance, different lithologic sequences are found on either side of the Beaver Creek lineament. In contrast, the rock sequences on either side of the Oswegatchie fault zone are quite similar.

Because the purpose of this report is to highlight the mineral-resource aspect of the area, geologic structure and stratigraphy will not be discussed further except in regard to resources and mineral occurrence.

MINERALIZATION HISTORY

INTRODUCTION

The rocks of this area represent more than a billion years of geologic history, and mineralization processes that produced potentially useful, collectible, or scientifically interesting minerals were active at several times. Nevertheless, for simplicity, the mineralization history can be divided into four major events or phases, and all resources and occurrences listed here are categorized in their respective genetic phase by number on the table on plate 1. The events, in chronological order, are 1) Sedimentation and penecontemporaneous mineralization, 2) Recrystallization and remobilization of phase 1 elements by regional tectonism and metamorphism, 3) Oxidation and hydrothermal activity close to the Proterozoic-Paleozoic unconformity, 4) Hydrothermal activity and vein deposition along vertical fractures in post-Ordovician time.

The minerals or chemical elements resulting from phase 1 mineralization were all remobilized and/or recrystallized by phase 2 metamorphism. Most of the

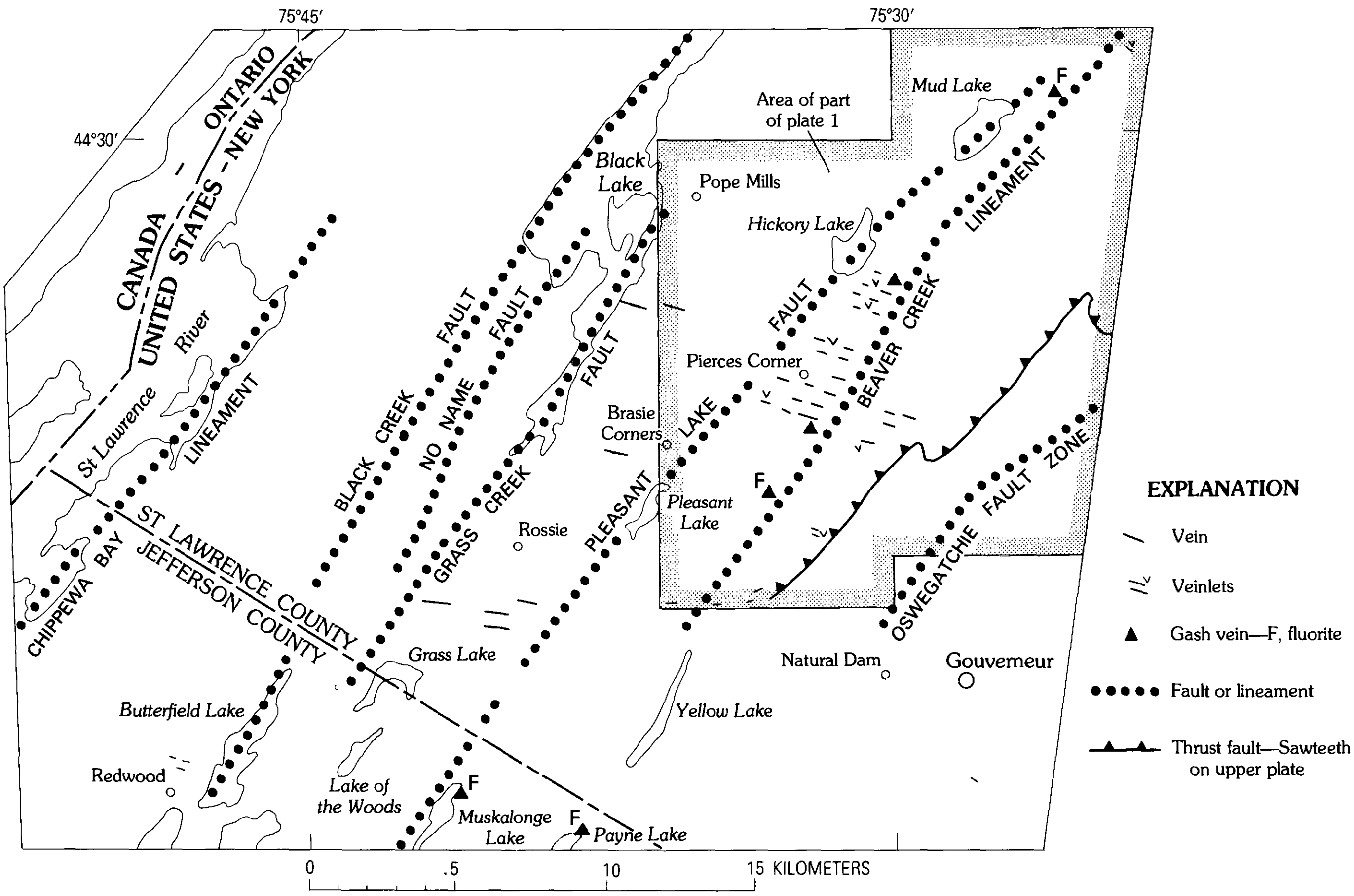


FIGURE 1.—Major structural features of Beaver Creek area discussed in text.

minerals that were oxidized during phase 3 were originally formed during phase 2, but some barite, pyrite, and other sulfides were possibly introduced at this time. Vein minerals resulting from phase 4 processes are probably derived from mineralizing solutions generated at considerable distance from the site of deposition.

SEQUENCE OF MINERALIZATION EVENTS

PHASE 1. SEDIMENTATION AND PENECONTEMPORANEOUS MINERALIZATION

The Grenville Complex was deposited as clastic sediments and/or chemical precipitates in Proterozoic time followed by a tectonic and metamorphic event that occurred about 1,000 m.y. ago. Some base-metal deposition, particularly zinc, occurred early in a marine-carbonate-depositing environment probably under evaporitic conditions as evidenced by the presence of an anhydrite unit in the same rock sequence that contains the stratabound sphalerite in the Balmat-Edwards, N.Y., mining district 15–20 km southeast of this study area (Lea and Dill, 1968; Dill and de Lorraine, 1978). Other chemical elements that later developed into mineral deposits probably were also concentrated early in the sediments. These include magnesium, iron, sulfur, and boron that are now stratabound talc-tremolite, pyrite, and tourmaline-rich zones, respectively.

PHASE 2. REGIONAL TECTONISM- AND METAMORPHISM-PRODUCED RECRYSTALLIZATION AND MOBILIZATION

All elements of Phase I have been modified and mobilized by subsequent tectonism and high-grade, regional metamorphism. For instance, zinc deposits of the Balmat-Edwards district are stratabound but are now mainly structurally positioned within specific strata in axial parts of folds. Several generations of folding have taken place, and each has had an effect on size, shape, and location of ore bodies (Dill and de Lorraine, 1978). Sulfides under high P-T conditions of regional metamosphism are apparently mobilized at different rates than other mineral matter and, thus, have migrated laterally along pressure gradients during tectonism.

Magnesium-rich zones (now talc-tremolite schist) and anhydrite behaved in a similar manner to the sulfides. Recrystallization has produced a variety of mineral deposits of silicates and sulfides that locally are very coarsely crystalline. The minerals at many of the occurrences shown on the map (pl. 1) were produced during phase 2 about 1,000 m.y. ago. Examples of minerals produced during phase 2 are shown in fig. 2. During this phase, pegmatites, granites, and gabbros were emplaced, and rocks were affected by anatexis, migmatization, and probably metasomatism. Late in phase 2, and probably when rocks were at a higher level in the Earth's crust, cataclasis along zones of translation produced some granulated, strongly lineated, and fine-grained rocks (mylonites). Retrograde metamorphism also was a late phase 2 process that affected the region widely and possibly overlapped somewhat with some mineralogic effects described under phase 3. Some of the resulting minerals of this retrograde metamorphic event are serpentine and talc that are an alteration of diopside, tremolite, anthophyllite, and forsterite that formed earlier in phase 2 in siliceous dolomitic marble. At a later time, retrograde metamorphism formed segregations of green hornblende and chlorite with sulfides in some gneiss units; biotite is commonly altered to chlorite and magnetite, and feldspar is sericitized.

PHASE 3. OXIDATION AND POSSIBLY HYDROTHERMAL ACTIVITY SUBJACENT TO THE PROTEROZOIC-PALEOZOIC UNCONFORMITY

The third major phase of mineralization took place after many kilometers of crystalline rocks were eroded down to an area of low relief close to sea level. Lateritic weathering produced a rubbly surface covered with hematite-enriched and cemented bouldery residuum somewhat similar to the "canga"-covered surfaces in Brazil (Guild, 1957, p. 59). The "canga" in Brazil forms a blanketing deposit that at places merges downslope with bauxitic deposits (Guild, 1957) and is spatially related to occurrences of Precambrian iron-formation.

The iron-rich deposits in the Grenville lowland in contrast to the Brazilian canga are associated with underlying pyritic metamorphic rocks, and no bauxitic weathering products are known. These remnants of the Proterozoic topographic surface are preserved close (horizontally and vertically) to remnants of Potsdam Sandstone of Late Cambrian age that covered and preserved this surface.

Surficial lateritic weathering alone cannot easily explain all of the features of these deposits. Most iron-oxide-rich material in the hematite deposits of the Grenville lowlands is siliceous, red, earthy hematite, but crystalline specularite commonly occurs as well as magnetite and maghemite. In addition, secondary pyrite, chalcopyrite, millerite, barite, sphalerite, galena, willemite, ilvaite, and grossularite have been described associated with this type of mineralization (Brown, 1936). Obviously, the process was more complex than simple oxidation by weathering. Furthermore, whatever the process, it apparently started before the deposition of the Potsdam Sandstone and continued after the sandstone was in place because blocks of typical bedded Potsdam Sandstone are included in hematitized and silicified breccia masses produced by collapse into ancient solution cavities where marble is bedrock.

Simple collapse cannot explain all instances of masses of Potsdam Sandstone or similar material in unusual locations in relation to metasedimentary rocks of the Grenville Complex. New roadcuts close to Richville, N.Y., including locality 92 (pl. 1) reveal an intriguing variety of relations between Potsdam Sandstone and marble of Proterozoic age. One of these roadcuts close to Welch Church has marble reverse faulted against Potsdam Sandstone. Associated with the fault zone is brecciated basal sandstone and quartz pebbles and hematite-stained sandstone dikes that intrude along fractures and solution cavities in the marble. Another roadcut (locality 92, pl. 1) has a 7-m-high section of hematized material exposed. The top of the roadcut is oxidized pyritic, tremolitic, quartzite of Proterozoic age that grades downward into a hematite-rich zone which includes sheared phacoid-shaped masses which include blocks of vitreous quartzite that look like Potsdam Sandstone. Marble occurs at the bottom of the outcrop. The reverse fault, highly sheared and hematite-enriched rock, and sandstone dikes intruding all available cavities apparently record a laterally compressive tectonic event that also was part of phase 3 activity. Reverse faulting has also been observed at the contact between marble and other isolated areas of Potsdam Sandstone by the author.

Hematite deposits resulting from the third phase of mineralization were mined in the vicinity of Antwerp and Keene 8–15 km south of Gouverneur, N.Y. Mining started there about 1812 and continued until the early 1900's. Ore was smelted at Rossie, N.Y. Some mine workings are more than a quarter of a mile long and 200 feet deep (Buddington, 1934, p. 198). However, the mining record is sketchy because very little was written about these mines while they were operating. Buddington (1934) provided the best description of the abandoned mines and listed the few earlier references to them. He and Leonard also described hematite mine workings in eastern St. Lawrence county (Leonard and Buddington, 1964, p. 232–239) and called them "Sub-Potsdam (supergene) hematite deposits." They believed

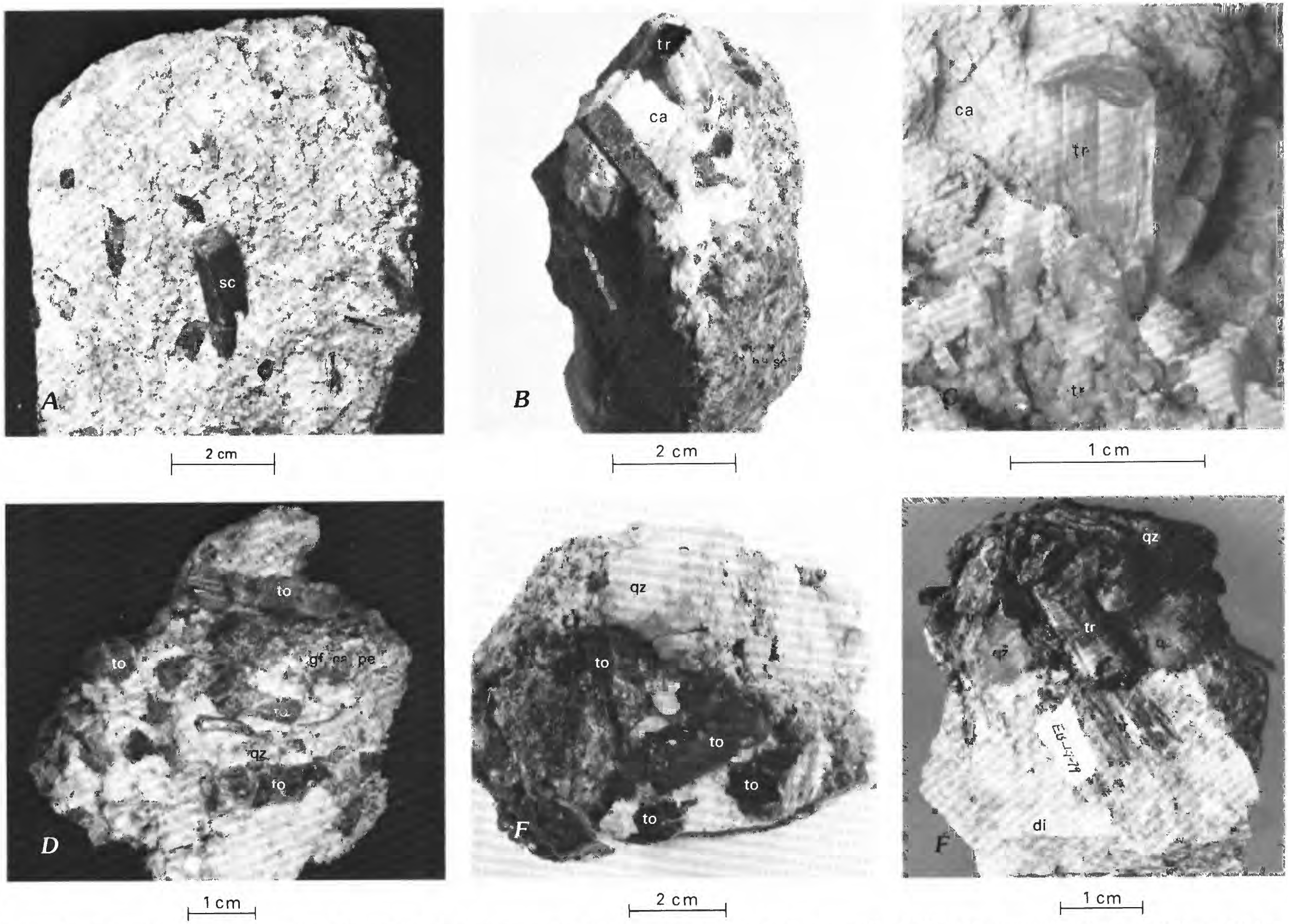


FIGURE 2.—Examples of minerals produced by phase 2 mineralization. *A*, Black scapolite crystals (meionite, sc) in crumbly calcitic marble from locality 40. *B*, Dark, grayish-green scapolite (meionite, sc), with calcite (ca), and pale grayish-green, translucent tremolite (tr) from locality 85, Lavack Mica mine; wallrock is composed of diopside (di), tremolite (tr), phlogopite (ph), and scapolite (sc). *C*, Translucent pale-green tremolite (tr) with calcite (ca) from locality 75. *D*, Brownish-amber tourmaline (uvite, to) in pegmatitic clot in graphitic marble (ca) from locality 31. Graphite (gf); quartz (qz); perthite (pe). *E*, Coffee-brown tourmaline (to) with quartz (qz) from locality 26. *F*, Grayish-green tremolite crystals (tr) and quartz (qz) that fill fracture in quartz-diopside (di) wallrock. Tremolite has transverse striping. Collected 150 m southeast of locality 56. (D. Dwornik, photographer.)

that the deposits were mainly products of pre-Late Cambrian weathering with only minor mineralization after deposition of the sandstone cover (Buddington, 1934, p. 201).

All of the aforementioned hematitic deposits are above marble that is in the vicinity of outcropping pyritic schists and gneisses, but at least one deposit overlies an altered stratabound pyritic, zinc ore body. Smyth (1917) and Newland (1917) described a hematite deposit close to Balmat, N.Y., that apparently is the result of oxidation of pyritic zinc ore. Their description indicated that massive, hard, bluish-gray hematite and soft red hematite at the surface grade downward through a zone of intimately intermixed secondary sphalerite and hematite that, at about 75 feet, changes to normal dark sphalerite and pyrite of a stratabound zinc ore body.

Within a few years after mining commenced in 1927 at Balmat, much of the upper ore zones was exposed, and Brown (1936) presented a valuable paper on his observations of the supergene mineralization there including the ore described earlier by Smyth (1917) and Newland (1917). Brown reported secondary sphalerite, galena, chalcopyrite, magnetite, willemite, ilvaite, and chlorite and their relation to hematite and primary minerals. Pough verified the secondary nature of these minerals in a mineralogical study done in 1940 (Pough, 1940). Brown attributed the origin of these minerals to deeply migrating meteoric waters that were highly charged with sulfur after chemically altering iron sulfides. He differed slightly with Buddington in believing that much of the mineralization continued after the Potsdam Sandstone was deposited. Brown stated that the effects of alteration and hematite mineralization have been observed in the mines as much as 1,000 feet below the surface. More recent mining has revealed that the effects are nearly twice as deep.

Other minerals that I attribute to phase 3 mineralization are grossularite with the willemite in Balmat No. 2 mine (Lea and Dill, 1968, p. 39), millerite with hematite at the Sterling mine at Antwerp (Dana, 1914, p. 71), and barite blades that are intermixed in hard hematite ore near Pierrepont, N.Y. (Leonard and Buddington, 1964, p. 234). In the Beaver Creek area, anastomosing veinlets of cream-colored barite with pyrite in weathered marble (locality 73, pl. 1) close to outliers of Potsdam Sandstone are also believed by me to be a product of phase 3 mineralization.

Buff to cream-colored dolomite that occurs pervasively or in wide zones along joints in normally blue-gray magnesian marble is in many places close to Potsdam Sandstone. Locally, thin veinlets of cryptocrystalline silica are associated with the dolomitized rock, and pink hematite stains are along fractures. The dolomitization, silicification, and hematite staining are all effects of phase 3 mineralization, I believe.

PHASE 4. PALEOZOIC HYDROTHERMAL ACTIVITY ALONG VERTICAL FRACTURES

This phase of mineralization mainly formed veins of coarse white to flesh-colored calcite with associated sphalerite, galena, rare green fluorite, barite, and celestite known collectively as "Rossie veins" (Smyth, 1903). The veins are mainly in rocks of Proterozoic age and are essentially vertical, trending northwest and west in recurrent minor faults. A vein 600 m north of Redwood, N.Y. (fig. 1), cuts shattered Potsdam Sandstone of Late Cambrian age, and to the northwest in Ontario similar veins are in rocks of Ordovician age (Uglow, 1916). The Rossie veins are discussed further in a later section (see "Lead mining").

Other hydrothermal effects mainly along northwest-trending joints possibly are related to the Rossie-type of vein mineralization. In impure marble, joint-controlled serpentinization of diopside and some calcitization of dolomite took place, causing the narrow altered zone along these joints to stand out as ribs on weathered outcrops. Similar alteration also affected country rock adjacent to many thin Rossie-type veinlets (see locality 89, and fig. 3*A*). In hornblendic and biotitic gneisses, mafic minerals along joints are altered to epidote and chlorite; plagioclase is reddened and less calcic; and quartz, pyrite, and epidote are deposited along the joints. This alteration is not ubiquitous in the region, and there is no obvious geologic control for its localization; affected areas do not necessarily correspond to areas of Rossie-type veins.

Undeformed northeast-trending diabase dikes in the Grenville lowlands possibly provide a date for this hydrothermal event. The dikes are truncated and highly hematitized by phase 3 mineralization at the unconformable contact with the Upper Cambrian Potsdam Sandstone. They display chilled borders against the wallrock and are amygdaloidal; hence, they must have been intruded into shallow crustal rocks. These geologic relations indicate that their possible age ranges from Proterozoic Z to Middle Cambrian. The dikes, although totally undeformed, are chloritized, and I have observed epidote of phase 4 veining them.

Potassium-argon age dates on feldspar and pyroxene from the dikes give dates of 405 ± 11 m.y. and 440 ± 10 m.y., respectively (Brown, 1975). These dates are Silurian to Late Ordovician and are much younger than the field relations allow for the age of emplacement. The age might have been reset by the phase 4 hydrothermal event, and therefore the dates might be an approximation of the time of that activity instead.

OTHER LATE MINERALIZATION PHENOMENA

Some mineralization effects, although they are obviously at a shallow position in the Earth's crust, lack specific criteria to categorize them as being a result of either phase 3 or phase 4 mineralization. Light-blue patchy alteration in amphibolites and diopside, scapolite paragneisses, and along joints in the dioritic paragneisses in the outer zone of the gneissic dome 2,000 m west of Pierces Corner has been identified by the author as pumpellyite. The latter rocks also have rare, thin, light-gray layers and cross-cutting seams of extremely fine-grained massive sericite specked with millimeter-sized brown grossularite that are also obviously a late alteration, but that possibly preceded the mineralization associated with phase 3.

Fluorite and calcite in large showy crystals occur in northeast-striking gash veins (fig. 1) that dip to the northwest at locality 98 (pl. 1). Similar deposits are found at Muskalonge Lake (Kunz, 1889) and Vrooman Lake (now Payne Lake) (Whitlock, 1905). Minerals at localities 2, 24, and 41 have the same mode of occurrence. Some fluorite is also found with calcite in the Rossie-type veins, but they are in vertical west- to northwest-trending fractures. Whether the two types of deposits are related is open to question (see section entitled "Fluorite deposits"). A veinlet of fluorite and pink calcite at locality 43, however, fills a northwest-trending vertical fracture, and I believe that it is a result of phase 4 mineralization. A study of fluid inclusions and possibly isotopes is needed to better identify and categorize the minerals of various late mineralization events.

PAST MINING IN THE GRENVILLE LOWLANDS WITH REFERENCE TO ABANDONED MINES AND PROSPECTS IN THE BEAVER CREEK AREA

A great variety of mineral resources has been mined from the Grenville lowlands mainly from St. Lawrence County but also from the northern part of Jefferson County. Iron, lead, sulfur (from pyrite), zinc, talc, graphite, marble, feldspar, and wollastonite were the principal commodities extracted, and table 1 shows the chronology of the mining activity. Table 1 also includes some minor mining operations for garnet and fluorite. Although most of the commodities are no longer mined because the deposits are subeconomic, major zinc and talc mines, a few quarries in marble, and a small wollastonite mine near Lake Bonaparte are still being operated in the lowlands.

The Beaver Creek area (pl. 1) includes mainly the drainage basin of Beaver Creek and some area along Birch Creek to the west and the Oswegatchie River to the east. This area has occurrences of all of the minerals and types of deposits mined in the lowlands except wollastonite. The discussion that follows concerns mainly deposits in the Beaver Creek area. Some other deposits and occurrences elsewhere in the region are discussed under the section entitled "Mineralization history."

IRON MINING

Iron ore, mainly hematite, was mined from 1812 to 1910 from mines mainly near Antwerp and Keene 8–15 km southwest of Gouverneur, N.Y. (Newland, 1921; Buddington, 1934). The ore, a result of phase 3 mineralization (see section entitled "Mineralization history"), is in rocks of Proterozoic age close to the contact with the overlying Potsdam Sandstone. One of these deposits is in the Beaver Creek area at Hedgehog Hill (locality 36) that is capped by Potsdam Sandstone. Blocks of a hard, massive, fine-grained, dark-gray mixture of hematite and magnetic maghemite locally associated with jasper are on the old mine dump. The country rock is a rusty pyritic gneiss. An unpublished reconnaissance ground magnetometer survey done in 1972 by students from Columbia University School of Mines and the author proved an associated high magnetic anomaly in the zone between localities 35 and 36.

Although phase 3 ore is mainly soft red hematite, the iron mineral at locality 90, 2 km north of Little Bow, is flaky specularite in veins in coarse crumbly marble. Elsewhere, a few small pits in soft red hematite close to the basal Potsdam Sandstone contact were dug by local residents partly for a pigment for homemade barn paint.

A zone of hematite-mineralized rock, previously discussed, is exposed along the relocated U.S. route 11 southwest of Richville (locality 92). Here, the rock before alteration was an interlayered pyritic and tremolitic quartzite. A nearby small patch of Potsdam Sandstone proves the proximity of this zone to the Proterozoic surface. Although hematite was not mined in the vicinity of Richville, the rock in the roadcut is typical of the iron ore mined near Antwerp in the 1800's.

LEAD MINING

During the 1830's galena was discovered in predominantly calcite veins 1.5–3 km south of Rossie, N.Y. (fig. 1). These veins were mined mainly from about 1836 to 1852, and 6,000 tons of lead (table 1) were produced from them during that period (Neumann, 1952). Other veins were found elsewhere in St. Lawrence County, including those in the Beaver Creek area about 1.5 km southeast of Macomb (now Pierces Corner) (pl. 1,

TABLE 1.—*Chronology of mining in the Grenville lowlands and estimates of production*

Commodity and type district	1800 1850 1900 1950 1980	Estimated total production (short tons)
Iron (hematite) (Antwerp)	1812 – 1910	2,500,000 tons containing 35–40% Fe[1]; 1942–small amount for pigment[11]
Lead (galena) (Rossie)	1836[10] – ?	9,500 tons PbS[2]
Sulfur (pyrite-pyrrhotite) (Pyrites-Antwerp)	1883 – 1921	660,000 long tons containing 40% S[3]
Zinc (sphalerite) (Balmat-Edwards)	1915 –	1915 to 1964[4]–17,432,184 tons containing 10.1% Zn; 1964 to 1976–846,368 tons recoverable Zn[5]
Talc (Fowler)	1878[9] –	1883 to 1918–1,314,262 tons[13] 1918 to 1980–9,000,000 tons[6]
Marble A. Dimension stone (Gouverneur)	1878 – 1941	?
B. Fluxstone[7] (Richville)	1905 – 1917	?
C. Landscape stone and white filler (white crystal dolomite)		?
Graphite (Pope Mills)	1907 - - - - 1942	$20,000^+$ tons containing 20–25% C[6]
Feldspar (McLear pegmatite)	1910 - - — 1938	$1910^\pm$ to 1929–120,000 tons feldspar[8]; 1929 to 1938—?
Fluorite[12] (Macomb)	? ?; 1885 – ?	15^+ tons CaF_2[12]
Garnet[7]		?
Wollastonite (Lake Bonaparte)		?

[1]Buddington, 1934.
[2]Neuman, 1952.
[3]Prucha, 1957.
[4]Lea and Dill, 1968.
[5]U.S. Bureau of Mines Minerals Yearbooks.
[6]C. E. Brown, estimate.
[7]Cushing and Newland, 1925, p. 85, 119.
[8]Shaub, 1940.
[9]Smock, 1888.
[10]Nason, 1888.
[11]Otte, 1943, p. 24.
[12]Kunz, 1889.
[13]Newland, 1921, p. 285.

fig. 1). These were mined during the Civil War, but some mining possibly continued as late as the early 1900's. Although sphalerite occurs in the veins, none was recovered. Iron sulfides are rare, and thus rock on the old mine dumps is not iron stained.

The Macomb mines produced about 1,000 tons of lead (Neumann, 1952), and production was mainly from the mines at localities 3, 4, 5, 9, and 11 (pl. 1). Little information is available about these, and none for the few mines on the east side of Beaver Creek (localities 80, 81, 82, 83, 84, 86, and 87). Buddington (1934) describes the lead mines briefly and lists earlier references to them, and Whitney (1854) has an excellent account of their early operation.

The U.S. Bureau of Mines in 1950 drilled 18 holes to explore for deeper mineralization and extensions of the veins. Nine of the holes were drilled in the vicinity of localities 4 and 5, and downward vein extensions were found (Neumann, 1952).

Veins are exposed at many of the old mine workings, and, even though sulfide mineralization is lean, sphalerite and galena are easily found. Although extensions of the veins are known and unmined veins were found in this study, the lean ore grades and small size of ore bodies will probably continue to discourage their being exploited again.

Barite, celestite, and green fluorite occur in these deposits, but they are rare. At Madoc, Ontario, considerable production of fluorite in the early 1900's came from fissure vein deposits very similar to nearby northwest-trending, galena-bearing veins. In St. Lawrence County a very small production of fluorite came from two prospects (see section entitled "Fluorite mining"). Geologists have assumed from the literature that these latter occurrences are in vertical veins like the galena-bearing veins (Heyl and Van Alstine, 1976, p. 78), but a close examination by me of the larger of these two occurrences (locality 98, pl. 1) did not reveal westward-trending vertical veins. Instead, the mineralization is coarsely crystalline calcite and fluorite crystals in short gash veins that trend northeast and dip northwest. Similar occurrences nearby suggest a different mode of fracture development and mineralization here from that of the vein fillings typical of the galena veins (see sections entitled "Fluorite mining" and "Fluorite deposits").

DESCRIPTION, AGE, AND ORIGIN OF VEINS

The veins near Rossie, N.Y., were first described by Emmons (1838, 1842). Smyth (1903) called them "The Rossie lead veins," and that name is now used locally for all veins of this type. The veins, formed during phase 4 mineralization, are mainly of flesh-colored and white calcite and contain sphalerite, galena, and minor amounts of fluorite, barite, and celestite. Some veins are as much as 1.7 m wide, but most are narrower. Some have been mined for a few kilometers along strike and less than 100 m deep. The veins continue below the bottom of mining (Neumann, 1952). They fill minor faults that generally trend northwest with short segments that trend more westerly. The sense of horizontal movement along the mineralized fractures in the Macomb area is right lateral. Anastomosing veinlets are common. During mineralization, repeated fracturing caused mineral crustification in the veins to be truncated at low angles and smeared, and a new sequence of vein deposition filled the openings along the new fracture (fig. 3*D*). Thin dikes of well-rounded and cemented quartz sand in the veins indicate that sudden fracturing allowed hydraulic intrusion of a slurry of sand probably from disaggregated overlying Potsdam Sandstone (fig. 3*C*, *D*, *E*).

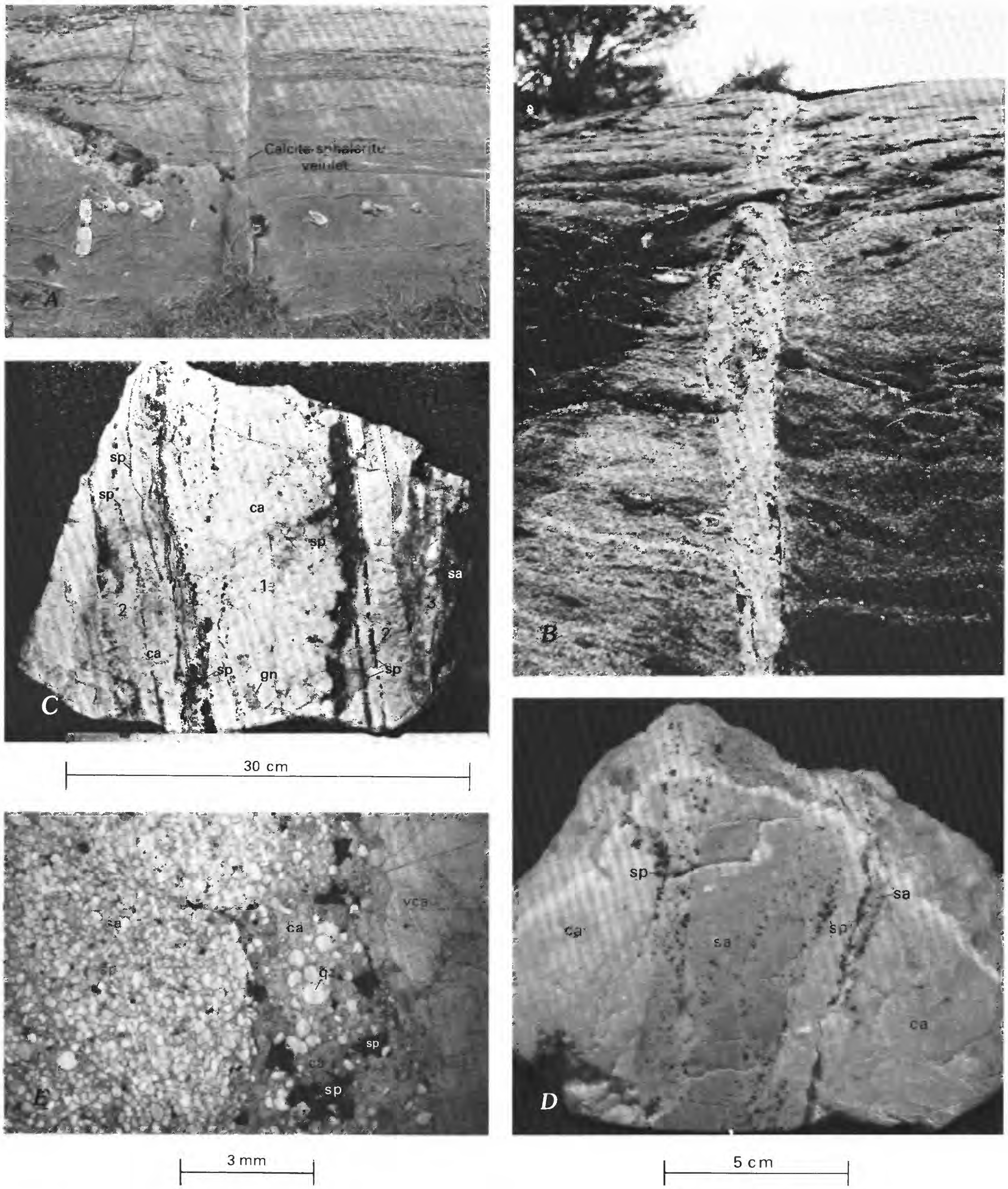
Figure 1 shows the distribution of lead-mining areas and lead-zinc-bearing veins in parts of St. Lawrence and Jefferson Counties. Veins cut a variety of wallrocks of Proterozoic age, from granite to marble, and veins that are 1.2 km north of Redwood, and 3 km southwest of Rossie (J.S. Brown, written commun.), are in fractures in the Potsdam Sandstone. Lead-calcite-fluorite (Whitlock, 1905, p. 188) veins 80 km to the south near Martinsburgh, N.Y., are in rocks of Middle Ordovician age (Buddington, 1934). Uglow (1916) described veins similar to Rossie veins in southeastern Ontario, and a few of these cut limestone of Early and Middle Ordovician age (fig. 4). Therefore, the field relations prove a post-Middle Ordovician age for deposition of the veins.

A zone of lead-and zinc-bearing veinlets (figs. 1 and 3*A*) southeast of Hickory Lake is included on figure 1. These veinlets were found during this study, and similar areas might be located elsewhere, if a detailed field study of the whole region were done.

The Rossie-type veins in New York are in an area of northeast-trending faults and lineaments (fig. 1) that originally formed in the Proterozoic in a deep-seated zone of ductile deformation. Brecciated rock including fragments of lower Paleozoic rocks along some of these indicates reactivation of ancient faults probably in Paleozoic time.

The author has found brittle deformation along the Pleasant Lake fault, and Guzowski mapped the Grass Creek fault a few kilometers to the west and found Potsdam Sandstone fragments in fault breccia along it (Guzowski, 1979, p. 102). The fault zone along the Oswegatchie River also has much brecciated rock (Bannerman, 1972), and the Black Creek fault has Potsdam Sandstone faulted against Proterozoic rock. Westward-dipping gash veins filled with calcite and fluorite that are parallel and close to the Beaver Creek lineament also suggest late vertical movement along that feature.

The minor faults that contain the galena-bearing veins I believe are genetically related to the deformation that caused the late movement on the major faults and possibly also to the broad upwarp known as the Frontenac axis. A plot including similar veins in Ontario that were described by Uglow (1916) shows that they occur mainly along the Frontenac axis and close to


Calcite-sphalerite veinlet
A
B
sp
sp
ca
sp
1
2
2
3
sa
ca
sp
gn
sp
C
30 cm
sa
ca
vca
sp
q
sp
ca
sp
E
3 mm
sp
sa
ca
sa
sp
ca
D
5 cm

northeast-trending faults. The calcite-fluorite veins near Madoc show the same relations and are in faults with right-lateral offset (Wilson, 1929, p. 46) as are many of the vein fractures in St. Lawrence County. I believe these mineralized faults are conjugate shears repeatedly opened during strike-slip reactivation of the northeast-trending faults. This could have been caused by compressive force operating in approximately a north-south direction that possibly also produced the Frontenac axis upwarp (fig. 5).

The source of mineralizing solutions for veins of consistent mineralogy that are in rocks of such diversity of age and lithology and that are found spottily over an area 100 by 140 km, is cause for speculation. Because the vein mineralogy is very simple and consistent from area to area, it is reasonable to propose a source that also had little variation over this large region. To suggest an extensive igneous body or several igneous bodies deep in the crust that would give off hydrothermal solutions over an area of more than 14,000 km^2 and that would deposit mainly calcium carbonate with minor zinc and lead sulfide seems unreasonable. The only geologic unit that probably was continuous over the entire Frontenac axis area and which probably contained brines capable of depositing these veins was the early Paleozoic basin that covered this region with as much as a kilometer of sediment and water. Strike-slip faulting of the basement rocks perhaps in Silurian time also ruptured into the lower part of the blanketing sediment package and released trapped basin brines under pressure into the faults below. Where these passed through sandstone, a slurry of disaggregated sand at times also was carried downward into the newly formed fracture opening. A study of fluid inclusions in vein minerals is needed to establish the veracity of this theory.

BARITE PROSPECTS

Anastomosing veins of cream-colored barite resulting from phase 3 mineralization locally occur in buff-colored dolomitized marble close vertically to remnant patches of Potsdam Sandstone. Locality 61 is a prospect in buff dolomite containing veins of barite; locality 73, that has not been prospected, is in a similar geologic situation. Although such occurrences are fairly common, there is no record of barite recovery in the district. Possibly the prospects that expose barite veins are inadvertent results of prospecting for galena veins.

PYRITE MINING

Pyrite and minor amounts of pyrrhotite were mined in St. Lawrence and Jefferson Counties, N.Y., for the production of sulfuric acid. The mines and prospects are described and discussed by Buddington (1917) and Prucha (1957) and are the sources of most of my data. Pyrite was first mined in 1883 in St. Lawrence County from the Stella mine close to Hermon, N.Y., (northeast of the area shown on pl. 1) about 14 km northeast of Richville. Other deposits of pyrite were found in a northeast-trending discontinuous belt that extends southwestward from the Stella mine to the vicinity of Antwerp in Jefferson County, N.Y. Pyrite occurs as stratabound massive deposits in metasedimentary quartz-mica gneiss of the Grenville Complex and resulted from phase 2 mineralization. The deposits were prospected and mined from the 1880's to 1921, when pyrite mining ceased here.

Two mines, the Cole mine and the Hendricks prospect (localities 94, 93), are in the map area (pl. 1) south of Richville. The Cole mine, operated from 1900 to 1921, was second only to the Stella mine in production, yielding about 100,000 long tons of ore averaging 25 percent sulfur (Prucha, 1957, p. 55). As shown on table 1, total production from the pyrite deposits in St. Lawrence and Jefferson Counties is more than 600,000 long tons of ore averaging 40 percent sulfur (Prucha, 1957, p. 15). Mining ceased here because of the opening of rich deposits of native sulfur in Louisiana, and not because of a shortage of pyritic ore.

FIGURE 3.—Features of Rossie-type, phase 4 mineralization. *A*, One-centimeter-wide veinlet of calcite, sphalerite, and galena that cuts impure dolomitic marble rich in diopside, phlogopite, graphite, and tremolite. Veinlet weathers in relief due to undetermined alteration, possibly calcitization or silicification, of the wallrock. Note thin quartzite layer (at left) that is disrupted and rotated because of flowage of the marble. Outcrop is along west side of Old State Road 3.7 km northeast of Pierces Corner. *B*, Rossie-type vein at locality 14 in country rock similar to that of figure 3*A*. Black specks and lines are sphalerite. Nonparallel vein walls and offset of layering in country rock prove that vein was deposited in a minor fault. Machete is 40 cm long. *C*, Fragment of vein from locality 5 showing multiple filling and shearing of vein material. Zone 1 is unsheared coarse calcite, sphalerite (sp), and galena (gn) that cuts across earlier vein banding; zone 2, sheared calcite (ca) with lines of granulated sphalerite (sp); zone 3, fractured calcite vein material injected by quartz sand (sa) like in figure 3*D*. *D*, Polished specimen of vein from locality 5 mainly of coarse crystalline calcite (ca) showing dike of rounded quartz sand (sa) and tiny dark-colored clasts of sphalerite (sp) ripped up during intrusion of the sand. Sandstone dike was subsequently ruptured and veined by later calcite and sphalerite. Sand is similar to that in the Potsdam Sandstone which in the geologic past was probably no more than 50–100 m above this locality. (D. Dwornik photo.) *E*, Photomicrograph of sandstone dike in vein shown in figure 3*D*. Granulated calcite (ca) and sphalerite (sp) along contact between sandstone (sa) and vein calcite (vca). Sphalerite appears opaque in photo because of extreme contrast between it and light minerals in section.

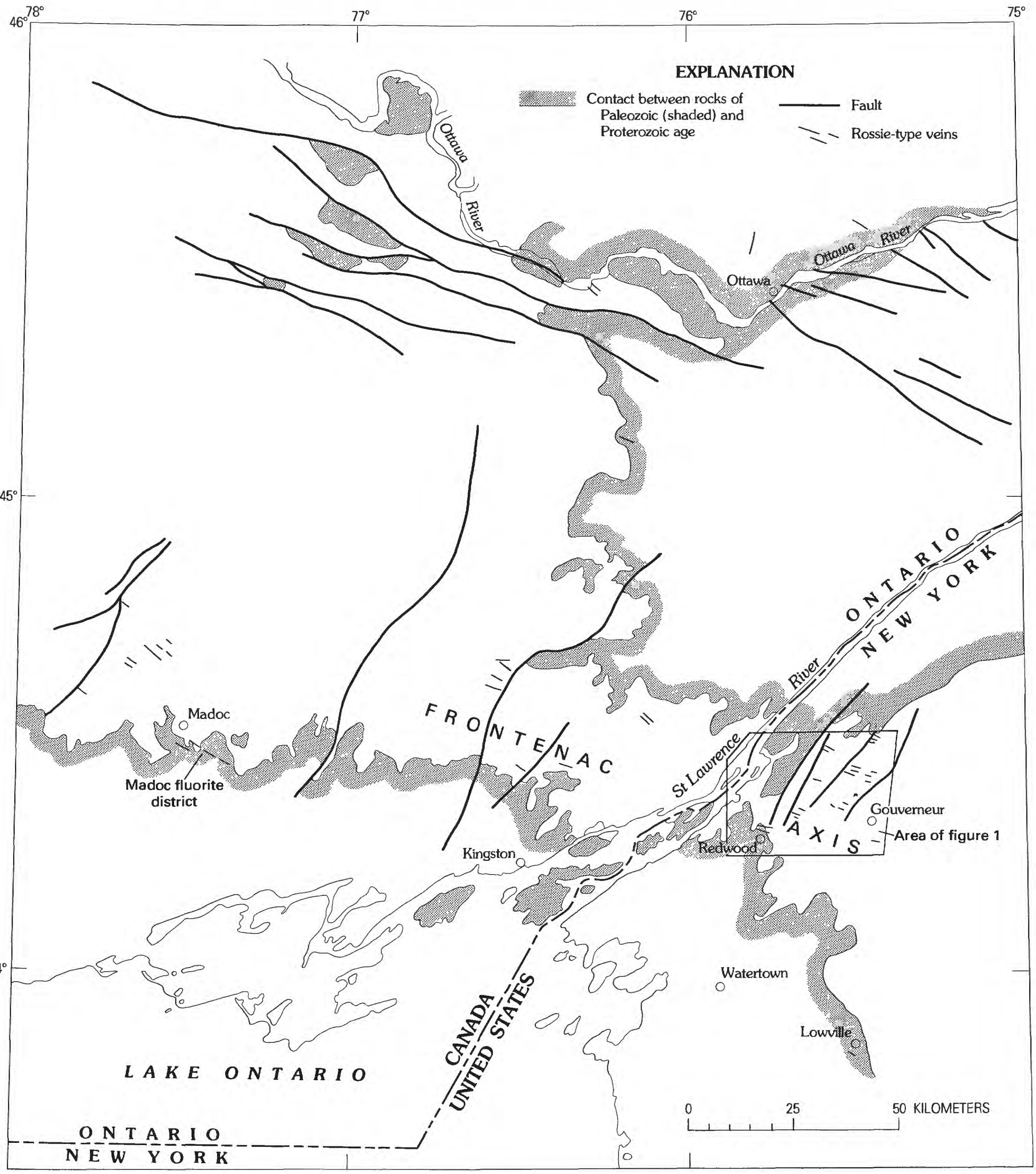


FIGURE 4.—Distribution of galena-bearing veins in area of the Frontenac axis. Adapted from Uglow, 1916; Wilson, 1929; New York State Geological Survey, 1966; Ontario Department of Mines and Northern Affairs, 1971.

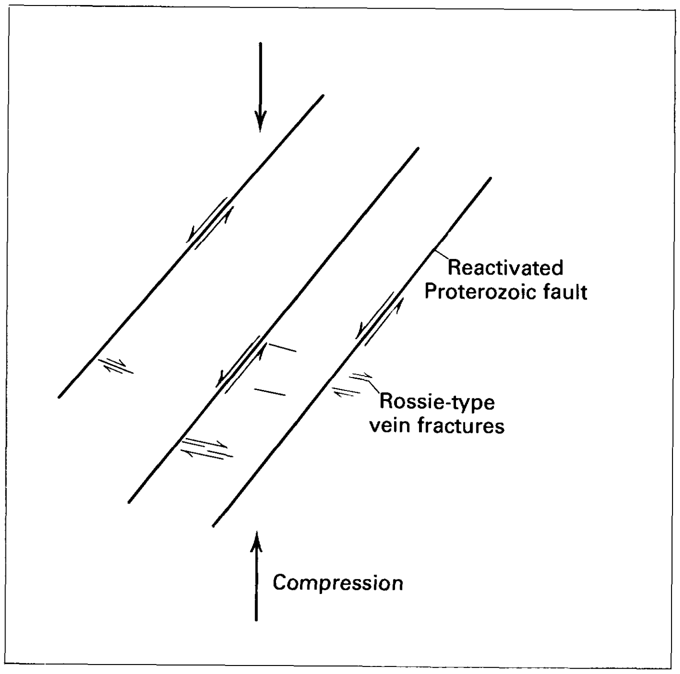


FIGURE 5.—Relation between Rossie-type vein fractures, reactivation of Proterozoic faults, and compression of the Frontenac axis. Arrows show sense of relative movement.

MARBLE MINING

Marble for dimension stone and monuments was mined from at least a dozen quarries close to the southern limits of the village of Gouverneur intermittently from 1878 to 1941 when the last quarry closed. So much marble was cut and shipped in that period that Gouverneur to this day is known as the "Marble Village." One quarry close to Gouverneur is still operated for crushed rock and agricultural lime.

Several shades of gray marble were produced, and many buildings, curbstones, and sidewalks in this part of New York are made of it. The quarries closed mainly because the market preferred lighter colored and finer grained marble from Vermont and Georgia. There remains an almost unlimited resource of marble of many shades and varieties in the Grenville lowland. Only one quarry that produced dimension stone is in the area of plate 1, that is, the "white crystal dolomite" at locality 95 discussed under the heading, "High purity marble," in "Identified mineral resources."

FELDSPAR MINING

The McLear pegmatite deposit 8 km northeast of Richville (beyond area of pl. 1) was mined from about 1910 to 1938 for perthitic feldspar (table 1) for use in the glass and pottery industry (Schaub, 1929, 1940). Up to 1929, 120,000 short tons of feldspar were produced. Tan (1966) reports that the perthitic feldspar contains about 36 percent albite. Although pegmatites like this one are fairly common in the Grenville lowlands, the McLear deposit is the only one that was mined.

FLUORITE MINING

Kunz (1889) described a small deposit of fluorite "...one and one-half miles from the well-known Macomb Lead Mines..." that was being mined in the late 1880's. At that time miners broke into a large cavity lined with green fluorite crystals of museum quality, and about 15 tons was removed. Many clusters of crystals from here were bought by mineralogical museums. The New York State Museum purchased groups of large green fluorite crystals from here in both 1889 and 1890. Four specimens were purchased from George F. Kunz (N.Y. State Museum Ann. Rept., 1889, p. 64; 1890, p. 30; see Frontispiece).

The exact location of the "Macomb fluorite mine" has been essentially unknown since Kunz's report of 1889. In 1981, Robert Paul Rice, a local mineral collector, showed me an overgrown shallow mine along Rastley Road where abundant chips of clear and green fluorite are on the dump (locality 98, pl. 1). The site fits the description by Kunz, and I have no doubt that it is one and the same.

A similar deposit was along the northeast shoreline of Muskalonge Lake (fig. 1) where fluorite was mined and groups of sea-green fluorite crystals were recovered (Buddington, 1934, p. 222). Whitlock (1905) also mentioned a deposit on Vrooman Lake (now Payne Lake) "2 miles" east of the Muskalonge Lake mine. The date of the mining at Muskalonge Lake was about 1850 (Kunz, 1889) (see sections entitled "Mineralization history" and "Fluorite deposits").

GARNET MINING

A mine for garnet abrasives was operated from about 1902 to 1905 at a locality about 3¼ km north of the Gouverneur village limits on the road to Peabody Bridge (Cushing and Newland, 1925). This locality is close to but outside of the southern edge of plate 1. Apparently, the deposit was in a garnet-rich zone between alaskite and marble. No record of the production is known, and mining ceased because the garnet quality was not as good as abrasives from other sources.

GRAPHITE MINING

Graphite, a product of phase 2 mineralization, occurs in many rock types in the Grenville Complex, particularly as an accessory mineral in carbonate rocks. Graphite is abundant in some marble layers and also occurs in veins with magnesian tourmaline and other silicates, such as the prospect at locality 30 where the graphite is coarse grained. Another type of graphite occurrence is as a major mineral in quartz-rich graphitic schist. This type was mined in the Beaver Creek area at locality 17, the Pope Mills graphite mine (pl. 1). Alling (1917) described this deposit and the mining that was done there in the early 1900's. The graphite ore, although fairly rich, is fine grained and thus has limited usefulness. A similar unprospected occurrence is at locality 18. The schist unit in both places is metasedimentary and probably extends for a considerable distance beyond the outcrop. Because of complex folding and spotty outcrops, the extent of the schist unit has not been determined at either occurrence.

IDENTIFIED MINERAL RESOURCES IN THE BEAVER CREEK AREA

NONMETALLIC MINERAL DEPOSITS

HIGH-PURITY MARBLE

An extensive belt of very coarse grained (2–3 cm), slightly graphitic marble west of Beaver Creek was sampled at localities 16 and 33 and found to be potentially useful as commercial "high-calcium limestone." Most samples contain more than 95 percent $CaCO_3$. Another zone in the northeast part of the map (locality 45) has marble that is almost as pure. These occurrences have been described by the author (Brown, 1978; and 1980a), and the discussion is not repeated here. The marble zones on plate 1 show some additional areas of high-purity calcitic marble (ca) found since the earlier publications.

White, pure dolomitic marble occurs close to the Oswegatchie River (locality 95) and is presently being mined for white landscaping chips and is also pulverized for a white filler in plastics. Dimension stone from two small quarries operated here at the turn of the century provided very attractive white marble for the bell tower of the Metropolitan Life Insurance building in New York City and for the Webb Horton mansion in Middletown, N.Y. (Prucha, 1953). This deposit is extensive, and similar occurrences might be found elsewhere.

Prucha (1953) described and sampled the dolomitic marble, known as the "white crystal dolomite," and chemical analyses of the samples proved that the rock is nearly a theoretically pure dolomite. Three holes were drilled during that investigation and 13,580,000 short tons of reserves of white dolomite were measured. Some of the dolomitic marble is off-white, and total reserves of white, gray-white, and tan marble are 68,010,000 short tons (Prucha, 1953, p. 9).

Although during my investigation pure white dolomitic marble was not specifically sought, one zone (locality 96) of very attractive, slightly phlogopitic, translucent, white, dolomitic marble is shown as a possible site where high-quality marble might be developed. Undoubtedly, more such zones are in the area designated as qm on the map.

TALC

Talc-tremolite schist known locally as "talc" has been mined from near Fowler and Talcville, N.Y., 16–20 km southeast of Richville since 1880 (pl. 1). It is used mainly for paint extender, mineral filler in many products, and raw material for ceramic tile (Brown, 1973). Deposits similar to those mined there occur elsewhere in St. Lawrence County, and deposits found close to Rock Island Road (localities 52 and 67) in the Beaver Creek area have been described by the author (Brown, 1969). The schist layer at locality 67 is 35 m thick, and dips are less than 20 degrees northeast. Because of the low dip, considerably more area is within mining depth than is apparent from the narrow outcrop width. Outcrops in the Beaver Creek swamp (locality 52) indicate that a significant thickness of talc is probably bedrock beneath peat and lacustrine clay of the valley fill. Some additional unpublished locations of talc-tremolite rock close to Beaver Creek, such as locality 79, are shown on plate 1. Talc is spotty in occurrence and commonly does not crop out. Therefore, a distinctive thinly laminated quartz-tremolite rock (tq) that occurs approximately at the same stratigraphic horizon as the talc-tremolite schist (tt) is shown as a guide to other possible hidden occurrences of talc.

Another zone of talc-tremolite schist was mapped by H. M. Bannerman (1963 and 1972) along the Oswegatchie River (see pl. 1). These occurrences are in the Oswegatchie faulted zone, and therefore projection of the deposits much beyond the outcrops cannot be done with confidence.

PEGMATITES

The McLear pegmatite deposit discussed under "Feldspar mining" is the only pegmatite that was developed and mined in the lowlands for albite-rich perthite feldspar for use in the glass and ceramic industry. Many similar small pegmatite bodies occur in the region mainly intruding marbles and other carbonate-rich metasedimentary rocks. Except for crystals of apatite, tourmaline, phlogopite, tremolite, and sphene that are found mainly in the border zone of some pegmatites, the mineralogy is principally feldspar and quartz. The McLear pegmatite also contains uraninite crystals (Shaub, 1940). The feldspar in the pegmatites that intrude carbonate metasedimentary rocks is white to light-gray perthite, and feldspar in pegmatites that intrude feldspathic, amphibolitic, or micaceous rocks is red microcline and light-gray oligoclase. Tourmaline in the pegmatites likewise varies with wallrock type in that black shorl is with the red feldspar pegmatites and generally brown uvite or dravite is in carbonate-enclosed pegmatites.

Feldspar for the glass and pottery industry is always in demand. Consequently, all significantly large pegmatites in the Beaver Creek area are shown on the map. Most of these are predominantly perthite and quartz and have potential commercial value. Many more pegmatites occur in the area but are not shown here because of their small size.

PEAT

The many flat, marshy, valley floors in this poorly drained, glaciated area are underlain by glacial lake sediments and peat. At the author's suggestion, C. C. Cameron of the U.S. Geological Survey, in 1968 and 1969, investigated the peat potential here with a hand-driven peat probe and sampling device. Plate 1 shows some selected data from the unpublished results (C. C. Cameron, written commun., 1980).

Commercial peat for horticultural and fuel purposes contains less than 25 percent ash by definition. Consequently, selected holes along Cameron's sampling traverses are shown along with the thickness, in feet,[2] of commercial-quality peat. Most is high-quality woody, reed-sedge peat, and the swamp north of Hickory Lake also contains valuable sphagnum peat that overlies reed-sedge peat. Thick deposits of limnic peat (lake-bottom deposits) containing more than 25 percent ash lie below the reed-sedge peat in all traverses. For instance, the easternmost test hole in the traverse 720 m north of Osborn Lake has 35 feet of limnic peat below 20 feet of high-quality peat. Thickness of limnic peat is not shown.

[2]English system of measurements is used because that is the system of measurement used by Cameron in obtaining data. Also, the peat industry uses feet in measurement.

The swamps, marshes, and flat valley floors of the Beaver Creek area contain a significant resource of high-quality peat. The surrounding region in the St. Lawrence lowlands contains additional peat resources beneath some of its filled valleys. As well as I can determine, peat has never been mined in this area except for local consumption.

METALLIC MINERAL DEPOSITS

STRATABOUND SPHALERITE

Large deposits of sphalerite are being mined in the Balmat-Edwards district 13–19 km south and east of Gouverneur (beyond area of pl. 1). These are found in a heterogeneous sequence of marbles described by Brown and Engle (1956). Although similar rocks are found in the region outside the mining district, very little drilling has been done, and no significantly zinc-mineralized rock like that being mined has been found. However, in the Beaver Creek area, two occurrences of stratabound sphalerite have been located (localities 77 and 88 on pl. 1; fig. 6) in a sequence of calcitic or dolomitic marbles rich in silica or silicates (qm) similar to ore-bearing zones in the mining district. Thus, these rocks are zinc bearing, and there is a strong probability that significant stratabound zinc deposits exist in the Beaver Creek area. Hence, the distribution of these marbles (qm) is shown on the map as a guide for further prospecting. The occurrence at locality 77 and its accompanying geochemical anomaly have been described (Brown, 1970).

Foose (1980) discussed geologic correlations supporting the thesis that stratabound zinc-bearing marbles of the Balmat-Edwards district can be structurally projected beyond the mining district. He, too, has studied an occurrence of stratabound zinc closer to, but outside, the zinc mining district (Foose, 1981).

STRATABOUND PYRITE-PYRRHOTITE

Identified resources of pyrite and pyrrhotite exist mainly in the belt of pyritic and graphitic, quartz mica gneiss (qmg) southeast of Richville. Prucha (1957) discussed the mining, exploration, and evidence of remaining ore at the Cole mine and Hendricks prospects (localities 93 and 94). The ore is stratabound and at the Cole mine appears to have been remobilized and thickened along the northeast-plunging axial portion of a cross fold. Elsewhere in this zone, massive pyritic layers a couple of meters thick are truly stratabound and continue on strike for hundreds of meters (Prucha, 1957, p. 21). The ore is notably deficient in base metals, and

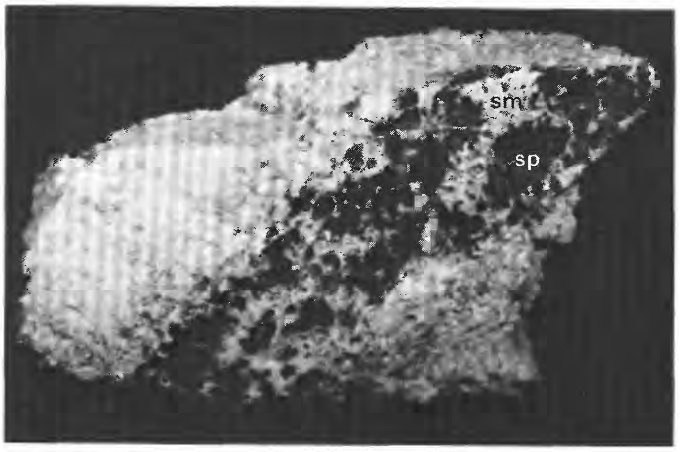


FIGURE 6.—Layer of sphalerite in marble from qm unit (pl. 1) at locality 77. Most sphalerite (sp) is partly weathered to secondary smithsonite (sm) and limonite. Primary mineralization is a product of phase 1, modified by 2, and is similar to mineralization at Balmat and Edwards mining district (Brown, 1970). (D. Dwornik photo.)

only at Pyrites, N.Y., 20 km northeast of Richville, have minor quantities of zinc and copper been reported (Prucha, 1957, p. 76).

In the Beaver Creek area, pyrite and pyrrhotite are common components of the rocks, but at most places they are not significantly concentrated. The tourmaline-bearing feldspathic quartzite, mica gneiss and schist in unit qmt, at many places has extremely rusty zones at the surface. One of these zones was intersected when Rock Island Road was relocated in 1971–72, and a zone of massive and disseminated pyrite was exposed (locality 57). Probably some massive pyrite occurs beneath the other rusty zones that are in the outcrop area of qmt, particularly in the vicinity of Rock Island Road in the town of DeKalb.

The pyritic rocks (qmg) southeast of Richville and the quartzites, schists, and gneisses (qmt) mentioned above might be correlative units. However, because of distinct lithologic differences, such as the abundance of tourmaline in qmt and graphite in qmg, they are shown as separate units on plate 1.

RUTILE

Megascopic rutile occurs as an accessory mineral in thin albitic, aplite bodies along Maple Ridge Road that intrude paragneiss that contains 1 to 2 percent sphene (locality 50). Tiny dark reddish-brown prisms of rutile less than 0.5 mm long are disseminated in the sugary pink aplite (ra on plate 1). Samples of aplite collected by Eric Force of the U.S. Geological Survey contain 1–2 percent TiO_2 in rutile (written commun.); this is an inferred subeconomic resource (U.S. Bureau of Mines and U.S. Geological Survey, 1980). Rutile is important because it currently is the only mineral used to produce titanium metal and most of it is imported.

GALENA AND SPHALERITE IN VEINS

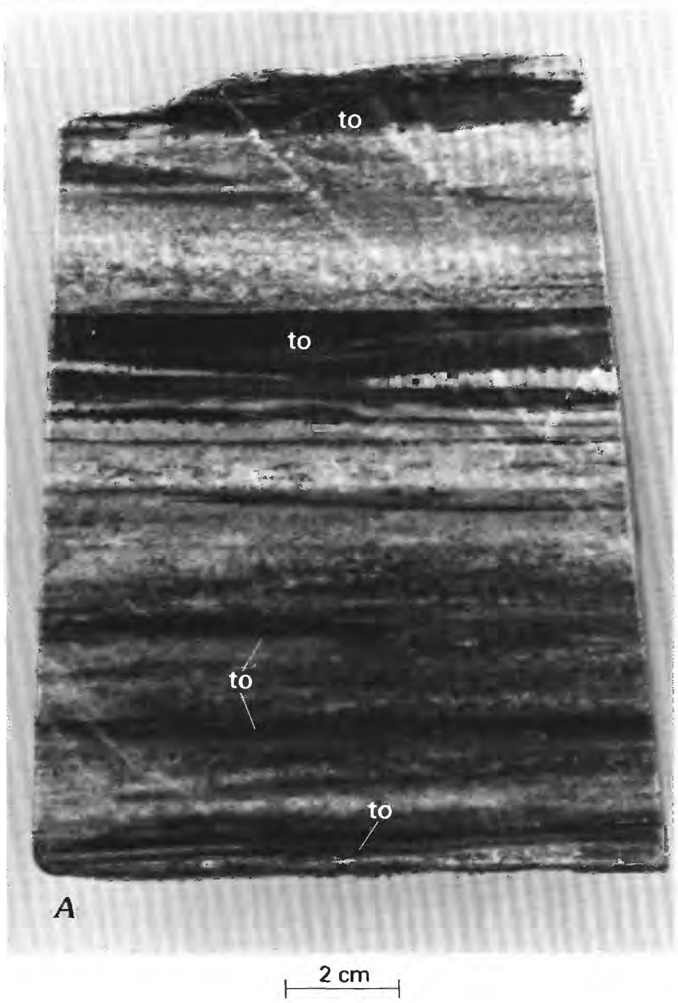
The Rossie-type veins previously discussed under the section entitled "Lead mining" contain both galena and sphalerite in veins that are predominantly calcite. Drilling has proved that the veins at the Macomb lead mines continue downward (Neumann, 1952), and the veins have not been exhausted along their length. Therefore, although the mineralization is lean, they represent an indicated subeconomic resource of both lead and zinc.

SPECULATIVE RESOURCES

BASE-METAL MASSIVE SULFIDE DEPOSITS

The rock unit, qmt, which structurally overlies the talc-tremolite zone east of Beaver Creek, is characterized by the presence of much magnesian tourmaline (dravite and/or uvite) as minute stubby green or brown prisms locally in layers. This unit consists of a mixture of metamorphosed clastic sediments that are now interlayered gneiss, aluminous schist, and quartzite. The feldspathic pyritic quartzite that directly overlies the talc-tremolite zone has fine granular tourmaline throughout, and thin local layers have more than 50 percent tourmaline (figs. 7*A* and *C*) (Brown, 1969, p. D5). Bannerman (1963 and 1972) has mapped similar rocks associated with a talc-tremolite unit along the Oswegatchie River west of Richville. Here, the tourmaline-rich rock is brecciated along faults and is recemented (fig. 7*B*). Bannerman had about 25 samples of tourmaline-rich rock analyzed (Brown, 1980b) in an inconclusive attempt to determine its genesis and possible significance. The significance possibly is revealed by studies of Ethier and Campbell (1977), who reported on tourmaline concentrations in Proterozoic sedimentary rocks of the southern Cordillera of Canada. They found an association between high concentrations of magnesian tourmaline in metasediments and stratiform sulfides such as at the Sullivan mine, British Columbia, and other similar base-metal ore bodies. Ethier and Campbell believe that the tourmaline-rich rock probably represents submarine boron emanations that followed the same routes to the sea floor as did hydrothermal metal-bearing solutions. Slack (1980) found a similar association of magnesian tourmalines, magnesium-rich metasedimentary rocks, and massive zinc, lead, copper sulfide deposits at the Black Hawk mine in Maine. Because of this association and that at the Sullivan mine, Slack (1980) suggested magnesian tourmaline-rich zones as a prospecting guide.

Tourmaline is a very common mineral in the Beaver Creek area in several lithologies, but the most potentially significant association is the quartzitic sequence in qmt that contains 20–50 percent magnesian tourmaline (fig. 7*A* and *B*) superjacent to the magnesium-rich metasedimentary rocks (tt and tq). This association marks an unusual event in the geologic history that can be explained on the basis of hydrothermal seafloor emanations rich in magnesium, boron, and possibly base metals. This geologic combination of features associated elsewhere with stratabound zinc, lead, and copper deposits implies the intriguing possibility that similar deposits could be found here. Pyrite is very common in the tourmaline-bearing quartzites, gneisses, and schists (qmt). Except for one possibly significant occurrence of chalcopyrite (locality 53), base-metal minerals have not been found in these rocks. Because of the criteria put



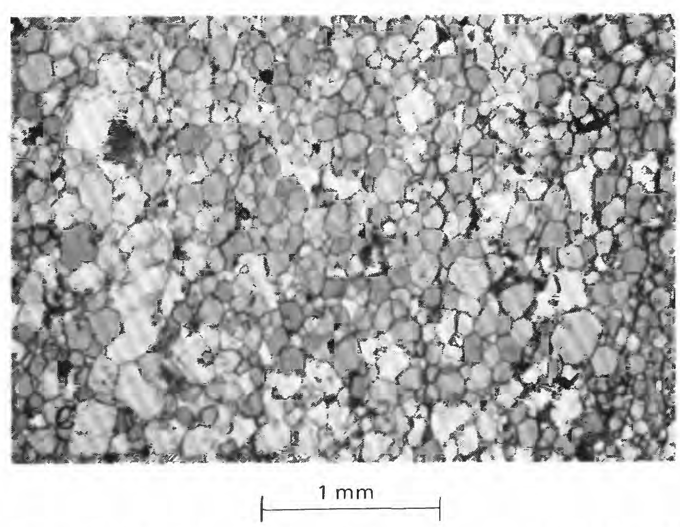


FIGURE 7.—Tourmaline-rich metasedimentary rocks. *A*, Well-layered quartz, oligoclase, tourmaline, biotite granofels (qmt on pl. 1). Black layers are as much as 50 percent resinous, green to brown dravite (tourmalinite, to). Light-colored layers are quartz, oligoclase, and microcline with tourmaline. Gray layers contain biotite. From road-cut on Rock Island road at locality 66. (D. Dwornik photo.) *B*, Brecciated quartz, microcline, tourmaline granofels (tourmalinite) from road cut through fault zone 200 m south of the Oswegatchie River along Rock Island Road. (D. Dwornik photo.) *C*, Photomicrograph of tourmalinite as in figure 7*A*. Gray grains are brown tourmaline; clear grains are quartz, oligoclase, and microcline.

forth by Slack (1980), tourmaline-bearing metasediments (qmt) in close proximity to zones rich in magnesian minerals, mainly talc and tremolite (tt), are shown on plate 1 as a guide to areas that might contain stratabound base-metal deposits.

The stratabound zinc deposits at Balmat and Edwards that are believed to be remobilized syngenetic deposits (Lea and Dill, 1968) are not associated with tourmaline-rich gneisses and quartzites. Because of an associated anhydrite unit, they are believed to have been deposited in an evaporite-producing environment (Dill and de Lorraine, 1978) and thus may have a genesis different from, but possibly distally related to, the speculated boron-associated deposits.

FLUORITE DEPOSITS

Fluorite has been mined near Madoc, Ontario, 160 km west of the study area. The ore is in northwest-trending faults that show right-lateral offset (Wilson, 1929, p. 46) similar to the Rossie-type veins, and the veins consist of green fluorite with calcite and barite and no galena and sphalerite. Galena-bearing veins like those at Rossie, N.Y., which also contain minor amounts of fluorite and barite, are found a few kilometers northwest of the Madoc fluorite district. Despite the absence of galena and sphalerite in the fluorite veins, I have no reason to believe that they do not have a similar genesis. Although the mineral assemblage in Rossie-type veins is similar throughout the Frontenac axis, the absence of lead and zinc minerals at Madoc might be caused by local zoning. The difference could also be attributed to the fractures and veins at Madoc being produced at a late period during paragenesis when galena and sphalerite were not being deposited and when the ore fluids were locally rich in fluorine because of mixing with ore-bearing solutions from another source.

A very small production of fluorite came from two prospects in St. Lawrence County in the 1800's. One of these is at locality 98 (pl. 1), and the other is 14.5 km to the southwest, on the northeast shore of Muskalonge Lake, (see section entitled "Fluorite mining"; fig. 2). A similar occurrence was mentioned by Whitlock (1905) along Vrooman Lake (Payne Lake) ". . . 2 miles east of Muskalonge Lake . . . ." Whitlock (1905) stated that the Muskalonge Lake deposit is in ". . . a vein of considerable width . . .," and Heyl and Van Alstine (1976) stated that the fluorite mined here was from two of several fissure veins in the Rossie district. Heyl and Van Alstine assumed that the fluorite reported in the literature occurred in vertical veins like those containing the calcite-galena veins near Rossie that also have a minor amount of fluorite.

A close examination of the prospect at locality 98 does not reveal a vertical, northwest trending vein like in the Madoc district and the nearby Macomb lead mines, but rather a vuggy coarse-grained filling of calcite and fluorite in short gash veins that strike northeast and dip northwest. The fluorite and calcite at locality 41 (pl. 1) also are found in a gash vein with a similar attitude, and two other occurrences that have coarse calcite crystals, but no fluorite, are also in gash veins (localities 24, and 2). All of these gash-vein occurrences are less than 0.5 km west of the Beaver Creek lineament in fractures parallel to it (fig. 1). The fluorite at Payne Lake is in a similar position relative to the projection of the lineament. Therefore, the fracture development appears to be related to late (probably vertical) movement along the Beaver Creek lineament and thus related to the postulated origin (see "Lead mining") of the Rossie-type veins in faults conjugate to the late reactivation of faults of Proterozoic age.

If this relation is true, other fluorite deposits might occur in proximity to major faults that have evidence of late movement. In fact, the occurrence of fluorite at Muskalonge Lake is very close to the Pleasant Lake fault (fig. 1) that also has evidence of late movement.

OUTLOOK FOR MINERAL EXPLORATION IN THE BEAVER CREEK AREA

In the 1800's, when hematite was being sought for iron, galena for lead, pyrite for sulfuric acid, and talc for a mineral filler, the principal prospecting technique was to examine bedrock outcrops for these minerals. Many ore finds were undoubtedly made by observant farmers and foresters who reported unusual rocks to the miners. Because the lowlands are characterized by abundant bedrock exposure, most outcropping ore and outstanding mineral localities were found soon after the land was occupied and cleared by settlers. For instance, the occurrence of pyrite and sphalerite-mineralized marble on the Balmat farm at Balmat, N.Y., was reported by Emmons as early as 1838. This deposit apparently had been found earlier by lead prospectors seeking Rossie-type lead veins. The abundant sphalerite was noted, but, because sphalerite had little value at that time, only galena was recovered. Serious zinc mining did not commence at Balmat until about 90 years later. Talc prospectors likewise, because of an abundance of outcrops, discovered several talc deposits soon after a profitable market developed for the material.

Despite the great variety of mineral resources and a tradition of mining there, the Beaver Creek area is not well explored. Except for the following three projects, no exploratory drilling has been done: 1) In 1950, the

U.S. Bureau of Mines explored lead veins for downward extensions at the Macomb mines (Neumann, 1952). 2) Shortly after the talc-zone discovery at North Gouverneur was announced (Brown, 1969), a company drilled a few shallow holes which verified the downdip continuation of the talc zone close to the outcrop. No drilling was done for the projected deeper occurrence of talc. 3) In 1952, several holes were drilled near locality 95 to test the quality and extent of white dolomite (Prucha, 1953).

The Balmat-Edwards district is one of the most important zinc mining areas in the United States; yet, most prospecting has been done only in rocks of the rather restricted synformal structure that contains the known ore bodies. Geochemical exploration has been done outside that district, but in limited areas. In 1980, discovery of an ore body by drilling near Pierrepont, N.Y., was announced by St. Joe Zinc Corporation in a quarterly report to stockholders. The ore body is outside the district and thus undoubtedly will cause more interest in zinc occurrences in similar rocks elsewhere in the region.

An insignificant amount of exploration on the ground has been done since the early reconnoitering for iron, lead, and pyrite. However, talc, stratabound zinc, and high-calcium limestone located during my study prove that exposed deposits can still be found in the Grenville lowlands. Some remote-sensing techniques such as radiometry were tried by private companies, but results are not available. Aeromagnetic surveys have been completed by the U.S. Geological Survey (1975).

Hidden deposits such as stratabound zinc in the marbles (qm on pl. 1) might be explored by first sampling soil and analyzing for trace elements followed by grid drilling of anomalous areas. Because this type of deposit contains associated mercury (Brown, 1970), perhaps a survey by means of a mercury detector over the area of these marbles might help one select drilling targets (Vaughn, 1967, McCarthy and others, 1969).

The speculative deposits of massive base-metal sulfides (see "Speculative resources") can be explored by airborne electromagnetic and other modern geophysical techniques that to my knowledge have not been tried extensively here.

Although the outlook is encouraging for finding ore deposits in the Grenville lowlands, the system of ownership of mineral rights in this part of New York State provides a serious deterrent to mineral exploration. Ownership of surface and mineral rights can be separated here. Because early property owners were aware of the potential value of minerals, many owners reserved the mineral rights when properties were sold, or landowners sold mineral rights in time of financial need. Taxes are assessed on mineral rights only in special cases where there are operating mines or proved deposits; therefore, the reserved mineral rights, where they are not taxed, continue on to the heirs of estates generation after generation. Exploration companies, seeking to purchase or lease rights to explore or mine are usually confronted with a difficult genealogical and legal problem—finding all heirs and then getting legal agreement from each to explore. Another sensitive aspect is that owners of properties where mineral rights have been separated from the surface rights are insecure because they are aware that another party, often unknown to them, has a legal right to explore and mine on their property and their only redress is to collect payment for damage to the crops and land.

CONCLUSIONS

Lead, iron, pyrite, graphite, fluorite, and marble have been mined in the Beaver Creek area. Continuations of these deposits are known, and, except for pyrite and marble, they are small and lean and probably are presently subeconomic. Nevertheless, other more extensive mineral deposits, high-purity limestone and dolomite, talc, feldspar, and peat, have been identified here. A sequence of marble which contains occurrences of stratabound zinc is believed by me to have potential for containing deposits like those mined nearby at Balmat and Edwards, N.Y.

A quartzitic unit, rich in magnesian tourmaline in association with a magnesium-rich, talc-tremolite zone, matches geologic conditions that, in comparable rocks elsewhere in the world, are genetically associated with stratabound, base-metal sulfide deposits. This suggests the possibility of similar deposits here.

Occurrences of fluorite alined parallel to and west of the Beaver Creek lineament (fault) present an intriguing possibility of a fluorite mineralized zone related to that feature. Fluorite having a similar mineral assemblage was mined near Madoc, Ontario, but there it is in northwest-trending fault fractures like those in which the Rossie-type lead-calcite veins occur. The occurrences along Beaver Creek unlike the Madoc deposits are not in obvious fault fractures but rather are in minor westward-dipping fractures that possibly were produced by late vertical fault movement on the Beaver Creek lineament. If this is the case, a previously unknown type of deposit is indicated, and other old faults that show late movement such as the Pleasant Lake and Grass Creek faults (fig. 1) could have similar deposits.

St. Lawrence County is a famous area for mineral collecting by hobbyists and for profit. The Beaver Creek area has many sites where fine mineral specimens can be found. Some of the area is included in State Forest land, but most is privately owned, and permission from the owners of property and mineral rights is required to enter for mineral exploration or collecting.

REFERENCES CITED

Agar, W. M., 1921, The minerals of St. Lawrence, Jefferson, and Lewis Counties, New York: The American Mineralogist, v. 6, no. 11, p. 158-164.

_____1923, Contact metamorphism in the western Adirondacks, American Philosophical Society Proceedings, v. 62, no. 3, p. 95-174.

Alling, H. L., 1917, The Adirondack graphite deposits: New York State Museum Bulletin 199, 150 p.

Bannerman, H. M., 1963, Preliminary geologic map of strip along the Oswegatchie River from Little Bow to Richville, Townships of Gouverneur and DeKalb, St. Lawrence County, New York: U.S. Geological Survey Open-File Report, 1 sheet.

_____1972, Geologic map of the Richville-Bigelow area, St. Lawrence County, New York: U.S. Geological Survey Miscellaneous Investigations Map, I-664.

Beck, L. C., 1842, Mineralogy of New York: Albany, New York, New York State Natural History Survey, 536 p.

Brown, C. Ervin, (1980a), Reconnaissance investigations of high-calcium marble in the Beaver Creek drainage basin of St. Lawrence County, New York, *in* Proceedings of the 14th Annual Industrial Minerals Conference: New York State Museum and Science Service Bulletin 436, p. 97-104.

_____(compiler), 1980b, Chemical analyses of Precambrian rocks from St. Lawrence County, New York, made by the U.S. Geological Survey, 1963 through 1972: U.S. Geological Survey Open-File Report 80-664, 60 p.

_____1978, Reconnaissance investigation of high-calcium marble in the Beaver Creek area, St. Lawrence County, New York: U.S. Geological Survey Circular 774, 10 p.

_____1975, Problematical age of an alkaline analcite-bearing olivine diabase dike in St. Lawrence County, New York [abs.]: Geological Society of America Abstracts with Programs, v. 7, no. 1, p. 31.

_____1973, Talc: U.S. Geological Survey Professional Paper 820, p. 619-625.

_____1970, A sphalerite vein and associated geochemical anomalies in St. Lawrence County, New York: U.S. Geological Survey Professional Paper 700-D, p. D162-D168.

_____1969, New talc deposit in St. Lawrence County, New York: U.S. Geological Survey Bulletin 1272-D, 13 p.

Brown, J. S., 1936, Supergene sphalerite, galena, and willemite at Balmat, New York: Economic Geology, v. 31, no. 4, p. 331-354.

Brown, J. S., and Engel, A. E. J., 1956, Revision of Grenville stratigraphy and structure in the Balmat-Edwards district, northwest Adirondacks, New York: Geological Society of America Bulletin, v. 67, no. 12, p. 1599-1622.

Buddington, A. F., 1917, Report on the pyrite and pyrrhotite veins in Jefferson and St. Lawrence Counties, New York: New York State Defense Council, Bulletin 1, 40 p.

_____1934, Geology and mineral resources of the Hammond, Antwerp, and Lowville quadrangles: New York State Museum Bulletin 296, 251 p.

Buddington, A. F., and Leonard B. F., 1962, Regional geology of the St. Lawrence County magnetite district, northwest Adirondacks, New York: U.S. Geological Survey Professional Paper 376, 145 p. 4 plates.

Cushing, H. P., and Newland, D. H., 1925, Geology of the Gouverneur quadrangle: New York State Museum Bulletin 259, 122 p.

Dana, E. S., 1914, The system of mineralogy of James Dwight Dana, 1837-1868 (6th ed.): New York, John Wiley and Sons, 1134 p.

Dill, D. B., and de Lorraine, William, 1978, Structure, stratigraphic controls and genesis of the Balmat zinc deposit, northwest Adirondacks, New York [abs.]: Geological Society of America Abstracts with Programs, v. 10, no. 7, p. 389.

Emmons, Ebenezer, 1838, Report of the second geological district of the State of New York: New York Geological Survey, Ann. Rept. 2, p. 185-250.

_____1842, Geology of New York. Part II, comprising the survey of the second geological district: Albany, New York, 437 p.

Ethier, V. G., and Campbell, F. A., 1977, Tourmaline concentrations in Proterozoic sediments of the southern Cordillera of Canada and their economic significance: Canadian Journal of Earth Science, v. 14, no. 10, p. 2348-2363.

Foose, M. P., 1981, Geology, geochemistry, and regional resource implications of a stratabound sphalerite occurrence in the northwest Adirondacks, New York: U.S. Geological Survey Bulletin 1519, 18 p.

_____1980, A reinterpretation of the structural and stratigraphic setting of the Balmat-Edwards zinc deposits, northwest Adirondack lowlands, New York: Economic Geology, v. 75, no. 1, p. 130-133.

Foose, M. P., and Carl, J. D., 1977, Setting of alaskite bodies in the northwestern Adirondacks, New York: Geology, v. 5, p. 77-80.

Guild, P. W., 1957, Geology and mineral resources of the Congonhas district Minas Gerais, Brazil: U.S. Geological Survey Professional Paper 290, 90 p.

Guzowski, R. V., 1979, Stratigraphy, structure, and petrology of the Precambrian rocks in the Black Lake region, northwest Adirondacks, New York: New York, Syracuse University, unpublished Ph.D. dissertation, 184 p.

Heyl, A. V., and Van Alstine, R. E., 1976, Central and Eastern United States, *in* Shawe, D. R., ed., 1976, Geology and resources of fluorine in the United States, U.S. Geological Survey Professional Paper 933, p. 62-81.

Kunz, G. F., 1889, Mineralogical notes on fluorite, opal, amber, and diamond: American Journal of Science, 3rd ser., v. 38, p. 72-74.

Lea, E. R., and Dill, D. B., Jr., 1968, Zinc deposits of the Balmat-Edwards district, New York, *in* Ore Deposits of the United States, 1933-1967 (Graton-Sales Volume), v. 1: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, p. 20-48.

Leonard, B. F., and Buddington, A. F., 1964, Ore deposits of the St. Lawrence County magnetite district, northwest Adirondacks, New York: U.S. Geological Survey Professional Paper 377, 259 p.

McCarthy, J. H., Jr., Vaughn, W. W., Learned, R. E., Meuschke, J. L., 1969, Mercury in soil, gas, and air—A potential tool in mineral exploration: U.S. Geological Survey Circular 609, 16 p.

Nason, Frank L., 1888, Some New York minerals and their localities: New York State Museum Bulletin 4, 20 p.

Neumann, G. L., 1952, Lead-zinc deposits of southwestern St. Lawrence County, N.Y.: U.S. Bureau of Mines Report of Investigations 4907, 25 p.

Newland, D. H., 1921, The Mineral resources of the State of New York: New York State Museum Bulletin 223, 224, 315 p.

_____1917, The zinc-pyrite deposits of the Edwards district, New York: New York State Defense Council, Bulletin 2, 72 p.

New York State Geological Survey, 1966, Landforms, and bedrock geology of New York State: New York State Museum and Science Service Educational leaflet no. 20, 1:1,000,000.

New York State Museum, 1889, 42nd Annual report of the trustees of the New York State Museum of Natural History for the year 1888, New York State Museum Annual Report, 496 p.

New York State Museum, 1890, 43rd Annual report of the regents for the year 1889, New York State Museum Annual Report, 306 p.

New York State Museum and Science Service, 1971 Geologic map of New York, 1970: New York State Museum and Science Service, Map and Chart Series no. 15, 6 sheets.

Ontario, Department of Mines and Northern Affairs, 1971, Ontario geological map, southern sheet, Map 2197, 1:1,013,760.

Otte, Herman F., 1943, The expanding mineral industry of the Adirondacks: State of New York Department of Commerce, Publication 10, 50 p.

Parker, A. C., 1920, The Archeological history of New York, part 2: New York State Museum Bulletin 237-238, p. 471-743.

Pough, F. H., 1940, Willemite morphology and paragenesis at Balmat, New York: American Mineralogist, v. 25, no. 7, p. 488-496.

Prucha, J. J., 1953, The white crystal dolomite deposit near Gouverneur, New York: New York State Science Service Report of Investigations, no. 9, 13 p.

______1957, Pyrite deposits of St. Lawrence and Jefferson Counties, New York, New York State Museum and Science Service Bulletin 357, 87 p.

Shaub, B. M., 1929, A unique feldspar deposit near DeKalb Junction, New York: Economic Geology, v. 24, no. 1, p. 68-89.

______1940, Age of the uraninite from the McLear pegmatite near Richville Station, St. Lawrence County, New York: American Mineralogist, v. 25, no. 7, p. 480-487.

Slack, J. F., and others 1980, Tourmaline alteration at the Black Hawk (Blue Hill) Mine, Hancock County, Maine [abs.]: Geological Society of America, Abstracts with Programs, v. 12, no. 2, p. 83.

Slocum, H. W., 1948, Rambles in a collector's paradise, Part 3: Rocks and minerals, v. 23, no. 8, p. 675-680.

Smock, John C., 1888, Building stone in the State of New York: New York State Museum Bulletin 3, 152 p.

Smyth, C. H., Jr., 1903, The Rossie lead veins: Columbia University, The School of Mines quarterly, v. 24, no. 4, p. 421-429.

______1917, Genesis of the zinc ores of the Edwards district, St. Lawrence County, New York: New York State Museum Bulletin 201, 41 p.

Tan, Li-Ping, 1966, Major pegmatite deposits of New York State: New York State Museum and Science Service Bulletin 408, 138 p.

Uglow, W. L., 1916, Lead and zinc deposits in Ontario and in Eastern Canada: Ontario Bureau of Mines, 25th Annual Report, v. XX-XV, pt. 2, 56 p.

U.S. Bureau of Mines and the U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

U.S. Geological Survey, 1975, Aeromagnetic survey of Ogdensburg and vicinity, New York: U.S. Geological Survey Open-File Report 75-526, 16 pls.at 1:62,500, 1 pl. at 1:250,000.

Vaughn, W. W., 1967, A simple mercury vapor detector for geochemical prospecting: U.S. Geological Survey Circular 540, 8 p.

Whitlock, H. P., 1903, List of New York mineral localities: New York State Museum Bulletin 70, 108 p.

______1905, Minerals not commercially important: New York State Museum, 57th Annual Report, p. 180-192.

Whitney, J. D., 1854, The metallic wealth of the United States: Philadelphia, Pa., Lippincott Grambo and Co., 510 p.

Wilson, M. E., 1929, Fluorspar deposits of Canada: Canada Geological Survey, Economic Geology series 6, 97 p.