Spencer's Cave: An Adirondack Anomaly

by

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Abstract

This Report is a morphological and mineralogical survey of Spencer's Cave in Essex County, New York. Discovered in 1978 by Ranger Spencer Cram of the New York State Department of Environmental Conservation (DEC), this small cave is situated in a geologically complex area of anorthosites, syenites, gneisses, calc-silicates, and metasediments. Spencer's Cave is a water carved feature in a body of white, green, or blue marble containing small amounts of augite, magnetite, and many diverse members of the diopside-hedenbergite solid solution series. The rocks surrounding the marble body are garnetiferous and represent the effects of regional and contact metamorphism, assimilation, and metasomatism. Formation of the cave was probably controlled by differential dissolution along a zone of fracture in Grenville metasediments.

Introduction

The Adirondack Mountains of northern New York are a southern extension of the Grenville Province of Canada. Precambrian igneous rocks within the Adirondack mass (Figure 1) are among the oldest in the United States with an age calculated to be 1300 mybp (Silver, 1969). These crystalline rocks have been subjected to numerous cycles of deformation and intrusion, and their history is deduced from the structures and minerals present. This report is concerned with a small area located at the northern edge of the Mount Marcy quadrangle (Figure 2) along State Route 73 in a valley that contains the Cascade Lakes.

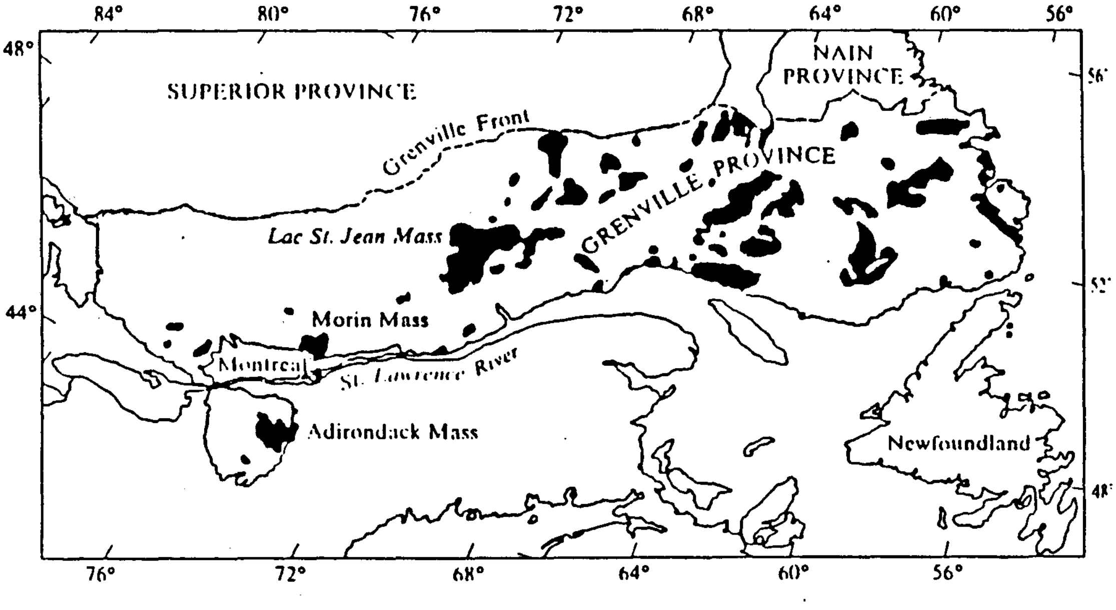


Figure 1 The Grenville Province of Canada and New York. Anorthosites (black) intruded and metamorphosed Grenville Series sediments (white). (reprinted from Petrology: Igneous, Sedimentary, and Metamorphic (Ehlers and Blatt, 1980) after J. Martignole and K. Schrijver, 1970).

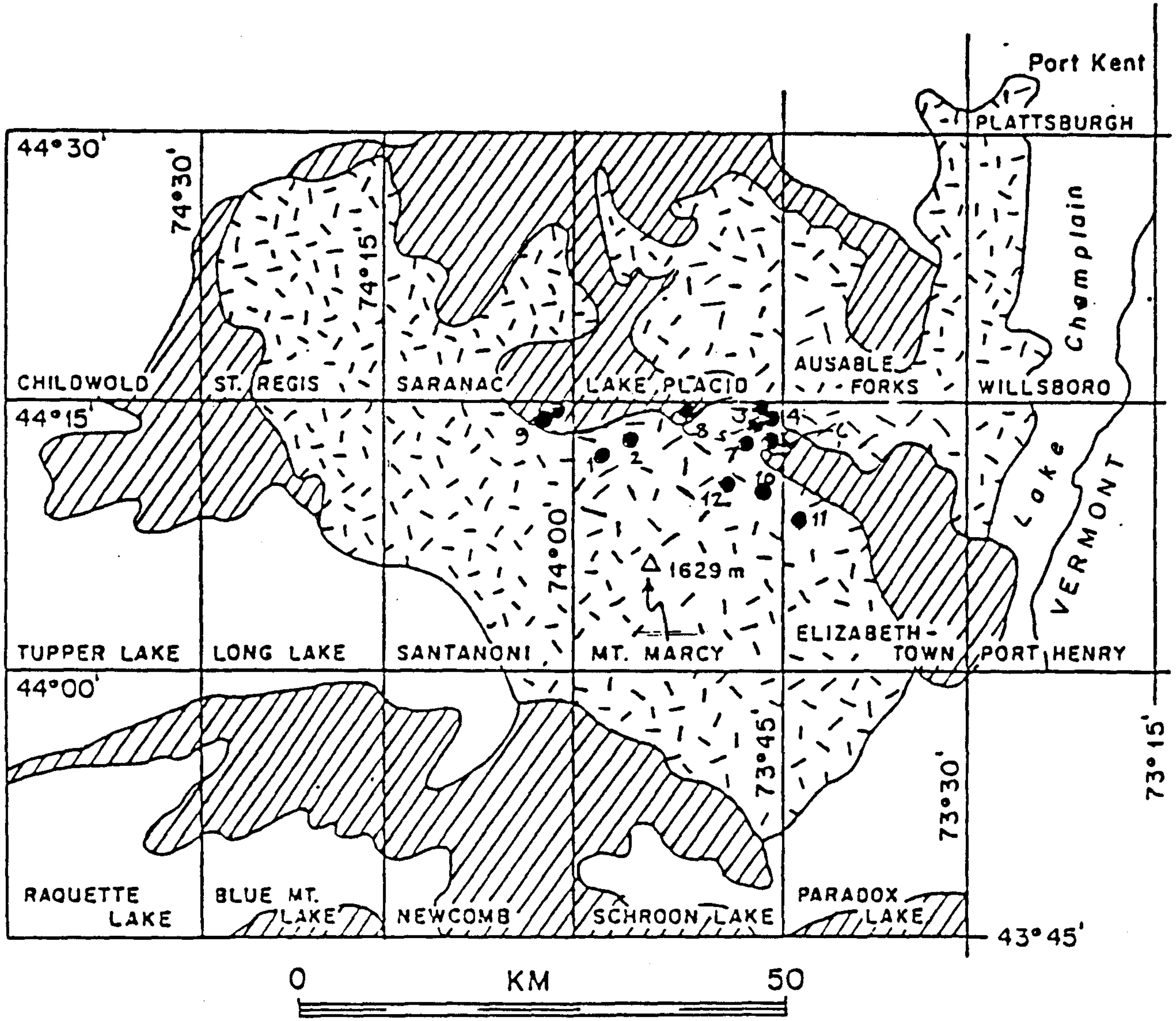


Figure 2 Spencer's Cave is located in the valley of the Cascade Lakes near the center of the northern edge of the Mount Marcy quadrangle close to location 8. (reprinted from Jaffe et al (1983) <u>Bedrock Geology of the High Peaks Region, Marcy Massif, Adirondacks, New York</u>)

Three major families of rock- anorthosite, syenite, and Grenville metasediments-comprise the vast majority of the Adirondack high peak region. Of these three, anorthosite is the most abundant with exposures on many of the highest peaks. The Marcy anorthosite is composed of blue lathlike phenocrysts of plagioclase imbedded in a crushed white matrix of similar composition. The phenocrysts (up to 3 cm in length) commonly exhibit Carlsbad and albite twinning and lie in the range of andesine-labradorite (An 40-60).[1] By definition anorthosite contains over 90% plagioclase.[2] In this region minor constituents include lime garnets and magnetite which are visible macroscopically, and hornblende and augite which are seen with a microscope. An interesting feature of this anorthosite is schiller iridescence, a blue-green play of color seen on some labradorite crystals when wet. The Opalescent River takes its name from this property of the feldspars.

The syenites of the Adirondacks are a variable group of highly deformed intrusive rocks that represent a period of intrusion later than that of the anorthosites. The variability of this group is evidenced by the wide range of names. Baillieul (1976) used the term pyroxene-microperthite gneiss, deWaard (1968) employed the names mangerite, jotundite, farsundite, and charnockite, Jaffe (1983) used the name Pitchoff gneiss, and Buddington (1939) called it pyroxene-quartz syenite. Early geologists believed that the syenite-gneiss suites represented rocks formed by the intruding anorthosites.[3] Present thinking suggests they are the result of an independent period of intrusion complexed with the effects of the assimilation of country rocks, ion exchange between magma and the country rocks, and contact metamorphism. Samples of this group, especially those taken from the slopes of Pitchoff Mountain, contain pink feldspar (K feldspar and plagioclase), clear to gray quartz, and bands of dark amphibole. The presence of quartz in this group indicates a change of the amount of free silica in the parent magma. The anorthosites are notably quartz poor. Studies by Jaffe[4] indicate that members of the Pitchoff gneiss which include syenitic-monzonitic-syenodioritic facies are a result of separate batches of melt and do not represent a true magmatic fractionation process.

The third and oldest family of rocks in the Adirondacks are the metamorphosed Grenville metasediments. Deposited in a marine environment, the Grenville metasediments (quartzites, marbles, shists, and gneisses) have also been interpreted in a number of different ways because of their complex relations with adjacent facies. Fragments of the Grenville Series in anorthositic and syenitic rocks and evidence of repeated partial melting and recrystallization suggest several periods of intrusion and deformation. Unusual calc-silicate and microperthite gneiss sequences are the product of metamorphic alteration, assimilation, and metasomatism of the Grenville Series during the emplacement of the Marcy anorthosites.

Regional Adirondack Geology

Rocks of the Adirondacks show evidence of numerous geologic events superimposed on previous structures. The Grenville sediments were deposited 1300-1350 mybp over the course of 12-67 my.[5] In this time interval the Grenville Series sediments had also been metamorphosed and subjected to two periods of folding. Intrusion of anorthosites, syenites, and melagabbro dikes occurred in pulses during 300 million years of the Precambrian. Metamorphism of these facies is believed to have taken place at a depth of 35 km (21 mi).[6] These pulses of activity and the long time interval account for the wide composition range of the anorthosites. Andesitic anorthosite composes the core facies of the Adirondack mass, and gabbroic anorthosite and syenitic rocks represent the type of intrusion occurring near the perimeter of the mass.

Still later in the Precambrian the andesitic anorthosite core facies were thrust over gabbroic and syenitic rocks. Remnants above the thrust fault comprise many of the summits in the high peak region, especially in the Great Range(Fig. 3). An interesting contact between the core facies and the overthrusted autochthonous mass is located on Basin Mountain along the trail east of the summit.[7] Figure 3, reprinted from Jaffe _et al_. (1983) shows the generalized relations of different anorthosites and syenitic gneisses throughout the Great Range. The Cambrian period brought another interval of intrusion, this time Adirondack rocks were injected with camptonite and diabase (both are very fine-grained black rocks) dikes. Since the Cambrian, many kilometers of material have been

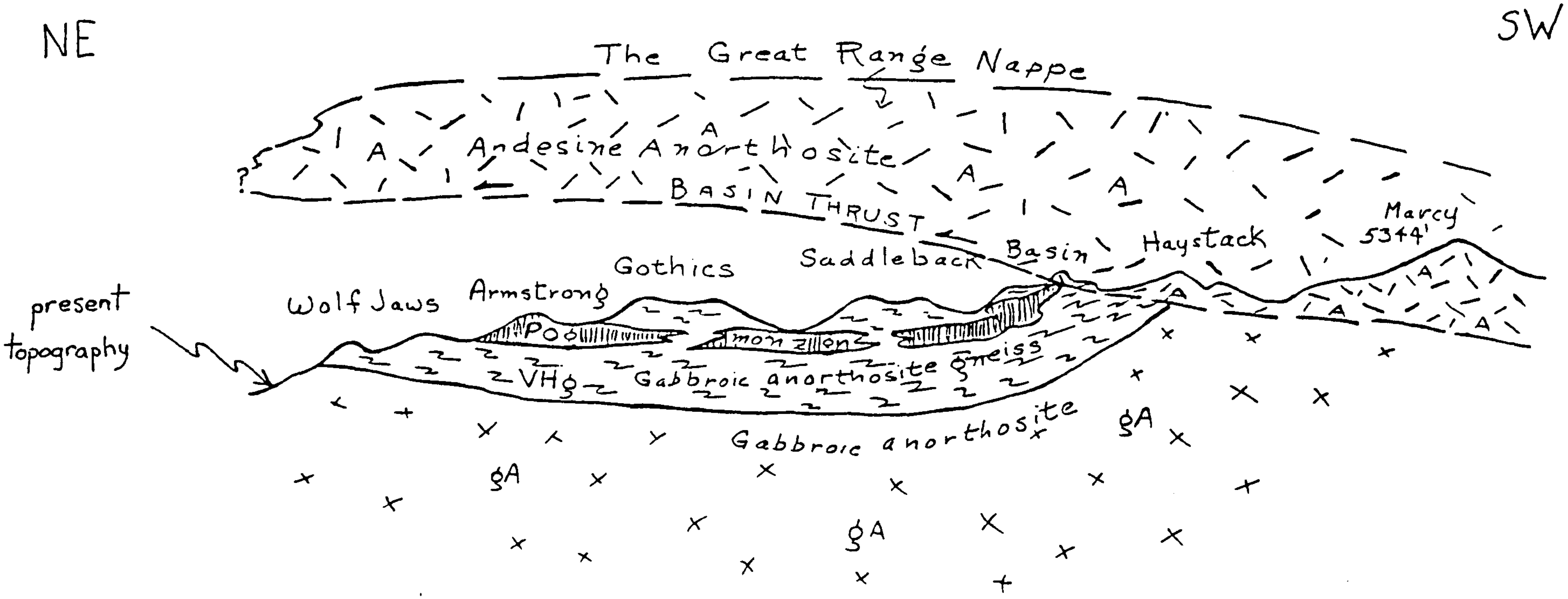


Figure 3 This diagram is a generalized cross section of the Great Range showing the andesitic anorthosite core facies (A) thrust over intensely deformed gabbroic anorthosite gneiss (VHg) and ferromonzonitic gneiss (POg) and (monz gn). Cascade Valley is approximately 10 km north of the northeast end of the cross section.

eroded and uplifted to expose these deep seated rocks.

Geologic interpretation of the Adirondacks is constantly being revised. Information from individual studies serve to augment preexisting knowledge. The rock here still eludes an explanation that encompasses all of the structures and relationships observed. In 1905, John Clarke wrote that Adirondack field work was hampered by the lush indigenous undergrowth that obliterated outcrops, and the frequent rains (on trails here hikers joke, "I'll bet it will rain today, it hasn't rained in nearly 24 hours."). He also remarked about the difficulties imposed by the refuse of lumbermen, and the distance from settlements, but said that these hardships were offset by the healthful climate and plentiful good water[8]. Today these factors still apply to the ongoing mapping and mineralogical studies with the recent exception of good water, which has been contaminated with the Giardia parasite due to the high concentration of hikers and campers.

Ebenezer Emmons (1842) mentioned Cascade Valley in an early geologic report as the site of a mine for the Elba Iron and Steel Company. He was interested in this location because of the intriguing juxtaposition of hypersthene rock (his description of the Marcy anorthosites) and what he called primary limestone. The magnetite mines here had been in operation for several decades (the deed for the land was dated 1812) and they obtained the ore from veins and clusters disseminated in white marble. Emmons declared that intimate association of the limestones and the supporting anorthosites and gneisses proved that the marbles were the result of igneous magmatic injection. James Kemp made several important revisions in his report of 1920[9]. Signifigant advances had been made in the intervening years with respect to metamorphism and contact effects, and he recognized the marbles as fragments of the original country rock, metamorphosed by intruding anorthosites and syenites. Partial melting and assimilation gave rise to the calc-silicate suites and microperthite gneisses of the contact zones. In Kemp's day small family owned iron mines and bloomaries (furnace and forge used to make bars or blooms of wrought iron) still operated in Cascade Valley, providing wrought iron goods for the surrounding villages.

Spencer's Cave

Caves in the Adirondacks are "rare as hen's teeth," DEC Ranger Spencer Cram asserted as we started our ascent to the cave he discovered several years prior. In fact, subterranean cavities are considered unusual in any Precambrian crystalline rocks. In this area folk lore and fireside tales account for the majority of the reports of caves, but many of them centered around the Cascade Lakes vicinity. Watson's <u>History of Essex County</u> recalls accounts of caves high on the slopes of Cascade mountain,[10] and stories I heard as a child told of caves on Pitchoff Mountain accessible only by shimmying up the trunk of a birch tree. Shrugged off as fantasy by many, some people explained the stories as exaggerated descriptions of deep overhangs formed by balanced rocks, or frost wedged cracks on steep rock faces. The author generally regarded most Adirondack cave reports as tall tales

Chronology of Cascade Valley

pre-1650's	Area ihabitated by Algonquin Indians (the Cascade Lakes were called Long Pond by early settlers)
1812	Cascade Lakes land purchased by the Elba Iron and Steel Company owned by Archibald McIntyre
1830 (?)	the great Cascade Valley avalanche
1842	Ebenezer Emmons publishes Geology of New York part 2 which mentions Cascade Valley. (around this time, the lakes were renamed Edmund's Ponds by the Weston family.)
1872-1880	Wood iron mine and bloomary operated by the Weston family.
1878	Westons open a hotel between Upper and Lower Cascade Lakes.
late 1870's	Westons rename the lakes Upper and Lower Cascade Lakes
1879	Cascadeville post office opens at the hotel
1880	Hale iron mine opens. Owned by the family of LeGrande Hale, famous Adirondack guide
1885	Creation of the Adirondack Forest Preserve
1903	Forest fire in Cascade Valley

Figure 4 This brief chronology shows some reasons for economic, geologic, and scenic interest in Cascade Valley.

until I had the opportunity to see one firsthand. In late autumn of 1978 a small underground cavity was discovered by Adirondack park ranger Spencer Cram. He was unprepared to explore it, but he noted the location and later brought two University of Massachusetts geology professors (Howard and Elizabeth Jaffe) to the site. Several years later Cram guided the author to the cave, by then dubbed Spencer's Cave. He had hoped I would not divulge the exact location of the cave to save it from desecration by overzealous rockhounds and cavers.

Cave Morphology

The cave entrance lies in the bed of a dry brook almost completely concealed by trees, undergrowth, and forest litter. The opening is in a pit approximately three meters deep surrounded by white marble on all sides except the southwest. This pit, which is a portion of collapsed cave roof, is mimicked by other smaller depressions downslope. To the southwest of the entrance is a deeply weathered anorthosite with dark blue plagioclase crystals in a granular, almost friable matrix which suggests it has gone through profound change from its original magmatic composition. The contact between the anorthosite and the marble is sharp with an adjacent zone of fractured marble about ten cm thick. Figure 5 shows this contact located just behind the author. Eight or ten meters up the brookbed another steeply dipping blue marble is exposed. During my observation at the end of a dry summer the brook flowed under the visible marble

Figure 5 The entrances to Spencer's Cave are in the pit pictured above. One entrance is just below the author, and the other is on the side of the pit closest to the photographer. Notice the sharp contact between the garnet pyroxene granulite (left) and the blue marble, and the graded boundaries between the different types of calcites.

through an opening 0.3 meters in diameter, and into Spencer's Cave. The condition of the brookbed indicated that while the portion of the brook above was a permanent feature, the portion between the two marble exposures flowed intermittently, and the section below the cave entrance was a watercourse only in times of flood or spring thaw. The brook reemerged from its underground channel about 175 meters downslope from the cave entrance in a pool cluttered with organic matter.

In the pit at the cave opening two entrances were found, one of which led into a larger chamber. The cave revealed white marble walls which appeared smooth and glistened under a flashlight. On closer inspection this section of wall was not wet as it appeared, and had a rough, almost hackly texture due to a combination of tiny mineral inclusions and fracture of coarse subhedral calcite crystals. This chamber, which was not quite large enough to permit standing, contained a large crevasse in the floor in which water flowed. The brook was followed upstream; progress was slow owing to sharp protrusions of marble. Locating the spot where the brook entered the cave, another collapse feature which was not visible from above the ground surface was evident. Water cascaded onto a pile of rubble, and found its way into a narrow channel carved into the marble floor flanked by more sharp, bladed ridges that marked the former progress of the brook. Figure 6 shows one of these features with an opening eroded into it.

Figure 6 One of the bladed protrusions of marble has a hole eroded into it by the cutting action of the brook. The black rock pictured here is loose rubble that remains from a collapse feature of the roof just upstream.

Most of the cave was surprisingly free of sediment and rubble. Rushing waters of spring thaw flow through the cavity and wash it free of loose material. Bits of leaves and organic matter are wedged into cracks and wrapped around small projections high on the cave wall. The loose ends of the vegetal material point downstream like hair blowing in the wind. During flood events and at the height of snowmelt this cave is virtually submerged. During this dry summer though the flow was reduced to a shallow course of water measuring about two cm wide.

The water-carved forms of the floor and walls of the cave were not evident in the ceiling. The crevasse that formed the brook channel continued along the roof with an orientation similar to that of the marble-anorthosite boundary. This suggests that the crevasse was formed by the weathering of a less resistant zone, perhaps provided by fault breccias or groundwater dissolution along a joint. On either side of the ceiling crevasse, large, flat, horizontal leaves of marble hang from the roof and upper walls. If these leaves are slowly stoping off, their rubble is not apparent below. Figure 7 shows the relation between the ceiling structure and surrounding rocks in the cave. The horizontal nature of the leaves of roof rock indicate that they were formed by percolating groundwater rather than the presence of a fault or fracture zone. Sample 11 is a fragment of one of the ceiling leaves. The side that faces the cave air is more heavily weathered and oxidized. Inside the cavern water droplets clung to the ceiling, but the sides of the rock leaves that faced away from the main air space were dry and only lightly covered with dust and alteration products. The margin of the marble body at the cave entrances and the crevasse both have an approximate N5W strike, dipping steeply to the southwest, so it is doubtful that these horizontal rock leaves are structurally related to the crevasse or the marble-anorthosite boundary.

The second cave entrance led to a section of dry brookbed. The brook above runs into a deep crack just inside the first entrance, probably to a channel at a lower level. Just inside the second entrance sediment and organic matter had accumulated around the margins of the dry brookbed where spring runoff water flowing into the entrances did not completely clear away the debris. The outlet of the dry brookbed in this portion of the cave led into a narrow triangular passage (pointed at the top) which became progressively smaller with increasing distance from the entrance. In this passage more evidence was found to strengthen the hypothesis that the brook channel trended along a fracture zone. A crack on the northeast side of the passage showed how the marble had been pulled apart about ten cm. The two sides of the crack would fit together if the gap were closed. This feature had a different orientation than the large crevasse along the main brook channel, yet it shows that the forces neccessary to fracture the rocks were active in the area. A slightly imperfect calcite rhomb with crystal faces about eight cm across was collected from this crack near location A on Figure 7

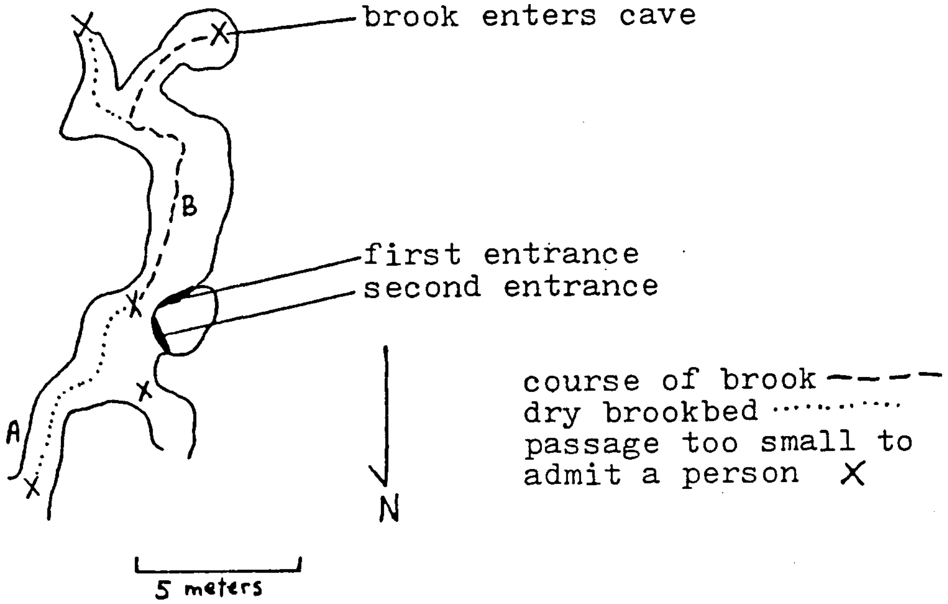
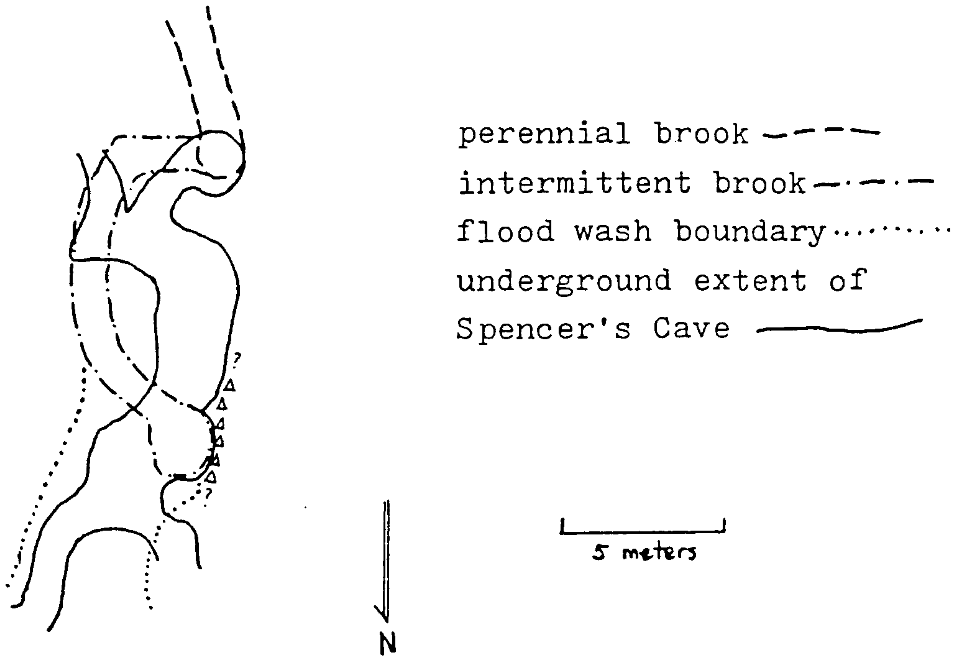


Figure 7 Above is a sketch of the extent of Spencer's Cave. The dotted or dashed line represents the course of the unnamed brook that runs through the cave. The sketch below shows Spencer's Cave in relation to the course of the brookbed on the ground surface above. The approximate location of the sharp marble-granulite contact is shown by the small triangles.



(collection of K.L. Waldhauer). The crack appeared freshly broken with no evidence of weathering or alteration products, so it seems unlikely that it was caused by Precambrian or Cambrian faulting, or fracturing due to a volume change at the time of recrystallization. Instead, this type of fracturing could be related to the current uplifting of the Adirondack high peak region, local instability caused by the erosion of the lower channel into which the brook flowed, or stresses resulting from downslope movement of overlying soil, rocks, and sediment.

Although the orientation of the crack near location A (Figure 7) was oblique to that of the main brook channel near location B (Figure 7), the narrow passageway near location A was subparallel to the main brook channel. Further studies may show that the collapse feature where the brook enters the cave lines up with the brook channel and the narrow passage, thereby reinforcing the hypothesis of a fracture zone (a fault?) trending N5W dipping steeply to the southwest. A more detailed study would have to be conducted to determine the age of fracturing, and if it is a fault, the amount of slip.

Several veins of diopside and augite in Spencer's Cave run through the marble body at various orientations. Some are cylindrical tubes of loosely packed euhedral crystals, others are tabular in shape and contain a more densely packed crystal mass. Both types are gently folded showing they were either deformed after formation or they were formed along irregular zones that favored their crystallization. Sample 17 is a piece of one of the cylindrical apophyses that was exposed on the cave wall shrouded in a thin veil of sediment and reddish oxides. Formation of these apophyses may be controlled by gases escaping from Precambrian magmas. Studies by Jaffe[11] indicate that the volatile gas component of Precambrian melts played an important role in crystallization of many Cascade Valley minerals. Assimilation of some of the calcite into the intruding anorthosite melt desilicates the magma[12] and enriches it in calcium. This process can produce lime garnets, diopside, wollastonite, and other minerals found in Cascade Valley.

Mineralogy of Spencer's Cave

The marbles and calc-silicates of Cascade Valley are not common in the anorthositic terrain of the Adirondacks. Many of the minerals found near Spencer's Cave were formed when large remnants of Grenville Series sediments were rafted upward in plumes of intruding magma. The margins of these remnants reacted with the melt, and cooled slowly to form a host of calc-silicate minerals. The marbles from which the cave was carved reacted less with the magma, but the high pressures and temperatures caused changes in the Grenville limestone. The fluid and gas phases of the magma influenced the formation of magnetite, garnet, and pyroxenes, and veins and clusters of these minerals cut the marble body at various orientations. The nature of the volatile phase of Precambrian magmas is the current

PARENT ROCKS

limestone (dolomitic or argilllaceous)	anorthosite
$CaCO_3$ with minor quartz, clays, and dolomite	$NaAlSiO_3$-$CaAl_2Si_2O_8$

IONS AVAILABLE FOR REACTION
DURING REGIONAL METAMORPHISM

CO_3 Ca Mg Fe Na Al CO_2 H_2O

COMMON MINERAL PRODUCTS

Calcite $CaCO_3$

Diopside $CaMgSi_2O_6$

Garnet $Ca_3(Fe,Al)_2(SiO_4)_3$

Wollastonite $CaSiO_3$

Augite $Ca(Mg,Fe,Al)(Si,Al)_2O_6$

Hedenbergite $CaFeSi_2O_6$

Magnetite $FeFe_2O_4$

UNUSUAL MINERALS OF CASCADE VALLEY

Scapolite $(Na,Ca)_4(Al,Si)_{12}O_{24}(Cl,CO_3)$

Monticellite $CaMgSiO_4$

Vesuvianite (idocrase) $Ca_{10}(Mg,Fe)_2Al_4(SiO_4)_5(Si_2O_7)_2(OH,F)_4$

Forsterite $(Mg,Fe)_2SiO_4$

Orthoferrosilite $Fe_2Si_2O_6$

Figure 8 This chart lists the parent rocks which were a source of ions for many Cascade Valley minerals. The common minerals are exposed over a wide area of Cascade Valley, and the more unusual varieties are found only as small deposits in restricted locations.

subject of much speculation and research. A detailed study of Cascade Valley marbles and calc-silicates may provide some of the clues.

Calcite

The calcite samples from Spencer's Cave exhibit a variety of colors including white, green, blue, and occasionally pink. By far the most abundant is the white or light tan types that are centrally located within the marble body. Augite is the principal accessory mineral in this marble with other minor pyroxenes and magnetite. The accessory minerals occur as veins and small disseminated crystals. Although the crystals are generally small (up to 0.5 mm) they are readily apparent in hand samples because of the difference in color and luster. In the white marble indistinct bands of pink calcite, such as the one exposed in Sample 10, are probably due to the incorporation of trace amounts of manganese.

Close to the perimeter of the mass the marble grades into a blue color with concentrations of garnet increasing toward the garnet pyroxene granulite. An early report by Emmons (1842) states that green marble is found only at depth, and that it changes to blue marble upon exposure[13]. It seems more plausible now that the blue calcite reflects a particular zone of assimilation between the Grenville Series sediments and the intruding Precambrian melt. The blue marble is found at the entrances to Spencer's Cave in contact with the garnet pyroxene granulites and gneisses showing that this calcite was able to react with the intruding rocks more than the white calcite varieties. An indistinct zone between the white and blue marbles is composed of highly fractured green calcite with many of the same accessories as the white marble. The fracturing around the green marble zone may be caused by a change in volume of the mass during late stages of metamorphism.

Other researchers have found that some of the calcites from Cascade Valley fluoresce deep violet or orange, but little evidence of this has yet been found in samples from Spencer's Cave. Baillieul found that the calcite fluorescence was due to microscopic fluid inclusions[14]. Tiny tubes of some fluorine compound oriented randomly through the calcite were responsible for orange fluorescence under short wave ultraviolet radiation (3600 A). At Spencer's Cave the volatile fluorine compound inclusions have either escaped, or they were never incorporated into this marble mass.

Pyroxenes

Pyroxenes of this calc-silicate suite include widely varied members of the diopside-hedenbergite solid solution series as well as augite. Figure 9 shows the field of composition for Cascade Valley pyroxenes found by Baillieul at the nearby Cascade Slide. Across the valley on Pitchoff Mountain, Jaffe used the orthopyroxenes there as a gauge of the pressure and temperature of formation[15]. He indicates that the pyroxenes and felspars reached a chemical equilibrium during the peak of Adirondack metamorphism, and later readjusted, creating exsolution lamellae and textural changes

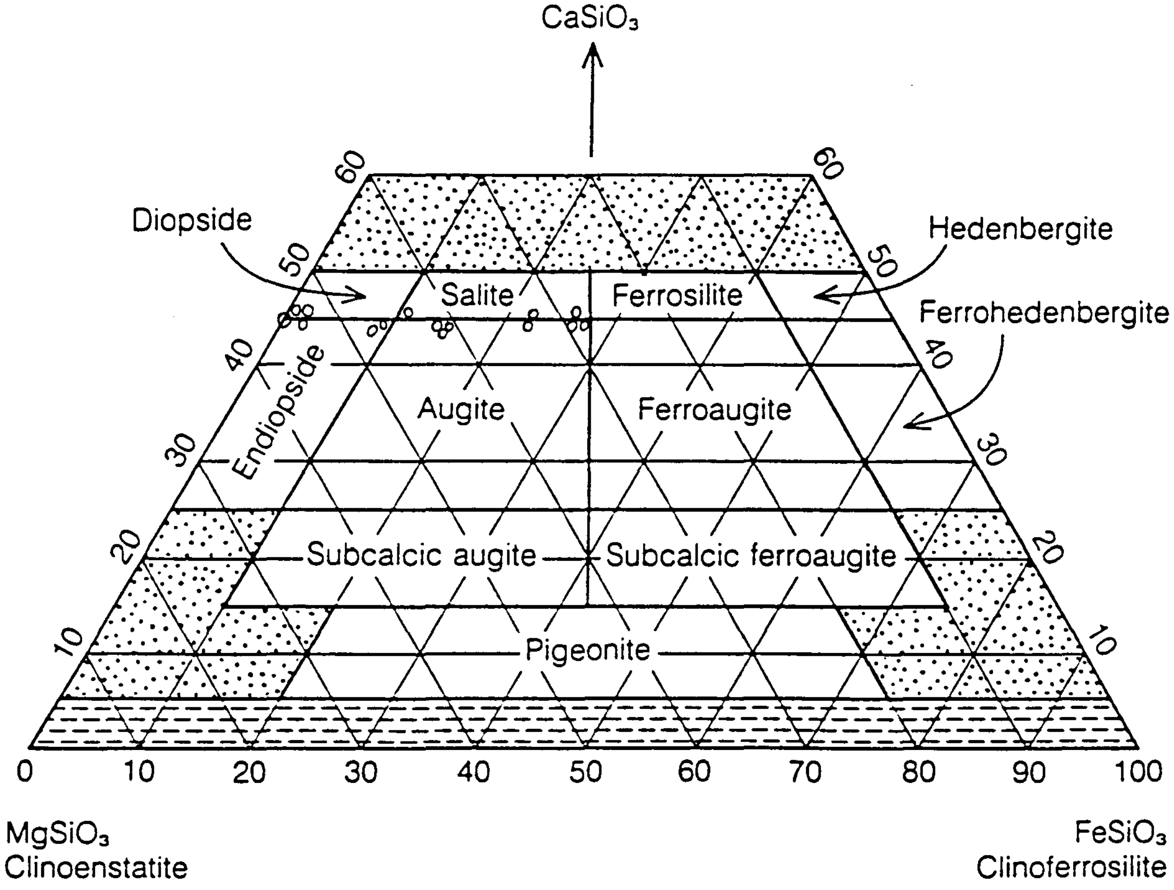


Figure 9 Composition of monoclinic pyroxenes. The open circles show the composition of clinopyroxenes analysed by Baillieul. (after Berry, Mason, and Dietrich, 1983)

in these rocks. The temperature of metamorphism was thus determined to lie near the high pressure stability limit of sillimanite at 7-9 kb at 600 C, or 9-11 kb at 800 C. On Pitchoff Mountain coexisting augite and orthopyroxene, and the absence of inverted pigeonite suggest that temperatures never exceeded 800 C.

Augite

Augite is one of the most frequent impurities of the green and white marbles occurring in small euhedral to subhedral crystals. The color ranges from pale to dark green depending on the amount of iron present. Baillieul reports augite megacrystals up to 1 cm, but the largest crystals found in place here are much smaller (up to 2 mm). Baillieul's area of study, the Cascade Slide, offers a much larger area of recently exposed rock. At Spencer's Cave augite crystals occur as small equant grains or short prisms. Figure 10 illustrates idealized forms for the augite grains contained in the idioblastic augite marble. An analysis by Jaffe for an iron rich augite gives the composition[16];

$(Na_{0.06}Ca_{0.83}Mn_{0.02}Fe_{0.10})(Fe_{0.85}Zn_{0.01}Mg_{0.07}Fe_{0.04}Al_{0.03})$

$(Al_{0.02}Si_{1.98})O_6$

Diopside-Hedenbergite

Occurrence of members of the diopside-hedenbergite solid solution series is expected in view of the abundance of calcium and iron. The source of calcium is from the parent limestones which also contribute some magnesium. The iron may come from volcanics deposited with the Grenville

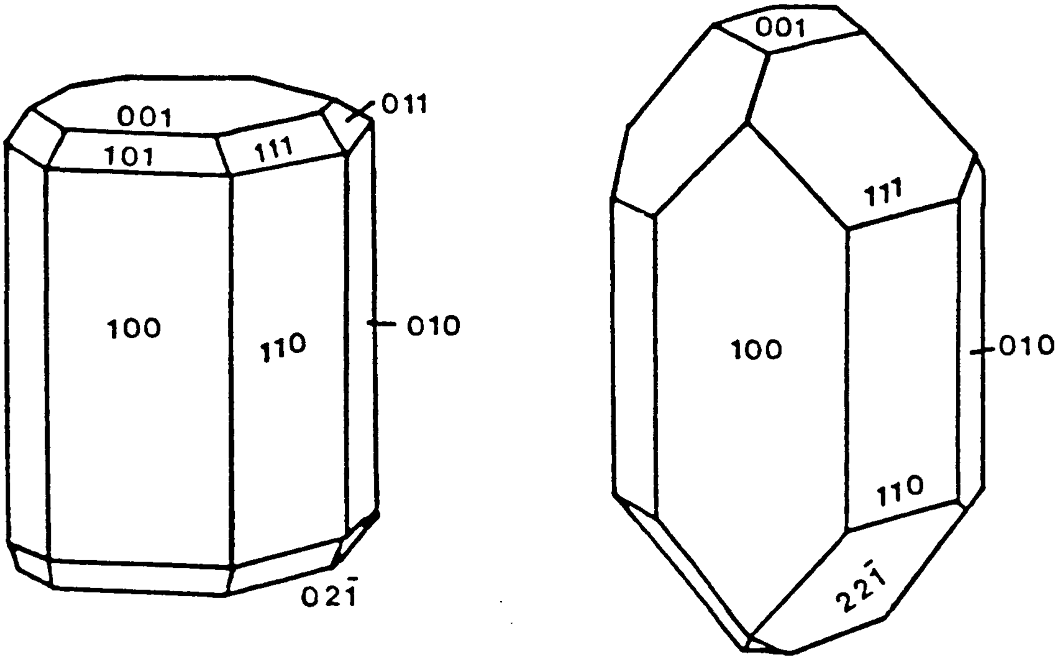


Figure 10 Idealized crystal forms for augite crystals in the white marble of Spencer's Cave. (from Baillieul, 1976).

sediments[17], as well as from hypersthene of the anorthositic and syenitic intrusions. Hand samples of these minerals are indistinguishable from augite, yet chemical analyses suggest their presence. Diopside, augite, and hedenbergite are minor components in the marbles, but they make up a greater volume in the pyroxene garnet granulite that borders the marble mass. Near the veins and clusters of magnetite, the pyroxene composition probably trends toward the hedenbergite end of the solid solution series due to higher concentrations of iron.

One loose megacrystal of pyroxene measuring 23 mm was found in the rubble of a collapse feature inside Spencer's Cave. Petrographic analysis by Jeff Swope suggested that the exterior of the megacrystal had a diopsidic composition, but further studies would be required to find whether the composition varied within the sample. The ionic radii of iron (0.61 A) and magnesium (0.65 A) are similar enough that ionic substitution can occur[18]. Analyses by Baillieul show that most of the clinopyroxenes in the area have only small amounts of aluminum and titanium[19]. In general the pyroxenes of Cascade Valley calc-silicates are the most important indicator of the conditions of crystallization.

An interesting unverified report of a diopside-hedenbergite mass with a rumpled exterior (collection of Spencer Cram) is thought to represent a reduction in volume of the original material. Spencer Cram described the appearance of the sample as a "baked potato"[20], and showed the rock to Howard and Elizabeth Jaffe who surmised the composition macroscopically. Whether ionic substitution of iron for magnesium, or a loss of volatiles is involved remains entirely speculative.

Garnet (grossular and andradite)

Garnet is found in the Adirondacks as an accessory mineral in almost every rock type. In the southern Adirondacks a large deposit composed of hornblende, plagioclase, and almandite was mined for several decades at Gore Mountain. Today the garnet mine is out of operation due to past exploitation of the best deposits and competition from synthetic abrasives. Garnet is inappropriate for commercial production elsewhere in the Adirondacks because small deposits occur in a larger volume of other igneous and metamorphic rocks. Varved deposits along brooks and rivers record the annual fluctuation in Adirondack stream velocity. Spring runoff leaves layers of garnet and magnetite sand, while quartz rich sands are deposited in times of lower flow.

In Cascade Valley two types of garnet, grossular and andradite have been reported; both are related to the alteration of limestones. Grossular forms by regional or contact metamorphism of impure limestone or dolostone, and is generally associated with many Cascade Valley minerals such as calcite, wollastonite, and vesuvianite[21]. Andradite can result from metasomatic alteration of limestone by iron rich solutions in association with ore deposits in calcareous rocks[22]. The magnetite mines of the 1880's attest to the presence of ore bodies in Cascade Valley, and in the marble of Spencer's Cave small green or honey-brown crystals of garnet can be more plentiful than the pyroxenes. The largest garnet crystal found was over 3 mm in diameter (Sample 10), and at least three veins of small (0.5-1.0 mm) lime garnet crystals criss cross the marble body near the second entrance. In the rocks bordering the cave, red garnet is found in the pyroxene granulites (Sample 21) and garnet skarns (Sample 14). In the marbles garnet makes up only one percent of the volume, but in the marble-anorthosite border facies garnet may comprise up to 30 percent of the rock volume.

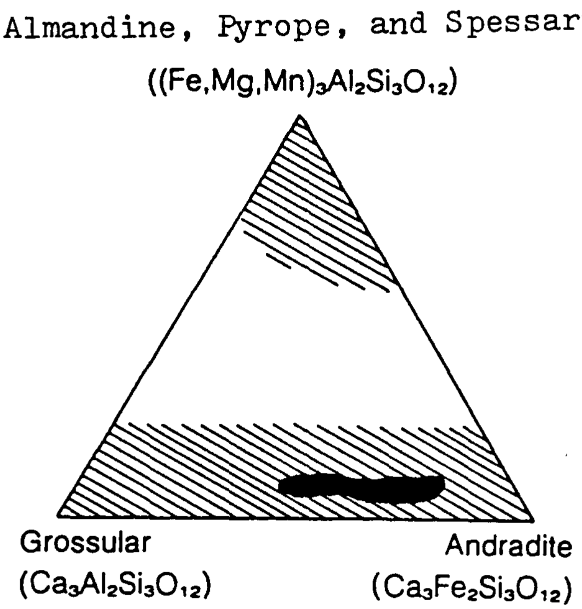


Figure 11 Grossular and andradite have both been reported from Cascade Valley. The darkened area represents the range of garnet composition from a report by Baillieul in 1976. (after Berry, Mason, and Dietrich (1983))

Magnetite

Once mined for commercial use, magnetite is found in close proximity to marble in Cascade Valley. The marble mass from which Spencer's Cave is carved shows no evidence of large ore bodies, but small crystals do occur. This magnetite exhibits polarity, and caused Ebenezer Emmons to read his compass with suspicion[23] because ore bodies have induced local deflections of the magnetic field. James Kemp also studied this area, and searched through piles of tailings left by iron mining operations for clues about the geology. He wrote, "On the dump was much limestone, charged with pyroxene, lime silicate hornfels, consisting of green pyroxene containing multitudes of little garnets. There is also a green rock consisting of diopside about 75 per cent and calcite 25 per cent. All these rocks are undoubted contact effects, and the magnetite which was mined and of which a few stray pieces are still available was one of the characteristic attendant features."[24] The iron-rich solutions that produced pyroxenes and garnets also produced magnetite. The highest concentration of magnetite was observed in the green marble as crystals up to 0.75 mm, but even here the magnetite comprised only one or two percent of the volume.

Calcite, different types of pyroxenes, feldspars, and garnet make up the major volume of rock around Spencer's Cave, but a variety of unusual minerals such as the ones listed at the bottom of Figure 8 occur here as well.

Other researchers have confirmed the presence of these minerals by means of chemical, optical, and x-ray analyses. Monticellite, vesuvianite (idocrase), sphene, graphite, scapolite, and wollastonite have all been mentioned in previous reports about the area, but their importance seems minor near the cave. A single crystal of a scapolite group mineral (meionite?)[25] was located in a sample of white marble because of its yellow-orange fluorescence, but no others have yet been found. Only one small sample of wollastonite was among those studied from the cave; it occurs in a garnet-pyroxene granulite (Sample 21) within 4 cm of a contact with blue marble.

One interesting structure in Spencer's Cave is the black column of rock pictured in Figure 12. At first glance it seemed to be a magnetite ore body close to the margin of the marble. On closer inspection this rock was magnetic only in isolated places and exhibited a glassy luster. Fresh surfaces revealed a matrix of small dark green-to-black fused crystals and anhedral particles of calcite. The column was riddled with fractures and horizontal joints in which calcrete was deposited. Calcrete also grew outward from the exposed faces in nodules up to one cm in height. X-ray analysis suggested that it contained calcite, but it did not produce a pattern characteristic of an amorphous substance. Thus my hypothesis that the column was a dike or vein of fused diopside was not supported by x-ray work.

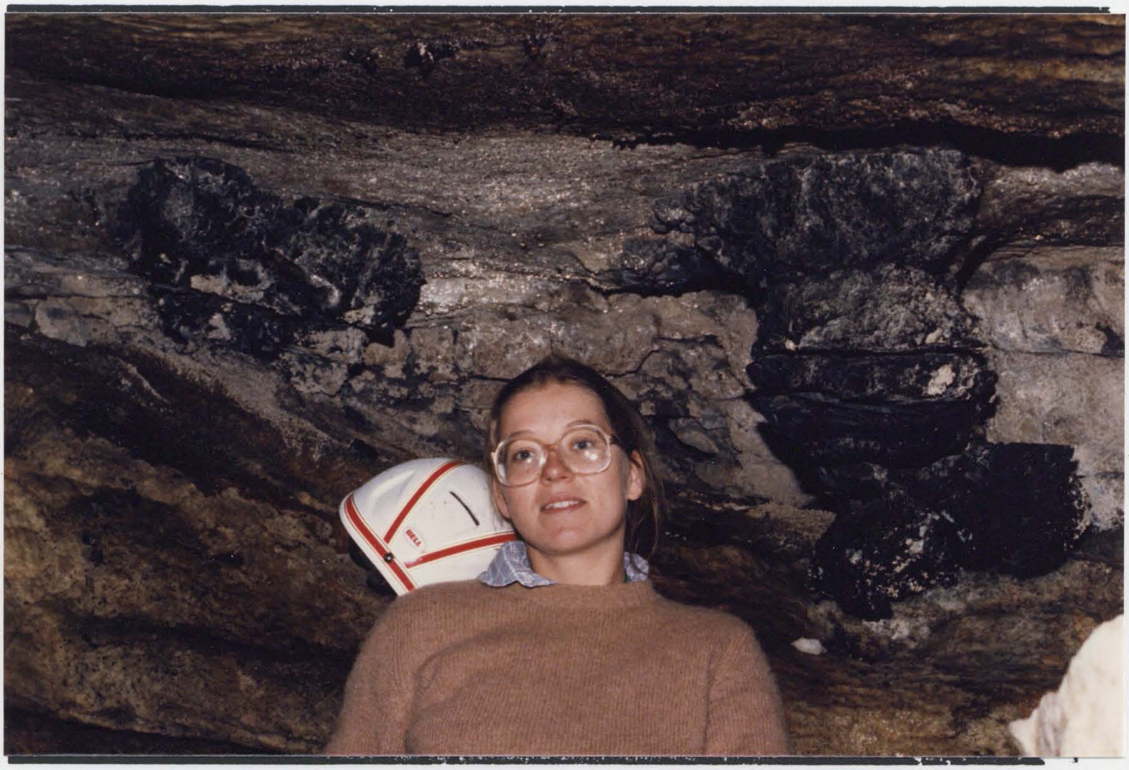


Figure 12 The shiny substance (above the author) is water droplets that cling to the walls and ceiling. The black column of rock behind the author was highly fractured, and there was a greater growth of calcrete there than any other location in the cave. The composition of the column has not yet been determined.

Discussion of Results

Cascade Valley is the site of complex relations between marbles, calc-silicates, syenites, gneisses, and anorthosites. On the 1920 edition of the Mount Marcy quadrangle map, James Kemp noted a fault at the base of Cascade Valley[26], but underestimated the importance of Grenville metasediments. Robert Balk, in a later report on the Newcomb quadrangle, shows a contact zone between Grenville metasediments and syenites (Figure 13). The contact zone in Cascade Valley seems to be of the same nature. Bodies of marble intersect the land surface with no apparent order, each surrounded by different combinations of gneisses, syenites, and gabbroic anorthosites. If we take Balk's generalized picture of a Grenville contact zone, fault it along the vertical portion near the center of Figure 13 so that the SSW end is uplifted, and thrust andesitic anorthosites over the SSW end of the contact zone, we create a picture similar to that of Cascade Valley. The mineralogy, foliation (where present), flow structures, and orientation of rocks here support this idea. Howard Jaffe observes evidence that Adirondack metamorphism occurred in a series of pulses[27], allowing repeated injection, heating, and cooling of the rocks. Dikes and veins are commonly offset by later intrusion so that a network of intersecting strucures occur. The complexity of small strucures is only hinted at in the generalized relations diagrammed in Figure 14. This diagram shows the nature of the contact on Pitchoff

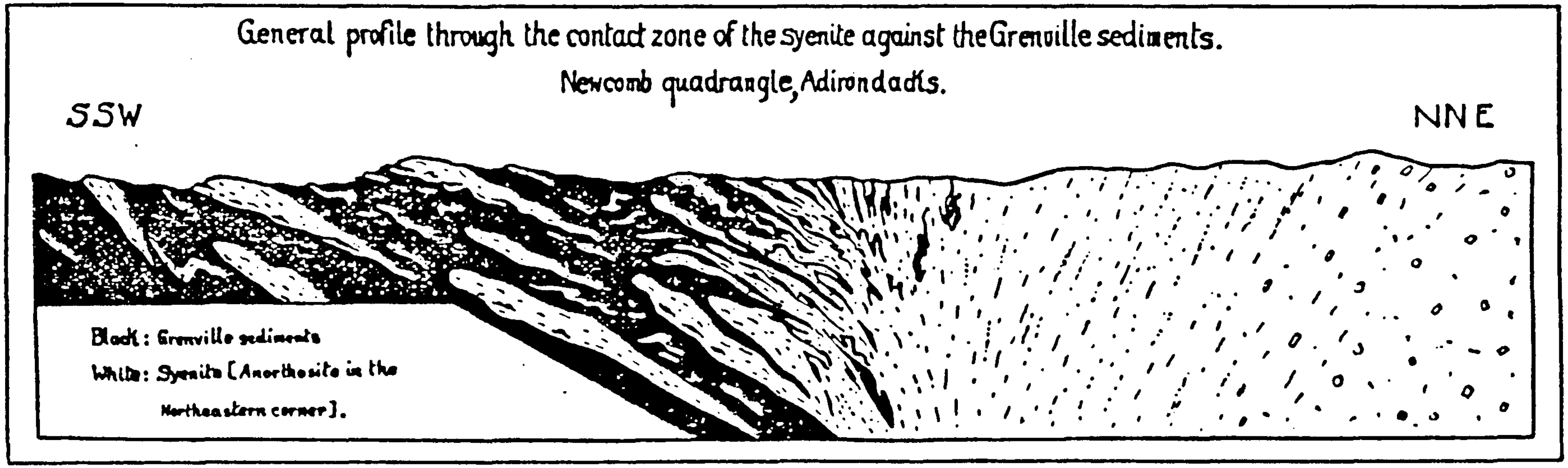


Figure 13 The syenite-marble contacts in Cascade Valley resemble this diagram from Balk, 1931.

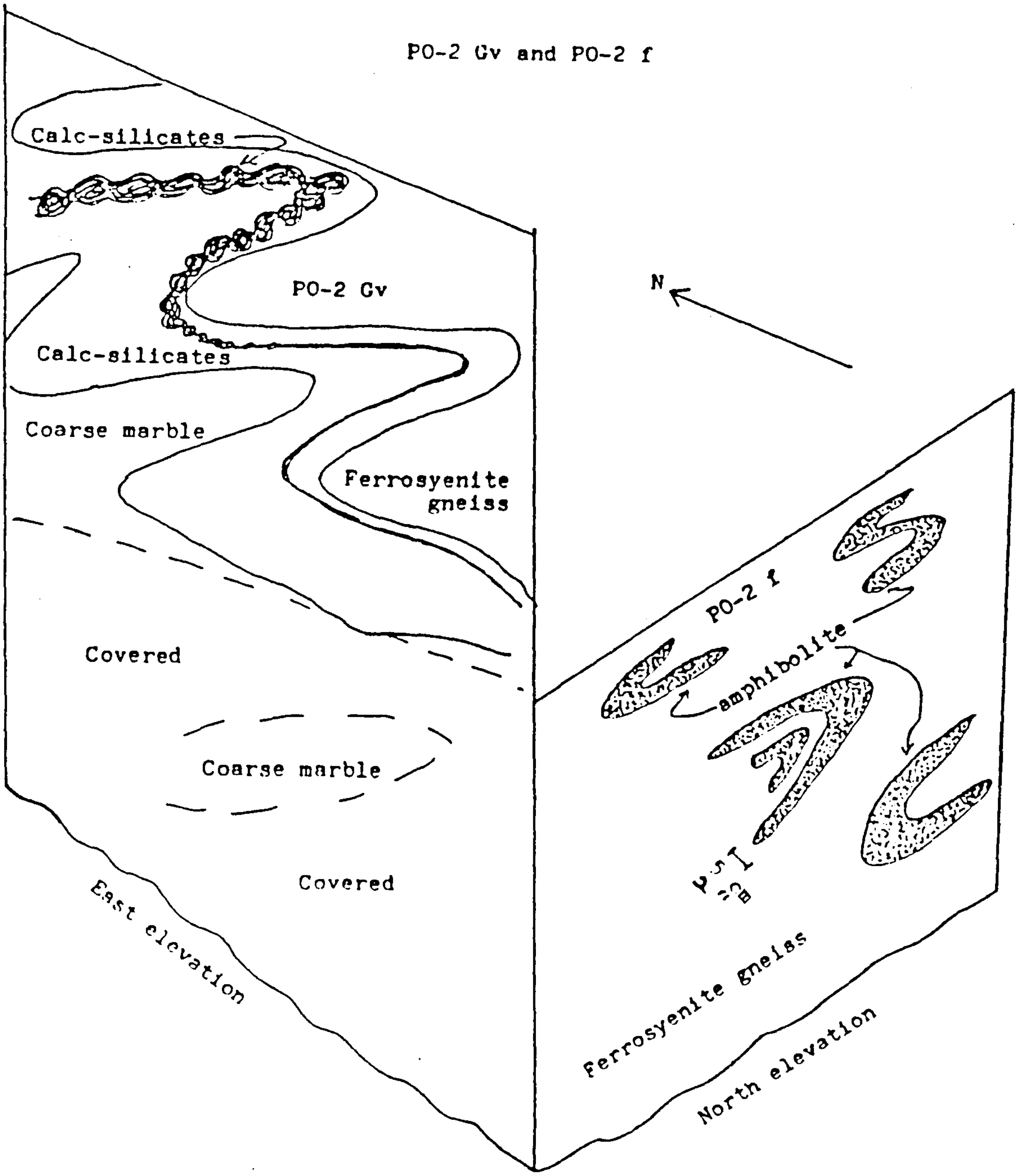


Figure 14 A generalized diagram of the marble-calc-silicate-gneiss facies on the slopes of Pitchoff Mountain (from Jaffe <u>et al</u>., 1983).

Mountain between the idioblastic Grenville marbles and the border facies that formed from the metasomatism and assimilation during Precambrian intrusion. In the studies of Spencer's Cave no amphibolite was identified in the vicinity, but Jaffe located some tightly folded amphibolite across the valley from the cave on the slopes of Pitchoff Mountain.

One continuing controversy among Adirondack geologists concerns the composition of volatile components in Precambrian intrusives. Magnetite, pyroxenes, and andradite are evidence of the presence of iron in the melt, but most all of the volatile components were driven off. Baillieul reported fluorine (and possibly manganese)[28] as the cause of fluorescence in calcite; this may be a clue about the composition of the volatile fraction. The dissociation of calcite as the result of high temperatures would produce carbon dioxide as a volatile component in the melt. If the parent limestones were not completely dewatered then water vapor would contribute to the volatiles. One problem with this line of thinking is that the temperature required to dissociate calcite is around 1000-1100 C at atmospheric pressure[29], and the temperature of metamorphism calculated by Jaffe was only 600-800 C at high pressure. The melting point of calcite at the pressures involved would be much higher than the temperature deduced by Jaffe. If carbon dioxide was an important volatile substance during the intrusion sequence, calcite must have been dissociated elsewhere and somehow dispersed through the rock column.

These and several other ions are thought to be involved in the volatile component of the melts, but researchers have yet to discover their composition or mode of transport.

Conclusion

Geologic interpretation has come a long way since Ebenezer Emmons presented his evidence that Cascade Valley marbles were of an igneous origin. At that time he believed that the anorthosites and syenites had been intruded by a calcium carbonate magma. Continued regional research determined that remnants of the original marbles were rafted upward, deformed, and partially assimilated by Precambrian intrusive magmas. Modern geological concepts and technological advances now help to unravel the history of Adirondack rock. Bowen's reaction series gave geologists new insight into the low temperatures and high pressures involved in the formation and recrystallization; radiometric dating shows the age and time span involved for these processes. Analyses by chemical, optical, and x-ray techniques further refine the study of these old rocks, but no replacement has been found for the most basic mode of study. Every geologist from Emmons to Ollila (a present researcher in the area) spent countless hours in the field examining outcrops from every possible viewpoint. The recent remapping of the Mount Marcy quadrangle, headed by Howard and Elizabeth Jaffe, entailed several summers of bushwacking over every mile of forest land in search of obscure outcrops and contacts to refine the geologic picture.

Cascade Valley is a unique place to study Adirondack geology. The dense vegetal covering characteristic of Adirondack lands is here broken by cliffs and slides. The variability of petrology at this locale provides a good view of Precambrian metamorphic activity.

An unusual feature of Cascade Valley, the caves, have only recently undergone rediscovery. In this area limestone was deposited, buried, and folded before the onset of the great anorthositic intrusion. During these episodes of intrusion, which occurred at a calculated depth of 35 km, the limestones were heated and partially assimilated by intruding melts. Pulses of activity produced long sequences of temperature change, deformation, and recrystallization in the marbles and surrounding rocks. The evidence that remains in Cascade Valley suggests that huge fragments of Grenville Series sediments were rafted upward in the magma plumes. Their margins reacted with the melt to produce a suite of calc-silicates that is unique in the Adirondack geologic setting.

Since the great Precambrian intrusions an enormous volume of rock has been removed by exposure to the elements or scoured by glaciers. The intruding rocks, andesitic and gabbroic anorthosites, syenites and microperthite gneisses, now comprise the vast majority of surface exposures in the area, but Cascade Valley is well endowed with marble and calc-silicate deposits. The combination of marbles, less resistant than surrounding rocks, and plentiful

Adirondack rains provided a suitable environment for Spencer's Cave to form. The cave was probably first generated by groundwater dissolution along joints and fractures which are especially common in the marbles. Today, Spencer's Cave has captured a stream and the roof has collapsed in at least two places. Depressions downslope from the entrances show where the cave ceiling has been stoped away so that in places the ground surface is on the verge of collapse. The unnamed brook that now runs through Spencer's Cave carves deep channels in the marble and leaves unusual bladed projections. Most of the cutting and scouring occurs during the floodwaters associated with spring snowmelt when rubble from roof collapses and stream sediment are washed from the cave. Spencer's Cave is a unique phenomenon; not often do caves occur in Precambrian crystalline rocks. This unique setting does not produce an abundance of travertine or cave formations, but it holds the mystery and beauty of an underground cavity, and offers notable exposures of the marble body and the border facies associated with the reaction between calcareous and intrusive rocks. These facies may hold some important clues about the remaining questions in Adirondack geology. Future studies of the accessory minerals, and analysis of the structures exposed inside the cave may reveal the nature of the volatiles produced by Precambrian melts, and the forces necessary for their escape.

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9. Kemp, James,1920, NY State Museum Bulletin 229-230, "Geology of the Mount Marcy Quadrangle, Essex County, New York" p. 17
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