

Article



Mineralogy of Chub Lake-Type Hematite Deposits in St. Lawrence County, NY

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Abstract: Numerous localities of specular hematite have been found in the Grenville Province in St. Lawrence County, New York. Here, we focus on six of them: the Dodge mine, the Chub Lake prospect, the Toothaker Creek prospect, the Bowman prospect, the Whitton prospect, and the Toothaker Pond prospect. We used literature research, interviews, and personal observations to establish the history of each site as a source of mineral specimens. We examined extensive holdings of specimens from each site in the New York State Museum. We used sight identification, chemical tests, x-ray diffraction, and scanning electron microscopy with energy dispersive spectroscopy as necessary to identify all the mineral species present. We had determinations made of the stable oxygen isotope content of quartz, hematite, and calcite from the Chub Lake prospect, reported as ¹⁸O relative to Vienna Standard Mean Ocean Water (VSMOW). We conclude that these occurrences formed from groundwaters at a temperature of about 170 °C in areas of low topography on the surface of the Precambrian basement rocks. Two hypotheses for this process are presented and evaluated. Well-crystallized specimens of bladed specular hematite and Cumberland-habit quartz are the most common minerals found. Noteworthy accessory crystallized minerals include barite, calcite, and goethite. All six deposits are relatively free of sulfides, so that secondary goethite formed from weathering of iron-rich carbonates at some sites. It is likely that more such deposits will be discovered in this region in the future.

Keywords: specular hematite; St. Lawrence Co., NY; oxygen stable isotopes

1. Introduction

In the first half of the 19th century, St. Lawrence County, as part of the Macomb Purchase of 1792, was being actively explored for mineral wealth by settlers arriving from Vermont along the St. Lawrence River. Talc was mined for use in making paper from before the Civil War in the Gouverneur area [1]. The Rossie lead veins were exploited on a very small scale for galena [2]. The hematite deposits that occur in a line, the Antwerp-Keene belt, from Jefferson County northward into St. Lawrence County, were discovered and exploited as major (for the time) deposits of iron [3]. During this period of exploration, a number of surficial deposits of crystallized specular hematite and quartz were discovered in the Adirondack Lowlands, but most were too small to be commercially viable. For example, the Lowden mine near Hermon, NY, was abandoned in 1877 by the owner (A. Pardee of Hazelton, PA) after a thorough search failed to find a workable deposit of hematite [4,5]. Some of these deposits, especially the Chub Lake prospect, produced notable mineral specimens, but have never been adequately characterized and are the subject of this paper. Our set of study localities includes the Dodge mine, the Chub Lake prospect, the Toothaker Creek prospect, the Bowman prospect, the Whitton prospect, and the Toothaker Pond prospect (Figure 1).



Figure 1. Grenville geology showing location of our six study sites. 1—Bowman prospect; 2—Chub Lake prospect; 3—Dodge mine; 4—Whitton prospect; 5—Toothaker Creek prospect; 6—Toothaker Pond prospect. Map courtesy of Jeff Chiarenzelli.

2. Materials and Methods

The first author spent 30 years visiting these sites as they were discovered or rediscovered. He personally collected, or supervised the collection of nearly all of the samples used in this study, so the accuracy of the locality information is assured. Many of his specimens have been donated to the New York State Museum and bear numbers beginning with "C". Some of his specimens are in the process of being donated and bear numbers without the "C".

Concurrently, the first author tracked down historical information about each locality from the published literature, from specimens in institutional collections, and from local collectors and residents, many of whom have subsequently passed on. The historical date of discovery in this study is taken as the date of the earliest mineral specimen with good provenance uncovered in our historical research.

The most common species—calcite, hematite, and quartz—were easily sight-identified when crystallized. In some cases, such as massive carbonates, barite, and pseudomorphous replacements, the identification was made with SEM/EDS (SEM, FEI Quanta 400 ESEM, ThermoFisher Scientific, Hillsboro, OR, USA; EDS, EDAX Model Octane Prime EDS System, EDAX, Mahwah, NJ, USA) at Hamilton College by Dave Bailey and Steve Chamberlain. Crystallized black hematite and crystallized black goethite were differentiated when necessary by X-ray diffraction at St. Lawrence University by Jeff Chiarenzelli.

Stable oxygen isotope analyses were performed by Julia Cox, University of Georgia, using a method modified from Valley and colleagues [6]. Samples (1–2 mg) were reacted under vacuum with BrF_5 while heated with a variable power CO_2 laser (Synrad, 10,510–10,650 nm wavelength, 75 W max power). Generated O_2 was converted to CO_2 with heated graphite, and the CO_2 was analyzed on a Finnigan MAT 252 mass spectrometer (Thermo Scientific, Waltham, MA, USA). Sample analyses each day were accompanied by standard mineral analyses. Sample results were adjusted according to the

daily average of standard results. Results are reported as ¹⁸O relative to Vienna Standard Mean Ocean Water (VSMOW).

Essential assistance in interpreting our stable oxygen isotope data was graciously provided by William Peck, Colgate University [7]. Details appear in the results section below.

3. Results

3.1. History

Our study set of localities includes the Dodge mine, the Chub Lake prospect, the Toothaker Creek prospect, the Bowman prospect, the Whitton prospect, and the Toothaker Pond prospect, all of which we were able to visit. We have not included the Fullerville occurrence in the Town of Fowler, the Tate and Polly occurrences in the Town of Edwards, nor the Lowden mine in the Town of Hermon—all localities mentioned in the 19th century literature, but currently lost.

There are probably many more of these types of small occurrences remaining to be discovered or rediscovered. Samuel Robinson [8] makes no mention of noteworthy localities for hematite and quartz in the region. This is reasonable, as local villages were just then being established by settlers arriving along the St. Lawrence River from Vermont [1].

Lewis Caleb Beck [9] mentions occurrences of plates of hematite crystals with dodecahedral quartz and barite in the Towns of Edwards and Hermon. Ebenezer Emmons [10] specifically mentions the Dodge mine in the Town of Edwards. Franklin Hough [11] mentions specular hematite and quartz occurrences in the Towns of Gouverneur, Fowler, Edwards, and Hermon, as not being important commercially, but producing outstanding mineral specimens, especially the mine at Chub Lake in the Town of Fowler. This seems to be the first mention, by name, of this locality.

The catalog of localities included in the first edition of Dana's textbook [12] includes noteworthy hematite and dodecahedral quartz in the Towns of Edwards, Fowler, Hermon, and Russell. These entries are continued in the updated catalog of localities at the end of the 6th edition of the *System of Mineralogy* [13].

Thereafter, knowledge of these earlier described occurrences seems to have faded. Whitlock [14] makes no unambiguous mention of any of them in his *New York Mineral Localities*. Jensen [15] mentions none of them, but adds the "iron-rose" locality near Pierrepont, which we have not included as a focus locality. More recently, Lupulescu [16] reviewed some of these specular hematite localities.

In the past 30 years, efforts have been made by serious amateur collectors to rediscover old sites for hematite crystals and quartz crystals. In the process, several new sites have been discovered.

Although some of our six localities may have been known locally by Native Americans, we are taking as the discovery date that time when the locality became known to mineral collectors and specimens were recovered. They are, arranged from the oldest to youngest discovery dates: Dodge mine (1842), Town of Edwards; Chub Lake prospect (1853), Town of Fowler; Toothaker Creek prospect (1950), Town of Pitcairn; Bowman prospect (1991), Town of Hermon; Whitton prospect (1992), Town of Pitcairn; and Toothaker Pond prospect (2015), Town of Pitcairn.

3.2. Geology

All of the crystallized hematite and quartz deposits of interest sit on top of the Precambrian crystalline rocks of the Adirondack Lowlands and were originally covered by the oldest Basal Member of the Cambrian Potsdam Sandstone (Figure 2), sometimes with localized lenses of massive calcite or dolomite. The Basal Member is an argillaceous, hematitic, arkosic sandstone with some dolomite and conglomerate lenses [17]. Depressions in the surface topography seem to be the determining factor for where they occur, rather than any particular metamorphic rock type in the underlying Precambrian basement complex. Given that the unconformity between the underlying metamorphic rocks of age 1–1.3 billion years ago [18] and the overlying Basal Member of the Potsdam Sandstone of Upper Cambrian age (520 million years ago), the deposits of iron oxides may have formed an integral part of

the "smooth" weathered surface onto which the components of the Basal Member were subsequently deposited or could have replaced the lower surface of the Basal Member early in diagenesis. Thus, the magnitude of the unconformity between the iron oxide deposits and the Precambrian crystalline rocks could be somewhat smaller or somewhat larger than the regional unconformity between the Potsdam Sandstone and the basement rocks.



Figure 2. Schematic geology of specular hematite occurrences in St. Lawrence County, NY. The ore sits directly on the Precambrian crystalline rocks at the unconformity (Unc.). Originally, the ore was overlain by the Potsdam Sandstone.

3.3. Oxygen Isotopes

Table 1 shows stable oxygen isotope data for calcite, hematite, and quartz from the Chub Lake prospect. Note that the apparent uniformity of our modest data set is consistent with the small sizes of these occurrences and the simplicity and uniformity of the structure and texture of each deposit. Note also that in hand specimens, hematite, quartz, and calcite are cogenetic, with both hematite and calcite embedded in quartz crystals.

Table 1. Stable oxygen isotope ratios for calcite, hematite, and quartz from the Chub Lake prospect.Measurements made by Julia Cox, University of Georgia.VSMOW—Vienna Standard MeanOcean Water.

Sample	Species	δ^{18} O (VSMOW)
CL-1	Hematite	-4.0
	Hematite	-3.5
	Calcite	15.8
CL-2	Quartz	19.9
	Quartz	19.9
	Quartz	20.5
	Calcite	15.7
CL-3	Calcite	15.9
CL-4	Calcite	18.9

In comparing our oxygen isotope data for calcite with published data for precipitation of strontianite and witherite in septarian concretions in the Marcellus Shale from Salina Group brines mixed with glacial meltwater [19], the calcite at the Chub Lake prospect seems to have formed at a somewhat higher temperature. Similarly, comparison of our oxygen isotope data for hematite with those from goethite in surface bog iron deposits [20] suggests a somewhat higher formation temperature for the Chub Lake hematite.

Two-mineral, oxygen isotope fractionation for calcite-quartz is 4.4‰ and suggests an oxygen isotope equilibrium temperature of 172 °C [21]. There is no reliable comparison data for the calcite–hematite fractionation of 19.5‰; however, comparison with calcite–magnetite for 19.5‰ yields 223 °C [22], and calcite–rutile for 19.5‰, yields 130 °C [23]. Given the structures of magnetite, hematite, and rutile, the calcite–hematite fractionation should give a temperature between 223 °C

and 130 °C, which is consistent with our calcite–quartz temperature of 172 °C [7]. These temperature estimates suggest formation by low-temperature, hydrothermal solutions.

At all of the sites where specular hematite masses were observed, the Paleozoic covering is completely weathered away, which is probably a precondition for these small deposits to have been discovered. The Basal Member of the Potsdam Sandstone is sometimes present several hundred meters away (as at the Dodge mine), but not above, nor immediately adjacent to the iron oxide deposits themselves. Sometimes the Basal Member remaining in the vicinity has barite crystals to several centimeters frozen directly in the sandstone matrix [24]. Generally, the surface weathered surface of the iron oxide deposits is smoothly conformable with the surface of the adjacent Precambrian rocks.

3.4. Mineralogy of Individual Localities

3.4.1. Dodge Mine

The Dodge mine (44°21′31″ N, 75°14′26″ W), is north of Campbell Road and east of Trout Lake in the Town of Edwards. Emmons describes this occurrence [10] (p. 44):

A mass of ore which was explored in this place ... seemed to be a vein extending along the rock nearly north and south. At the surface it was three or four feet wide ... The mass was opened by Mr. Dodge of Gouverneur, directly in the face of the same. It was pursued regularly, and the ore removed; but its width soon began to diminish, until finally the whole of the ore was raised and removed; the vein or mass having been followed in its prolongation in each direction as well as downward, as long as any ore could be found ... After the ore was exhausted, it was determined to attempt to find or recover the lost vein by a lateral cut from east to west (at the north end), so as to intersect it, provided it was lost by a shift in the position of the rocks. But after carrying out this plan as fully as necessary, the whole work was abandoned; having never encountered even a thin vein.

When the authors first visited in 1983 (Figure 3), the excavations were exactly as described by Emmons. The main opening is north of Campbell Road, but appears to have extended under and south of the current road. Most of the mine dumps appear to be on the west side of the main excavation and contain quartz crystals and masses of crystallized hematite. On the east side, the excavation is bordered by tan, iron-rich dolomite, which contains scattered single crystals and crystal masses of quartz. Dumps around the cross-cut on the north end are barren of hematite or quartz, except at the eastern end where loose quartz crystals that have weathered out of the dolomite are abundant. No minerals of interest to collectors were exposed on any of the walls or floor of the north–south nor east–west excavations. We are not aware of any documented specimens from this locality placed in institutional collections before the period of modern collecting that began in the 1980s.



Figure 3. Dodge mine looking north to the wall of the east–west cross cut as it appeared in September, 2008. SC.

Anhydrite (?) xl cavities: Crystal cavities in quartz up to 5 mm across and several cm long are occasionally encountered. These are always square or rectangular in cross-section and show no modifying faces. If orthorhombic, the forms are lateral pinacoids; if tetragonal, a simple prism. Anhydrite is a common original mineral elsewhere for cavities such as this [25], but since none of the cavities here contain any original mineral, there are other possibilities.

Calcite: Massive calcite enclosing hematite and quartz crystals is rare. Most calcite consists of late-stage transparent tan crystals to several centimeters that formed in open spaces. The common form is nailhead spar with the prism m{100} and the rhombohedron e{012} (Figure 4).



Figure 4. Calcite and iron-rich dolomite from the Dodge mine. The calcite crystal is 1 cm high. Chamberlain Collection, NYSM 11380. SC.

Dolomite: Tan dolomite forms large masses to the east of the hematite/quartz body that was mined. This dolomite is iron-rich with 8 mole % Fe as determined by SEM/EDS. Occasionally, cavities are lined with rhombohedral dolomite crystals to several mm. Dolomite also encases hematite/quartz in the main ore body (Figure 5), although most of it has weathered away.



Figure 5. Sawn surface showing tan dolomite encasing brown quartz with oriented layers of black hematite. Dodge mine. Field of view, 8 cm. Chamberlain Collection, NYSM 11380. SC.

Goethite: Goethite is largely a trace mineral in small millimeter-sized masses scattered throughout the locality. Sulfides, such as pyrite and marcasite, are found as trace minerals and probably produced minor goethite during weathering. The iron-rich dolomite only rarely shows replacement by spongy goethite.

Hematite: Judging from material found on the dumps, hematite ore consisted of coarse masses of black platy crystals to 2 cm (Figures 6 and 7), sometimes with quartz. The edges of these tabular crystals tend to be irregular without clear crystal faces. Microscopic crystals of specular hematite often occur as zones in quartz crystals (Figure 5). Bands of red hematite-colored crystalline country rock are occasionally encountered in the dumps, but this material probably did not constitute an important part of the ore that was mined and removed.



Figure 6. Hematite, Dodge mine. 11.2 cm. Chamberlain Collection, NYSM 41046. SC.



Figure 7. Hematite and goethite, Dodge mine. 10.9 cm. Chamberlain Collection, NYSM C5031. SC.

Quartz: Quartz is a common mineral in occurrence. It occurs as glassy transparent-to-white shards with Cumberland-habit crystals covering some surfaces. Very glassy crystals formed by the rhombohedra $r\{101\}$ and $z\{011\}$ with very minor lines around the girth of the crystal formed by the prism $m\{100\}$ are commonly associated with hematite crystals. These vary from colorless to white to smoky (Figure 8) to almost black. Isolated crystals to 2 cm and clusters of such crystals to 20 cm or more are commonly embedded in massive dolomite or weathered into the soil. Most of these crystals incorporated grains of dolomite during formation and have a spongy internal texture with pitted crystal faces from voids left by the dissolved dolomite.



Figure 8. Quartz and hematite, Dodge mine. 5.2 cm. Chamberlain Collection, NYSM C5010. SC.

3.4.2. Chub Lake Prospect

The Chub Lake prospect (44°19′56″ N, 75°21′34″ W) is near the boat launch on the northwest side of Chub Lake, off Chub Lake Road in the Town of Fowler. Hough described this as an important source of mineral specimens [11] (p. 694):

The mines of crystallized specular iron in Gouverneur, Fowler, Edwards and Hermon all afford splendid crystals. The iron mine near Chub Lake, in Fowler, afforded beautiful crystals, nearly transparent, and quite brilliant.

Mineral collectors have been aware of this locality for more than 150 years, and specimens, sometimes just labeled Fowler, have been present in institutional collections since the 19th century. Knowledge about the precise location was essentially lost by the 1980s. Chamberlain and Robinson [26] (p. 87) reported details of its contemporary rediscovery.

In 1983, in preparing for a lecture at the 10th Rochester Mineralogical Symposium, Steven C. Chamberlain and George W. Robinson visited the historic Oren Root Collection at Hamilton College and noted several outstanding hematite, quartz, and barite specimens labeled as being from Chub Lake. Later that year, Schuyler Alverson and George W. Robinson rediscovered the locality. Independently, Syracuse collector Ronald Waddell, tracked down the owner of Chub Lake—Max Tessmer—who knew about the old iron prospect on his property, and thereby also rediscovered the locality, sharing it with William P. Dossert, Steven C. Chamberlain, and William S. Condon. In 1983, the dumps appeared largely undisturbed since the 19th century. For the next twenty years, Chub Lake was a popular collecting site. Local collectors, Robert Johnson, Charles Bowman, Eric Edie, Vernon Phillips, and others visited the site frequently. The dumps were completely turned over and outcroppings of the mineralization were uncovered and directly exploited. Mineral clubs and collectors from far and wide visited the locality and collected specimens. Today the locality is again infrequently visited.

The southeastern side of a low hill, facing Chub Lake, has been prospected intermittently since the last century, exposing specular hematite ore. The exposure sits facing the lake behind a low ridge with a large swampy area between them. A large dump extended from the center of the exposure some distance to the southwest, which yielded many specimens. A smaller dump extended along the center of the exposure and northeast to the flank of the hill. To the southwest, the exposure was mostly specular hematite with vugs of well-crystallized hematite, occasionally with frosted white calcite crystals perched individually on the hematite. The center of the exposure dipped below the base of the dumps and exposed "veins" of quartz crystals and hematite crystals. Most of the barite crystals appear to have occurred in this portion of the exposure. To the northeast, individual and small clusters of quartz crystals were loose in the soil, having weathered out of massive calcite. At the base of the northeast end of the hill, at the level of the adjacent swamp, there were large pieces of massive specular hematite containing barite crystal cavities and quartz pseudomorphs after barite.

Barite: Crystals of yellow to golden-yellow barite to 3 cm are uncommon. These formed as late-stage mineralization in cavities lined with quartz and hematite crystals. Some barite crystals are sharp with prism faces $o\{011\}$ and $d\{102\}$ and lateral pinacoid $b\{010\}$ (Figure 9) with occasional smaller faces of other forms. Other crystals have irregular (e.g., $o\{011\}$) and frosted or stepped faces (e.g., $d\{102\}$ (Figure 10). Barite crystal cavities are present in massive specular hematite near the bottom of the exposure at the edge of the swamp. Some of these have been filled with later plumose grey quartz. Occurrences of barite and barite crystal cavities at the base of the Potsdam Sandstone have been previously reported [24].

Calcite: Massive white calcite with embedded single crystals and clusters of quartz forms most of the northeastern portion of the exposure. Massive calcite may also have originally filled the vugs of hematite and quartz crystals before being dissolved by weathering. Late-stage calcite crystals to more than 6 cm, often with frosted faces, occasionally occur in vugs of hematite crystals (Figure 11). The habit of these crystals is usually the scalenohedron v{615} terminated by the rhombohedron r{101}. Occasionally late-stage calcite crystals are composed only of the scalenohedron.



Figure 9. Barite and hematite, Chub Lake prospect. 3 cm. Alverson Collection, NYSM 20929. JS.



Figure 10. Barite, Chub Lake prospect. 2.3 cm. Chamberlain Collection, NYSM C12184. SC.



Figure 11. Calcite and hematite, Chub Lake prospect. 5.5 cm. Chamberlain Collection, NYSM C12216. MW.

Dolomite: Dolomite is relatively rare; however, small aggregations of massive dolomite occur in massive calcite on the northeast portion of the deposit. SEM/EDS analysis shows this to be iron-rich dolomite with 9 mole % Fe. Weathering has not produced any significant goethite.

Goethite: Goethite is largely a trace mineral in small millimeter-sized masses scattered throughout the locality. The paucity of iron-rich dolomite, and the absence of sulfides such as pyrite and marcasite, has resulted in the absence of significant secondary goethite.

Hematite: Massive specular hematite constitutes the largest volume of the occurrence. Cavities in massive hematite to 20 cm are densely lined with sometimes splendent blades of black hematite up to 2 cm. Some of these have indistinct edges, but others have sharp thin faces (Figure 12), probably the rhombohedra a{110} and r{3010}. In some cavities, the hematite blades form rosettes (Figure 13). Towards the center of the exposure, hematite blades are intermixed with Cumberland-habit quartz (Figure 14), sometimes occurring as minute inclusions in quartz crystals that occasionally protrude beyond the surface of the quartz crystals. Rarely, the coating of small hematite crystals so thickly covers quartz crystals so as to constitute encrustation pseudomorphs of hematite after quartz.



Figure 12. Hematite, Chub Lake prospect. 8 cm. Chamberlain Collection, NYSM C12234. SC.



Figure 13. Hematite, Chub Lake prospect. 9.1 cm. Chamberlain Collection, NYSM C5964. SN.



Figure 14. Hematite and quartz, Chub Lake prospect. 9 cm. Chamberlain Collection, NYSM C9492. SC.

Quartz: Quartz occurs as crystals lining vugs and as isolated crystals and crystal clusters embedded in massive calcite. Most of the quartz from the center of the occurrence has Cumberland-habit with the rhombohedra r{101} and z{011) forming bypyramidal appearing crystals always with a thin or very thin girdle formed by the prism m{100}. (Figure 15). Such quartz crystals range from colorless (Figure 16) to white to reddish purple to almost black and up to 4 cm. Inclusions of small hematite crystals and indistinct patches of hematite (Figure 17) and tan phantoms produced by included goethite are common (Figure 18). Occasionally elongated quartz crystals of prismatic habit or very elongated, nearly acicular, crystals have been encountered. Quartz embedded in massive calcite or weathered free into the soil has the same range of colors and habits, but has a spongy texture (Figure 19) caused by small grains of calcite that were included within the crystal during formation and have subsequently weathered away.



Figure 15. Quartz and hematite, Chub Lake prospect. 2.7 cm. Chamberlain Collection, NYSM C5935. SN.



Figure 16. Quartz, Chub Lake prospect. 3 cm. Chamberlain Collection, NYSM 12183. SC.



Figure 17. Quartz with hematite inclusions, Chub Lake prospect. Field of view, 10 cm. Chamberlain Collection, NYSM 12191. SC.



Figure 18. Quartz and hematite, Chub Lake prospect. 7.1 cm. Chamberlain Collection, NYSM C4371. MW.



Figure 19. Spongy quartz, Chub Lake prospect. Note voids caused by dissolution of enclosed calcite and prismatic habit of crystals. 8.7 cm. Chamberlain Collection, NYSM 35967. SC.

3.4.3. Toothaker Creek Prospect

The Toothaker Creek prospect (44°12′09″ N, 75°18′30″ W) is a small pit on the southern flank of Cooper Hill, east of Garrison Road in the edge of the Toothaker Creek State Forest, in the Town of Pitcairn. There seems to be no mention of this locality in the literature and no documented specimens in institutional collections before contemporary collecting commenced in the early 1980s. The locality appears to have been discovered by Buck Brissette, a local mineral collector who was trapping along the southern flank of Cooper Hill in the 1960s. In 1982, working from vague directions provided by Brissette, William S. Condon and Steven C. Chamberlain discovered and first began collecting at the site, and intermittent collecting has proceeded at a low level thereafter.

There are several shallow prospects dug in an east–west line south of Cooper Hill, but only one shows any mineralization. The crystallized hematite, quartz, barite, and goethite has been found as loose chunks downhill from a shallow pit. Everything collected at this site has been found as pieces in loose soil and glacial sand. No hematite was present in the floor or walls of the pit. The small original showing of iron ore seems to have been broken up and dumped down the hill.

Barite: Barite occurs sparingly as crystals on hematite, although occasionally an isolated aggregate of barite crystals has been found. The crystals are white with thin tabular habit made up of a large basal pinacoid c{001} modified by the prisms o{011}, d{102}, and m{110}. They are usually smaller than 1 cm.

Calcite: White massive calcite probably filled the centers of crystal-lined cavities at this locality, but almost all of it has weathered away, and remnants with rounded weathering surfaces are only rarely encountered.

Goethite: Goethite occurs with hematite crystals as smooth brown spheres to several millimeters. Dense botryoidal clusters of these spheres are occasionally found (Figure 20). On broken surfaces, these spheres show a texture of radial crystals typical of primary goethite rather than a replacement texture.

Hematite: Black, specular hematite is the major constituent of the occurrence; red hematite is rare. Splendent tabular crystals line cavities to 20 cm or more. The edges of such crystals are irregular, and some form rosettes (Figure 21). Hematite often forms the lining of vugs filled with quartz crystals.

Quartz: Essentially all of the quartz crystals are of the Cumberland-habit. Crystals are rarely isolated, but form druses with individual crystals usually smaller than 1 cm in cavities to 15 cm. Most crystals are transparent and lustrous (Figure 22). Many are colorless, but some lavender specimens of pale amethyst are occasionally encountered (Figure 23).







Figure 21. Hematite, Toothaker Creek prospect. 10 cm. Chamberlain Collection, NYSM 11650. SC.



Figure 22. Quartz and hematite, Toothaker Creek prospect. 13 cm. Chamberlain Collection, NYSM 14201. SC.



Figure 23. Quartz, variety amethyst, Toothaker Creek prospect. 5 cm. Chamberlain Collection, NYSM C7032. SN.

3.4.4. Bowman Prospect

The Bowman prospect (44°25′12″ N, 75°17′14″ W), is northwest of Kents Corners on Rock Hollow Road in the Town of Hermon. This locality seems not to have been specifically mentioned in the literature. The site was discovered in the early 1990s when the family of local collector Charles Bowman bought the parcel of land containing the iron ore outcrop to build a hunting camp.

When first visited in 1991, the locality consisted of a linear array of red and black hematite ore and quartz crystals in vugs and seams. The country rock seems to be largely Grenville Marble.

Calcite: Massive white calcite that filled the centers of crystal-lined cavities has largely weathered away.

Dolomite: Rarely, small clusters of typical curved tan dolomite crystals occur.

Goethite: Stains and thin coatings of goethite have formed from weathering.

Hematite: Significant quantities of both massive red and massive black specular hematite occur. Tabular black hematite crystals to several mm line cavities.

Quartz: Quartz crystals, often with small black hematite crystals as inclusions, are common (Figure 24). Some quartz crystals have bright red hematite phantoms (cherry quartz) often with a later generation of colorless quartz (Figure 25). Crystals are colorless to white excluding inclusions. Some have the Cumberland-habit, but others have elongated prism faces.



Figure 24. Quartz, hematite inclusions, Bowman prospect. 8 cm. Chamberlain Collection, NYSM C4662. SC.





3.4.5. Whitton Prospect

The Whitton prospect (44°12′57″ N, 75°20′06″ W) is near Lost Pond, north of Stone Road and Geers Corners in the Town of Pitcairn. There seem to be no preserved specimens nor mention in the literature. Evidence at the site suggests that around 1900 a machine-dug, square shaft was sunk at a small angle from vertical in the middle of numerous old hand-dug pits. Excavation was stopped after only a few tens of feet when the bottom of the ore was reached. Everything removed appears to have been dumped downhill from this shaft. In the 1990s, a natural gas pipeline was installed through the area, and the cleared right-of-way came within a few feet of the hematite exposures. Mineral collector Michael Whitton, whose family owns a hunting camp and preserve, discovered the locality as he was exploring the right-of-way along the side of the preserve farthest from the camp. Whitton arranged a mineral club field trip in June of 1992, and for a decade the site was popular with local collectors. Now the access road is overgrown and the site is hard to find.

In 1992, dumps extended from the shaft downhill to the access trail. Several shallow hand-dug pits were to the right of the adit. Veins of crystallized quartz and hematite were present along the top of the hill and part way down the hill to the access trail on the right of the shaft.

Barite: Prismatic barite crystals with pinacoid and prism faces up to 7 cm were found in pockets between the old shaft and the new right-of-way. The crystals are transparent with included veils and range from pale tan to pale blue in color. Smaller white barite crystals on specular hematite were occasionally encountered in the dumps from the shaft.

Calcite: Rhombohedral white calcite crystals smaller than 1 cm were occasionally encountered. Much of the original calcite, if any, in the deposit has probably weathered away.

Dolomite: Most of the specimens of coarse black hematite crystals from the shaft were thickly covered by a layer of rhombohedral carbonate, now completely replaced by goethite. In cavities, individual rhombohedral crystals have typical carbonate crystal forms. Most often surfaces of the altered carbonate have sharply-formed, interlocked crystal shapes that range from yellow-orange through reddish brown to almost black. All of dozens of specimens tested were goethite. The original carbonate was probably iron-rich dolomite or siderite or a combination of these.

Goethite: Goethite is abundant as an alteration product of a carbonate that formed between plates of hematite. The surfaces of this pseudomorphous material are often covered with drusy crystals that are lustrous, sometimes with iridescence (Figure 26); however, inside the texture is spongy, even earthy. There appears to be no primary goethite.



Figure 26. Goethite pseudomorphs after iron-rich dolomite, Whitton prospect. Field of view, 3 cm. Chamberlain Collection, NYSM 41317. SC.

Hematite: Most of the hematite removed from the shaft is specular with tabular crystals to 2 cm lining curved, almost stalactitic surfaces. These black blades, however, are virtually always covered with space-filling carbonate, now altered to goethite, so that hematite crystals are only visible on broken surfaces. In older, hand-dug shallow pits adjacent to the shaft, the massive hematite is red and sometimes earthy.

Quartz: Quartz was an uncommon accessory mineral in the portions of the occurrence removed by sinking the shaft. Above and to the right of the shaft, however, lenticular pockets of quartz on a matrix of specular hematite or red hematite are common. Much of the quartz has Cumberland-habit, and some of this has phantoms of red hematite (cherry quartz). Other quartz formed white to colorless elongated prisms, sometimes with black hematite crystals (Figure 27). Most of the quartz crystals are sharp and lustrous, but rarely exceeded 1 cm in size.



Figure 27. Quartz and hematite, Whitton prospect. Field of view, 7 cm. Chamberlain Collection, NYSM 11651. SC.

3.4.6. Toothaker Pond Prospect

The Toothaker Pond prospect (44°12′18″ N, 75°17′29″ W) is west of Fullerville Road at Toothaker Pond in the Town of Pitcairn. This is a newly discovered specular iron occurrence. In the summer of 2015, Donald M. Carlin, Jr., a local mineral collector, was prospecting for ginseng along the sides of Cooper Hill when he found a shallow pit near the western end next to Toothaker Pond. Large pieces of solid specular hematite to nearly 100 lbs with crystal-lined cavities were scattered around the pit. It appears that the surface showing of iron mineralization was broken up at some time in the past and just dumped around the excavation.

Calcite: Massive calcite likely filled all the crystal-lined cavities in massive specular hematite, but almost all of it has weathered away. Very rarely relict small masses of white calcite are found with hematite and quartz in cavities.

Goethite: Lustrous black crystallized goethite is relatively common in cavities with quartz crystals and platy hematite. It forms aggregates of prismatic black crystals, as well as hemispheres and partial hemispheres that show a texture of terminal faces on the surface (Figure 28). The largest aggregates are up to 2 cm.



Figure 28. Goethite and hematite, Toothaker Pond prospect. Field of view, 5 cm. Chamberlain Collection, NYSM 35866. SC.

Hematite: Except as red phantoms in quartz crystals, only specular hematite occurs at this locality. Many of the cavities, up to 15 cm, in massive specular hematite are lined with tabular hematite crystals up to 1 cm with splendent main faces and irregular edges, sometimes intermixed with quartz crystals and goethite crystals and hemispheres.

Quartz: Most quartz occurs as colorless crystals of Cumberland-habit, lining cavities in massive specular hematite. More rarely, quartz crystals contain internal phantoms of red hematite with a colorless external layer (cherry quartz). All of these crystals are smaller than 1 cm. Very rarely, masses of grey to black chalcedony to 8 cm, associated with crystallized quartz and hematite, have been encountered.

4. Discussion

4.1. Origin

None of these small specular hematite deposits are particularly earth-shattering in their importance, and only one of them (the Dodge mine) seems to have produced any useable iron ore. However, these small, scattered patches of specular hematite seem to be a consistent feature at the unconformity between Precambrian and Paleozoic in parts of the southern Grenville Province and thereby merit at least some description and analysis.

Our stable oxygen isotope data has established the temperature of formation to be around 172 °C. The two major minerals, hematite and quartz, crystallized or recrystallized at elevated temperature along the unconformity between Precambrian crystalline rocks and upper Cambrian Potsdam Sandstone.

In the absence of detailed study of any of these hematite deposits, the conventional wisdom has been that they formed in dissolution cavities in the Grenville Marble from the actions of mineralized groundwater flowing along the unconformity [26]. The details of how this occurred are uncertain. On the basis of the results of the present study, we note two observations that seem inconsistent with conventional wisdom. First, some of the occurrences do not occur on the Grenville Marble necessary to have formed dissolution cavities. Second, examination of the local geology at all six sites shows no evidence of Potsdam Sandstone.

There are, however, regional examples of crystallized specular hematite and quartz hosted directly in the Potsdam Sandstone (e.g., the Pierrepont Iron Rose locality, 44°30′46″ N, 75°01′05″ W). None of these other occurrences appear to include beds of specular hematite.

We present two hypotheses to guide future research into the origin of Chub Lake-type hematite deposits.

4.1.1. Hypothesis 1

Low temperature hydrothermal solutions, containing dissolved iron and silica, migrated along the unconformity and precipitated specular hematite and quartz in solution cavities formed in the Basal Unit of the Potsdam Sandstone at places of low topography of the unconformity. The underlying Precambrian crystalline rocks formed an effective confining layer that enabled such hydrothermal activity to proceed over an adequate length of time to form localized beds of specular hematite up to several 10s of meters thick. This would have occurred when the overlying thickness of Potsdam Sandstone produced appropriate elevated temperatures.

4.1.2. Hypothesis 2

During the period of the unconformity, localized deposits of iron oxides, probably red hematite, formed in depressions in the Precambrian surface from chemical precipitation or bacterially mediated precipitation or both. As such, these deposits may be vaguely analogous to bog iron deposits of hematite [20]. The resulting deposits would have been conformable with the overall surface of the Precambrian crystalline rocks. As the Potsdam Sandstone began to accumulate, groundwaters would have flowed continuously along the top of the Precambrian surface. When the burial depth was sufficient to raise the temperature to around 172 °C, these groundwaters caused recrystallization of pre-existing hematite to specular hematite and dissolved silica to euhedral quartz crystals.

4.1.3. Evaluation of Hypotheses

Hypothesis 1 has the simplicity of not invoking an iron concentrating and precipitating process acting during the period of the unconformity on the Precambrian surface. The source of the iron and quartz could have been leaching and transport from the Basal Member of the Potsdam Sandstone. On the other hand, hypothesis 1 requires the formation of solution cavities in a quartz-cemented, quartz-grain sandstone to make space for the hematite and crystallized quartz. The dissolution of the base of the Potsdam Sandstone would have to have been complete, as no relict masses of quartz sandstone have been observed in any of the hematite occurrences. Invoking low-temperature hydrothermal solutions to precipitate a mixture of red hematite and specular hematite in the same deposit might require variability in the nature of the hydrothermal solutions, including temperature. Finally, masses of hematite/quartz precipitation seem to be restricted to the dips in the Precambrian surface and are not typical features of the unconformity elsewhere.

Hypothesis 2 has the advantage of not requiring the low-temperature hydrothermal groundwaters to produce solution cavities, since the iron oxide deposits were already in place before deposition of

the Potsdam Sandstone began. The main role of the hydrothermal solutions was to recrystallize what was already there into specular hematite and euhedral quartz. This process could have preserved the cavities and stalactitic textures formed at the surface. However, the observation of barite crystal cavities in the specular hematite at the base of the specular hematite mass at Chub Lake is problematic, since the source of the barium otherwise is presumed to be the limited abundance of barite crystals in the bottom of the Basal Member of the Potsdam Sandstone [24], which could have been remobilized and deposited as crystals on hematite and quartz at Chub Lake and Toothaker Creek.

Now that the basic geology and mineralogy of six specular hematite deposits have been established, we intend to determine what trace minerals and elements are present in the specular hematite and primary goethite, where present, at each of the deposits. This will reveal how much regional variability may be present in the trace chemistry of these deposits. In addition, we plan to perform the same analyses on hematite at sites that are clearly hosted in the Potsdam Sandstone. Significantly different fingerprints of these two categories might then permit future investigations to sort out which deposits at the unconformity predated the Potsdam Sandstone and which formed after the Basal Unit of the Potsdam Sandstone had been laid down.

4.1.4. Final Comments

Both hypotheses presented above depend on the conversion of red hematite into specular hematite under the temperature conditions determined by out stable oxygen isotope data. That this is reasonable can be easily demonstrated by producing flocculent red hematite by precipitation in water, heating the mixture to boiling for a period of time to reduce the amount of water, and then inspecting the residue, which will be found to have minute crystals of black specular hematite. Many exposures of red hematite just above the unconformity in the region show thin layers of specular hematite as though the conversion by low-temperature hydrothermal solutions had begun but not gone to completion. The Whitton prospect and the Bowman prospect also show this partial conversion.

Finally, the presence of primary crystallized goethite on specular hematite at Toothaker Creek and Toothaker Pond suggest that the conditions of precipitation or recrystallization must have varied somewhat across the array of specular hematite occurrences.

4.2. Other Ore Deposits in the Adirondack Lowlands

The other significant iron deposits in the region are the hematite mines of the Antwerp-Keene belt that extend from southern St. Lawrence County along a line into Jefferson County. The ore bodies are largely red hematite with lesser amounts of specular hematite. They are much larger and have far more complicated mineralogy than the Chub Lake-type hematite deposits, including major gangue minerals such as stilpnomelane and trace minerals such as millerite. Moreover, they formed after the deposition of the Potsdam Sandstone [3].

The Rossie-type lead veins were a useful source of lead in colonial times, but are small by modern standards. They are fracture-filling deposits in nearly vertical fractures in both Precambrian and Paleozoic rocks [2].

The most commercially significant ore deposits in the region occur in the Balmat District [1]. Both talc and zinc were mined in large quantities in the 19th and 20th centuries. The talc occurs in a particular layer of a Precambrian metasedimentary sequence and found particular use as a filler in paper beginning before the American Civil War. The zinc sulfide ores are sedimentary exhalative deposits in a Precambrian metasedimentary sequence and were exploited from the early 20th century, continuing into the present.

None of these ore deposits are associated with the Precambrian-Paleozoic unconformity.

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