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The Mineralogy of Warsaw Formation Geodes

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Abstract. Mineral inclusions found in geodes from the Warsaw formation of southeastern Iowa are described. The following are reported as present: quartz, chalcedony, calcite, dolomite, ankerite, barite, aragonite, smithsonite, iron pyrite, marcasite, chalcopyrite, sphalerite, sulfur, goethite, hematite, pyrolusite, kaolinite, malachite, selenite, and limonite. Tenorite and chalcocite have been tentatively identified.

The geodes found in the Warsaw formation of southeastern Iowa and adjacent areas present a number of interesting mineralogical inclusions, many not previously described in the literature. For the past ten years an intensive study has been made of the mineral inclusions found in geodes collected from thirty-two different exposures in the Keokuk, Iowa, area. To date, the author has conclusively identified nineteen different mineral inclusions and tentatively five others, all new.

Some of the mineral inclusions, such as the capillary marcasite and capillary iron pyrite, have been mistaken for millerite, blue barite for celestite, and brown rhombic calcite for fluorite. Other mineral inclusions observed in geodes have never been described, or are inadequately described. This paper will attempt to describe accurately all the known mineral inclusions found in the Warsaw formation geodes.

Quartz

The most abundant mineral of the Warsaw geodes is quartz. It is the primary constituent of the shells and is generally well crystallized. The commonly observed color of the quartz crystals is milky-white, although water-clear crystals, measuring to one and one-half inches, are often present. Some water-clear crystals contain light-brown feathery inclusions, giving a "phantom" aspect. Rarely observed are crystals of a deep smoky-amber color. Various shades of red, brown, yellow, black, and light green discolorations of the quartz, due to different oxidation states of included iron compounds, have been observed, particularly in badly weathered geodes. Some observers have reported amethyst quartz, but closer examination proved the quartz to be of the smoky variety. To date, the author has not observed amethyst-type quartz in the Warsaw geodes.

The quartz crystals are usually crowded together so that only the hexagonal pyramidal terminations are exposed inside the geodes.

However, at certain localities, the hexagonal prism will predominate, terminated by the hexagonal bipyramid of the first order. The pyramid habit is rare. When present, the positive rhombohedron is greatly enlarged, thus giving the crystal a pseudo-cubic aspect. On exceptional crystals, alternate prism faces are lacking. Crystals of the pyramid habit are exceptionally brilliant and are not marred by triangular configurations on the pyramid faces. Crystals with prism faces are generally horizontally striated with the pyramid faces marred by the triangular configurations. Some geodes are filled with thousands of tiny, sugar-like granules of quartz crystals. These quartz crystals are rarely elongated. When elongated, they include a stalagtitic core of chalcedony.

Chalcedony

Chalcedony is commonly found with the crystallized quartz in the geode shells. At several geode localities, however, the shells are wholly composed of, and the interiors lined with, orbs of chalcedony measuring up to an inch in diameter. The chalcedony assumes imitative shape—botryoidal knobs, mammillary structures, stalagtitic forms, and encrusting pseudomorphic forms after other minerals. Quartz crystals are commonly observed to be encrusted with chalcedony. Chalcedony pseudomorphs after fluorite have been reported in Warsaw geodes, but closer examination of the material proved it to be a coating of chalcedony on rhombohedral faces of quartz crystals.

The chalcedony is commonly color-banded, pale blue to blue-gray. Milky-white has been observed at several localities, but this is restricted to geodes containing quartz crystals with the pyramidal and pseudo-cubic habits. Some such chalcedony peels off along the banding like onion rings.

In badly weathered geodes, the chalcedony is generally stained brown to yellow due to oxidation of iron sulfides. A black stain usually indicates an oxide of manganese or iron.

Calcite

Calcite displays more variations than any other inclusion of the Warsaw geodes. At certain localities, ½-inch acute pink scalenohedrons, in combination with large dark-brown cuboid rhombohedrons, are common. The largest cuboidal crystals observed were 2 inches across. At other localities, colorless calcite scalenohedrons terminated with obtuse rhombohedrons and measuring up to 4 inches along the C-axis are phantomed with pink scalenohedrons. Possibly the largest single crystal of calcite recorded in the Warsaw geodes measures 3 inches along the horizontal axes and 3 inches along the vertical axis. Parallel growths of merged-together individual crystals are frequently found. Very commonly, crystals of

different periods of formation and of unlike habit may be overgrown in parallel position. Rhombohedral crystals may thus cap crystals of scalenohedral or other acute habits, or the earlier-formed crystals may be entirely enclosed and rendered visible by films of impurities such as marcasite, iron pyrite, or light brown, cellophane-like material of unknown composition. At several localities single flat rhombohedrons occur; but, in other places, they are present as curved composite crystals, typical of dolomite. Earthy to mealy crusts of calcite may occur as deposits lining the interior of the geodes; these usually fluoresce greenish-yellow to white and may phosphoresce for a short period. This prosphorescent type is usually soft and friable and may be stained brown, yellow, or black, due to oxides of iron and manganese.

Dolomite

The dolomite occurs as light-pink to rose-red pearly aggregates of saddle-shaped crystals. Pure white crystals have been found infrequently, and are always extremely small, measuring at most 2 millimeters across. Saddle-shaped crystals measure up to 10 millimeters. Upon extensive weathering, the ferroan dolomite assumes a very dark-brown color. A transitional series is believed to occur, from iron-free dolomite through ferroan dolomite to ankerite. Beautifully formed limonite pseudomorphs after dolomite are commonly found.

Ankerite

The ankerite occurs as light to dark brown, curved, saddle-shaped crystal aggregates. The luster is usually dull, although a greasy luster has been observed in isolated instances. Size of the crystals is the same as that of dolomite. The ankerite and dolomite are often found together in the same geode.

Barite

In the Warsaw geodes, barite always occurs well crystallized in thin to thick tabular crystals. Rosette-like aggregates of tabular crystals are also common. The usual colors are sky-blue through white. The blue crystals are always zoned with white along the margins. A reverse color position has been noted in the white crystals. Pale green crystal aggregates have been observed in a single geode, but this color is believed to be highly unusual. At one isolated locality, geodes containing light yellow, highly complex crystals of barite measuring up to 3 inches across are found. The largest crystals of blue barite measure 1 inch across.

Aragonite

Aragonite occurs as white crusts, divergent submacroscopic fibers, or stellate groups of acicular crystals. In the more massive forms, the aragonite exhibits a radially fibrous structure. Under long-wave

ultraviolet, the aragonite fluoresces and phosphoresces greenish-yellow; under short-wave ultraviolet, greenish-white to blue-white. Pale rose has been observed under long-wave, but this is rare.

Celestite

The occurrence of blue celestite has been reported, but close examination proved the material to be barite.

Smithsonite

Smithsonite is exceedingly rare, only one specimen having been observed by the author. The smithsonite is in the form of a greenish-yellow botryoidal crystalline incrustration lining the geodes. The crust thickness averages ¼ inch. It is assumed the smithsonite was derived from the alteration of sphalerite, which is found abundantly in the Warsaw geodes.

Iron Pyrite

Iron pyrite occurs most commonly as cubic crystals measuring up to 10 millimeters, and often as cubes modified by the octahedron. Less commonly, the crystals are pyritohedral. The pyritohedral faces are, in many cases, striated and duller than the cube faces. Usually, the pyrite is tarnished red or with iridescent colors. Limonite pseudomorphs are rather common. Contact twinning has been observed in several specimens. At one locality, the pyrite is in the form of capillary crystals up to ½ inch long. In some examples, these capillary crystals have grown normal to other capillary crystals of iron pyrite. These crystals have been mistaken for millerite by others. Pyrite may also be found implanted on the rhombohedron faces of quartz, as stacked cubes on dolomite or ankerite, on chalcedony, as phantom inclusions in calcite, or as oriented growths with capillary marcasite.

Marcasite

Marcasite is found as striated, singly bladed or divergent, capillary crystals measuring up to 25 millimeters. Generally the marcasite has been replaced by brown limonite pseudomorphs. Rarely the marcasite occurs as brilliant metallic, tin-white, or iridescent crystals. Twinning is quite common, the crystals crossing at an angle of nearly 60 degrees. Much marcasite is oriented with iron pyrite, either penetrating diagonally or terminated by the latter mineral. The marcasite is most frequently found associated with rhombic calcite, dolomite, blue barite, and sphalerite. In some cases, the marcasite penetrates the quartz crystals lining the geodes or is directly implanted on botryoidal chalcedony. At several locations, the marcasite has been observed to form the "phantom" inclusions in scalenohedral calcite crystals.

Chalcopyrite

Chalcopyrite has been infrequently observed in the Warsaw goedes. It occurs as typical sphenoids of a dull, rarely brilliant, luster, with crystals measuring to 2 millimeters. Usually, the crystals are superficially oxidized to malachite, or chalcocite, and possibly the melaconite variety of tenorite. Associated with the chalcopyrite are quartz, white barite, iron pyrite, and dolomite. Chalcopyrite has been found oriented with sphalerite. One specimen was observed having the chalcopyrite crystals implanted on botryoidal chalcedony.

Sphalerite

One of the more spectacular mineral inclusions in the Warsaw geodes is the marmatite variety of sphalerite, the only variety which occurs. It is present as black, splendent, complex to distorted crystals, measuring up to 3 inches across. Cleavage masses of sphalerite over a foot across have been found. Octahedral and dodecahedral crystals have been identified. Usually associated with the sphalerite are blue barite, dolomite, kaolinite, quartz, calcite and marcasite. The sphalerite is usually implanted directly on the quartz crystals lining the geodes, but occasionally on botryoidal chalcedony. The sphalerite contains oriented inclusions of chalcopyrite in places, or rarely may be partially encrusted with sulfur crystals. An encrusting pseudomorph of smithsonite was observed in one geode.

Millerite

To date, no millerite has been observed. Both the capillary iron pyrite and the capillary marcasite have been mistaken for this mineral.

Galena

Some observers claim to have found galena in the Warsaw geodes, but closer examination has proven the mineral to be either sphalerite or oxidized pyrite.

Sulfur

Beautiful lustrous yellow-green sulfur crystals occur infrequently. They are always found as complex forms measuring up to 1 millimeter. Disphenoids have been identified. The sulphur is found on altered sphalerite or iron pyrite in weathered geodes.

Goethite

Most of the goethite occurs as black, single capillary crystals measuring up to 7 millimeters. In some occurrences, two or more crystals are found in sub-parallel positions and always associated with quartz crystals. Generally sulfide minerals are present in the same geode with goethite. This mineral has been mistakenly identified as rutile.

Hematite

Thin tabular obtuse rhombohedral crystals of hematite have been very rarely observed as dark blood-red crystals measuring up to 1 millimeter, brilliantly metallic in luster. They are always directly associated with quartz crystals lining the geodes. The more common occurrence of the hematite is as reddish to pink earthy coatings on calcite or quartz. One geode was under observation which had alternating red and yellow rings of hematite in pyramidal crystals of quartz.

Pyrolusite

Pyrolusite appears to be a common mineral inclusion. It occurs as subcrystalline aggregates on quartz crystals or as black dendritic patterns of submacroscopic size on rhombic calcite.

Fluorite

Dark brown pseudo-cubic crystals of calcite have been mistakenly identified as fluorite by some observers. To date, fluorite has not been identified by the author.

Kaolinite

A white flocculent material tentatively identified as kaolinite is commonly found associated with dolomite, sphalerite, blue barite and rhombic calcite.

Malachite

Deep green crusts of malachite are occasionally found on chalcopyrite crystals. Infrequently the malachite shows a sub-fibrous structure, or is present as submacroscopic spots on quartz crystals.

Tenorite

Dark-brown to black coatings found on chalcopyrite have been tentatively identified as the melaconite variety of tenorite, but further work is in progress for positive identification.

Chalcocite

Black vitreous coatings on chalcopyrite may be chalcocite. The material is being given further study.

Selenite

Clear elongated prisms of selenite occur quite commonly. They measure to 1½ inches in length, are sometimes coarsely striated, and are usually sharply terminated. The crystals are found as single prisms or as stellate or radial growths. Selenite is found implanted on chalcedony or quartz crystals and infrequently on calcite.

Limonite

Limonite occurs as earthy or loose coatings, iridescent or varnish-like stains on quartz crystals, or as sharp pseudomorphs after iron pyrite, marcasite and dolomite. Colors range from yellow-brown in the dull earthy material to rich red-brown in pyrite pseudomorphs. Limonite pseudomorphs after capillary marcasite are sometimes transparent.

Unidentified Mineral Inclusions

Two apparently new mineral inclusions in the Warsaw geodes have recently been observed by the author, and thus far the inclusions have not been positively identified. One of the inclusions occurs as microscopic, pale yellow, transparent fibers, believed to be the result of alteration of marcasite.

The other inclusions are black microscopic isometric crystals of octahedral forms. Work is being done on these two mineral inclusions.

Geode Zones

Intensive studies have shown that the geodes generally occur in four traceable zones immediately along the Mississippi River, in twenty of the thirty-two exposures examined. However, it appears impossible to trace these units westward beyond three or four miles because of bedding changes and changes in mineral suites. In the areas of traceable lithologic units, the geodes can also be traced by the mineralogical inclusions they contain. It is interesting to note that these traceable geode zones are generally interlayered with flattened, crushed, or otherwise deformed geodes, thus giving rise to speculation on origin. For a given geode zone, a general suite of minerals will be found consistently even though several of the exposures may be as much as twenty miles apart. However, the mineral suites generally differ for each geode zone, although some repetition has been observed.

A future paper will discuss the author's views on the origin, mode of formation, and the distribution of the Warsaw geodes.

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