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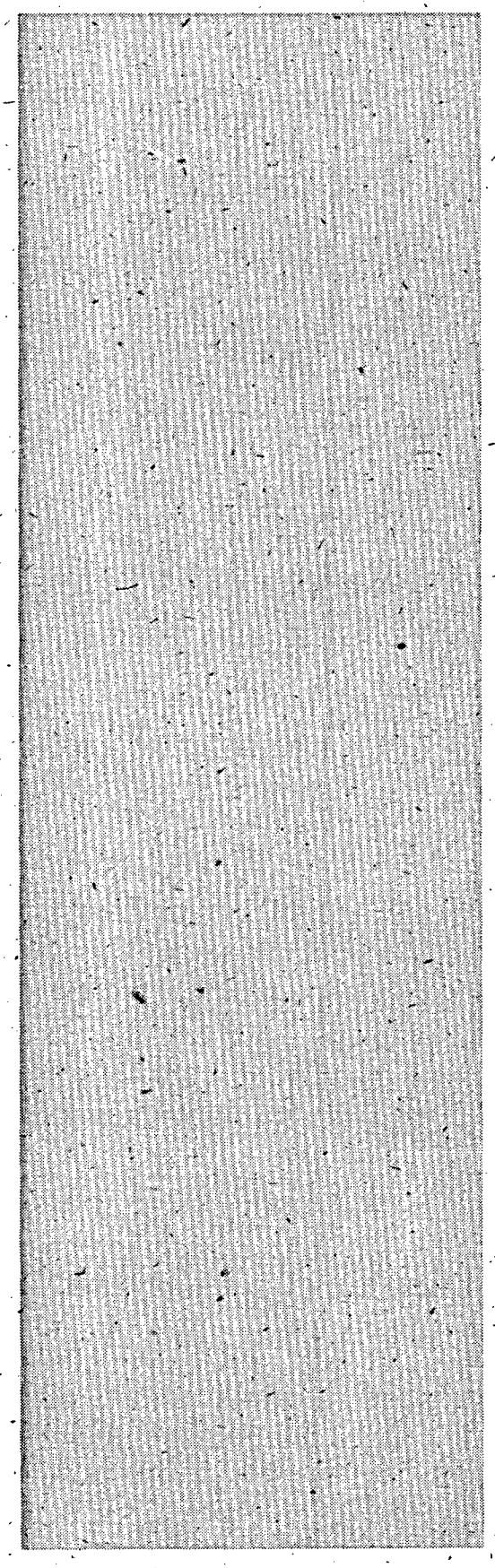

Field Guide to Fracture-Lining Minerals at Yucca Mountain, Nevada

Los Alamos
NATIONAL LABORATORY

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FIELD GUIDE TO FRACTURE-LINING MINERALS AT YUCCA MOUNTAIN, NEVADA

by

Barbara A. Carlos

ABSTRACT

This guide is intended to provide descriptions useful to those researchers who are logging core or mapping fractures with the aid of a hand lens or binocular microscope. Many minerals are fine-grained and cannot be distinguished at 10× magnification, but the information contained in this guide should at least allow the possibilities to be constrained. Although some of these minerals are more easily identified using hardness or acid tests, the descriptions do not include information on hardness or response to acid because scratching and use of acid on core are not permitted at the drill site or in the sample management facility. Because these descriptions are intended for use in the field, they are organized by visual properties rather than by mineralogy or chemistry. Five primary groups are used, and individual minerals are discussed within the visual-characteristic groups.

TABLE I

White or clear, visible crystal morphology at 1-25×
- Silica Polymorphs
  - tridymite
  - quartz
- Zeolites
  - stellerite
  - heulandite/clinoptilolite
  - mordenite
  - analcime
  - chabazite
  - phillipsite
- Calcite
- Fluorite

White or clear with no visible crystal morphology
- Silica
  - opal
  - cristobalite
  - quartz
- Clays
  - palygorskite
  - sepiolite
  - smectite
- Zeolites
  - mordenite
  - erionite
- Calcite

Colored minerals with visible crystal morphology
- Fluorite (purple)
- Amphibole (yellow-orange to brown)

Colored minerals with no visible crystal morphology
- Opal (bluish)
- Mordenite (bluish)
- Sepiolite and palygorskite (yellowish)
- Smectite
- Illite (green)
- Hematite (rusty red)

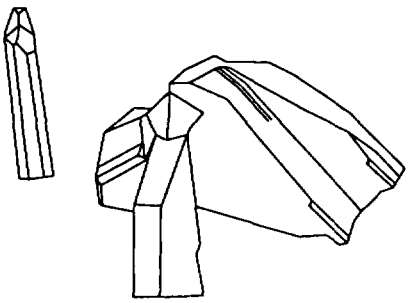
Black minerals, with or without visible crystals
- Manganese oxide minerals
- Hematite (blades)
- Garnet

WHITE OR CLEAR CRYSTALS

Silica Polymorphs

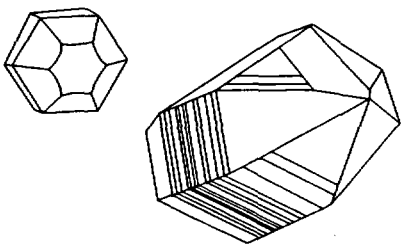
Tridymite

Tridymite crystals (usually < 1 mm across) occur as vapor-phase coatings in lithophysal cavities and in fractures associated with lithophysae. Cristobalite or quartz may form pseudomorphs after tridymite, but this is not evident in hand sample. Tridymite usually displays a characteristic twinning, and more rarely occurs as single crystals. Crystals may be milky white, clear, or (rarely) zoned; intergrown crystals may include both clear and white individuals. Crystals are usually oriented perpendicular to the surface of the fracture or cavity (Plate 1).



Quartz

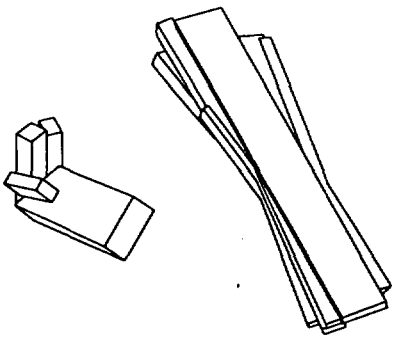
Euhedral quartz crystals may occur with or in place of tridymite. Euhedral quartz crystals also occur as singly- or doubly-terminated crystals in fracture coatings that are not of vapor-phase origin. Quartz crystals may be single or form sprays or rosettes. Crystals may have any orientation, including flattened crystals parallel to the surface of the fracture. Quartz crystals are usually clear, but they may be stained reddish with hematite or may approach opaque white in color.



Zeolites

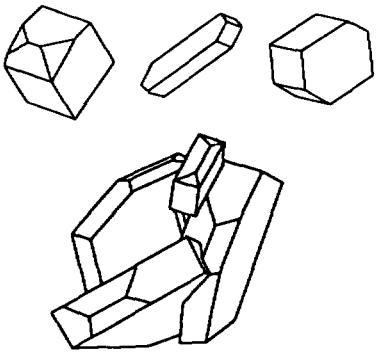
Stellerite

Stellerite occurs as clear prismatic crystals that resemble beams of lumber, with flat terminations perpendicular to the length of the crystal. Stellerite may be present as randomly oriented single crystals or in sprays or rosettes of crystals. Although some crystals are large enough to identify with a hand lens, others are identifiable only at 25×, and some cannot be visually distinguished from heulandite/clinoptilolite. In these cases, only reflective faces are visible with a hand lens, and identification must be made by X-ray diffraction (XRD) or by scanning electron microscope (SEM) with energy-dispersive chemical spectra.



Heulandite/clinoptilolite

Heulandite and clinoptilolite are isostructural and cannot be distinguished in hand sample. Previous analyses of drill cores have shown that heulandite occurs in fractures in the Paintbrush Tuff and clinoptilolite is the dominant isomorph in tuffs below that. Heulandite and clinoptilolite occur as prismatic crystals with inclined terminations or as six-sided tabular crystals. The tabular crystals are easily identifiable with a hand lens. Prismatic crystals may be large enough to be visually identifiable or may be visible only as reflective faces indistinguishable from stellerite. Both forms are usually clear or, more rarely, cloudy white.

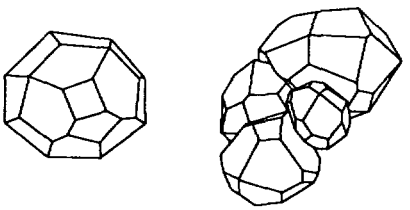


Mordenite

Mordenite occurs as mats of fibrous crystals. Sometimes these crystals are large enough to resemble white fur or cotton batting. When the crystals are large enough to see, they are white when dry, but may appear clear or translucent when wet.

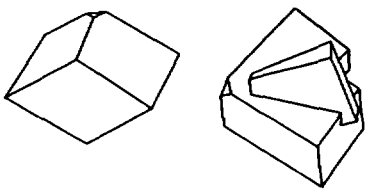
Analcime

Analcime occurs as white or clear crystals in the deeper, more altered (usually greenish) intervals of the Crater Flat Tuff. It has not been identified above the Crater Flat Tuff at Yucca Mountain. The trapezohedral crystal habit distinguishes it from other white to clear minerals (Plate 2).



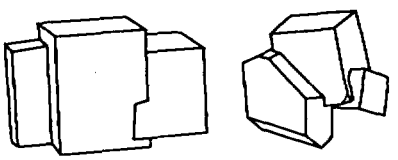
Chabazite

Chabazite forms pseudo-isometric crystals that are often intergrown. It has been identified so far only from fractures below the water table, and is present as clear crystals < 50 μm in diameter in the single fracture on which it has been visually identified in SEM images. Other occurrences have been identified by XRD only.



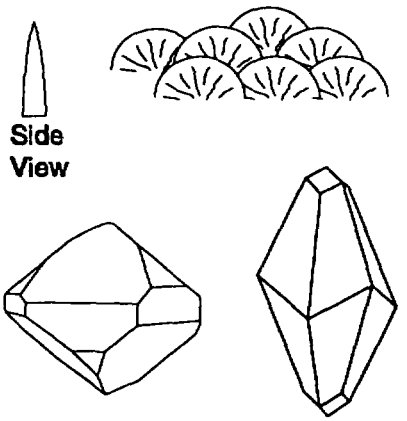
Phillipsite

Phillipsite occurs as clear to grayish blocky crystals that resemble chabazite in the only fracture so far examined that contains visible crystals of this mineral. The crystals form small ring-like aggregates. Identification has been by XRD, and all occurrences identified to date have been limited to the basal vitrophyre of the Topopah Spring Member.



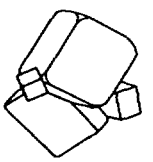
Calcite

Calcite occurs as bladed crystal aggregates, as blocky modified rhombs, and as sparry calcite with no visible crystal morphology but usually with distinctive rhombohedral cleavage. Calcite may be clear, white, or yellowish. Bladed calcite is most abundant in fractures and lithophysal cavities of the lithophysal zones of the Paintbrush Tuff. Modified rhombs of calcite may also be present in these intervals. Calcite is also abundant in some intervals of the Crater Flat Tuff, where it is usually sparry. Calcite may occur in fractures in other intervals (notably in and immediately above the basal vitrophyre of the Topopah Spring Member of the Paintbrush Tuff), but it is less common than in the first two mentioned intervals.



Fluorite

Although fluorite usually occurs as purple cubes, fluorite crystals also may be clear or slightly grayish translucent. See "fluorite" in the section for colored minerals with visible crystal morphology.

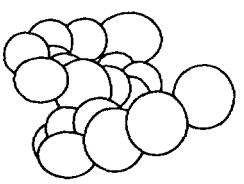


WHITE OR CLEAR WITH NO VISIBLE CRYSTAL MORPHOLOGY

Silica

Opal

Opal is easily identifiable as translucent, white, or faintly bluish botryoidal clusters. Individual balls are often 1–2 mm in diameter. Opal commonly occurs with calcite in the Paintbrush Tuff. It usually fluoresces greenish-yellow in short-wave ultraviolet light and can be identified by its fluorescence even when it is covered by calcite. Opal also occurs as thin translucent bluish coatings in the vitrophyres of the Paintbrush Tuff, but it cannot be positively identified without XRD analyses.



Cristobalite

Cristobalite occurs as pseudomorphs after tridymite and opal (the botryoidal form of opal becomes a bit bristly). It also forms very small acicular aggregates that appear as a white powdery coating at less than about 2000× magnification. XRD analysis is required for the positive identification of cristobalite.

Quartz

Quartz forms solid granular fracture fillings that may be white, clear, or stained red-brown by hematite. It can be identified by its hardness.

Clays

Palygorskite

Palygorskite occurs as white or yellowish crusts on fractures in the Paintbrush Tuff and can be distinguished from other clay minerals and from mordenite only by XRD.

Sepiolite

Sepiolite also occurs as crusts on fractures in the upper portion of the Paintbrush Tuff, may be white or yellowish, and can be positively identified only by XRD.

Smectite

Smectite is the most abundant clay mineral at Yucca Mountain. It usually forms white crusts or powdery coatings but may also be beige or brown. It is a common component of brecciated coatings on many slickensided fractures. It can be distinguished from other fine-grained white coatings by XRD.

Zeolites

Mordenite

Fine-grained mordenite forms crusts that have a waxy luster, are often translucent white or bluish, and are frequently banded. They commonly resemble drips of candle wax (Plate 3). Slightly coarser mats of fine-grained mordenite may resemble crusts of thick white paint. Fine-grained mordenite cannot be positively identified without XRD. Generally the crusts become larger and more abundant with depth in the Paintbrush Tuff.

Erionite

Erionite has been identified from the basal vitrophyre of the Topopah Spring Member and the partially devitrified altered material immediately above it, where it occurs as a very fine-grained white coating that cannot be visually distinguished from mordenite. It has also been identified from fractures in the vitric and argillic/zeolitic Topopah Spring Member between the basal vitrophyre and the Calico Hills Formation. It occurs as fine, clear to white acicular crystals approximately 0.1 mm long that cannot

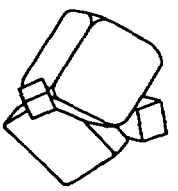
be distinguished at 10× magnification, but can be seen at 25-40×. XRD analysis is required for positive identification.

Calcite

Although calcite usually has some visible crystal faces, sparry calcite may form a continuous coating within a fracture. These calcite coatings may be water clear to white (rarely, slightly yellowish) in open or closed fractures. In the Crater Flat Tuff, calcite may be intergrown with manganese oxide minerals to form "black calcite."

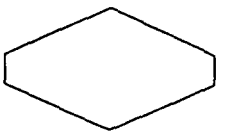
COLORED MINERALS WITH VISIBLE CRYSTAL MORPHOLOGY

Fluorite



Fluorite occurs as small purplish cubes, most commonly with calcite in the Paintbrush Tuff (Plate 4). Fluorite may also be clear to grayish or may grade from purple to clear. Aggregates of fluorite cubes may form rough balls that occur separately or as overgrowths on the single cubes.

Amphibole



cross section

Calcic amphibole occurs as yellow-orange to brown acicular or prismatic crystals having characteristic amphibole cross section. Crystals often exhibit longitudinal striations. They occur with tridymite and hematite and sometimes with or in calcite in lithophysal cavities and fractures in the Paintbrush Tuff.

COLORED MINERALS WITH NO VISIBLE CRYSTAL MORPHOLOGY

Opal

Both botryoidal opal and thin layers of opal may have a bluish tint. See "opal" in the section for white or clear minerals with no visible morphology.

Mordenite

Fine grained crusts of mordenite are commonly bluish or banded bluish and translucent white.

Sepiolite and Palygorskite

Crusts of these chain clay minerals may be yellowish or distinctly yellow.

Smectite

Although crusts and powdery coatings of smectite are usually white or off-white, they may also be beige to brown.

Illite

Illite occurs as a bright to dark green waxy coating on some fractures in the more altered portions of the Crater Flat Tuff. It has been identified only by XRD.

Hematite

Fine-grained hematite is a rusty-red color and may occur as a loose powder on fracture surfaces or, more commonly, staining quartz. It may also be intergrown with manganese oxide minerals, resulting in a brownish coating.

BLACK MINERALS WITH OR WITHOUT VISIBLE CRYSTALS

Manganese Oxide Minerals

There are many manganese oxide minerals lining fractures at Yucca Mountain, but as they cannot be visually distinguished, they are lumped together in this description. Most black microcrystalline fracture coatings at Yucca Mountain are manganese oxides. In the Paintbrush Tuff, manganese oxides most commonly occur as black spots 0.5 to 1.0 mm in diameter (resembling mildew), as small raised crusts 1 to 2 mm in diameter (Plate 5), or as lobate dendrites up to about 1 cm in diameter (Plate 6). Manganese oxide minerals in the Crater Flat Tuff usually form thicker, sooty-looking coatings (that readily come off on your hands). In some cases, the crystals may be large enough to be seen at 10× as matted or radiating needles. The manganese oxide minerals may be intergrown with quartz or calcite. Manganese oxide minerals occur as black specks and sooty smudges in fractures in the Calico Hills Formation, but manganese oxides are less abundant in the Calico Hills Formation than in the

Paintbrush or Crater Flat Tuffs.

Hematite (Blades)

Blades of hematite are common with tridymite in lithophysal cavities and fracture coatings in the Paintbrush Tuff. They are usually gray to black with a metallic luster. Hematite blades also occur without accompanying tridymite. Hematite blades may underlie prismatic zeolites in non-lithophysal intervals of the Paintbrush Tuff. The zeolite coating obscures the metallic luster and makes the black hematite crystals difficult to differentiate from spots of manganese oxide minerals. Bladed hematite has not (yet) been identified in fractures in other stratigraphic units at Yucca Mountain.

Garnet

Garnet is not abundant, but single black crystals have been identified in lithophysal cavities in the Paintbrush Tuff.

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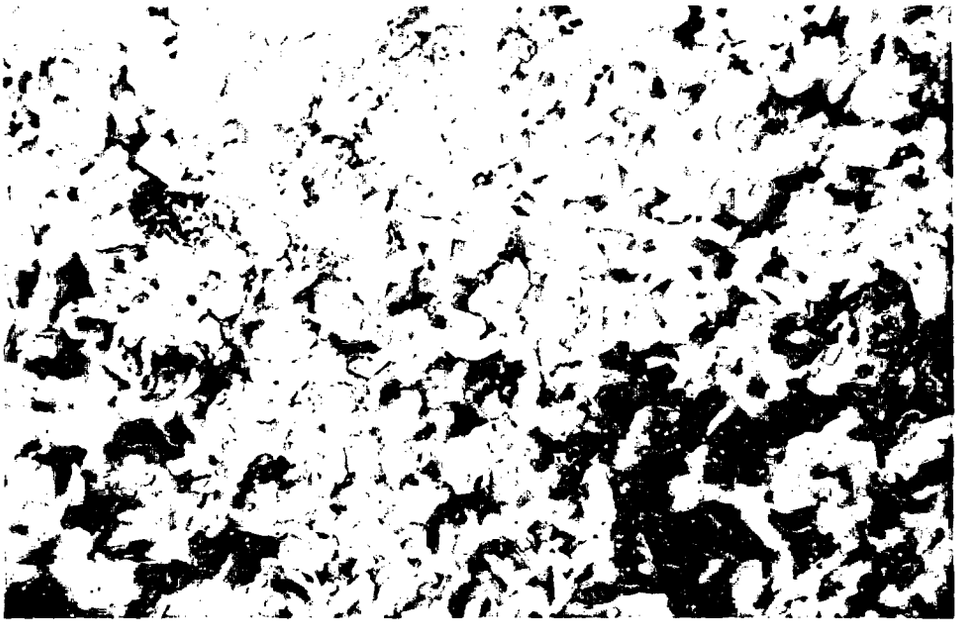
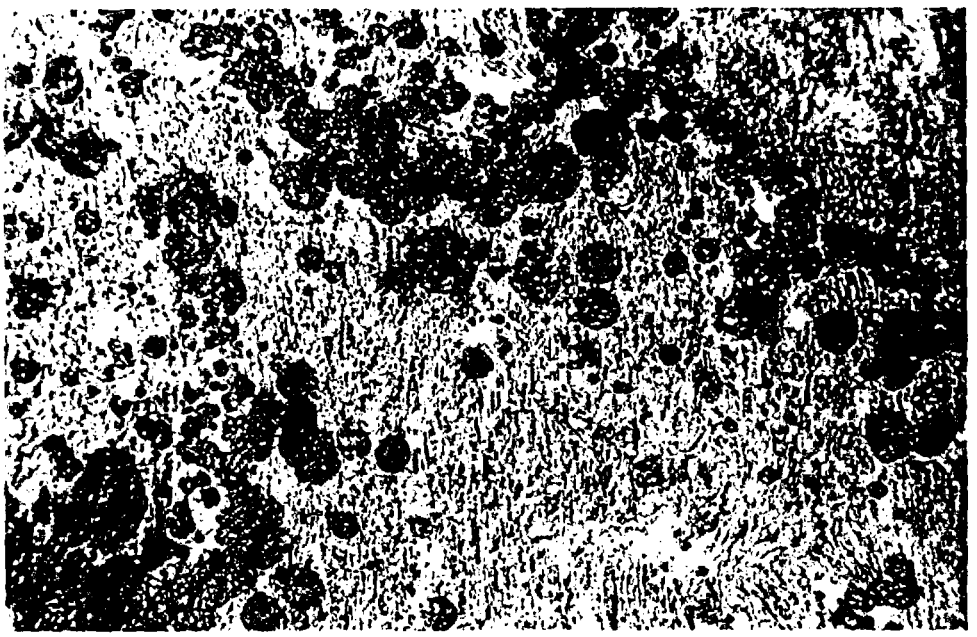


1. Lithophysal coating of tridymite. Field of view is 12 mm.

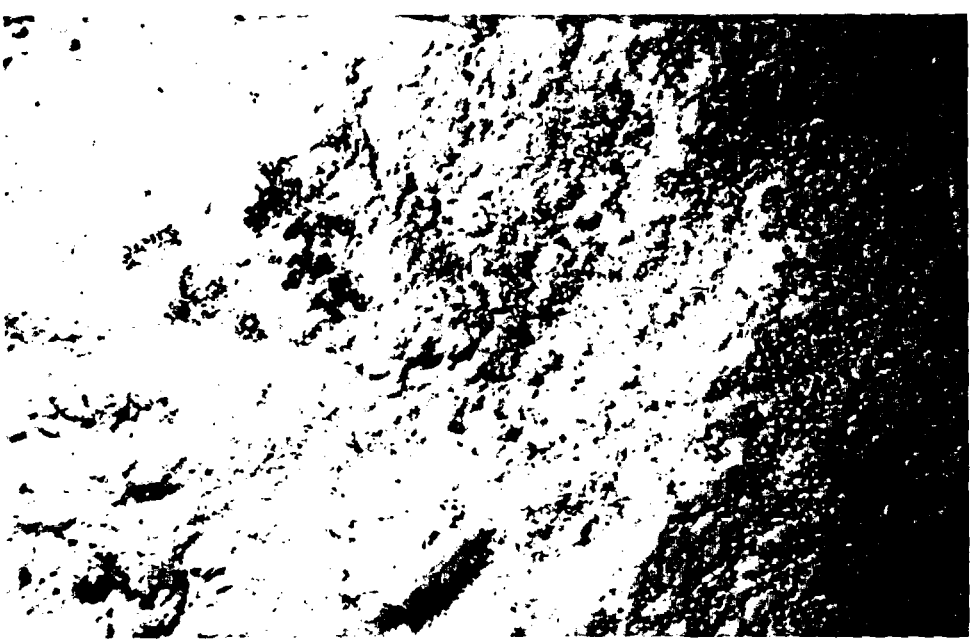
2. Analcime in fracture from the Crater Flat Tuff. Field of view is 12 mm.

3. Fine-grained (waxy) mordenite. Field of view is 12 mm.

4. Fluorite under calcite in lithophysal cavity. Field of view is 12 mm.



5. Spots of manganese oxide mineral(s) on fracture in Topopah Spring Member. Field of view is 12 mm.



6. Manganese oxide dendrites on smectite and erionite in fracture in Paintbrush Tuff. Field of view is 12 mm.

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