

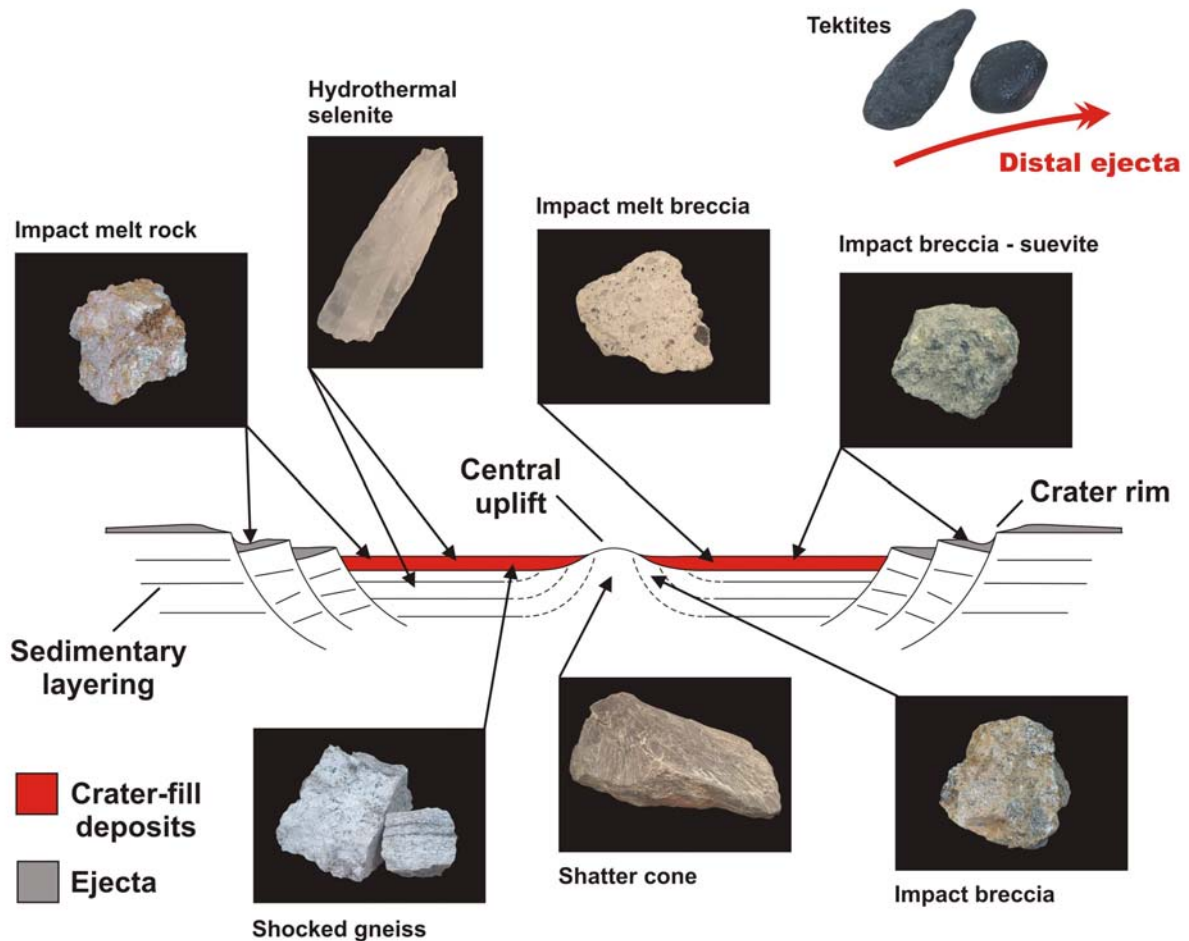
# IMPACT ROCKS KIT

## How to use this kit

This Impact Rock Kit contains samples from several meteorite impact structures around the world. The following descriptions can either be used on their own with the rock kits, or they may be used with the interactive Impact Rocks webpage:

<http://www.psi.edu/explorecraters/impactrocks.htm>

The diagram below shows you where an impact crater the various different types of impact rocks are found. This diagram is also available as a separate download from the Impact Rocks webpage.



# SAMPLE DESCRIPTIONS

## Shatter Cones

(sample from the Houghton structure, Devon Island, Canada)

Shatter cones are distinctive cone or fan-shaped features in rocks, with radiating fracture lines that resemble a horsetail. Shatter cones are found in only two places on Earth: in nuclear test sites and meteorite impact structures. They are formed as a result of the high pressure, high velocity shock wave produced by a large impacting object or a large explosion. They range in size from less than 1 centimeter to more than 5 meters across and indicate that the original rock was shattered – rather like a car's windscreen being hit by a stone.

The exact mechanism of formation of shatter cones is still not well understood. Besides large asteroid or comet impacts, only nuclear tests generate enough heat and pressure to even roughly mimic the process; the first man-made shatter cone was produced in 1959 during an underground nuclear explosion. As such, as long as you know that you're not in a nuclear test site, if you see a shatter cone in a rock, it is definitive evidence for a meteorite impact event. Shatter cones are actually the only shock indicators that can be seen with the naked eye. Others, such as so-called planar deformation features (PDFs) can only be seen with the aid of a microscope.

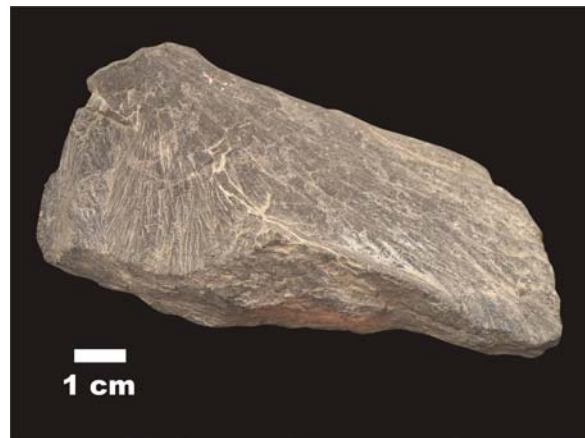
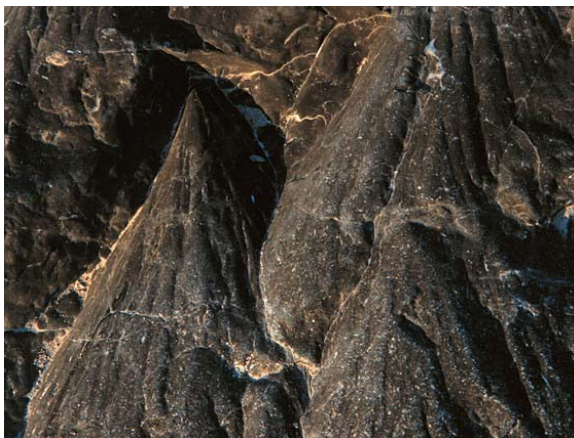
Shatter cones can be found within the central uplifts of large impact structures and occasionally within the crater-fill deposits (see photo of a shatter cone in Impact Melt Breccias below). At Houghton, we find shatter cones in both these settings:

The Virtual Tour stop where you can see shatter cones within the central uplift is

<http://www.psi.edu/explorecraters/stop3.htm>

The Virtual Tour stop where you can see shatter cones within the crater-fill deposits is

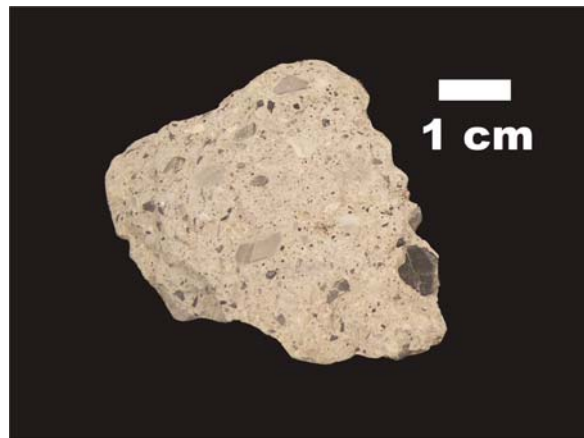
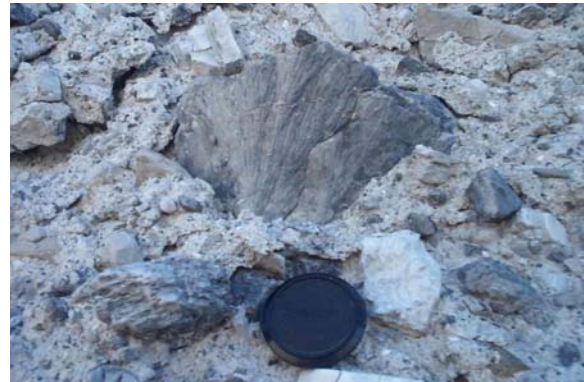
<http://www.psi.edu/explorecraters/stop8.htm>



**Photos:** Shatter cones from the central uplift of the Houghton structure, Canada. The photo on the left shows a series of shatter cones in limestone, all about 15 cm high.

## Impact Melt Breccia

(sample from the Haughton structure, Devon Island, Canada)



**Photos:** Locality in the Haughton structure where the impact melt breccia sample was collected. Notice the shatter cone in the top right photo!

A breccia (from a Latin word meaning "broken") is a rock that is composed of angular fragments of other rocks surrounded by a fine-grained "matrix" that may be of a similar or a different material. Breccias can be formed by a number of geologic processes (tectonic, volcanic, sedimentary) and from a variety of materials.

The sample in the Impact Rock Kit (bottom right photo) was collected at the Haughton structure. It is an "impact melt breccia", which means that the matrix cementing the fragments is crystallized impact melt. It is the primary evidence for a cataclysmic impact event, where the heat generated from the impact shatters and melts the target rock. The pale gray/white to dark gray/black fragments are mostly carbonates. Occasionally you'll see a fragment of gneiss (there is a large sample of gneiss in this Rock Kit) that was excavated from 2 km down by the impact event, brought to the surface, and mixed in with other rock fragments to form this new rock: impact melt breccia. This rock forms the crater-fill deposits at the Haughton structure.

The Virtual Tour stop where this sample was collected is

<http://www.psi.edu/explorecraters/haughtonstop6.htm>

## Suevite

(sample from the Ries structure, Germany)



**Photos:** The suevite samples in the Impact Rock Kits were collected at the Aumühle quarry near the north rim of the Ries structure. The suevites are the prominent greenish rock in the left photo. The reddish rock is another impact breccia called Bunte Breccia.

**Suevite** is an impact breccia composed of angular fragments of different rock types as well as glass inclusions, set in a fine-grained matrix. This type of rock was first recognized at the Ries impact structure. In the suevite sample and in the photos above, you can see lots of glass fragments (black glassy areas, generally smoother than typical rock fragments) and crystalline fragments (white, speckled). These glasses are derived from rocks that were heated to such high temperatures during the impact event that they melted. They then cooled very rapidly (quenched) to form glass – if a melt cools slowly, it can form an impact melt rock (see sample in the Impact Rock Kit and the description below).

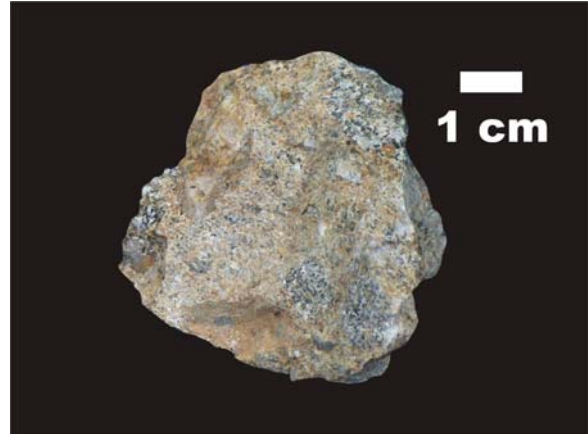
Suevites at the Ries structure form the crater-fill deposits and are also found in the ejecta blanket.

The Virtual Tour stop where this sample was collected is

<http://www.psi.edu/explorecraters/riesstop3.htm>

## Impact Breccia

(sample from the Ries structure, Germany)



**Photos:** Locality in the Ries structure where the impact breccia sample was collected.

As described above, a breccia is a rock that is composed of angular fragments of other rocks surrounded by a fine-grained "matrix" that may be of a similar or a different material. Breccias are extremely common in meteorite impact craters and attest to the destructive power of the impact event. Impact melt breccias and suevites both contain melt derived from the melting of target rocks; however, not all breccias contain melt. The breccia shown in the photo above contains no melt and is simply termed an "impact breccia". It contains fragments of gneiss and granite surrounded by a fine-grained matrix formed of pulverized grains from the same rocks. These gneiss fragments were not subjected to pressures as high as the shocked gneiss from the Haughton structure (see description above and sample in this kit) so that they remain about as heavy as the original gneiss. In fact, it's hard to tell that these gneiss fragments are shocked – we can only tell this by looking at them under a microscope.

Impact breccias can be found in many different settings within impact structures, such as within the central uplift, in crater-fill deposits, and in the ejecta blanket.

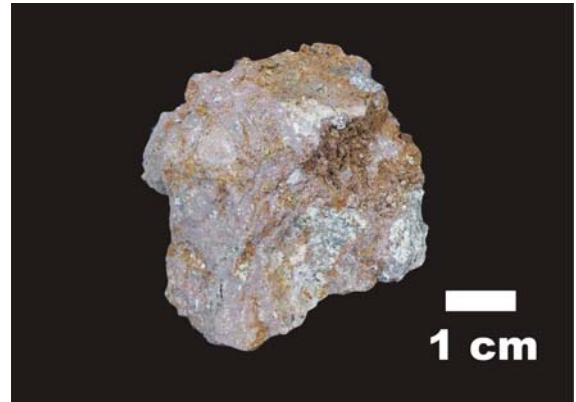
The Virtual Tour stop where this sample was collected is

<http://www.psi.edu/explorecraters/riesstop12.htm>

## Impact Melt Rock

(sample from the Ries structure, Germany)

Impact melt rocks are basically volcanic rocks, such as basalt lava, and they attest to the extreme conditions generated by the impact event. Pressures and temperatures in the target rocks surrounding the point where the asteroid or comet hits are so high that large volumes of rock can be instantaneously melted. Pieces of this melt can cool rapidly to form glass and be incorporated in suevites (see description above and sample in the Impact Rock Kits). However, sometimes, so much melt is produced that it forms a pool in the central parts of an impact crater to form crater-fill deposits. This pool of melt then cools slowly over time and solidifies to form a new rock, which we term impact melt rock. An impact melt rock contains only a few fragments of target rock, maybe up to ~25% fragments in extreme cases. If the melt contains a lot of fragments of target rock, then we term this an "impact melt breccia", which is the case at the Haughton structure (see description above and sample in this Rock Kit). Impact melt rocks can be found in crater-fill deposits (see photo below of the Mistastin structure) and in ejecta deposits as at the Ries structure.



**Photos:** The impact melt rocks in the Impact Rock Kits are from a small outcrop in Polsingen, which is near the northwest rim of the Ries impact structure, Germany. This reddish impact melt rock contains about 10 % fragments of target rock. The bottom right photo shows a massive 80 m thick sheet of impact melt rock from the Mistastin impact structure, Labrador, Canada. If you look closely, you can see "columnar joints", which are typically of volcanic rocks and which form as the melt layer cools. Photo courtesy of Derek Wilton.

The Virtual Tour stop where this sample was collected is

<http://www.psi.edu/explorecraters/riesstop7.htm>

## Shocked Gneiss

(sample from the Haughton structure, Devon Island, Canada)

Gneiss (pronounced “nice”) is a foliated or banded metamorphic rock, which forms when igneous or sedimentary rocks are buried to deep levels in the Earth's crust (up to several kilometers deep!) where they are changed by extreme heat and pressure.

On Devon Island, where the Haughton impact structure formed, gneiss was present at depths of 2 km in the target sequence. These gneisses, which are over 3 billion years old, were then excavated by the impact of an asteroid or comet and brought to the surface where we see them today. These gneiss fragments are actually found as fragments within the pale gray impact melt breccias (see photo below) that line the interior (= crater-fill deposits) of the Haughton structure (description above and the sample in this kit). Gneiss is normally a dark dense rock, but at Haughton, the gneiss resembles pumice stone – it is ash-white, porous and very lightweight. In fact, some of these fragments float in water! The reason why this gneiss is so light is due to the air spaces or bubbles, which formed as the gneiss was compressed by the shock wave, and then released. Certain minerals in the rock were also vaporized, leaving behind a porous ghost of the gneiss it originally was.



**Photos:** The person in this photograph (Gordon "Oz" Osinski) is standing beside a huge piece of shocked gneiss within the impact melt breccias at the Haughton impact structure.

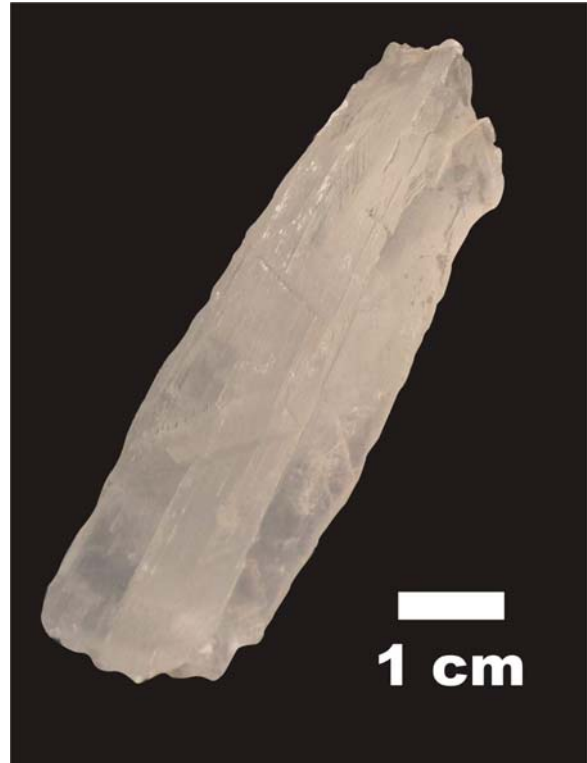
Click here to go to the Virtual Tour stop where this sample was collected:

<http://www.psi.edu/explorecraters/haughtonstop7.htm>

## Selenite Crystal, Hydrothermal (sample from the Haughton structure, Devon Island, Canada)



**Photos:** The photo above shows a large mass of selenite within the impact melt breccias at the Haughton structure. Note the 30 cm long rock hammer for scale! The photo on the left shows a smaller piece of selenite like the one within the Impact Rock Kits.



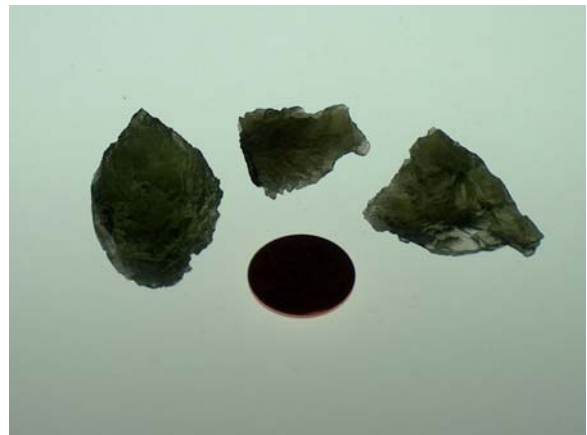
Selenite is the colorless and transparent variety of gypsum (calcium sulfate:  $\text{CaSO}_4 \cdot \text{H}_2\text{O}$ ) that shows a pearl like luster and has been described as having a moon-like glow. The word selenite comes from the greek word for Moon and means moon rock. Gypsum is one of the more common minerals in formed sedimentary environments, such as tropical seas.

At Haughton, selenite was formed by hydrothermal activity associated with the impact event. The only hydrothermal systems active today are associated with volcanic regions (e.g., Yellowstone National Park), but it turns out that impact craters can also provide the two most important components of a hydrothermal system: heat and water. The heat source at Haughton were the pale gray impact melt breccias (see description above and the sample in this Rock Kit), which were originally at temperatures of  $>1000$  °C. As groundwater and rainwater came into contact with these hot rocks, these fluids were heated and circulated through the crater. Some of the target rocks at Haughton contained sedimentary gypsum, which was dissolved by these hot hydrothermal fluids. These fluids then migrated through the crater and re-deposited gypsum or selenite within cavities in the impact melt breccias as they cooled.

Click here to go to the Virtual Tour stop where this sample was collected:

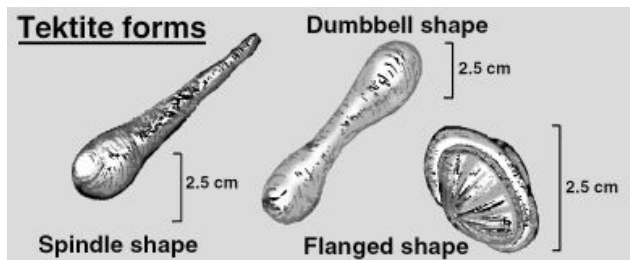
<http://www.psi.edu/explorecraters/haughtonstop8.htm>

# Tektites

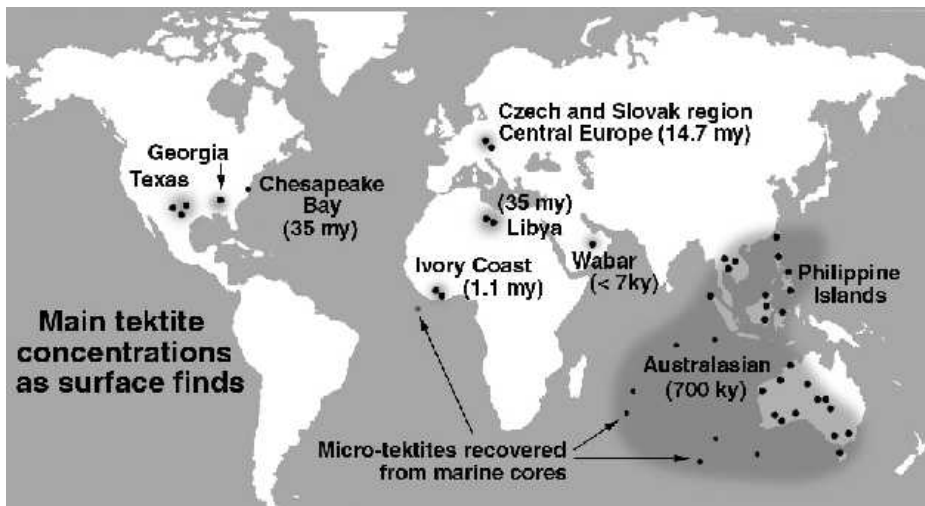


**Photos:** Images of typical Australasian tektites (left) and moldavites (right).

Tektites are small, glassy pebble-like objects that form during meteorite impact. They represent droplets of molten target rock that are ejected up into the Earth's atmosphere, which then fall back to the surface up to several hundred kilometers from where their source impact crater. They often acquire aerodynamic shapes as they fly through the atmosphere.



Their name comes from the Greek word 'tektos', meaning 'molten'. The first written reference to tektites was about one thousand and fifty years ago, by Liu Sun in China, who gave them a name meaning 'Inkstone of the Thundergod'.



Tektites often occur in so-called strewn fields (see map above), areas over which tektites with similar chemical and physical properties are found. The four main strewn fields known are the central European (linked to the Ries crater in Germany), Ivory Coast (linked to the Bosumtwi crater in Ghana, West Africa), North American (linked to the Chesapeake crater, North America) and Australasian (source crater still unknown, although a large crater in Western Cambodia, Lake Tonle Sap, has been proposed).

Tektites do not contain any water. They can be mistaken for obsidian or pitchstone (black volcanic glasses), but these will emit some water on strong heating. Their density is similar to, or a little lighter than, quartz beach sand.

## Australasian Tektites

The Australasian strewnfield is the largest and geologically youngest of the tektite deposits and the only one that has thus far had no known impact crater associated with it. The tektites are generally very dark in color, for the most part essentially black (see photo above). Thin edges or broken parts will have a yellow or brown color when examined with back lighting. They have a wide range of forms: Teardrops, dumbbells, spheres, rods, discs and all types of irregular shapes.

The Australasian strewnfield covers more than 10% of the Earth's surface, and is expected to be associated with a young, gigantic crater that has yet to be identified with certainty. The age of these tektites is 0.7 million years or perhaps younger. Because the strewnfield is so large they have been classified into sub-groups, according to their location: Australites (from Australia), Indochinites (from Indochina), Chinites (from China). They all appear mostly black in color.

## Moldavites

Moldavites are an unusual type of tektite with a beautiful translucent green clarity. The moldavites are tektites derived from the Ries impact structure, German. Moldavite is a special term coming from German and means 'Vltava River Stone'. Moldau is the German name for the Czech river Vltava.

