Making an impact: Shatter cones

In 1990, a group of geologists discovered a large number of shatter cones in southwestern Montana. Shatter cones are a type of metamorphosed rock often found in impact structures (the remains of a crater after a meteor impact and years of Earth activity). Scientists have discovered only 168 impact craters around the world.

If rocks could talk, they would be able to tell the story of the events that formed them. But because they can’t, geologists must use rocks as clues to reconstruct Earth’s history. For this science exploration, we began by discussing some of the very questions geologists sought to answer at the Beaverhead, Montana, site. Beyond the shatter cones, there was no visible evidence of a meteor crater. Geologists wondered: How big was the impact crater? Where was the actual impact center? How long ago did the impact occur? Why can’t you see a crater today?

Looking for clues

Sometimes craters are easy to see because they have not been erased by erosion or deposition or altered by volcanic or tectonic activity. Others can be very difficult to identify, so geologists have agreed on four identifying characteristics of an impact crater:

1. Evidence of shock metamorphism, such as shatter cones
2. Crater morphology
3. Geophysical anomalies
4. The presence of meteorites

The most incontrovertible pieces of evidence are the presence of shock effects and meteorites (Koeberl 1997).

Shatter cones can be as small as one inch or rise up to more than six feet tall. They are generally found buried below the floor of the crater under sediment and sometimes in the raised area at the center of the impact strike. Only a sudden intense pressure on existing rock can cause the shatter cones to form. Within seconds after an impact, intense shock waves create the cone-shaped fractures (Hargraves et al. 1990).

After visiting the Beaverhead site, we used a global positioning (GPS) device to create a map pinpointing the longitude and latitude of shatter cone locations. We created an interactive map using special mapping software made available through NASA’s Earth Observing System Education Project at the University of Montana (see ArcView GIS).

This software allowed us to add layers to the map that included information such as population density and topography. The software also allowed us to add hotlinks on the map, which students could click on to view detailed photos of the shatter cones and even view a short animation of a meteor impact. (A version of this map is available at chewbaccas.cec.umt.edu/sc/shattercones.aspx.)

The movie can be viewed at members.cruzo.com/~inscript/mpgs/crater1.MPG.

After reviewing the map as a class, we then discussed how scientists piece together information to form understandings about phenomena. Students began to see how technology aids scientists in observing patterns and in building more complete explanations.

Experimenting with impact craters

Next, we challenged students to figure out the size of the impact crater using the map of the shatter cone sites (Figure 1). The mapping program provided students with tools for measuring distance and estimating area onscreen, but these same measurements can be made using a hard copy of the map with the scale provided, a ruler, and a compass. To help them with their impact crater estimations, we explained that geologists believe shatter cones are usually located no more than one third of the crater radius distance from the center of the impact structure. Then we posed the question: “How does this help you estimate the crater impact size?” What we hoped students would

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FIGURE 1 Beaverhead shatter cone sites
realize is that the line of shatter cones represents the outer edge of the central impact zone. This circumference is extended using the computer drawing tools or a compass (see line A in Figure 1). Students then measured the radius of this circle, which they know is equal to one third of the entire radius of the crater. Again, using drawing tools or a compass, students added this circle to their map to calculate the probable size of the crater.

After students completed their estimations of the crater size, they shared their work with the class. To compare their work with that of geologists, students visited the Earth Impact Database (www.unb.ca/passc/ImpactDatabase/austr.html) for more information on the Montana impact crater (Figure 2). At this site students learned that scientists now believe that the center of the crater is in Idaho, not in Montana, as some geologists had earlier hypothesized, and that the crater is approximately 600 km in diameter. Students were then challenged to use the database to find the location of the largest impact crater in North America, as well as the smallest, oldest, and youngest.

After seeing how big the Beaverhead crater is, many students began wondering how such a meteor strike would affect Montana if it impacted today. To answer the question, students downloaded a state population map from www.nris.state.mt.us/gis/gis.html and added it as a layer to their interactive map. (The same can be done by transferring the population map to a transparency, which could then be used as an overlay on the shatter cone map.) This allowed students to visualize how an impact would affect Montana residents.

Assessment
We assess students’ understanding by having them write a shatter cone story that includes responses to the following:

- What are identifying characteristics of shatter cones? Impact structures?
- What stories can shatter cones tell?
- How do geologists determine the size and center of an impact structure?
- Your ideas about your shatter cone are being challenged by a geologist who claims that the shatter cone presence is the result of a large volcanic explosion. How can you defend the evidence in your story?
- A friend claims there is an impact crater on her grandma’s ranch. What evidence would you need to be convinced?
- List two further questions you now have about impact craters. How might you go about answering these questions?

This is a homework assignment that students complete over the weekend. We require that they address the questions outlined above within three to four pages. Students’ rock stories are evaluated based on an accurate and thorough understanding of the scientific concepts, successful use of data to defend and elaborate ideas, and writing organization and clarity.

Going further
After all students’ ideas are discussed, we invite them to test their ideas by completing the interactive lessons located at www.smv.org/jims/crater/CraterDataSheet.htm (open
inquiry) or education.jpl.nasa.gov/educators/craters_ics.html (guided inquiry). Here, students can explore answers to how a crater is made and how the size and speed of the impacting object affects the formation of the crater.

**References**

**Resources**
Earth Impact Database—[www.unb.ca/passc/ImpactDatabase/astr.html](http://www.unb.ca/passc/ImpactDatabase/astr.html)

The Montana Natural Resource Information System Geographic Information System—[www.mris.state.mt.us/gis/gis.html](http://www.mris.state.mt.us/gis/gis.html)
Open inquiry—[www.smv.org/jims/crater/CraterDataSheet.htm](http://www.smv.org/jims/crater/CraterDataSheet.htm)
Guided inquiry—education.jpl.nasa.gov/educators/craters_ics.html

**ArcView GIS**
Montana teachers have access to free ArcView GIS software if they complete a GIS training provided by the EOS Education Center. This access to ArcView GIS software was made possible by purchase of a state license from ESRI (producers of the software) via funding provided by the University of Montana and Senator Conrad Burns. South Dakota and Utah also have state ArcView GIS licenses for teachers. Alaska and Oregon are currently negotiating similar options for teachers. To investigate state, district, and building licensing of ArcView and other ESRI GIS tools, please contact the ESRI K–12 Education Program staff at k12-lib@esri.com. To learn more about GIS in education, visit [www.esri.com/k-12](http://www.esri.com/k-12).