



Objective

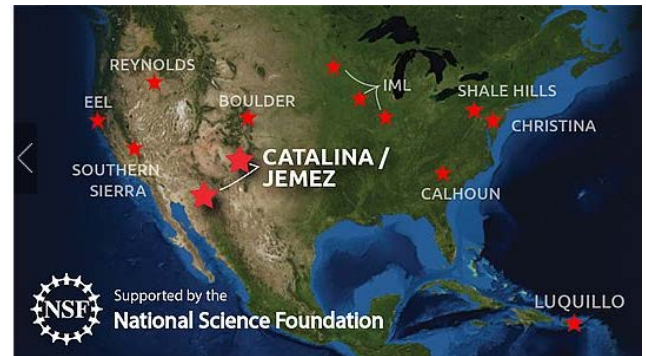
This activity familiarizes students with the geoheritage of volcanism in the Valles Caldera National Preserve (VCNP) in New Mexico. It focuses on the development of skills and knowledge involving scale of geologic features, volcanic geology, and the denudation of this modern caldera landscape by wildfires and climate change. It also draws attention to the role of Critical Zone (CZ) science in studying and understanding the processes that formed and continue to shape this nationally valued landscape.

Materials

- Computer with internet access
- Paper and pen or pencil

The Critical Zone

The Critical Zone is defined as the zone at Earth's land surface extending from the top of the vegetation canopy through soil to subsurface depths at which fresh groundwater freely circulates. This is the zone where most terrestrial life, including humanity, resides. CZ Observatories (CZO) provide important platforms for studying the processes in the CZ (see Criticalzone.org). The Jemez CZ Observatory lies in the Jemez River Basin, with a central feature being the Valles Caldera at the top of the watershed. In 2000, the U.S. government purchased this land and created the VCNP to sustain the scientific, scenic, geologic, watershed, fish, wildlife, historic, cultural, and recreational values of this environment. This federal action recognizes the geoheritage of the VCNP, a landscape shaped by volcanism as in much of the intermontane southwestern U.S. and now protected for future generations. The Jemez CZO contributes to this national effort by working to understand the dynamic of CZ processes within the caldera and the impact on its watershed. Jemez CZO researchers have three sites within the caldera: one unburned and two burned zero order basins affected separately by the 2011 Las Conchas fire and the 2013 Thompson Ridge Fire. Several watersheds draining northern and southern aspects of Redondo Peak, the highest peak in the caldera, create a unique situation where headwater streams of the Jemez River originate on different aspects of the same mountain, providing the opportunity to study the movement of water in contrasting microclimates on a uniform parent material with a common precipitation regime.



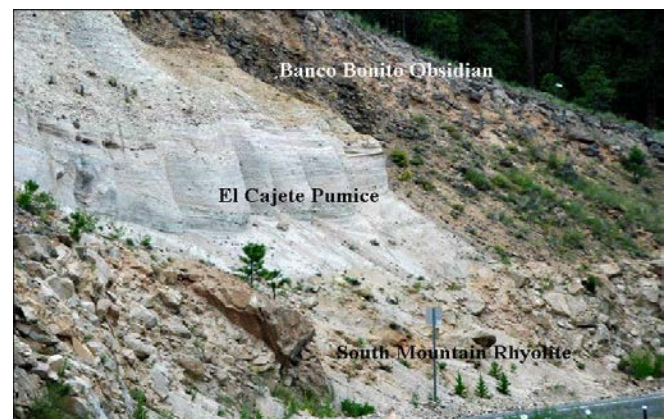
What is a caldera?

A caldera forms when a large magma chamber erupts and the ground above it collapses to form a large, steep depression. Magma is hot fluid or semi-fluid material below or within Earth's crust from which lava and other igneous rock are formed. Calderas vary in size and can be classified into three types: 1) by the collapse of a stratovolcano, 2) the summit collapse of a shield volcano, and 3) in the interaction of multiple volcanoes during a series of eruptions. The Valles Caldera (seen right) is associated with the third type, known as a resurgent caldera, forming an almost perfect circular depression and one of the most studied calderas in the world.



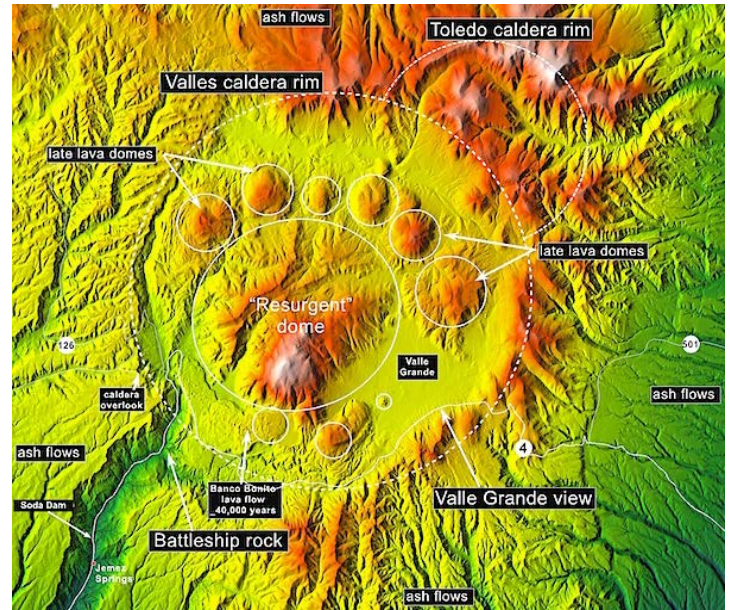
The Valles Caldera

The Valles Caldera is also defined as a "supervolcano", which is any volcano capable of producing a volcanic eruption with an ejecta mass greater than 10^{15} kg. Supervolcanoes occur when magma in the mantle rises into but cannot penetrate the crust. Pressure builds in a large and growing magma chamber until the crust can no longer contain the pressure. When supervolcanoes explode, they form huge, hot clouds of pumice, ash, crystals, and hot gas, called pyroclastic flows, which radiate outward from the caldera at speeds of 50 to 200 miles per hour. The Valles Caldera formed during eruptions from 1.47 to 1.15 million years ago (mya) and deposited 75 cubic miles of the Bandelier Tuff—a thick sequence of pyroclastic deposits. The circular topographic rim of the Valles Caldera is 22 km (13.7 mi) in diameter, and it contains several resurgent domes, the largest being Redondo Peak—a structural dome made up of Bandelier Tuff that was uplifted by the swelling or rising of the caldera floor due to movement in the magma chamber beneath it. Since this uplift, several smaller rhyolitic domes have erupted along a ring fracture within the caldera. The El Cajete Pumice (pictured above), Battleship Rock Ignimbrite, Banco Bonito Rhyolite, and the VC-1 Rhyolite were emplaced during the youngest eruption of the Valles Caldera about 50,000 to 30,000 years ago. Seismic investigations show that a low velocity zone (LVZ) lies beneath the caldera - an LVZ is a change in the mantle from solid to less dense material, indicating the presence of magma - and an active geothermal system with hot springs and fumaroles exists today. Volcanologists consider the Valles Caldera to be dormant.



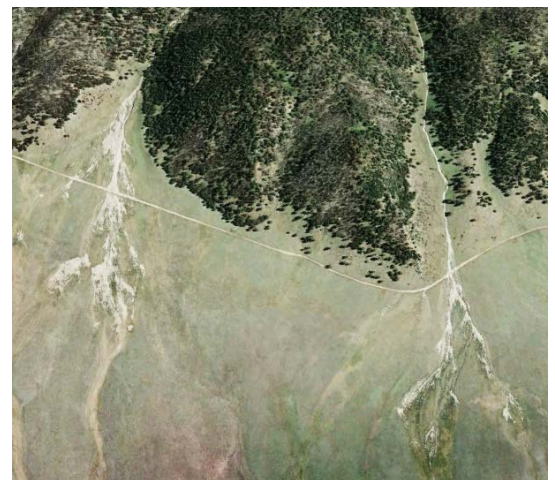
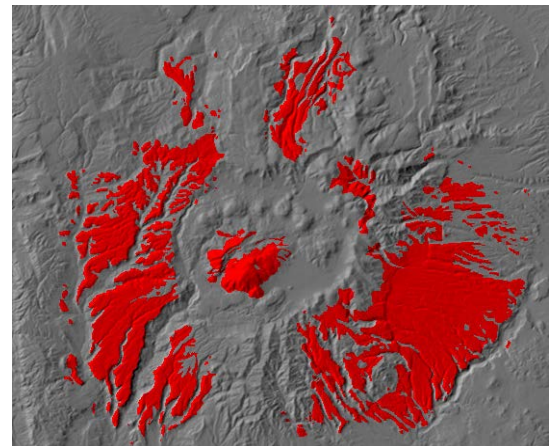
Classroom Activity: The Past, Present & Future of the Valles Caldera

1. Open Google Maps, enter Earth view, and visit the following coordinates: 35.901°, -106.549°. Zoom out so that the scale bar is 5 miles and describe this landscape.
2. Now do the same at Mauna Loa on Hawaii (19.471°, -155.592°), Crater Lake Caldera in Oregon (42.944°, -122.109°), and a volcano of your choice (ex. Mt. St. Helens, Vesuvius, Yellowstone Caldera). Don't forget to use the Street View icon (yellow person) to get an up-close view of these areas. How do they compare in size, shape and volcanic features to the Valles Caldera?
3. The supervolcano eruption that formed the Valles Caldera should have left a large footprint of ash and other debris. Visit 35.8729, -106.2332 and drag the Street View icon here to see an example of the famous Bandelier Tuff formation. These layers represent pyroclastic flow material ejected into the air and across the landscape. The extent of the 75 cubic miles of the formation can be seen in red to the right. How do you think these might compare to the other volcanoes considered in step 2?



Credit: Dr. Larry Crumpler, NM Museum of Natural History and Science

4. Venture back to the Valles Caldera and zoom in so the edges of the caldera fill your screen. What features in the caldera could indicate volcanic activity? Do you notice a pattern?
5. Search in Google Maps for the Parkdale Lava Flow in Oregon and note the ridge topography of the flow. Now search for similar ridges in the Valles Caldera.
6. A lava flow can drastically change a landscape, but on a shorter time scale this area is prone to wildfire. Fire has been a common occurrence in forests of the Southwest for a long time, and at low intensity, it can be healthy for growth of the forest. However, recently the fires have intensified by burning hotter, and across more acreage. What might be causing this change?
7. Visit the following coordinates and zoom to a 100ft scale: 35.892°, -106.451°. This area was among the 156,000 acres affected by the 2011 Las Conchas fire. What do you observe on the landscape that indicates something dramatic happened to this landscape? Think about how this change in the vegetation could impact the soil, hydrology and ecosystem here.
8. During a high intensity fire, the soil can be heated to the point of being impermeable and during subsequent rain events, severe erosion can occur. Knowing this, can you see any features that might infer that erosion has occurred?
9. Now zoom out to a scale of 500ft and move south. The white features (shown right) you see are debris fans made of sediment that has flowed down from burned ridges during rain events due to the lack of vegetation. A study found that erosion in the aftermath of fire is responsible for at least 90% of denudation (long-term sum of processes that cause the wearing away of Earth's surface) in the Valles Caldera.
10. From this exercise, what changes to the environment would you expect if the Valles Caldera or another supervolcano were to erupt? How would it affect climate, surrounding landscape, existing geology, etc.?



Teacher's Notes: 1) Circular feature seen is the Valles Caldera— have the students right click, select Measure Distance, note distance of caldera width, and right click to clear the measurement. Students should repeat for examples in step 2. 2) Mauna Loa is an example of shield volcano collapse with one large summit caldera and smaller ones moving SE; Kilauea is another example moving east of Mauna Loa; Crater Lake Caldera was the collapse of Mount Mazama stratovolcano. 3) In comparison, 1980 eruption of Mt. St. Helens deposited 0.25 mi³. 4) There are 10 domes within the caldera. Redondo Peak is a structural dome made from uplift of the caldera itself. The remaining are rhyolite domes— 6 along the north rim and 3 along the south. The domes have erupted in a circular pattern, indicating a ring fracture in the caldera. 5) Lava flow ridges can be best seen on the east flank of the westernmost northern dome (San Antonio Mountain) and between Redondo Peak and Route 4 (Banco Bonito Flow). 6) Climate change has led to overall hotter and drier climate in the southwest, causing more intense wildfires. 7) The vegetation has died, and trees has since fallen. This leads to increased runoff and nothing to retain soil on the slope. 8) There are 5 noticeable erosion channels across the slope. 9) Article on mentioned study from Univ. of Arizona: <http://bit.ly/1U5CXwi>.