MBMG
Montana Bureau of Mines and Geology

Montana Geology 2017

Big Butte and Lowland Creek Volcanics

Photo by David Nolt, Montana Tech, All Rights Reserved. Although it takes the conical form typical of central-vent volcanoes, Big Butte is a breccia deposit formed at the edge of a much larger vent. It's volcanic, but it's not a volcano!

January

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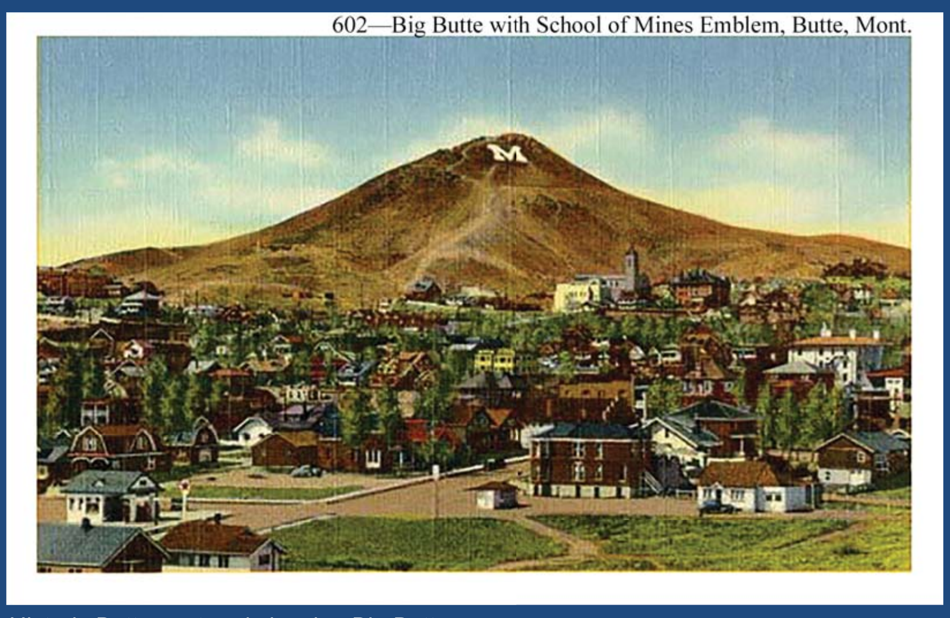
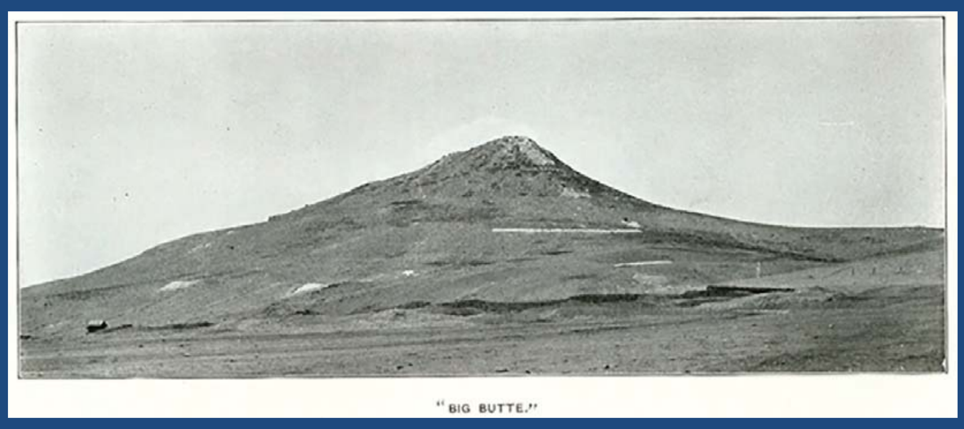


Historic Butte postcard showing Big Butte.



Big Butte, 1900. From "A Brief History of Butte, Montana, the World's Greatest Mining Camp," Harry C. Freeman, Publisher, courtesy of the Montana Memory Project.

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INTRODUCTION

Volcanoes erupted ash and lava across portions of central and western Montana throughout the Late Cretaceous–Tertiary periods (85 to 40 million years ago; fig. 1). One of these volcanic episodes, from 53 to 49 million years ago, produced the Lowland Creek Volcanic field. This field consists of 340 mi³ of volcanic rock covering 600 mi² in the hills and peaks north and west of Butte (fig. 2; Smedes, 1962; Dudas and others, 2010).

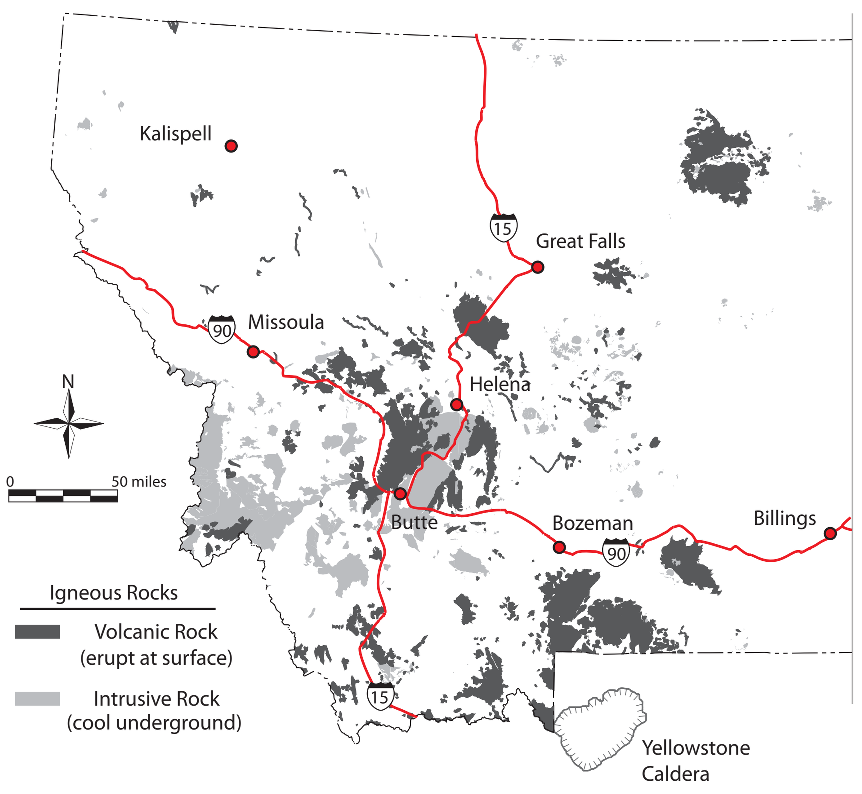

Figure 1. Distribution of igneous rock in western and central Montana (after Vuke and others, 2007). The vast majority of igneous rocks formed during the Late Cretaceous–Tertiary periods and are associated with precious and base metal mineral deposits (Foster and Childs, 1993). Also shown is the active Yellowstone caldera.

GEOLOGY

The Lowland Creek Volcanic field filled a northeast-trending topographic basin within Late Cretaceous Boulder Batholith and Elkhorn Mountains Volcanics rocks (fig. 2). Lowland Creek rhyolites, dacites, andesite lavas, and tuffs are as thick as 6,000 feet and record two eruptive cycles (fig. 3). Basin formation and volcanism may have occurred simultaneously (Houston and Dilles, 2013a).

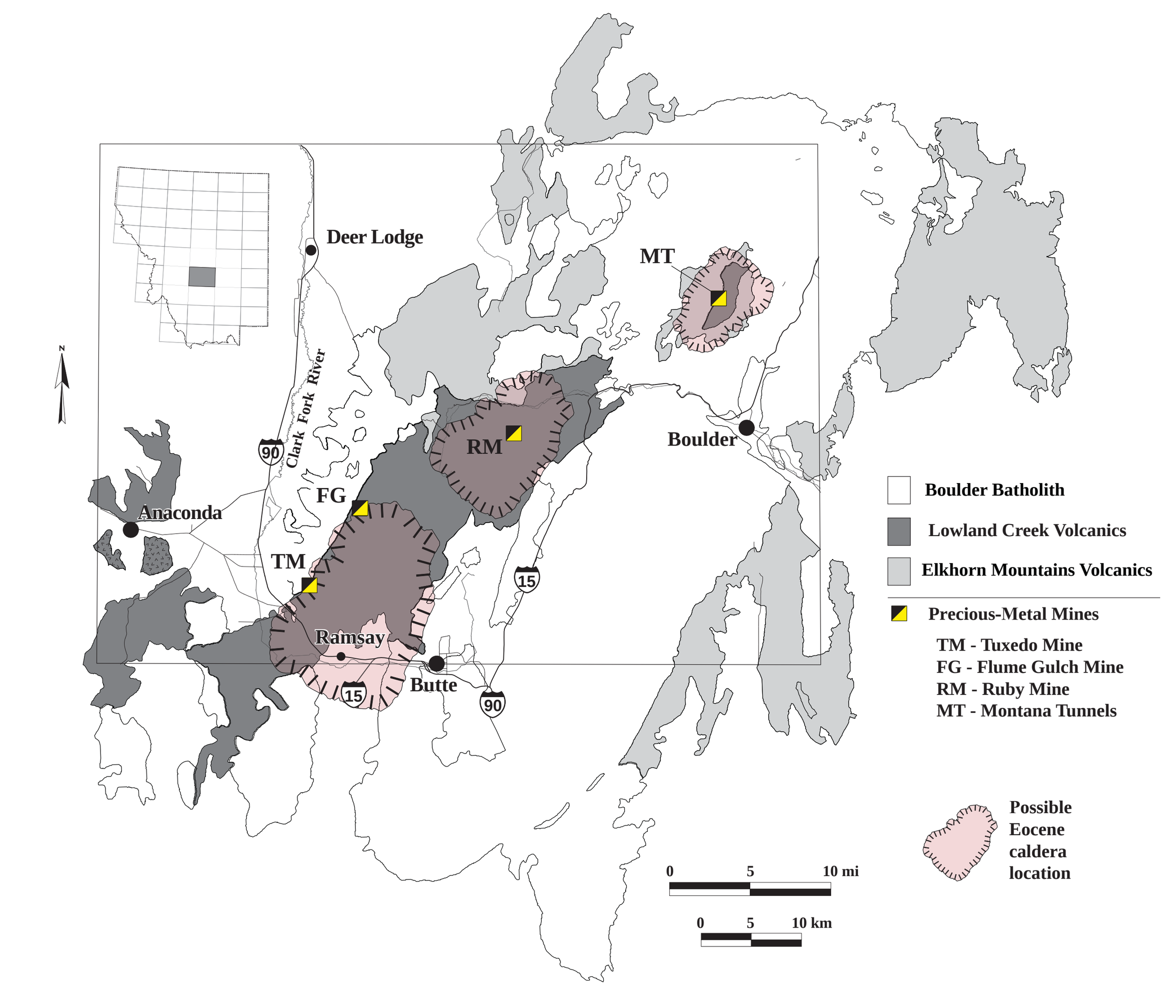

Figure 2. The Eocene Lowland Creek Volcanic field and Late Cretaceous igneous rocks of the Boulder Batholith and the Elkhorn Mountains Volcanics. Caldera vents are no longer active.

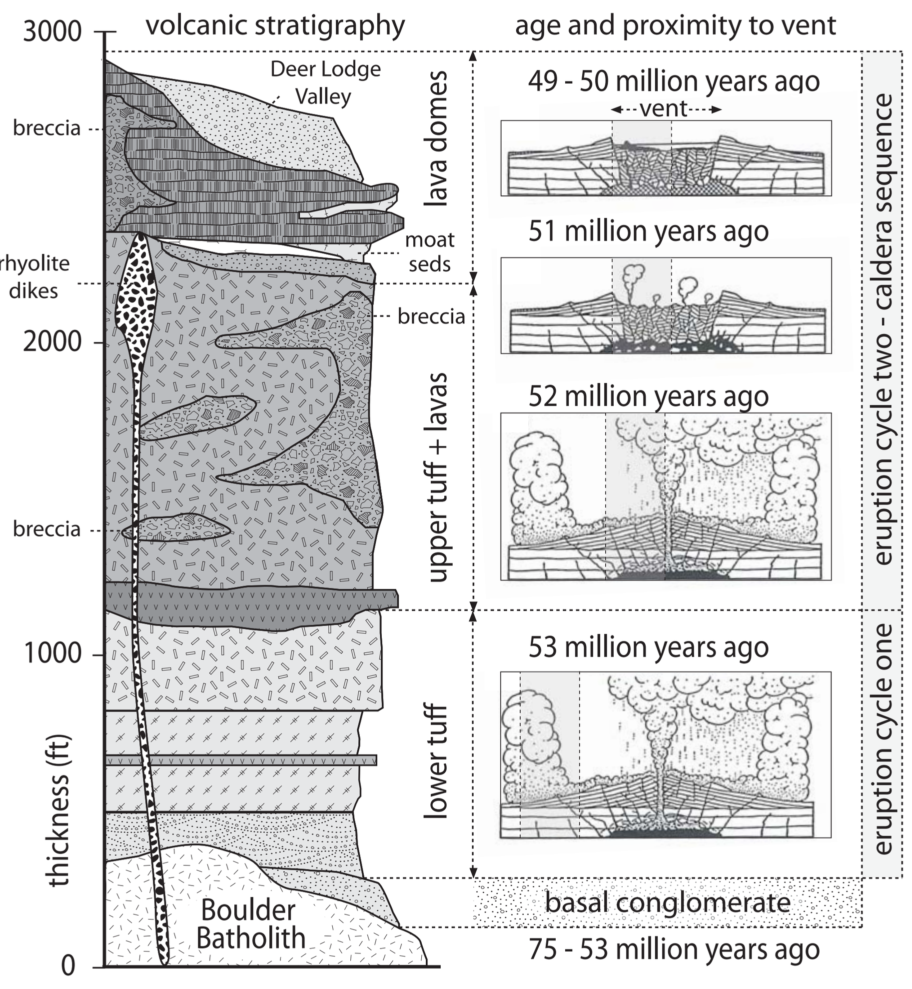

Figure 3. Lowland Creek volcanic stratigraphy between Butte and Anaconda. The deposits formed during two main eruption cycles, one sourced from a distant vent and another sourced from within a caldera.

The wide distribution of the Lowland Creek volcanic deposits suggests that they formed during multiple caldera eruptions. Calderas are volcanoes with vents several to tens of miles wide. Calderas form during catastrophic volcanic eruptions that quickly expel the contents of a magma chamber into the atmosphere as ash, lapilli, and volcanic bombs. Once the magma chamber is emptied, its roof collapses to form the caldera. For example, the active Yellowstone caldera south of Bozeman, Montana (fig. 1) is 28 mi wide and 53 mi long (Lipman, 1984). The Lowland Creek calderas were likely about 10 mi wide by 15 mi long (fig. 2).

Calderas erupt materials that are hot, turbulent, and fast moving. When settled, caldera deposits are commonly described as ash-flow and air-fall tuffs. Internal heat can cause welding, transforming the mass of loose ash and other rock material into coherent, even glassy, rock.

VOLCANIC STRATIGRAPHY

Three thousand feet of the Lowland Creek Volcanic field (fig. 3) is exposed along the I-90 corridor between Butte and Anaconda in southwestern Montana (Scarberry and others, 2015). The volcanic units, their origins, and age are shown in figure 3. From oldest to youngest, these units are:

Basal Conglomerate

A mix of volcanic and sedimentary clasts found at the base of the Lowland Creek Volcanic field record the early stages of volcanism. The rocks were deposited about 53 million years ago within a pre-volcanic depositional basin that formed after crystallization of the Boulder Batholith 74 million years ago. Locally the conglomerate mixes with and grades upwards into the lower tuff.

Figure 4. Laminar bed forms in rhyolite ash of the lower tuff unit.

Lower Tuff

Approximately 500 feet of white to light gray rhyolite ash was deposited during the initial Lowland Creek eruption cycle. Cross-beds, laminar beds of ash (fig. 4), and rip-up clasts of older volcanic rocks are common. These features indicate that the tuff formed from a turbulent ash cloud erupted from a distant vent. Heat and pressure from thick accumulations of the hot ash welded the upper part of the lower tuff into zones of hard, competent rock. Variable states of welding near the top of the unit indicate that several discrete eruptions occurred during volcanic activity about 53 million years ago.

Upper Tuff and Lavas

The upper tuff and lavas represent the beginning of the second Lowland Creek eruption cycle (fig. 3) and are mostly maroon, crystal-rich, rhyolite tuff and dacite lava. Early upper tuff deposits formed during an explosive eruption cycle that culminated in a caldera collapse 51 million years ago. Small single-vent volcanoes and fumaroles formed in the caldera as magma continued to work itself to the surface. A remnant of lavas banked into a vent wall (fig. 5) covers 5 mi² north of I-90 between Butte and Anaconda (fig. 2).

Rhyolite Dikes

Gray and tan, crystal-rich rhyolite dikes cut upward through the lower tuff, the upper tuff, and the lavas (fig. 3). The dikes trend northeast, mimicking the northeast elongate pattern of the volcanic field (fig. 2), and reach the level of the caldera floor. Zircon crystals within the rhyolite are much older than the dikes themselves, indicating that they were scavenged from the Boulder Batholith, eruption cycle 1, or other older rocks as the dikes made their way to the surface around 51 million years ago.

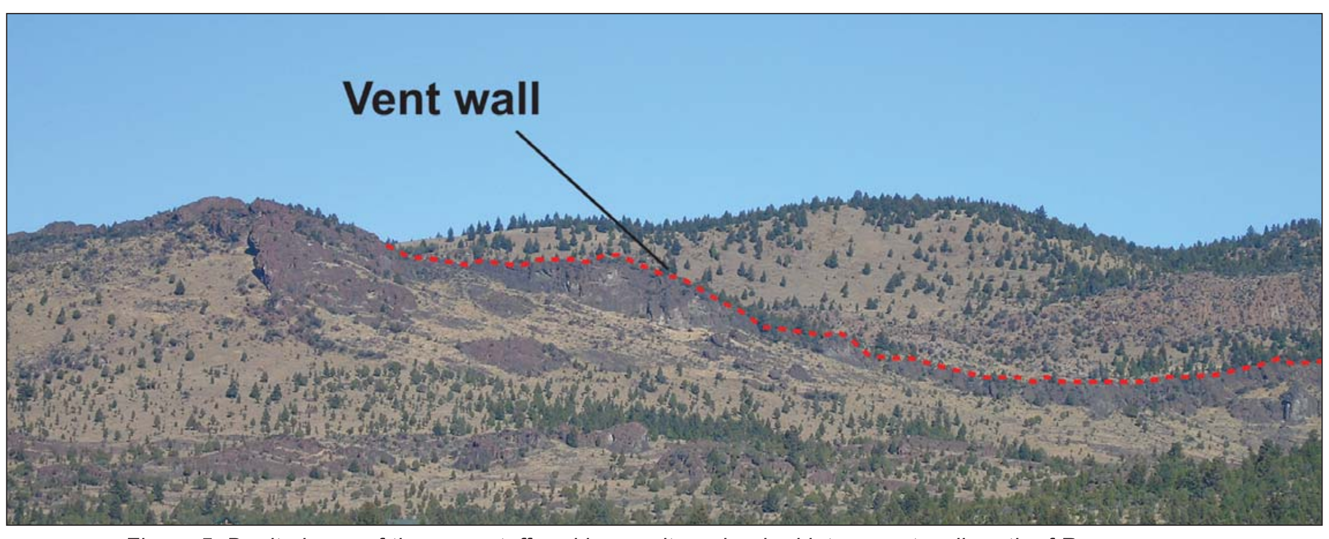

Figure 5. Dacite lavas of the upper tuff and lava unit are banked into a vent wall north of Ramsay.

Lava Domes

Andesite–dacite lava domes cap the Lowland Creek Volcanic field. The domes formed within the caldera at a time when it held water. The Hackney lava dome (Scarberry and Elliott, 2016) covers 3 mi² west of Ramsay (fig. 2) and is cut by I-90. The westbound lanes cross rocks that transition from dark lavas to white, ashy lake/moat sediments (fig. 6). Pillow lavas, recognized by light green volcanic glass surrounding cores of lava (fig. 7), formed near the base of the lava dome sequence. Pillow textures result from lava flowing into water where it is rapidly cooled. The lava domes formed between 49 and 50 million years ago during resurgent doming of the caldera floor.

Figure 6. Moat sediments formed along the caldera margins prior to resurgent doming.

Breccia

Most Lowland Creek Volcanic field breccia formed near volcanic vents. Some of the breccia have subtle textural and composition differences that make them distinct.

Lower tuff breccia. Big Butte (front photos), located just north of the Montana Tech campus in Butte, is a vent breccia (Houston and Dilles, 2013b) that formed during eruption cycle one. The Big Butte vent breccia contains angular blocks of older rocks, such as granite of the Boulder Batholith, in a fragmented rhyolite matrix.

Upper tuff and lavas breccia. Flow breccia (fig. 8, top) formed at the base of lava sequences or ash-flow tuffs while the deposit was still moving during cooling. Block and ash flows (fig. 8, bottom) are a breccia of bombs, lapilli, and ash fragments ejected from collapsing dacite–rhyolite vents.

Figure 7. Pillow lavas mark the contact between moat sediments and the Hackney lava dome.

Lava dome breccia. Hydrothermal breccia occurs in the roots of lava dome fissures. This breccia is hard and silicified. Low-temperature (< 300–350°F) hydrothermal minerals formed in vent fumaroles and hot springs.

METALLIC ORE DEPOSITS

Precious-metal ore deposits occur within or near calderas. Magma intrusion along caldera ring-fractures and long periods of hydrothermal fluid circulation concentrate and mobilize ore-bearing fluids. In near-surface fumaroles, caldera ring fractures, and fault zones, fluids precipitate metal-bearing minerals in veins or lode deposits. In the Lowland Creek Volcanic field, precious-metal ore deposits developed after caldera formation (Foster, 1987). These ore deposits have provided significant gold and silver production at four well-known mines (fig. 2).

Figure 8. Block and ash deposits (bottom) transition upward to dacite breccia and lava flows (top) in the upper tuff and lava unit.

Tuxedo Mine

The Tuxedo Mine operated between 1920 and 1950 and produced silver and smaller amounts of gold. The production values are unknown. The mine is located 5 mi northwest of Ramsay (fig. 2) along a caldera ring-fault fracture that juxtaposes granite of the Boulder Batholith and the lower rhyolite tuff of the Lowland Creek Volcanic field (fig. 2). The fracture was created during caldera collapse about 51 million years ago (fig. 3). Circulating hydrothermal fluids deposited ruby silver (proustite and pyargyrite) and argentite in rhyolite dikes that intruded the fracture. The mine sits on an estimated 6 million tons of gold- and silver-bearing breccia that forms a 2-mi-long northeast-trending ridge. Several generations of quartz within the breccia indicate repeated cycles of crack and seal.

Flume Gulch Mine

The Flume Gulch Mine is a collective of several properties that produced silver and gold as early as 1903 (Hargrave, 1990). The production values are unknown. The mine is located about 7 mi northeast of the Tuxedo Mine (fig. 2). Like the Tuxedo Mine, gold–silver mineralization was caused by rhyolite intrusion and hydrothermal circulation in a caldera wall setting. Gold and silver ores occur in altered and brecciated rhyolite intrusions. Ore-bearing rock forms a semicircular 0.5-mi-wide northeast–southwest ridge that extends for about 3 mi.

Ruby Mine

The Ruby Mine was discovered in 1883, and between 1885 and 1912 the mine produced gold and silver valued today at over $90 million. In 1887, Marcus Daly, one of Butte's famous "copper kings," was involved in early development of the mine, which is centrally located in the Lowland Creek Volcanic field 15 mi west of Boulder (fig. 2). Mineralization is thought to reflect cooling and alteration of the upper tuff and lava unit (fig. 3) within fumaroles on the caldera floor (fig. 2). The mineralized resource is estimated at 12,500 tons of ore that has 0.5 ounces per ton gold, and 20 ounces per ton silver. The main deposit is four nearly vertical breccia and vein shoots hosted in densely welded tuff. Ore minerals include electrum and ruby silver. Native silver occurs locally.

Montana Tunnels Mine

The Montana Tunnels Mine (fig. 9) is located near the northeast end of the Lowland Creek Volcanic field, approximately 10 mi north of Boulder (fig. 2). The mineralized resource is exposed over 0.5 mi², extends 1,000 feet into the subsurface, and has produced gold and silver valued today at over $2.3 billion. Gold occurs in electrum, pyrite, and sphalerite. Silver is found principally in galena (Sillitoe and others, 1985). The pipe-shaped structure is an explosion breccia hosted in a sediment-bearing ash-flow tuff and may be within a vent for the lower tuff unit (fig. 3). Maar volcanoes, which form during violent explosions caused by the interaction of magma with groundwater, often creates explosion breccia.

Figure 9. Open pit gold mine in explosion breccia at the Montana Tunnels Mine. Photo courtesy of John Dilles, Oregon State University. All rights reserved.

ACKNOWLEDGMENTS

Text by Kaleb Scarberry, MBMG. All back photos by Kaleb Scarberry unless otherwise noted; all rights reserved. Thanks to John Dilles for providing figure 9. Front photos courtesy of David Nolt, Montana Tech; Dick Gibson; iStock; and the Montana Memory Project. Figures by Susan Smith, MBMG; technical editing by Tom Patton, MBMG; additional editing and layout by Susan Barth, MBMG.

FURTHER READING

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MONTANA BUREAU OF MINES AND GEOLOGY

Montana Tech of The University of Montana

Scope and Organization

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 as a non-regulatory public service and research agency for the State of Montana, to conduct and publish investigations of Montana geology, including mineral and fuel resources, geologic mapping, and groundwater quality and quantity. In accordance with the enabling act, the MBMG conducts research and provides information.

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