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THE STATE AGENCY FOR GEOLOGIC INFORMATION

MISSION

To collect and archive information about the geologic character, processes, hazards, and mineral and energy resources of Arizona and to inform, advise, and assist the public in order to foster understanding and prudent development of the State's land, water, mineral, and energy resources.

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- Increase understanding of the geology of areas with potential population growth and economic development.
- Improve effectiveness of administering Arizona's oil and gas statutes.
- Expand the customer base of the Arizona Geological Survey.
- Improve access to digital geologic information to all users.

Volcanism in Arizona

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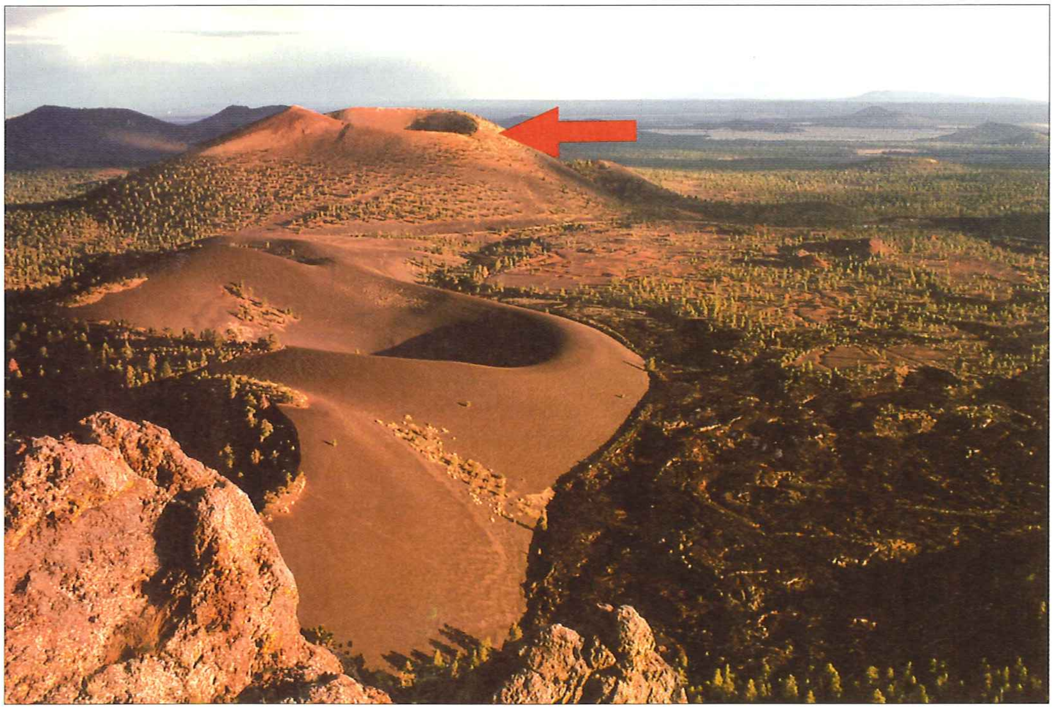

Figure 1. *Sunset Crater (arrow) northeast of Flagstaff in Coconino County, Arizona. Note cinder cones in left foreground and background. Basalt that flowed from the base of Sunset Crater can be seen in the lower right portion of the photo.*

Blobs of red-hot, molten rock sprayed into the air like a huge Roman candle, cooled as they fell to the ground, and formed a cinder cone. Ash and cinders were scattered over the adjacent area and covered the pit houses of the Native Americans who lived there. Lava oozed from the vent and cooled to form lobes of a dark-gray to black *basalt*. Residents discovered that when they pressed an ear of corn into the soft lava it left an impression before it ignited.

This eruption began at Sunset Crater northeast of Flagstaff in 1064 A.D. and continued intermittently for about 150 years (Figures 1 and 2). Nearly 600 cinder cones were already formed in the area during the preceding four million years . No eruptions have occurred in Arizona since then, and there is no evidence that any are imminent.

Volcanic eruptions were common. Volcanic eruptions took place sporadically throughout Arizona, but especially during the last 40 million years (Figure 3). During the first 15 million years of this time period volcanism generally

Figure 2. *Basalt (darkest areas), and cinders cover the ground west of Sunset Crater. The base of Sunset Crater is in the upper left of the photo. Note an old cinder cone (arrow) in the upper right.*

progressed across the State from southeast to northwest. Most of the volcanic rocks younger than 15 million years are located near the southwestern boundary of the Colorado Plateau physiographic province. The youngest volcanic rocks in Arizona, those that are four million years old or less (shown in red on Figure 3), are clustered in six areas throughout the State. Those that crop out along the International Border southeast of Yuma are on the northernmost edge of the Pinacate volcanic field, which is a large, spectacular, young field that is almost entirely in northern Sonora, Mexico.

Non-explosive eruptions. Most eruptions during the past 15 million years had comparatively minor explosive activity. The lava flowed like hot tar and cooled to form basalt. During the past two million years lava with that consistency flowed into the western part of the Grand Canyon near Vulcan's Throne at least a dozen times, temporarily damming the Colorado River. Lava also flowed into and along the Little Colorado River and dammed it in two places. Grand Falls, on the Navajo Reservation about 40 miles northeast of Flagstaff, is the most easily accessible place to view the results (Figure 4). Several times from about 8 to 2 million years ago lava spilled into what was then a large lake but is now the Verde River Valley between Clarkdale and Camp Verde. Basalt there is interbedded with lake-bed sediment. Between Camp Verde and Strawberry lava cascaded southward over the Mogollon Rim and completely obscured it.

Explosive eruptions. Many eruptions were explosive. The lavas that accompanied them were richer in silica and, therefore, more viscous (less fluid) than the basaltic flows. Viscosity of the lava was determined by its composition, which, in turn, determined the ease with which trapped gases could escape. Much of this lava solidified as *rhyolite* or associated rock types. Ash, pumice, and rock fragments were ejected into the air. San Francisco Mountain, 10 miles north of Flagstaff, is the remnant of one of Arizona's best-known explosive volcanoes (Figure 5). Humphreys Peak, which has an elevation of 12,633 feet, is the highest point on San Francisco Mountain and the highest point in Arizona. Sometime between 200,000 and 400,000 years ago, however, San Francisco Mountain was 15,000-16,000 feet high before the top and northeast side blew off during a violent eruption. About 2,500-3,000 feet of the summit was destroyed. (That's essentially what happened to Mount St. Helens in Washington in May 1980, except that elevation of St. Helens prior to the eruption was 9,677 feet and 1,300 feet of its summit was blown off.) Pumice and volcanic ash from San Francisco Mountain were scattered toward the northeast and accumulated in low places.

In the Superstition Mountains, about 23 miles east of downtown Phoenix, a volcano exploded about 18 million years ago. Volcanic ash beds associated with these eruptions are exposed spectacularly along the Apache Trail, which follows the Salt River northeast of Apache Junction. Geologists named the thickest and most widely distributed ash deposit the *Apache Leap Tuff.*

About 27 million years ago a series of explosive eruptions took place in the Chiricahua Mountains in southeastern Arizona and resulted in deposition of the *Rhyolite Canyon Tuff* and other ash beds to a thickness of about 2,000 feet. These units were subsequently eroded to form spectacular pinnacles and columns (Figure 6). The Organ Pipe Cactus National Monument is also an excellent laboratory in which to observe rhyolite, volcanic ash, and other rocks associated with explosive volcanism.

(continued on page 4)

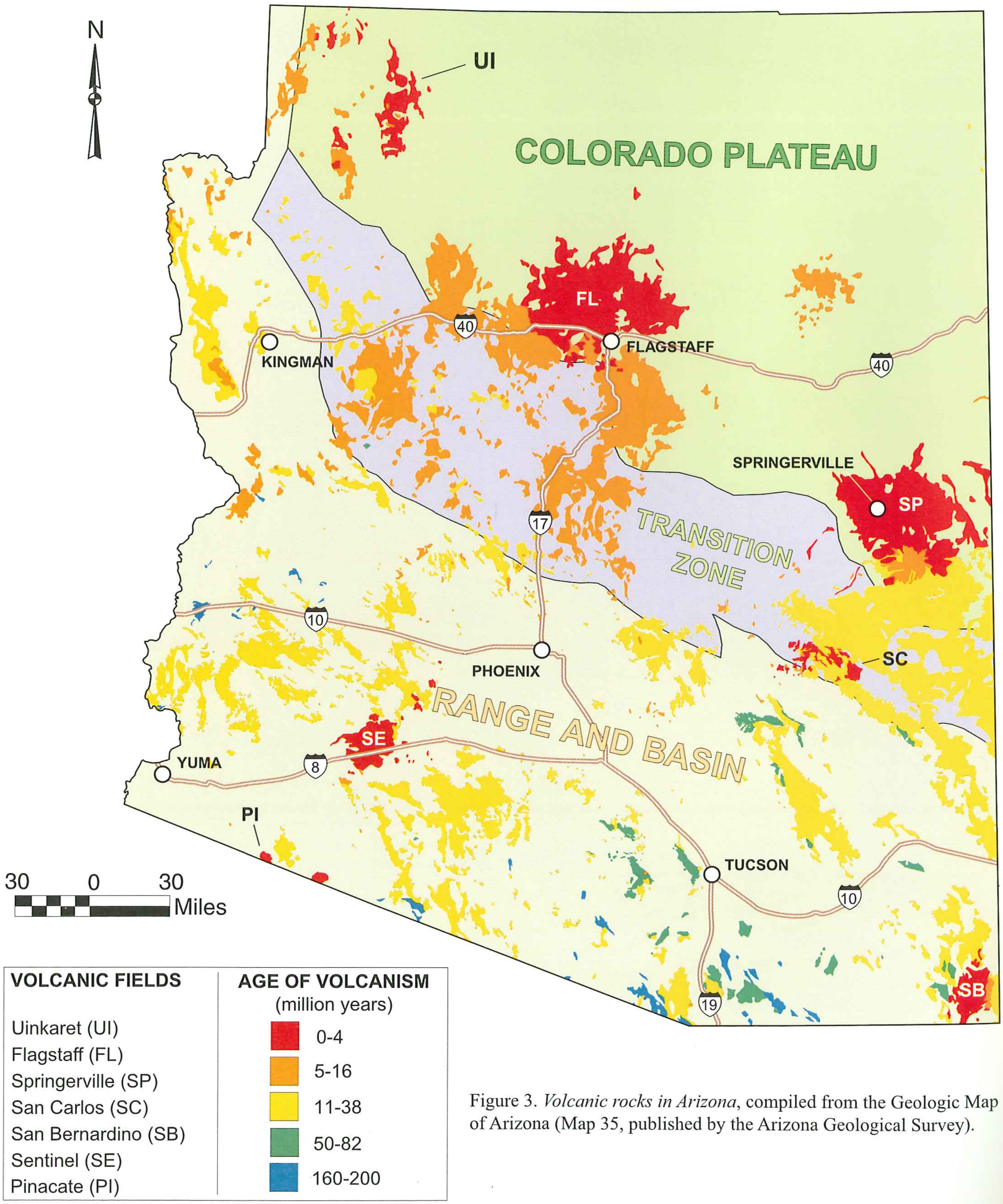

Figure 3. *Volcanic rocks in Arizona*, compiled from the Geologic Map of Arizona (Map 35, published by the Arizona Geological Survey).

Figure 5. *San Francisco Mountain as viewed from the northeast toward the inner basin (IB). This side of the mountain was blown out during a violent eruption. Note volcanic debris and cinder cones in the center foreground. Sunset Crater (arrow) is at the left of the photograph.* Photo by J. Dale Nations

Does Arizona have a volcano hazard?
Geologically, the volcanic activity that took place in Arizona during the last four million years is very young. Those volcanic fields that are less than four million years old should probably be considered dormant, but not extinct.

Volcanoes do not erupt without giving some type of warning. Warning signals include frequent small earthquakes caused by upward movement of molten rock *(magma)*. The land surface might even bulge slightly. Shallow magma heats ground water, commonly enough to cause it to boil. Hot springs are common. In addition, gases such as carbon dioxide that are associated with magma might bubble from the ground and, if sufficiently concentrated, even cause plants to die. Although "swarms" of small earthquakes have occurred near the Grand Canyon, seismologists do not attribute them to the movement of magma. No evidence suggests that magma is currently moving toward the surface in Arizona.

Figure 4. (Left) *Grand Falls on the Little Colorado River northeast of Flagstaff on the Navajo Reservation. The river originally flowed from the upper right toward the lower left. A lobe of lava flowed from right to left, plugged the channel (arrow), and extended a short distance to the left. The red line marks the contact between basalt and the underlying bedrock. The river eventually flowed around the basalt lobe and returned to its original channel, forming the Grand Falls. Basalt in the foreground is an eroded remnant of part of the flow that extended downstream.*

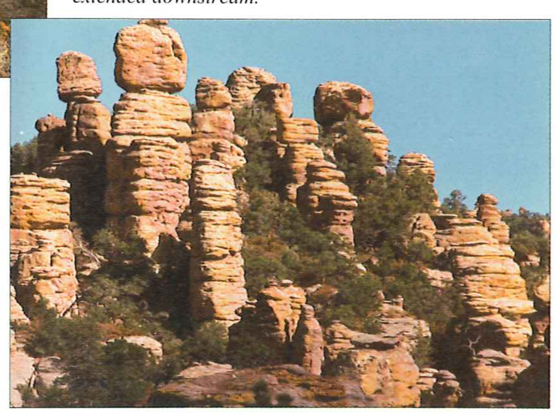

Figure 6. (Right) *Columns of rhyolite formed by erosion of compacted volcanic ash, pumice, and rock fragments. This explosive volcanic activity occurred in what is now the Chiricahua National Monument in Cochise County, southeastern Arizona. Columns and other geological features present within the Monument are described in* Field Guide to the Geology of the Chiricahus National Monument. *See Selected Refrences.*

SELECTED REFERENCES

Volcanoes of northern Arizona, sleeping giants of the Grand Canyon region: W. A. Duffield, 1997, Grand Canyon, Arizona, Grand Canyon Association, 68 p.

Field guide to the geology of the Chiricahua National Monument: J.V. Bezy, 1998, Arizona Geological Survey Down-to-Earth 8, 32 p.

A guide to the geology of Organ Pipe Cactus National Monument and the Pinacate Biosphere Reserve: J.V. Bezy, J.T. Gutmann, and G.B. Haxel, 2000, Arizona Geological Survey Down-to-Earth 9, 63 p.

Just Released

Geologic map of the Oracle Junction 7.5' quadrangle and the eastern third of the Tortolita Mountains 7.5' quadrangle, Pima and Pinal Counties, Arizona: S.J. Skotnicki, 2000, Arizona Geological Survey Open-File Report 00-04 (Pub. number OFR 00-04), 19 p., 1 sheet, scale 1:24,000. $5.50 plus shipping and handling

Compilation geologic map of the Oracle 7.5' quadrangle, Pinal and Pima Counties, Arizona: J.E. Spencer, S.M. Richard, and C.A. Ferguson, 2000, Arizona Geological Survey Open-File Report 00-05 (Pub. number OFR 00-05), 30 p., 1 sheet, scale 1:24,000. $8.00 plus shipping and handling

Geologic map of the southern Roskruge Mountains (the San Pedro and southern half of La Tortuga Butte 7.5' quadrangles), Pima County, Arizona: C.A. Ferguson, W.G. Gilbert, P.A. Pearthree, and T.H. Biggs, 2000, Arizona Geological Survey Open-File Report 00-06 (Pub. number OFR 00-06), 40 p., 1 sheet, scale 1:24,000. $11.00 plus shipping and handling

Geologic map of the Cocoraque Butte 7.5' quadrangle, Pima County, Arizona: S.J. Skotnicki and P.A. Pearthree, 2000, Arizona Geological Survey Open-File Report 00-08 (Pub. number OFR 00-08), 27 p., 1 sheet, scale 1:24,000. $6.50 plus shipping and handling

Tritium as a tracer of groundwater sources and movement in the Safford Basin, Graham County, Arizona: R.C. Harris, 2000, Arizona Geological Survey Open-File Report 00-09 (Pub. number OFR 00-09), 56 p. $10.00 plus shipping and handling

Maps showing surface exposures of salty lacustrine sediments in the Safford Basin, Graham County, Arizona: R.C. Harris, 2000, Arizona Geological Survey Open-File Report 00-10 (Pub. number OFR 00-10), 9 p., 11 figures, scale 1:24,000. $4.00 plus shipping and handling

Geologic map of the Four Peaks 7.5' quadrangle, Maricopa and Gila Counties, Arizona: S.J. Skotnicki, 2000, Arizona Geological Survey Open-File Report 00-11 (Pub. number OFR 00-11), 34 p., 1 sheet, scale 1:24,000. $8.00 plus shipping and handling

Geologic map and geologic hazards of the Three Points 7.5' quadrangle, Pima County, Arizona: P.A. Pearthree, C.A. Ferguson, W.G. Gilbert, and S.J. Skotnicki, 2000, Arizona Geological Survey Open-File Report 00-12 (Pub. number OFR 00-12), 19 p., 1 sheet, scale 1:24,000. $10.00 plus shipping and handling

Surficial geologic maps and geologic hazards of the Green Valley-Sahuarita area, Pima County, Arizona: P.A. Pearthree and A.M. Youberg, 2000, Arizona Geological Survey Open-File Report 00-13 (Pub. number OFR 00-13), 21 p., 2 sheets, scale 1:24,000. Text $4.00, each sheet $8.00, Text and sheets $20.00 plus shipping and handling

Annual report of the Arizona Geological Survey, FY 2000: L.D. Fellows, 2000, Arizona Geological Survey Open-File Report 00-14 (Pub. number OFR 00-14), 27 p. $5.00 plus shipping and handling

Digital geographic index of geologic literature for the east half of the Phoenix North 30' x 60' quadrangle, Arizona: T.R. Orr, 2000, Arizona Geological Survey Digital Information Series 20 (Pub. number DI 20), 3 ArcView shapefiles, 6DBF files, and other files; 1 CD. $30.00 plus shipping and handling

Geology of the Los Adobes Rancho area, Sonora, Mexico, and Santa Cruz County, Arizona: W.G. Gilbert and D.J. Lajack, 2000, Arizona Geological Survey Contributed Map 00-C (Pub. number CM 00-C), 5 p., 1 sheet, scale 1:24,000. $3.50 plus shipping and handling

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Arsenic Update

In the Fall 2000 issue of *Arizona Geology* we featured arsenic in ground water relative to the U.S. Environmental Protection Agency's (EPA) proposal to reduce the maximum contaminant level (MCL) from 50 to 5 parts per billion (ppb) by weight. Our purpose was to show that arsenic is widely distributed in ground water in Arizona, is a natural substance whose distribution is controlled by geologic processes, and that conforming to the EPA's proposed reduction in the MCL will require remediation of a large number of wells. A reader informed us that we had missed the whole point: scientific justification for lowering the MCL for arsenic is insufficient.

To follow up, we reviewed "Arsenic in Drinking Water," prepared by the National Research Council (NRC) at the request of the EPA. The 310-page report is available on the internet (http://books.nap.edu/books/0309063337/html/R11.html). The NRC committee based its characterization of arsenic risk on findings from international studies, experimental data on the mechanisms through which arsenic causes cancer, and available information on human susceptibility. No human studies of sufficient scope in the U.S. have directly examined whether regular consumption of arsenic in drinking water at EPA's current standard increases the risk of cancer or other adverse health effects. Epidemiological studies in Taiwan, Chile, and Argentina provide sufficient evidence that ingestion of arsenic in drinking water poses a hazard of cancer of the lung and bladder, in addition to cancer of the skin. International populations studied, however, were exposed to drinking water with several hundred ppb arsenic or more. Applicability of the international studies to U.S. populations is uncertain. Because few data address the degree of cancer risk at lower concentrations of ingested arsenic, the committee concluded that more research is needed. The committee also identified a number of other uncertainties and specific topics that need additional research.

In spite of what appear to be limited and inconclusive research results, the NRC committee reached a consensus that the current EPA MCL for arsenic in drinking water of 50 ppb does not achieve EPA's goal for public health protection and, therefore, requires downward revision as promptly as possible. The EPA proposed that the MCL be reduced from 50 to 5 ppb.

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