3.12 RISK ASSESSMENT: VOLCANIC ERUPTIONS

DESCRIPTION

Volcanic hazards may be divided into two categories based on the range of their impact from the eruptive center or active vent. Proximal hazards have an impact limited to a distance of 30 miles or less from the active vent. Distal hazards have an impact far beyond the active vent.

East Butte, a rhyolitic volcanic dome, lies on the eastern Snake River Plain in southern Idaho / Source: Scott Hughes, Idaho State University

Not all volcanic activity will result in all of the hazards listed here. The nature of the lava (rhyolitic or basaltic)[1], the history of eruptions at the site, the presence of groundwater, and other factors influence the size, character, and duration of the eruption and the resultant hazards.

Proximal Hazards

Lava Flows are pouring or oozing collections of lava extruded from vents. These flows can destroy all structures in their paths and start forest fires, but they advance relatively slowly, so they seldom endanger people. Lava flows damage or destroy everything in their paths by burying, crushing, or burning. Large areas of productive and/or developable lands may be lost to lava flows. They can also generate additional hazards by damming or diverting streams.

Pyroclastic Flows are avalanches of hot ash, rock fragments, and gas that move down the sides of a volcano during explosive eruptions or lava dome collapses. These flows can be as hot as 1,500^{o}F and move at speeds of up to 100 to 150 miles per hour. They are capable of knocking down and incinerating everything in their paths. Such flows tend to follow valleys and are generally restricted to the immediate vicinity of the volcano. Lower-density pyroclastic flows, called pyroclastic surges, can easily overflow ridges hundreds of feet high.

[1] Rhyolitic lava tends to result from explosive events, and basaltic lava tends to result from non-explosive events and has a lower viscosity (i.e., is more fluid) than rhyolitic lava.

Lahars and Debris Avalanches: Lahars are mud or debris flows, composed mostly of eruptive materials, on the flanks of a volcano. These flows can travel at speeds of 20 to 40 miles per hour and cover long distances. Debris avalanches are rapid downhill movements of rock, snow, and/or ice. They range from small movements of loose debris on the surface of a volcano to massive collapses of the entire summit or side of a volcano. Debris avalanches on volcano slopes are triggered when eruptions, heavy rainfall, or large earthquakes cause these materials to break free and move downhill.

Volcanic Gases: Volcanoes emit a number of potentially toxic gases, both during and between eruptions. The majority of the gas is water vapor (steam), derived from recent precipitation and groundwater. Other common volcanic gases include carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and fluorine.

Toxic gases can have both short-term effects and long-term effects on human lives and the natural environment. Carbon dioxide is heavier than air and can be trapped in low areas in concentrations that are deadly to people and animals. Sulfur dioxide is a respiratory poison and also reacts with atmospheric water to create acid rain, causing corrosion and harming vegetation. Hydrogen sulfide is a highly toxic respiratory poison. Fluorine is a highly toxic respiratory poison and can be absorbed onto volcanic ash particles that later fall to the ground, poisoning livestock grazing on ash-coated grass and also contaminating domestic water supplies.

Tephra is solid and molten rock fragments, ranging in size from large "bombs" (from fist-sized to over 3 feet in diameter) to fine dust. The largest rock fragments usually fall back to the ground within 2 miles of the vent. Tephra deposits can pose a risk to lives and structures if they accumulate in a thickness sufficient to collapse roofs. More commonly, they reduce visibility and clog vehicle air filters, posing a hazard on highways. Deposits can topple or short-circuit electric transformers and power lines and clog other infrastructure (such as water and sewage treatment facilities). Tephra clouds also commonly generate lightning that can interfere with electrical and communication systems and start fires. The fine material is extremely slippery, hampering driving and walking, and can damage the lungs of small infants, the elderly, and those with respiratory problems.

Distal Hazards

Eruption Columns and Clouds are created when small fragments (less than about 0.1 inch across) of volcanic glass, minerals, and rock are released during explosive eruptions and rise high into the air. Eruption columns can grow rapidly and reach more than 12 miles above a volcano, forming an eruption cloud. Large eruption clouds can extend hundreds of miles downwind, resulting in falling ash over enormous areas; the wind carries the smallest ash particles the farthest. The volcanic ash in the cloud can pose a serious hazard to aviation; engines of jet aircraft have suddenly failed after flying through clouds of even, thinly dispersed material. Recent volcanic eruptions in Iceland caused tens of millions of dollars in losses to European counties due to travel restrictions, airline cancellations, and lost tourism.

Ashfall: As an eruption cloud drifts downwind from the volcano, the material that falls from the cloud typically becomes smaller in size and forms a thinner layer. Though called "ash," volcanic ash is not the product of combustion, like the soft fluffy material created by burning wood, leaves, or paper. Volcanic ash is hard, does not dissolve in water, is extremely abrasive and mildly corrosive, and conducts electricity when wet. Damages from ashfall are similar to those from tephra (ash being a form of tephra). Communities far from the actual eruption may be seriously disrupted by ashfall. The volcanic ash in an eruption cloud can pose a serious hazard to aviation; engines of jet aircraft have suddenly failed after flying through clouds of even, thinly dispersed material. The weight of ashfall can collapse buildings.

LOCATION, EXTENT, AND MAGNITUDE

According to the USGS, three active and potentially active areas of volcanic activity are most likely to have direct effects on Idaho: the Snake River Plain, particularly the "Craters of the Moon" area in south-central Idaho; the Yellowstone Caldera, which overlaps Idaho, Wyoming, and Montana; and the Cascade Mountains to the west (see Figure 3.12.D at the end of this section). The Snake River Plain and the Yellowstone Caldera have not had eruptions within the past 2,000 years, but Yellowstone is being particularly closely watched because of seismicity and ground deformation in recent decades.

There are more than a dozen potentially active volcanoes in the Cascade Mountains (see Figure 3.12.A). The composite volcanoes are the most likely to have a far-reaching impact, as they tend to erupt more explosively and over longer periods of time (tens to hundreds of thousands of years) than other types of volcanoes found in the Cascades. Mount St. Helens and Mount Shasta are examples of composite volcanoes in the Cascade Mountains.

Source: ThinkStock.com

Figure 3.12.A: Active and potentially active volcanoes of the Cascade Range to the west of Idaho, excluding Canada. All but Mount Adams, Mount Jefferson, Mount McLaughlin, and Crater Lake have been active within the past 2,000 years / Source: Cascades Volcano Observatory (1992)

The Volcanic Explosivity Index (VEI) is one way to describe the relative size of explosive volcanic eruptions (see Figure 3.12.B, below). Scores range from 0 to 8, with each number representing an increase in magnitude from the previous number by a factor of approximately ten. Several factors are taken into consideration to determine the magnitude, including the volume of erupted pyroclastic material (for example, ashfall, pyroclastic flows, and other ejecta), height of eruption column, duration in hours, and qualitative descriptions. VEI does not necessarily relate to the amount of sulphur dioxide injected to the atmosphere, which is critical in determining the climatic impacts of an eruption.

Large explosive eruptions occur much less frequently than small ones. Data from the Global Volcanism Program of the Smithsonian Institution demonstrate that "through 1994, the record of volcanic eruptions in the past 10,000 years . . . shows that there have been four eruptions with a VEI of 7, 39 of VEI 6, 84 of VEI 5, 278 of VEI 4, 868 of VEI 3, and 3,477 explosive eruptions of VEI 2".

If a large eruption of a composite volcano in the Cascade Mountains were to occur, Idaho would likely experience distal impacts. Effects from the 1980 Mount St. Helens eruption can serve as an example of potential effects from future volcanic eruptions in the northwest region. This eruption measured at 5 on the VEI scale. As shown in Figure 3.12.C, roughly half of Idaho experienced ashfall from this event, and portions of the State experienced some of the event's highest concentrations of ashfall.

PAST OCCURRENCE

The only significant volcanic event in Idaho during recorded history was ashfall from the eruption of Mount St. Helens in 1980 (detailed below). The area has seen extensive volcanic activity in the more distant past, however. Within the Snake River Plain, the Craters of the Moon lava field had extensive flows up to 2,000 years ago, and the Boise area experienced large lava flows 1 million years ago. The Gem Valley area in southeastern Idaho has also been volcanically active; the last eruptive activity occurred about 30,000 years ago.

In the Yellowstone region, major explosive eruptions occurred 2, 1.3, and 0.6 million years ago. The most recent eruptions, 75,000-150,000 years ago, produced thick lava flows. With respect to Cascadian eruptions, an average of two eruptions occur per century - the most recent were at Mount St. Helens, Washington (1980-86), and Lassen Peak, California (1914-17). Although not the case with this most recent eruption at Lassen Peak, Rockland Ash from an eruption at Lassen 600,000 years ago can be found in southern Idaho.

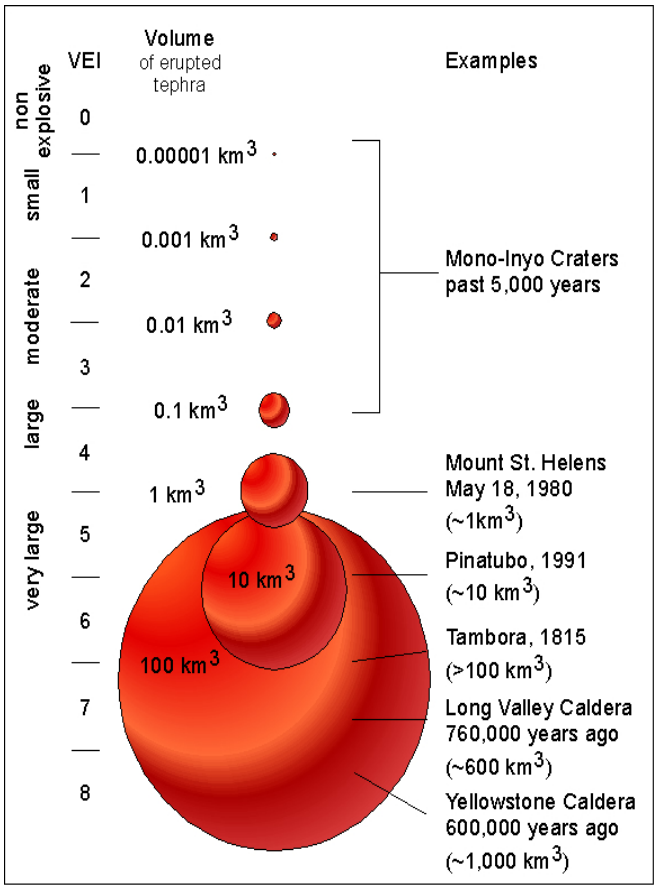

Figure 3.12.B: Volumes of several past explosive eruptions and the corresponding Volcanic Explosivity Index (VEI)

Mount St. Helens: On May 18, 1980, Mount St. Helens, Washington, erupted, killing 57 people and causing over 1 billion dollars of damage in the Northwest. The eruption followed two months of earthquakes and minor eruptions, and this warning allowed most people in the proximal hazard area to evacuate prior to the eruption.

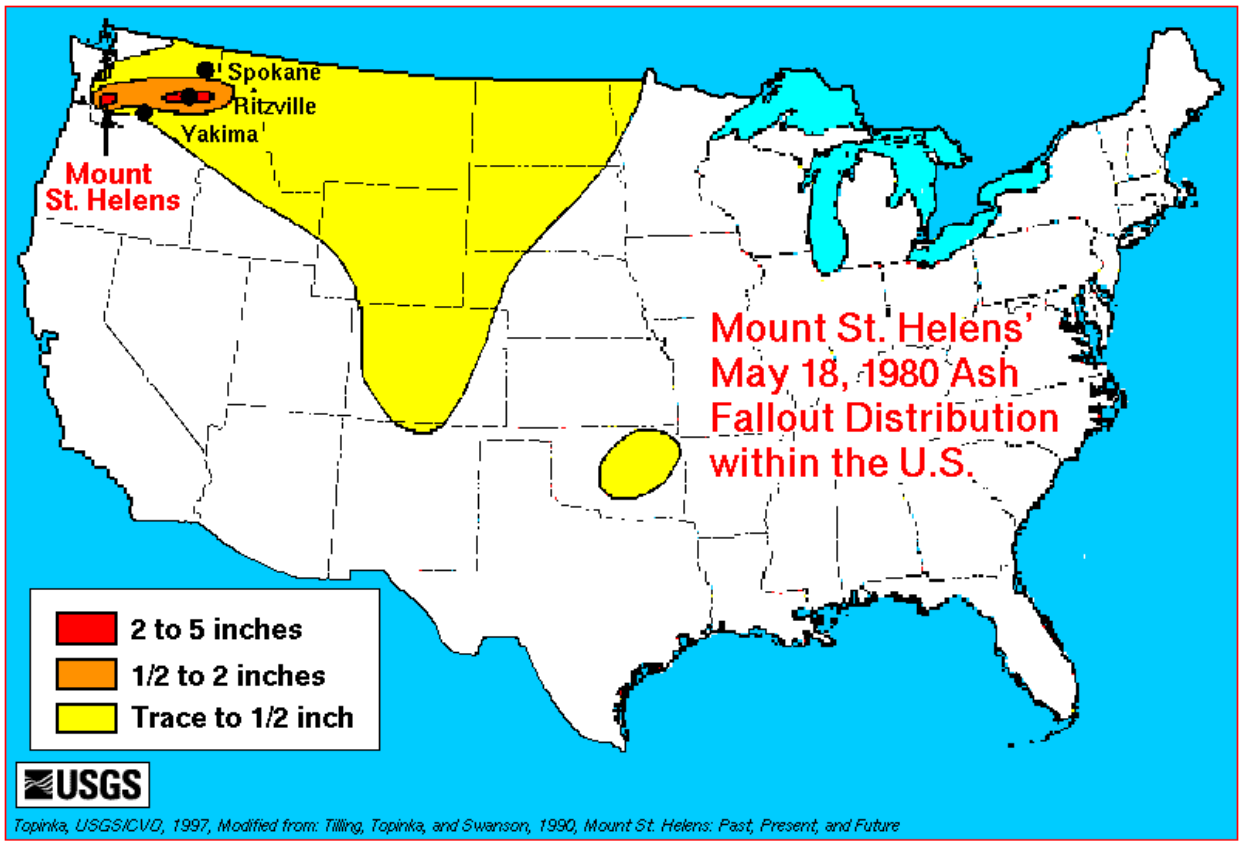

Figure 3.12.C: Generalized map shows the distribution of ash fallout within the United States, from May 18, 1980 eruption / Source: Cascades Volcano Observatory (1997)

Ashfall from the 1980 eruption of Mount St. Helens impacted northern Idaho, covering roads, affecting crops, machinery and vehicles, and creating health issues. The damage resulted in a Presidential disaster declaration that included Benewah, Bonner, Boundary, Clearwater, Kootenai, Latah, and Nez Perce Counties.

FUTURE OCCURRENCE

Idaho faces two likely future volcanic hazard scenarios: distal hazards from volcanic activity in the Cascades, and proximal as well as distal hazards from the Yellowstone Caldera.

Volcanic eruptions generally occur only after significant warning. Volcano monitoring can detect and measure changes caused by magma movement beneath the volcano. This movement will typically lead to swarms of earthquakes, swelling or subsidence of a volcano's summit or flanks, or release of volcanic gases from the ground and vents. Monitoring can project volcanic activity within a time frame of days to

months. Longer-term hazard projection is more difficult and is generally dependent on analyses of past activity.

The USGS operates five volcanic observatories, including one in the Yellowstone region and one in the Cascades region. These observatories maintain websites and issue warnings as well as weekly updates on volcanic activity. Recently (2010), the Yellowstone Volcano Observatory developed protocols for a geologic hazards response in the Yellowstone region. The report states, "Within the next few decades, large and moderate earthquakes and hydrothermal explosions are certain to occur. Volcanic eruptions are less likely, but are ultimately inevitable in this active volcanic region." Similarly, the Cascades Volcano Observatory produces hazard assessments for the multitude of volcanoes in the Cascades.

Projected Idaho Events

Yellowstone Caldera: The hydrothermal features of the Yellowstone National Park area are fueled by the large magma plume (the "hotspot") that lies below the region. These features are volcanic activity, although not of a generally hazardous nature. The high levels of seismic activity and active deformation of the surface in the area also indicate the volcanic potential of Yellowstone. However, if one were to use past eruptions as a guide, the yearly probability of another catastrophic eruption within Yellowstone is 1 in 730,000 (the average of the years between past events). A more likely type of volcanic eruption from Yellowstone (averaging every 16,000 years in the past) is a basaltic eruption along the margins, including the basin of Island Park, Idaho. The principle hazard from such an event would be coverage of an area of several square kilometers by lava, one to a few tens of meters thick.

Snake River Plain: Most past volcanic activity in the Snake River Plain was confined to "volcanic rift zones," linear areas of cracks in the earth's crust. Volcanic activity in this area has been characterized by eruptions of basaltic lavas resulting in extensive lava flows. These flows resulted from eight distinct eruptive periods with an average recurrence interval of 2,000 years. As the most recent flows in the area occurred approximately 2,000 years ago, extrapolation suggests that activity may resume in the not too distant future; however, there has not been recent evidence of activity.

Cascades: Ten volcanoes (or volcanic centers) within the Cascade Mountains have been active within the last 2,000 years; an additional four are regarded as potentially active. As the eruption of Mount St. Helens demonstrated in 1980, activity in this region can have significant impact over a wide area, including Idaho. According to the U.S. Geological Survey, portions of Idaho have a 1:1,000-1:5,000 annual probability of receiving 1 centimeter or more of ashfall from any major Cascade volcano; there is a less than 1:10,000 probability of 10 centimeters or more.

RELATIONSHIPS TO OTHER HAZARDS

A volcanic event would certainly have a large impact and influence over many of the hazards that pose a risk to the State. The location of the eruption would dictate these impacts. For a repeat event in the Cascade Range, ashfall would be the main cause for concern. This could increase susceptibility for avalanches, by depositing a weak layer in the snowpack. An ashfall event could also affect the short term storm patterns. Additionally, the movement of magma upward during an eruption could initiate seismic events.

A Yellowstone event would pose the greatest threat to the State, and has the ability to increase the risk posed by many of the natural hazards. The largest impact would relate to human-caused hazards, theoretically dramatically increasing the likelihood of all to occur.

Source: ThinkStock.com

ENVIRONMENTAL IMPACTS

In areas of the State where proximal volcanic hazard exists, a volcanic eruption could cause dramatic environmental effects. Vegetative communities, wildlife, historic and archeological sites, farms, and parks could be buried, crushed and burned by a lava flow. Volcanic eruption would affect geology and soils in areas of Idaho proximal to the event. Long-term effects could include forced changes in land-use patterns. Throughout the State, distal volcanic hazards could reduce air quality, damage historic resources (e.g., ashfall on old roofs), clog streams, and have health impacts on fish and wildlife.

DEVELOPMENT TREND IMPACTS

Because volcanic eruptions tend to be far apart in time, it is unlikely that the threat of their effects will be considered in overall development trends. When an eruption does occur, economic activity can be stymied even far from the center of activity, as evidenced from the disruption to flight schedules in the wake of the 2010 Iceland volcanic eruption. If an eruption occurs within Idaho, developable land can be lost to lava flows, as in the Craters of the Moon volcanic field.

CRITICAL INFRASTRUCTURE AND STATE FACILITY IMPACTS

All infrastructure and State facilities could be at risk of ashfall from a major eruption. Critical facilities near Island Park are at greater risk than other areas of the State for lava flow.

VULNERABILITY ASSESSMENT

No specific, statewide vulnerability assessment exists for the volcano hazard.

Local Hazard Mitigation Plan Vulnerability Assessments

Forty-seven local mitigation plans were analyzed to determine the major hazards in each jurisdiction. Volcanic eruptions were not ranked as a major hazard by any jurisdiction. Detailed information related to local vulnerability may be found in local hazard mitigation plans.

LOSS ESTIMATION

No specific, statewide loss estimation exists for this hazard.

Local Hazard Mitigation Plan Loss Estimations

Because no local mitigation plans ranked volcanic eruptions as a major hazard, these data were not aggregated, and it is assumed that annual loss estimates would be low. Detailed information related to local loss estimates may be found in local hazard mitigation plans.

MITIGATION RATIONALE

Volcanic eruption has a relatively low probability (compared with other hazards) in any given year. Additionally, the most likely event, a volcanic eruption in the Cascade Mountains, is expected to only produce moderate impacts within Idaho.

While improbable, the potential for severe damages resulting from a major event in Idaho is real. The geologic history of Idaho and the region has a significant component of volcanic activity. Consequently, the State is well advised to undertake mitigation planning.

GENERAL MITIGATION APPROACHES

Given the low probability and unique nature of these events, volcanic eruptions pose a special problem for emergency management personnel. Some special characteristics that influence emergency response and mitigation include:

- Eruptions generally have many precursors, but these potential warnings are often ambiguous (i.e., we can often forecast activity generally, but rarely precisely).
- There is a large range in the magnitude/frequency relation for eruptions (i.e., there is no way to easily anticipate the scale of the impending eruption).
- The scale of eruptions may far surpass any other hazard.
- Some of the hazards associated with an eruption can be fast moving.
- The impacts from volcanic eruptions can be very long lasting – centuries or more.

Volcanic eruptions are outside of most people's realm of experience; consequently, the public has a minimal appreciation of the hazards.

Hazard Management

As eruptive activity rarely comes without significant warning, mitigation efforts in likely proximal hazard zones should ensure that critical or high-investment development is not sited in high-risk areas. This will reduce the potential overall disaster cost without unnecessarily constraining land use.

Information/Outreach and Public Education

Because of the infrequent nature of volcanic activity in the State, the public's appreciation of the hazards is limited. Information regarding distal hazards should be made available to citizens and property owners through the State. Information on proximal hazards should be prepared and readily available if an event does become likely.

Implementing the new Yellowstone Volcano Observatory protocols (2010) and providing information on the USGS Volcano Hazards Program (http://volcanoes.usgs.gov/) could reduce losses due to volcanoes.

Infrastructure

Infrastructure should not be sited in probable proximal hazard zones if feasible alternatives exist.

Regulatory

Building codes should ensure that new development can withstand probable ashfall loads. Land-use regulations can mandate the siting considerations discussed under Hazard Management.

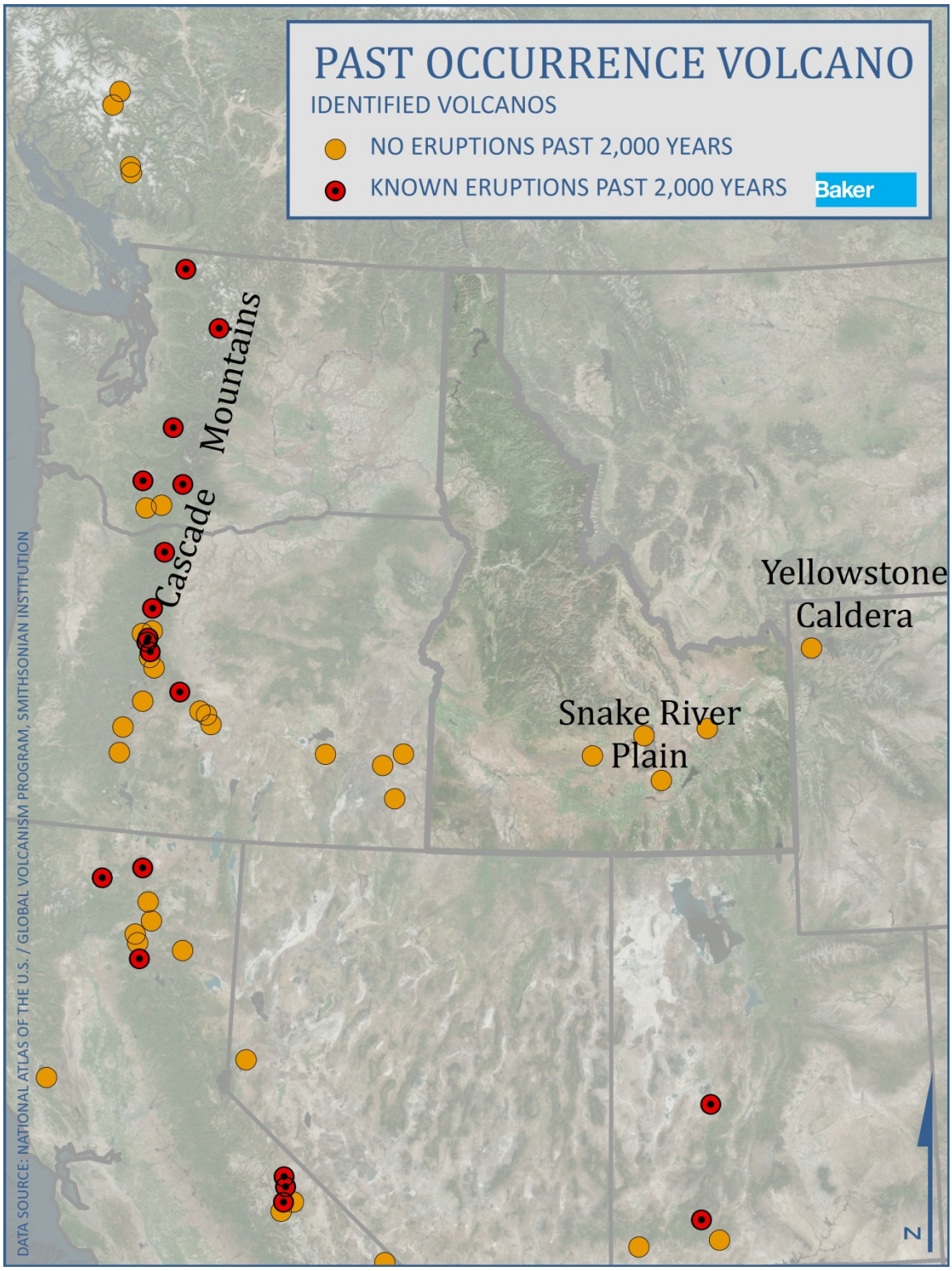

Figure 3.12.D: Volcano Locations and Extent

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