Yellowstone: Sitting on Top of a Cataclysmic Volcano?

Angie Quinn

Quest Club

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In 1905, Nathaniel Pitt Langford wrote:

> "Ever since the first year of my residence there I had frequently heard rumors of the existence of wonderful phenomena in the region where the Yellowstone, Wind, Snake and other large rivers take their rise, and as often had determined to improve the first opportunity to visit and explore it, but had been deterred by the presence of unusual and insurmountable dangers. It was at that time inhabited only by wild beasts and roving bands of hostile Indians. An occasional trapper or old mountaineer were the only white persons who had ever seen even those portions of it nearest to civilization…Of these some had seen one, some another object of interest; but as they were all believed to be romancers their stories were received with great distrust. The old mountaineers of Montana were generally regarded as great fabricators. I have met with many, but never one who was not fond of practicing upon the credulity of those who listened to the recital of his adventures. James Bridger, the discoverer of Great Salt lake, who had a large experience in wild mountain life, wove so much of romance around his Indian adventures that his narrations were generally received with many grains of allowance by his listeners..."

> "I first became acquainted with Bridger in the year 1866. He told me at that time, of the existence of hot spouting springs in the vicinity of the source of the Yellowstone and Madison rivers, and said that he had seen a column of water as large as his body, spout as high as the flag pole in Virginia City, which was about

sixty (60) feet high. The more I pondered upon this statement, the more I was impressed with the probability of its truth. If he had told me of the existence of falls one thousand feet high, I should have considered his story an exaggeration of a phenomenon he had really beheld; but I did not think that his imagination was sufficiently fertile to originate the story of the existence of a spouting geyser, unless he had really seen one, and I therefore was inclined to give credence to his statement, and to believe that such a wonder did really exist."

"I was the more disposed to credit his statement, because of what I had previously read in the report of Captain John Mullan, made to the war department…Feb. 14, 1863, and a copy of which I still have in my possession, I find that Captain Mullan says: 'I learned from the Indians, and afterwards confirmed by my own explorations, the fact of the existence of an infinite number of hot springs at the headwaters of the Missouri, Columbia and Yellowstone rivers, and that hot geysers, similar to those of California, exist at the head of the Yellowstone…This is as true as it is strange, and shows unerringly that there exists in this zone an atmospheric river of heat, flowing through this region, varying in width from one to one hundred miles, according to the physical face of the country.'"[1]

Langford and a small group of explorers journeyed to Yellowstone Park in 1870, and their trip was recently described on the PBS series "The National Parks: America's Best Idea." The

[1] Langford, Nathaniel Pitt. *The Discovery of Yellowstone Park: Journal of the Washburn Expedition to the Yellowstone and Firehole Rivers in the Year 1870*. 1905

findings of their expedition and of several more in the next year were excitedly reported back east. By 1872, there had been sufficient exploration of the area to suggest that it was a unique site, and Congress passed an act making Yellowstone the first National Park.

Yellowstone National Park is situated in the northwest corner of Wyoming, approximately 1600 miles west of Fort Wayne, Indiana. It is 3472 square miles, or approximately 5 times the size of Allen County. The National Park Service describes it as "home to a large variety of wildlife including grizzly bears, wolves, bison, and elk. Preserved within Yellowstone National Park are Old Faithful and a collection of the world's most extraordinary geysers and hot springs, and the Grand Canyon of the Yellowstone."

Yellowstone is located in the Rocky Mountain chain, but its geological story is different. Grand Teton National Park is located just a few miles south of Yellowstone's southern border, but is a completely different type of landscape. Within Yellowstone, areas of typical mountain varieties of trees and flowers are punctuated by wide, saline flats with bubbling cauldrons of mud, or water, or a mineral soup.

An impressive array of animals are found at Yellowstone as well. I saw my first elk at Yellowstone, and throughout our family's visit to the park two years ago we saw small groups of elk along the Firehole River frequently. And, yes, we blocked traffic along with all the other visitors, to photograph a moose chomping happily some tasty branch along the side of the road—a picture so perfect one wondered where the ranger was who set up the shot. We didn't see wolves, but they have returned to the park. Bison are there as well, and are sometimes the targets

for slaughter by angry neighboring ranchers, when they roam from the park, potentially carrying a disease that decimates their cattle herds.

The built environment at Yellowstone is also impressive, and the architecture of the park has been studied for its character-defining "park-rustic" style. During the Great Depression, relief projects sent thousands of workers to national and state parks to complete construction projects that ranged from roads and bridges to deluxe inns and visitor centers.

And, then, there are those geothermal wonders. Geologists describe Yellowstone as "the site of one of the world's largest hydrothermal systems including Earth's largest concentration of geysers."[2]

Yellowstone abounds with steaming rivers and creeks, geysers, mudpots, hotsprings. Why are they there and how do they work? Until the mid 1970s, most park visitors and even scientists assumed that the geothermal activities were vestiges of long ago volcanism, and benign. As a child in the early 1970s, I first read about Yellowstone Park in a volume from Readers Digest entitled *Scenic Wonders of America*. Published in 1973, it described Yellowstone: "Essentially, Yellowstone is a dying volcanic area. The mountains surrounding it are the eroded remnants of piled-up lava flows and pyroclastic materials. Pyroclastic means fire-broken: the molten rock and gases hurled out of an erupting volcano that cooled and hardened in the air and fell to the ground as solid particles of dust, ash and cinders."[3] Since the 1970s, however, increased research, monitoring of changing geothermal and geological conditions, and the establishment of a

[2] http://volcanoes.usgs.gov/yvo/about/. Accessed October 5, 2009.
[3] *Scenic Wonders of America*. Pleasantville, New York: Reader's Digest Association, Inc. 1973. Pp. 315-316.

permanent volcano observatory by the United States Geological Survey, have resulted in a new understanding of Yellowstone. A 2008 article entitled "Monitoring a Supervolcano in Repose: Heat and Volatile Flux at the Yellowstone Caldera" presents a much more sinister description:

> Although giant calderas ("supervolcanoes") may slumber for tens of thousands of years between eruptions, their abundant earthquakes and crustal deformation reveal the potential for future upheaval. Any eventual supereruption could devastate global human populations, so these systems must be carefully scrutinized. Insight into dormant but restless calderas can be gained by monitoring their output of heat and gas. At Yellowstone, the large thermal and CO2 fluxes require massive input of basaltic magma, which continues to invade the lower to mid-crust, sustains the overlying high-silica magma reservoir, and may result in volcanic hazard for millennia to come. The high flux of CO2 may contribute to the measured deformation of the caldera floor and can also modify the pressure, thermal, and chemical signals emitted from the magma. In order to recognize precursors to eruption, we must scrutinize the varied signals emerging from restless calderas with the goal of discriminating magmatic, hydrothermal, and hybrid phenomena.[4]

Two Key geological concepts are necessary to understand how Yellowstone works: Plate Tectonics and Volcanism.

[4] Lowenstern, Jacob B. and Shaul Hurwitz. "Monitoring a Supervolcano in Repose: Heat and Volatile Flux at the Yellowstone Caldera." *E L E M E N T S*, VO L. 4, P P. 35–40. U.S. Geological Survey, Menlo Park, CA. Accessed online October 6, 2009 at http://volcanoes.usgs.gov/yvo/publications/2008/ElementsJBL_SH.pdf

Plate Tectonics: The earth is unique in the solar system in that it consists of a balance of liquid molten core, and solid crust. The crust floats above the molten lava in large pieces, known as "Plates" and the study of their interaction as they collide, pass by, or overtake each other is known as tectonics. Yellowstone is located in the western third of the North American Plate, and it is moving in a generally westerly and southerly direction. The North American Plate and the Pacific Plate interact along the west coast, and cause the large earthquakes of the region.

Volcanism: When the molten liquid—magma—of the earth's core pushes through a vent to the solid plates above, the activity is called volcanism. Volcanoes are found worldwide, often at the edges of the solid plate. Types of volcanoes include:

Cinder cones: Lava is ejected through a single vein, and hardens into particles or cinders that fall back to earth in a circular pattern, creating the cone. There is usually a round crater at the top.

Stratovolcanoes: can rise as much as 8000 feet above the surface as lava is ejected through numerous vents near the center, but also in fissures on the sides of the cone. Mount Fuji, Mount Shasta, and Mount St. Helens are stratovolcanoes.

Shield volcanoes: develop as wide, shallow domes that result from almost continuous liquid lava that flows in all directions from a central vent or group of vents. The Hawaiian Islands are shield volcanoes. The magma of the Hawaiian Islands flows from a "hot spot," a large vent of magma that flows from deep in the earth. As the crustal plate of the central Pacific floated over this Hot

Spot, it created a series of volcanoes. The northwest volcanoes in the chain are older than those in the southeast.

Calderas are the largest volcanic eruptions and explosions on earth, and can eject hundreds of miles of gasses, ash, and magma to the surface of the earth, according to the US Geological Service. After the eruption, the ground below collapses due to the large void created by the emerging lava. Calderas usually exhibit a range of geothermal activities such as geysers, mudpots, fumaroles—eruptions of gas and steam—and rising domes of earth. The USGS notes that calderas can be very active for years or even centuries between eruptions.

Yellowstone National Park is the result of three caldera events that have occurred over the past 2.1 million years, as a portion of the North American Plate floated over a "hot spot." Hot spots have been identified in recent years by scientists as they have sought to understand why some volcanoes form in the inner regions of tectonic plates. My sister's college geology textbook provided an understandable definition: "Hot Spots are the volcanic manifestations of jets or plumes of hot material that rise from deep within the mantle (perhaps even the core-mantle boundary), penetrate the lithosphere, and erupt at the surface. These columnar currents are supposedly fixed in the mantle and do not move with the lithosphere plates. As a result, the hot spot leaves a trail of extinct, progressively older volcanoes as the plate moves over it."[5] Hawaii is a classic example of hot spot volcanism, as are the Galapagos Islands. In the past few years, as the theory has gained ground, scientists have identified approximately two dozen hot spots globally. Most are in the ocean, and rarely are they found mid-continent. The hot spots are usually accompanied by a large area that has been elevated over the spot, from several hundred

[5] Press, Frank and Raymond Siever, *Understanding Earth*. New York: W. H. Freeman and Company, 1994. P. 113.

feet to several thousand feet. Yellowstone sits on top of a topographical swell—a broad area where Earth's surface bulges upward due to the magma pushing up from below. The swell is three hundred miles wide, and the park is elevated approximately 1700 feet above areas outside the swell.

The Yellowstone hot spot has erupted many times over the past 16 million years, and some have been the most violent eruptions the earth has known. There is evidence of this hot spot-- similar to the chain of Hawaiian Islands—found in the cinder cones, caldera remnants, lava flows, and geological features of the eastern Snake River Valley, running from the western Nevada in a crescent east to Yellowstone. Rhyolite is a type of lava that results in large explosive eruptions, and there is evidence for over 100 separate rhyolite lavas in the Snake River valley, suggesting that there may have been over 100 strong, explosive volcanoes from this hot spot.

Volcanism in what is now Yellowstone began with the Island Park Volcano, 2.1 million years ago. This caldera-forming explosive volcano was centered just west of the park, in Idaho, and the caldera 50 miles long and 40 miles wide, and extends from Island Park, Idaho to the eastern half of Yellowstone. It sent a heavy ash, pumice, and rocks over 60 miles away, covering the ground over 300 feet and eventually hardening into a type of rock known as the Huckleberry Ridge tuff. Even more ash spread eastward and covered most of the western half of the United States. It was one of the largest known eruptions ever to happen on Earth.

A second eruption 1.3 million years ago created the Henry's Fork Caldera on the west end of the Island Park Caldera. This volcanic eruption was cataclysmic, leaving ash as far south as the Gulf of Mexico and east as far as what is now St. Louis.

A third cataclysmic eruption 630,000 years ago created the caldera centered in Yellowstone Park. It was also cataclysmic, and created a caldera that includes the entire eastern half of the first Island Park Caldera, all of which is within the boundaries of Yellowstone.

In our lifetimes, the Mount Saint Helen's eruption represents for many of us, a major, cataclysmic eruption. It ejected almost ¼ of a cubic mile of ash and other materials. In comparison, the 2-million year Yellowstone eruption ejected 600 cubic miles of ash and debris. The 630,000 year Yellowstone eruption ejected 67 cubic miles of ash and debris.

Although the caldera's formation occurred at the end of the major volcanic episode, smaller eruptions have continued at Yellowstone. Geologists have found evidence of smaller lava flows within the caldera between 150,000 and 70,000 years ago. Smaller eruptions have continued even during the past 10,000 years, during the "Holocene" or modern, current geological age.

Current Levels of Volcanic Activity at Yellowstone are monitored by the United States Geological Survey at the Yellowstone Observatory. The Observatory issues a monthly summary of activity. The October 1, 2009 statement says:

Current Update, last updated **Oct 1, 2009 15:54 MDT:**

September 2009 Yellowstone Seismicity Summary

During the month of September 2009, 177 earthquakes were located in the Yellowstone region. The largest event was a magnitude 2.3 on September 20 at 6:42 PM MDT, located about 4 miles northwest of Canyon Junction, WY. Two swarms were recorded in September. The first swarm of 39 earthquakes occurred September 12-17. It was located about 6 miles north northwest of West Yellowstone, MT, with magnitudes ranging from -0.9 to 1.6. The second swarm of 66 earthquakes occurred September 13-18. It was located further south, about 7 miles south southwest of West Thumb, YNP, with magnitudes ranging from -0.5 to 1.8.

Earthquake activity in the Yellowstone region is at relatively normal background levels.

Ground Deformation Summary: Through September 2009, continuous GPS data show that uplift of the Yellowstone Caldera has slowed and may have stopped… The general uplift and subsidence of the Yellowstone caldera is of scientific importance and will continue to be monitored closely by YVO staff.[6]

[6] http://volcanoes.usgs.gov/yvo/

What are the risks of the Yellowstone Volcano? Will there be another cataclysmic eruption? Would we be affected in Fort Wayne?

Perhaps a way to assess the cataclysmic potential of Yellowstone is to compare it to other volcanoes or other types of violent geological activity such as earthquakes.

There are 169 active volcanoes in the United States, with most in Alaska. The USGS Volcano Hazards Program has 6 observatories at the most active locations, including: Alaska, Cascades, Hawaii, Long Valley, Yellowstone, and the Northern Mariana Islands.

An analysis of activity at these locations since 1980 was prepared by A. Diefenbach and J.W. Ewart for the USGS in early 2009. Using data from the Global Volcanism Program of the Smithsonian Institute, the team prepared a report of all activities that met the GVP definition for volcano activity:

> "As defined by the GVP, an eruption is the arrival of solid volcanic products at the Earth's surface. Following this definition, volcanic events such as steam emissions (that do not produce ash), no matter how vigorous, are not counted as eruptions in this report. Arrival of juvenile magma at the surface, however, is also not required; eruptions that eject non-juvenile material are included in the GVP definition of an eruption and are included in this report. The end of an eruption is determined by the conclusion of eruptive activity, even though a formal declaration by an observatory may not occur until months later.[7]

[7] Diefenbach, A.K., Guffanti, M., and Ewert, J.W., 2009, *Chronology and References of Volcanic Eruptions and Selected Unrest in the United States, 1980-2008:* U.S. Geological Survey Open-File Report 2009-1118, 85 p. Accessed October 7, 2009 at http://pubs.usgs.gov/of/2009/1118/of2009-1118.pdf

The team also studied incidences of pre-volcanic "unrest", which included a wide range of events that were considered important enough for USGS to issue alert-level notifications about the activity, or other updates about changes in behavior. The team also determined that the calderas at both Yellowstone National Park and Long Valley, California were at continual levels of unrest during the entire 20-year period of the study.

Long Valley, California is the location of a caldera type volcano that has had large cataclysmic eruptions during its history and areas of geysers, hot springs and fumaroles, much like Yellowstone. Long Valley is located south of Yosemite, near Mammoth Lake. The Long Valley system has erupted several times during the past 5000 years, and the Observatory website notes that during periods when there is a lack of unrest—when the system is quiet—the chances of eruption are similar to the chances that there'll be an 8.0 earthquake along the San Andreas fault—or about 1 in 100. The last eruption was 250 years ago, and there has been an extended period of increased unrest during the past decade or so. The Long Valley Observatory issues a daily statement regarding changing conditions. On Wednesday, Oct. 7, 2009, the Observatory noted that there were seven earthquakes in the caldera area during the past 24-hour period.[8]

Compared to Long Valley, the Yellowstone system is reasonably quiet. There were 600-700,000 year gaps between the past three major caldera-producing eruptions at Yellowstone. However, the last of these was 640,000 years ago, and there are some scientists who believe

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[8] http://volcanoes.usgs.gov/lvostatus.php. Accessed Oct. 9, 2009.

that the geothermal activities are indicative of an approaching eruption. However, these scientists also agree that there are no indications that an eruption is imminent.

Large, cataclysmic volcanoes at either Yellowstone or Long Valley could affect Fort Wayne indirectly, if airplane routes, transportation or communication were affected by the eruption. It is unlikely, though, that ash would extend to Allen County. However, researchers of the evolution of humans using modern DNA analysis have noted that there appears to have been some event that caused only a small number of humans to pass on their genetic material about 70,000 years ago—about the same time of the last major Yellowstone eruption with extensive ash and volcanic rock that spread through the atmosphere and lowered temperatures substantially for several years. If the Yellowstone eruption caused the extinction of the majority of human beings 70,000 years ago, a future large eruption at Yellowstone could have devastating effects on Allen County.

It is much more likely that Fort Wayne and Allen County would suffer from a cataclysmic earthquake during the relatively near future than a volcano. During a seven-day period from October 1 to October 7, 2009, the Yellowstone National Park area had a total of three small earthquakes, ranging from 1.1 to 1.5 in intensity. At the same time, and closer to home, the New Madrid, Missouri area had a total of ten earthquakes, ranging from 1.1 to 2.5 in intensity.

The USGS recently updated their potential earthquake hazard maps for the United States, and noted that in the New Madrid Area three earthquakes measuring approximately 7.5-8.0 occurred during the winter of 1811-1812. Earlier series of major quakes had occurred approximately 1400

years ago, and 900 years ago, suggesting that the average period between major earthquakes in the New Madrid system is about 500 years, and that they often occur in pairs or trios due to the type of fault system below the Mississippi River in Missouri, Illinois and Tennessee. A spur of this fault system extends to southern Indiana. Another large quake could happen sometime in the next 250-300 years, and Fort Wayne could suffer some damage if the quake is severe.[9]

Yellowstone National Park will undoubtedly undergo great changes in the future, but no one knows exactly when or how severe such changes will be. As the North American Plate continues to drift across the Yellowstone Hot Spot, the next large eruption could occur at the east end of the park, or perhaps even farther north and east. Some scientists believe that the Rocky Mountain chain has created a buffer of sorts, and has slowed the volcanism. On the other hand, current activities at Yellowstone are continuously being monitored. The ongoing swell or rise of a dome located in the eastern part of the park and the recent swarm of earthquakes in December of 2008 and January of 2009 could well point to a period of increased activity in the future.

Is Yellowstone a cataclysmic volcano? Yes. It has been several times in the past, and most likely will erupt again in the future. But should we lose sleep over the possibility? I'm not.

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