VOLCANOLOGY

Project title: Monitoring Caldera Unrest at the Yellowstone Caldera: A Global Positioning System (GPS) Crustal Deformation Study and Hot Springs Temperature Study by the Eastern Illinois University Geology Field Camp

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Objective: The purpose of our study is to monitor caldera unrest at the Yellowstone Caldera by annually collecting GPS data and hot springs temperatures from a network of data collection points. Although the data collected in this study can contribute to more detailed monitoring efforts of the caldera, the primary goal of this project is to provide an on-going, hands-on field experience for undergraduate geology majors at the Eastern Illinois University Geology Field Camp.

Findings: On 6/29-7/1/1999, and 6/28-6/29/2000 we deployed 3 Trimble 4000Ssi receivers at pre-established GPS control stations in the park. During a 48 hour interval each year, data was collected from 8 different control stations along a NW-SE traverse across the Yellowstone Caldera.

Following the 1999 survey, the data was processed and a set of 8 GPS baseline coordinates was established. During the 2000 GPS campaign, the 8 control stations were re-occupied. The data collected during the 2000 campaign was compared to the baseline data. Our results indicate that all of our data stations were displaced horizontally with components of southerly and westerly motion. Vertical motion, in the form of subsidence, also occurred at almost all stations. Southerly displacement of our stations was the least, ranging from 1 mm to nearly 2 cm, whereas westerly displacement ranged from about 1 cm to over 2 cm. With the exception of one control station, subsidence ranged between 3 and 10 cm. Maximum horizontal and vertical displacements occurred in the northern section of the network.

Although subsidence rates of up to 3 cm per year have been reported for the Yellowstone caldera, our subsidence values are significantly higher and may have associated errors. A review of the data collecting and processing procedures has not yet produced an insight into the potential source of error. A more detailed report of this study, including data tables and a map is available at: http://wilkes1.wilkes.edu/~gis/yellowstone/yell2k/.

A second component of our study is monitoring hot springs temperatures at selected thermal areas within the Yellowstone Caldera. After consultation with park officials, three areas in the Lower Geyser Basin were chosen for our study including thermal areas along Rabbit Creek, White Creek, and Sentinel Meadows. On 6/28 and 6/29/2000, faculty members led small groups of students through these thermal areas to measure hot springs temperatures that will serve as baseline data for our study. Hot springs in the

Sentinel Meadows area mostly measured in the 90s, with several as high as 94 C. These consistently high temperatures qualified Sentinel Meadows as the overall hottest of our 3 study areas. Rabbit Creek and White Creek thermal features were more variable, with temperatures ranging from about 40 to 93 C. Maps and data tables for this study can be viewed at: http://oldsci.eiu.edu/geology/camp/YNP/ynpres.htm.

Project title: Eruption Observation of Selected Remote Geysers

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Objective: To obtain eruption interval and duration measurements of selected remote geysers at Shoshone Geyser Basin (Double Geyser, Frill Spring), Gibbon Geyser Basin (Phoenix Geyser, Oblique Geyser), Heart Lake Geyser Basin (Glade Geyser, Rustic Geyser), Lone Star Geyser Basin (Buried Geyser, Unnamed geyser SW of bridge).

Findings: Shoshone Geyser Basin: Double Geyser erupted every 4745-6196 seconds (mean of 34 intervals = 5319 sec); Frill Spring did not erupt between 07 July and 10 August 2000 and was very likely dormant during this time. Gibbon Geyser Basin: Phoenix Geyser erupted every 12874-14617 seconds (mean of 56 intervals = 14001 sec). Heart Lake Geyser Basin: Glade Geyser erupted every 95616-135605 seconds (mean of 8 intervals = 109683 sec). Lone Star Geyser Basin: Buried Geyser erupted roughly every 10-15 minutes; Unnamed geyser SW of the Lone Star-Shoshone Lake trail bridge was probably dormant between 12-14 August 2000.

Project title: Volcano Emissions

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Objective: Survey and characterize carbon dioxide emissions from Yellowstone soils and thermal areas in order to identify possible areas of anomalous degassing from depth and to provide a baseline with which to compare future surveys of carbon dioxide in the event of volcanic unrest. The study involves airborne

measurements of carbon dioxide and other gases in the air above the park as well as ground measurements of carbon dioxide soil efflux within the park.

Findings: Several areas of carbon dioxide efflux have been measured within the park that are greater than what would be expected from normal biologic activity in the soil. In addition, several carbon dioxide plumes from various sources within the park were successfully measured in the air above the park in 1998 and 1999 utilizing sensitive instrumentation mounted in fixed-wing aircraft. Similar measurements utilizing helicopters as the airborne platform are anticipated. The detailed analysis of data is not yet complete.

Project title: Geochemistry, Biochemistry, and Stable Isotope Systematics of Sublacustrine Hydrothermal Vents in Yellowstone Lake

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Objective: The objectives of this study are to understand hydrothermal processes in sublacustrine hydrothermal vents in the context of the Yellowstone ecosystem and subaerial hydrothermal systems in and around Yellowstone National Park. In particular, we are using chemical composition, especially minor and trace elements and stable isotopes (H, C, N, O, and S), to understand processes of hydrothermal mineralization and to track potentially toxic and nutrient elements from hydrothermal vents into the micro- and macro-fauna of Yellowstone Lake and the greater Yellowstone ecosystem. To this end we have sampled lake waters, streams flowing into and out of Yellowstone Lake, sublacustrine sinter deposits and altered sediments, lake and cutthroat trout, bacterial mats and small crustaceans from vent localities, and similar materials from selected subaerial hydrothermal systems.

Findings: The geochemistry of Yellowstone Lake is strongly influenced by sublacustrine hydrothermal vent activity. The geothermal source fluid feeding the lake is identified by comparing the predicted Cl and hydrogen isotope data on water column, porewater, and vent samples from Yellowstone Lake. The chemical composition of sublacustrine hydrothermal vent fluids and the geothermal source fluid indicates strong enrichment of As, B, Cl, CO2, Ge, Hg, H2S, K, Li, Mo, Na, Rb, Sb, Si, and W.

The Cl concentrations indicate that Yellowstone Lake is about 1 percent geothermal source fluid and 99 percent inflowing stream water and that the flux is about 20 percent of the total geothermal water flux in Yellowstone National Park. With recent swath-sonar mapping studies that show numerous new hydrothermal features, Yellowstone Lake should now be considered one of the most significant geothermal basins in the park. Hg enrichments in hydrothermal vents and associated fauna contribute to elevated Hg concentrations in lake and cutthroat trout. Enriched Hg in cutthroat has potentially serious implications for grizzly bear, otter, eagle, and osprey populations that feed on cutthroat trout who spawn in the rivers.

Hydrothermal deposits occur on the lake bottom near active and presently inactive hydrothermal vents. Centimeter- to decimeter-sized siliceous deposits are cemented and recrystallized diatoms and represent pathways for hydrothermal fluid migration. A second major type of hydrothermal deposit comprises hard, porous siliceous spires that were discovered near Bridge Bay in 1997 by Dave Lovalvo and the UW Milwaukee group. At least 8-10 spires up to 7 m tall consist of diatom-rich areas and fibrous masses and globules of amorphous silica that could be of microbial in origin. Preliminary U-series dating gives an age of 11 ka for the silica spires. Bridge Bay spires formed in place by growth of chimney-like features from vigorous or long-lived lake-bottom hydrothermal vents. Chemical analyses indicate that siliceous vent deposits are almost always strongly enriched in As, Ba, Cs, Hg, Pb, and Sr, and are often enriched in Fe, Mo, Mn, Nb, Rb, Ta, Th, Tl, and W relative to normal Yellowstone Lake sediments. Oxygen isotope analyses of silica deposits indicate formation at temperature between 80 and 160 C. Chemical reaction modeling indicates that amorphous silica saturated fluid that vents into bottom waters at temperatures above 145 C can precipitate amorphous silica by mixing with cold, dilute lake waters.

Project title: Operation And Development of an Earthquake and Volcano Information System at Yellowstone and Ancillary Research on the Geodynamics of the Yellowstone Hotspot

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Objective: The primary objectives of the Yellowstone earthquake and volcano information system is to operate seismic and GPS networks, the Yellowstone seismic and GPS networks, necessary to monitor seismicity and ground deformation that may be related to volcanic, hydrothermal and tectonic earthquake activity. In addition ancillary research funded by the National Science Foundation titled "Geodynamics of the Yellowstone Hotspot" use the data and support in part the student and faculty research described herein.

Findings: In addition to routine network operations, notable efforts during the report period related to upgrading and maintaining seismograph and GPS stations against the harsh winter conditions of Yellowstone. Specific tasks included:

- Visiting 15 of the 22 stations of the Yellowstone seismograph network;
- Occupying five temporary digital seismographs at Lewis Lake, Nez Perce Creek, Canyon sewer plant, at the east entrance and at the NE entrance;
- Occupying of 60 temporary GPS receivers at sites established in the Yellowstone area;
- Moving the Little Thumb Creek seismic station out of the to be reclaimed gravel pit;

• Maintaining the continuous GPS stations at Lake, Mammoth, Old Faithful, Hayden Valley and White Lake;

• Continuing analysis on the systematic determination of local magnitudes;

• Submitting 19 years of Yellowstone seismic waveform data to the IRIS Data Management Center in SEED format;

• Submitting, several times per day, earthquake catalog data for the Yellowstone region to the Council of the National Seismic System's composite catalog;

• Assisting the National Park Service with long-term plans for implementing volcano and earthquake hazard assessment needs;

• Participating in the NPS-USGS workshop on Volcanoes in National Parks held at Mt. Lassen National Park;

• Discussing the development of a Yellowstone Volcano Observatory with the USGS Volcano Hazards group and NPS staff;

• Continuing analysis of ground deformation of the caldera using GPS and its relation to faulting and earthquakes of the nearby Hebgen Lake fault zone; and

• Presenting the findings and objectives of our research to Yellowstone NPS personnel, July 2000 as well as to several scientific meetings.

Project title: Water Temperature and pH Measurements

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Objective: To take temperature and pH measurements in two separate hot pools in Yellowstone National Park and demonstrate high temperatures and varying levels of pH to an educational tour group.

Findings: We took temperature and pH measurements in Ojo Caliente runoff and in the road culvert near Roaring Mountain of Yellowstone National Park. Ojo Caliente runoff exhibited a higher temperature and opposite pH than Roaring Mountain.