GIS Analysis of Yellowstone Earthquakes and Geothermal Activity

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Introduction

Located in Wyoming and extending into Montana and Idaho, Yellowstone National Park is best known for its amazing geothermal geysers, diverse wildlife, and untamed wilderness. Geologically, Yellowstone is a relatively young volcanic system, having erupted numerous lava flows (basalts) and explosive ash (rhyolites) over the last 2 million years. Yellowstone National Park also is one of the most hydrothermally active systems on Earth, including the numerous geysers and hot springs. Intra-caldera earthquakes are also observed frequently in the park, many with Magnitudes less than 3. Many universities along with United States Geological Survey (USGS) conduct studies and constantly monitor factors such as earthquakes and geothermal activity. Using ArcGIS, the aim of this project was to test the correlation between the earthquake and geothermal activity within the Yellowstone caldera. A correlation between earthquakes and geothermal activity could lead to new predictions.

Methods

For base map layers, files were downloaded from the University of Utah. Digital elevation data was taken from the USGS National Map Seamless server.

Geothermal data was provided by the Montana State University. This dataset included pH and temperature readings for the Gibbon Canyon, Mirror Plateau, Central Plateau, Upper Geyser, Madison Plateau, West Thumb and Yellowstone Lake thermal regions. Data imported and manipulated Microsoft Excel. Average pH and temperature data was created and entered into corresponding tables for polygon files created in ArcGIS.

To the thermal regions polygon layers, a JPEG image from the University of Montana was geo-referenced to the base map layer. These layers were named according to the thermal regions mentioned above, and correlated with average pH and temperature data by year.

Earthquake data was taken from the University of Utah Seismographic Stations website, for the years 2000 to 2005. These tables were imported into Excel, and then made into point files in ArcGIS according to their longitude and latitude.

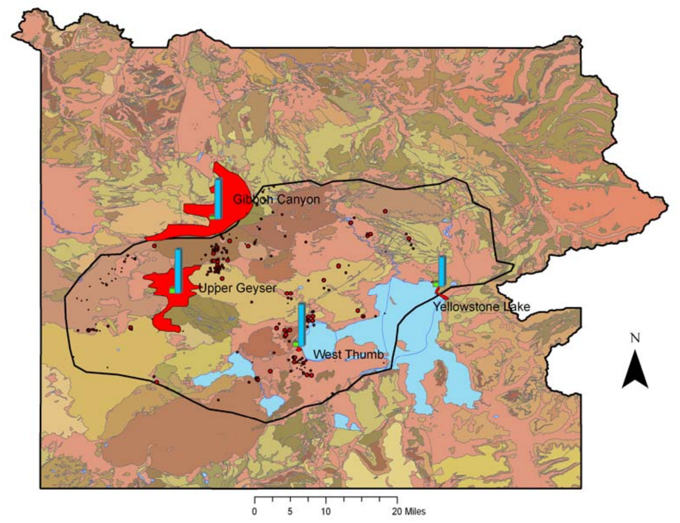
Four years with the most complete data were chosen to define a correlation between the numerous earthquakes and pH/temperature. These years were 2000, 2001, 2002, and 2005. Thermal region data from these years were merged into polygon files according to year; all data for the year 2000 for example became a single polygon. These were then symbolized by multiple attributes, with the color representing the average temperature, and the symbol size representing pH.

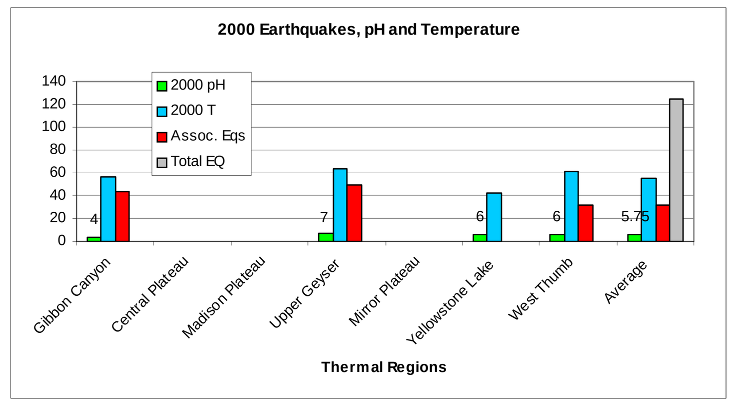
Earthquakes and Geothermal Activity

These 4 maps show each year's thermal data along with earthquakes. Temperature (blue) and pH (green) are represented by a bar graph within each thermal region polygon, and earthquakes are points categorized by size by magnitude. For data correlation, a 5 mile buffer was set up with each thermal region. Earthquakes which occurred within this buffer are most likely to be correlated with the thermal regions. The number of earthquakes was entered into an Excel spreadsheet. The Excel spreadsheet contains thermal region data for all four years examined, taking the average temperature and pH for each year. Along with the number of associated earthquakes, graphs were set up for each year to examine possible correlations.

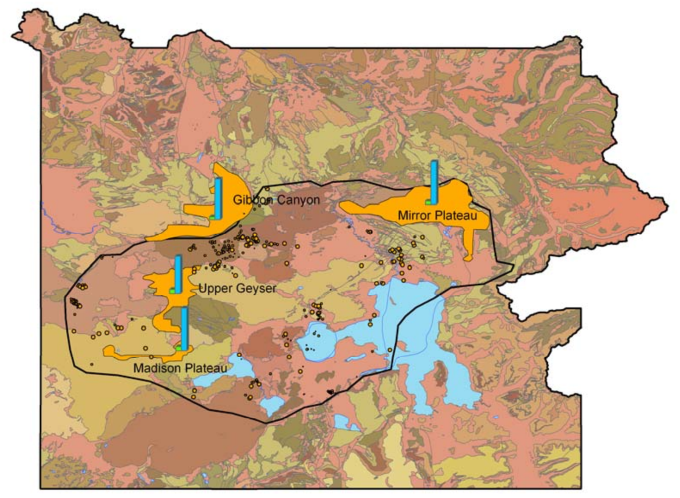
Earthquakes 2000 · Earthquakes 2002 · Earthquakes 2001 · Earthquakes 2005 · Caldera Boundary

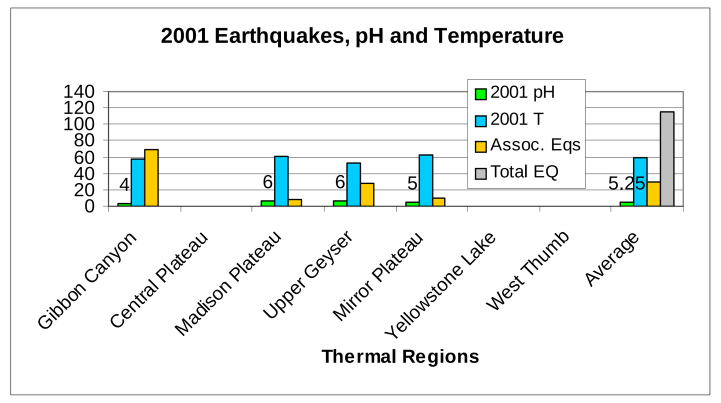
Maps and Charts of Earthquakes and Geothermal Activity 2000-2005



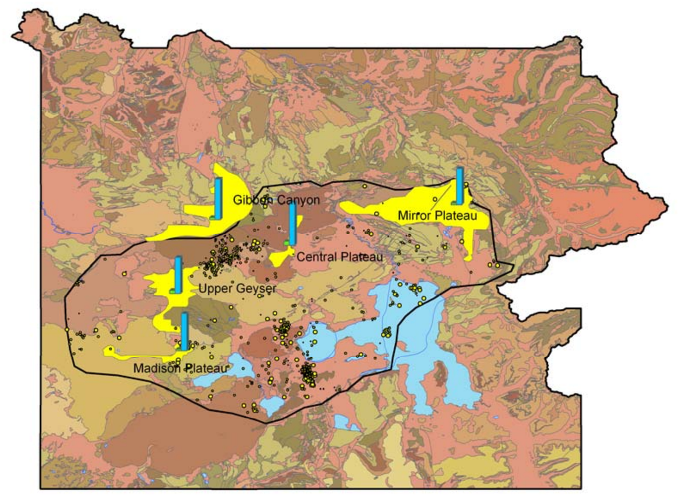


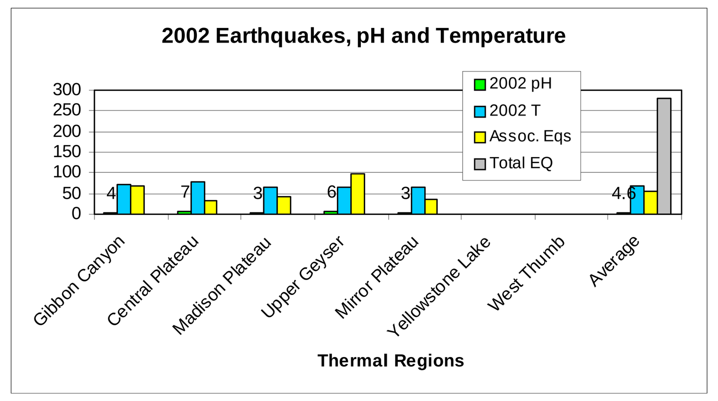
Map and Graph for 2000



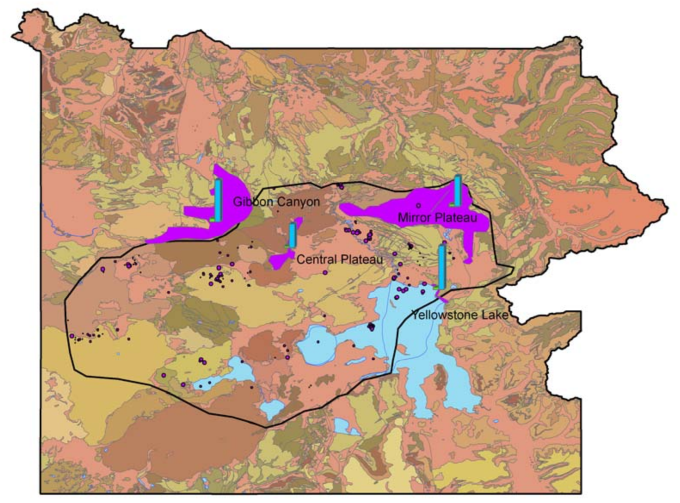


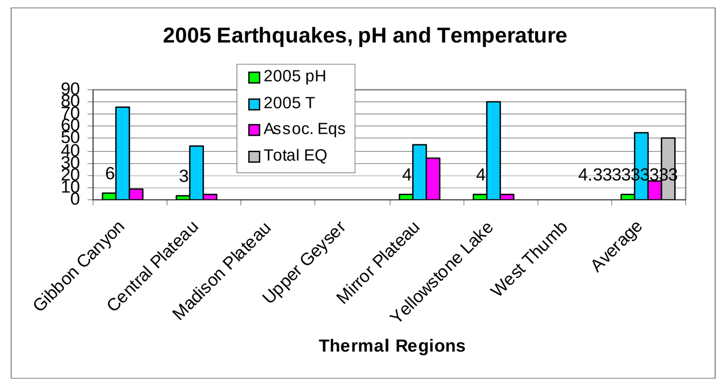
Map and Graph for 2001



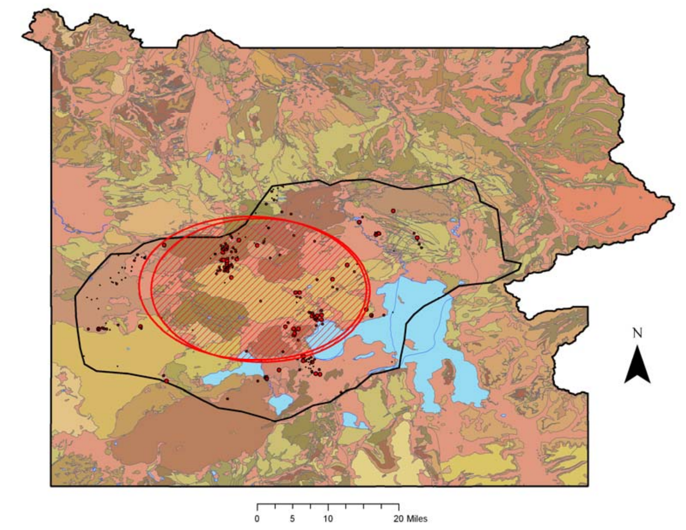


Map and Graph for 2002





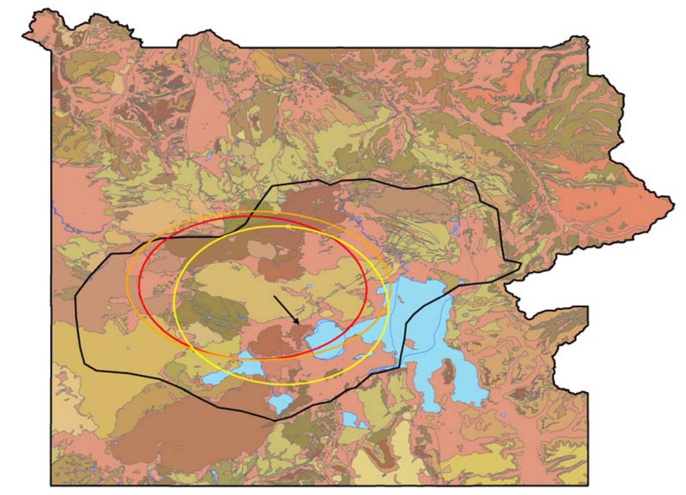
Map and Graph for 2005

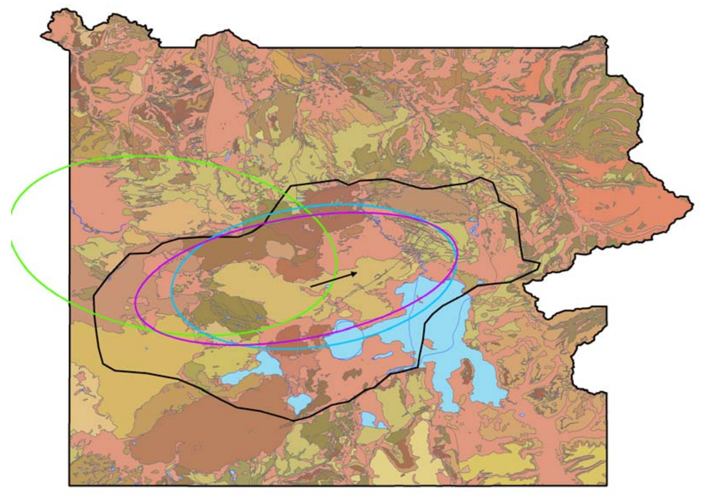


Map of 2000 Earthquake directional distribution for 2000. Overlain on area Geologic Map

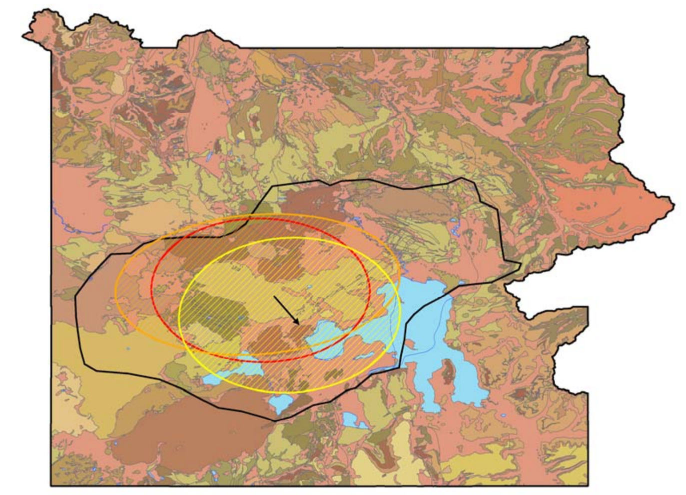
Earthquake Analysis

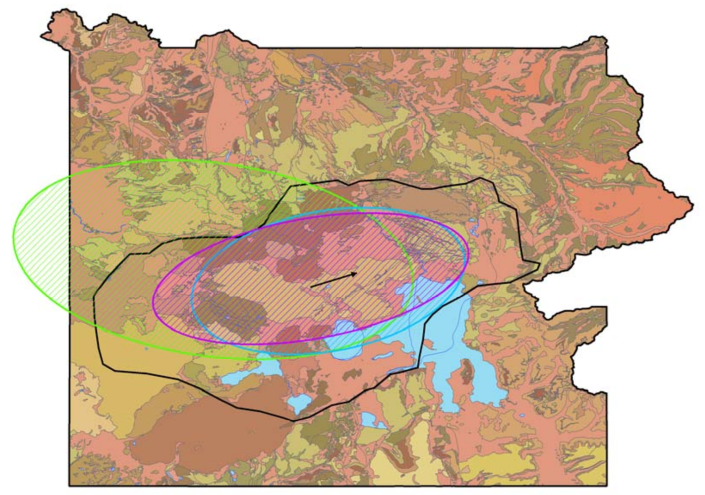
The earthquake analysis was done using an ArcGIS spatial analysis tool called Directional Distribution. This tool takes point features on a map, and classifies them into an ellipse shape file based on the density and locations of the entered points. Two analyses were run: one with just the earthquake data for each year, and the second was run weighting the magnitude field of the earthquake data. The 3 maps show the results of the analysis; they show the migration of earthquakes over time.





Direction distribution earthquake data (non-weighted) for 2000 – 2005. Overlain on Geologic Map





Directional distribution earthquake data (weighted by magnitude) for 2000-2005. Overlain on Geologic Map

Results

No apparent correlation between pH and earthquakes is evident. Many of the thermal regions showed similar average pH, with both high and low numbers of corresponding earthquakes. Temperature exhibited a trend similar to pH, multiple temperature ranges corresponded to varying numbers of corresponding earthquakes. However, 2002 was the most tectonically active year, and had the highest average temperature.

Earthquake data trends were clearer than the pH, temperature and earthquake activity correlations. Using directional analysis, a distinct migration in earthquake foci was evident. Earthquakes appear to migrate first south, and then northeast through the caldera.

The analysis weighted by magnitude emphasizes this trend further.

This project was limited by only taking average pH and temperature data; correlations might appear if data was over months rather than in years. Also, using data such as maximum and minimum temperature and pHs may correlate more effectively. A longer period of analysis of earthquakes could reveal other patterns in earthquake movement. Data obtained from analyses such as these could lead to better predictive models of earthquake and geothermal activity; the USGS constantly monitors the Yellowstone area, and hazard prediction correlations could help protect Yellow-

Sources

Data From:
University of Utah Earthquake Information Center
http://www.quake.utah.edu/EQCENTER/eqcenter.htm

Montana State University YNP Data Resources
http://www.rcn.montana.edu/resources/?nav=11

Yellowstone-Teton Epicenter
http://www.yellowstonegis.utah.edu

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