The Faults and Hot Springs of Surprise Valley: Perspectives from Detailed Magnetic Data

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Abstract

The central section of Surprise Valley, NE California, in the westemmost portion of the Basin and Range province contains a geothermal system related to extensional tectonics. Most geophysical research related to this system has focused primarily on the Lake City hot springs. Our work includes several other hot springs within the valley and their associated faults. Magnetic profiles reveal two distinct fault types: intra-basin normal faults, some with significant offset, and those previously inferred along the NW-trending Lake City Fault Zone, that likely accommodate very little, if any, displacement. Our work provides additional detail that complements existing aeromagnetic data, suggesting that north-trending normal faults within the basin that may intersect the obliquely-trending Lake City Fault Zone. Because several hot springs (Lake City, Seyferth, and Leonards) occur at the projected intersection of these obliquely-trending fault sets, it is possible that fault interactions play an important role in maintaining open pathways for hydrothermal fluid flow. This research has better defined the locations of faults, and constrained portions of the Lake City Fault Zone and surrounding faults. This bears significance for the prospective development of geothermal energy as a regional resource.

Introduction

Our research area is located in Surprise Valley, the westemmost graben of the Basin and Range, in the northeast corner of California and northwest corner of Nevada (FIGURE 1). This area acts as a transition zone between the unextended Modoc Plateau to the west and extended Basin and Range to the east. A series of N-S striking normal faults have formed in Surprise Valley that accommodate this extension. On the western margin of the valley the east-dipping Surprise Valley Fault separates the valley from the Warner Mountains and may accommodate over 7 km of normal slip (Egger et al., in review) and on the eastern margin of the valley, a west-dipping normal fault has exhumed the Hays Canyon Range.

Previous research in Surprise Valley has focused on the geothermal systems and on their potential for energy generation. Hot springs in Surprise Valley suggest that the area is typical of other extensional geothermal systems in the Basin and Range, which arise from deep circulation of meteoric water along major normal faults. Previous research, that includes several drill holes taken at Lake City, low resolution aeromagnetic surveys, and mapping of Holocene fault scarps, suggests that springs occur at fault intersections.

In addition to the N-trending normal faults, a diffuse fault- fracture system called the Lake City Fault Zone (LCFZ) is inferred to cross the valley. The sub-basin to the north of the LCFZ is characterized by small-offset, steep-dipping normal faults. The sub-basin to the south is characterized by anticlinal, large-offset normal faults that create a large horst structure. One of the goals of this work was to better map structures to assess whether hot springs indeed occur at major fault set-intersections, and to resolve whether the LCFZ represents a structural transition zone between different faulting regimes.

Methods

We performed magnetic measurements along a series of transects to aid in mapping structures that may control the geothermal system. The magnetic data were collected using a cesium vapor magnetometer along several linear transects crossing perpendicularly to the inferred structural features. A portable proton-precession base-station magnetometer was used to record, and subsequently correct for, diurnal variations of the Earth’s magnetic field during the surveys. Magnetic data reflect variations in the magnetic field due to large contrasts in the magnetic properties of the underlying rock units. These magnetic variations are directly related to the depth and geometry of magnetic sources, and variations in the concentration and type of magnetic minerals within rock units. The data were corrected for any diurnal variation, and filtered to remove other magnetic disturbances such as cars, fences, and power lines.

Magnetic data in conjunction with field observations and existing aeromagnetic surveys were correlated between transects to map fault locations. Faults were recognized as changes in the amplitude and frequency content of anomalies that reflect a change from near-surface to deeper magnetic sources (FIGURE 2). Near surface magnetic sources are characterized by high-amplitude short-wavelength anomalies, while deeper sources are characterized by small-amplitude longer-wavelength anomalies.

Results

Previous studies identify several structures on the west side of the valley (e.g., the prominent Surprise Valley Fault)

- Our data reveal many parallel small-offset intra-basin faults on the east side of the Valley

Results from the east side of the Upper basin:
- Series of small-offset normal faults occur in a stair step fashion
- These normal faults are possibly transected to the south by the LCFZ

Results from the east side of the Middle basin:
- Anticlinal normal faults form a horst structure

Previous studies suggest interactions of structures and hot springs

- We find that the hot springs on the east side of the valley are clearly related to north-south structures
- We do not find any significant anomalies associated with the LCFZ where it crosses our profiles. If the LCFZ indeed exists, we can predict that it accommodates any significant vertical offset. Additional data focusing on the LCFZ may reveal subtle anomalies associated with it that may aid in identifying whether it interacts with the more prominent basin-parallel faults.