A Case History of Mapping Faulting in Valley-filled Sediments using Nonsesmic Data-Environmental, Engineering and Exploration Applications

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Summary:

The southern part of Utah Valley, Utah County, Utah lies along the Wasatch fault zone and is experiencing rapid population growth. One of the growing communities is Payson, Utah, where the Wasatch Fault forms the boundary between the Basin and Range Province and the Colorado Plateau. To enhance the understanding of the concealed fault structures in this area, geophysical studies were conducted to map the subsurface. Gravity and magnetic data were acquired, processed, modeled and interpreted. The resulting data are being used to help with building, zoning, and safety and emergency planning decisions, as well as potential hydrocarbon exploration.

Introduction

Payson city is located at the southern end of Utah Valley in Utah County, Utah. The study area (Figure 1) is experiencing rapid population growth and lies along a part of the Wasatch fault zone, which extends north-south through most of the state of Utah. The Payson Fault is a branch off of the Wasatch Fault that breaks away from the main portion of the Wasatch Fault and trends north through Payson into Utah Valley. Microearthquake, trench, and fission track data indicate that the Wasatch Fault is still active. An earthquake along the Wasatch Fault could produce rupture along this portion of the fault, which might result in significant damage to property and pose a serious threat to human life. Gravity and magnetic methods were used to obtain a better understanding of the location and structure of the Payson Fault.

Geologic Setting

The study area is approximately 25 km^2 and lies at the southern end of Utah Valley, just south of Utah Lake and east of West Mountain (Figure 1). All of the mountains that bound the study site are predominantly Paleozoic limestone in composition, with some dolomite, sandstone, and shale. Over 90% of the study area is covered by Quaternary alluvium and lake sediments from Pleistocene Lake Bonneville. The northern end of the study area consists primarily of clays, silts and sands from the Provo Formation and younger lake bottom sediments.

Data Acquisition

Between 1997 and 2000, gravity and magnetic data were collected along twenty-seven traverses throughout the study area. Along each of the traverses, gravity and magnetic data were collected at each station at spacings of 12 m (40 ft). Gravity data were collected using a Worden gravimeter, which has a precision of 0.01 mGals. The latitude, longitude, and elevation of each station were found using differential GPS data.

Magnetic data were collected with a Geometrics proton-precession magnetometer, which has a maximum precision of one nanoTesla. Three to five readings were taken at each station and averaged. Stations were not recorded where readings fluctuated by more than 10 nanoTeslas due to cultural noise.

Data Processing

Corrections to the gravity data include drift, free air, Bouguer, latitude, terrain, and regional. Readings taken at the base station every three to four hours facilitated the drift correction. To determine Bouguer and terrain corrections, density data were obtained from a nearby well, rock samples, previous geophysical surveys (Davis, 1983; Cook et al., 1997; Benson and Mustoe, 1995), and the Parasnis (1961) method. The regional correction was determined by using polynomial surface-trend fits to the data. The magnetic data were corrected for drift, as well as latitude corrections that were made using the International Geomagnetic Reference Field.

Isometric Projections

Isometric projections of the residual gravity data and reduced magnetic data were produced with Surfer™ contouring software. A plot of the residual gravity data in the southern part of the study area shows anomalies that are suggestive of both the Payson Fault and other associated faults, including the Hollow Graben (Figure 2). A plot of the northern part of the study area also shows expression of the west-dipping Payson Fault, as well as the Hollow Graben.

Modeling and Interpretation

Geologic interpretation of the structure of the Payson Fault was based primarily on the residual gravity, supported with the reduced magnetic data. Subsurface models, using GMSYS™ software, were generated for representative traverses in order to provide a reasonable map of the subsurface structures. Care was taken in interpretation to ensure that the models produced from the residual gravity and reduced magnetic data agreed with other available data and were a reasonable representation of the subsurface geology. Anomalies along the data traverses are referenced according to their distance east of the westernmost station in the survey, which is located along the 7550 South traverse.

500 South Traverse

The 500 South traverse begins at Main Street in Payson and continues to the east over Rocky Ridge, for a distance of approximately 960 m (3,150 ft). A hollowed-out area, between Main Street and 200 East, is located near the west end of this traverse. This hollow is thought to have formed as a result of fluvial activity from the creek running out of Payson Canyon, located to the south of the study area. However, the residual gravity data indicate that the hollow is a northerly-trending graben structure associated with the Payson fault zone (Figure 3). The residual gravity values decrease by as much as 0.8 mGals in this area. This change strongly suggests the presence of a graben, referred to as the Hollow Graben. The residual gravity data at the eastern end of the traverse indicate a smaller graben associated with the Payson Fault.

Modeling the residual gravity data using GMSYS™ shows about 560 m (1,837 ft) of vertical offset in the interpreted Hollow Graben (Figure 3). The model also shows the interpreted Payson Fault with a dip angle of 76° W and a depth to the upthrown block of 20 m (66 ft). The model indicates a net vertical offset of about 320 m (1,050 ft).

700 South Traverse

Across the 700 South traverse, the signature associated with an abrupt change of over 0.6 mGals in the residual gravity indicates the presence of the Payson Fault (Figure 4). This change occurs at about 1,650 meters, near the location of a canal on the west side of Rocky Ridge. The magnetic data show a sharp increase in the magnetic field of over 200 nanoTeslas at about the same location as the increase in gravity.

A geological model based on both the gravity and magnetic data created with GMSYS™ shows the fault block structure along this traverse. Susceptibilities are 6 and 8 cgs units for alluvium and consolidated sediments, respectively. The modeled gravity data show the Payson Fault and associated graben (Figure 4). From this model, the depth to the upthrown block is approximately 30 m (98 ft), and the dip angle along the Payson Fault is 75° W. The net vertical offset along the fault is about 390 m (1,279 ft).

Integrated Interpretation

The interpreted location of the Payson Fault and associated concealed faults based upon models generated from the residual gravity data along all the traverses were plotted (Figures 5). There is good correlation between the location of the Payson Fault mapped by Machette (1990) from field studies and that mapped from the interpretation of the geophysical data.

Conclusions

Several concealed faults in the Payson area were mapped using geophysical data. The Hollow Graben, Payson Fault Graben, and Rocky Ridge Graben all show expression in the residual gravity data in places where little or no surface expression of these structures exist. Estimates of the location of the Payson Fault based on residual gravity profiles and GMSYS™ models correspond closely with the location of the fault as mapped by Machette (1990) from surficial evidence. Models of selected traverses throughout the study area show reasonably consistent location and structure of the Payson Fault and Graben. The results are being used to assist Payson City with hazard assessment, zoning regulations, emergency planning, and possible hydrocarbon exploration.

References

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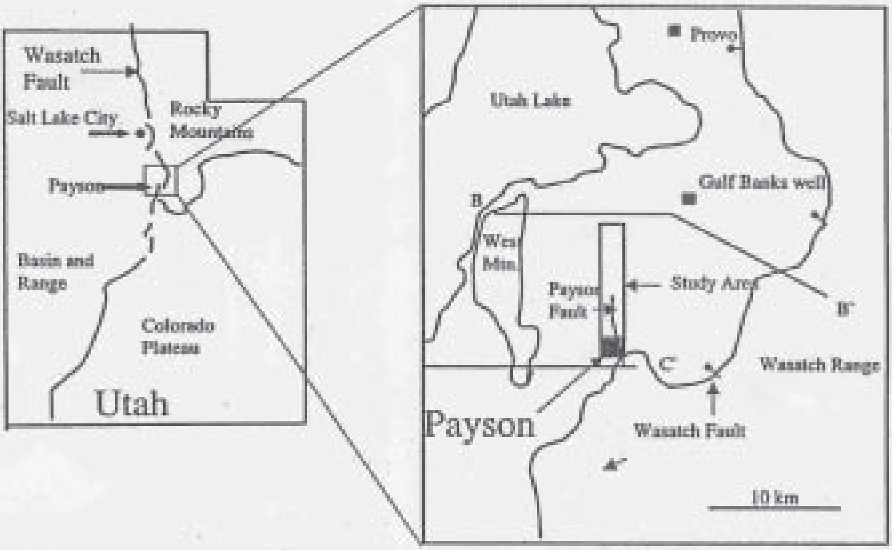

Figure 1: Index map of the Payson study area, showing the Wasatch Fault zone. Lines B-B' and C-C' are gravity traverses from Davis (1983).

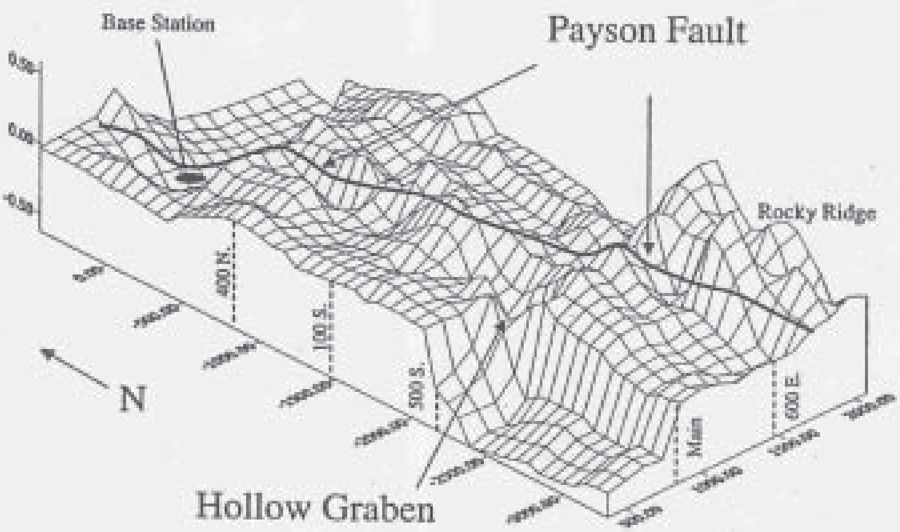

Figure 2: Residual gravity data in the southern part of the study area. Vertical axes in mGals. Horizontal axes in meters south of the baseline and east of the westernmost data point in the survey. Dashed lines indicate locations of selected streets.

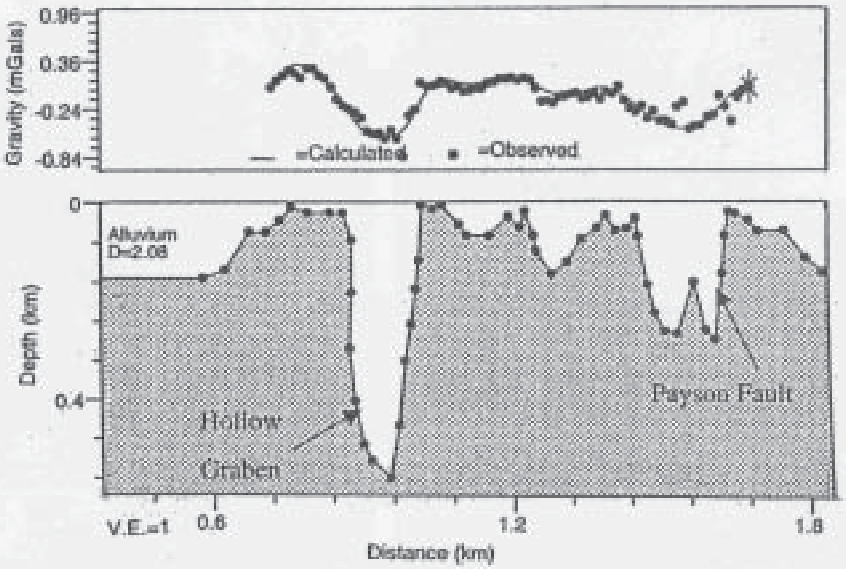

Figure 3: Model of residual gravity data along 500 South traverse, Payson. Density of consolidated sediments is 2.53 g/cc.

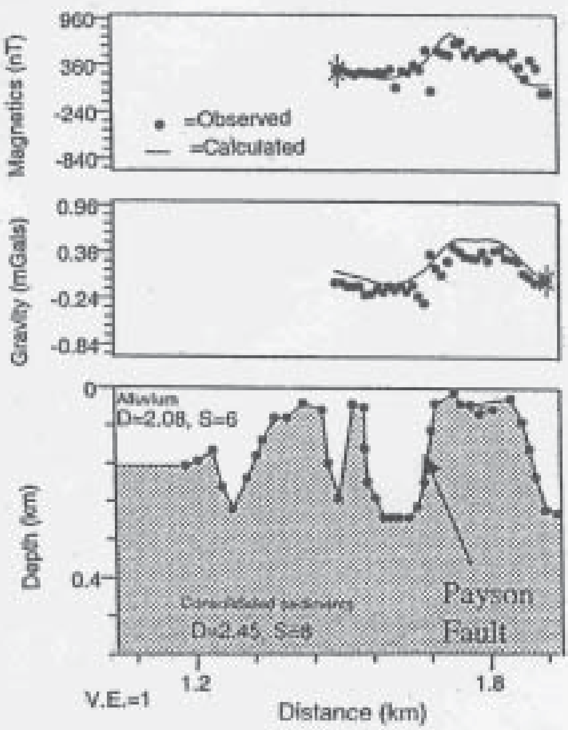

Figure 4: Model of residual gravity data along 700 South traverse, Payson. Density of the consolidated sediments is 2.45 g/cc and susceptibility is 8 micro-cgs units.

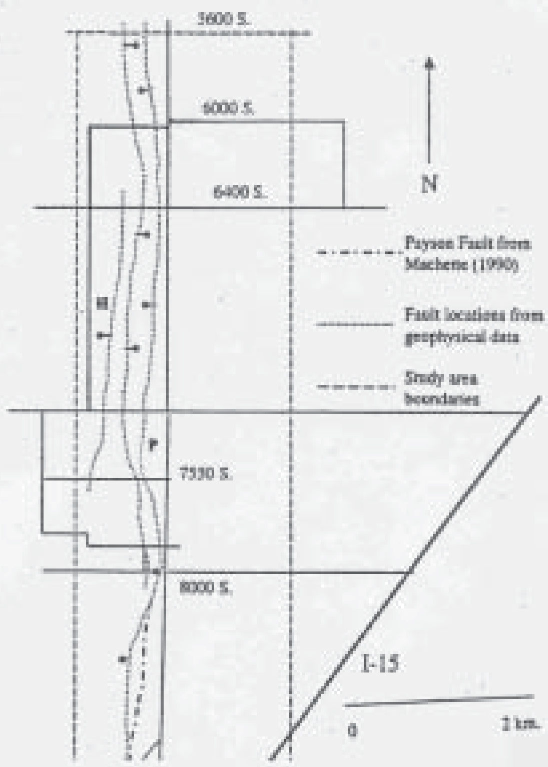

Figure 5: Map of Payson Fault as mapped by Machette (1990), and location of faults based on residual gravity profiles and GMSYS™ models.