THE EXPLORATION SIGNIFICANCE OF LOW-ANGLE FAULTS IN THE ROOSEVELT HOT SPRINGS AND COVE FORT-SULPHURDALE GEOTHERMAL SYSTEMS, UTAH

Dennis L. Nielson and J. N. Moore

Earth Science Laboratory
University of Utah Research Institute
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

ABSTRACT

Low-angle normal faults of Tertiary age have been documented by detailed geologic mapping at both the Roosevelt Hot Springs and Cove Fort-Sulphurdale geothermal fields in Utah. At Cove Fort-Sulphurdale the low-angle structures cap the geothermal system and inhibit the rise of H_2S from the thermal fluids as evidenced by the lack of alteration within the zone of low-angle faulting. Low-angle faults in the Roosevelt Hot Springs KGRA have produced structures in the southern portion of the reservoir which, where intersected by later faults, provide significant permeability controls on the geothermal system. Low-angle normal faults are more common in this portion of the Basin and Range than indicated by existing maps, and their presence and importance should be evaluated in exploration programs.

INTRODUCTION

The geothermal fields of Utah occupy a diffuse north-trending belt along the eastern margin of the Basin and Range Province. Exploration activities by the geothermal industry have concentrated primarily on the Roosevelt Hot Springs and Cove Fort-Sulphurdale KGRAs (Fig. 1).

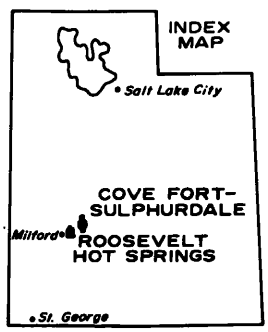

Figure 1. Index Map of Utah Illustrating the Locations of the Cove Fort-Sulphurdale and Roosevelt Hot Springs KGRA.

Our studies (Nielson and others, 1978; Moore and Samberg, 1979) indicate that low-angle normal faults can be very important in both localizing geothermal reservoirs and masking the alteration and thermal gradients associated with geothermal systems. These low-angle faults are similar to the denudation faults that have been identified in the hinterland of the Sevier Orogenic Belt (Armstrong, 1972). Because of the shallow dips associated with denudation faults, they are often difficult to recognize on aerial photographs and on the ground. Our mapping suggests that these faults may be present to a greater extent within the Basin and Range province than was previously thought.

REGIONAL GEOLOGIC SETTING

The Roosevelt Hot Springs and Cove Fort-Sulphurdale geothermal fields lie on the eastern margin of the Basin and Range Province in south-central Utah. This portion of the Basin and Range exhibits widespread Cenozoic intrusive and volcanic activity which forms part of a broad, east-trending belt extending from Pioche, Nevada to Marysvale, Utah (Callaghan, 1973). Quaternary volcanic activity (Lipman and others, 1978; Condie and Barskey, 1972), centered on the eastern end of the belt, is spatially related to the areas of geothermal activity. This volcanism produced rhyolite domes in the Mineral Range adjacent to the Roosevelt Hot Springs geothermal field and basalt flows in the Cove Fort area.

Basin and Range faulting began during the mid-Tertiary (Steven and others, 1977) and continued throughout the Cenozoic in the Roosevelt Hot Springs and Cove Fort-Sulphurdale areas. The dominant Basin and Range Faults include high-angle north-trending faults that control much of the present topography. Low-angle faults developed during the early stages of Basin and Range faulting as a result of gravitational instability and represent displacement of allochthonous blocks toward adjacent basins. Their listric form and normal offset are documented in Nielson and others (1978) and in Moore and Samberg (1979). Holocene activity is represented by numerous northerly trending fault scarps in the Quaternary alluvial fans.

Nielson, D.L., and Moore, J.N.

GEOLOGY OF THE COVE FORT-SULPHURDALE GEOTHERMAL SYSTEM

The generalized geology in the Cove Fort-Sulphurdale KGRA is illustrated in Figure 2. The northern portion of the geothermal area consists primarily of Paleozoic to late Mesozoic sedimentary rocks and mid-Tertiary dacitic lava flows. To the south, in the northern Tushar Mountains, these rocks are covered by mid-Tertiary ash-flow tuffs and intruded by latite and quartz- monzonite stocks and dikes. The volcanic rocks thicken southward and eastward toward the interior of the Marysvale volcanic field.

In the Cove Fort-Sulphurdale geothermal field, the low-angle faults truncate Miocene rhyolitic ash-flow tuffs that are overlain by isolated remnants of basalt flows and coarse clastic sedimentary rocks. We believe these younger units correlate with the widespread mid-Miocene Sevier River Formation which ranges in age from 7-14 my (Steven and others, 1977).

The geothermal reservoir is located primarily within fractured Paleozoic carbonate rocks. In the central portion of the KGRA, low-angle faults and overlying impermeable volcanic rocks are an effective caprock to the upward flow of hydrothermal fluids. Figure 2 illustrates the geometry of the low-angle faults in the southern portion of the geothermal field. Convective flow of hydrothermal fluids beneath the low-angle faults is probably controlled by steeply dipping faults and fractures. In the upper 1500 meters of the geothermal system, the rapid temperature decrease may reflect heat loss by conduction and by mixing with cold meteoric water. This interpretation is supported by the presence of cold springs occurring throughout the northern portion of the Tushar Mountains.

Near the northern and southern margins of the low-angle faults, leakage from the geothermal system results in the deposition of native sulfur and produces intense acid leaching of the alluvium and underlying bedrock (Fig. 2). The acid leaching resulting from the downward migration of sulphuric acid (Schoen and others, 1974) has left porous, siliceous residues that retain many original sedimentary structures of the parent rock.

The Cove Fort-Suphurdale area illustrates a situation where low-angle faulting has capped a geothermal system with a thick sequence of allochthonous volcanic and sedimentary rocks. Surface alteration produced by H_2S seeps is found both to the north and south of the zone of low-angle faulting but not within that zone. In addition, temperature gradient measurements indicate that the allochthonous rocks have served as a thermal cap on the system separating a convective thermal regime beneath the fault from a zone of conductive heat transport and probable fresh water influx above the principal fault zone.

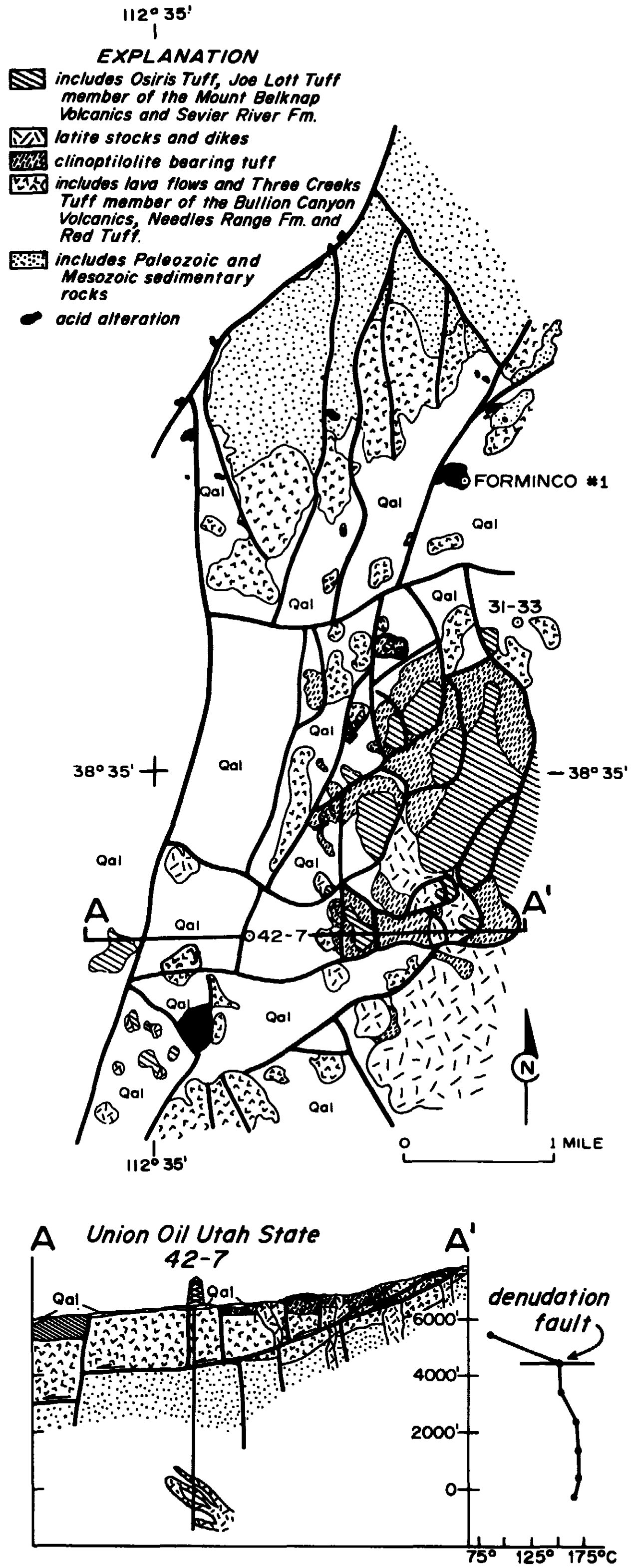

Figure 2. Geology of the Cove Fort-Sulphurdale Geothermal Area.

Clearly, exploration in this environment utilizing shallow temperature measurements is fraught with uncertainty if structures have not been documented by field mapping.

GEOLOGY OF ROOSEVELT HOT SPRINGS GEOTHERMAL SYSTEM

The geothermal system at Roosevelt Hot Springs KGRA is controlled by structures cutting plutonic and metamorphic rocks of Tertiary and Precambrian age (Fig. 3). A major low-angle normal fault, mapped along the western margin of the Mineral Mountains (Nielson and other, 1978; 1979), is characterized by intense mylonitization of the crystalline country rock. Offset has been determined to be approximately 600 meters in a westerly direction. The hanging wall of this fault is intensely brecciated where friction between large blocks has produced steeply dipping mylonite zones. Both the steep- and shallow-dipping mylonite zones have been altered and silicified to produce an impermeable but brittle rock. Strong jointing with increased permeability is often found adjacent to the mylonite zones. Permeability in the upper levels of the geothermal field occurs from the intersection of the mylonite zones formed during denudation faulting with the steeply dipping normal faults similar to the Opal Mound Fault.

Geothermal fluids are conveyed from depth along the Opal Mound Fault and parallel structures. These fluids enter shallow reservoirs, in the area of 72-16 and 25-15, which result from the increased structural permeability in the hanging wall of the denudation fault. Also, within this environment it is possible that geothermal fluids may be channeled laterally along denudation faults and subsidiary structures such that surface and near-surface manifestations of geothermal activity are laterally displaced from deeper reservoirs.

SUMMARY

Detailed geologic mapping in the Roosevelt Hot Springs and Cove Fort-Sulphurdale KGRAs has shown that low-angle faults contribute to the structural controls of some reservoirs while masking any near-surface manifestations of other geothermal systems. If structures of this type are present in the area of geothermal exploration, an understanding of their geometries is necessary for effective exploration.

ACKNOWLEDGEMENTS

This research was supported under the Industry Coupled Program of the Department of Energy, Division of Geothermal Energy, contract nos. EG-78-C-07-1701 and DE-AC07-78ET-28392.

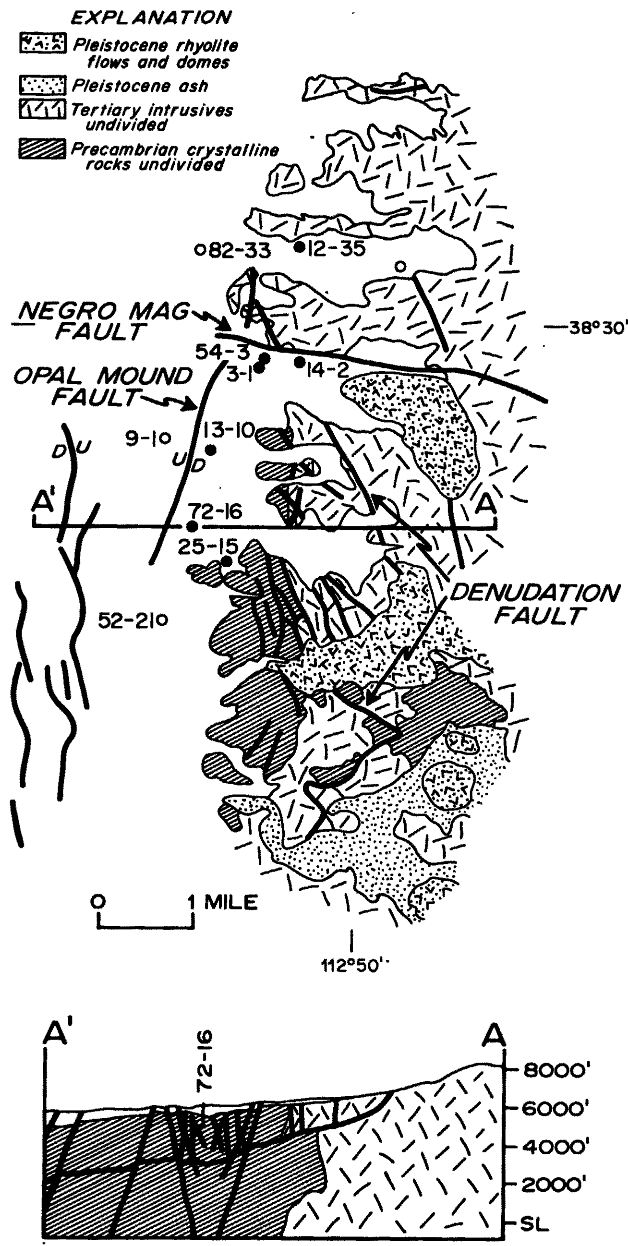

Figure 3. Geology of the Roosevelt Hot Springs Geothermal Area.

REFERENCES CITED

Armstrong, R.L., 1972, Low angle (denudation) faults, hinterland of the Sevier orogenic belt, eastern Nevada and western Utah: Geol. Soc. America Bull., v. 83, p. 1729-1754.

Callaghan, E., 1973, Mineral resources of Piute County, Utah and adjoining area: Utah Geol. Miner. Survey Bull. 102, 135 p.

Nielson, D.L., and Moore, J.N.

Condie, K.C., and Barsky, C.K., 1972, Origin of Quaternary basalts from the Black Rock Desert Region, Utah: Geol. Soc. America Bull., v. 83, p. 333-352.

Lipman, P.W., Rowley, P.D., Mehnert, H.H., Evans, S.H., Nash, W.P., and Brown, F.H., 1978, Pleistocene rhyolite of the Mineral Mountains, Utah - geothermal and archeological significance: Jour. Research U.S. Geol. Surv., v. 6, no. 1, p. 133-147.

Moore, J.N., and Samberg, S.M., 1979, Geology of the Cove Fort-Sulphurdale KGRA: Univ. Utah Res. Inst., Earth Science Lab. Rept. No. 18, Salt Lake City, Utah, 44 p.

Nielson, D.L., Sibbett, B.S., McKinney, D.B., Hulen, J.B., Moore, J.N., and Samberg, S.M., 1978, Geology of Roosevelt Hot Springs KGRA, Beaver Co., Utah; Univ. Utah Res. Inst., Earth Science Lab. Rept. No. 12, Salt Lake City, Utah, 121 p.

Nielson, D.L., Sibbett, B.S., and McKinney, D.B., 1979, Geology and structural control of the geothermal system at Roosevelt Hot Springs KGRA, Beaver Co., Utah (abs.): Amer. Assoc. Petroleum Geologists Bull., v. 63/5, p. 836.

Schoen, R., White, D.E., and Hemley, J.J., 1974, Argillization by descending acid at Steamboat Springs, Nevada: Clays and Clay Minerals, v. 22, p. 1-22.

Steven, T.A., Cunningham, C.G., Naeser, C.W., and Mehnert, H.H., 1977, Revised stratigraphy and radiometric ages of volcanic rocks and mineral deposits in the Marysvale area, west-central Utah: U.S. Geol. Surv. Open-File Report 77-569, 45 p.