THE COVE FORT-SULPHURDALE, UTAH GEOTHERMAL FIELD

INTRODUCTION

The Cove Fort-Sulphurdale (CFS) Known Geothermal Resource Area (KGRA) is located in Millard and Beaver Counties in south-central Utah, near the intersection of Interstate Highways 15 and 70 (Figures 1 and 2).

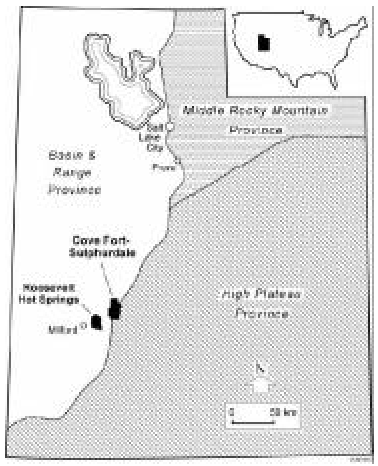

Figure 1. Location map of the Cove Fort-Sulphurdale resource area.

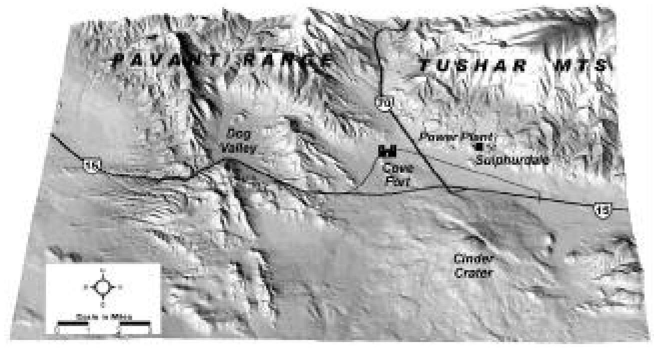

Figure 2. 3-Dimensional map of the Cove Fort-Sulphurdale area.

Cove Fort is an old stone fort built by Mormon settlers in 1867 as a way station for travelers. The presence of sulfur mines, gas seeps that emit hydrogen sulfide and altered ground initially suggested the existence of an extensive and exploitable geothermal resource. The site of the old mine at Sulphurdale is the largest of these sulfur deposits (Figure 3).

Figure 3. Photomontage of the sulfur mine and buildings.

In 1893, all of the nation's native sulfur, about 1200 tons, came from Sulphurdale. The mines produced a total of 30,000 long tons between 1885 and 1952, when competition from other sources forced it to close. (Callaghan, 1973).

GEOLOGY

The CFS KGRA lies near the junction of the Pavant Range and Tushar Mountains on the eastern margin of the Basin and Range province (refer to Figures 1 and 2). These mountains mark the transition between the Colorado Plateau and the Basin and Range provinces. They are composed primarily of Paleozoic to Mesozoic sedimentary rocks that are covered to the south and east of Cove Fort by Tertiary volcanic rocks (Steven and Morris, 1981; Figure 4). Intrusive rocks related to the volcanic activity are exposed at several places within the area.

Numerous reports and maps have been published on the geology of the CFS area. Ross and Moore (1985) provide an excellent summary. The sedimentary rocks of the CFS area are part of a broad, north-trending thrust belt deformed during the Late Cretaceous Sevier Orogeny. Rocks penetrated to depths of up to 7,700 feet in Union Oil Company's deep geothermal wells consist largely of limestone and dolomite that were variably metamorphosed by Tertiary intrusions (Figure 5). Sandstone occurs near the top of the sedimentary sequence

The Tertiary volcanic rocks erupted between about 30 and 19 m.y. ago from widely scattered centers in two distinct volcanic terranes – the Marysvale volcanic field of the southwestern High Plateaus to the east of Cove Fort and the Basin and Range to the west. They include lava flows, volcanic breccias and thick sequences of ash flow tuffs

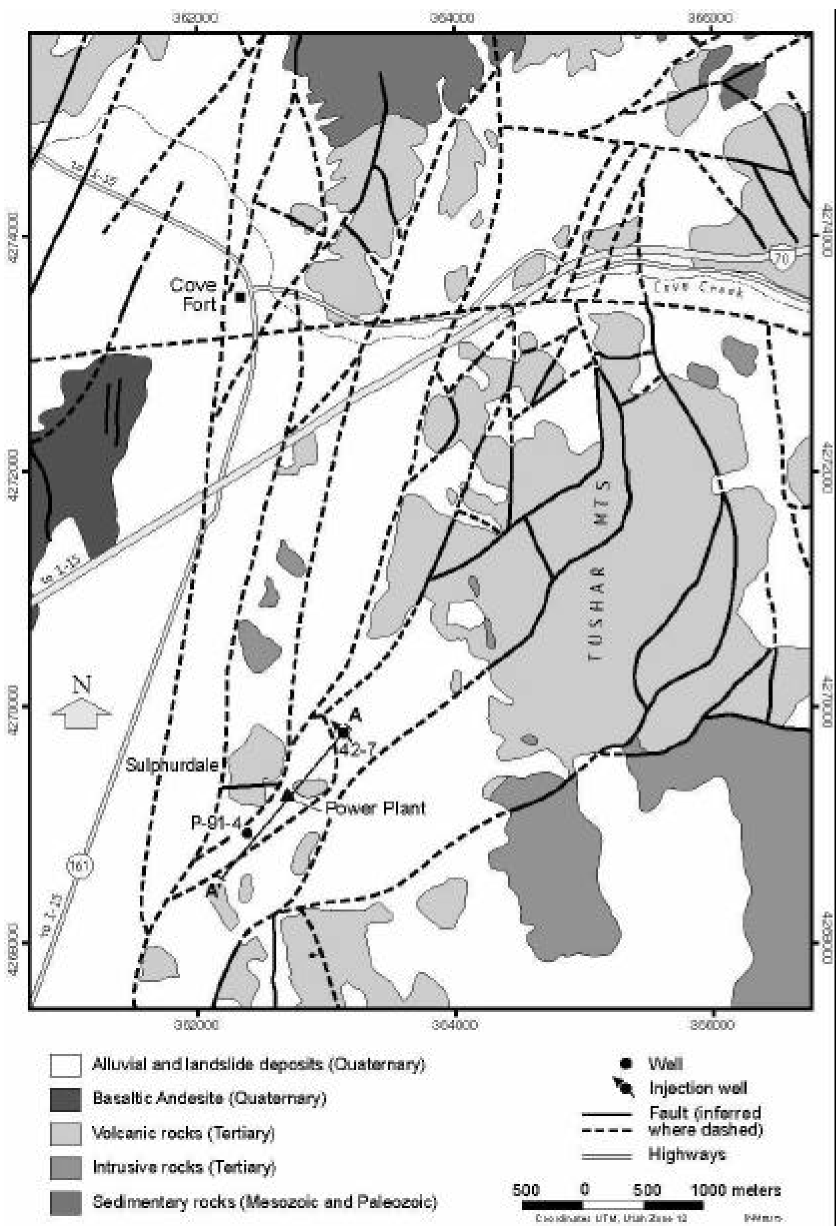

Figure 4. Simplified geologic map of the Cove-Fort–Sulphurdale area (modified from Steven and Morris (1981) and Ross and Moore (1985)).

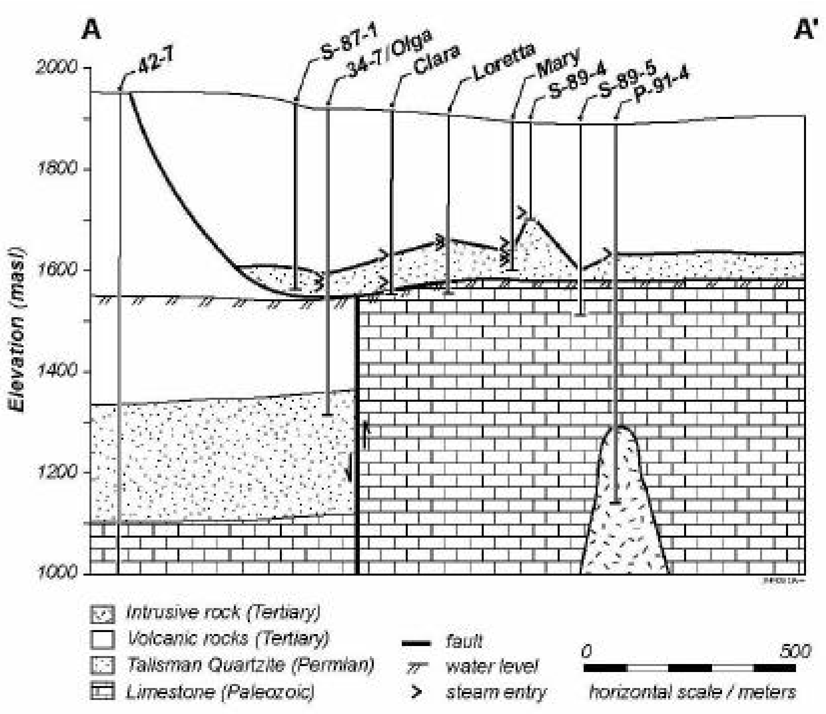

Figure 5. ***Northeast-southwest cross section showing the distribution of rocks encountered in the wells. See Figure 4 for the location of the cross section.***

derived from local and distant sources. The base of the volcanic sequence near Cove Fort consists mainly of locally derived lava flows and breccias of intermediate composition (Steven and others, 1979). The upper parts of the Tertiary volcanic sequence consist predominately of ash-flow tuffs. Some of the units reach thicknesses of several thousand feet. Many of the ash flow tuffs are distinctive and widely distributed, and they are important marker horizons that have allowed detailed mapping of structures within the geothermal field (Moore and Samberg, 1979; Steven and Morris, 1981).

Renewed volcanic activity between 1 m.y. and 0.3 m.y. ago produced a shield volcano in the Cove Fort basalt field (Steven and Morris, 1981). Callaghan (1973) and Steven and others (1979) have suggested that the heat source of the Cove Fort-Sulphurdale geothermal system may be related to this basaltic volcanism, but there is no direct geochemical or thermal evidence to support this hypothesis.

In their review of the CFS area, Ross and Moore (1985) concluded that geologic and geophysical data indicate that the geothermal system is controlled by faults and fractures. The oldest structures are thrust faults that disrupted the sedimentary rocks during the Sevier Orogeny. Thrust faults may be widely distributed at depth in the reservoir rocks of the thermal area. Since Basin and Range tectonism began in the mid-Miocene (Steven and others, 1979), rocks of the CFS area have been disrupted by both high- and low-angle northerly and easterly trending normal faults. Continued activity is indicated by fault scarps in the alluvium and lava flows of the Cove Fort basalt field (Steven and Morris, 1981) and by a high level of microearthquakes in the vicinity of Cove Fort (Smith and Sbar, 1974). Here, at Sulphurdale, and along the western margin of the Pavant Range, the trends of the faults are marked locally by the alignment of sulfur deposits, acid-altered alluvium, and gas seeps.

Low-angle faults bound extensive gravitational glide blocks between Sulphurdale and the steeply dipping Cove Creek fault, which parallels Interstate 70. These westerly dipping low angle faults display pronounced arcuate trends in plan view (refer to Figure 4). The gravitational glide blocks form a nearly impermeable cover over the geothermal system that has profoundly influenced the distribution of the surficial alteration and shallow temperatures and thermal gradients along the northwestern flank of the Tushar Mountains (Ross and Moore, 1985).

EARLY EXPLORATION

The Thermex Company took the first fee geothermal leases in the CFS area in 1972 (Huttrer, 1994). In 1974, when the Federal geothermal regulations went into effect, a "land rush" began and fee, federal, and state leases were acquired by numerous companies, including AMAX (later Steam Reserve), Phillips Petroleum Company, Chevron Resources Company, Hunt Energy Corporation, and Union Geothermal Division. Also holding federal leases in the CFS area were Earth Power Corporation and the Grace-owned companies of Thermal Resources, Inc. and U.S. Geothermal Corporation. Federal leases held by Earth Power and the Grace companies were subsequently farmed out to Hunt Energy.

The companies started a massive exploration effort in 1974. During 1975 and the following three years, numerous rigs were operating throughout the CFS area drilling temperature-gradient holes. Competition was strong and secretive, to the point that gradient holes were being locked to prevent others from logging them. The attempts at locking holes were not always successful and numerous cases of hole "break-in's" were reported to government agencies.

More than 200 temperature-gradient holes were drilled in an area of more than 100 square miles (260 km^2) . Ultimately, most of the companies agreed to trade data. The results showed that the drilling efforts had defined a shallow thermal anomaly that covered more than 70 square miles (181 km^2) . It was also discovered that, despite the immense size of the shallow anomaly and all of the surface geothermal manifestations, the deeper and hotter source of the anomaly was still an elusive target.

Between 1975 and 1979, Union Geothermal Division drilled four deep exploration wells to test the geothermal system. The first well, CFSU 42-7, recorded temperatures of nearly 350°F (177ºC) below depths of 5,000 ft (1,524 m) (Figure 6). However, the high cost of drilling, high corrosion rates, low reservoir pressures, and the apparent limited extent of the high-temperature reservoir led to a premature conclusion by Union Geothermal Division in 1980 that the field was not economic for large-scale electric power production (Ross and Moore, 1985).

Figure 6. Photo of the CFSU 42-7 wellhead.

RESOURCE DEVELOPMENT

In 1983, Mother Earth Industries, Inc. (MEI) obtained fee leases from Steam Reserve, geothermal leases on the patented mining claims from Forminco and the Union Geothermal Division federal geothermal leases. In October 1983, while drilling their first well, 34-7, MEI penetrated a 100-psi (690-kPa) , 350°F- (177ºC-) dry steam resource at 1,165 feet in fractured sandstone (Talisman Quartzite) below the volcanic rocks (Huttrer, 1994; refer to Figure 5). The drillers were unable to contain the steam, and the well discharged uncontrollably for 24 days. Oil field techniques had to be used to cap the well. Although the well was lost, this blow out demonstrated the existence of a shallow steam reservoir. In January and May 1984, MEI completed wells 34A-7 and 34B-7, within 200 ft (60 m) of the original well, as dry steam producers. They too penetrated the steam at about 1,160 ft (354 m) (Huttrer, 1994).

In 1987, MEI began a broad scale exploration program that included a soil mercury survey and several geophysical studies, together with the drilling of slim diameter wells offsetting the existing steam production wells. The geophysical work included self potential (SP), ground magnetic, and controlled-source audio magnetotelluric (CSAMT) surveys. Based on the results of these surveys, ten new temperature gradient holes were drilled to an average depth of 100 ft (30 m) at sites around the Sulphurdale fee lands (Huttrer, 1994).

Following the encouraging results of the 1987 exploration studies and drilling, MEI drilled six slim holes and twinned three of them with production-scale wells in 1988 and 1989. All of the production wells and all but one of the slim holes produced steam from the Talisman Quartzite. Flow tests of these wells showed that permeability within the steam cap was very high and that all of the wells were hydraulically connected. No wells were drilled in 1990, but in 1991, steam pressure losses due to increased power plant demands dictated the need to explore for the hot-water reservoir long thought to underlie the steam cap. Well P91-4 was drilled at the northwest corner of the Sulphurdale pit (Figure 7). It encountered a 315°F- (157ºC-) liquid-dominated geothermal reservoir in Paleozoic carbonate rocks at a depth of about 1,800 ft (550 m) (Huttrer, 1994). Small amounts of steam were produced before the well hit the water table at 1,050 ft (320 m), but these zones were cased off.

Figure 7. Photograph of well P91-4. The well is equipped with a pump.

UTILIZATION

The CFS geothermal resource was developed in three phases. Construction of the first phase began in 1984 and came online in 1985. It consisted of four ORMAT binary units that used isopentane as a working fluid. These units had a combined generating capacity of approximately 1.5 MW_e . Figure 8 shows an overview of the plant and Figure 9 shows one of the four ORMAT binary units.

The second phase of development started in March 1988 with a non-condensing topping turbine capable of producing 1.8 MW_e . Both of these phases utilized steam from two wells on the federal lease. A third phase, consisting of a condensing turbine with a 7.5 MW_e capacity, was constructed in 1990 and utilized steam from three wells located on the fee land (Figure 10).

Figure 8. Overview of the power plant. The sulfur deposit and Cove Fort volcano are in the background.

Figure 9. One of the ORMAT binary units.

Figure 10. The condensing turbine.

From mid-1992 to April 1994, steam production from the federal wells was stopped, but wells on the fee land continued to produce steam for the 7.5-MW_e condensing turbine. Normal operations resumed in April 1994. In May 1996, the water well, P91-4, was put into production and the non-condensing topping turbine was removed from the system. Subsequently, all five steam wells and the water well supplied steam to the condensing turbine. A dual flash system was used to separate steam from water produced by well P91-4. The steam produced in a high-pressure separator supplied steam to the condensing turbine. The separated water from the high-pressure separator was flashed again in the low-pressure separator. This low-pressure steam was used in the ORMAT binary units to produce additional electricity. The separated water from the low-pressure separator was injected back into the reservoir through well CFSU 42-7.

About 1992, MEI sold the resource and property to the city of Provo, Utah and the Utah Municipal Power Authority (UMPA). Electricity was provided to five Utah cities. In June 2003, Provo and UMPA sold the plant and resource to Recurrent Resources. The plant has been shut down since the sale. No plans have been released by Recurrent Resources to restart the plant or for further development of the resource.

ACKNOWLEDGMENT

Photographs by Roger Bowers, Ely, NV and geologic maps by Joe Moore, EGI, Salt Lake City, UT.

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