[PS]Assessment of the Geothermal Resource in the Tomichi Dome Area, Colorado*

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Abstract

In response to geothermal lease nominations on the Grand Mesa-Uncompahgre-Gunnison National Forest, the U.S.D.A. Forest Service requested that the Bureau of Land Management assess the potential for future geothermal development in the area of the lease nominations.

The lease nominations are located in an intra-mountain geothermal system approximately 20 miles east of Gunnison, Colorado. The system includes approximately 38,628 surface acres of land surrounding Tomichi Dome and Waunita Hot Springs. While utilized for its surface thermal waters since the 1840's, very little information exists regarding the nature of the geothermal system at depth.

A detailed analysis of geologic maps, historical publications, and personal interviews has yielded a better understanding of the area's geothermal system and its potential as a geothermal energy. The geothermal system is bounded to the east, north, and west by fault-related contacts with Proterozoic crystalline rocks, and to the south by Tomichi Creek. The probable geothermal reservoir is the Cretaceous Dakota Sandstone. The Dakota is confined by the overlying Mancos Shale and the underlying shales of the Morrison Formation. Recharge principally occurs in the northwestern portion of the area where the Dakota is exposed at the surface. Geothermal heating of the system's water is directly related to the recent (Tertiary) igneous activity which emplaced Tomichi Dome and several other nearby laccoliths of similar composition. The geothermal gradient to depths less than 8,000 feet extrapolated from shallow (less than 330 feet) boreholes reveals a moderate temperature system which is likely hot-water (not steam) dominated. Localized faulting at these depths would enhance circulation and thermal recharge of geothermally utilized waters.

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Prepared by the Bureau of Land Management, Wyoming State Office, Reservoir Management Group for the U.S.D.A. Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests

Tomichi Dome as seen from Waunita Hot Springs circa 1914

Tomichi Dome Today

Abstract

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A detailed analysis of geologic maps, historical publications, and personal interviews has yielded a better understanding of the area's geothermal system and its potential as a geothermal energy resource. The geothermal system is bounded to the east, north, and west by fault-related contacts with Proterozoic crystalline rocks, and to the south by Tomichi Creek. The probable geothermal reservoir is the Cretaceous Dakota Sandstone. The Dakota is confined by the overlying Mancos Shale and the underlying shales of the Morrison Formation. Recharge principally occurs in the northwestern portion of the area where the Dakota is exposed at the surface. Geothermal heating of the system's water is directly related to the recent (Tertiary) igneous activity which emplaced Tomichi Dome and several other nearby laccoliths of similar composition. The geothermal gradient to depths less than 8,000 feet extrapolated from shallow (less than 330 feet) boreholes reveals a moderate temperature system which is likely hot-water (not steam) dominated. Localized faulting at these depths would enhance circulation and thermal recharge of geothermally utilized waters.

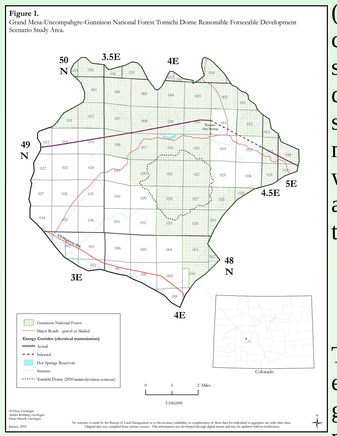

Figure 1.
Grand Mesa-Uncompahgre-Gunnison National Forest Tomichi Dome Reasonable Foreseable Development Scenario Study Area.

Background

The Study Area is located approximately 20 miles east of the city of Gunnison in Gunnison and Saguache counties, Colorado, and encompasses approximately 38,628 acres of State, Federal, and Fee lands, and approximately 20,158 surface acres of U.S.D.A. Forest Service Gunnison Nation Forest (Figure 1). A number of parcels of land have been nominated for geothermal leasing through the U.S.D.A. Forest Service (approximately 3,788 acres), the Bureau of Land Management (approximately 4,984 acres), and the State of Colorado (approximately 1,280 acres) (Figures 2 and 3). Since these lease nominations do not encompass the entire geothermal system (e.g., areas of recharge to the northwest of the nominated lands, the hot springs at Waunita Springs, etc.), the geologic setting was studied to determine the areal extent of the geothermal system and to identify logical boundaries for the Study Area.

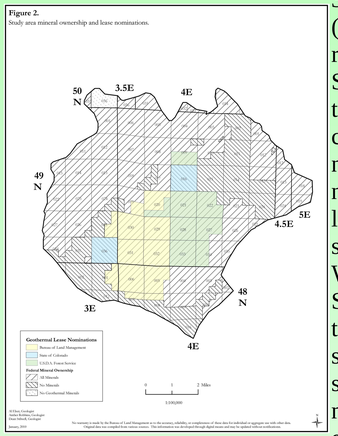

Figure 2.
Study area mineral-ownership and lease nominations.

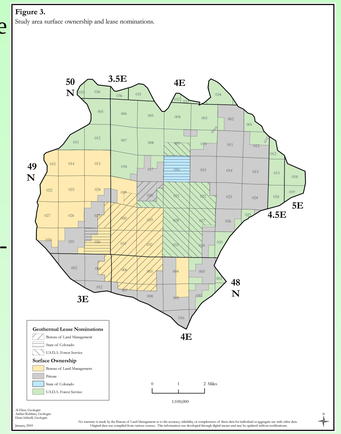

Figure 3.
Study area surface ownership and lease nominations.

Data and Resources

Existing research on the size and extent of the geothermal resource in the Study Area is sparse. Part of this is due to the limited number of studies conducted in the area. Part must also be attributed to the historically blurred distinction between the types of geothermal resources necessary to supply the variety of geothermal projects.

The 1973 oil crisis eventually sparked a greater interest in renewable and alternative energy. By the end of the 1970s and into the early 1980s a number of studies were published related to geothermal resources in Colorado, including the Tomichi Dome/Waunita Hot Springs area. These vintage data sources represent the bulk of the research available for review related to the geothermal resource in the Study Area (see References).

Geologic Setting

The Study Area represents the northeastern portion of an inter-mountain sedimentary basin (graben) within the southern Rocky Mountains. Proterozoic igneous and metamorphic rocks are exposed to the southeast and northeast (granite), as well as to the north and west (felsic and hornblendic gneisses) (Figure 4). The basin includes over 2,000 feet of sedimentary strata deposited during the Jurassic (Morrison Formation) and Cretaceous (Dakota Sandstone and Mancos Shale), as well as Tertiary-aged intrusives (Tomichi Dome rhyolite). Locally, the basin sediments generally dip to the southeast with the oldest sediments exposed in outcrop in the northwestern portion of the Study Area (K.W. Nickerson & Associates, 1981).

During the Tertiary, an igneous laccolith complex intruded into the area and is exposed as Tomichi Dome, a prominent (approximately 2 miles in diameter at the surface and 2,100 feet of vertical relief) rhyolite plug associated with a regional batholith which emplaced several domes of similar composition and age (e.g., Treasure Mountain Dome, Mount Emmons, Boston Peak and Round Mountain) (Ernst, 1980). A number of normal faults extend out a short distance from the dome into the surrounding formations, with offsets of as much as 250 feet. In the Dakota Sandstone (the inferred geothermal reservoir – see below) jointing and fracturing are common with sets of each generally trending north-south and east-west with vertical dips.

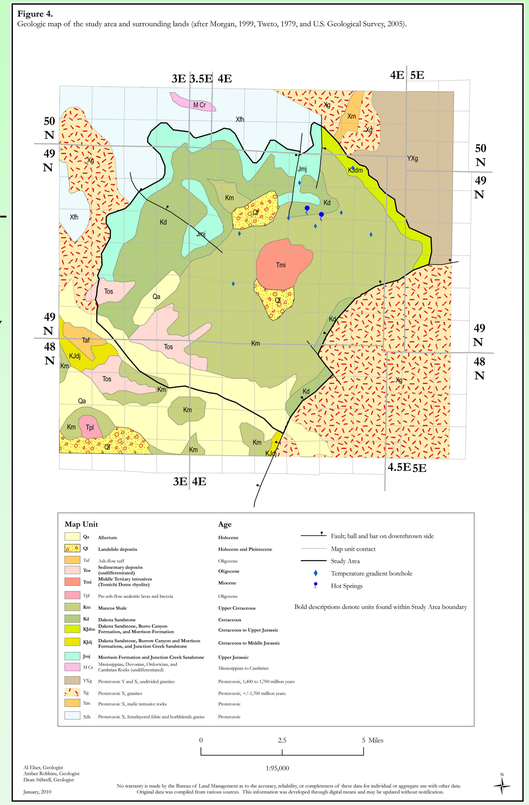

Figure 4.
Geologic map of the study area and surrounding lands (after Morgan, 1999, Tweto, 1979, and U.S. Geological Survey, 2005).

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Photo Credits:
Left: Tomichi Dome From Waunita Hot Springs, ca. 1914; U.S. Geological Survey Photographic Library
Right: Tomichi Dome; Darren Long, U.S. Department of the Interior, Bureau of Land Management


View of Tomichi Dome looking northeast

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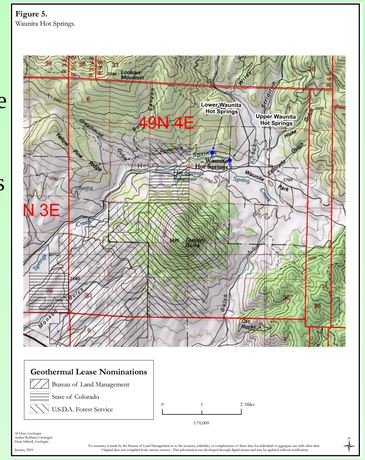
View from Tomichi Dome to the west

The Geothermal System

Thermal Springs

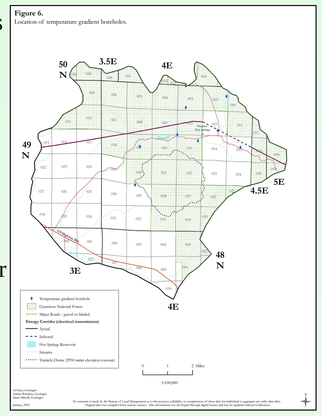
The thermal waters expressed at Waunita Hot Springs issue from the Dakota Sandstone (reservoir) where local faulting has exposed the Dakota through the younger Mancos Shale (upper confining bed) (Dellechaie, 1981). The waters surface as two distinct groups of springs located approximately one half mile apart (Figure 5).



Reservoir & Resource

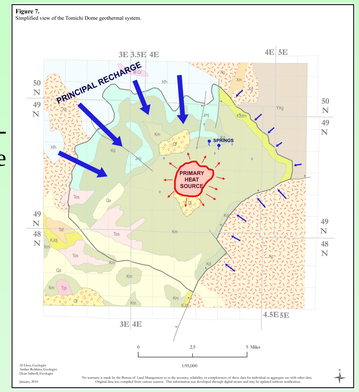
Locally, the Dakota Sandstone can be characterized as a quartz-rich medium-grained sandstone with a total thickness of 150 to 200 feet (K.W. Nickerson & Associates, 1981). Faults, fractures, intercalated shales and a basal conglomerate create a non-uniform, heterogeneous reservoir in both character and porosity/permeability. Highly variable horizontal permeabilities (0.1 to 66 Milidarcy) of the sandstone suggest thermal flow is along fractures and through the basal conglomerate. Thick shales above (Mancos) and below (Morrison) act as confining beds.

The subsurface thermal conditions of the reservoir's geothermal waters have only been inferred through analysis of the surface waters and geothermal temperature gradients measured from eight shallow boreholes located in the northeastern portion of the Study Area (Figure 6). These boreholes represent the only exploration in the Study Area for geothermal development to date. The average temperature gradients are in the range of 25 to 62 degrees Celsius per kilometer (40 to 100 degrees Fahrenheit per mile), with the steepest gradients in boreholes closest to the inferred heat source, the Tomichi Dome Tertiary intrusive. These gradients suggest that at a depth of 5,000 feet the reservoir temperature could be as much as 120 degrees Celsius (250 degrees Fahrenheit). If such is the case, the temperature of this system falls within the moderate temperature geothermal system classification as defined by the U.S. Geological Survey (Williams et. al, 2008). Such systems are generally hot-water dominated.



Principal recharge of the system's waters occurs in the northwestern portion of the Study Area where the Dakota Sandstone is exposed through erosion; boundary faults and faults/fractures associated with the Tomichi Dome intrusion also provide paths for recharge (Figure 7).

The only resource assessment performed which assigned a distinct energy value to the geothermal resource in the Study Area was performed by Dick and Pearl (1978). The resource size was calculated based on rough estimates of the reservoir's areal extent (1.4 square miles), thickness (200 feet), and average temperature (275 degrees Fahrenheit). A total of 0.0606 quads of geothermal energy resource (undiscovered) were calculated to be associated with the geothermal system. It should be noted, however, that the geothermal reservoir is likely to be significantly larger in areal extent than estimated in this early study.



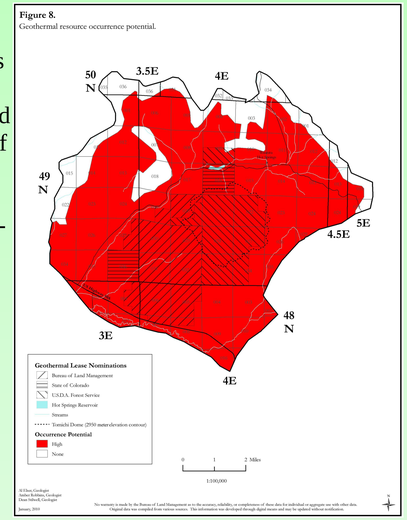
Resource Occurrence Potential

Department of the Interior guidance (Bureau of Land Management, 1993) outlines specific criteria necessary for ranking the potential for occurrence of energy and mineral resources within a given area. This ranking considers a variety of geologic characteristics, including presence of favorable (permissive) geologic environment, inferred geologic processes, reported mineral (resource) occurrence(s), geochemical/geophysical anomalies and known mines or deposits.

We consider that all of the Study Area lands where the Dakota Sandstone reservoir is present have a high potential for occurrence for a geothermal resource suitable for commercial electrical power generation (Figure 8). All lands therein have direct and indirect evidence of a favorable geologic environment (presence of the Dakota Sandstone reservoir and proximity to the inferred heat source of the Tomichi Dome-related Tertiary intrusives), favorable inferred geologic processes (demonstrated fracturing and faulting of the reservoir and known surface expression of the thermal waters), and known valid geochemical (geothermal) anomalies. Those areas within the Study Area classified as having no potential for occurrence are where there is direct evidence of the absence of the Dakota Sandstone reservoir due to erosion.

Conclusion

With an anomalous temperature gradient extrapolated from shallow boreholes, a moderate temperature geothermal system is suggested which is likely hot-water (not steam) dominated. Localized faulting would enhance circulation and thermal recharge of geothermally-utilized waters. A long-lived surface expression (Waunita Hot Springs), shallow heat source (Tertiary igneous activity related to Tomichi Dome), proximity to transportation and electrical corridors and encouraging data from early work all suggest the area to be an ideal candidate for further research and possibly exploration and development of the geothermal resource.



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Left: View of Tomichi Dome looking northeast; Right: View from Tomichi Dome to the west; Marnie Medina, U.S. Department of the Interior, Bureau of Land Management