

NOTICE CONCERNING COPYRIGHT RESTRICTIONS

This document may contain copyrighted materials. These materials have been made available for use in research, teaching, and private study, but may not be used for any commercial purpose. Users may not otherwise copy, reproduce, retransmit, distribute, publish, commercially exploit or otherwise transfer any material.

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specific conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

A GEOLOGICAL AND HYDRO-GEOCHEMICAL STUDY OF THE ANIMAS GEOTHERMAL AREA,
HIDALGO COUNTY, NEW MEXICO

Frank Dellechais

AMAX EXPLORATION, INC., 4704 Harlan Street, Denver, CO 80212

Abstract

The Animas Valley thermal area lies on the west pediment of the Pyramid Mountains. The Pyramids are composed of Cretaceous to Tertiary igneous rocks.

Two hot wells produce 101°C water at a depth of 20 meters. The wells seem to relate to a northerly trending fault having at least 500 meters displacement with the west block downthrown.

An elliptical heatflow anomaly extending about 3 km in length occurs in this area.

Thermal waters contain about 1200 mg/l of dissolved solids and low concentrations of Li, B, NH₃ and H₂S. Silica concentrations do not exceed 145 mg/l. Cations and anions occur as:



Last equilibrium with a volcanic suite of minerals and carbonates is evidenced. Geothermometers indicate subsurface temperatures of approximately 160°C.

Apparently the thermal waters are escaping rapidly from a deep (>4 km) reservoir along a conduit formed by fault intersections. Evidence of igneous heat is lacking.

Geology

A geothermal anomaly occurs in the Animas Valley, Hidalgo County, southwestern New Mexico (Figure 1). The region is arid, sparsely settled and only locally supports irrigated agriculture.

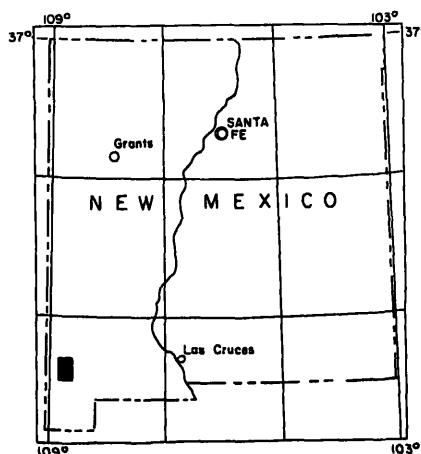


Figure 1. Location of the Animas geothermal area.

Six hot wells in T25S, R19W are the main indicators of geothermal potential. Two of the wells produce 101°C water from a zone of altered rhyolite at 20 meters depth. The thermal wells are on the pediment west of the Pyramid Mountains - a north trending range composed exclusively of Cretaceous to late Tertiary igneous rocks. The wells were drilled in the vicinity of a concealed range front fault with at least 500 meters displacement. This fault is evident on regional gravity maps (Figure 2) with sustaining evidence witnessed on imagery.

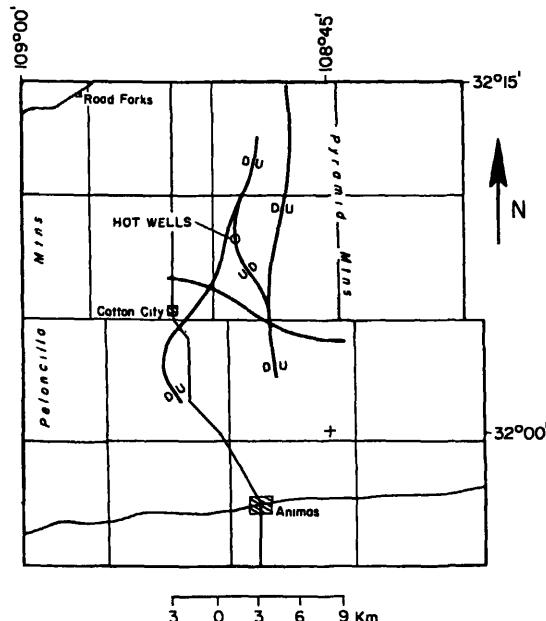


Figure 2. Concealed valley faults deduced from the regional gravity.

Additional evidence for the fault is supplied by a 2.25 km deep oil test some distance to the north (Summers, 1976). On the west side of the fault trace 500 meters of valley fill is encountered, while on the upthrown side, wells penetrate bedrock at less than 50 meters.

The Animas area is located in a region of crustal extension and thinning common to the Basin and Range province. The geologic history of the area consists of four main periods of volcanic activity and two main periods of intrusive activity. A thickness of about 600 meters of basalt was extruded during the lower Cretaceous.

A granodiorite stock was intruded into Cretaceous basalts during the early Tertiary when the mineral veins at the northern limit of the Pyramids were formed. A thickness of approximately 800 meters of andesite flows were erupted during early Tertiary times. These andesites were then intruded by a small monzonite stock. After a period of erosion, a thickness of 700 meters of rhyolite flows, tuffs, welded tuffs and basalt were erupted during the middle or late Tertiary. A second period of rhyolite eruption measuring about 200 meters in thickness occurred during middle-late Tertiary along with folding and high angle block faulting.

Lastly, quaternary basalts were erupted onto valley fill southwest of Cotton City. These obviously evidence sustained tectonism in the region but do not bear any visible relationship to the geothermal activity.

Heatflow

Heatflow determinations from 31 observation holes reveal a 3 km elliptical anomaly in the area of the hot wells. Well depths averaged less than 70 meters.

The resulting anomaly encloses values as high as 20 HFU. The shape and size of the anomaly seems consistent with a point source of hot water localized by a fault intersection. Dispersion is compatible with the northerly ground-water flow. The northern-most observation holes exhibit very high gradients at shallow depths but become isothermal at depth.

Seismic

The area is seismically inactive. Only one -1.0 magnitude earthquake was recorded during a 13 day microearthquake survey. Analysis of 130 mine blasts recorded during the survey failed to indicate any anomalous velocity structures.

Chemistry

Nonthermal waters of the area generally contain less than 400 mg/l of dissolved solids. Cations and anions occur as:



Cold waters contain an average of 24 mg/l of silica, 1.5 mg/l of fluoride and exhibit neutral pH.

Thermal waters exhibit neutral to slightly basic pH. Cations and anions occur as:



The low concentrations of chloride, boron, ammonia and lithium would indicate last equilibrium with a crystalline rock (Table 1). The high fluoride concentrations also point to equilibration with high fluoride igneous rocks. Mineral equilibrium computations (Kharaka 1973) indicate saturation with carbonates and several igneous minerals (Table 2).

Table 1. Chemical analyses of the thermal features from T25S, R19W. Units are mg/l unless otherwise noted.

	Superheated Hot Well	McCants Hot Well	Folks Hot Well
pH	7.8	8.1	7.0
Cl	112	84	130
F	15	12	7.8
HCO ₃	90	80	93
CO ₃	0	0	0
SO ₄	400	460	700
SiO ₂	145	130	99
Na	340	330	420
K	20	19	26
Ca	20	21	70
Mg	0.3	0.1	5.0
Li	0.5	0.5	0.8
B	0.4	0.3	0.2
NH ₃	0.12	0.12	0.20
H ₂ S	<0.2	<0.2	<0.2
TDS	1143	1137	1152
T°C	101	85	65
Flow (gpm)	---	50	35
TSiO ₂ °C	159	152	137
TNa/R°C	129	133	134
TNa-K-Ca °C	165	165	160
Cl/SO ₄	0.8	0.5	0.5
Cl/HCO ₃	2.1	1.8	2.4
Cl/F	4.0	3.7	8.8

Table 2. Gibbs Free Energies in kcal/mole for McCants Hot Well

Carbonates	Calcite	0.4
	Aragonite	0.3
Silicates	Fayalite	3.3
	Kenyaite	3.2
	Magadite	3.2
	Quartz	0.9
	Chalcedony	0.5
	Cristobalite	0.2

The hot wells are enriched in silica and chloride and depleted in bicarbonate relative to other thermal and nonthermal waters of the Animas area (Figure 3). The hot wells are, however, generally similar to the regional waters regarding other major elements. The silica and alkali geothermometers correlate well (Table 1) indicating subsurface temperatures of approximately 160°C. (Fournier and Trusdell, 1973; Fournier and Rowe, 1966).

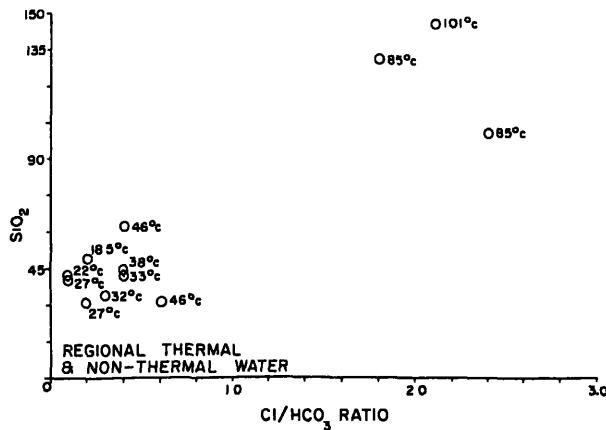


Figure 3. SiO₂ in mg/l versus the Cl/HCO₃ ratio for the waters of the Animas area.

Discussion

Detailed mapping of the Pyramid and Central Peloncillo Mountains has not revealed any Pleistocene siliceous rocks. The probability of a recent intrusive event is thereby diminished. The area's aseismicity further demonstrates the lack of an active intrusive. The lack of seismicity may also be symptomatic of a lack of extensive fracture permeability. The heatflow observations suggest a focused point of hot water leakage, likely a fault intersection, which is being dispersed by a northerly underflow.

Geochemistry indicates that waters are heated in igneous and carbonate rocks. That is inferred by the low concentration of chloride, boron, lithium and ammonia and the very high concentrations of fluoride. Mineral equilibria studies also indicate that the waters are slightly saturated with carbonates.

Geothermometers show last equilibration at about 160°C. Waters would have to circulate to a depth of more than 4.0 kilometers in order to reach 160°C, assuming a regional gradient of 35°C per kilometer constant with depth.

Figure 4, a stratigraphic section compiled from Gillerman (1958) and the extensive work of the late R. A. Feller, is bisected by a high angle fault. The depth to which water may need to circulate in order to equilibrate with the lower Paleozoic and Precambrian rocks is approximately 4.0 kilometers. Although many explanations are possible, the conclusions to be drawn from existing geology, geophysics, and geochemistry implies that deep circulation of cold ground-water is the source of the thermal waters in the Animas area.

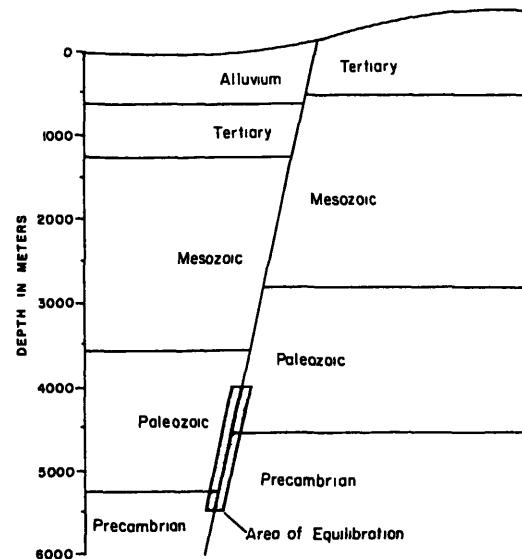


Figure 4. Stratigraphic section looking north in the vicinity of T25S, R19W.

References cited:

- Fournier, R. O., and Rowe, J. J. 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet steam wells; Am. Jour. Sci., v. 264, p. 685-697.
- Fournier, R. O., and Truesdell, A. H., 1973. An empirical Na-K-Ca geothermometer for neutral waters; Geochim et Cosmochim. Acta. v. 37, p. 1255-1275.
- Gillerman, E., 1958, Geology of the central Peloncillo Mountains, Hidalgo County, New Mexico and Cochise County, Arizona: N.M. Bur. Mines and Mineral Res. Bull. 57, 152 p.
- Kharaka, Y.K., and Barnes, I., 1973 "Solmneq" A computer program for solution-mineral equilibrium computations: U.S. Geolo. Survey NTIS Report No. PB-215-899.
- Summers, W. K., 1976, Catalog of thermal waters of New Mexico: Hydrologic Report 4, N.M. Bur. of Mines and Mineral Resources p17.
- Zeller, R. A., 1958, Playas 15-minute quadrangle: N.M. Bur. Mines and Mineral Res. Geol. map GM-7.
- Zeller, R. A., 1958, Dog Mountains quadrangle: N.M. Bur. Mines and Mineral Res. Geol. Map GM-8.
- Zeller, R. A., 1962, Southern Animas Mountains: N.M. Bur. Mines and Mineral Res. Geol. Map GM-17.