STRUCTURAL CONTROL AND ALTERATION AT BEOWAWE KGRA, NEVADA

Bruce S. Sibbett

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

ABSTRACT

The Beowawe geothermal system in northern Nevada is a structurally controlled, water-dominated resource with a measured temperature of 212°C (414°F). Surface expression of the system consists of a large, active opaline sinter terrace that is present along a Tertiary to Quaternary normal fault escarpment. The thermal system appears to be controlled by the subsurface intersection of the east-northeast trending, north dipping Malpais fault with a pre-existing northwest trending fault which dips south and has 884 m of vertical displacement.

Surface alteration associated with the geothermal system is vertically zoned along the Malpais escarpment with, from base to top: hematite stained, argillized rock along the fault trace; silicification and quartz veining; and argillic, acid leach zone at the top. Subsurface alteration generally increases with depth in the volcanic rocks and is most intense in basaltic-andesite lava flows which are capped by tuffaceous sedimentary rock.

INTRODUCTION

The Beowawe Geysers geothermal system is located 80 km southwest of Elko, Nevada, and 10 km southwest of the little town of Beowawe. The geothermal system is a high-temperature water dominated resource, which appears to be structurally controlled. A large, active opaline sinter mound has formed from springs and geysers issuing from half way up the Malpais fault escarpment (Middleton, 1961). The subsurface measured temperature of 212°C in the Ginn 1-13 well (Chevron Resources Co., 1979) is comparable to the calculated geothermometer temperature of 227°C (Mariner and others, 1974).

REGIONAL SETTING

The Beowawe geothermal system is located in the north-central part of the Basin and Range physiographic province. Northeast-trending ranges formed by east-tilted horst or structural blocks bounded by normal faults form the dominate regional structures in the Beowawe area.

The Beowawe KGRA lies within the Battle Mountain heat flow high where conductive heat flow is greater than 2.5 HFU (Sass and others, 1971). Heat flow values computed in the Beowawe KGRA average 2.6 HFU (Smith, 1983).

STRATIGRAPHY

In the Beowawe KGRA a 950 to 1300 m thick section of Miocene dacite to basalt lava flows interbedded with tuffaceous sedimentary rocks overlie and are faulted against Ordovician Valmy Formation rocks. The Valmy Formation in the area consists of siltstone, quartzite, chert and argillite. Over 1700 m of Valmy Formation rocks have been penetrated without reaching the base of the formation. The stratigraphy and correlation of units penetrated in four deep wells are shown in Figure 1. A more detail discription of the lithologies present is given by Struchsacker (1980).

STRUCTURE

There are five structural components in the Beowawe KGRA, a dome, three major faults and fault-line graben. The dome is centered at the hot springs and predates Malpais faulting and extrusion of the basalt flows (Tb). From the center of the dome in Sec. 17, T31N, R48E, the Td-Tf contact slopes down to the east, south and west (Figure 2). The 11° dip of the contact exposed on the horst to the west may be partly due to faulting but the Tf-Td contact on the Malpais rim to the south (SW 1/4, Sec. 19, T31N, R48E, not on Figure 2) bends down 76 m (250 ft) along strike with the monocline in the horst. The felsite flows (Tf) were eroded off this dome before deposition of the tuffaceous sediments (Tts) and extrusion of the basalt flow (Tb), both of which thin toward the dome's center. Also Tb and Tts are absent in thermal gradient holes west of the hot springs.

The second structural component is the Dunphy Pass Fault zone which trends north-northwest one mile east of the sinter terrace (Figure 2). This fault offsets the top of the Valmy Formation a total of about 150 m (500 ft) down to the west across three fault surfaces (only the western two appear on Fig. 2). The Dunphy Pass fault does not account for most of the large displacement of the Valmy Formation between outcrop exposure and the

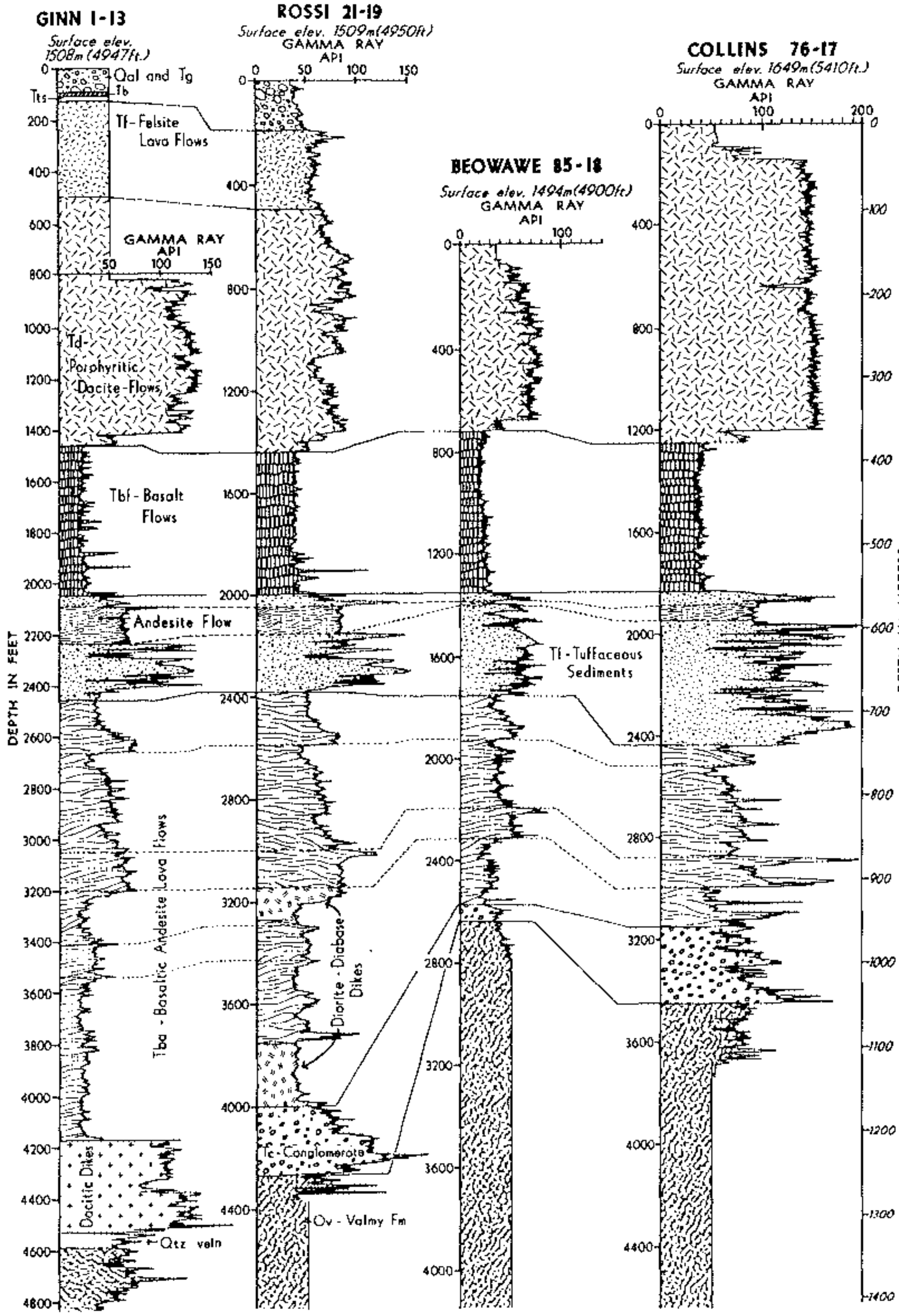


FIGURE 1. CORRELATION OF LITHOLOGIC AND GAMMA RAY LOGS FOR THE TERTIARY SECTION IN FOUR DEEP HOLES AT THE BEOWAWE KGRA. THE LOGS ARE VERTICALLY ADJUSTED TO ALIGN HORIZONTAL DATA PLANE AT THE TOP OF THE TUFFACEOUS SEDIMENTS UNIT (Tt). LOGS ARE NOT SHOWN TO TOTAL DEPTH. SEE FIGURE 2 FOR EXPLANATION OF UNITS.

deep exploration wells.

The third structure, the fault with the greatest displacement, trends about N70°W through Section 16, T31N, R48E (F1 on Figure 2). This fault offsets the top of the Valmy Formation 884 m (2900 ft) down to the south from surface outcrops in Section 16 to an elevation of 610 m (2000 ft) in the Collins 76-17 well. Offset of the base of the dacite (Td) is only 317 m (1040 ft), suggesting the N70°W fault was a growth-fault, active during extrusion of the Tertiary volcanic rocks. The N70°W fault is poorly exposed and its dip is uncertain, but the straight trace suggests a steep dip and the veins which parallel the fault dip 80 to 75° to the south (Fig. 2).

The fourth structure is the Malpais fault which offsets the felsite (Tf) about 366 m (1200 ft) down to the northwest near the hot springs (Fig. 3b). The dip of the Malpais fault is uncertain but the steep escarpment suggests a high angle. The small fault line grabens west and southwest of the sinter terrace (Fig. 2) are the fifth structural element and suggest an extensional component of displacement.

Alteration Zoning

Vertically zoned alteration which is directly related to the present geothermal system is exposed along the Malpais escarpment east of the sinter terrace in section 17. The lowest exposed zone consists of strongly hematitically stained, argillized rock exposed along and just above the Malpais fault. The matrix and phenocrysts of the dacitic rock are altered to clay but relic texture remains, with white, altered feldspar crystals in a hematite stained matrix. Alteration is most complete in flow breccia but less altered blocks remain. Minor botryoidal quartz is present and small areas of sinter are present at the surface. A zone of silica deposition occurs above the hematitically stained zone. The dacite flow breccia is unaltered to argillized along block surfaces and chalcedonic material fills open spaces and forms small veins. Some of the chalcedony is horizontally banded. The silica zone merges with the top of the sinter terrace to the west and slopes slightly down hill to the east, to end against the N70°W trending fault (Fig. 2). Above the silica zone is a zone of complete argillization and acid leaching. The dacite, both flow breccia and massive rock, is altered to clays, probably kaolinite. Gypsum and minor botryoidal quartz are present in this zone. The argillized and bleached zone occurs just above the sinter terrace and the silicified zone to the east. The alteration zones end to the east against the N70°W fault. Argillic alteration and some silicification are present in a flow breccia at about the same stratigraphic level in a thermal gradient hole 548 m (1800 ft.) southeast of the Malpais fault, on the west side of section 16.

Alteration northeast of the N70°W fault (F1 on Figure 2) is of a different style, with widespread moderate hematite staining and large quartz-calcite veins. Note also that this alteration does not extend into rocks younger than the basaltic-andesite (Tba). This alteration and the large veins are thought to be much older and unrelated to the present geothermal system.

Structural and Stratigraphic Controls of the System

It is evident from surface thermal phenomena that the Malpais fault controls the thermal system in the near surface, the N70°W fault bounds the system on the east, and the change in strike of the Malpais Fault appears to bound the system to the west. The continuation of the N70°W fault in the footwall block of the Malpais fault may control the hot springs in the south half of section 8. The hot springs in the NW1/4 NW1/4 of section 17 occur along the fault that bounds the northwest side of the horst block in section 18.

Stratigraphic control of the thermal system is evident in two places. Open flow breccias in the prophyritic dacite lava flows have channelled near surface thermal fluids as discussed above in the alteration section. The second and more important stratigraphic control is evident in Beowawe 85-18. Comparison of the temperature profile and lithologic log (Fig. 4) clearly suggests that a convecting thermal system is present in the basaltic-andesite lava flows (Tba) and the impermeable tuffaceous sedimentary rocks (Tt) form a cap rock on the system in Beowawe 85-18. Alteration studies in progress also support this conclusion. Thermal fluids rising along the Malpais fault and associated structure may spread out into permeable zones within the basaltic-andesite lava flows in the footwall block. A small structure and lost circulation zone was encountered in the upper part of the basaltic-andesite unit but lithologic and gamma ray log correlations between the deep holes (Fig. 1) indicates that only 30 to 46 m (100 to 150 ft.) of the unit has been faulted out in this interval. Comparison of stratigraphic elevations in the Beowawe 85-18 and Collins 76-17 holes (Fig. 1) demonstrates that both holes are in the horst or footwall block below the base of the porphyritic dacite (Td). Beowawe 85-18 therefore passed through the Malpais fault within the upper 700 feet of the hole.

Discussion

The intersection of the Malpais fault with the N70°W fault seems to have localized the surface expression of the geothermal system. To determine the subsurface results of this intersection consider Figure 3. Cross section 3a represents the structural setting before movement on the Malpais fault and is essentially the present condition from Collins 76-17 northeast to the surface exposure of the Valmy Formation. If the fault plane of the Malpais fault, which would be expected to dip north, was deflected by the preexisting, south-dipping fault plane, an overhang and open space would form as dip slip movement occurred on the Malpais fault. This would produce a zone of dilation, collapse breccia and a fault line graben as shown in Figure 3b. The size, depth and configuration of the dilation breccia

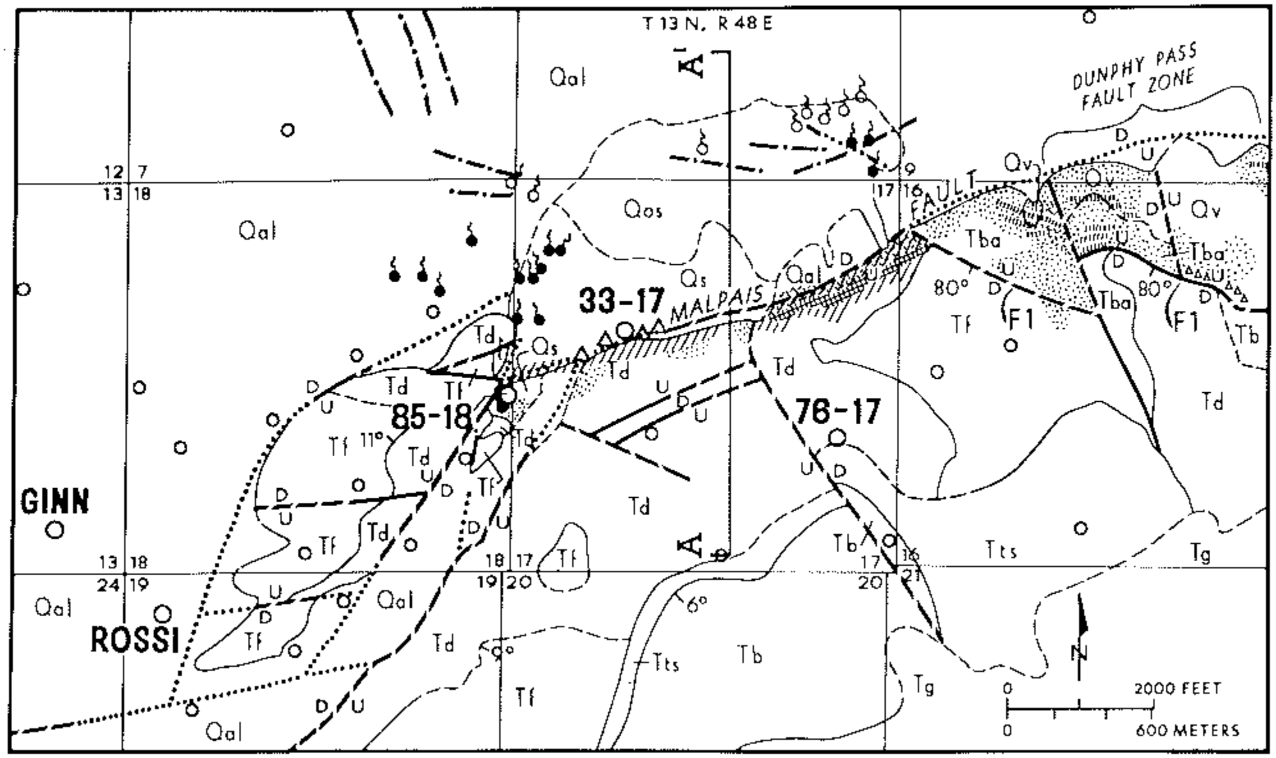


FIGURE 2. GEOLOGIC AND ALTERATION MAP OF THE BEOWAWE GEOTHERMAL AREA. EXPLANATION IS ON FACING PAGE.

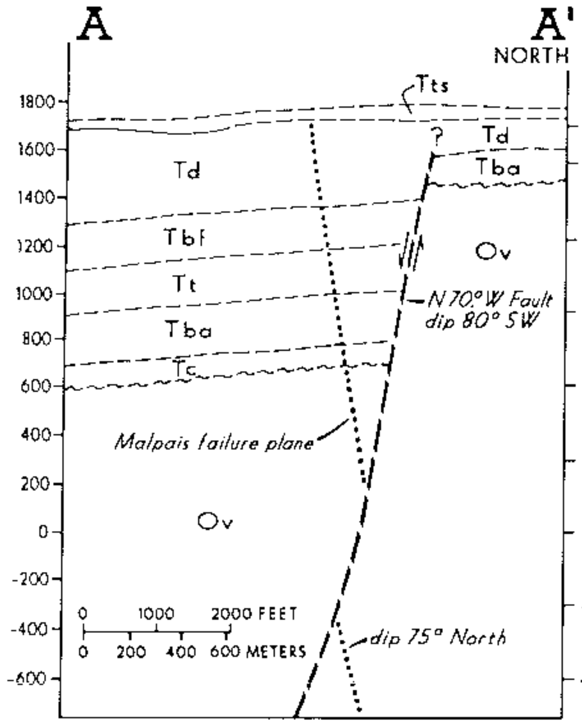


FIGURE 3a. CONCEPTUAL CROSS SECTION DEPICTING STRUCTURAL CONDITIONS PRIOR TO MALPAIS FAULT DISPLACEMENT.

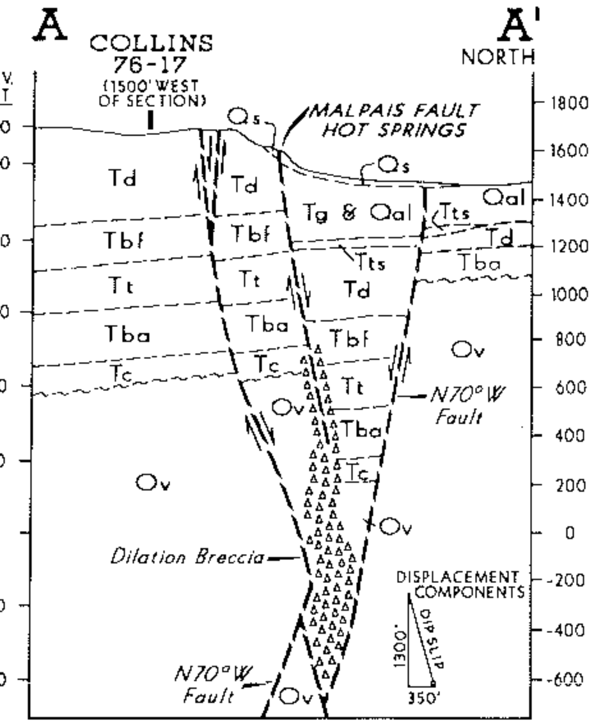
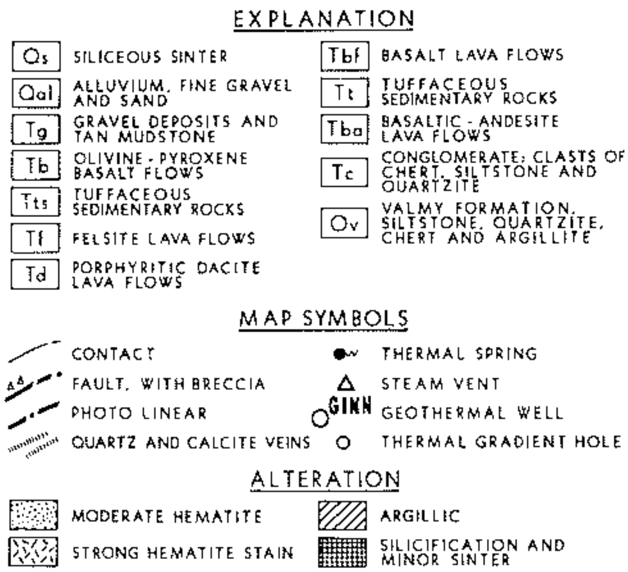


FIGURE 3b. PRESENT STRUCTURAL CONDITION OF MALPAIS FAULT AND N70°W FAULT BENEATH THE SINTER TERRACE.



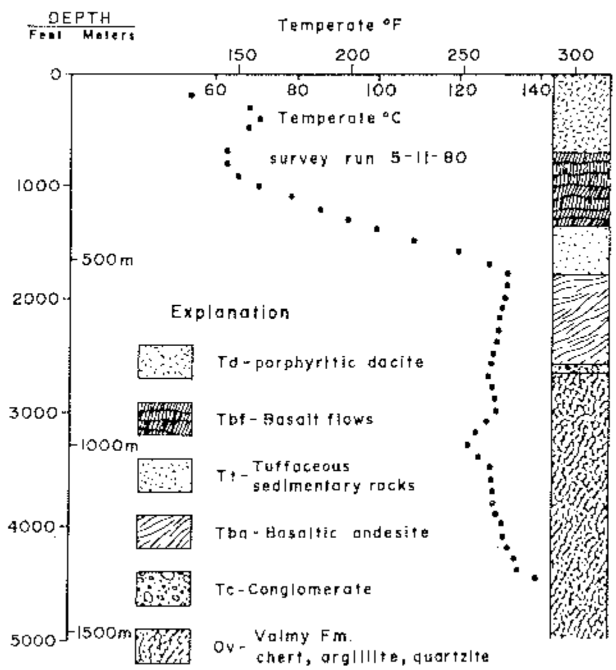


FIGURE 4. TEMPERATURE SURVEY AND LITHOLOGIC LOG FOR BEOWAWE 85-18. TEMPERATURE SURVEY FROM IOVENITTI (1981; FIG. 5).

zone would depend on the dip of the two fault planes and extent of deflection of the Malpais fault plane. The fault intersection and therefore the dilation breccia zone plunges to the west. The only deep well sited over the fault intersection is Chevon 33-17, which is proprietary and a lithology log is not available, but the hole did encounter considerable open breccia.

Conclusions

The geothermal system at Beowawe is controlled by the intersection of the Malpais fault and a south dipping, N70°W trending fault. The fault intersection, which has probably formed a dilation breccia, plunges steeply to the west. The heart of the geothermal reservoir lies under the north half of Section 17 and possibly extends at depth under the north half of Section 18, T31N, R48E.

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