RECEIVED BY OSTI OCT 31 1985

DOE/ID/12079-125
ESL-152

GEOPRODUCTS WEN-2 WELL
WENDEL-AMEDEE, CALIFORNIA

Bruce S. Sibbett

Prepared by
Earth Science Laboratory
University of Utah Research Institute

for

U. S. Department of Energy
Idaho Operations Office

1985

DO NOT MICROFILM
COVER

MASTER

Earth Science Laboratory

University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108
(801) 524-3422

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DOE/ID/12079--125

DE86 002010

GEOPRODUCTS WEN-2 WELL
WENDEL-AMEDEE, CALIFORNIA

Bruce S. Sibbett

Prepared by
Earth Science Laboratory
University of Utah Research Institute

for
U. S. Department of Energy
Idaho Operations Office

1985

Earth Science Laboratory

University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108
(801) 524-3422

GEOPRODUCTS WEN-2 WELL
WENDEL-AMEDEE, CALIFORNIA

Bruce S. Sibbett

Prepared by
Earth Science Laboratory
University of Utah Research Institute

for
U. S. Department of Energy
Idaho Operations Office

1985

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

NOTICE

This report was prepared to document work sponsored by the United States Government. Neither the United States nor its agent, the United States Department of Energy, nor any Federal employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

NOTICE

Reference to a company or product name does not imply approval or recommendation of the product by the University of Utah Research Institute or the U.S. Department of Energy to the exclusion of others that may be suitable.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT.....	1
INTRODUCTION.....	2
STRATIGRAPHY OF WEN-2.....	2
CORRELATION OF WEN-1, WEN-2 AND 2-ST.....	5
FAULTS.....	6
ALTERATION IN WEN-1 AND WEN-2.....	7
CONCLUSIONS.....	9
REFERENCES.....	10
APPENDIX - Lithologic Log of GeoProducts WEN-2 Well.....	11

LIST OF FIGURES

Figure 1. Geology and location of wells.....	3
Figure 2. Generalized lithology and correlation for WEN-1, WEN-2 and 2-ST.....	4
Figure 3. Alteration minerals in WEN-1 and WEN-2.....	8

ABSTRACT

The GeoProducts WEN-2 well, drilled 2200 feet northwest of Wendel Hot Springs in Lassen County, California, penetrated 4330 feet (1320 meters) of Tertiary basalt flows and volcanoclastics. Production of 251°F (122°C) thermal fluids comes either from a fault or from intergranular permeability in a 570-foot thick quartzite conglomerate channel overlying the granitic basement rocks at a depth of 4900 feet. The chemistry, temperature and hydrostatic head of the resource in WEN-2 are very similar to that of WEN-1 to the northeast. Unknown faults in the granitic basement rocks, other than the Wendel fault, may be important channelways for the geothermal system.

INTRODUCTION

WEN-2 is the second production well drilled by GeoProducts in the Wendel-Amedee KGRA, Lassen County, California. GeoProducts' exploration program in the KGRA has been supported by the U. S. Department of Energy (DOE) as part of the User Coupled Confirmation Drilling Program. Wendel Hot Springs, located on the north side of the Honey Lake basin, discharges boiling sodium sulfate water at 205°F (Zeisloft and others, 1984). WEN-1, 4700 ft northeast of the hot springs (Fig. 1) was drilled to a depth of 5788 feet (1764 meters), and produces geothermal fluids from a fault zone in granitic rock. Maximum downhole temperature in WEN-1 is about 251°F (122°C) (Juncal and others, 1982) and the well flows artesian at 680 gpm with a wellhead temperature of 242°F (117°C) (Benson, 1982). WEN-2 was drilled 2200 feet northwest of Wendel Hot Springs (Fig. 1) with the intent of intersecting the Wendel fault, which is thought to dip about 60°, near the top of the granitic basement rock.

STRATIGRAPHY OF WEN-2

Drill cuttings from WEN-2 were logged by the author and the detailed lithologic and alteration log is included in the Appendix. Generalized lithologic logs of the three deep holes, WEN-1, WEN-2 and S-ST near Wendel Hot Springs are presented in Figure 2. WEN-2 penetrated interbedded lithic sand, sandstone and tuffaceous siltstone down to 730 feet. Below the clastic beds, andesitic lava flows are present to 960 feet. Pyroclastic rocks 340 feet thick overlie the basalt flows which are present from 1300 feet to a depth of 3480 feet (Fig. 2). The volcanoclastic rocks between 3480 and 4330 feet consist of altered pyroclastics, flow breccia, and mudstone of basaltic to andesitic and possibly dacitic composition. These rocks contain smectite and stilbite and probably form an impermeable stratigraphic cap on the

Figure 1. Reconnaissance geologic map and locations of geothermal wells in the Wendel-Amedee Hot Springs area.

hydrothermal system. Leakage occurs along the Wendel fault. A coarse, quartzite and chert-clast conglomerate 570 feet thick overlies the granitic basement rocks.

CORRELATION OF WEN-1, WEN-2 AND 2-ST

Correlations of several rock units or contacts among the three deep wells in the Wendel Hot Springs area are indicated on Figure 2. The close correlation of the granitic rock paleo-erosional surface, which appears to slopes 2 degrees to the northeast, indicates that major faulting has not occurred between the holes although the Wendel Fault passes between 2-ST and the WEN holes. Correlation of the base of the basalt flows between WEN-1 and WEN-2 suggest a 9.6° slope at the top of the volcanoclastic unit, a possible original slope for a composite volcano.

The conglomerate in WEN-1 and WEN-2 consists of quartzite, chert and a few plutonic rock clasts. A few silicic volcanic rock clasts are also present. Based on clast compositions and apparent dip from WEN-2 to WEN-1 (the upper contact dips 2 degrees and the lower contact 1.6 degrees) it is concluded that the conglomerate is part of an early Tertiary channel which drained the Sierra Nevada Province on the west, to the east or northeast. The channel probably stripped away a siliceous tuff unit above the granite as intersected in 2-ST where the channel conglomerate is not present.

Identical temperature and similar fluid chemistry and hydrostatic head in both WEN-1 and WEN-2 indicate that they penetrate the same system. Juncal (personal communication, 1984) reports that the hydrostatic head at WEN-2 is about 30 feet higher, relative to the well head, than it is at WEN-1. However, ground level at WEN-2 is 34 feet lower than at WEN-1 (elevations are

listed incorrectly on the WEN-2 wireline logs), therefore there is no significant difference in hydrostatic head.

FAULTS

Although faults were indicated in the cuttings by slickensides on clay altered basaltic ash at several depths in WEN-2 (F's on Fig. 2), none of them are thought to represent major faults. The slickensides may be due to horizontal slippage in thin interflow ash beds during emplacement of the next lava flow. GeoProducts concluded that WEN-2 penetrated the Wendel fault in the conglomerate based on lost circulation, a production zone and hole enlargement indicated by the wireline logs (Juncal, personal communication, 1984). However, no direct evidence of faulting in the conglomerate is evident in the limited cuttings from the zone and the unit is not shortened. The conglomerate is 570 feet thick in WEN-2 and 500 feet thick in WEN-1. A non-cemented, highly permeable zone within the conglomerate could account for all the characteristics thought to indicate faulting.

The structural control of the Wendel geothermal system appears to be the northeast-trending Wendel fault (Fig. 1) which dips northwest. Both WEN-1 and WEN-2 were sited to intercept this fault at depth. Assuming that the producing fault at depth and the surface trace are the same structure, the Wendel fault dips 61° from where it crosses the highway to WEN-1 (Fig. 1), and dips 64° from the main hot springs to WEN-2. However, the fault zone as intersected in WEN-1 is a much larger structure than would be expected on the basis of the 10 to 20 feet of offset evident to the north on the Wendel fault. If the fault in WEN-1 dips 61° , the 140' intercept indicates a fault zone 68 feet thick. If WEN-1 intersected a buried east-west fault zone which controlled the bend in the younger Wendel fault at their intersection, the dip

north to WEN-1 from the west-trending segment would be 70° (Fig. 1) and the fault zone thickness would be 48 feet. The possible fault which WEN-2 intersected in the conglomerate appears to be 5 to 24 feet thick, much thinner than the fault zone penetrated in WEN-1. WEN-2 may not have penetrated the Wendel fault, or at least not the fault found in WEN-1. As explained above, the production zone in WEN-2 may not be a fault, and if the Wendel fault dips 66° or more, it would be below the bottom of WEN-2.

In summary, the Wendel geothermal system may be controlled by one of three different structures: 1) the Wendel fault may be a simple normal fault; 2) the Wendel fault may intersect a major east-west fault which does not cut the Tertiary volcanic rocks; 3) the Wendel fault may be an extensional fault between two northwest-trending dextral strike-slip faults which are related to the Walker Lane of western Nevada. The exact location of possible dextral faults is unknown in the area but such a structural setting would explain the curvature of the Wendel fault.

ALTERATION IN WEN-2

Alteration in the upper 4330 feet of WEN-2 consists of smectite, minor pyrite, secondary silica and stilbite (Fig. 3). All of these minerals can form under normal groundwater conditions in volcanic rocks. Within the conglomerate, pyrite and laumontite are present in both WEN-1 and WEN-2. The soft matrix material in the conglomerate has been mostly lost during drilling, but it appears that the lithic sand matrix is cemented and infilled by laumontite, a zeolite with composition $\text{Na}(\text{AlSi}_2\text{O}_6)\text{H}_2\text{O}$, which forms at moderate temperatures (about 250°F).

Figure 3. Alteration minerals in WEN-1 and WEN-2.

CONCLUSIONS

WEN-2 penetrated Tertiary volcanic rocks equivalent to those in WEN-1 and produces geothermal fluids from a possible fault intercept or permeable zone in the conglomerate overlying the granitic basement rocks. Geothermal fluids are present in the conglomerate and have formed laumontite cement. The overlying clay-rich volcanoclastic rocks form a stratigraphic cap over the geothermal reservoir present in the conglomerate and in faulted granitic rocks below. A conglomerate-filled channel and the surface of the crystalline basement dip about 1.7° to the north or northeast. Siting of additional production wells should consider both the conglomerate and possible faults trending east-west or northwest (Walker lane structures) as well as the Wendel fault as possible targets.

REFERENCES

- Benson, S. M., 1982, Well test data analysis from a naturally fractured, liquid-dominated hydrothermal system: Geoth. Res. Council Transactions, v. 6, p. 237-240.
- Juncal, R. W., Gertsch, W. D., and Johnson, K. R., 1982, WEN-1: First successful well in the Wendel-Amedee KGRA: Geoth. Res. Council Transactions, v. 6, p. 281-284.
- McNitt, J. R., and Wilde, W. R., 1980, Siting and drilling recommendations for a geothermal exploration well, Wendel-Amedee KGRA, Lassen County, California: GeothermEx, Inc., Berkeley, Calif., for GeoProducts Corp., Oakland, California, 51 p.
- Zeisloft, J., Sibbett, B. S., and Adams, M. C., 1984, Case study of the Wendel-Amedee exploration drilling project, Lassen County, California, User Coupled Confirmation Drilling Program: Earth Science Lab/Univ. Utah Res. Inst. Report ESL-125, 97 p.

APPENDIX

Lithologic Log of GeoProducts WEN-2 Well

EARTH SCIENCE LABORATORY

LITHOLOGIC STRIP LOG

DRILL HOLE WEN-2, GeoProducts, Wendel Hot Spr.
 STATE Calif. COUNTY Lassen PROJECT _____
 SEC. SW4NW423 TWP. 29N RGE. 15E; LOC. 2493'S. FNL, 1150'E. From NW Corner, Sec 23, Twp 29N, Rge 15E, FNL, 1150'E.
 TD 5030' BOTTOM HOLE FORMATION _____ SURFACE FORMATION Sediments
 LOGGED BY Sibbett DATE _____ SAMPLE INTERVAL(S) _____
 LITHOLOGIC LOG CORRECTED FOR LAG YES ☐ NO ☐
 SPUD DATE 4-9-84 COMPLETION DATE 5-14-84
 DEPTH DATUM KB ☐ DF ☐ GR ☒ ELEV. 4006'
 DRILLING FLUID(S) _____
 REMARKS referred to as Well #24-23 on the elec. logs.

DRILL
 SITE IN
 SECTION

	*	23	

DEPTH Feet	ALTERATION							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME MIN. / FT. SCALE
	Calc.	Chlor	2nd Clay	ep.	Py. Marc	1. WEAK 2. MOD. 3. STRONG				
300	123	123	123	123	123	123	123		20' sample interval 0-300' No samples, Conductor set to 309'	
20									300-470' Tuffaceous siltst., li. gray, euh. chlor. after bio.	
40									perlitic glass, few sand grains qtz, feldspar, lithic.	
60									Few pebbles, 2nd clay from alt. of tuff matrix	
80										
400										
60									f. sand to silt zone 430'-450'	
									~ 1/2 med. sand from 450'-	
500									470'-645 Sand, med. grain, lithic, 1/2-1/2 tuffac. siltst.	
									gypsum grains present	
									fine grainular py. cementing silt-tuff.	
									Mixed and interbedded Sand and tuff. zones	
600									Pyrite occurs as aggregates in tuffac. silt. or mudst.	
									arkose, poor sort, sub-round, gypsum.	
									Fossil Ostracode	
40										
645-710									Lithic Sandstone, med-fi grain, poor sort, pab.	
									med. gray, 2nd qtz coating on grains.	
700										
									710-730 Conglomerate? andesite clasts.	
									730-865 Andesite, porph.-plag. phen, part. silt to ep, calc.	
									med. gray, to olive gray, flow center to 840'	
800										
									840-865, andesite flow base, vesicular, amygdalae	
									oxidized to red & orange.	
									N.S.	
900									885-900 Andesite flow top or base, oxidized.	

DEPTH feet	ALTERATION							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION 20' to 10' sample intervals	DRILLING TIME MIN. / FT. SCALE
	Calc	Chlor	2nd clay	Zeolite	Py-Mad	2nd silicea	Gypsum			
900	123	123	123	123	123	123	123			
20									900-960' Andesitic lava flow, blk flow center to oxidized red-orange base, fessitic, anh. pyrox?	
40										
60										
80									960-1100' Dacitic tuff?, li. gray, porphy, alt. plag. some white, yel. or pale grn. chips.	
1000										
									N.S.	
									Variable character, Feld. alt to clay, no qtz. few lithic frag. in tuff, poss. celadonite heterogeneous, few lithic. frag, matrix alt. to clays.	
1100									N.S.	
									1120-1240' Mixed pyroclastics, brn tuff, andesite flow, white to gray tuffs, mica books alt. to clay, interbedded tuffs and tuffaceous sediments.	
1200										
									1240-1300 Tuff, li. gray, alt. to clay, peppered mafics, no phenocrysts. uniform unit, was vitreous ash.	
1300										
									1300-1570' Basalt or And?, dk olive-grn, porphy, vesicular, few anh. xls of Feldsp. & pyx, gypsum & chlor in vesicles, euh. gypsum xls, rock chips soft from alt.	
1400										
									N.S.	
1500									Basalt? or andesite flow continued, grn clay in vesicles or fract.	
									N.S.	
									Faulting at 1570, slickens, hem. stain,	
1600									1570-1590' Porphyritic Andesite, brn. matrix, white phenocrysts, alt. 3mm euh. plag. totally alt. to waxy clay, vesicular flow.	
									1590-3320 Basalt or andesite, vesicular, dk ol-grn, plag. phenocrysts, plag. is fresh, mafic mineral (pyx or olivine) alt. to hem. and clay.	
1700									zeolite? encrusted clay chip.	
									plag. alt to clay, Faulting, zeolite, natrolite, 1760 pass. litho. change, but prob. just alt.	
									1760-hem. red. stained alt. chips.	
1800									Fault, slicken sides, gouge, 1800'-Flow base, pass. ash bed, mixed chips of red clay alt, gray clay, olive rock fresh.	

[illegible]

DEPTH Feet	ALTERATION							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION 10' Sample Intervals	DRILLING TIME MIN. / FT. SCALE
	Calc	Chlor.	2nd clay	Zeolite	Py. Marc.	2nd silice	Gypsum			
3600	125	125	125	125	125	125	125			
20									3480 - 4380 Mixed volcanic pyroclastics, andesitic to dacitic ash, flow breccia, mudstone, lithic sandst.	
40									Tuff clast in the mudstone, gray, brn, light olive grn.	
60									Lava flow chips porphyritic with plag, pyx, hornb.	
80									mixed lava flow chips and mudstone cont.	
3700									Dacitic lava flow rock and ash or tuff, veinlet	
575									Slickenside on tuff, coated with Clay.	
									Slickensides in altered tuff	
3800									abundant Slickensides, poss. inter-formational slumping	
									Quartzite chips, few.	
									Mudstone chips not present below 3870'	
3900									Quartzite chips, rounded diorite clasts, few	
									Lithic tuff?	
									Chalcedony filled void.	
									qtz & div. xenoliths.	
									qtz-py veinlet	
4000									Continued pyroclastics, tuff, andesitic to dacite	
									veinlet, pale olive grn.	
4100									intergranular calcite in tuff chips,	
									clear to milky chalcedony	
									*rock is grading to more mafic appearance, more ash,	
									qtz amygdulites?	
4200									clear stilbite. crystals, euh.	
									qtz amygdulites	
									chert chip.	
									Volcano-clastics continued.	
4300									3480 - 4380 Volcanic ash, basaltic or andesitic, olive-grn.	
									med to coarse lithic grains, angular, in clay alb matrix	
									~1/2 chips contain calc. cement, few rhy. tuff chips.	
									Few clear qtz chips not in ash, poss. primary.	
									Few fresh basalt chips w/ olivine, few qtz chips.	
									4320 - Conglomerate top from elev. logs & adjusted for Deck Floor reference.	
4400									4380 - 4500 Mixed Litho's, 1/2 basaltic ash, 1/3 qtz xls,	
									~1/2 qtz and dio.?, euh. qtz, prob. vein., dio pebb. rnd.	
									Veins, qtz and gypsum	
									conglomerate component, rounded clasts surfaces.	
									Quartzite + diorite conglomerate content increases.	
4500									pebbles of basalt, sand to silt matrix	