INVESTIGATION OF A FLUID BOUNDARY

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Aminoil is a subsidiary of R. J. Reynolds Industries, Inc., and successor to Burmah Oil and Gas Company. Our drilling activities in the southeast part of The Geysers area have proved geothermal steam reserves to power 300 megawatts of electric generating capacity. In the past year Aminoil has conducted exploratory drilling activities outside of the proven productive area in order to establish additional reserves. One of these areas is discussed in the paper.

The area of investigation is characterized by the intersection of at least three regional lineaments. These lineaments are discernible from satellite imagery of the NASA LANDSAT (formerly ERTS) program. The lineaments are confirmed by medium to low altitude color stereo pair photographs. On the surface these lineaments sometimes lack enough discernible ground displacement to be characterized as faults. These lineaments do coincide with cliffs, truncated ridges, major creeks and stream offsets. Figure 1 indicates the location of these lineaments by long, dashed lines.

Shown also on Figure 1 by smooth, continuous lines are isopleths of heat flow gradients. They were obtained from Aminoil's extensive shallow (300 to 1000 feet) hole drilling in the area. The intersection of the lineaments also coincides with closely spaced isopleths. Heat flow gradients, while a good indication of geothermal resources at depth, do not always assure commercially productive wells.

Locations A through E indicate holes drilled to at least 7200 feet on Figure 1. Locations B and C are commercially productive steam wells. Even though Locations A and E are located in areas of higher heat flow than C, only minor steam entries were encountered at depths from 6000 to 8000 feet. A minor steam entry was also encountered in Location D.

The rocks of the steam-producing zones of Aminoil's proven areas are predominately silicified metagraywackes and lesser varying proportions of greenstone, chert, serpentine and argillite and may be more accurately described as a melange unit of the Franciscan formation. Locations B and C fit this description. Comparison of the productive sections with those encountered in Locations A, D, and E show the sections of the two areas to be quite different. The last three holes all drilled thick sections of arguillite with minor metagraywacke.

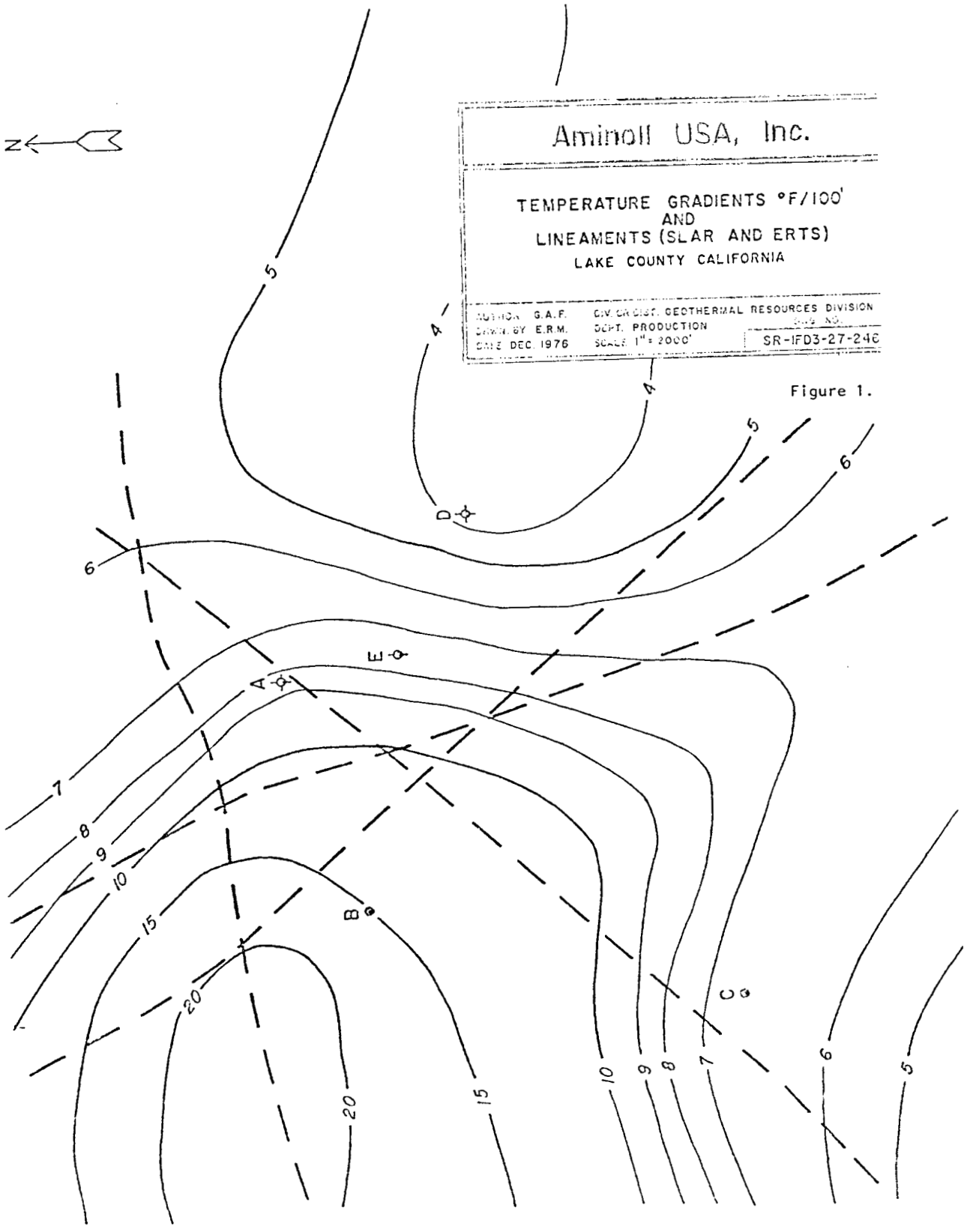
These three holes never drilled out of this sequence. The entire sequences in these three holes are also characterized by their general lack of silica. Silica is common in the majority of Aminoil's producing wells. A few of these deeper wells may have penetrated an argillite section below

productive metagraywacke and show minor or no production from those zones. Argillites did occur in the steam zone of one well but were associated with up to 60% silica.

Of particular interest is Location E. A water entry encountered at approximately 5100 feet was analyzed and is shown on Fig. 2. A sample was collected while air drilling and this analysis shows the water to be considerably more saline with less hardness than the water entries reported at the 1975 Stanford Geothermal Reservoir Engineering Workshop. Additional drilling encountered a minor steam entry below 7500 feet. The hole is now suspended and surface wellhead pressure is approximately 50 psia. The steam to noncondensible gas molar ratio is about 50 or more than a tenfold decrease of Location B. Methane and nitrogen account for most of the increase of noncondensible gases. An analysis of the steam condensate is shown on Fig. 2. The sulfide content, over twice Aminoil's field average, is consistent with the overall increased amount of noncondensible gases.

Fifteen days after the drilling rig was released at Location E, a static temperature and pressure survey was conducted. Saturated steam was recorded to a 7070 foot fluid level. Below this fluid level the liquid continually increased in enthalpy with increasing depth. A maximum temperature of 464^{o}F was recorded at total depth.

The phenomena discussed above led to the tentative conclusion that there is a fluid boundary with Locations B and C on the productive side and A, D, and E, all nonproductive. Aminoil believes the change in rock types to be significant. The change may be attributed to the lineaments although structural correlations in the Franciscan formation are difficult to substantiate. Even though there were minor steam entries in the nonproductive holes, the heat gradient surveys indicates a rapidly decreasing heat flux from the productive area. Changes in gas to steam molar ratio and the increased hydrogen sulfide at Location E may be attributable to the small volume of the steam entry with relation to the open hole surface area. However, the increased percentage of methane supports a fluid boundary conclusion. Further examination of the water in the hole at Location E is planned using a bottom hole sampler. These analyses will be designed to test for thermodynamic phase equilibrium of the fluid with known equilibria phenomena of the productive area.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Aminoil USA, Inc.
TEMPERATURE GRADIENTS °F/100'
AND
LINEAMENTS (SLAR AND ERTS)
LAKE COUNTY CALIFORNIA
AUTHOR G.A.F.
DRAWN BY E.R.M.
DATE DEC. 1976
DIV. OR DIST. GEOTHERMAL RESOURCES DIVISION
DEPT. PRODUCTION
SCALE 1" = 2000'
SR-IFD3-27-246
A
B
C
D
E
4
5
6
7
8
9
10
15
20

Figure 1.

CHEMICAL ANALYSES, LOCATION E

	Water Entry	Condensate
pH	9.0	6.1
Specific Conductance μmhos/cm @ 25° C	2250	400
Calcium, mg/l	< 1.0	< .4
Magnesium, mg/l	< 1.0	< .2
Sodium, mg/l	530	0.6
Potassium, mg/l	55	0.05
Sulfate, mg/l	65	< 0.5
Chloride, mg/l	480	1.5
Boron, mg/l	66	.06
Fluoride, mg/l	5.2	< .01
Aluminum, mg/l	< 0.1	-
Mercury, μg/l	< 0.002	.0
Silica, mg/l	205	1.3
Sulfide, mg/l	-	210
Ammonia	1.5	35
Bicarbonate	-	240

Figure 2. Chemical Analyses, Location E