BIEBER, CALIFORNIA

The geothermal gradient, thermal conductivity, and calculated heat flow values for the holes near Bieber, California are shown in the attached table. The thermal conductivity measurements have been described in a separate section. Also shown on the table are the depth interval of the geothermal gradient calculations, the direction of the terrain correction, and approximate lithology of the holes, where known. I did not have complete lithologic logs for the holes and there is some uncertainty as to the lithologies penetrated in some of the holes. The values below the gradients are the standard errors of the gradient measurements calculated for the mean of the interval gradients.

Most of the drill holes in Big Valley appear to have one of two values of geothermal gradient, either about 45-50°C/km or about 75-82°C/km. It is not clear that these two segments of gradient correlate with different lithologies. As noted in the discussion of thermal conductivity, the actual bulk values are very low for most of the pumaceous tuffs from Big Valley and if the effect of porosity were allowed for, some of these thermal conductivity values might be as low as 1.8 to 1.7 mcal/cmsec$^{\circ}$C. If this thermal conductivity is associated with the gradients of 80°C/km the heat flow values will be about 1.6 μcal/cm^{2}sec, probably within the range of normal for the area, although there are no nearby measurements of background heat flow. This heat flow would require thermal conductivities of about 3 for the holes where the gradients of 45°C/km are observed. It is not clear what rock this gradient would correspond to.

Another explanation for the variations in gradients are regional ground water motions. The geothermal gradients in holes BR-4, and BR-5 along the margin of the valley are convex downward, the measurements in BR-7 and BR-2 indicate possible artesian conditions in the holes, and BR-6 shows a possible regional upflow condition (in the form of a convex upward geothermal gradient curve). If these curved segments of gradient are due to ground water variations, an average gradient over the basin of somewhere between the two limits mentioned 45 and 85°C/km is implied. For the thermal conductivities encountered such a heat flow would be approximately normal.

The only drill holes which seem to have evidence of anomalous heat flow are the ones to the west, BR-1 and BR-2. In order to calculate a gradient for BR-2 I assumed that there was water moving up from near the bottom of the hole and out at very shallow depth. I took the bottom hole temperature and a 10 m temperature and calculated the average gradient between these two depths. If water comes from deeper horizon this procedure will overestimate the geothermal gradient. With the low values of thermal conductivity observed the high gradient of 98°C/km in BR-1 still indicates only a slightly anomalous heat flow. These conclusions are extremely tentative, but the heat flow does appear to be normal or somewhat subregional in the area except for BR-1 and BR-2. It would appear that any additional exploration ought to be concentrated to the west where the two anomalous gradients were encountered.

BIEBER, CALIFORNIA

Heat Flow, Geothermal Gradient, and Thermal Conductivity

Hole Number	Depth Interval meters	Gradient °C/km	Thermal Conductivity mcal/cmsec°C	Heat Flow mcal/cm²sec	Direction of Terrain Corr.	Lithology
BR-1	26-48	97.9 5.4	2.4	2.3	0	Sandy Gravels
BR-2	10-60	(230)	<3.0	(6.9)	(-)	Tan Tuff
BR-3	14-30	55.6 1.8	<2.7	<1.5	-	Tuffaceous Basalt
	30-78	45.1 1.2	<4.7	<2.1		Basalt
BR-4	18-60	46.1 2.9	<3.4?	<1.6?	0	?
	60-96	77.9 7.3	<2.8	<2.2		Tuffs
BR-5	15-35	47.4 2.3	2.0-2.6	0.9-1.2	0	Clay
	35-70	(47)	"	"		Clay
	70-98	(80)?	<2.6	<2.1		
BR-6	14-46	81.9 6.8			0	
	46-90	49.6 5.1	<2.9	<1.4		Pumaceous Tuff
BR-7	26-78	53.9 4.8	<2.75	<1.5	0	Pumaceous Tuff
BR-8	35-67	76.3 5.4	(<2.9)	<2.2	0	?

BIEBER, CALIFORNIA

Thermal conductivity measurements on 10 samples from near Bieber, California are shown in the attached table. Most of the samples are tuffs of various kinds, with one basalt sample, one clay sample, and one sample labeled sandy gravel. In general the thermal conductivities of the tuffs indicate that they are made up principally of glass fragments. Depending on the porosity of the tuffs *in situ* thermal conductivity values for these rocks could be very low. Typical apparent values of thermal conductivity for pumaceous tuffs near the Harney Basin, for example, are about 1.8 ± 0.2 mcal/cmsec^{o}C. On the other hand, if the rocks are fairly compact welded glassy tuffs, the *in situ* thermal conductivity values could be nearly equal to the measured bulk values. The bulk value of the basalt is typical of basalts, but it is difficult to estimate the *in situ* conductivity because of the unknown porosity. A reasonable value, if the basalt is not too vesicular, is about .1 which gives an *in situ* thermal conductivity of about 4.2 mcal/cmsec^{o}C. The sandy gravels and clay probably have porosities in the range of 0.4 ± 0.1 which give *in situ* thermal conductivity values of 2.4 ± 0.4 and 2.0 ± 0.4 for the gravel and clay samples respectively.

BIEBER, CALIFORNIA

Cuttings Thermal Conductivity Measurements

Sample No.	Approx. Hole Loc.		Porosity (assumed)	Bulk and *In Situ** Thermal Conductivity mcal/cmsec°C		Lithology
JD-1-75	BR-2	0-12.2 m		2.88		Pumaceous lithic tuff
	BR-5	89.9-91.4 m				
	BR-6	79.3-94.5 m				
	BR-7	24.4-33.5 m				
JD-2-75	BR-3	35.1-70.1 m	(0.1)	4.73	4.2	Basalt
JD-3-75	BR-3	0-35.1 m		2.68		Tuffaceous Basalt Agglomerate
JD-4-75	BR-1	36.6-50.3 m	0.4±0.1	3.35	2.4	Sandy Gravels
JD-5-75	BR-5	6-73.2 m	0.4±0.1	2.55	2.0	Clay
	BR-7	61.0-79.3 m				
JD-6-75	BR-2	54.9-67.1 m		2.99		Tan Tuff
	BR-4	94.5-97.5 m				
JD-7-75	BR-5	89.9-91.4 m		2.29		Pumaceous Tuff
JD-8-75	BR-4	94.5-97.5 m		2.49		Clayey Tuff
JD-9-75	BR-4	89.9-91.4 m		2.91		Pumaceous Lithic Tuff
JD-10-75	BR-4	85.3-89.9 m		2.79		White Tuff

*$K_{IS} = (K_B)^{1-\varphi}(1.4)^{\varphi}$

SMU Geothermal Laboratory
March 8, 1976

CROSS REFERENCE SHEET

File Folder: Califronia-Lassen-Bieber #641-Drilling

re/ info concerning contract w/Conners Well Drilling

SEE California-Lassen-Bieber #641-Drilling-Agree-Conners Well Drilling, Inc.

SHALLOW THERMAL GRADIENT HOLE SITE LOCATIONS

Modoc County

Hole #	Location
B-1	NE 1/4 SE 1/4 NE 1/4 sec. 29, Township 39 North Range 9 East The drill site location is on a tract of land controlled by Modoc County.

Lassen County

Hole #	Location
B-2	SE 1/4 NW 1/4 sec/ 21, Township 38 North, Range 9 East The drill site location is in the barrow ditch parallelling the Susanville Road (Lassen County Road A-2).
B-3	SE 1/4 NE 1/4 sec. 35, Township 38 North, Range 8 East The drill site location is in a harvested area adjacent to McClelland Road within the boundaries of Modoc National Forest.
B-4	NE 1/4 NE 1/4 sec. 30, Township 38 North, Range 8 East The drill site location is on private land which is presently held under valid geothermal resource lease by Eason Oil Company. AMAX Exploration, Inc. has entered into a joint-venture agreement with Eason Oil Company and is acting as project manager.
B-5	NE 1/4 SW 1/4 sec. 29, Township 38 North, Range 7 East The drill site location on county access easement is south of a bend in Kramer Road that occurs in the center of section 29.
B-6	NW 1/4 NW 1/4 sec. 3, Township 38 North, Range 7 East The drill site is on private land which is presently held under a valid geothermal resource lease by Eason Oil Company. AMAX Exploration, Inc. has entered into a joint-venture agreement with Eason Oil Company and is acting as project manager.
B-7	SW 1/4 SE 1/4 sec. 34, Township 39 North, Range 8 East The drill site is to be located in the barrow pit on the north side of an unnamed county road.