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AMAX EXPLORATION, INC.
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INTER-OFFICE MEMORANDUM

SUBJECT: AMAX #1 Livermore, Napa County, CA. DATE October 20, 1978

TO: R. A. Barker

FROM: W. M. Dolan

This memorandum addresses our conversation of this date concerning the captioned geothermal test spudded in on August 4, 1978.

As of 10/15/78, the well had proceeded to a depth of about 7,000' at a total cost of about $1.48 million (including $300,000 road and site costs). Casing set is 20" to 330', and @ 13-3/8" to 2,500'. Casing contemplated is a 9-5/8" liner in a 12-1/4" hole to 6,000', 7,000', or 8,000'. Hole diameters are 12-1/4" from 2,500' to 5,874' and 8-3/4" beyond that point. The hole will need to be opened to 12-1/4" insofar as 9-5/8" casing extends beyond 5,874'.

AMAX first leased in the subject area at the beginning of 1974. Our lease position comprises 16,000 acres predominantly in northern Napa County but extending slightly into Lake County. Progress has been painstaking as a result of Napa County's lack of familiarity with geothermal, and AMAX, at the outset. To elaborate, 4 years and 5 months elapsed from initial leasing until a permit to drill a test well was issued in May, 1978. AMAX expended about $1.1 million during that interval, more than half of which was property related.

In April of 1978 an agreement was concluded with Louisiana Land and Exploration (LL&E) and Anadarko Production Co. (APC) whereby they acquired respectively 37-1/2% and 25% interest in the prospect for a combined contribution of $1.65m ($900K from LL&E, $750K from Anadarko). Of that amount, $200K was directed toward 1978 lease maintenance costs and $1.45m toward the subject well.

As to the preliminary technical evaluations of the prospect:

(1) AMAX's thermal gradient information, based on both 500' and 2,000' observation wells, forecast temperature gradients of about 70°C/Km (3.84°F/100 feet) at the subject well site.

(2) The rock type mapped at the well site is the upper Franciscan greywacke series, presumably underlain by the lower Franciscan series. The latter is the celebrated reservoir rock at the Geysers and Castle Rock dry steam fields some 7 miles to the northwest. (Note: The evidence from our well suggests that the lower Franciscan was encountered at 5200')

(3) The well site is located precisely on the Franciscan trend and the Hg mineralization trend extends southeastward from dry steam production. In fact, the concentration of Hg mineralization in the vicinity of the subject well site increases pronouncedly in contrast to that portion of the Franciscan trend between there and the known steam fields.

(4) Some form of structural or lithologic hiatus appears to exist between the subject well site and the steam production area that is supported not only by a decrease in Hg occurrences, but by a notable decrease in thermal gradients (e.g. 30°C to 50°C/Km). The production areas boast thermal gradients between 60°C and 180°C/Km insofar as we have information.

(5) Thermal conductivities within the Franciscan series only vary slightly. That, accordingly, allows the projection of observed thermal gradients to depth with a reasonable degree of reliability (i.e. the heat flow velocity through the rocks will directly reflect the thermal conductivity and that will, accordingly, affect the observed changes in temperature per unit depth). Consequently, if thermal conductivity is known to be essentially constant, then projection of the thermal gradient (observed in comparatively shallow wells) to depth is a valid practice in judging the depth to reservoir temperatures. Application of the above-discussed criteria resulted in forecasting dry steam reservoir temperatures (240°C=463°F) at a depth of approximately 10,000' (employing average surface temperatures of 15°C=58°F).

(6) We have a further line of evidence though of a less precise nature. A magnetotelluric observation at the well site forecasts a decrease in electrical resistivity ($<$10 ohm meters) at a depth the order of 8,000 to 10,000 feet with a pronounced increase in resistivity below that ($>$100 ohm meters). The possible significance of this observation can be related to a USGS study in Yellowstone Park by Zohdy et al where it was noted that, "....the vapor dominated layer has a resistivity of about 75 - 130 ohm meters..... It is characteristically overlain by a low resistivity layer of about 2 to 6.5 ohm meters." Those conclusions have been supported by similar USGS observations at Kilauea crater in Hawaii.

Temperature observations made on the subject well have been designed to check the 70°C/Km gradient projection. Time-temperature observations employing a Kuster instrument were executed over nominal 2-1/2 hr. intervals several hours after cessation of circulation. From such information, a fairly accurate estimate of true rock temperature (as would be observed after days or weeks of thermal equilibration) can be calculated. The method employed follows on analytical procedures evolved by Lachenbruch and Albright, and modified to conform to industrial practice by Crosby (Phillips geothermal). The results of application of this procedure to the subject well are:

Depth	Deduced True Rock Temperature
5874'	280°F
6955'	308°F

The above results are displayed on the accompanying graph and appear to signify a temperature-depth progression conforming to a 65° to 70°C/Km range. It will be appreciated that data scatter is to be expected consequent to both observational and lithologic variations.

The chart also indicates that continued projection of the 65° to 70°C/Km gradient range to depth forecasts the presence of dry steam reservoir temperatures at depths between 10,400' and 11,400'.

It is clearly imprudent to regard the above-described evidence as conclusive! Apart from the fact that further confirmation of the depth-temperature forecasts is desirable, it must be noted that a rock temperature of 463°F may only signify:

(a) a hot dry rock, or

(b) An uneconomic hot water occurrence.

It is thus advocated that we drill to approximately 8,000', then repeat our time-temperature observations and determine whether our encouraging results are supported.

If our prior temperature observations are unsupported at 8,000', proper procedures should involve repeating our time-temperature runs as a check, then running a complete suite of applicable logs before a course of action can be elected.

If the time-temperature observations at 800 feet continue to favor dry steam temperatures near 11,000 feet, the arguments favor modifying the drilling procedure to accommodate drilling to 11,000 feet while being prepared to encounter a dry steam occurrence. The latter, of course, necessitates drilling with air as the circulating medium to avoid mudding off a steam entry (fracture conduits at 500 psi). It must also be considered that mud tends to behave poorly at elevated temperatures.

Heretofore with this well, except for minor instances, it has been necessary to employ mud as the circulating medium instead of air (air results in a much faster drilling rate) because of water entries. Accordingly, to proceed with air below 8,000 feet, it will be necessary to contain the mentioned water entries. That necessitates setting a 9-5/8" liner.

It is not feasible to obtain quantitative information as to the amounts of water entering from the several zones within the present open hole. In consideration, it is considered prudent to run the 9-5/8" liner to 8,000 feet in order to maximize the probability of successfully drilling with air to 11,000 feet.

It should be mentioned that experience suggests that air will permit drilling from 8,000' to 11,000' in about 10 days. With mud, apart from the other adverse consequences already discussed, the estimate is 30 days (at $10-$11 thousand/day)

COST SUMMARY

Through October 15 and to about 7,000 feet, the rounded costs are:

Expended

Drilling	$1.1m
Site and road	0.3m
Operator fee	0.08m
Lease maintenance	0.2m
Total	$1.68m (vs. $1.65m provided by LL&E and APC)

Future Options (direct costs)

Set 9-5/8" liner	to 6,000'	$0.1m
	to 7,000'	0.16m
	to 8,000' (includes drilling from 7,000')	0.29m

Complete with air to 11,000'

from 7,000' (@8-3/4")	$0.15m
from 8,000'	0.1m

Summarizing: (barring adverse water entries without contingency; including operator's fee): Well drilled to 11,000':

Case I:	pipe to 6,000'	$1.73m
Case II:	pipe to 7,000'	$1.79m
Case III:	pipe to 8,000'	$1.88m

For Case III, the overruns will amount to:

for AMAX - $0.161m
for LL&E - $0.161m
for APC - $0.107m

Completion and testing in case of success will push total costs over $2m.

ECONOMIC CONSIDERATIONS (current dollars)

If the well is successful, it is reasonable to anticipate that accumulated experience will result in completed future wells costing an average of $1.5m. Surface facilities (e.g. collection piping) may be expected to cost 20% of the wells or about $300K/well. Two confirmation wells, at nominally $3m total, will probably be required by a customer before entering into a steam purchase contract.

Cumulative investment by AMAX, LL&E, and APC at that point should be about $5.7m.

Permitting and plant construction (110MW) following the conclusion of a steam purchase contract will take about 4 years. Producer expenditures during years 3 and 4 of that period should be about $26.7m. (This is based on the average 150,000 lbs./hr./well prevailing at the Geysers - i.e. 2.5m lbs./hr. of available steam including reserve; 450,000lbs./hr. available from initial 3 wells; 13 additional wells and piping required @ $23.4m; piping for first 3 wells @ $0.9m; 10% for dry holes @ $2.34m)*

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Union's average depth for 27 wells drilled during 1976 and 1977 at the "Main" Geysers was 8,533'. Twenty-four were producers, two were suspended (injection wells?), and one was abandoned. Thermal Power Co., an affiliate of Union at the Geysers, has verbally indicated that $120/ft. is a reasonable 1978 figure for the Geysers drilling. That results in $6.80/lb./hr. of steam capacity (averages of 150,000lbs./hr and 8,533'/well). Those costs represent systematic development with long term drilling contracts. Thermogenics has verbally advised us that $10/lb./hr. of steam production capacity is currently regarded as the high figure at the Geysers.

Annual producer gross revenue (i.e. $15/MWhr) at 7,000 hrs. per year (i.e. 80% load factor) will be $11.5m. Subtracting a 12-1/2% royalty gives $10.1m. If we assume O & M costs of $500,000, we get $9.6m net operating profit. Applying this to the $32.4m total capital ($13/lb./hr. of capacity) and neglecting the effects of pre-production time, the approximate payback will be 3.4 years.

Nominal scheduling of preproduction expenses and the utilization of available tax advantages (IDC's, 22% depletion) should result in an effective payback of between 4 and 5 years and a consequent discounted cash flow rate of return between 20% and 25%!!!

If the Geysers experience maintains, about one square mile of steam field per 110 MW plant will prevail. We recognize about 3 sq. miles having favorable heat and lithology! Three times $9.6m net operating profit would result in:

For AMAX -	$10.8m
For LL&E -	$10.8m
For APC -	$7.2m

Corresponding capital investments will be:

AMAX	$12.15
LL&E	$12.15
APC	$ 8.1
Total	$32.4m

Lacking discovery of a dry steam resource, exposure will have amounted to (approximately):

AMAX	$1.3m
LL&E	$1.1m
APC	$0.9

Needless to say, the foregoing considerations neglect a number of factors and are only intended to provide a simple basis for appreciating the scope of the risk and the possible prize.

William M. Dolan

WMD:mp

References:

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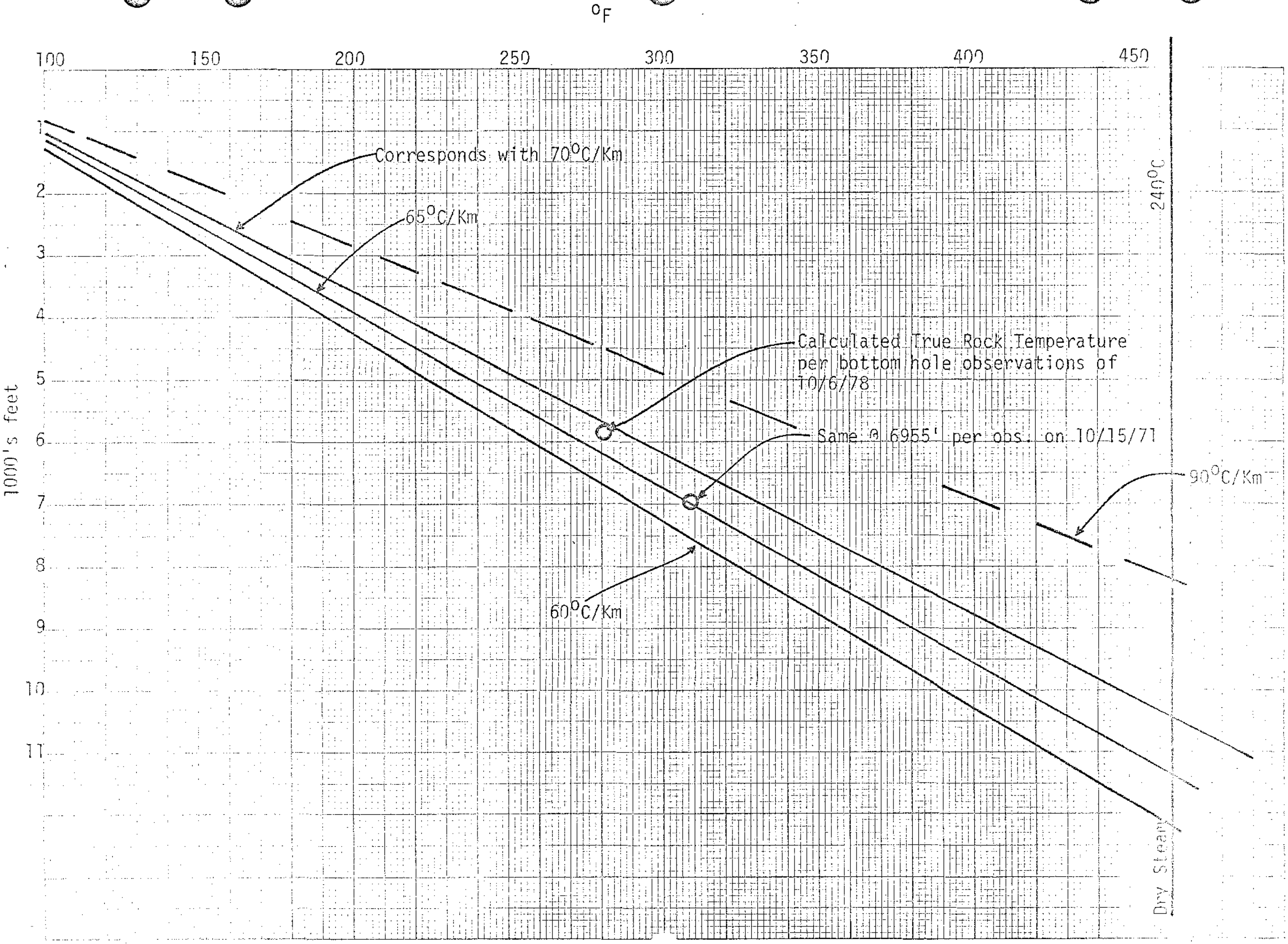
Ehring, T. W., et al, Formation Evaluation Concepts for Geothermal Resources, SPWLA 19th Annual Logging Symposium, June 13-16, 1978.

Zohdy A. A. R. etal, Resistivity, SP and IP Surveys of a Vapor-Dominated Geothermal System, Geophysics, Vol. 38, No. 6 (Dec., 1973) pg. 1130.


°F
100
150
200
250
300
350
400
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1000's feet
1
2
3
4
5
6
7
8
9
10
11
Corresponds with 70°C/Km
65°C/Km
Calculated True Rock Temperature
per bottom hole observations of
10/6/78
Same @ 6955' per obs. on 10/15/71
90°C/Km
60°C/Km
240°C
Dry Steam