(5451A)

Preliminary Evaluation of Logs From
Animas 55-7
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This analysis is basically a qualitative analysis of the suite of logs run by Schlumberger and Smith Exlog on the Animas 55-7 well. The quality of the logs appears to be good which aided in the interpretation.

The suite of logs include:

Geothermal data (mud) log
Temperature
Litho-density - Compensated Neutron
Dual Induction - SFL, 2" and 5"
Borehole Compensated Sonic, Sonic Density
Dipmeter/Arrow Plot Log

Quantitative analysis is limited because of lack of a computer with the appropriate analysis programs. With computer generated cross plots lithologic zones or trends can be delineated and additional analysis made possible. Such analysis would yield additional matrix properties and thus a tighter control on lithology in the zones of interest. Colorado Mines has a suite of programs but they are not operational on their present computer system.

The aims of the geothermal well log analysis are:

1. Identification of lithology
2. Detection of porous and fracture zones
3. Estimation of equilibrium formation temperature

This analysis and report will deal mostly with item 2, "detection of porous and fracture zones". Sufficient time has not passed for the well to return to near static condition so only the two post drilling temperature logs are available. This log does show some gradient changes which would reflect formation fluid invasion zones.

A very generalized (and simple) lithology column for the well can be listed as follows:

0-1990	Alluvium, tuff, solution deposit including calcite veining (Tertiary)
1990-2950	Siltstone, limestone (Paleozoic)
2950-3200	Intrusive dike
3200-3400	Siltstone, limestones
3400-3410	Intrusive dike
3410-3480	Limestone, chert
3480-3580	Intrusive dike
3580-4070	Limestsone, siltstone

4070-4480	Intrusive dike (granitic)
4480-4570	Limestone
4570-4750	Intrusive dike
4750-6520	Limestone, siltstone, traces of dolomite, solution deposits
6520-6622	Intrusive dike
6622-6750(?)	Dolomite
6750-6830	Sandstone
6830-TD	Granite

Some of the interfaces are sharp while others grade from one lithology to the next.

Fractures in geothermal systems can be detected and evaluated to varying degrees of certainty from the various well logs. According to Sanyal et al (1979), the best evaluation procedure is to combine the fracture detection criteria from the various logs and come up with a qualitative probability of occurrence and general nature of the fractures at various depths in a well. They recommend the following fracture identification criteria:

A. Drilling rate: usually fractured intervals show faster drilling rate.

B. Mud circulation data: Most open fracture zones cause lost circulation of drilling mud.

C. Drill cuttings data: Drill cuttings sometimes show "drusy" quartz or calcite indicating partial filling of fractures (Both quartz and calcite percentages are shown in the column).

D. Self potential (SP): Igneous type rock formations do not usually display self potential unless fractured when mud filtratation into fractures may give rise to a streaming potential.

E. Conductivity: Non Sedimentary type rock formations usually display very low conductivity (high resistivity) unless fractured. In fracture zones shallow investigation resistivity logs show higher conductivity because of the presence of mud in fractures. Thus, a comparison of the formation resistivity from the deep induction tool (approximately R_t) and a shallow focused device (approximately Rxo) can yield fracture indications. Rxo is usually greater than Rt (because mud filtrate resistivity is greater than formation water resistivity); but in fracture zones, the apparent Rxo maybe less than Rt. This is so because the shallow focused device reads vertical resistivity and thus will be affected more by vertical fracture than the induction log, which reads horizontal resistivity.

F. Separation between shallow guard and induction logs: In fractured igneous and metamorphic formations the shallow guard log should show higher conductivity than the induction logs which have a higher depth of investigation.

G. Hole enlargement (caliper log): Fractured sections show hole enlargement.

H. One arm vs 3 or 4 arm caliper data: An inclined fracture zone tends to make a drill hole non circular in cross section due to preferential hole enlargement in the direction of the fracture. A 3 or 4 arm caliper gives a better picture of the well cross section, whereas the one arm caliper with pad mounted device tends to give maximum borehole width. Thus a single arm tool will give a larger diameter than a 3 or 4 arm one. A keyhole cross section may also exist and should not be confused with (or for) a fracture zone.

I. SP curve: When the caliper logs shows large corrections to the density reading it may imply either mudcake buildup or the presence of fractures. In igneous lithology mudcake buildup is not common hence an unusual value of SP in a smooth section of the hole indicates fractures.

J. Neutron and density logs: In igneous or silicified type formations, fractures usually account for most of the porosity unless there is vesicular porosity. Thus these logs should indicate relatively higher porosities in fractured zones. Other features to look for are (1) negative peaks on the density logs and corresponding peaks or large corrections on the SP log and (2) a small or negative difference between Neutron and density values ($P_n - P_D \lesssim 0$)

K. Comparison of sonic and density porosities: In fractured zones, sonic log-derived porosity will be lower because the sonic log does not "see" most fractures. However, this test needs accurate values of the matrix travel times (Δtm) and the suite of logs allow this analysis.

L. Rock strength: The mechanical strength of a rock is proportional to $\rho/(\Delta t)^2$ where ρ is the bulk density and Δt is travel time of the compressional sonic wave. Rock with high mechanical strength can undergo brittle fracture; a rock with low strength usually does not show brittle fracturing.

The above criteria are applied to the respective logs and the resulting zones are listed in Table I. These zones are quite thick and in general satisfy the criteria as indicated, but scattered throughout the vertical section are thin zones (<10 feet) and these are listed in Table II. Figure 1 shows the 55-7 well in vertical section with the zones from Table I on the right of the drill hole and Table II on the left. Most of the thin zones are close to interfaces or contact boundaries of the thicker zones. Only three lost circulation zones were noted, but with the problems with the surface mud equipment other zones are certainly possible. Flowing the well with spinner surveys would delineate any fracture zones, that yield or accept fluid.

The Dip Log contains caliper, gamma ray, dip angle and direction and borehold drift curves. The borehole drift tends to be "up dip" so a very coarse indication of bedding plane dip direction can be obtained from that. In well 55-7, the borehole drift in the Tertiary section begins (at 1,100 feet) trending SW and rotates gradually counter clockwise to E and ESE by the 2,000 foot level. In the next 400 feet it reverses rotation and is drifting due west. This general drift direction is maintained to the bottom of the well. Dip values are apparent and not corrected for borehole deviation. The correction ranges from adding the drift to apparent dip when dip and deviation are in the opposite directions and subtracting when the two are in the same direction. (In the upper borehole where deviation is less than 10°). Borehole drift reaches 10° at 6,400 feet and increases to 18° at TD. Thus corrections are not applied because of the variation in the zone generally make the correction fall within the range given.

Fred Berkman (working papers) has made a gravity profile and section running E-W thru the 55-7/hot wells area. This section shows high angle faults both east and west of the well, with the intervening bedding dip westward. In contrast, the dip log shows prevailing dip 10-20° east to to southeast. Berkman also shows a carbonate bed (El Paso formation (?)) at an approximate 4,800 foot depth. This could be the interface between an intrusive dike and limestone beds located at 4,750 feet per the logs. However, from the chip boards, the El Paso formation is observed to be several hundred feet deeper, near 5980 feet. If the high angle faults, as shown by Berkman, are close to true, then the well appears to be about 300 feet down dip from the western fault. If the heat source is to the east or southeast of the well sites in section 7, then it is down dip from the well.

A temperature survey was run in the upper 2,600 feet of the hole on March 4, 1985, 18 days after the Schlumberger logging. This temperature profile is shown in Figure 1 along with the February 14 temperature log. The 4 March log shows a maximum temperature of 237°F at about 1,250 feet followed by an isothermal trend to the measured depth of 2,600 feet. The maximum blip at 1,250 feet sent me back to the logs to see what the well shape was and if the logs indicated fracture zones. In the interval of 1,200-1,250, three thin zones appear promising and satisfy the necessary criteria. Although the dip log is somewhat sketchy in this area, it is noteworthy that just above the 1,200 foot level dip is SE to E (about 40°) and at 1,255 feet dip is ENE (about 36-40°). In the interval of 1,200 to 1,250 feet, the dip is generally west and less than 16°. The well bore is relatively smooth and stable so this zone may be of higher interest.

The zone between 1,250 and 1,740 feet was also reexamined, but large borehole size (washouts) tends to diminish credibility in the other logs information. So no further delineation was done in this section and the March 4 temperature log shows no inflow signs.

General Conclusions

1. The well does not appear to penetrate a fault/fracture zone that is a major conduit of hot water. But the surface expression of the highest heat flow is to the east of 55-7 a few hundred feet. Thus well 55-7 is up dip from this heat zone.

2. The well does penetrate many fracture zones with 3 zones noted for lost circulation at 2275, 4060 and 4800 and six possible fluid invasion zones near 1250, 2030, 2600, 4560, 5400 and 6030.

3. Flowing the well coupled with a spinner survey and temperature surveys can show which, if any, of the fractures produce fluid.

4. The temperature log of March 4 shows maximum gradient between 150' and 1100 ft. with a blip (270°F; 137°C) at 1250-60 ft. Data from the other logs show three zones of fractures between 1200-1250 ft. The depths for this temperature log are uncorrected for stretch in the cable so the blip must correlate with the fracture zones. In contrast, production for the greenhouses comes from depths of a few hundred feet and temperatures near 214°F or 100°C. Geochemical extrapolations imply a minimum reservoir temperature of 150-170°C.

Recommendations:

1. Accoustic Emmission Survey: With the wells for the greenhouse being produced, the thermal fluid flow should provide a "noise" or energy source for monitoring and mapping the plumbing configuration in the area of Sec. 7, T255, R19W. Such a survey should show just where the major conduits are that provide fluid for the near surface system tapped by the nearby greenhouse wells. Cost estimates for a 2 week survey and report fall in the $15 to $25 thousand range.

2. Seismic Survey: A 6 mile line, generally E-W through the vicinity of Animas 55-7 would help delineate the high angle faults and other structure in the area. Such a line could be tied to the N-S line that traverses the N-S section line east of 55-7. Cost of this survey would be similar to the accoustic emmissions survey.

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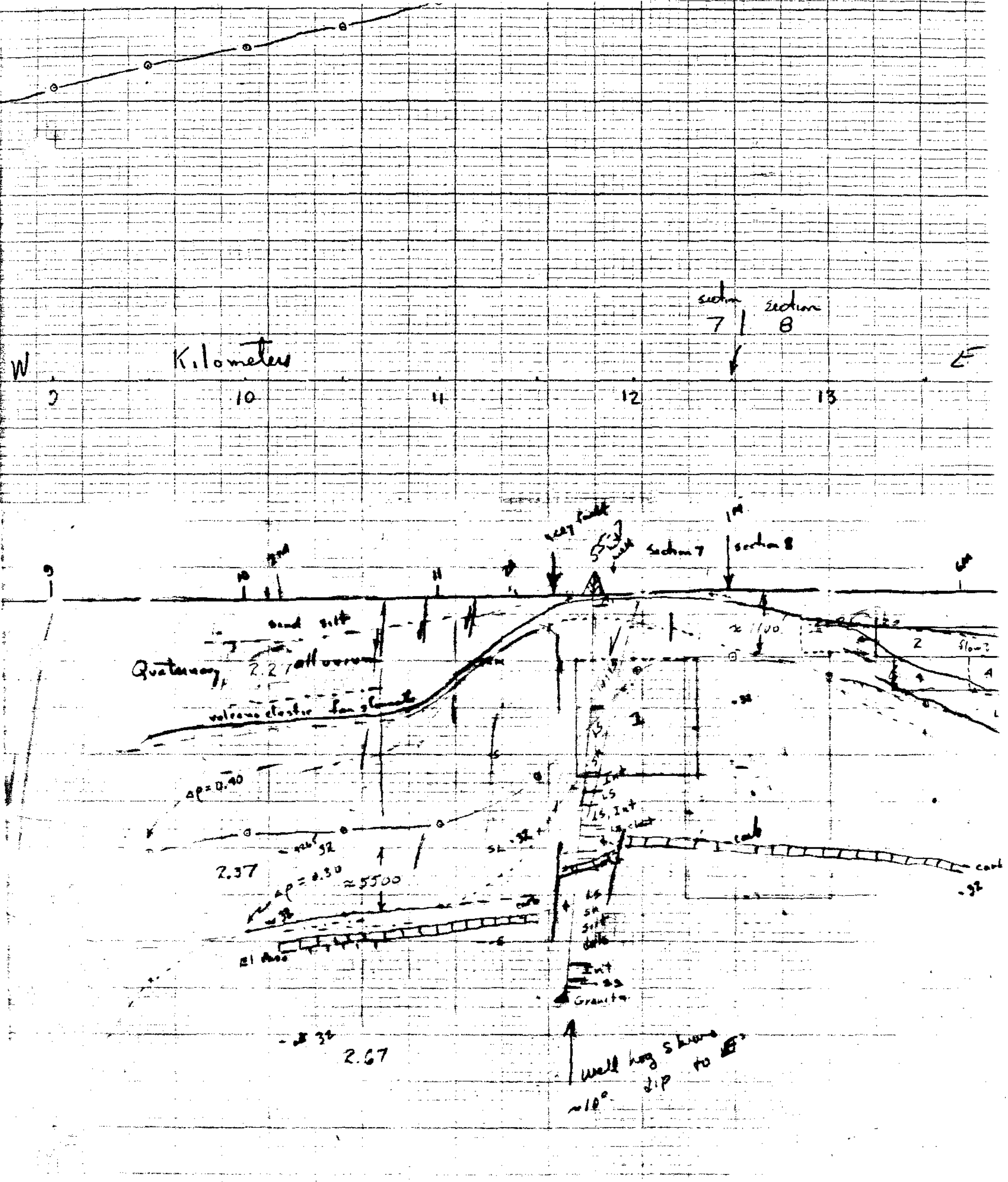
REFERENCES

Sanyal, S., Gardner, M., Koenig, J., McIntyre, J., 1980 Wellsite evaluation from logs of a geothermal well, GRC transactions, v.4, p.471-474.

Table 1: Animas Well 55-7

Zone	Lithology	A	B	C		D	E,F	G	H	I	J		K	L	Fracture	Dip Dir.	Comments
				q	c												
	Tertiary:																
1740-1800	Sol'n Deposits	mod	norm	710	710			mod		?	X			med	1740-55	20-30° NW	
																20° ESE	Dip Reversal at 1780.
1840-1920	Tuffs Trace																
	Sol'n Deposits	mod		2-4	710			mod		-	X			hi	?	?	
1960-1990	Contact Zone	m-lo		1-5	8			mod	ellip	X				med	X		
2086-2106	Paleozoic:																
	Siltstone	low		4	3			slite	X	X	X			hi	?	14-20, E	
2435-2501	Siltstone-LS	low	LC,2275	-	4-6	X	X	mod-slt	X	X	X	3		hi	2435-37	6-21,SE-S	
2510-2622	Siltstone-LS	low		0-10	5-10	X		slite	X	?	X			hi	X	10-30 SE; 2-10 SW, NW	
2665-2686	Siltstone-LS	low		-	4	X		slite	-	-	X	3		hi		14-20 SE	
2700-2950	Limestone,marl	low		-	2-5	X		slite	-	-	X	3		hi	intermitant	10-20 SE	Hi Qtz at 2880-90 very low P
2950-3200	Int. Dike	low-mod		2	3	?	X	mod	-		-			hi	X		
3200-3370	Limestone	mod		-	1-6	X		slite	X	?	X		X	h-low	X	8-40, NE-SW	
3466-3482	Chert-LS	mod		1	2-3	X		slite	X	X	X			hi		14 ESE	
3482-3560	Int. Dike	low-mod		1-2	1-2	X	X	slite	X	?	-			hi		---	
3734-3824	Siltstone-LS	low		-	2-4	?		slite	X	?	X			hi	intermitant	10-21 E-ESE	
3824-4060	Limestone	low-mod	LC,4060	-	1-3	X	X	slt-mod	-	X	X			hi		8-22, ENE-ESE	
4075-4130	Intrusive Dike	low-mod		-	1	X		slite	-	X	X			hi	X	11-16 ESE	
4160-4278	Intrusive Dike	low		-	-	X		slite	-	-	X		X	hi	intermitant	?	
4482-4520	Intrsv/Lmstone	low			4- 10	X	X	mod	-	X	X		X	hi	?		
4750-5360	Limestone	low	LC,4800	-	1-3	X		mod	-	X	X	3	=	hi	?	10-20 ESE	
5360-70	Shale-Siltstone							mod	ellp	X	X			m-hi	X	12-20 NE-SE	
5370-5408	Limestone	low		-	4-6	X		slite	-	X	X			hi	-	13-19 ESE	
5430-5445	Limestone	mod		-	3-6	X		mod	-	-	X		?	hi	-	48-54, NNW	
5930-40	Siltstone-Shle	low		-	-	?	X	slite	X	?	X		=	m-hi	-	-	
6110-80	Dolomite	low		-	2	X	X	mod		X	?		-	hi	intermitant		
6200-6370	Limestone	mod		-	2	X		slite	X	X	X	3		hi	intermitant	8-21, E-SE	Dip changes @ 6230, 6286-6300, 6300-38
6830-7000	SS-Granite	mod		?	-	X		-	X	X	X	3		hi	X	?	



From F. Berkman working papers - EW Gravity line through the "Hot Wells"

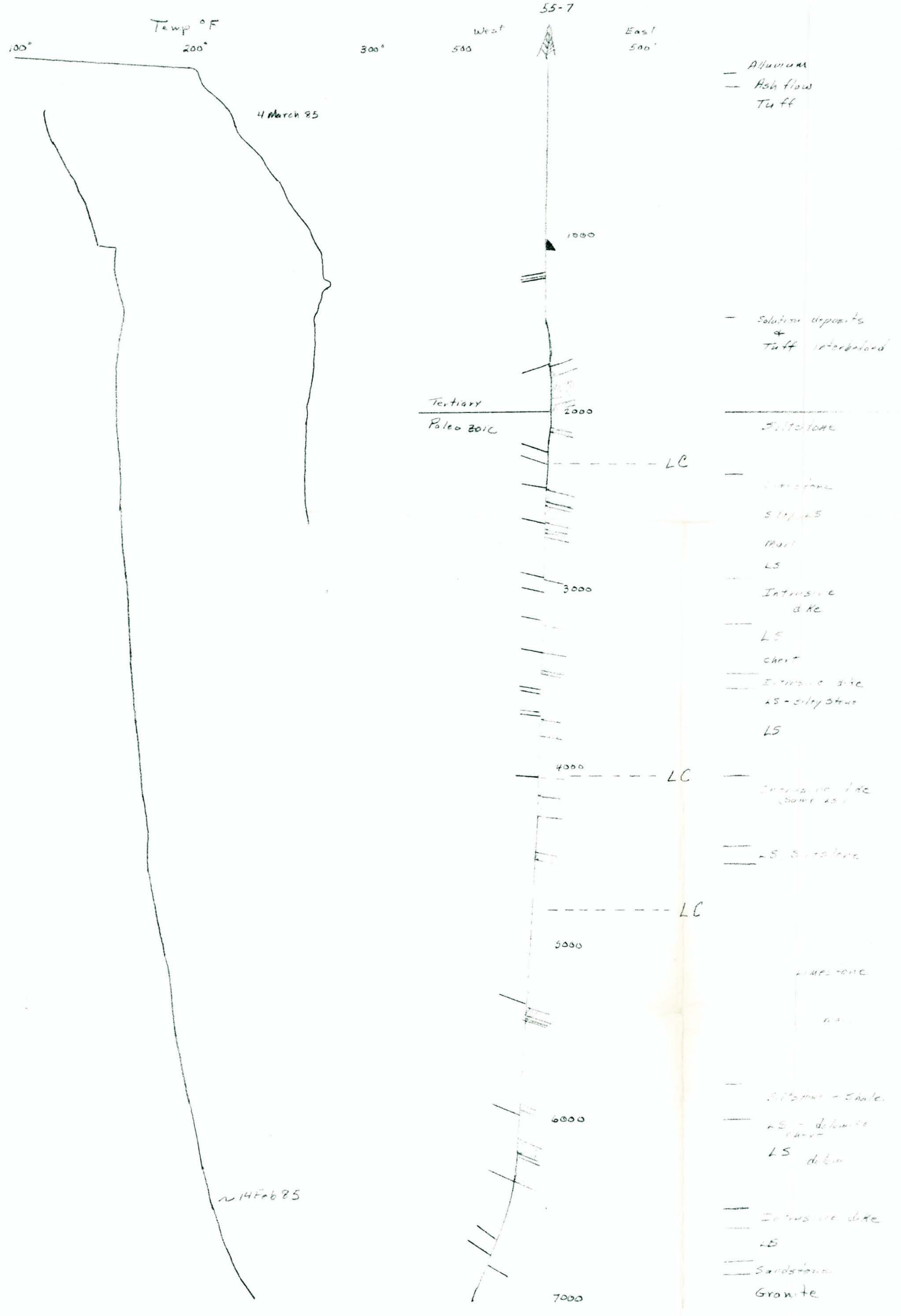


Figure 1: Temperature profiles, borehole and fracture profile and simple geologic section.

Animas, New Mexico, TFD 55-7
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