#37 Received 12-13-2011

(5357A)

Preliminary Evaluation of Log From Fish Lake Wells 88-11 and 88-11A

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March 29, 1985

This analysis is basically a qualitative analysis of a suite of logs run by Schlumberger on each well. The quality of the logs appears to be good; however, the SP for the logs from 88-11A appear to be attenuated compared to the logs from 88-11.

The logs run are listed for each well respectively:

88-11	88-11A
Geothermal data (mud) log	Geothermal data (mud) log
Temperature: 2" and 5"	Temperature log 5"
Formation Density, Compensated Neutron, Gamma Ray 2" and 5"	FDC-CNL-GR 2" and 5"
Dual Induction; Spherical Focus Log 2" and 5"	Dual Induction, SFL 2"& 5"
	Borehole Compensated Sonic 2"& 5"
	Four Arm caliper
	Dipmeter
Cement Evaluation Log (5/29 and 6/13/84)	Fracture Identification Log
Casing Collar Log	

Quantitative analysis is limited because of my lack of a computer and computer analysis programs. However, with compter generated cross plots, zones and trends of interest can be delineated and additional analysis made possible. Such analysis would show matrix properties and tighter control on the lithology within zones of interest.

The aims of 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 items 1 and 2. A suite of temperature logs for well 88-11 has already been interpreted and I could not add anything to that analysis. John Deymonaz has done an excellent analysis of the mud cutting for lithology identification of 88-11 (9/10/84 memo to H. J. Olson). In general, the lithology of 88-11A is similar with local variations. Flow characteristics and temperature evaluation have been performed on 88-11 and covered in a GeothermEx report (October 1984). GeothermEx concludes fluid flow in 88-11 is from the bottom hole (8149') and flow data from 88-11A is not yet available.

Deymonaz characterizes the 88-11 well into the following zones:

0 - 810	Rhyolitic lithic crystal tuff
810 - 3920	Tuffaceous sandstones and siltstones
3920 - 8149	Siltstone, sandstone, quartzite, phyllite and limestone

If a series of cross plots* can be made for zones of interest in the Paleozoic section, specific lithogies can be inferred for the individual zone. Colorado Mines has a program for this, but it has not been adapted to their present computer. Hopefully, it may be available in the next few months.

Fractures in geothermal systems can be detected and evaluated to a varying degree 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 (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.

*bulk density vs ϕ N, Δt vs ϕ N, bulk density vs ϕ N, bulk density vs Δ t

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 (o check in the table indicates this). 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 (Pn-Pd $\leqq 0$)

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 these values need a more quantitative approach for determination than can be done here.

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.

Table I shows the possible fracture zones for well 88-11 and Table 2 is for well 88-11A. A psuedo vertical section AA' striking N30E is shown in Figure 1. The section is drawn vertical with the well sections projected onto it. The plan view of the two wells and the strike of the section are shown in Figure 2.

In Table 1, columns H, K, and L have no entries because no multiarm caliper (H) or sonic logs (K,L) were run. A sonic log was run on well 88-11A, but the matrix characteristics in the specific zones of interest are not well enough defined to fill in column K in Table 2. A rock strength value (Column L) was determined for sections of well 88-11A by using $\rho/(\Delta t)^2$ values from the density and sonic logs. The values ranged from 2-10 (constant)(gr $ft^2/cc\ sec^2$). Values 2-4 are assigned low, 5-6 med and 7 or greater, high. To be useful rock mechanic values, the units should be rationized but for a comparitive use these values are adequate.

Deymonaz (9/10/84 memo) believes that the wellbore may be intersecting beds at a low angle above 6300 feet in 88-11. With the sudden change in deviation and azimuth, lithologic variation in cuttings increased suggesting a penetration angle more normal to the bedding. Both wells showed an increase of CO_2, methane and especially H_2S a couple of hundred feet before reaching production zones. Thus, the question was asked: Is there a "cap rock sealer" present? Both wells appear to have a dense limestone (?) bed near the well bottom which could be a "cap" rock. In 88-11A, there is a 36 foot thick dense zone at 7900-36 which shows essentially no porosity, low Δt ($\mu s/ft$) or high velocity and no fractures on the Fracture Identification Log. In 88-11, there are two similar though thinner beds at 7674-86 and 7518-28.

There appears to be no continuity of marker beds or contacts across the two wells. The Tertiary/Paleozoic interface is at 3920 in 8811 and at 3488 in 88-11A, an apparent difference of over 400 feet. The true depths may vary some, but there still will be a difference of a few hundred feet of displacement. Possibly the two wells straddle a fault that does not cut the surface. In 88-11 there is a zone from 4376-4520 that has a good sandstone SP response, very high resistivity values from the shallow focus logs. Immediately beneath this is a 30 foot zone showing lower resistivity, higher neutron porosity, lower gamma ray counts and decreasing SP. However, the action of the logs do not fit the fracture criteria. A zone similar to 4376-4520 is missing in 88-11A.

Fracture Identification Log (FIL) and 4 Arm Caliper and Dipmeter logs were run in 88-11A. As can be seen from Table 2, most of the zones delineated from analysis of the other logs contain intervals with fractures verified by the FIL. Looking at the FIL, one can see other sections that appear fractured, but the other logs did not as a group support listing them in the table. However, they should not be forgotten in case temperature logs show zones of interest. The 4 Arm Caliper Log and the One Arm Log (shown only on the Formation Density Log) correlated quite well in the lower (Paleozoic) portion of the well. Occasionally the well bore shows a slight ellipticity, but nothing like the washout (keyhole shaped) zones in the upper (Tertiary) section of the well.

A Dipmeter Log was in conjunction with the 4 Arm Caliper and FIL logs. In fact the raw data Dipmeter Log is part of the basic run for the FIL and 4 Arm Caliper Log. However, this raw dipmeter Log is extremely noise and thus it is difficult to do much with it. The processed log is much cleaner and shows discreet dips and direction, borehole drift, orthogonal caliper diamers and pad 1 resistivity. The angle of investion is smaller than the implied dip in the lower portion of the hole. Therefore, the beds with these high dip angles are not indicated. The log was reprocessed using a longer interval and viewing angle, but Schlumberger reported no improvement in the data. The log shows a completely random pattern to dip direction, but some apparent dips that corresponded with fracture zones were picked and are listed in Table 2. It should be remembered that these angles are with respect to the borehole axis. In the metamorphased Paleozoic section of the well the picked dips may just reflect fracturing planes resulting from the drilling. Additionally, the borehole drift generally trends up dip, and the implied dip trend is listed below.

Table 3. Implied Dip Direction from Borehole Drift

Depth	Borehole Drift	Implied Dip Direction
0-1500	SW	NE
1600-2100	NE	SW
2100-6100	NE to NNE (oscillates)	SW-SSW
6200-6400	N	S
6400-TD	N to NW	S to SE

Most of the apparent dip directions listed in Table 2 are in agreement with the values in Table 3, but the magnitude is highly questionable as being representative of apparent dip.

General Conclusions

1. Both wells penetrate a fracture zone that produces hot water. This zone appears to be a fault zone trending NNE which fits the observed fault pattern.

2. The lower portion of both wells contains interbedded fracture zones. Whether production could be induced from these zones is unknown. Flow testing may cause some additional zones to open up.

3. Additional temperature logs may show hot spots that should be correlated to fracture zones for development.

4. The findings of this exercise do not "shoot down" Deymonaz' hypothesis of a horst block structure. These wells penetrate one side of this hypothesized structure.

Recommendations

1. TDEM Survey: A TDEM (Time Doman Electromagnetic) survey should be utilized to map the tertiary volcanic/Paleozoic interface. The Tertiary has resistivity vaues (from the dual induction log) in the low tens ohm meter and moves (not abruptly) to the low hundreds in the region of the contact zone. Thus a TDEM survey should be able to give reasonably creditable values for the depth to contact. The MT interpretation gives a somewhat shallow depth to the contact, but with TDEM the MT can be reevaluated for better results.

2. Accoustic Emissions Survey: This passive seismic survey would locate areas of fluid migration through fault or contact zones. These areas could be specific drilling targets when correlated with other geologic (structural) and hydraulic information.

   An interesting test would be to flow 88-11 for awhile, shut it in and see if the accoustic emissions survey can pinpoint channels of fluid flow during production and the subsequent recovery. Then do a similar test with 88-11A as the producing well. Such a suite of tests should allow some definition of the plumbing system.

These two surveys should be available for $40 - 50,000 and could certainly aid in establishing drilling targets for future wells.

Jimmy Jacobson

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: Results from Well 88-11

Zone	Lithology	A	B	C	D	E	F	G	H	I	J	K	L	Comments
810-3920	Tuffaceous													
928	Sandstones		LC	Hole Cased to 1071 feet										
2800-2900	and	2'break	LC											
		2876	2876					large						
3077	Siltstones	2'break												
3340-3370		up	N		X	up	X	slight						Porous ss below dense zone
3645-3650	(Tertiary)	mod	N		X	up	X	slight		X	X			" zone
3844-3854		mod	N	6%	?	up		slight						
3864-3872		mod	N	7%	?	up		slight						
3920	Contact													4370-4520 dense resistive ss type
3920-8149														
5410-5420	Siltstones	5'break	small											
	sandstone	@5420	LC 5420	3%	X		X	slite						
		high												
5494-5502	qtzite/phylite													
	&limestone	low	N		X	very hi	X							
5790-5826		high	LC5820	7%	X		X	5812-15						
								high						
5826-5850		mod	N		X									
5934-42		mod	N		X	up								
6104-08		low	N					slite						
6120-24		mod	N					slite						
6250-54		low	N					slite						
6734-40		mod	N	3%		up	X	slite						
6900-6920		hi	N	2%			X	neg						
7150-7420		mod	N		X		X	neg-slight						possibly excess mudcake
7420-7510		mod	N	5-8%	X									
7516-7528		mod	N	10%			X							possibly calcite sealed fracture zone
7600-7650	sandy siltst	mod	N	10%			X							" " " " "

B: Normal: N
Lost Circ LC
C: % of Calcite
H: Only 1 arm caliper data available
K: No sonic log
L: No sonic log

Table 2: Results from Well 88-11A

Zone	Lithology	A	B	C	D	E	F	G	H	I	J	L	Dip Dir.	Frac Log	Comments
1070-2400	Tertiary	hi						extreme							No analysis attempted/SP log appears severely attenuated.
3346-60	Tuffaceous Sandstones Siltstones (volcanics)	low		2%	X	up	X	mod	X	X	X	low			
3488	Contact Zone														
3666-72	Paleozoic	low				?	?	slight			X	low		X	
3686-91		mod				X	X	slight			X	med		X	
3884-92	Siltstones	mod				?	X	slight		X	X	med		X	
4093-97	Sandstones	mod						slight		X	X	med		X	
4146-50	Qtzite phyllite	low						slight		X	X	med	20 WNW	X	
4200-04	Limestone	mod						slight		X	X	med		X	
4218-26		low						slight		X		hi	18^{o}S-36S	X	
4400-06		low		2%				slight		X	X	hi			
4424-26		low		2%	X		X	slight		X		hi	24 SE	X	
5130-34		low						slight		X	X	hi	57 NW	X	
5358-62		low						slight		X	?	hi			
5362-90		low		2-4%	X		X	slight		X	?	hi	40 SW		Interbedded zones
5940-70		mod		1-2%		?	?	slight		X		med	8-12;S-SW	X	
6660-80		low		3%	?	X		slight				hi	42 E	X	
6688-6712		low		10%				slight				hi	20-40;E,S,W	X	Tight - dense limestone
6744-48		low				X	X	slight						?	
7250-60		mod		6-8%		?	?	slight			X	hi		X	Increasing CO_2 + methane
7260-62		mod				X	X	slight				hi		X	
7444-48		mod				X	X	slight		X	X	hi	35 NNE	X	
7500-70		mod	LC	2-3%				slight				hi	30S-40ESE		
7666-68		low	LC			X	X	mod	X	X	X	hi		X	
7687-96		mod	LC	8%	X	X	X	ext	X	X	X	hi		X	
7699-7702		lo-med	LC			X	X	ext		X	X	hi			
7708-16		mod	LC			X	X	ext	X	X	X	hi		X	
7940-70		mod		5-6%	X	X	X	slight				hi	14 SW;4 NNE 50 W	X	Underlies dense tight limestone
8100-30		low		3-5%	X	X	X	slight		X	X	hi	20 E		
8328-32		low				X	X	slight		X	X	hi	45 ESE	X	
8344-47		low				X	X	slight		X	X	hi		X	
8374--		low				X	X	?	X	X	X	hi	72 SSE		

C: Calculate percentages
K: Not evaluated, Dip and Azimuth

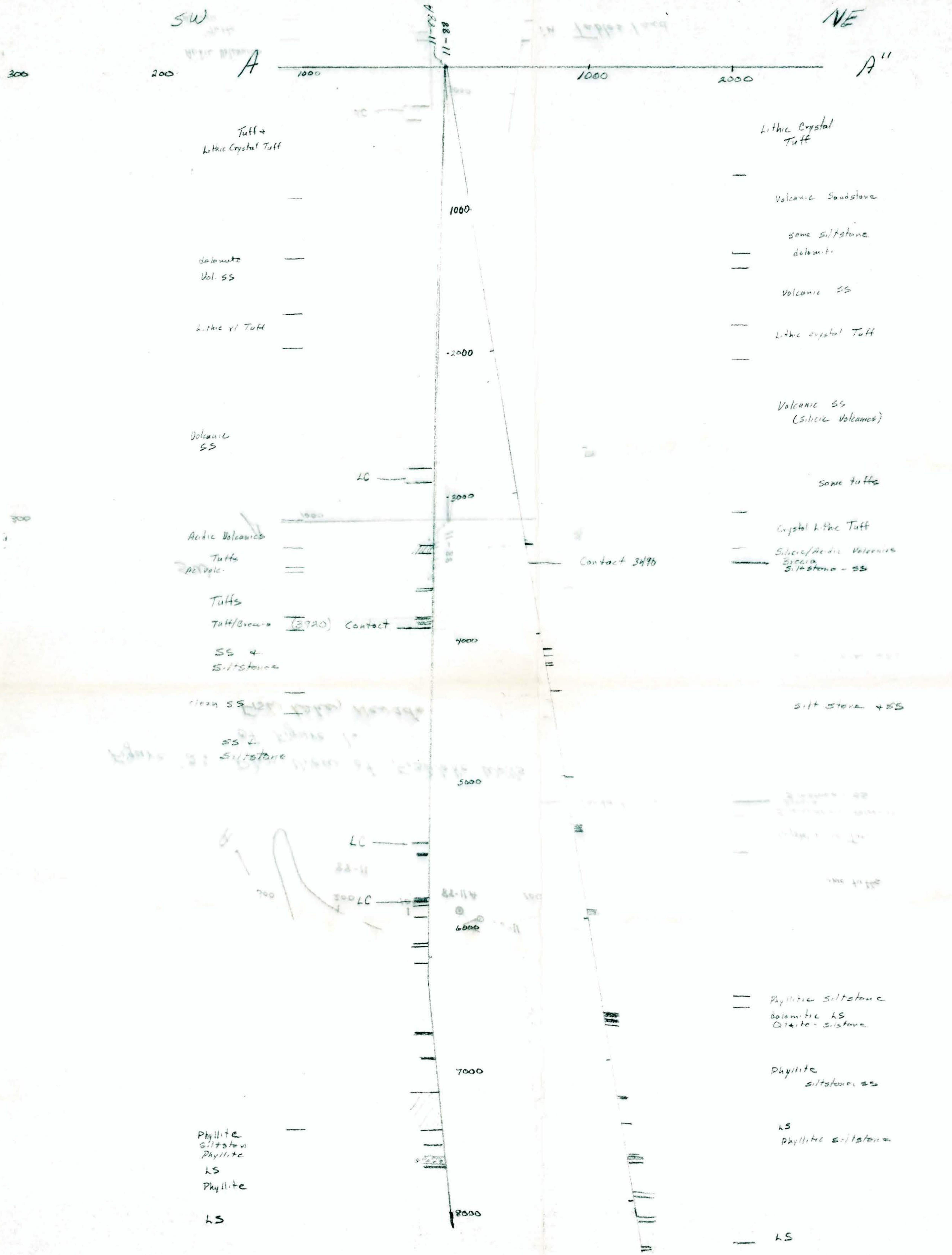

Figure 1: Probable Fracture Zones as listed in Tables 1 and 2.

Fish Lake, Nevada

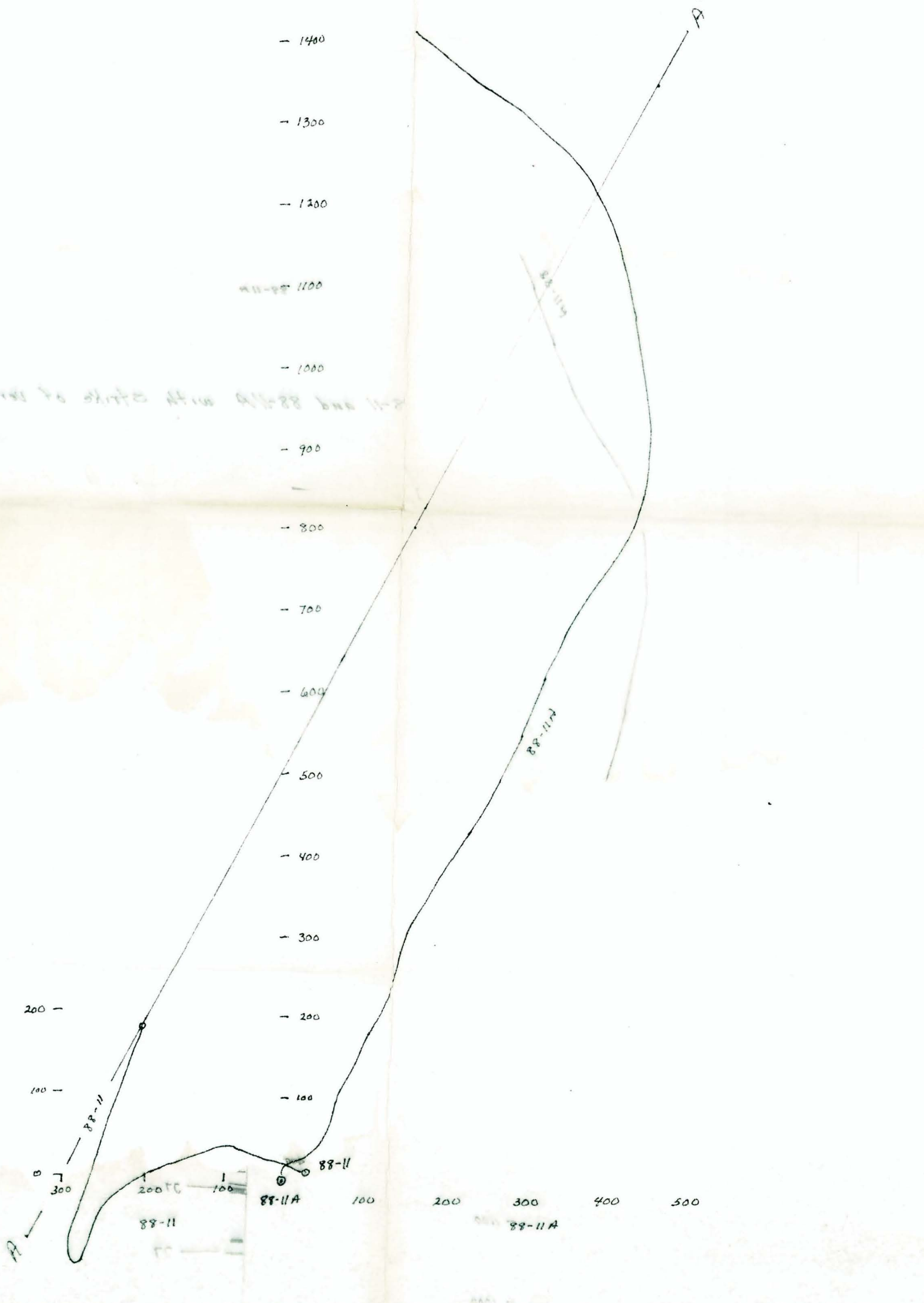

Figure 2: Plan View of Fishlake Wells 88-11 and 88-11A with strike of vertical section of Figure 1.
Fish Lake, Nevada