

**Appendix 9.** Location, physical characteristics, borehole-geophysical logs and interpreted structures for well Har 1.

Well Har 1 is located at the Trail Ridge condominium complex on the north side of Ayer Road in Harvard, MA. The condominium complex was under development in 2007. Trail Ridge sits on the edge of hill overlooking swampy lowland. Three wells were drilled for a pump-storage system designed for the complex. All three wells had yields estimated at less than five gallons per minute. The well used in this study was estimated at three gallons per minute. The site ID for this well is har1.060407. The well was logged from June 4 through June 7, 2007. The elevation of the site is approximately 130 meters above sea level.

The well has 5.8 meters of casing installed through approximately 2 meters of glacial overburden. The material at this site is a thin till which is a nonsorted, nonstratified matrix of sand with some clay, silt and boulders. The well is cased into bedrock, which is the Tadmuck Brook Schist. The Tadmuck Brook schist is a sulfidic, quartz-muscovite-biotite schist located along the Clinton-Newbury Fault zone that forms the northern boundary of the Nashoba Terrane. There is an outcrop of Tadmuck Schist only a few meters from the well.

The total depth of har1.060407 is 171 meters. There were a total of 89 fractures identified over the length of the well. Eight of the total fractures are subhorizontal unloading joints, 56 are tectonic joints and 25 are FPF. There are no subhorizontal joints below 40 meters.

The water table in the well was 5.64 meters below the ground surface. The well was pumped at 0.5 gallons per minute for four hours drawing the well down 0.3 meters over that time. Heat pulse flow meter tests revealed five flowing fractures over the length of the well. Of the total flowing fractures four are tectonic joints and one is a subhorizontal unloading joint. The flowing fractures were located at 20.2, 39.2, 43.6, 128.8 and 141.4 meters depth.

**Appendix 9, continued.** Midpoint depth, strike and dip of features identified in optical televiewer log, fracture type and heat pulse flowmeter data from Har 1 (azimuth and dip reported using right hand rule convention; t = tectonic fractures, s = sheeting joints, p = foliation parallel fractures). Data shown under the pumping test have been normalized.

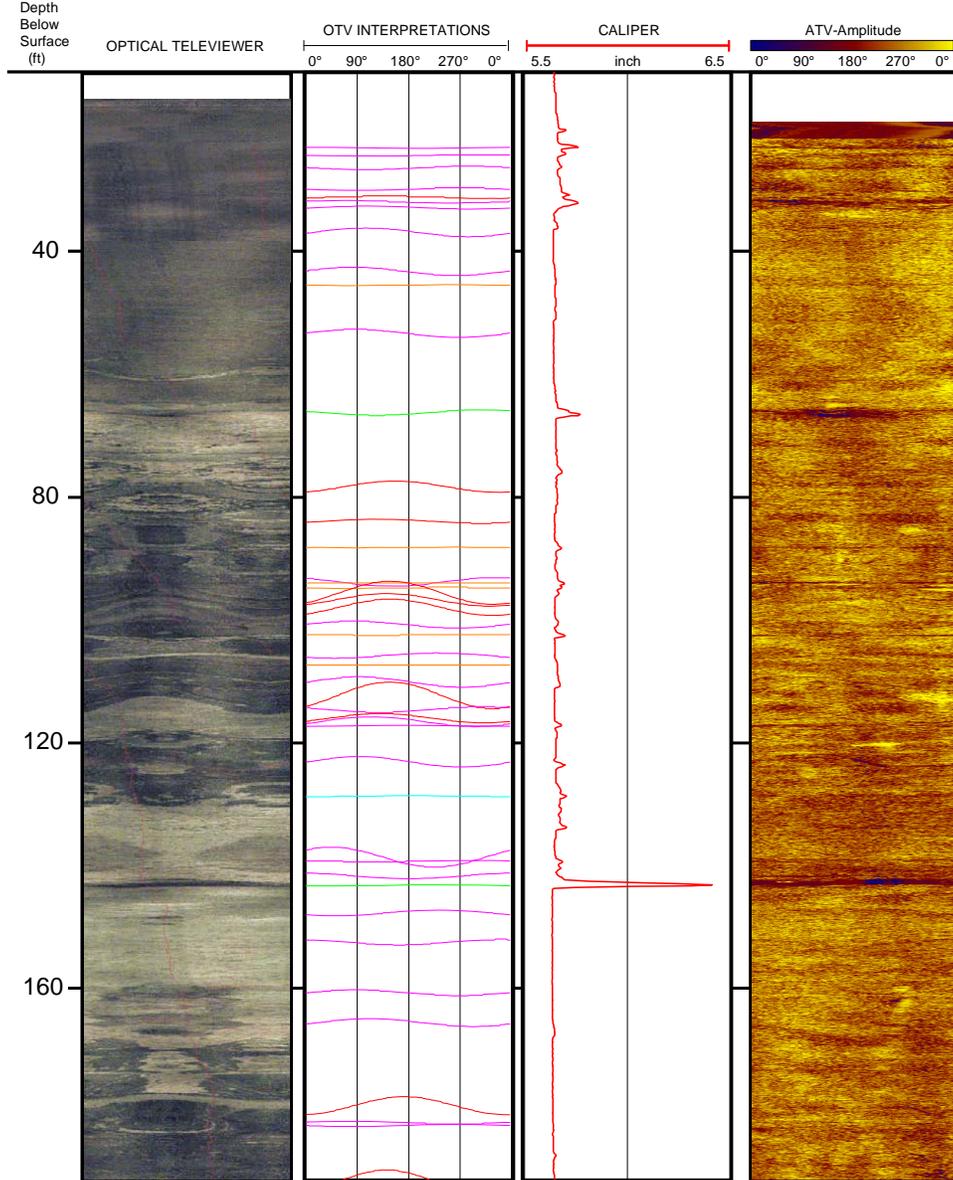
Site ID: har1.060407  
 Location: "Trail Ridge" Harvard, MA  
 Elevation (m) 130  
 Reported Yield (gpm) 3  
 Rock Type: Schist  
 Depth to water: 18.5 ft 5.64 m  
 Depth of casing: 19 ft 5.79 m  
 Depth of well: 560 ft 170.69 m  
 Land surface to MP: 3.95 ft 1.20 m

Number	Fractures					Ambient			Pump at 0.5 gpm		
	Depth (m)	Depth (ft)	Azimuth	Dip	Type	Flow (y/n)	gpm (amb)	notes	Flow (y/n)	gpm (pump)	notes
1	7.1	23.2	107	26	t	n	0		n	0.36	
2	7.4	24.4	24	37	t	n	0		n	0.36	
3	8.0	26.4	14	59	t	n	0		n	0.36	
4	9.1	29.9	0	50	t	n	0		n	0.36	
5	9.5	31.2	228	48	p	n	0		n	0.36	
6	9.7	32.0	159	44	t	n	0		n	0.36	
7	10.0	32.9	200	58	t	n	0		n	0.36	
8	11.2	36.9	194	77	t	n	0		n	0.36	
9	13.2	43.3	172	76	t	n	0		n	0.36	
10	13.9	45.5	347	20	s	n	0		n	0.36	
11	16.3	53.4	176	76	t	n	0		n	0.36	
12	20.2	66.3	34	69	t	y	-0.08	flow in	y	0.36	flow in
13	23.9	78.3	246	80	p	n	-0.08		n	0.1	
14	25.6	83.9	216	64	p	n	-0.08		n	0.1	
15	26.9	88.2	351	17	s	n	-0.08		n	0.1	
16	28.6	93.9	60	77	t	n	-0.08		n	0.1	
17	28.6	94.0	215	7	s	n	-0.08		n	0.1	
18	28.9	94.8	338	19	s	n	-0.08		n	0.1	
19	29.1	95.6	237	85	p	n	-0.08		n	0.1	
20	29.5	96.8	232	81	p	n	-0.08		n	0.1	
21	29.9	98.0	237	83	p	n	-0.08		n	0.1	
22	30.7	100.8	174	74	t	n	-0.08		n	0.1	
23	31.2	102.5	34	20	s	n	-0.08		n	0.1	
24	32.3	105.8	319	69	t	n	-0.08		n	0.1	
25	32.7	107.3	31	14	s	n	-0.08		n	0.1	
26	33.6	110.1	183	79	t	n	-0.08		n	0.1	
27	34.2	112.3	237	86	p	n	-0.08		n	0.1	
28	34.9	114.6	38	70	t	n	-0.08		n	0.1	
29	35.4	116.0	221	78	p	n	-0.08		n	0.1	
30	35.5	116.6	206	78	t	n	-0.08		n	0.1	
31	35.7	117.2	267	25	s	n	-0.08		n	0.1	
32	37.5	123.1	183	79	t	n	-0.08		n	0.1	
33	39.2	128.7	275	22	s	n	-0.08		y	0.1	flow in
34	42.2	138.6	135	84	t	n	-0.08		n	0	
35	42.5	139.3	28	26	t	n	-0.08		n	0	
36	43.2	141.7	90	70	t	n	-0.08		n	0	
37	43.6	143.2	323	39	t	n	-0.02	flow out	y	-0.07	flow in
38	45.0	147.7	322	71	t	n	-0.02		n	-0.07	
39	46.5	152.5	73	69	t	n	-0.02		n	-0.07	
40	49.0	160.7	177	70	t	n	-0.02		n	-0.07	
41	50.5	165.6	202	75	t	n	-0.02		n	-0.07	
42	54.6	179.1	262	84	p	n	-0.02		n	-0.07	
43	55.4	181.8	170	53	t	n	-0.02		n	-0.07	
44	55.6	182.3	352	53	t	n	-0.02		n	-0.07	
45	58.4	191.7	231	85	p	n	-0.02		n	-0.07	
46	58.9	193.2	230	85	p	n	-0.02		n	-0.07	
47	69.1	226.9	343	58	t	n	-0.02		n	-0.07	

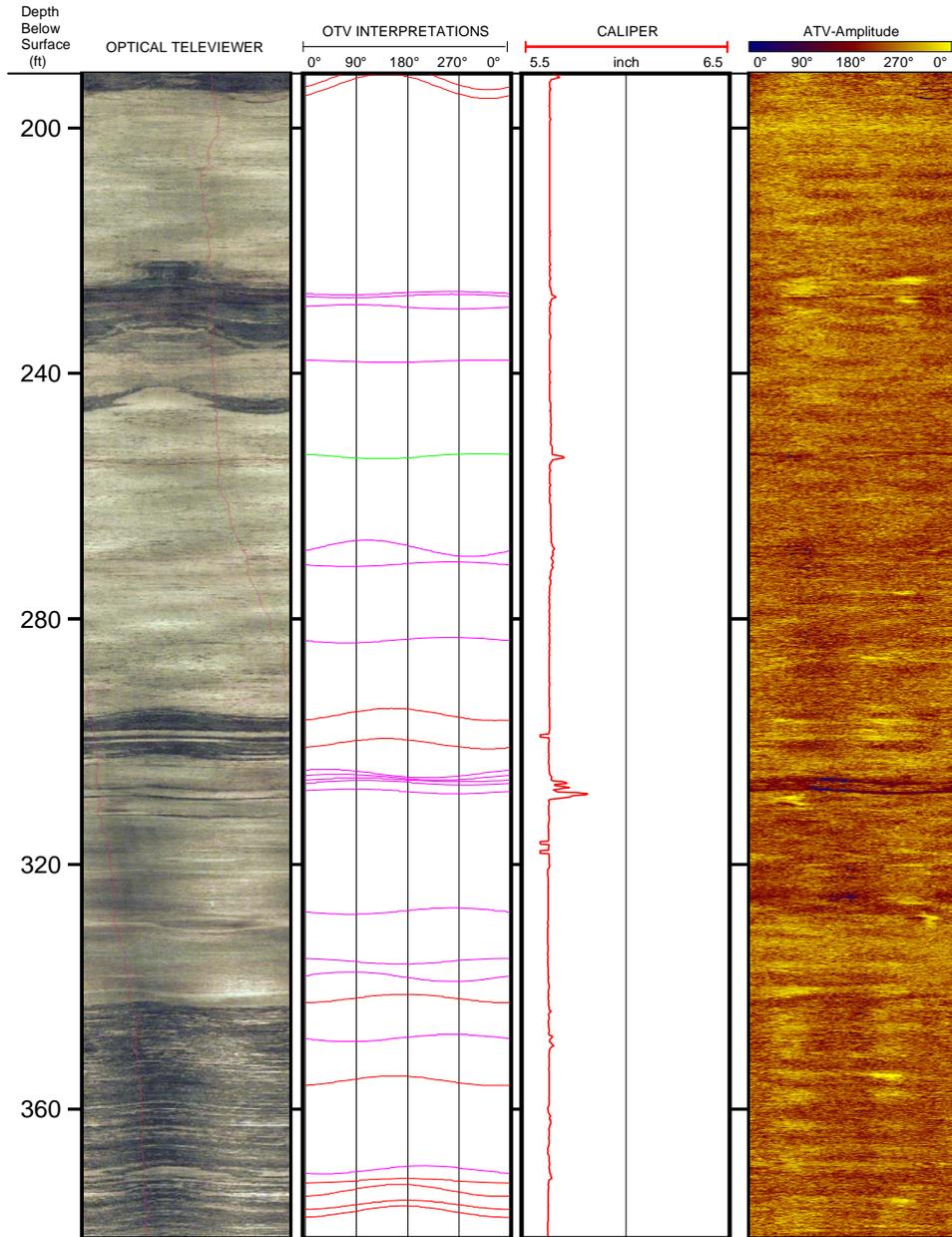
**Appendix 9, continued.** Midpoint depth, strike and dip of features identified in optical televiewer log, fracture type and heat pulse flowmeter data from Har 1 (azimuth and dip reported using right hand rule convention; t = tectonic fractures, s = sheeting joints, p = foliation parallel fractures). Data shown under the pumping test have been normalized.

48	69.3	227.4	346	63	t	n	-0.02	n	-0.07	
49	69.9	229.2	175	65	t	n	-0.02	n	-0.07	
50	72.5	238.0	58	53	t	n	-0.02	n	-0.07	
51	77.3	253.5	41	68	t	n	-0.009	flow out	n	-0.07
52	81.8	268.5	199	83	t	n	-0.009	n	-0.07	
53	82.6	271.1	344	66	t	n	-0.009	n	-0.07	
54	86.4	283.5	343	70	t	n	-0.009	n	-0.07	
55	90.1	295.6	242	81	p	n	-0.009	n	-0.07	
56	91.6	300.4	230	79	p	n	-0.009	n	-0.07	
57	93.0	305.3	125	77	t	n	-0.009	n	-0.07	
58	93.2	305.8	146	71	t	n	-0.009	n	-0.07	
59	93.4	306.3	182	63	t	n	-0.009	n	-0.07	
60	93.5	306.8	193	67	t	n	-0.009	n	-0.07	
61	93.9	308.2	173	67	t	n	-0.009	n	-0.07	
62	99.9	327.7	348	73	t	n	-0.009	n	-0.07	
63	102.3	335.8	78	71	t	n	-0.009	n	-0.07	
64	103.1	338.4	169	78	t	n	-0.009	n	-0.07	
65	104.2	341.9	264	76	p	n	-0.009	n	-0.07	
66	106.2	348.4	348	74	t	n	-0.009	n	-0.07	
67	108.3	355.4	247	78	p	n	-0.009	n	-0.07	
68	112.7	369.9	299	76	t	n	-0.009	n	-0.07	
69	113.3	371.7	266	65	p	n	-0.009	n	-0.07	
70	113.8	373.2	254	80	p	n	-0.009	n	-0.07	
71	114.5	375.6	269	77	p	n	-0.009	n	-0.07	
72	114.8	376.7	262	80	p	n	-0.009	n	-0.07	
73	119.8	393.1	38	27	t	n	-0.009	n	-0.07	
74	121.5	398.8	260	68	p	n	-0.009	n	-0.07	
75	125.4	411.6	114	37	t	n	-0.009	n	-0.07	
76	128.8	422.5	346	76	t	n	-0.009	γ	-0.07	flow out
77	129.2	423.8	28	73	t	n	-0.009	n	-0.03	
78	131.2	430.6	133	74	t	n	-0.009	n	-0.03	
79	140.7	461.5	281	74	p	n	-0.009	n	-0.03	
80	141.4	463.8	105	53	t	n	-0.009	γ	-0.03	flow out
81	154.3	506.1	255	81	p	n	-0.009	n	0	
82	162.3	532.5	134	73	t	n	-0.009	n	0	
83	166.9	547.5	231	69	p	n	-0.009	n	0	
84	167.1	548.2	220	77	p	n	-0.009	n	0	
85	167.9	550.8	131	68	t	n	-0.009	γ	0	
86	168.2	551.9	325	71	t	n	-0.009	n	0	
87	168.3	552.2	103	60	t	n	-0.009	n	0	
88	168.5	552.7	243	83	p	n	-0.009	n	0	
89	168.8	553.7	100	46	t	n	-0.009	n	0	

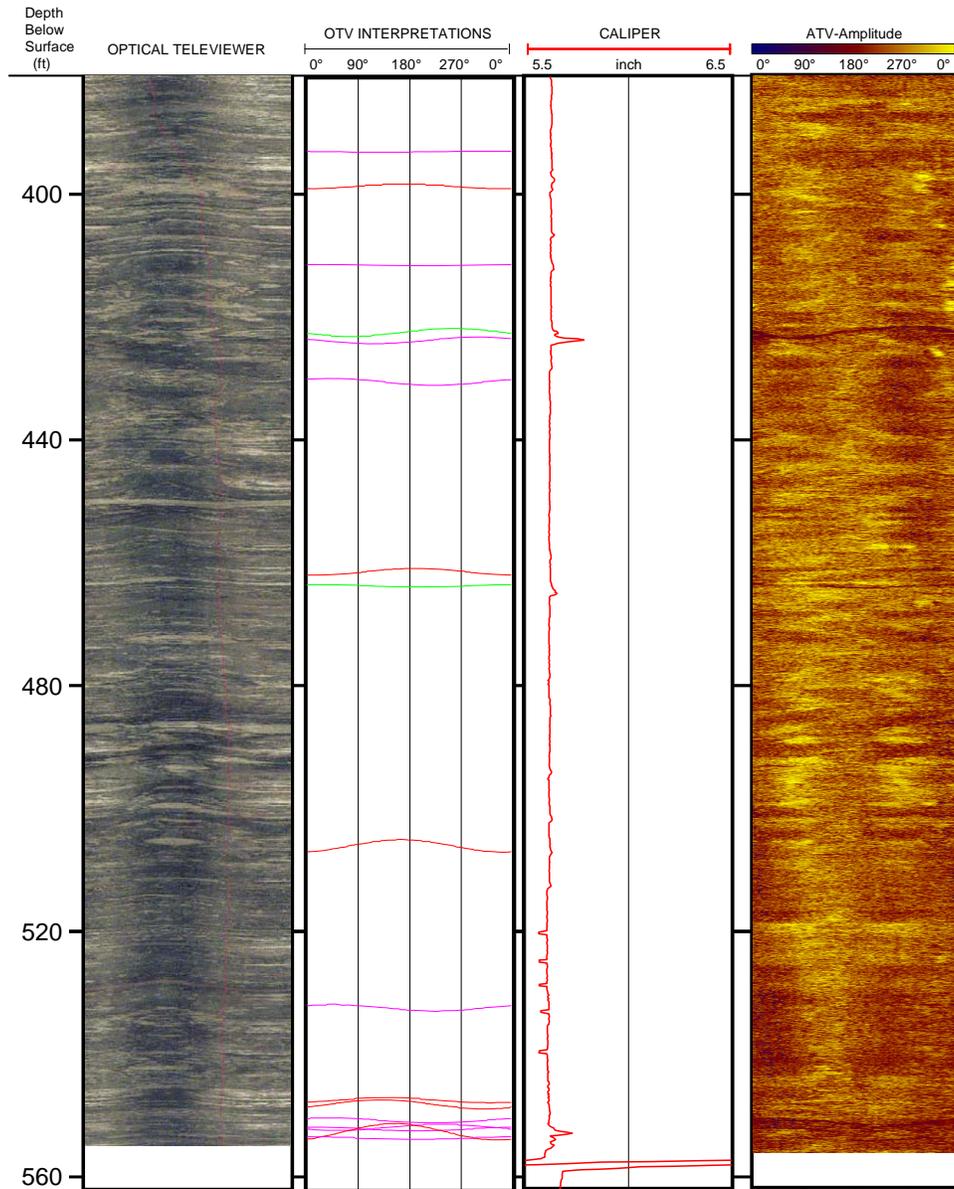
**Appendix 9, continued.** Interpreted features for Har 1. Optical televiewer interpretations indicated by color: orange – subhorizontal sheeting joint; magenta – tectonic joint; red – foliation parallel fracture (FPF); cyan – transmissive subhorizontal sheeting joint; green – transmissive tectonic joint; grey – transmissive foliation parallel fracture (FPF). OTV – optical televiewer; ATV – acoustic televiewer.



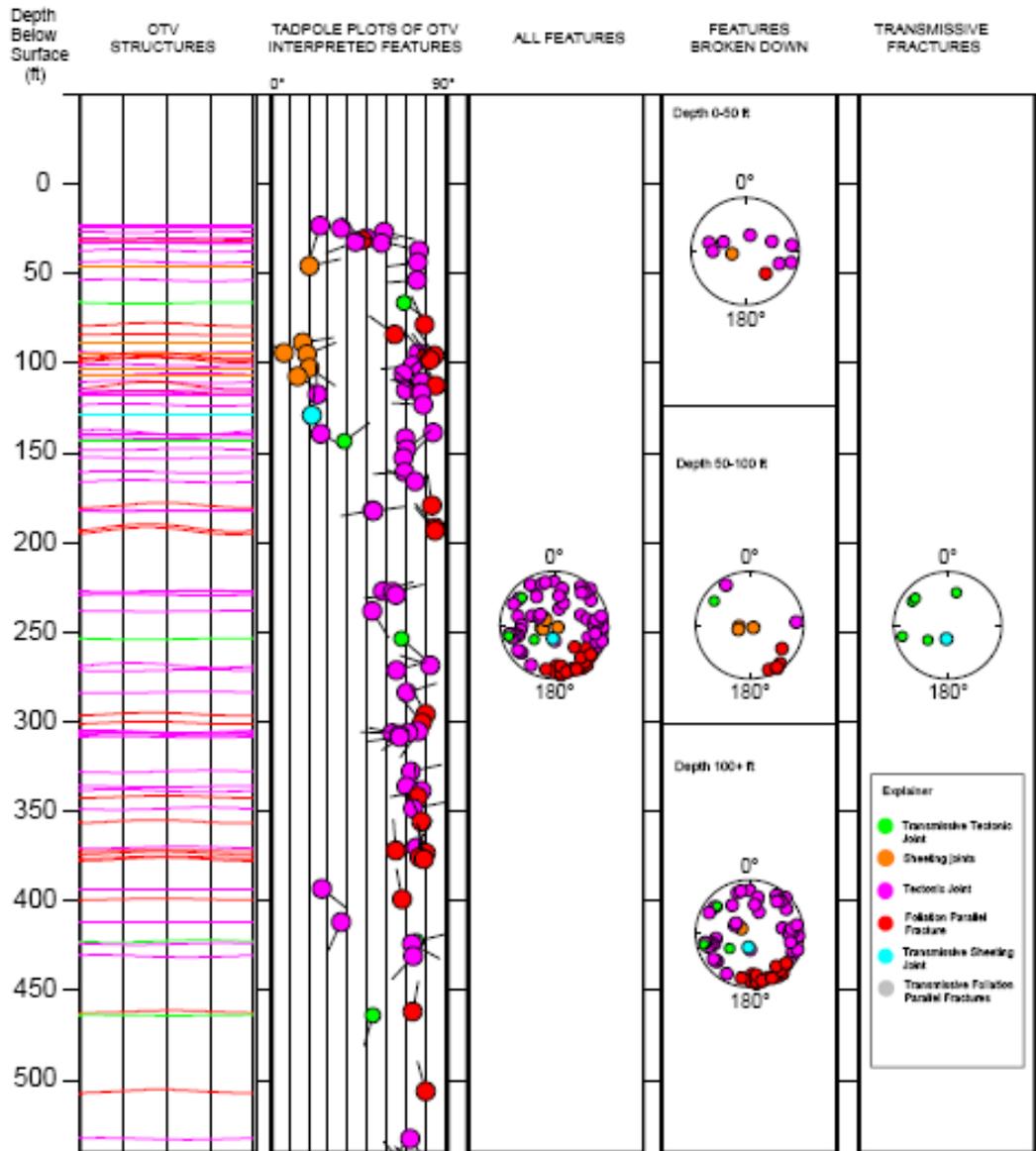
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**Appendix 9, continued.** Tadpole plots and stereoplots of interpreted optical televiewer (OTV) structures for Har 1. In the tadpole plot depth is plotted along the y-axis and magnitude of the dip plotted on the x-axis. The tail of the tadpole points in the direction of the dip, relative to true north, which is toward the top of the page. The stereonets represent poles to planar features plotted on a lower-hemisphere equal-area stereonet. Stereonets use right hand rule convention. Colors on the OTV structures plot correspond to those in the tadpole explanation.



**Appendix 9, continued.** Composite log for Har 1 of natural gamma, fluid resistivity, fluid temperature and heat pulse flowmeter data under ambient and stressed (pumping) conditions. For the heat pulse flowmeter data collected under pumping conditions, the well was pumped at 0.5 gallons per minute and data have been normalized.

