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32. *DATA REPORT:* ANISOTROPY OF MAGNETIC SUSCEPTIBILITY OF A SET OF SAMPLES FROM THE CASCADIA MARGIN[1]

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INTRODUCTION

This paper reports measurements of anisotropy of magnetic susceptibility made on samples collected on Ocean Drilling Program (ODP) Leg 146 by B. Clennell, a member of the shipboard party. The samples were collected primarily for the purpose of studying scaly fabric and thus represent a subset rather than a comprehensive suite of the material encountered in coring. Leg 146 drilling took place in two areas of the Cascadia margin: Sites 888–890 on the Vancouver Island Margin, and Sites 891 and 892 on the Central Oregon Margin. From the Vancouver Island Margin, measurements have been made on four samples (from Hole 889A); from the Central Oregon Margin, results are presented for 13, 15, 20, and 2 samples from Holes 891B, 892A, 892D, and 892E, respectively.

MEASUREMENT TECHNIQUES

Samples were prepared by B. Clennell and mounted in standard plastic cubes of nominal volume (7 cm^3). Measurements of magnetic susceptibility and susceptibility anisotropy were made on a modified Molspin Minisep system. In this system, one instrument, using coaxial drive and sensor coils, is used to measure axial susceptibility; susceptibility differences are measured on a separate instrument, using orthogonal drive and sensor coils. The nominal field strength applied is 0.7 mT and the drive frequency is 10 kHz. Since the susceptibility differences encountered in the samples were often small, particular care was taken during measurement to estimate and correct for noise arising from the sample holder.

Sample remanence was measured in the hope that the samples might thereby be oriented; a 2G cryogenic magnetometer in the Department of Oceanography, University of Southampton, measured remanence and alternating-field demagnetization (in fields of up to 40 mT). However, as a means of sample reorientation, the remanence measurements proved unsatisfactory and the results are not reported here. At least two reasons can be offered for this failure. First, Westbrook, Carson, Musgrave, et al. (1994) comment on the widespread occurrence of magnetic sulfides and their unsatisfactory response to alternating-field demagnetization. Thermal demagnetization of the present samples, which may have been more successful but would inevitably have induced thermal alteration, was precluded since the samples were to be used in other studies. Second, components of the magnetic mineralogy of the samples are unstable in the atmosphere and significant changes to the remanence may have occurred between drilling and measurement.

MAGNETIC SUSCEPTIBILITY ANISOTROPY

Anisotropic magnetic susceptibility is a second-rank, symmetric tensor and thus involves six independent quantities. In Table 1, the tensor is specified in terms of its three principal susceptibilities (maximum, k_{max}, intermediate, k_{int}, and minimum, k_{min}) and the orientation of the three corresponding orthogonal principal axes. In the absence of core orientation data (as is the general case for the data reported here), directions can only be specified relative to the core reference frame (where a direction of 0° azimuth and 0° dip points horizontally into the archive half of the core). However, for the piston cores from Hole 889A, Multishot data are available for core orientation (Westbrook, Carson, Musgrave, et al., 1994, table 5, p. 170); for samples from this hole, corrected axis directions (relative to north) are included, in italics, in Table 1.

Table 1 also quotes values for a previously used (Owens, 1993) set of susceptibility parameters. These are the mean susceptibility, k_{mean}, and two other parameters, H and μ, which convey, respectively, indications of the strength of the magnetic fabric and of the "shape" of the fabric:

$$k_{mean} = (k_{max} + k_{int} + k_{min})/3.$$

$$H = (k_{max} - k_{min})/k_{mean}\ \%.$$

$$\mu = \tan^{-1}[(k_{max} - k_{int})/(k_{int} - k_{min})].$$

The parameter H is defined as the difference between the maximum and minimum susceptibilities, expressed as a percentage of the mean susceptibility. The parameter μ expresses, as an angle, the slope of a line from the origin to a point on a graph plotting the maximum/intermediate susceptibility difference against the intermediate/minimum susceptibility difference. (Thus, for an oblate fabric $\mu = 0°$ and for a prolate fabric $\mu = 90°$.)

RESULTS AND CONCLUSIONS

In Table 1 principal susceptibilities are quoted to 10^{-7} (SI units) and principal axis directions to 0.1°. This precision is not warranted in an absolute sense—for example, axial susceptibilities, to which susceptibility differences are added to obtain the quoted principal axis values, can be measured, relative to a calibrating sample, to about 2×10^{-6}, or 4×10^{-4} times the susceptibility, whichever is the greater. This precision is employed to maintain the relative accuracy of the susceptibility differences. These are obtained from the orthogonal coil instrument, and are precise, for the weaker samples, to some parts in 10^{-7}. (The ODP convention of quoting depths below seafloor to centimeters, is based on a comparable principle.) Similar considerations apply to preserving the relative orthogonality of the principal axis directions; by contrast the "subjective accuracy estimate" quoted

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Table 1. Magnetic susceptibility anisotropy measurements.

			Principal susceptibilities									Anisotropy parameters		
Core, section, interval (cm)	Depth (mbsf)	Sample volume (cm^3)	Maximum ($\times 10^{-6}$)	Azimuth (°)	Dip (°)	Intermediate ($\times 10^{-6}$)	Azimuth (°)	Dip (°)	Minimum ($\times 10^{-6}$)	Azimuth (°)	Dip (°)	Mean susceptibility	H %	μ (°)
146-889A-														
10H-5, 57–63	110.24	6.6	1389.21	36.5	64.8	1315.78	335.4	-12.8	1278.27	70.5	-21.3	1327.75	8.4	63
					227.5	*64.8*		*166.4*	*-12.8*		*261.5*	*-21.3*		
11H-2, 0–11(a)	114.93	5.9	2295.12	188.6	42.4	2213.00	96.2	2.6	2134.45	183.4	-47.4	2214.19	7.3	46
					203.6	*42.4*		*111.2*	*2.6*		*198.4*	*-47.4*		
11H-2, 0–11(b)	114.93	6.6	2337.18	155.9	–40.7	2299.93	61.3	-5.3	2144.70	325.2	-48.9	2260.61	8.5	13
					170.9	*–40.7*		*76.3*	*-5.3*		*340.2*	*-48.9*		
12H-5, 123–138	125.27	6.6	165.23	95.7	–26.7	164.54	0.9	-9.5	162.35	252.9	-61.4	164.04	1.8	18
					341.7	*–26.7*		*246.9*	*-9.5*		*138.9*	*-61.4*		
146-891B-														
33X-1, 32–34	260.52	4.4	2640.43	87.7	35.2	2535.47	5.5	-10.9	2458.13	110.1	-52.6	2544.67	7.2	54
33X-1, 64–66	260.84	6.1	4438.42	216.0	82.5	4247.38	179.5	-6.0	4150.92	270.0	-4.4	4278.91	6.7	63
35X-1, 77–79	269.77	2.0	2131.28	45.3	–32.6	2102.67	310.7	-7.1	2064.05	209.9	-36.4	2099.33	3.2	37
37X-1, 10–12(a)	278.90	6.6	271.78	49.3	–39.6	267.96	115.4	26.2	261.67	1.7	39.2	267.13	3.8	31
37X-1, 10–12(b)	278.90	6.6	267.14	70.2	–61.9	265.76	103.1	24.1	265.07	7.0	13.5	265.99	0.8	63
38X-2, 50–52	288.37	6.0	2139.34	73.9	–23.2	2115.70	344.5	1.4	2008.48	257.7	-66.8	2087.84	6.3	12
42X1, 113–116	322.73	6.0	3519.31	146.9	42.3	3472.35	31.1	25.6	3183.50	100.0	-36.9	3391.72	9.9	9
43X-2, 108–111	331.76	5.8	4906.54	294.2	–43.0	4705.85	87.6	-43.7	4425.54	11.0	13.7	4679.31	10.3	36
43X-2, 139–142	332.07	6.2	4139.80	117.6	–0.9	4077.75	27.0	-34.5	3913.26	208.9	-55.5	4043.60	5.6	21
52X-1, 99–101	411.49	6.0	3704.06	206.8	54.4	3595.08	32.8	35.4	3554.33	120.8	-2.9	3617.82	4.1	69
55X-1, 8–9	437.08	3.5	4804.17	68.0	–35.7	4716.56	337.6	-0.5	4618.46	246.9	-54.3	4713.07	3.9	42
55X-3, 15–17	439.33	6.6	850.32	299.4	38.3	824.74	290.3	-51.3	795.86	25.8	-4.4	823.64	6.6	42
56X-1, 64–66	446.44	6.4	834.66	145.9	–17.0	792.02	52.6	-10.8	737.95	291.6	-69.7	788.21	12.3	38
146-892A-														
1X-1, 48–50	0.48	6.4	165.17	202.4	–4.6	164.52	112.6	2.2	162.13	47.8	-84.9	163.94	1.9	15
1X-2, 55–57	2.05	6.6	129.09	54.1	–1.5	128.81	324.2	5.6	126.41	309.3	-84.2	128.10	2.1	7
3X3, 68–72	22.68	6.4	165.43	207.3	–1.7	164.17	116.1	-35.4	162.97	299.6	-54.5	164.19	1.5	46
3X-3, 82–84	22.82	5.6	145.95	139.6	6.0	144.77	48.8	7.9	143.17	86.4	-80.0	144.63	1.9	36
4X-2, 25–27	29.77	6.4	137.57	158.5	1.7	136.18	68.6	-3.1	133.82	220.2	-88.5	135.86	2.8	30
6X-4, 110–113	44.64	6.6	97.55	184.2	–8.3	96.43	91.7	-16.6	95.67	299.9	-71.4	96.55	1.9	56
7X-2, 46–48	50.48	6.6	124.75	184.8	–8.3	124.11	93.6	-8.4	122.55	318.9	-78.1	123.81	1.8	22
7X-2, 81–83	50.83	6.6	159.90	207.8	10.2	159.70	123.5	-28.9	153.93	280.4	-59.0	157.84	3.8	2
7X-3, 123–128(a)	52.75	6.0	210.72	84.6	22.9	209.21	355.2	-1.3	202.84	88.3	-67.1	207.59	3.8	13
7X-3, 123–128(b)	52.75	6.6	212.66	46.8	24.0	211.63	337.6	-38.5	206.71	293.2	54.9	210.33	2.8	12
8X-1, 61–64	58.61	6.6	194.22	228.3	35.9	193.34	133.1	7.2	189.39	213.4	-53.2	192.31	2.5	13
8X-1, 136–139	59.36	6.6	181.63	0.6	–6.0	178.00	258.7	-62.8	177.13	93.6	-26.8	178.92	2.5	77
8X-3, 121–123	62.28	6.6	171.30	140.0	29.6	170.62	63.5	-22.4	170.23	184.6	-51.4	170.72	0.6	60
8X-4, 128–130	63.82	6.6	168.66	37.9	–4.6	166.40	156.6	-80.5	164.16	127.2	8.3	166.41	2.7	45
8X-5, 49–51	64.53	6.6	146.84	246.1	–23.9	145.93	117.4	-54.7	142.93	347.7	-24.3	145.23	2.7	17
146-892D-														
5X-4, 46–49(a)	42.02	6.3	160.89	213.5	20.6	160.59	308.1	12.1	158.08	66.5	65.8	159.85	1.8	7
5X-4, 46–49(b)	42.02	6.2	170.28	277.4	22.9	169.78	191.2	-8.8	167.57	300.8	-65.2	169.21	1.6	13
5X-4, 52–56(a)	42.08	6.6	273.17	157.1	–5.2	272.56	69.6	25.3	271.52	56.4	-64.1	272.42	0.6	31
5X-4, 52–56(b)	42.08	6.6	306.94	170.3	–20.4	305.96	86.4	16.0	305.81	31.8	-63.6	306.23	0.4	81
6X-1, 97–100	47.47	6.6	137.63	133.8	10.9	137.11	42.1	8.7	135.93	94.4	-76.0	136.89	1.2	24
6X-5, 60–63(a)	52.88	6.6	113.71	185.9	14.5	113.33	279.9	15.1	111.50	54.0	68.9	112.84	2.0	12
6X-5, 60–63(b)	52.88	6.4	106.91	238.3	15.0	106.62	150.4	-7.6	104.40	266.4	-73.1	105.98	2.4	7
7X-4, 78–82(a)	58.94	6.6	85.54	115.4	–21.6	85.31	203.2	5.7	84.26	99.1	67.6	85.03	1.5	12
7X-4, 78–82(b)	58.94	6.6	87.18	155.3	–9.8	86.99	63.4	-10.8	85.65	286.6	-75.3	86.61	1.8	8
7X-5, 8–11(a)	59.76	6.6	160.77	285.1	32.1	159.20	4.5	-16.3	157.50	71.6	53.0	159.16	2.1	43
7X-5, 8–11(b)	59.76	6.6	168.08	124.6	–24.2	166.83	213.0	3.5	164.35	115.2	65.5	166.42	2.2	27
7X-5, 26–29	59.94	6.6	153.34	205.2	8.4	152.37	119.0	-24.4	150.04	277.7	-64.0	151.92	2.2	22
8X-3, 27–30(a)	64.74	6.3	183.02	56.8	–20.7	182.68	155.4	-21.8	178.78	107.5	59.2	181.49	2.3	5
8X-3, 27–30(b)	64.74	6.6	179.63	115.9	–22.2	178.94	206.9	-2.4	176.42	122.8	67.7	178.33	1.8	15
9X-1, 26–30	69.56	6.4	172.89	86.6	–34.3	172.32	342.2	-20.1	170.92	227.6	-48.7	172.04	1.1	22
10X-6, 56–59	106.88	6.4	261.76	157.7	–45.0	260.25	240.1	7.5	257.78	142.8	44.1	259.93	1.5	32
10X-6, 109–112	107.33	6.6	178.35	64.8	62.4	176.23	11.7	-17.4	173.71	108.5	-20.7	176.10	2.6	40
10X-8, 45–50(a)	109.77	6.4	173.53	352.9	60.7	173.16	100.8	9.8	168.54	196.0	27.3	171.74	2.9	5
10X-8, 45–50(b)	109.77	6.6	178.01	236.3	–43.5	177.69	127.6	-18.6	173.87	20.8	-40.6	176.52	2.3	5
12X-3, 60–63	122.63	6.6	149.77	145.8	–0.8	149.33	55.5	-20.4	148.21	238.0	-69.6	149.10	1.0	22
146-892E-														
3H-4, 109–112	37.72	6.6	144.05	140.4	8.1	142.29	49.2	8.6	140.25	93.1	-78.1	142.20	2.7	41
3H-4, 122–124	37.95	6.6	135.21	192.0	–0.7	134.69	102.1	9.2	132.52	97.6	-80.8	134.14	2.0	13

Note: Directions = core reference frame in normal type; multishot-corrected in italics; (a) and (b) = duplicate specimens within interval.

for Multishot data is 20°–30° (Westbrook, Carson, Musgrave, et al., 1994, p. 30).

At a number of depths, duplicate samples have been measured (see Table 1). In general, there is good agreement between pairs of samples, which attests to the quality of the sample preparation and the reliability of the measurements. (The major discrepancy, between samples from the interval 0–11 cm in Section 146-889A-11H-2, may be real, since the sediments were identified as heterogeneous gravity-flow deposits [Westbrook, Carson, Musgrave, et al., 1994, p. 154].)

A full interpretation of these data awaits the integration of the magnetic measurements with the results of other studies on the samples. Features worthy of note but not discussed here, nor related to the observations in the *Initial Reports* volume, Leg 146 (Part 1), include the following:

1. The contrast between the relatively high and variable values of mean susceptibility seen in Holes 889A and 891B and the relatively low and consistent values obtained from Site 892.
2. The wide range in orientation, style, and strength of the magnetic fabrics encountered. They are, for example, considerably more varied than those reported from the Nankai accretionary prism (Owens, 1993).

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