SUB-TILL VARVE SITE, OLYPHANT, PA (OLY)
Dec. 2007-Jan. 2008

Location

Olyphant, PA 7.5-minute Quadrangle. East of "new" US 6 between exits 1 and 2.
Latitude: 41º26´44´´ Longitude: 76º34´23´´

Stratigraphy

Recorded by Duane Braun, December, 2007 at excavation of site for mine fire reclamation.

Thickness (m)	Lithology
TOP	
10+	Compact, stony, silty till
2-3	Varves deforming by overriding ice
2-3	Layered diamicton, debris flow-dominated zone, a few clay drapes, and a few regular clay-silt varves between flow units.
0.2-0.3	5-10 varves, abundant dropstones, some deformation of layering by overriding ice or mass flow.
0.02-0.04	**Upper sample zone (OLY1)**. 3-5 varves, thin silt laminations separating clay beds. Samples tend to split along upper surface of silt layers. Dropstones and dark gray diamicton pellets abundant. 12 samples kept out of 20 attempted, 8 discarded with dropstones visible on one or more sides.
0.67	30-50 varves, mostly 0.25-0.5 cm silt (summer) layers with 2-cm clay (winter) layers.
0.02-0.04	**Middle sample zone (OLY2)**. 3-5 varves, thin silt laminations separating clay beds. Fewer dropstones than above but dark gray diamicton pellets still abundant. 12 samples kept out of 16 attempted, 4 discarded with dropstones visible on one or more sides.
0.8	Up to 50 varves. Clay beds separated by silty laminations.
0.03-0.04	**Lower sample zone (OLY3)**. 4-5 varves with thin silt beds separating clay beds. Fewer dropstones than above but dark gray diamicton pellets still abundant. 12 samples kept out of 15 attempted, 3 discarded with dropstones visible on one or more sides.
5+	Varves with 0.5-2 cm thick couplets. Clay and silt varves.
BOTTOM	

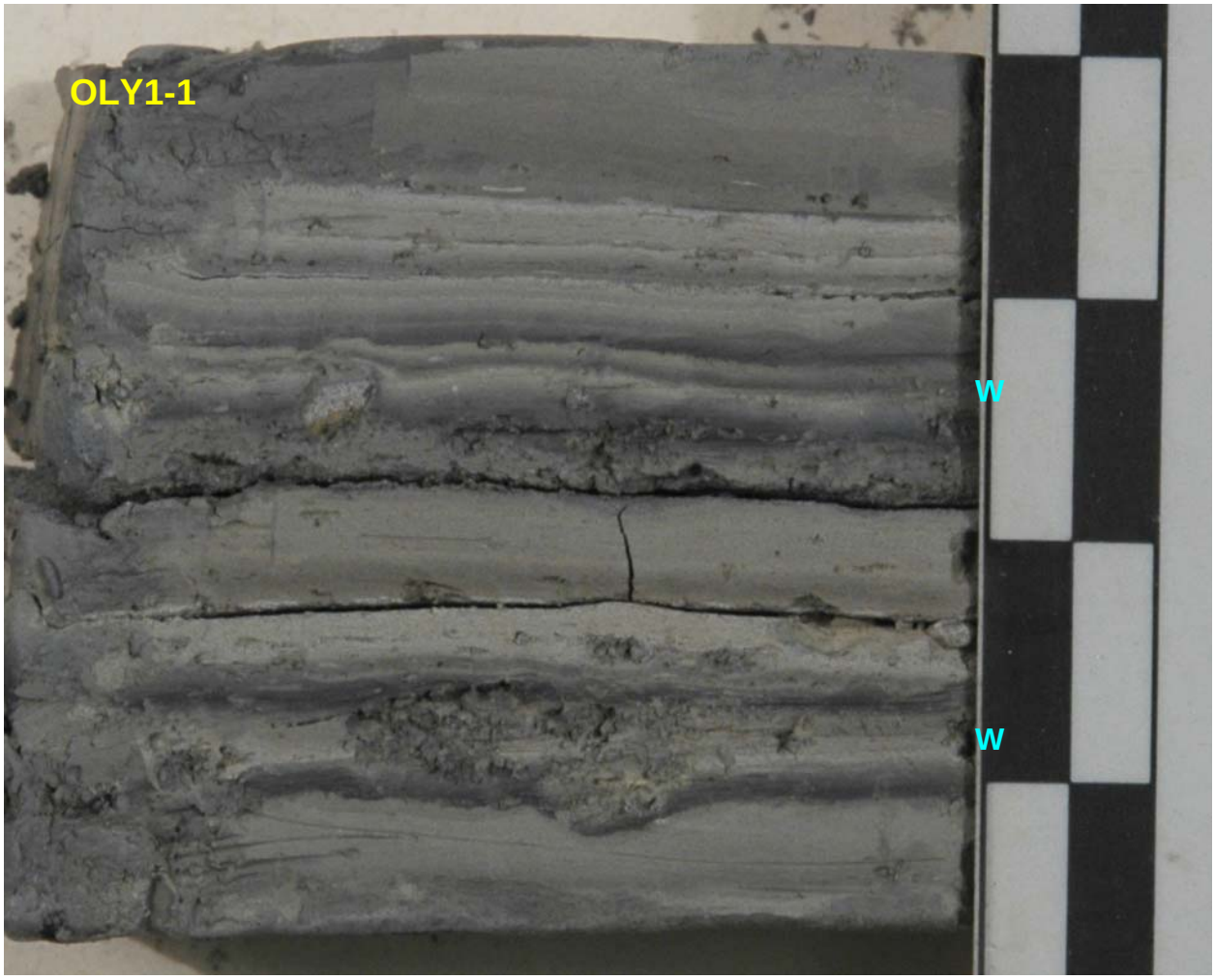
General note: The entire varve section is undulating, rising and falling 10's of cm over several meters of exposure. Undulation may be due to underlying dropstones, 1-4 meters in diameter, combined with compaction of section. Several large dropstones were exposed elsewhere in pit and were Pottsville conglomerate or Pocono Sandstone joint blocks.

Varve Stratigraphy

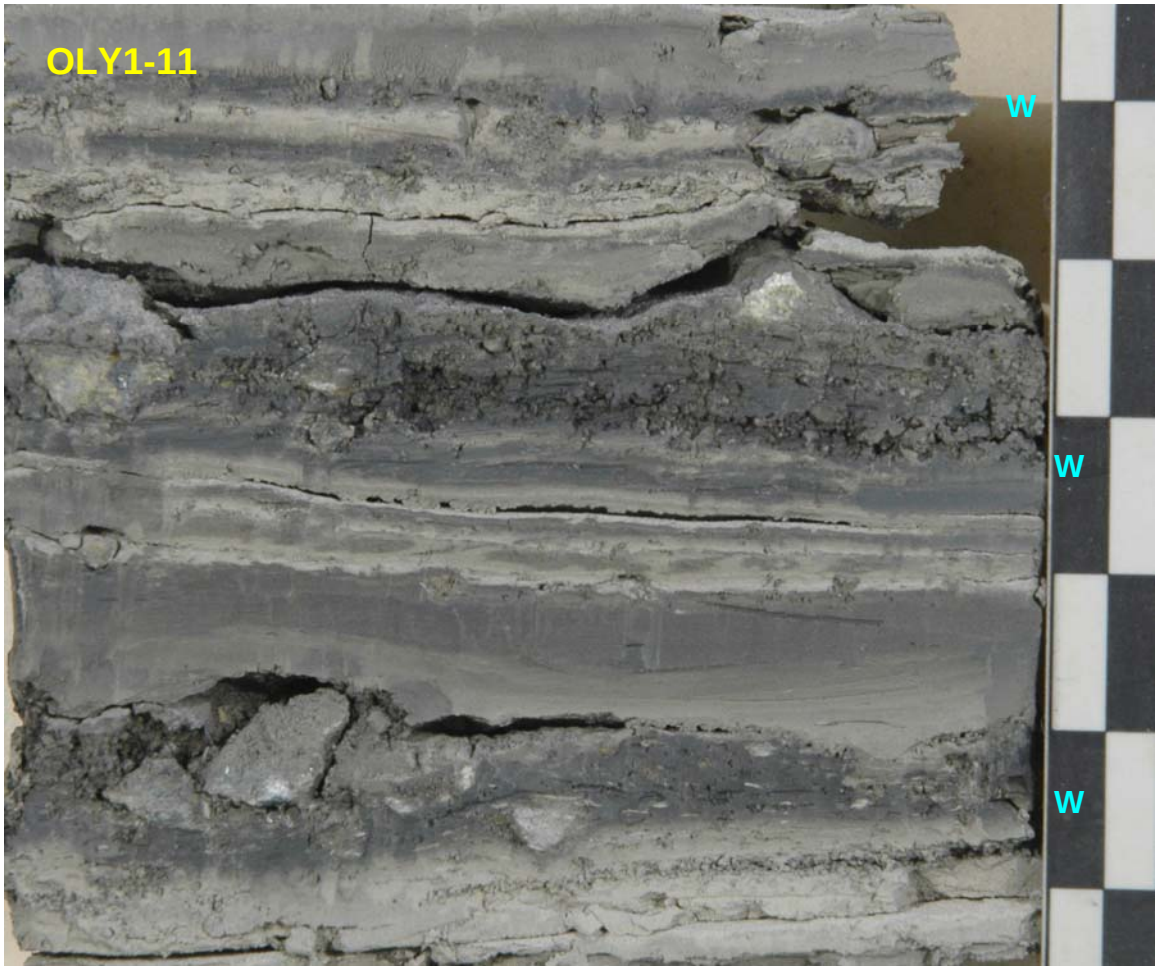
In the following images are close-up views of the varves in paleomagnetic samples from the Olyphant section. The samples were imaged from the sides waste blocks from paleomagnetic samples. Each imaged surface was carefully scraped with a razor knife and then partially dried to produce a contrast between clay (dark) and silt/sand (light) layers.

Samples from OLY1

Samples from the top-most (most ice-proximal) sample interval contain abundant drop sediment, especially dark gray to black diamicton pellets. Clay beds in these varves, which are interpreted as winter layers (W), are generally very dark gray to black and thin, and are disrupted by many silt and fine sand layers. The clay beds, sometimes split by light silt beds, also have many flecks of white silt that is drop sediment in the form of flattened fine sand to silt pellets composed of rock flour. The varves also have disturbed bedding in many places as exemplified in OLY1-6, which contains a fold (top middle) and set of small en echelon faults. The faults are related to differential compaction and deformation by overriding ice while the fold may be a product of mass movement. Beds in these varves do not have a uniform thickness as there appear to be intra-varve erosion surfaces and many bedding disturbances due to mass movement.

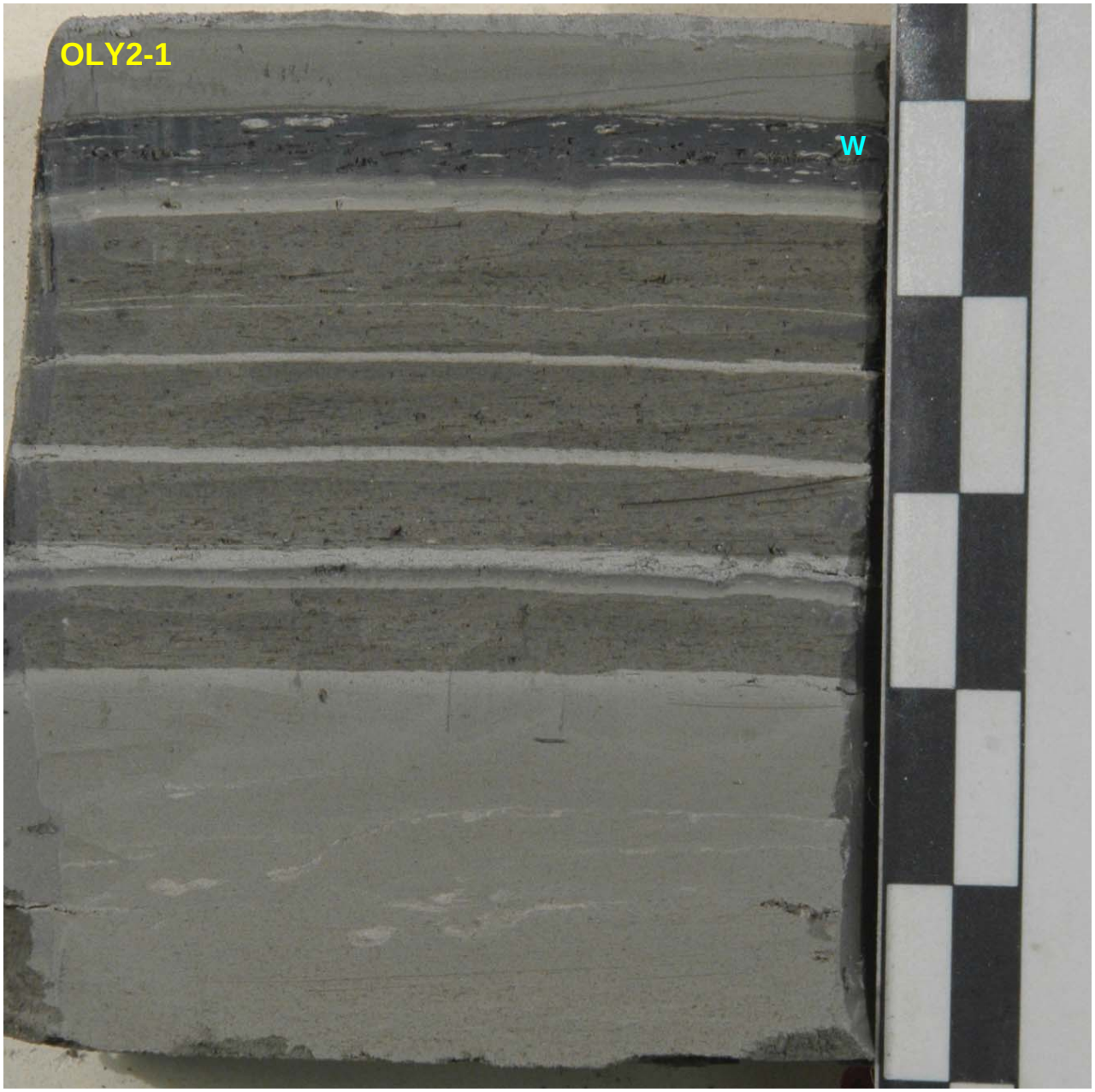


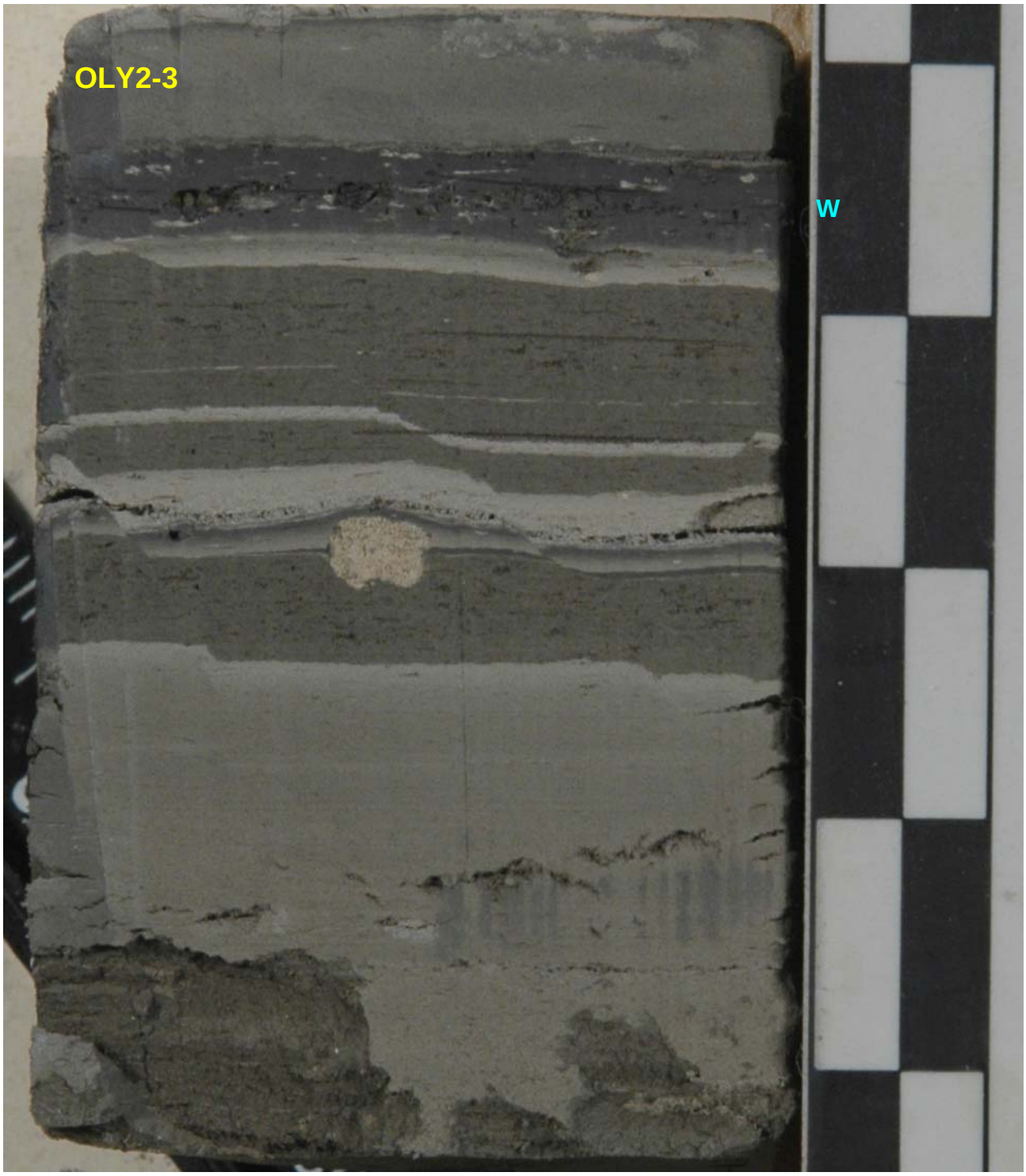
The lower winter bed (W) in OLY1-6 and those in OLY1-1 are capped by black diamicton debris. Note the fold (top middle) and set of small high-angle faults. The faults are most likely related to deformation (small horizontal compression) by overriding ice while the fold may be a product of mass movement.


OLY1-11
W
W
W

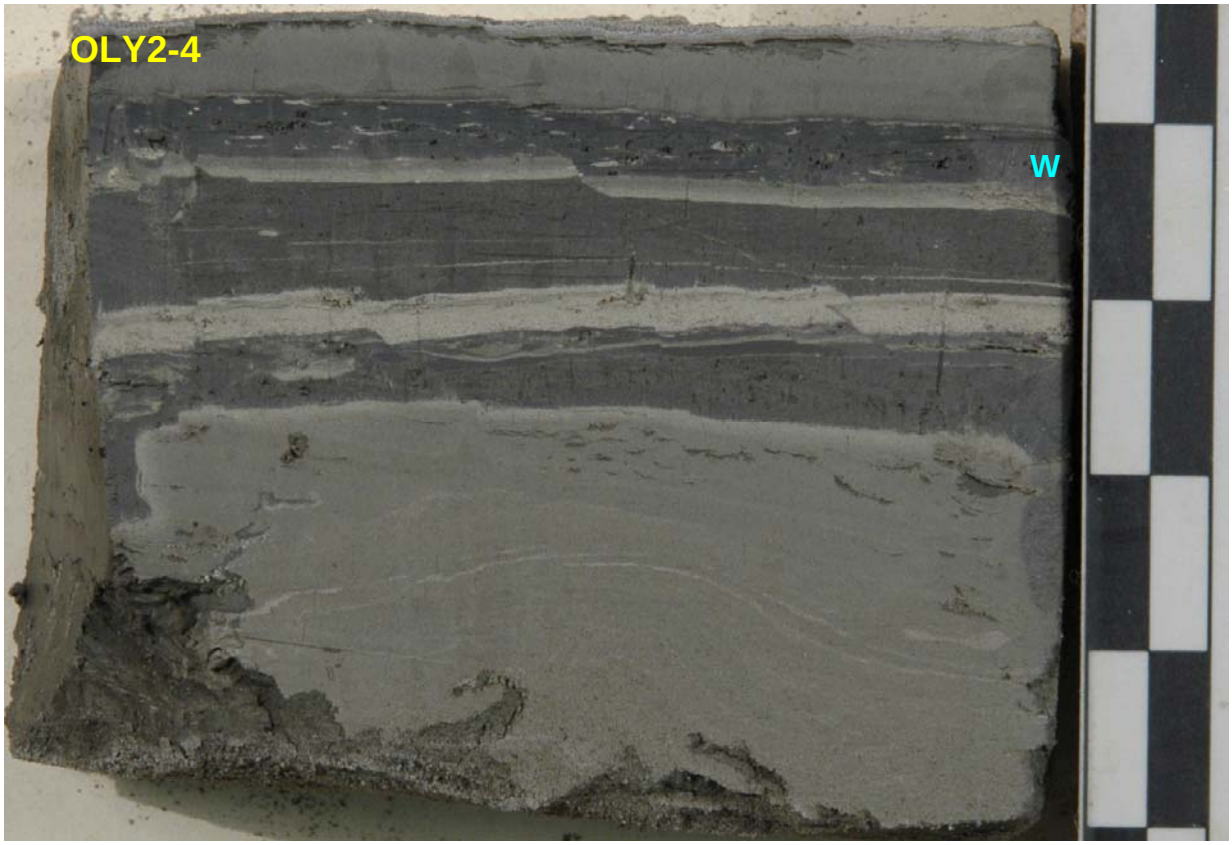
Samples from OLY2

Varves in the middle sample interval have the lowest abundance of large drop sediment fragments and also seem to have a laterally consistent stratigraphy. The bottom of the couplet is massive medium gray silt with white fine sand and silt wisps and laminations. This is overlain by darker and sandier medium gray trashy layers punctuated with white fine sand and silt layers and partings. The dark sandy layers appear to have drop sediment sprinkled throughout in the form of large sand grains and granules. The winter bed is black to dark gray with small flattened light silt pellets that are derived from rock flour. All of the images (OLY2-1,3,4,6,7, 8,11) are of the same varve, which appears to occasionally have bedding disruptions.

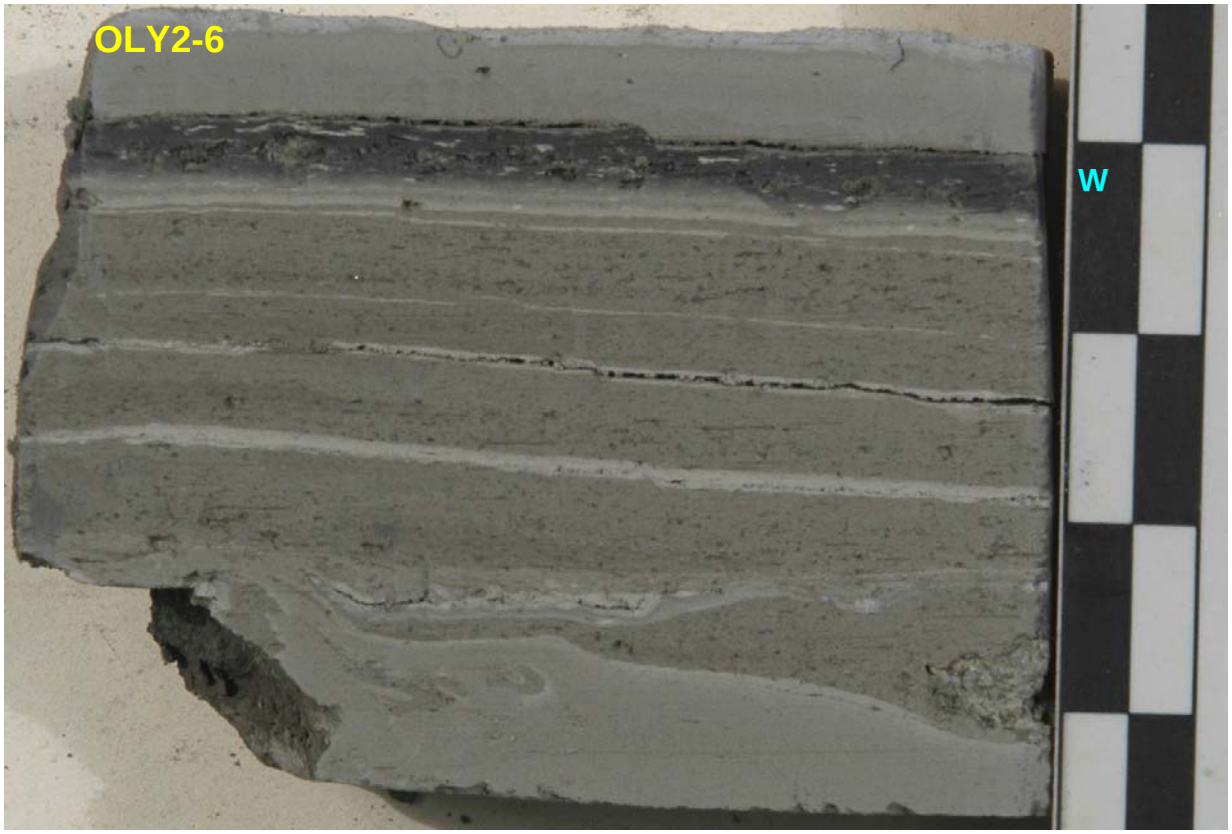


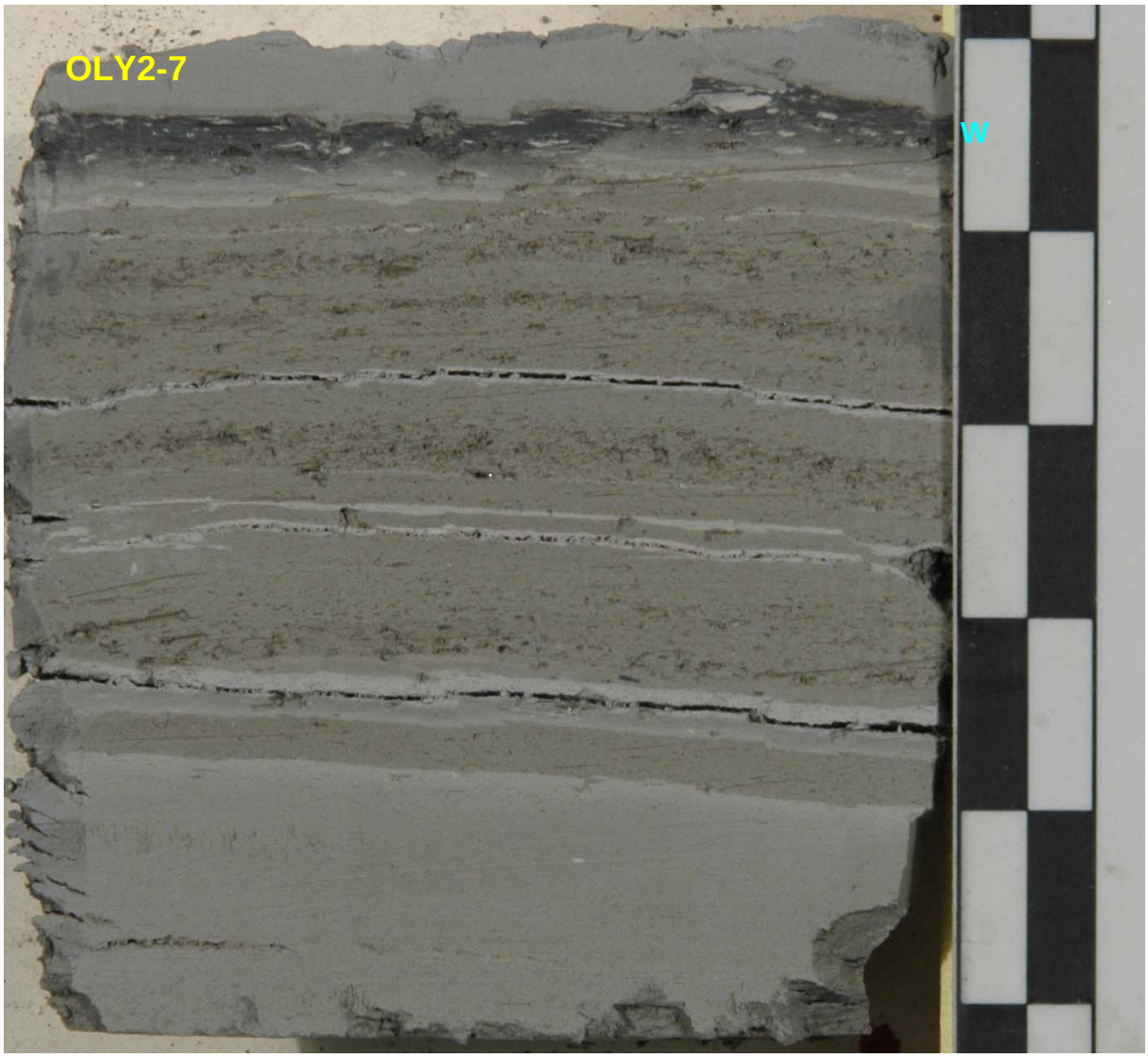


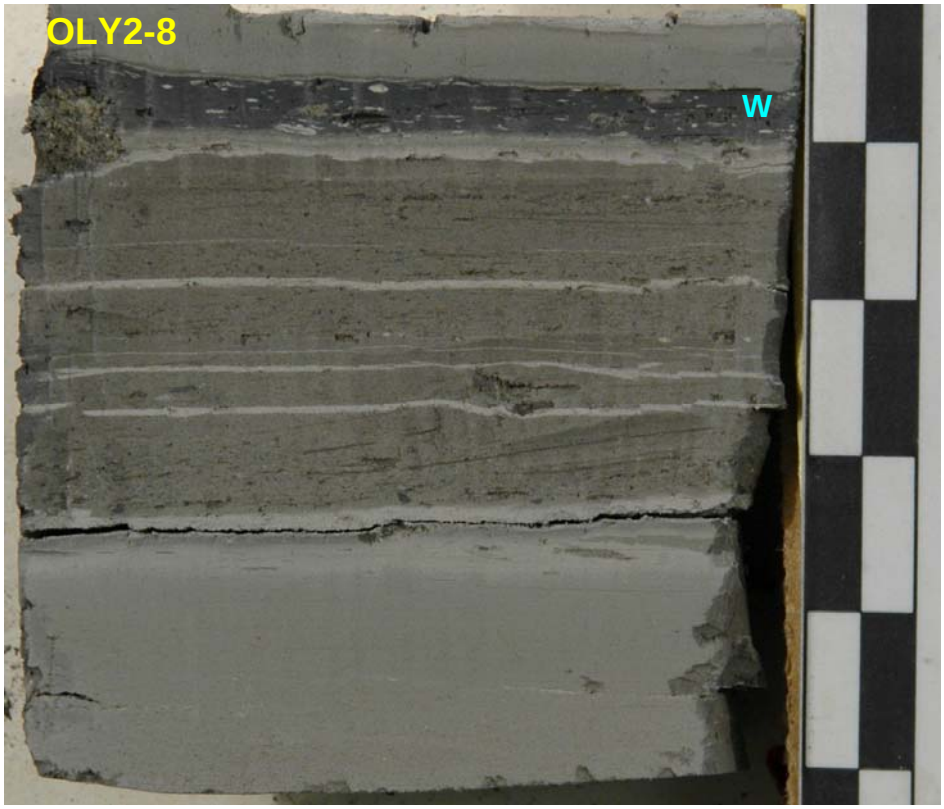
Note sandstone dropstone in center of OLY2-3.

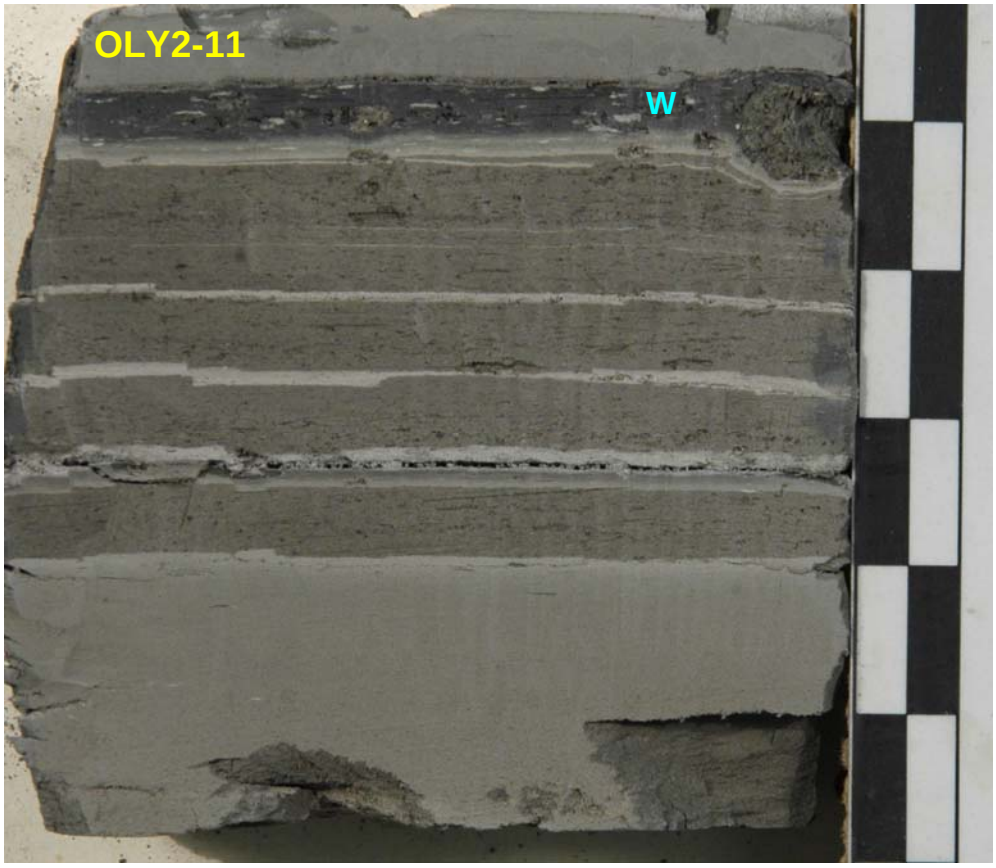


Note low-angle faults and warped bedding in OLY2-4 and contorted layers due to mass flow at base of OLY2-6.




OLY2-7
W

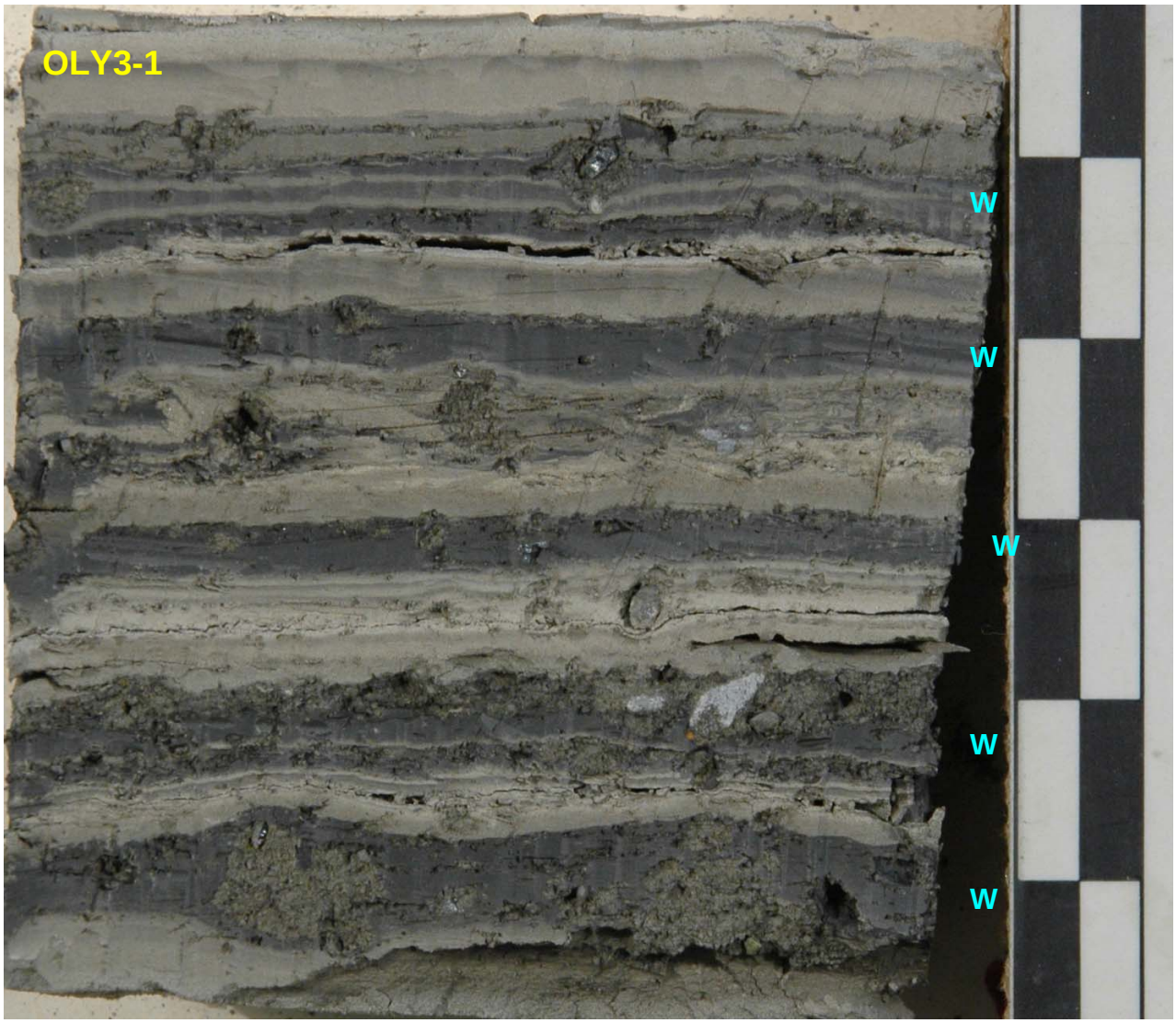


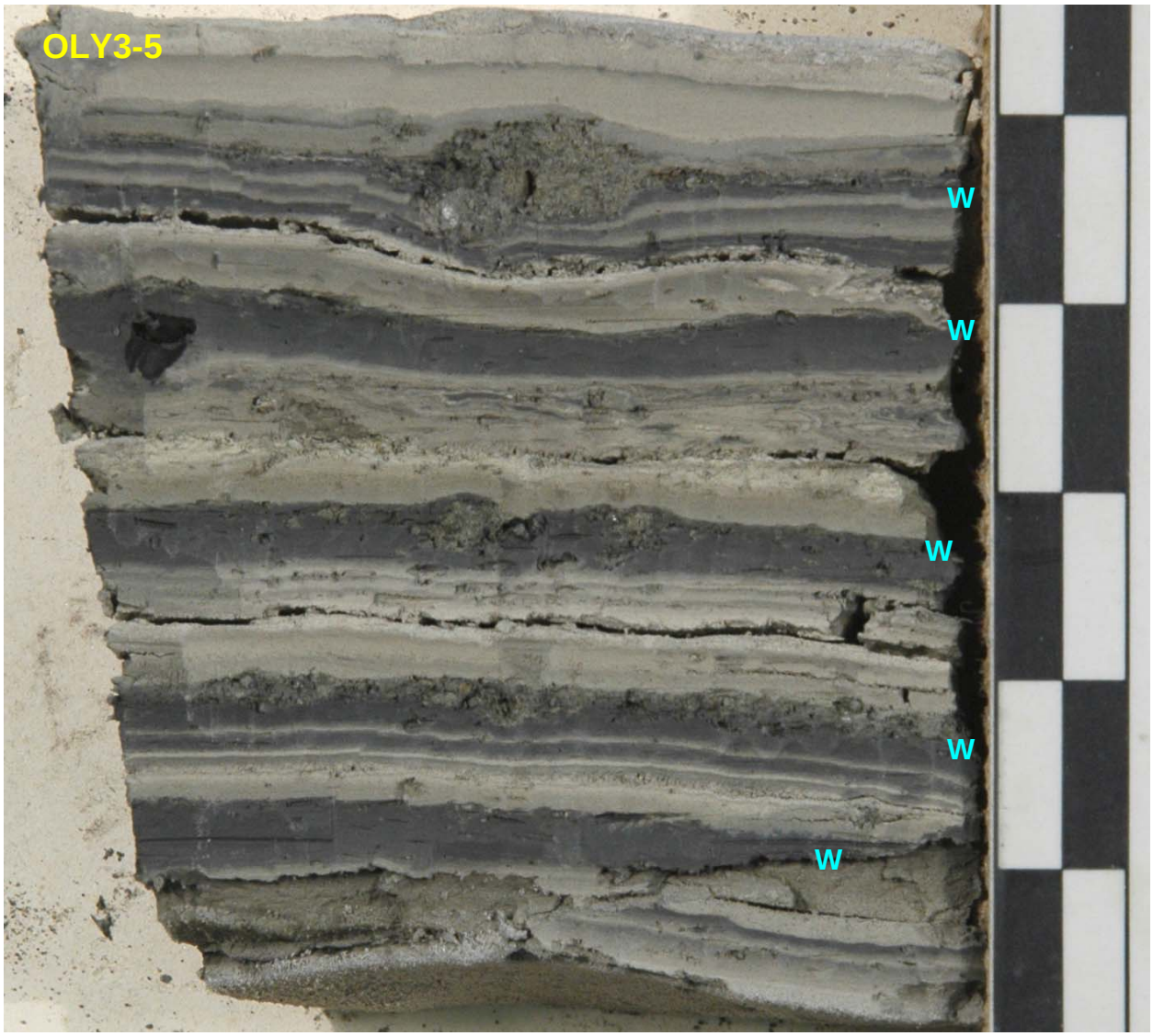


Note large dark gray diamicton pellet in right side of winter layer in OLY2-11. Note small high-angle faults on left side of OLY2-11.

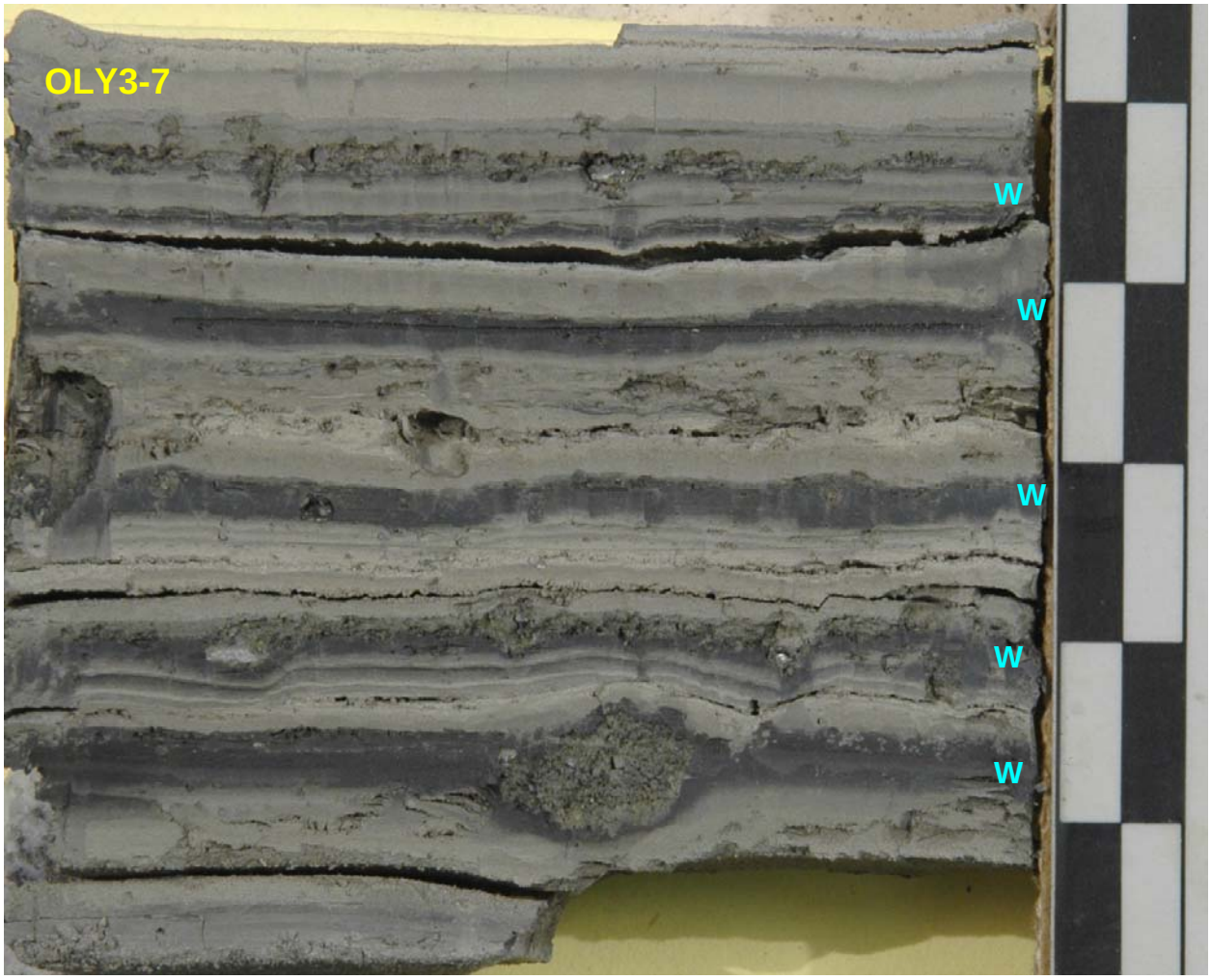
Samples from OLY3

Varves in the bottom sample interval (OLY3) are extremely trashy but instead of drop sediment being dominantly stones and dark gray diamicton pellets the drop sediment is dominated by medium gray sandy pellets and many small stones (granules) that have a high concentration in and at the tops of winter clay beds. All sample images are of the same set of varves. The varves are thinner than higher in the section.





Note the large medium gray muddy sand pellet in the top of OLY3-5 and the cavity where a dropstone pulled out of the left side of the second winter layer from the top. Drop sediment seems to more heavily concentrated in the upper half of each couplet including the top of the summer and winter layers. The bottom of each couplet has a laminated medium to light gray silt/fine sand unit with a lower drop sediment concentration than in units above.



The image of OLY3-7 shows a large medium gray muddy sand pellet in the bottom winter layer and a heavy concentration of the medium gray muddy sand at the top of the 2nd winter layer from the base.

Paleomagnetic Sampling Procedure

Block samples, oriented in the field using a Brunton compass, were trimmed with a razor knife to fit in 2.54-cm long, 2.54-cm OD, and 2.2-cm ID styrene plastic tubes. The tubes were then sealed at top and bottom with clear 5-minute epoxy. Sample collection was by Duane Braun and his students, Bloomsburg University. Paleomagnetic sample preparation was by Jack Ridge, Tufts University.

Paleomagnetic Procedures

Remanences were measured on a Molspin Minispin spinning magnetometer. Due to the low remanence magnitudes of the samples a long (24 sec.) spin routine was used. Alternating Field (AF) demagnetization was performed on 2 pilot samples per sample interval at the following peak field steps using a Sapphire Instruments SI-4 single axis demagnetizer: 2.5, 5, 10, 20, 30, 40, 50, 60, 70, 80, 100, and 120 mT. Bulk (Z-axis) susceptibility was measured on a Molspin bulk susceptibility device while Anisotropy of Magnetic Susceptibility (AMS) was measured on a Molspin Minisep spinning AMS device. All measurements made by Jack Ridge at Tufts University

Paleomagnetic Results – Natural Remanent Magnetization (NRM)

On the following pages are tables and polar plots of the NRM data.
α_{95} is a conical 95% confidence interval about the 3-D vector mean of the samples.
k or cluster coefficient is a measure of the clustering of the samples with higher values representing tighter clustering.
The isolated declination and inclination means and their α_{95} values are:
1) the mean of declination using just the 2-D plain of the X and Y components of magnetization and ignoring the Z component in calculating the α_{95} value, i.e. treating Z as though it has no variation, and 2) the mean of inclination using just the 2-D plain of the horizontal (resolved X and Y) and vertical (Z) components of magnetization and ignoring directional variability of the H component in calculating the α_{95} value. This is simply a mean and 95% confidence interval of the inclination values.

NRM values showed excellent uniformity of intensity and excellent directional clustering despite some bedding irregularities, fracture displacements, and varying abundances of diamicton pellets in the sample blocks. NRM intensities were generally very low as compared to samples collected in the western Mohawk Valley and in New England where there are abundant nearby igneous and metamorphic rocks. Intensities clustered in the range of about 6-21 mA/m, about 1-2 orders of magnitude below typical samples from the areas mentioned above.

NRM declinations clustered in the range of about 15-25º East, a direction greatly different from the modern declination at the site (12.5º West).

NRM inclinations were very low with a range of about 10-30º. This is likely due to compaction as will be seen with the presentation of AMS results.

The highest sample interval in the section (OLY1) showed more directional scatter than the lower two intervals (OLY2 and OLY3), possibly resulting from a greater disturbance (compaction and light shearing) by overriding ice.

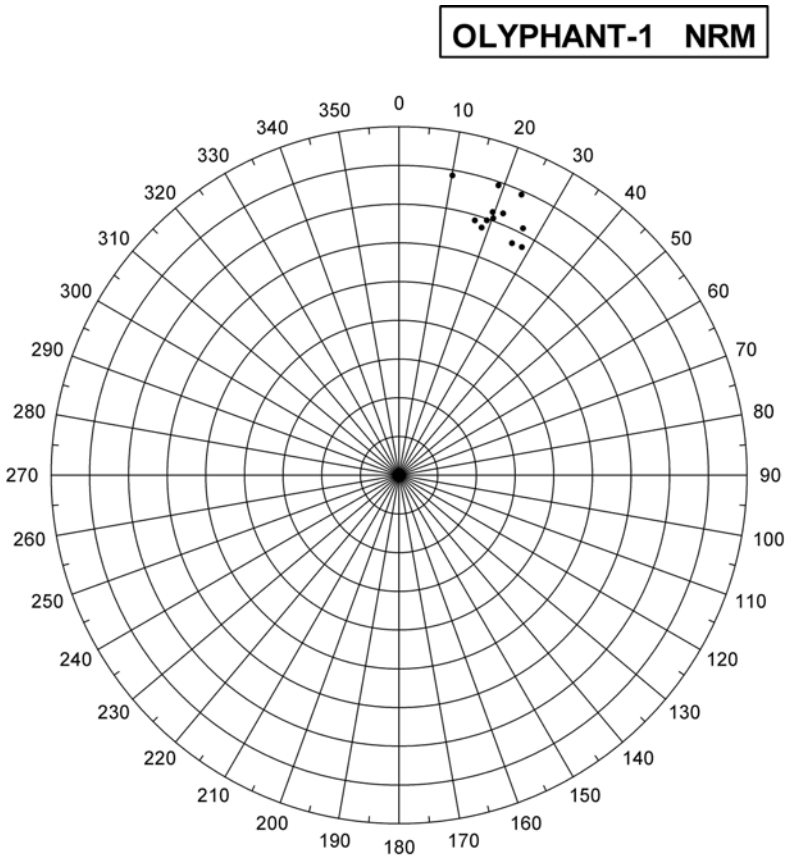
Sample group: OLYPHANT-1

Treatment type: NRM

Specimen type: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

Remanence moments (mA/m)

X	Y	Z	Specimen
10.67	1.90	2.17	OLY1-1 NRM
10.64	5.73	5.15	2
9.69	4.72	4.65	3
11.24	3.35	4.59	4
10.77	3.95	4.02	5
10.77	3.69	2.18	6
12.05	4.79	4.02	7
11.03	5.55	4.17	8
11.68	3.89	5.12	9
12.01	5.25	2.52	10
12.43	4.42	4.25	11
11.75	4.05	4.63	12



Decl.	Incl.	Intensity (mA/m)	Specimen
10.11	11.34	11.05	OLY1-1 NRM
28.31	23.07	13.14	2
25.98	23.34	11.74	3
16.58	21.36	12.60	4
20.14	19.33	12.16	5
18.92	10.83	11.60	6
21.67	17.24	13.58	7
26.69	18.65	13.04	8
18.44	22.57	13.33	9
23.61	10.90	13.35	10
19.59	17.87	13.86	11
19.02	20.41	13.26	12

Mean Magnetic Intensity = 12.73 mA/m

Declination mean = 20.71

Inclination mean = 18.14

Cluster coefficient = 148.19

Cone of confidence (semi-arc 95%) = 3.58

Isolated Declination and 95% confidence interval: 20.76 +/- 2.67

Isolated Inclination and 95% confidence interval: 18.08 +/- 2.51

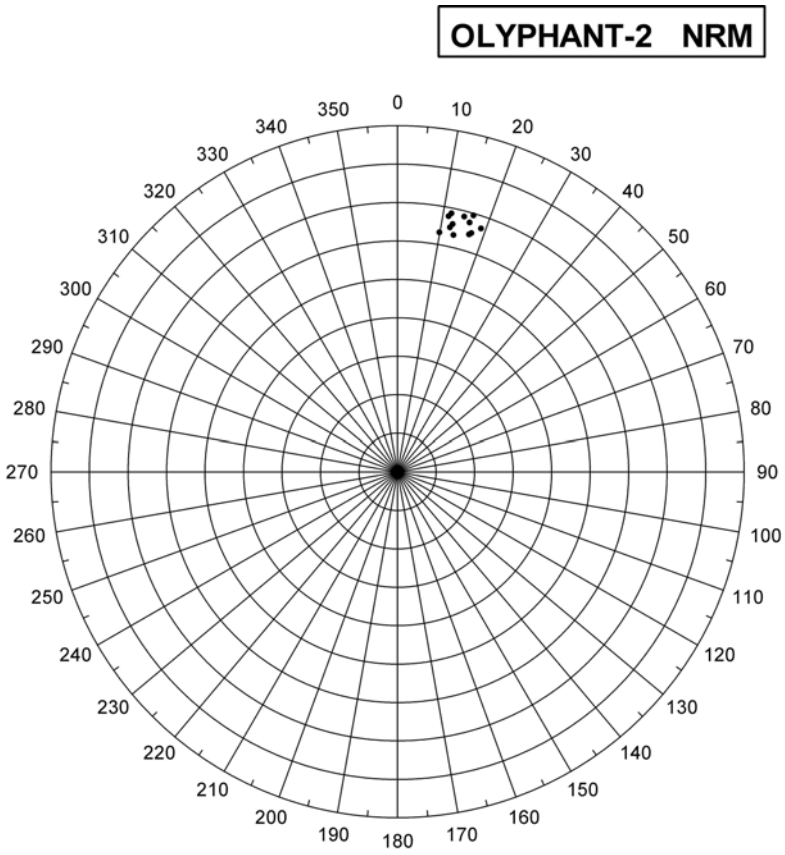
Sample group: OLYPHANT-2

Treatment type: NRM

Specimen type: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

Remanence moments (mA/m)

X	Y	Z	Specimen
7.81	1.36	4.00	OLY2-1 NRM
7.93	1.58	3.31	2
9.26	2.06	4.23	3
10.70	3.22	5.35	4
11.85	3.42	5.12	5
7.34	2.17	2.86	6
6.59	1.55	3.41	7
6.56	1.40	3.13	8
5.98	2.05	2.70	9
7.18	1.50	2.87	10
6.03	1.86	2.95	11
8.30	2.16	3.37	12



Decl.	Incl.	Intensity (mA/m)	Specimen
9.90	26.79	8.88	OLY2-1 NRM
11.26	22.25	8.74	2
12.52	24.02	10.39	3
16.73	25.57	12.39	4
16.09	22.54	13.35	5
16.45	20.51	8.18	6
13.24	26.76	7.58	7
12.06	25.02	7.40	8
18.90	23.15	6.88	9
11.77	21.37	7.88	10
17.14	25.04	6.96	11
14.59	21.44	9.21	12

Mean Magnetic Intensity = 8.99 mA/m

Declination mean = 14.23

Inclination mean = 23.73

Cluster coefficient = 585.29

Cone of confidence (semi-arc 95%) = 1.80

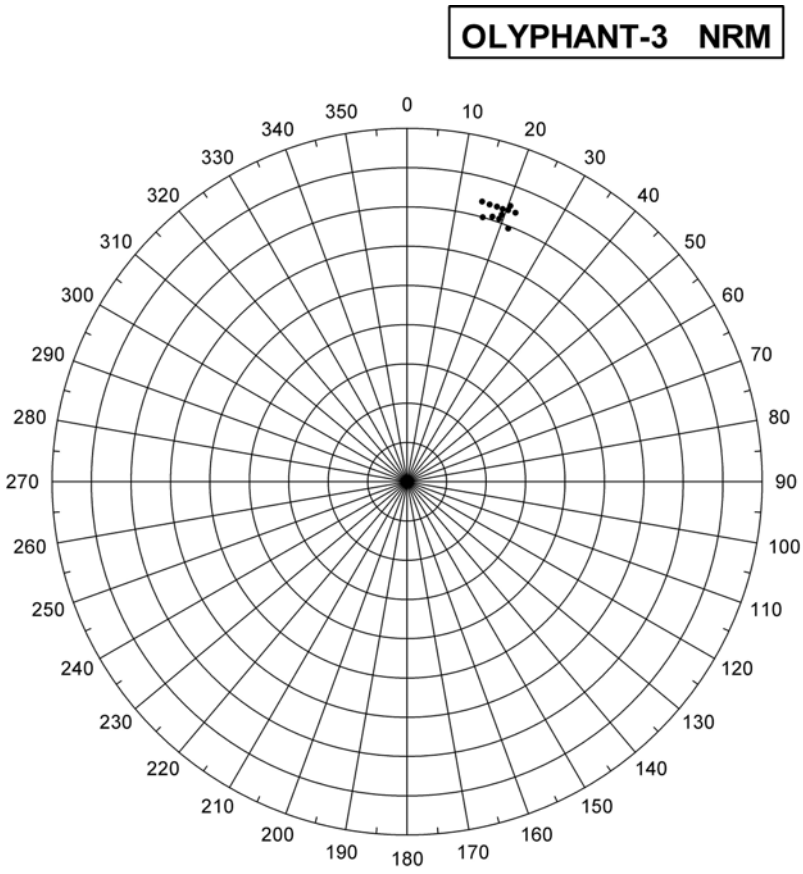
Isolated Declination and 95% confidence interval: 14.22 +/- 1.51

Isolated Inclination and 95% confidence interval: 23.70 +/- 1.15

Sample group: OLYPHANT-3
Treatment type: NRM
Specimen type: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

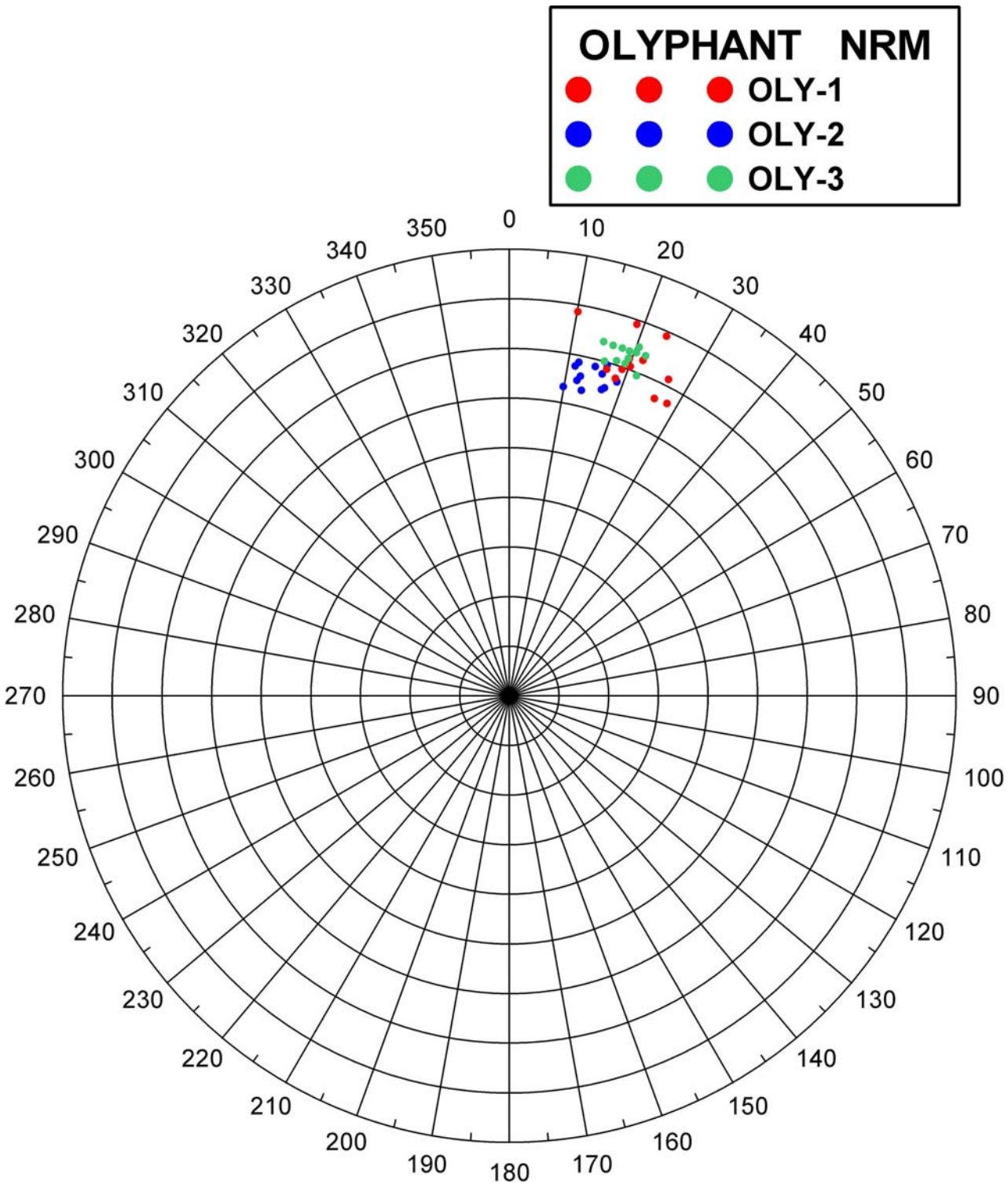
Remanence moments (mA/m)

X	Y	Z	Specimen
18.67	5.52	5.72	OLY3-1 NRM
17.89	5.09	6.75	2
18.12	6.30	5.66	3
15.88	4.22	4.76	4
16.15	6.40	6.53	5
16.83	5.85	6.18	6
17.30	5.54	6.30	7
15.68	5.53	5.36	8
17.01	6.82	5.33	9
17.34	6.46	4.97	10
17.64	5.74	5.44	11
14.96	5.54	4.64	12



Decl.	Incl.	Intensity (mA/m)	Specimen
16.48	16.38	20.30	OLY3-1 NRM
15.88	19.94	19.79	2
19.18	16.44	20.00	3
14.89	16.14	17.11	4
21.63	20.60	18.56	5
19.17	19.12	18.86	6
17.74	19.13	19.23	7
19.41	17.88	17.47	8
21.84	16.22	19.09	9
20.42	15.04	19.16	10
18.02	16.35	19.33	11
20.33	16.22	16.61	12

Mean Magnetic Intensity = 18.79 mA/m
Declination mean = 18.75
Inclination mean = 17.47
Cluster coefficient = 852.44 (Extremely tight clustering coefficient!!!)
Cone of confidence (semi-arc 95%) = 1.49
Isolated Declination and 95% confidence interval: 18.75 +/- 1.18
Isolated Inclination and 95% confidence interval: 17.45 +/- .97


OLYPHANT NRM
OLY-1
OLY-2
OLY-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

Paleomagnetic Results – Progressive AF Demagnetization

Progressive AF demagnetization was conducted to test the stability of NRM values and the influences of viscous remanence components on the NRM signal. Included on the next several pages for each pilot sample (OLY1-3, OLY1-10, OLY2-5, OLY2-12, OLY3-1, OLY3-10) are: 1) tables of the AF demagnetization data, 2) plots of normalized remanence during AF demagnetization, and 3) Zjderveld or remanence vector plots during AF demagnetization. The Zjderveld diagrams show the plots of the Vertical (down or Z) vs. N (dark circles) and E-W vs. N (open circles) components of remanence for each AF demagnetization step listed at the bottom of each plot. Shown on the page preceding the Olyphant data for comparison are examples of AF demagnetization plots for a varve sample in the Connecticut Valley near Hartford, Connecticut (black; KFC-11-1B, East Windsor, Conn.) along with the data from sample OLY1-3 (red). Following that is the data from the Olyphant samples.

Normalized Remanence Plots

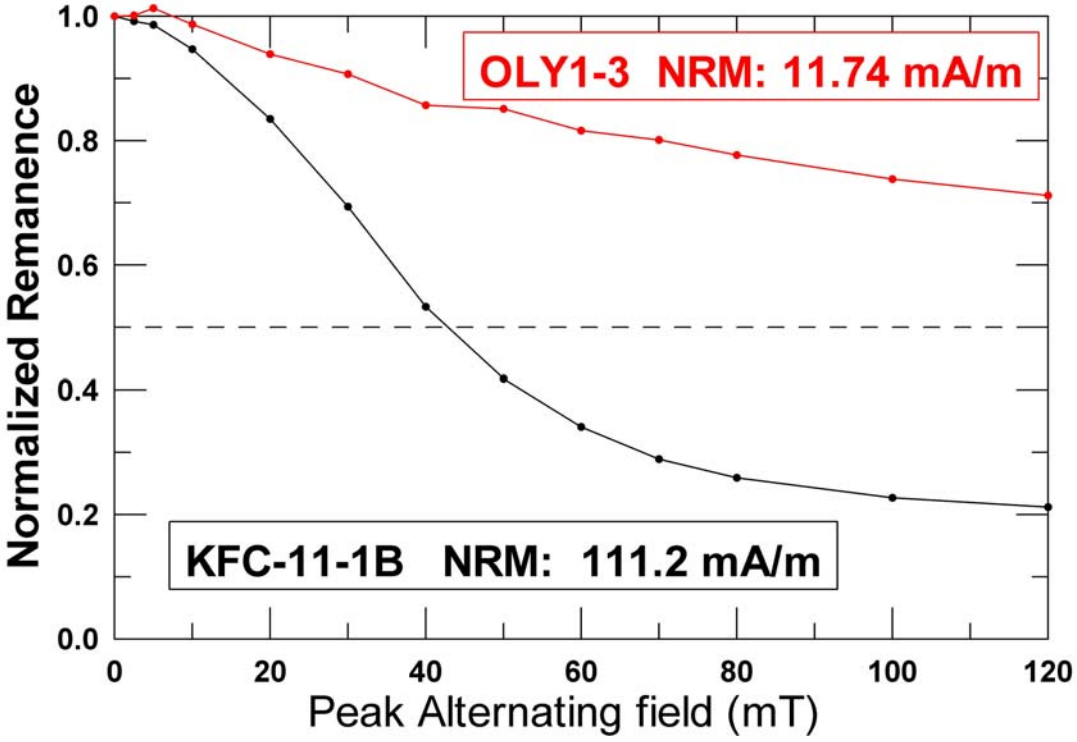
AF demagnetization revealed that the samples have exceptionally "hard" remanence with Median Destructive Fields (MDF) not reached, except in one sample (OLY2-12 @ 79 mT), even after subjecting samples to a peak AF field of 120 mT. MDF values are the AF peak field values necessary to destroy 50% of the original NRM intensity of the samples. In fact only 70% of the original NRM intensity was destroyed at the 120-mT level in the OLY1 samples and 67% in the OLY 3 samples, while OLY2-5 had 51% remaining at 120 mT. Samples from other areas of the northeastern US (western Mohawk Valley and New England) typically have MDF values of 25-45 mT and have magnetite as their dominant carrier of remanence (see the Connecticut Valley example on next page). The New England sample is very different from the Olyphant samples and strongly implies that the Olyphant samples have a remanence dominantly carried by minerals that are highly resistant to AF demagnetization, i.e. other than magnetite. Given the character of local sedimentary rock units, hematite or other oxide/hydroxide minerals of high remanence stability but low remanence magnitude are prime candidates.

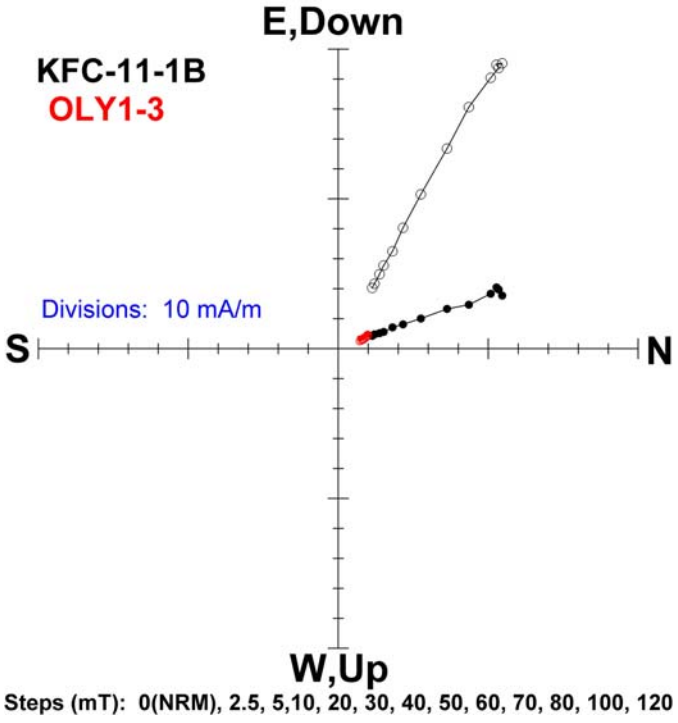
Zjderveld (AFD vector) Plots

The Zjderveld plots show very little change in direction, which is to be expected given the very high resistance of the samples to AF demagnetization. During AF demagnetization samples typically show unchanged directions represented by straight lines that converge toward the origin of the plot after viscous remanence is removed at low peak field values (see Connecticut Valley example). The Olyphant samples show little change in direction during AF demagnetization but do not progress toward the origin very rapidly due to the "hardness" of the magnetic carrier.

Using the AF demagnetization results it was decided that an AF peak field value of 30 mT should be used to remove viscous remanence components from the rest of the samples. This value was chosen because in the AF demagnetization data tables there was a slight shift in remanence directions up to 20 mT while after that relative stability in the directions occurred.

Example data from varves of the Connecticut Valley near Hartford, Connecticut. This sample has an NRM intensity about an order of magnitude above the Olyphant samples but shows a rapid decrease in intensity during AF demagnetization with an MDF value of about 42 mT. On the Zjderveld diagram (below) the plots show an initial minor direction change in remanence direction (small hook) followed by a straight line decent toward the origin. For comparison results from OLY1-3 (red), which plot on top of each other on the vector diagram at this scale, are plotted with the Connecticut data.

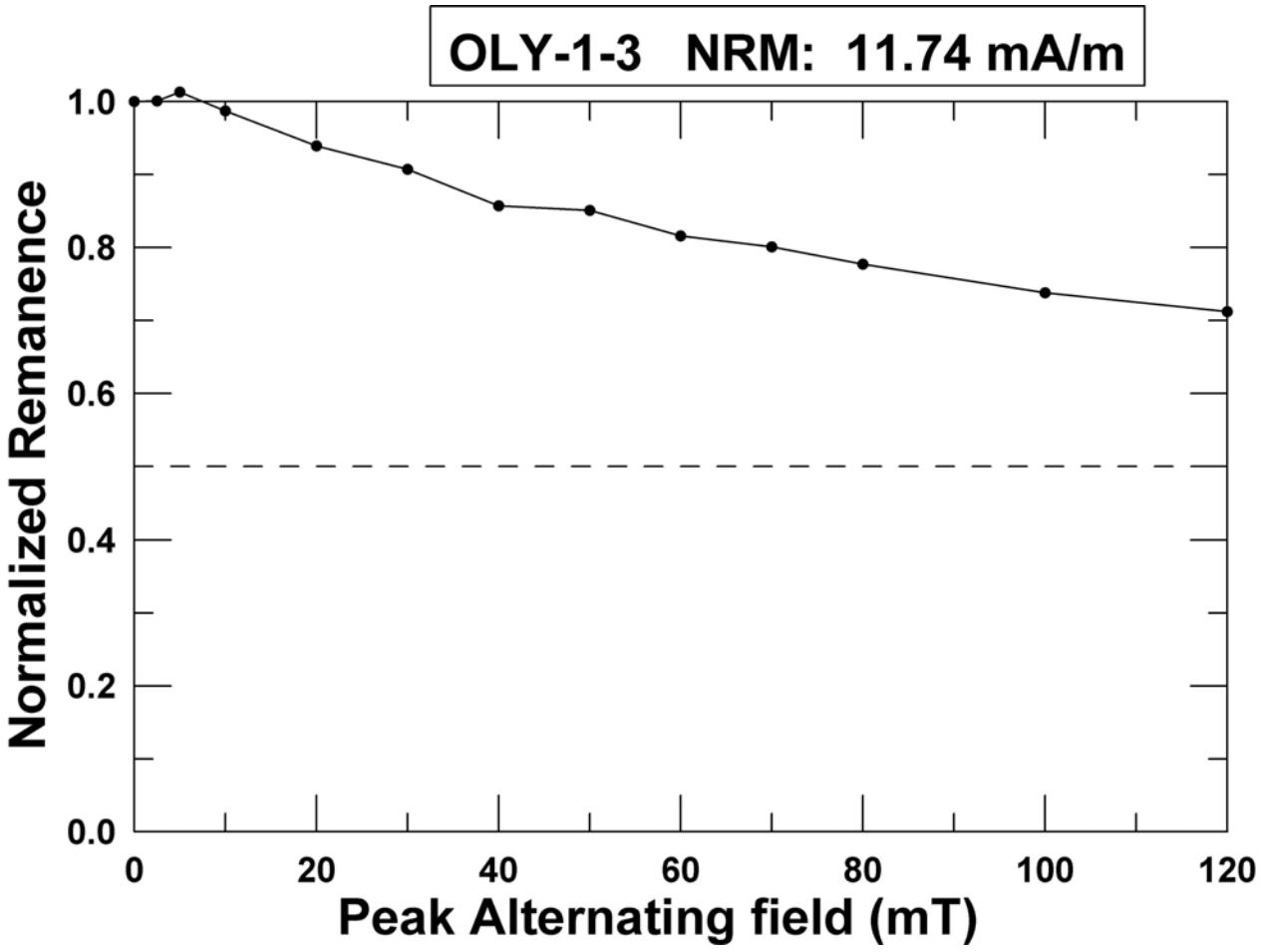


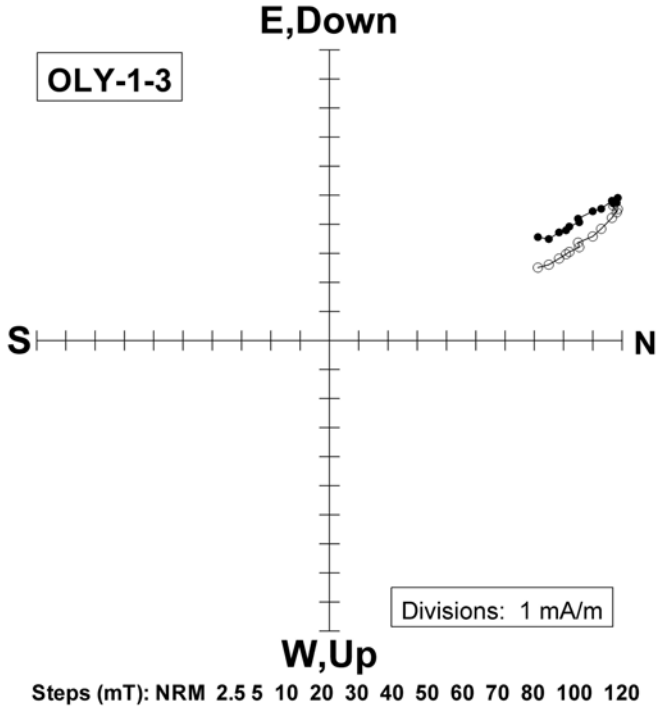


SPECIMEN: OLYPHANT-1-3
SPECIMEN TYPE: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

TREATMENT (mT)	DECLINATION	INCLINATION	INTENSITY (mA/m)	NORMALIZED INTENSITY
.0	25.98	23.34	11.74	1.000
2.5	25.77	22.01	11.75	1.001
5.0	26.50	22.35	11.89	1.013
10.0	26.51	21.39	11.58	.987
20.0	26.01	20.37	11.02	.939
30.0	26.34	19.65	10.65	.907
40.0	26.29	19.60	10.05	.857
50.0	25.51	18.77	9.98	.851
60.0	25.55	18.54	9.58	.816
70.0	25.11	18.38	9.40	.801
80.0	25.37	17.99	9.12	.777
100.0	25.01	17.56	8.67	.738
120.0	26.58	17.49	8.35	.712

TREATMENT (mT)	REMANENCE INTENSITIES (mA/m) X	Y	Z
.0	9.69	4.72	4.65
2.5	9.81	4.74	4.41
5.0	9.85	4.91	4.52
10.0	9.65	4.81	4.22
20.0	9.28	4.53	3.84
30.0	8.99	4.45	3.58
40.0	8.49	4.19	3.37
50.0	8.53	4.07	3.21
60.0	8.19	3.92	3.05
70.0	8.08	3.79	2.97
80.0	7.84	3.72	2.82
100.0	7.49	3.49	2.61
120.0	7.12	3.56	2.51


OLY-1-3 NRM: 11.74 mA/m
Normalized Remanence
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Peak Alternating field (mT)

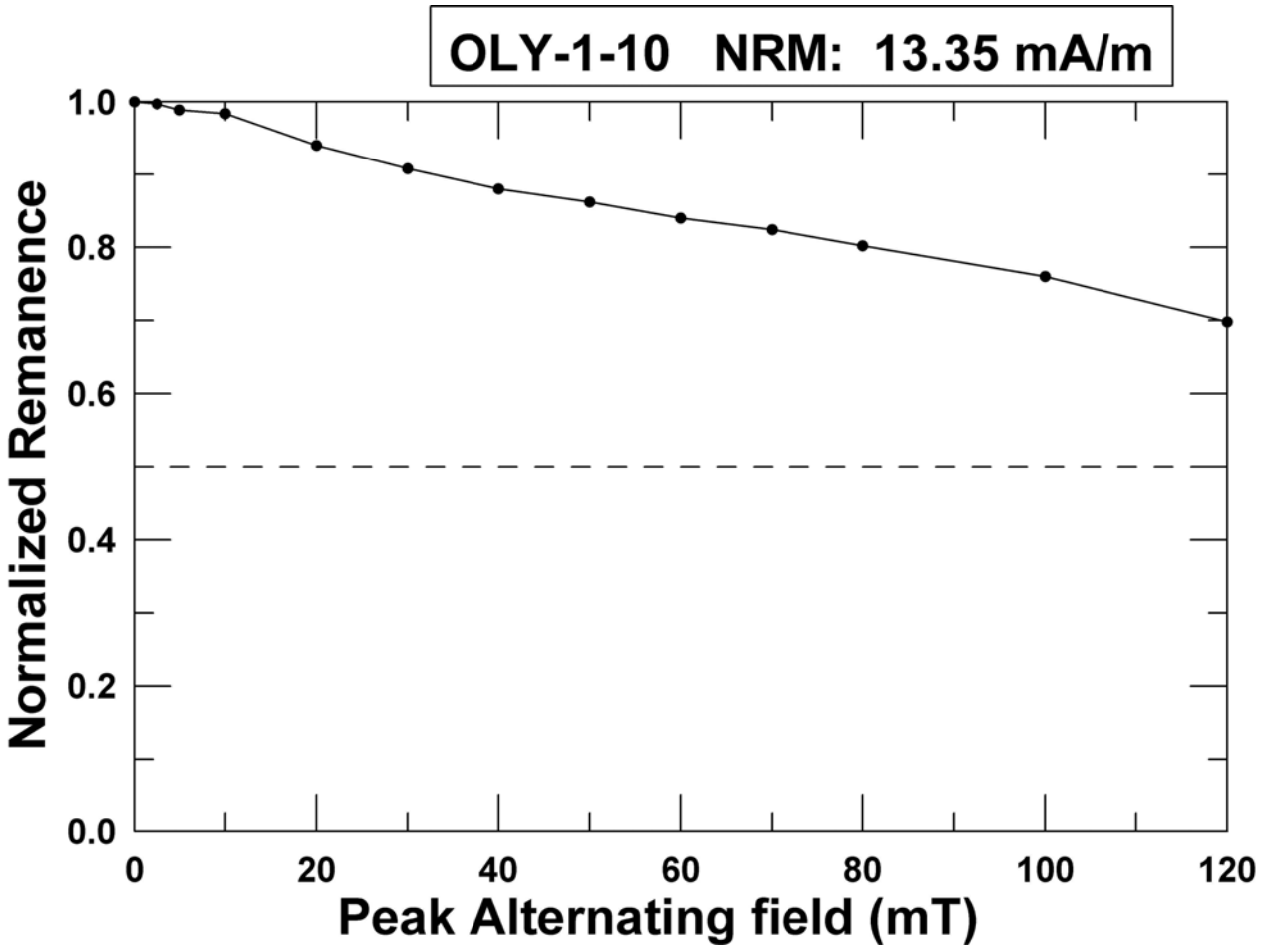

E,Down
OLY-1-3
S
N
Divisions: 1 mA/m
W,Up
Steps (mT): NRM 2.5 5 10 20 30 40 50 60 70 80 100 120

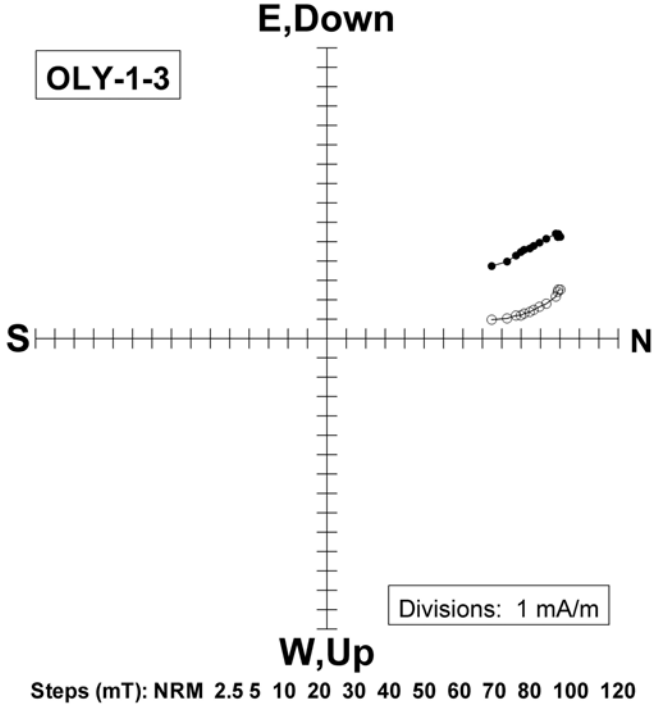
SPECIMEN: OLYPHANT-1-10

SPECIMEN TYPE: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

TREATMENT (mT)	DECLINATION	INCLINATION	INTENSITY (mA/m)	NORMALIZED INTENSITY
.0	23.61	10.90	13.35	1.000
2.5	24.38	10.95	13.32	.997
5.0	23.81	10.50	13.21	.989
10.0	24.65	9.44	13.14	.984
20.0	24.52	8.25	12.54	.940
30.0	24.34	7.79	12.12	.908
40.0	24.21	7.21	11.75	.880
50.0	24.01	6.82	11.51	.862
60.0	24.26	6.60	11.21	.840
70.0	24.08	6.21	11.00	.824
80.0	23.76	6.41	10.70	.802
100.0	23.19	5.88	10.14	.760
120.0	23.79	6.00	9.32	.698

TREATMENT (mT)	REMANENCE INTENSITIES (mA/m) X	Y	Z
.0	12.01	5.25	2.52
2.5	11.91	5.40	2.53
5.0	11.88	5.24	2.41
10.0	11.78	5.41	2.16
20.0	11.29	5.15	1.80
30.0	10.94	4.95	1.64
40.0	10.64	4.78	1.48
50.0	10.44	4.65	1.37
60.0	10.15	4.58	1.29
70.0	9.98	4.46	1.19
80.0	9.73	4.28	1.19
100.0	9.27	3.97	1.04
120.0	8.48	3.74	.97

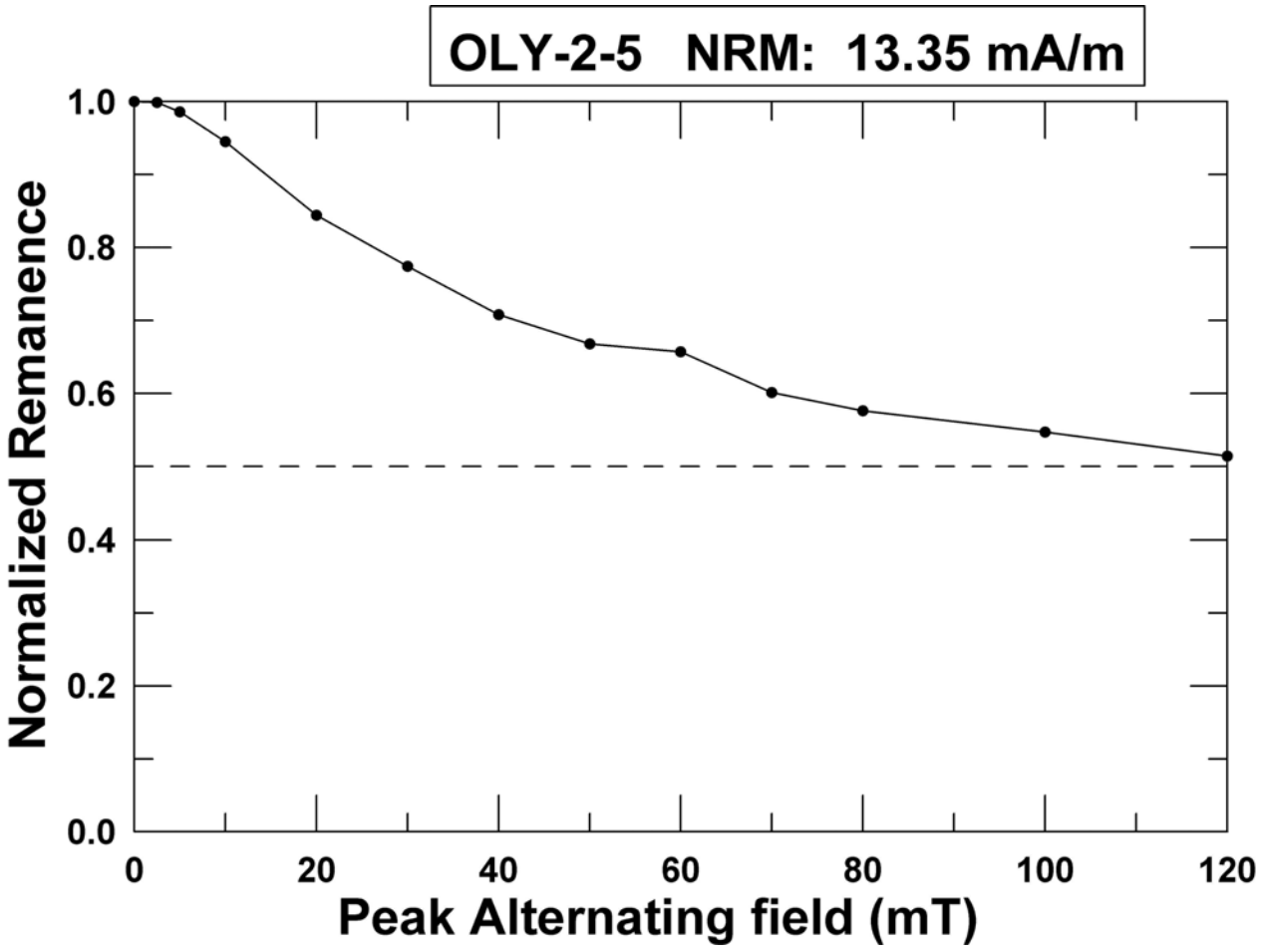

OLY-1-10 NRM: 13.35 mA/m
Normalized Remanence
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Peak Alternating field (mT)

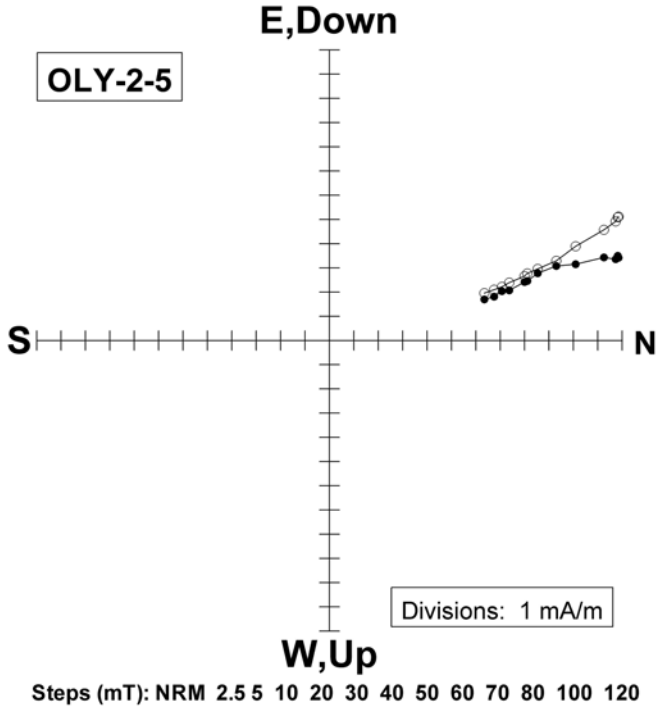

E,Down
OLY-1-3
S
N
Divisions: 1 mA/m
W,Up
Steps (mT): NRM 2.5 5 10 20 30 40 50 60 70 80 100 120

SPECIMEN: OLYPHANT-2-5
SPECIMEN TYPE: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

TREATMENT (mT)	DECLINATION	INCLINATION	INTENSITY (mA/m)	NORMALIZED INTENSITY
.0	16.09	22.54	13.35	1.000
2.5	16.50	22.45	13.33	.999
5.0	15.97	21.97	13.16	.986
10.0	16.96	21.25	12.61	.945
20.0	17.33	20.20	11.26	.844
30.0	18.35	18.57	10.33	.774
40.0	18.01	18.26	9.46	.708
50.0	16.89	18.08	8.91	.668
60.0	16.86	17.63	8.77	.657
70.0	15.68	17.36	8.02	.601
80.0	16.09	16.82	7.68	.576
100.0	14.99	16.70	7.30	.547
120.0	15.01	16.62	6.86	.514

TREATMENT (mT)	REMANENCE INTENSITIES (mA/m) X	Y	Z
.0	11.85	3.42	5.12
2.5	11.82	3.50	5.09
5.0	11.73	3.36	4.92
10.0	11.25	3.43	4.57
20.0	10.09	3.15	3.89
30.0	9.30	3.08	3.29
40.0	8.54	2.78	2.96
50.0	8.11	2.46	2.77
60.0	8.00	2.42	2.66
70.0	7.37	2.07	2.39
80.0	7.07	2.04	2.22
100.0	6.75	1.81	2.10
120.0	6.35	1.70	1.96


OLY-2-5 NRM: 13.35 mA/m
Normalized Remanence
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Peak Alternating field (mT)

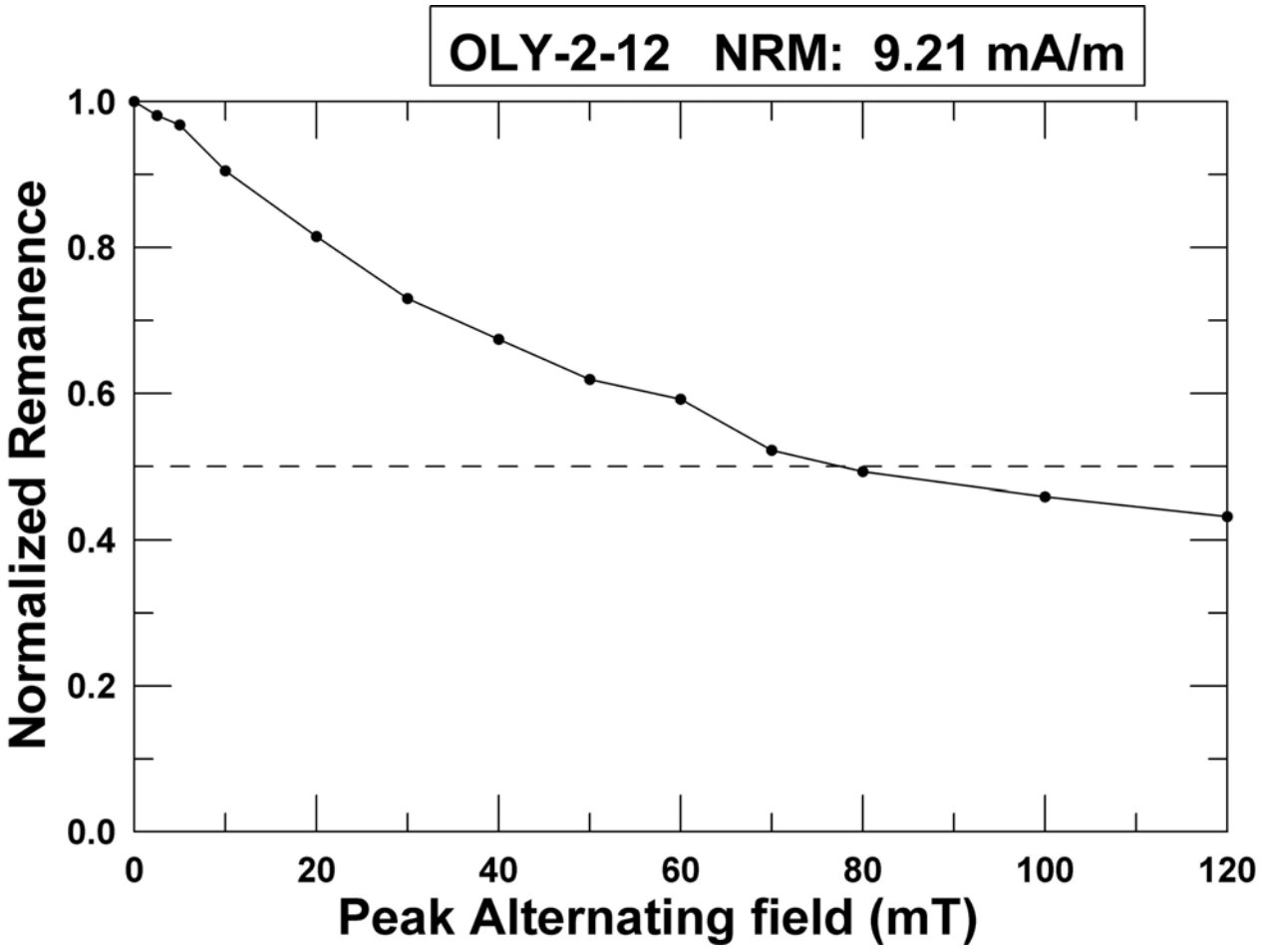

E,Down
OLY-2-5
S
N
Divisions: 1 mA/m
W,Up
Steps (mT): NRM 2.5 5 10 20 30 40 50 60 70 80 100 120

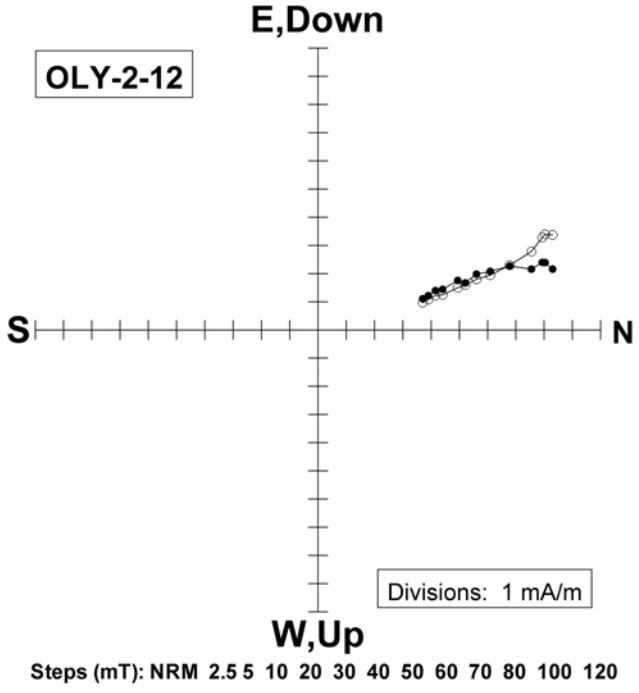
SPECIMEN: OLYPHANT-2-12

SPECIMEN TYPE: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

TREATMENT (mT)	DECLINATION	INCLINATION	INTENSITY (mA/m)	NORMALIZED INTENSITY
.0	14.59	21.44	9.21	1.000
2.5	16.60	22.05	9.04	.981
5.0	16.83	21.56	8.91	.968
10.0	15.96	19.46	8.33	.905
20.0	18.49	17.84	7.51	.815
30.0	18.87	16.78	6.72	.730
40.0	19.50	16.89	6.21	.674
50.0	17.80	16.33	5.70	.619
60.0	19.60	15.96	5.46	.592
70.0	18.07	15.13	4.81	.522
80.0	18.71	15.58	4.54	.493
100.0	17.37	14.86	4.23	.459
120.0	16.75	14.15	3.98	.432

TREATMENT (mT)	REMANENCE INTENSITIES (mA/m) X	Y	Z
.0	8.30	2.16	3.37
2.5	8.03	2.39	3.39
5.0	7.93	2.40	3.28
10.0	7.55	2.16	2.78
20.0	6.78	2.27	2.30
30.0	6.09	2.08	1.94
40.0	5.60	1.98	1.80
50.0	5.21	1.67	1.60
60.0	4.94	1.76	1.50
70.0	4.41	1.44	1.25
80.0	4.15	1.40	1.22
100.0	3.90	1.22	1.08
120.0	3.70	1.11	.97

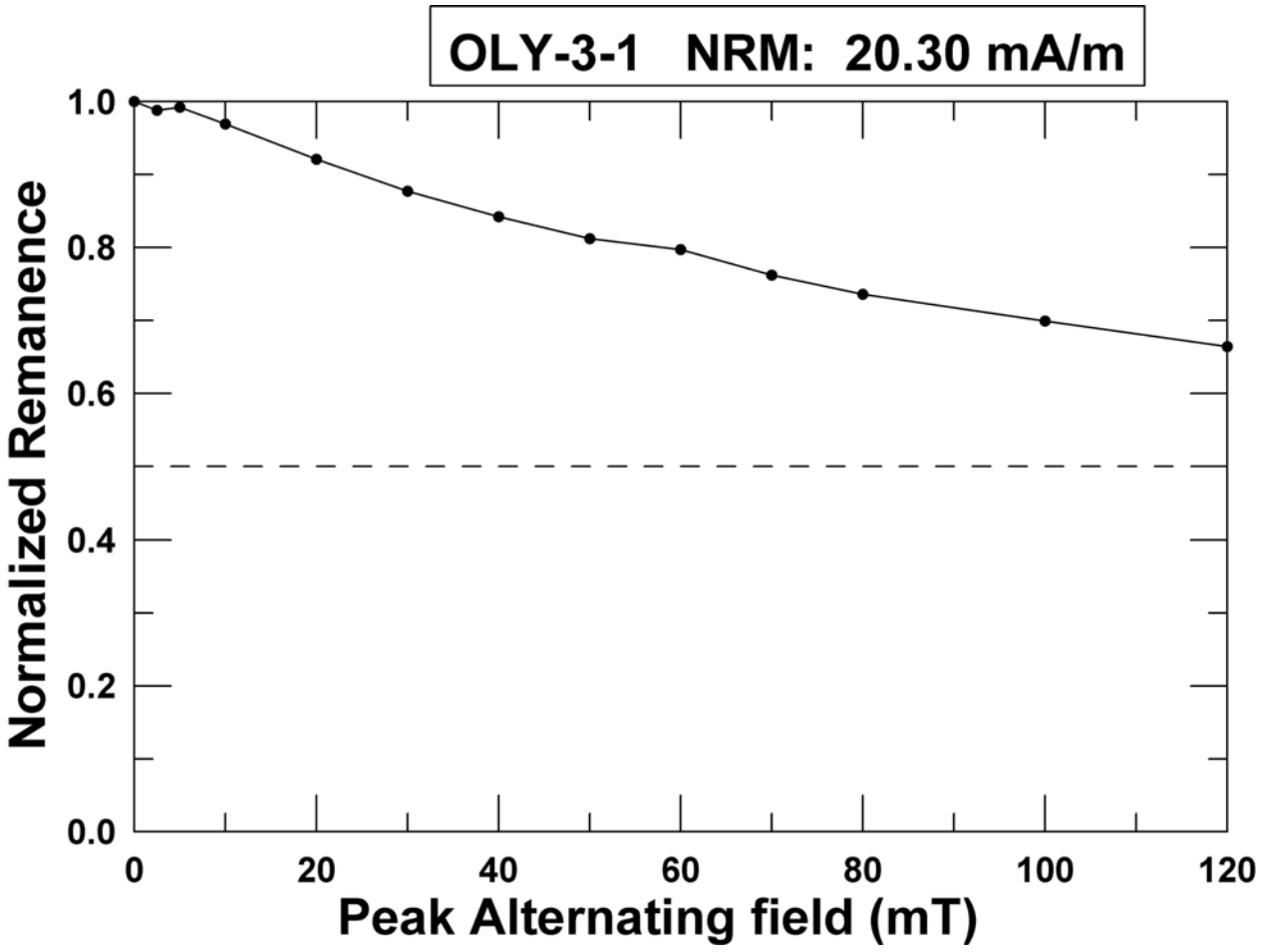

OLY-2-12 NRM: 9.21 mA/m
Normalized Remanence
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Peak Alternating field (mT)

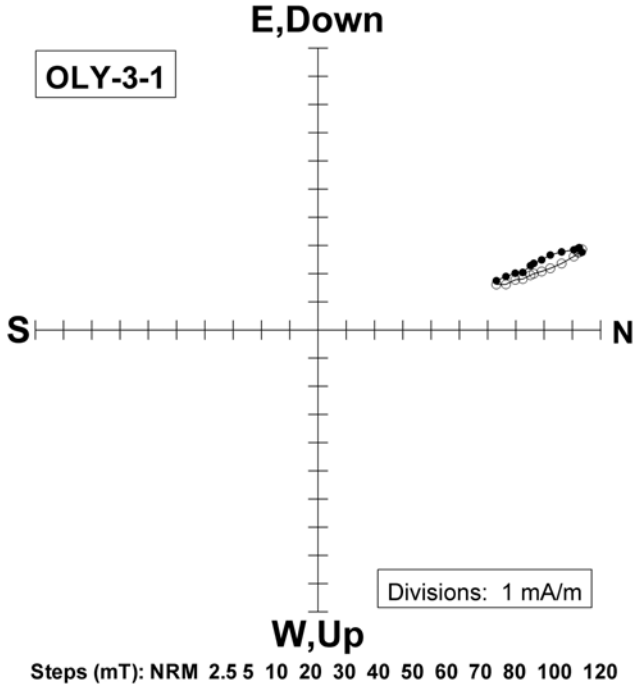

E,Down
OLY-2-12
S
N
Divisions: 1 mA/m
W,Up
Steps (mT): NRM 2.5 5 10 20 30 40 50 60 70 80 100 120

SPECIMEN: OLYPHANT-3-1
SPECIMEN TYPE: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

TREATMENT (mT)	DECLINATION	INCLINATION	INTENSITY (mA/m)	NORMALIZED INTENSITY
.0	16.48	16.38	20.30	1.000
2.5	17.48	15.89	20.05	.988
5.0	17.55	15.89	20.14	.992
10.0	17.42	15.38	19.67	.969
20.0	17.81	14.58	18.70	.921
30.0	17.90	14.22	17.81	.877
40.0	17.43	14.04	17.09	.842
50.0	17.21	14.07	16.47	.812
60.0	16.88	13.88	16.18	.797
70.0	15.75	13.54	15.47	.762
80.0	16.11	13.76	14.95	.736
100.0	15.92	13.20	14.19	.699
120.0	15.49	13.87	13.47	.664

TREATMENT (mT)	REMANENCE INTENSITIES (mA/m) X	Y	Z
.0	18.67	5.52	5.72
2.5	18.40	5.79	5.49
5.0	18.47	5.84	5.51
10.0	18.09	5.68	5.22
20.0	17.23	5.54	4.71
30.0	16.43	5.31	4.37
40.0	15.82	4.97	4.15
50.0	15.26	4.73	4.00
60.0	15.03	4.56	3.88
70.0	14.48	4.08	3.62
80.0	13.95	4.03	3.56
100.0	13.29	3.79	3.24
120.0	12.61	3.49	3.23



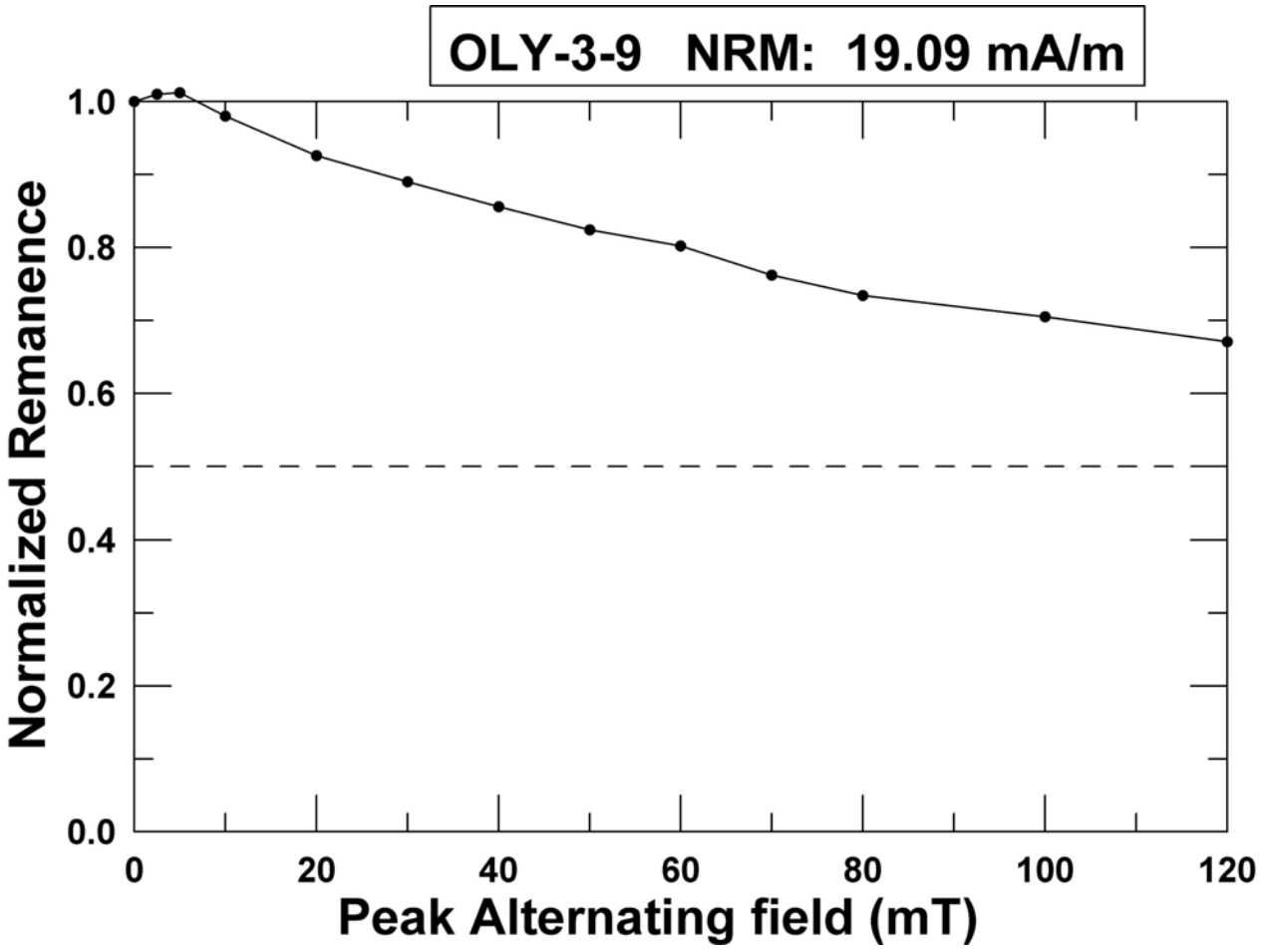


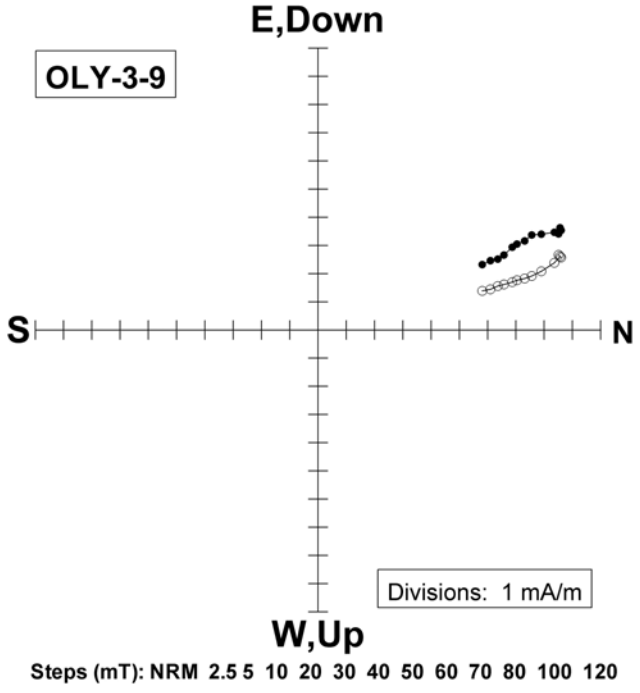
Steps (mT): NRM 2.5 5 10 20 30 40 50 60 70 80 100 120

SPECIMEN: OLYPHANT-3-9
SPECIMEN TYPE: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

TREATMENT (mT)	DECLINATION	INCLINATION	INTENSITY (mA/m)	NORMALIZED INTENSITY
.0	21.84	16.22	19.09	1.000
2.5	22.35	15.47	19.28	1.010
5.0	22.96	15.68	19.32	1.012
10.0	22.52	14.74	18.70	.980
20.0	23.30	13.61	17.68	.926
30.0	24.04	13.04	16.98	.890
40.0	23.37	12.93	16.33	.856
50.0	23.45	12.96	15.74	.824
60.0	23.13	12.78	15.32	.802
70.0	21.97	12.84	14.54	.762
80.0	21.59	12.85	14.02	.734
100.0	21.97	12.34	13.46	.705
120.0	21.79	12.50	12.81	.671

TREATMENT (mT)	REMANENCE INTENSITIES (mA/m) X	Y	Z
.0	17.01	6.82	5.33
2.5	17.19	7.07	5.14
5.0	17.12	7.25	5.22
10.0	16.71	6.93	4.76
20.0	15.79	6.80	4.16
30.0	15.11	6.74	3.83
40.0	14.61	6.31	3.65
50.0	14.07	6.10	3.53
60.0	13.74	5.87	3.39
70.0	13.15	5.31	3.23
80.0	12.71	5.03	3.12
100.0	12.19	4.92	2.88
120.0	11.61	4.64	2.77


OLY-3-9 NRM: 19.09 mA/m
Normalized Remanence
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Peak Alternating field (mT)


E,Down
OLY-3-9
S
N
W,Up
Divisions: 1 mA/m
Steps (mT): NRM 2.5 5 10 20 30 40 50 60 70 80 100 120

Paleomagnetic Results – Group Remanence after AF Demagnetization - 30 mT

Sample groups were all treated with AF Demagnetization at 30 mT. On the following pages are tables and polar plots of the sample groups after AF demagnetization at 30 mT.

α_{95} is a conical 95% confidence interval about the 3-D vector mean of the samples.
k or cluster coefficient is a measure of the clustering of the samples with higher values representing tighter clustering.
The isolated declination and inclination means and their α_{95} values are:
1) the mean of declination using just the 2-D plain of the X and Y components of magnetization and ignoring the Z component in calculating the α_{95} value, i.e. treating Z as though it has no variation, and 2) the mean of inclination using just the 2-D plain of the horizontal (resolved X and Y) and vertical (Z) components of magnetization and ignoring directional variability of the H component in calculating the α_{95} value. This is simply a mean and 95% confidence interval of the inclination values.

Based on the AF demagnetization results (previous section) it was decided that an AF peak field value of 30 mT should be used to remove viscous remanence components from the rest of the samples. This value was chosen because in the AF demagnetization data tables there was a slight shift in remanence directions up to 20 mT while after that relative stability in the directions occurred. AFD demagnetization resulted in a slight improvement of the clustering of samples in two sample groups (OLY2, OLY3), while it resulted in no significant change in clustering in OLY1.

In all sample groups remanent declinations shifted slightly to the west by 1-3º and inclinations increased by about 2-5º from NRM values after AF demagnetization.

The sample sites generally have very low remanent inclinations 17-24º, probably due to sediment compaction.

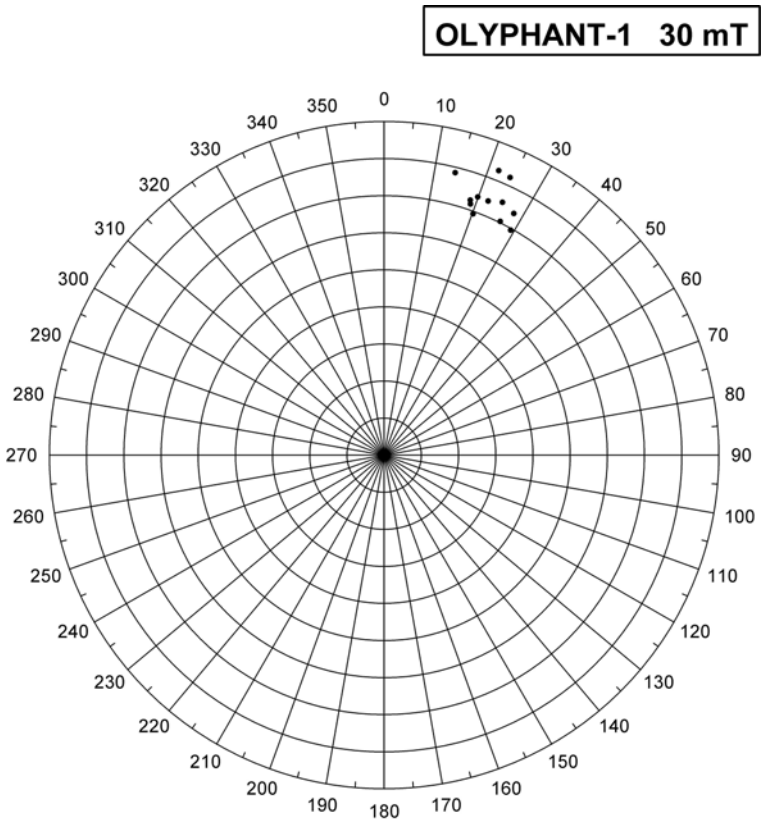
The sample sites have remanent declinations of 14-21º East, far removed from the modern geomagnetic declination of site (12.5º West).

Sample group: OLYPHANT-1

Treatment type: 30 mT
Specimen type: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

Remanence moments (mA/m)

X	Y	Z	Specimen
9.16	2.29	1.91	OLY1-1 30 mT
9.23	5.18	3.94	2
8.99	4.45	3.58	3 300 AVG
10.14	3.41	3.36	4
9.90	4.03	3.06	5
9.72	3.90	1.34	6
10.79	5.04	3.13	7
9.98	5.34	3.26	8
10.54	3.87	4.22	9
10.94	4.95	1.64	10 300 AVG
11.22	4.05	3.41	11
10.52	3.60	3.70	12



Decl.	Incl.	Intensity (mA/m)	Specimen
14.07	11.44	9.63	OLY1-1 30 mT
29.28	20.43	11.30	2
26.34	19.65	10.65	3 300 AVG
18.58	17.43	11.21	4
22.16	15.96	11.12	5
21.87	7.27	10.56	6
25.03	14.74	12.32	7
28.14	16.06	11.77	8
20.16	20.61	12.00	9
24.34	7.79	12.12	10 300 AVG
19.84	15.96	12.40	11
18.89	18.38	11.72	12

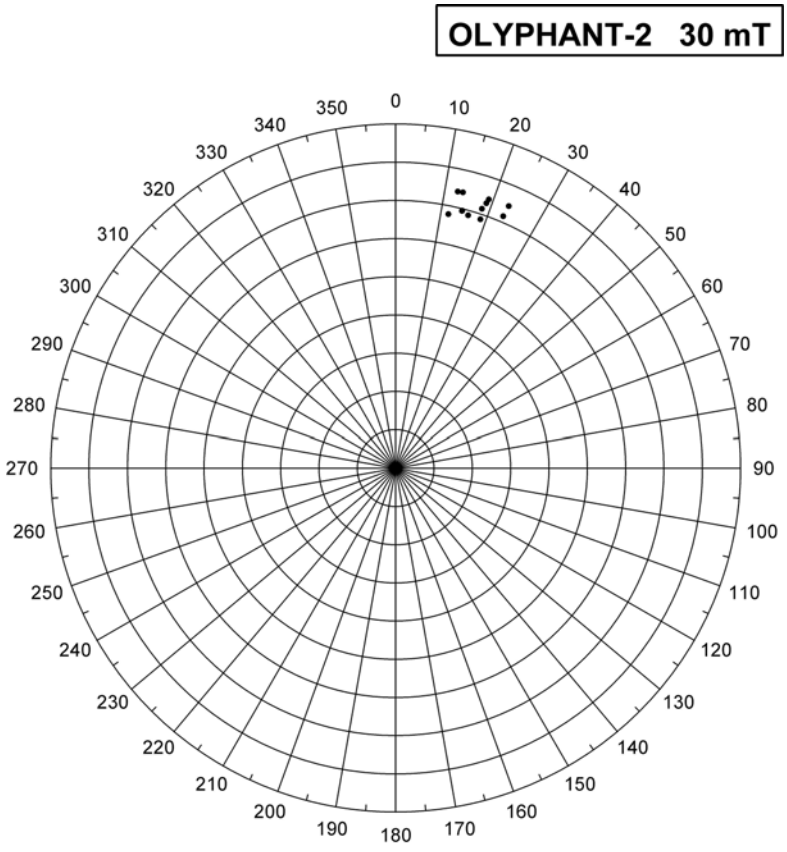
Mean Magnetic Intensity = 11.40 mA/m
Declination mean = 22.37
Inclination mean = 15.52
Cluster coefficient = 170.87
Cone of confidence (semi-arc 95%) = 3.33
Isolated Declination and 95% confidence interval: 22.39 +/- 2.37
Isolated Inclination and 95% confidence interval: 15.48 +/- 2.42

Sample group: OLYPHANT-2
Treatment type: 30 mT
Specimen type: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

Remanence moments (mA/m)

X	Y	Z	Specimen
6.01	1.25	2.50	OLY2-1 30 mT
6.29	1.41	1.83	2
7.24	1.86	2.80	3
8.36	2.83	3.44	4
9.30	3.08	3.29	5 300 AVG
5.41	1.87	1.60	6
4.79	1.37	1.94	7
4.79	1.23	1.85	8
4.24	1.83	1.27	9
5.23	1.27	1.52	10
4.18	1.78	1.51	11
6.09	2.08	1.94	12 300 AVG

Decl.	Incl.	Intensity (mA/m)	Specimen
11.70	22.18	6.63	OLY2-1 30 mT
12.63	15.88	6.70	2
14.43	20.56	7.98	3
18.73	21.28	9.47	4
18.35	18.57	10.33	5 300 AVG
19.07	15.65	5.95	6
15.97	21.26	5.35	7
14.44	20.50	5.28	8
23.32	15.41	4.79	9
13.67	15.77	5.60	10
23.08	18.42	4.79	11
18.87	16.78	6.72	12 300 AVG



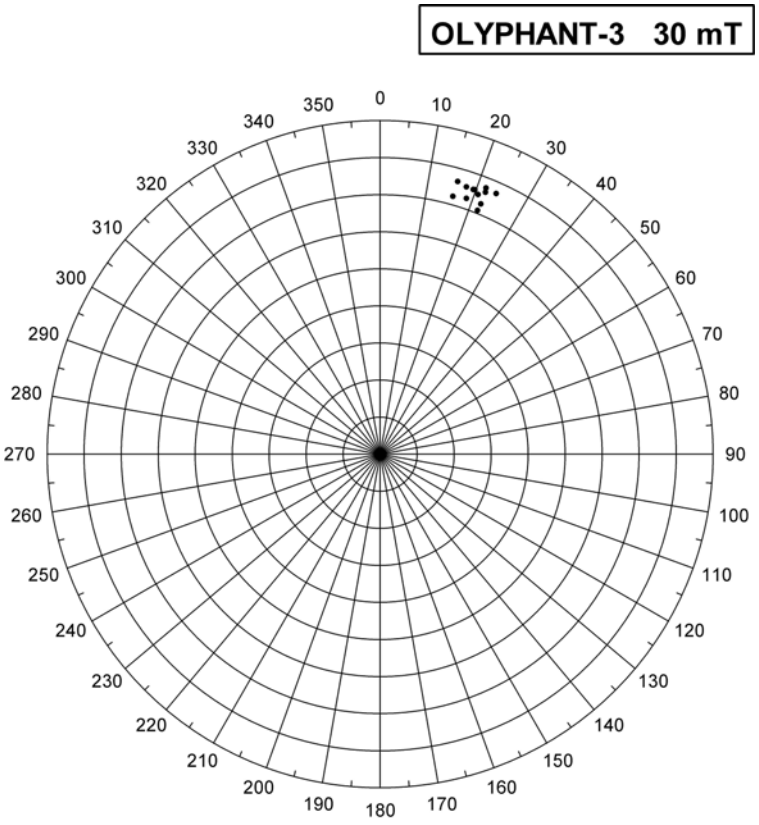
Mean Magnetic Intensity = 6.63 mA/m
Declination mean = 17.04
Inclination mean = 18.56
Cluster coefficient = 331.46
Cone of confidence (semi-arc 95%) = 2.39
Isolated Declination and 95% confidence interval: 17.02 +/- 2.06
Isolated Inclination and 95% confidence interval: 18.52 +/- 1.37

Sample group: OLYPHANT-3
Treatment type: 30 mT
Specimen type: Plastic tubes, L=1.8-1.9 cm, D=2.2 cm, V=7.0 cc

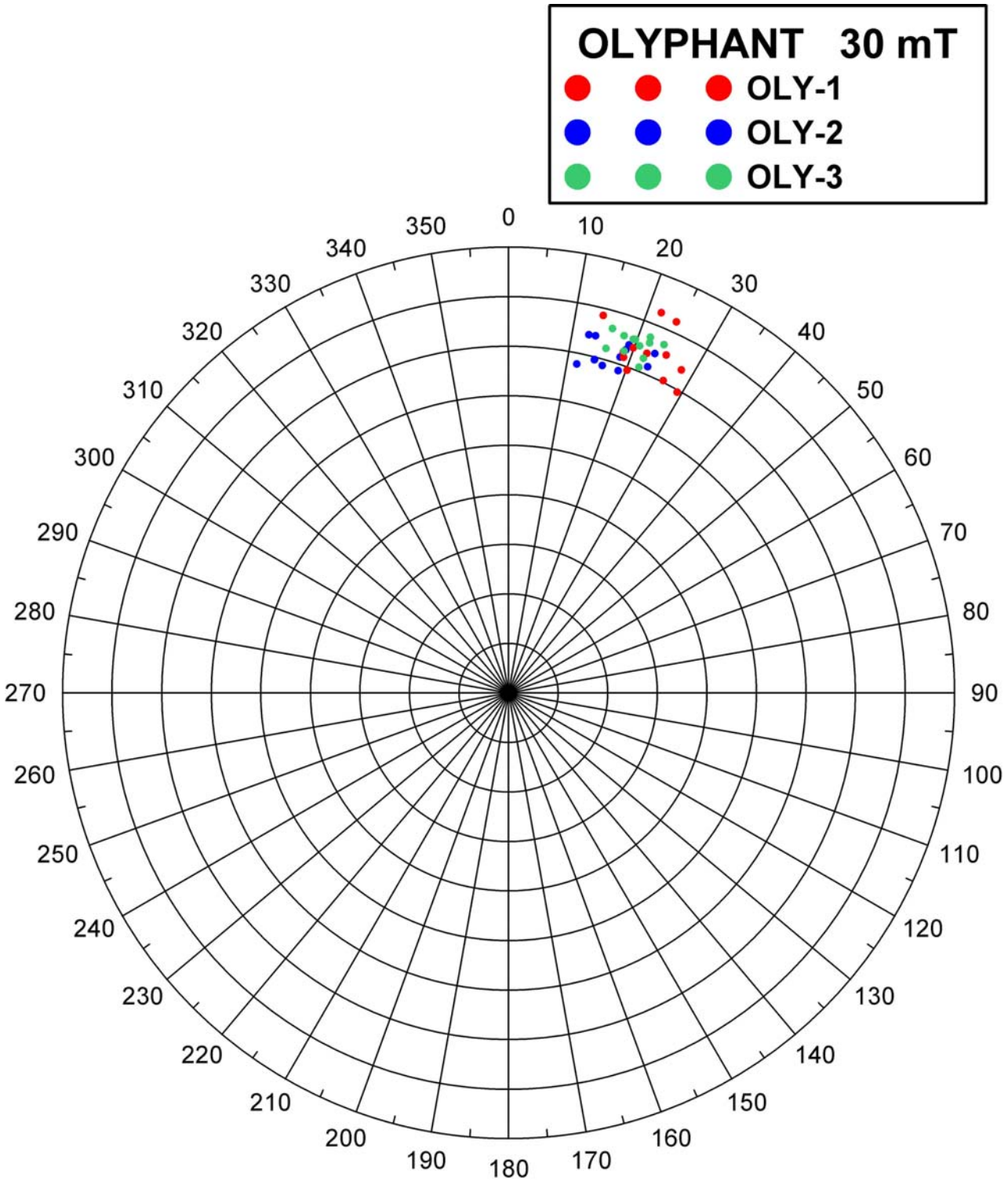
Remanence moments (mA/m)

X	Y	Z	Specimen
16.43	5.31	4.37	OLY3-1 30 mT
15.99	4.52	5.30	2
16.08	5.67	4.35	3
14.07	4.01	3.52	4
13.94	5.58	5.22	5
14.69	5.92	4.90	6
15.25	5.15	4.96	7
13.63	5.15	3.94	8
15.11	6.74	3.83	9 300 AVG
15.15	6.03	3.69	10
15.59	5.60	4.19	11
13.10	5.28	3.47	12

Decl.	Incl.	Intensity (mA/m)	Specimen
17.90	14.22	17.81	OLY3-1 30 mT
15.78	17.70	17.44	2
19.43	14.30	17.60	3
15.91	13.52	15.05	4
21.81	19.17	15.89	5
21.95	17.20	16.58	6
18.66	17.13	16.84	7
20.70	15.12	15.09	8
24.04	13.04	16.98	9 300 AVG
21.71	12.74	16.72	10
19.75	14.18	17.09	11
21.94	13.80	14.54	12

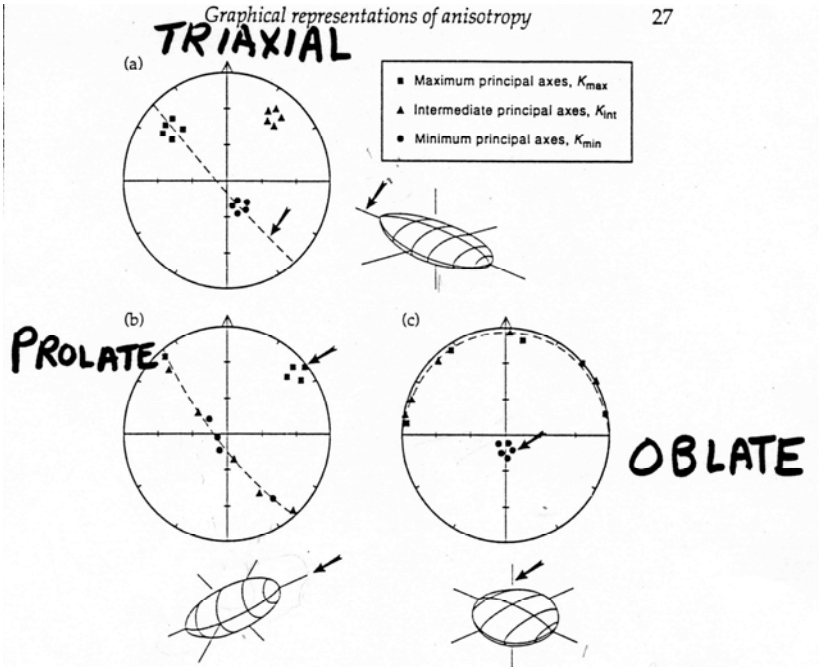


Mean Magnetic Intensity = 16.47 mA/m
Declination mean = 19.97
Inclination mean = 15.19
Cluster coefficient = 629.16 (Extremely tight clustering coefficient!!!)
Cone of confidence (semi-arc 95%) = 1.73
Isolated Declination and 95% confidence interval: 19.97 +/- 1.37
Isolated Inclination and 95% confidence interval: 15.18 +/- 1.12


OLYPHANT 30 mT
OLY-1
OLY-2
OLY-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

Paleomagnetic Results – Bulk Magnetic Susceptibility (MS) and Anisotropy of Magnetic Susceptibility (AMS)

On the following pages are tables of magnetic susceptibility data, polar plots of the principal axes of magnetic susceptibility (orthogonal values of $K_1 = K_{max}$, $K_2 = K_{int}$, and $K_3 = K_{min}$), and Flinn plots (K_{max}/K_{int} vs. K_{int}/K_{min}). The Flinn plots are a means of evaluating the shape of the principal susceptibility ellipsoid as prolate vs. oblate.



MS (Z-axis Bulk K) values are relatively low ranging from 0.65 – 1.00 SI units.

All samples have K_{max} values that are scattered with a low inclination angle (on the outer edge of the polar plot) or have a slight preference of trend, with low inclination angle, in the NW-SE direction. These values appear to have no relationship to the remanent magnetization direction of the samples, which is to the NNE. The slight NW-SE clustering of K_{max} values may be a reflection of current directions during sediment deposition or a weak shearing of the sediment in that direction. However, it must be stressed that the samples are not prolate (distinct and strongly oriented K_{max}) and have a strongly oblate ellipsoid indicating only small differences between K_{max} and K_{int} values. Any trend in K_{max} is very weakly developed. The top-most sample intervals (OLY1 and OLY2) have a more prolate tendency but they also exhibit the greatest scatter of K_{max} trends. These samples still have K_{max} values not much different from K_{int}.

K_{min} values are very distinct from K_{int} and are steeply inclined (80-75º degrees) with no preference in horizontal direction. This is also expressed as a horizontally flattened or oblate susceptibility ellipse that suggests sediment compaction and horizontal alignment of elongate or plate-like mineral grains. This may be the result of magnetic mineral grains aligning in the horizontal during deposition or compaction, or mineral grains adhering to plate-like clay minerals that are subsequently flattened to the horizontal during sediment compaction.

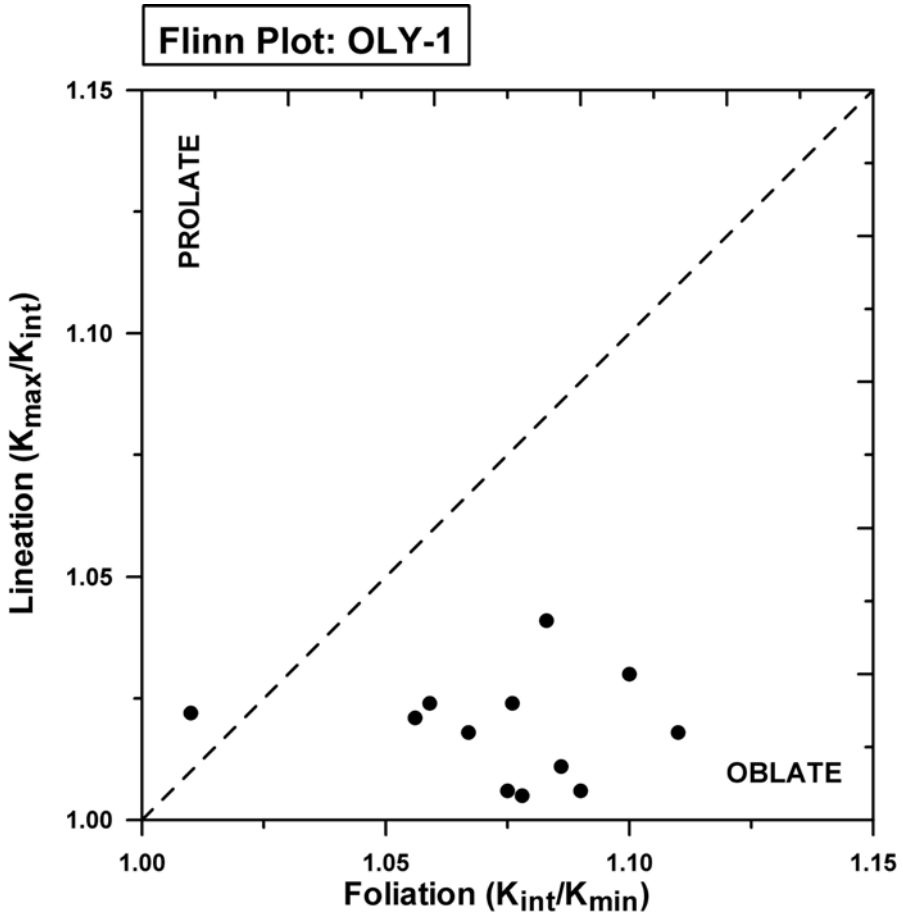
Sample site: OLYPHANT-1
Specimen type: Plastic tubes, V = 7.0 cc

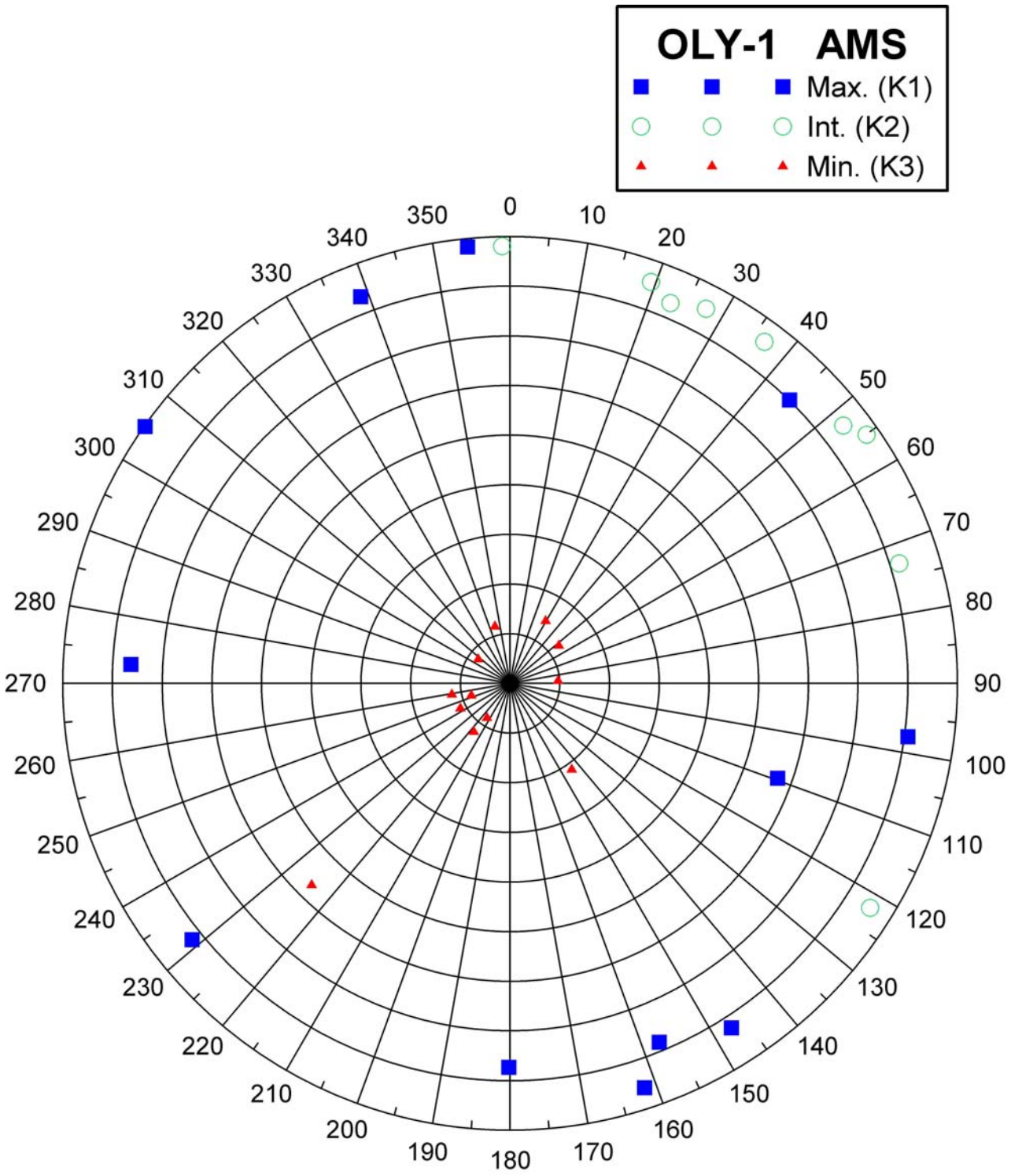
All angles are recorded in the lower hemisphere.
(Units of K are 10E-04 SI units.)

K1	DEC1	INC1	K2	DEC2	INC2	K3	DEC3	INC3	Bulk K	Name
0.750	97.67	9.28	0.745	6.65	6.23	0.683	243.19	78.79	0.686	OLY1-1
0.767	44.57	9.88	0.754	135.73	6.64	0.679	259.12	78.06	0.683	2
0.926	231.11	7.81	0.904	321.88	5.61	0.840	87.21	80.36	0.842	3
0.712	109.56	32.93	0.697	347.13	39.63	0.690	224.50	33.07	0.699	4
0.754	354.42	1.67	0.741	84.65	8.01	0.694	252.72	81.82	0.694	5
0.822	180.18	12.65	0.818	271.73	6.89	0.758	29.68	75.53	0.763	6
0.791	305.14	0.19	0.783	35.16	8.38	0.721	213.88	81.62	0.723	7
0.750	147.32	7.56	0.728	56.96	2.71	0.661	307.37	81.97	0.664	8
0.791	272.84	13.64	0.787	6.85	16.10	0.732	144.46	68.65	0.739	9
0.838	157.44	11.73	0.805	247.76	1.51	0.743	344.99	78.17	0.747	10
0.851	161.61	4.21	0.831	252.48	11.63	0.785	52.02	77.61	0.787	11
0.758	338.89	6.52	0.743	70.08	10.25	0.703	216.96	77.81	0.705	12

Means:	Max.	Int.	Min.
K:	0.793	0.778	0.724
Dec:	149.4	62.5	231.3
Inc:	6.1	4.5	86.0

Avg. Bulk K = 0.728
Mean K = 0.765
L = 1.019 H = 0.088
F = 1.074 T = -0.157
P = 1.094 Pp = 1.100




OLY-1 AMS
Max. (K1)
Int. (K2)
Min. (K3)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

Sample site: OLYPHANT-2
Specimen type: Plastic tubes, V = 7.0 cc

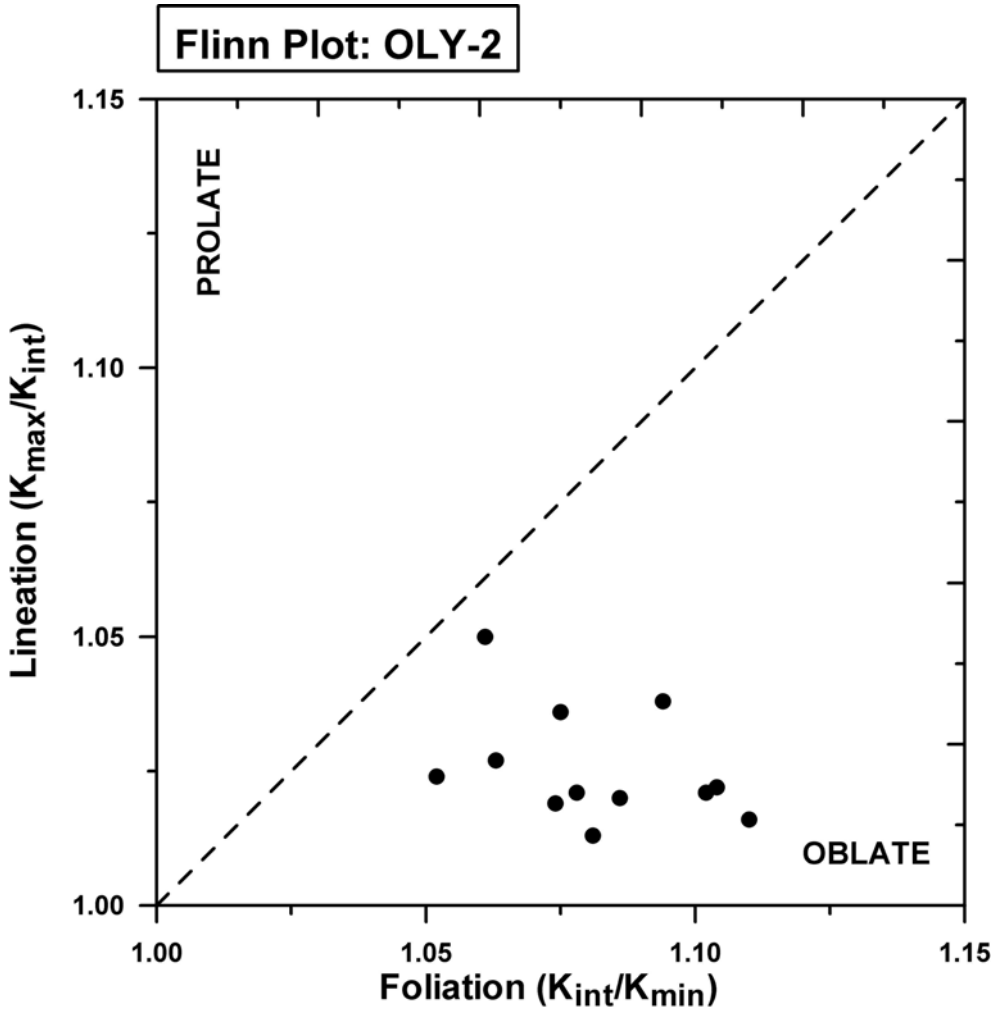
All angles are recorded in the lower hemisphere.
(Units of K are 10E-04 SI units.)

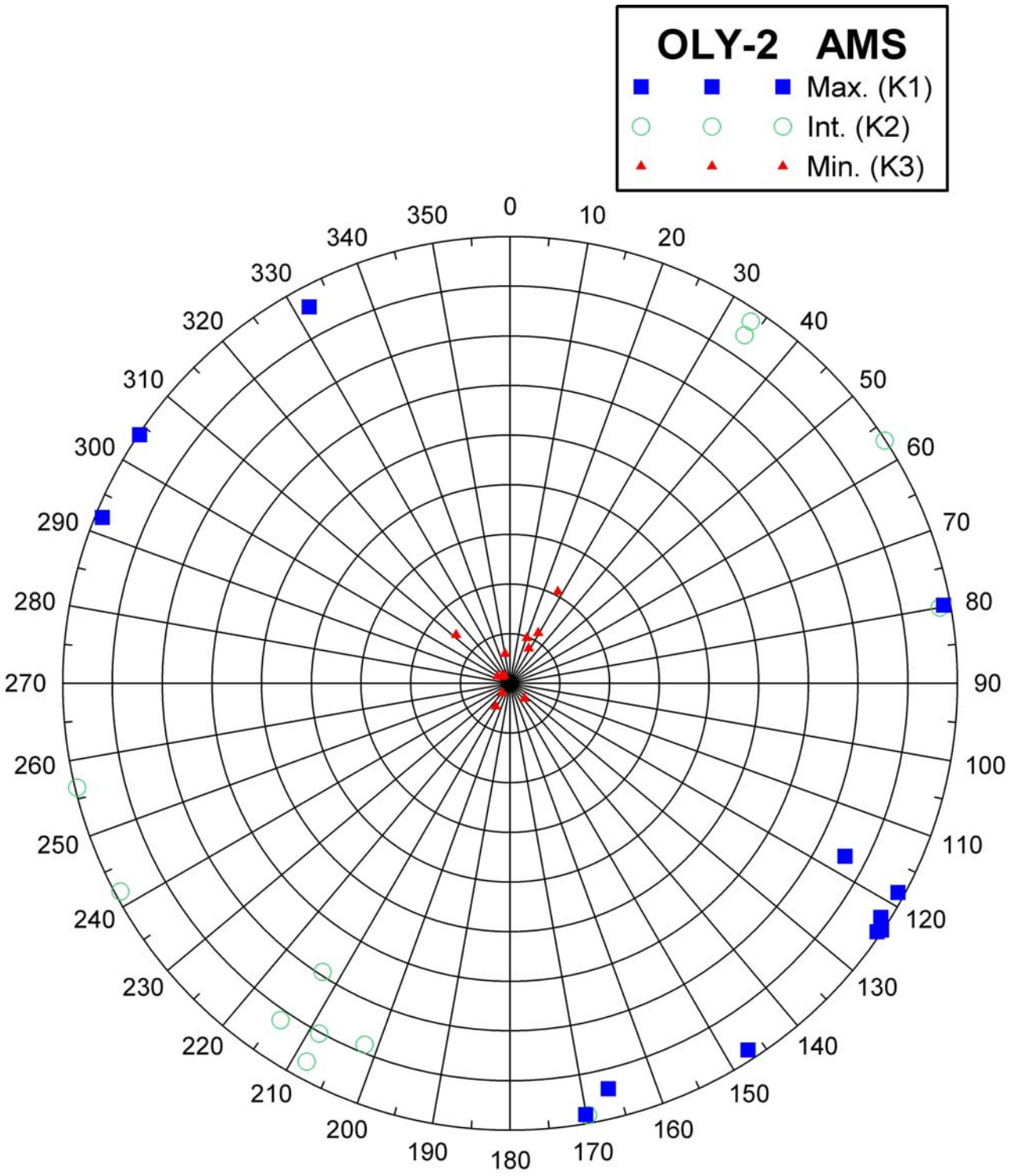
K1	DEC1	INC1	K2	DEC2	INC2	K3	DEC3	INC3	Bulk K	Name
1.054	303.89	0.19	1.030	33.91	5.48	0.979	211.92	84.52	0.979	OLY2-1
1.074	170.07	1.87	1.054	79.99	2.23	0.981	299.95	87.09	0.981	2
0.963	166.40	6.00	0.944	256.44	0.44	0.875	350.59	83.99	0.875	3
1.074	147.05	2.02	1.052	57.05	0.17	0.955	322.35	87.98	0.955	4
1.032	124.12	0.86	1.010	214.24	7.94	0.915	27.99	82.01	0.917	5
0.972	123.61	0.27	0.926	33.59	2.52	0.873	219.78	87.46	0.873	6
1.016	79.76	1.40	1.003	169.80	1.61	0.928	308.64	87.87	0.928	7
0.961	117.34	14.16	0.926	208.24	3.53	0.847	311.92	75.39	0.853	8
1.021	122.29	1.82	0.985	212.98	20.72	0.917	27.50	69.19	0.926	9
0.972	292.17	1.40	0.957	201.89	11.56	0.862	28.97	78.36	0.866	10
0.922	118.35	1.38	0.897	208.58	9.67	0.844	20.29	80.23	0.847	11
1.109	331.93	4.05	1.087	241.85	1.14	1.001	136.14	85.80	1.001	12

Means:	Max.	Int.	Min.
K:	1.014	0.989	0.915
Dec:	129.7	220.0	3.4
Inc:	2.1	4.4	85.4

Avg. Bulk K = 0.917
Mean K = 0.973

L = 1.025 H = 0.100
F = 1.081 T = -0.174
P = 1.109 Pp = 1.114




OLY-2 AMS
Max. (K1)
Int. (K2)
Min. (K3)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

Sample site: OLYPHANT-3
Specimen type: Plastic tubes, V = 7.0 cc

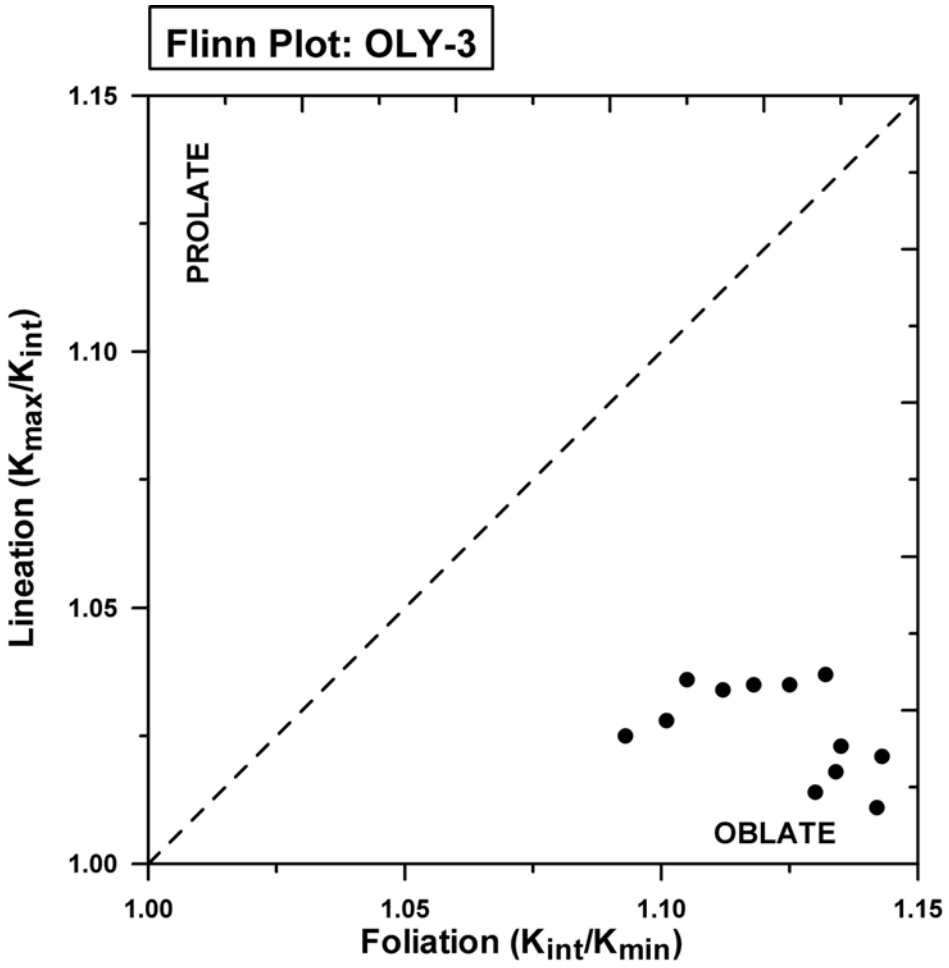
All angles are recorded in the lower hemisphere.
(Units of K are 10E-04 SI units.)

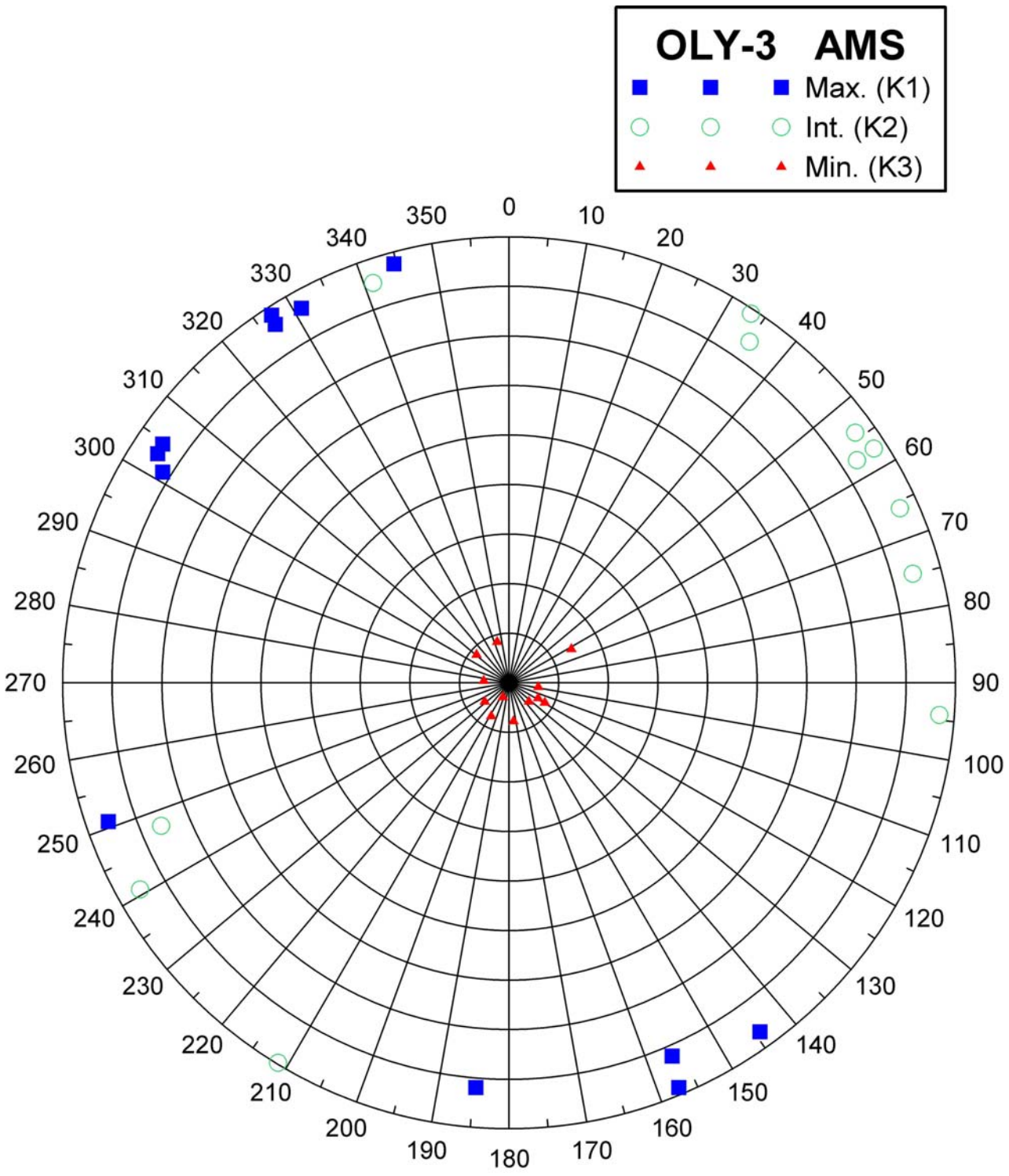
K1	DEC1	INC1	K2	DEC2	INC2	K3	DEC3	INC3	Bulk K	Name
0.906	157.26	1.45	0.875	247.63	14.18	0.783	61.53	75.75	0.789	OLY3-1
0.904	301.33	8.24	0.882	211.29	0.30	0.807	119.24	81.75	0.809	2
0.970	250.86	4.53	0.959	341.24	4.81	0.840	117.76	83.39	0.842	3
0.966	327.16	1.73	0.933	57.24	2.61	0.829	203.72	86.87	0.829	4
0.970	144.34	3.29	0.950	54.12	3.92	0.831	274.25	84.88	0.831	5
0.988	304.61	5.16	0.966	35.14	5.84	0.851	173.38	82.19	0.853	6
0.966	326.93	3.69	0.939	57.37	6.72	0.853	208.33	82.32	0.855	7
1.019	156.43	7.83	0.985	65.92	3.71	0.886	310.78	81.32	0.888	8
1.023	303.11	5.45	1.005	33.21	1.00	0.886	133.52	84.45	0.888	9
0.972	184.70	8.03	0.959	94.27	3.02	0.849	343.83	81.42	0.851	10
0.981	331.01	3.61	0.946	240.71	4.71	0.836	98.38	84.06	0.838	11
0.939	344.63	2.37	0.906	74.87	5.70	0.820	232.17	83.82	0.820	12

Means:	Max.	Int.	Min.
K:	0.967	0.942	0.839
Dec:	325.5	55.4	135.0
Inc:	1.1	1.4	88.5

Avg. Bulk K = 0.841
Mean K = 0.916

L = 1.026 H = 0.136
F = 1.123 T = -0.269
P = 1.152 Pp = 1.163




OLY-3 AMS
Max. (K1)
Int. (K2)
Min. (K3)
0
10
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80
90
100
110
120
130
140
150
160
170
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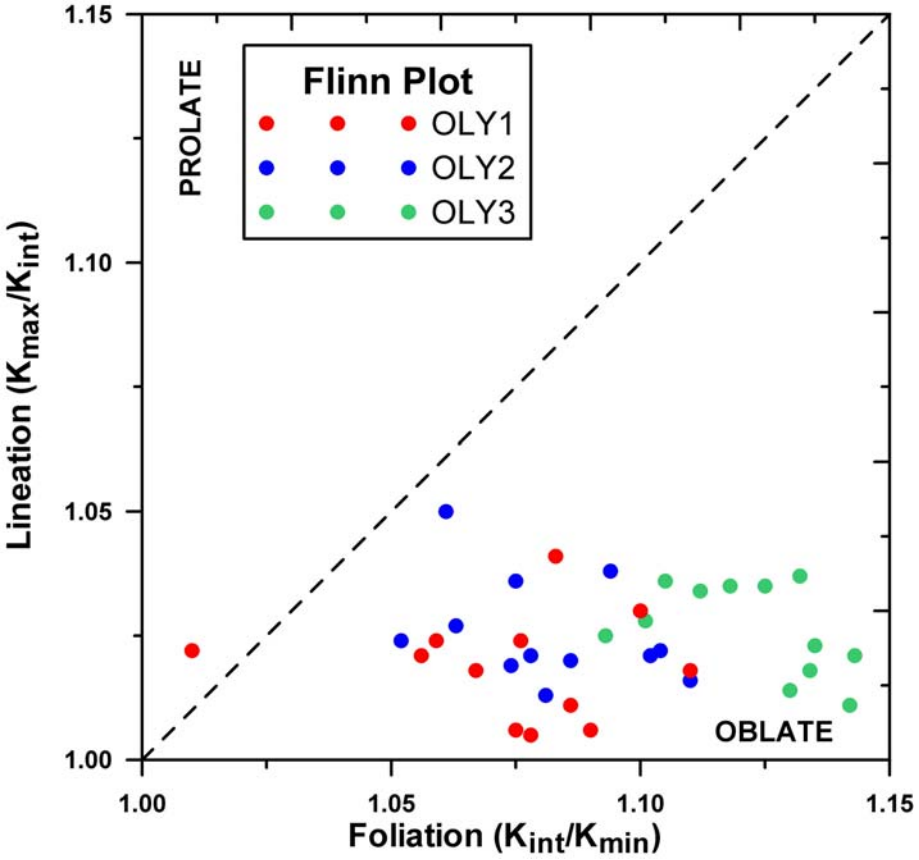
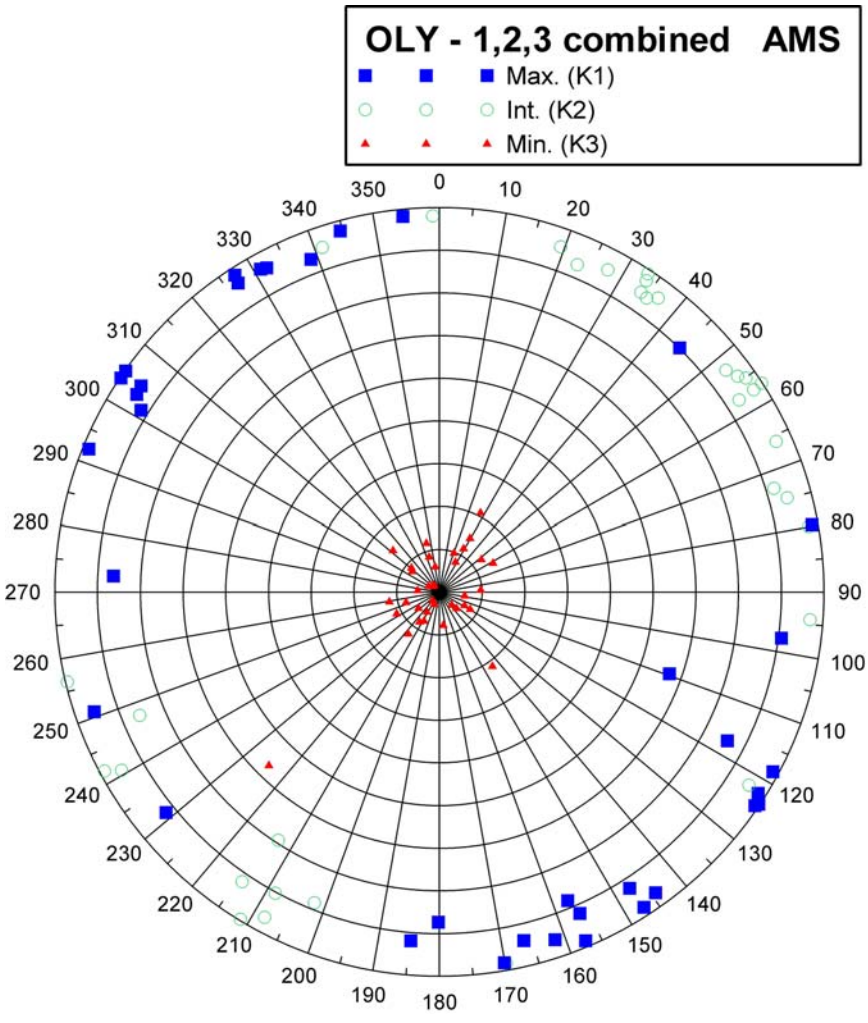
340
350


Flinn Plot
OLY1
OLY2
OLY3
PROLATE
OBLATE
Lineation (K_{max}/K_{int})
Foliation (K_{int}/K_{min})
1.00
1.05
1.10
1.15


OLY - 1,2,3 combined AMS
Max. (K1)
Int. (K2)
Min. (K3)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
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