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Final Report

MASTER

Magnetostratigraphy of the Grande Ronde Basalt Pasco Basin, Washington

Prepared for

Rockwell Hanford Operations
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MAGNETOSTRATIGRAPHY OF THE GRANDE RONDE BASALT PASCO BASIN, WASHINGTON

by

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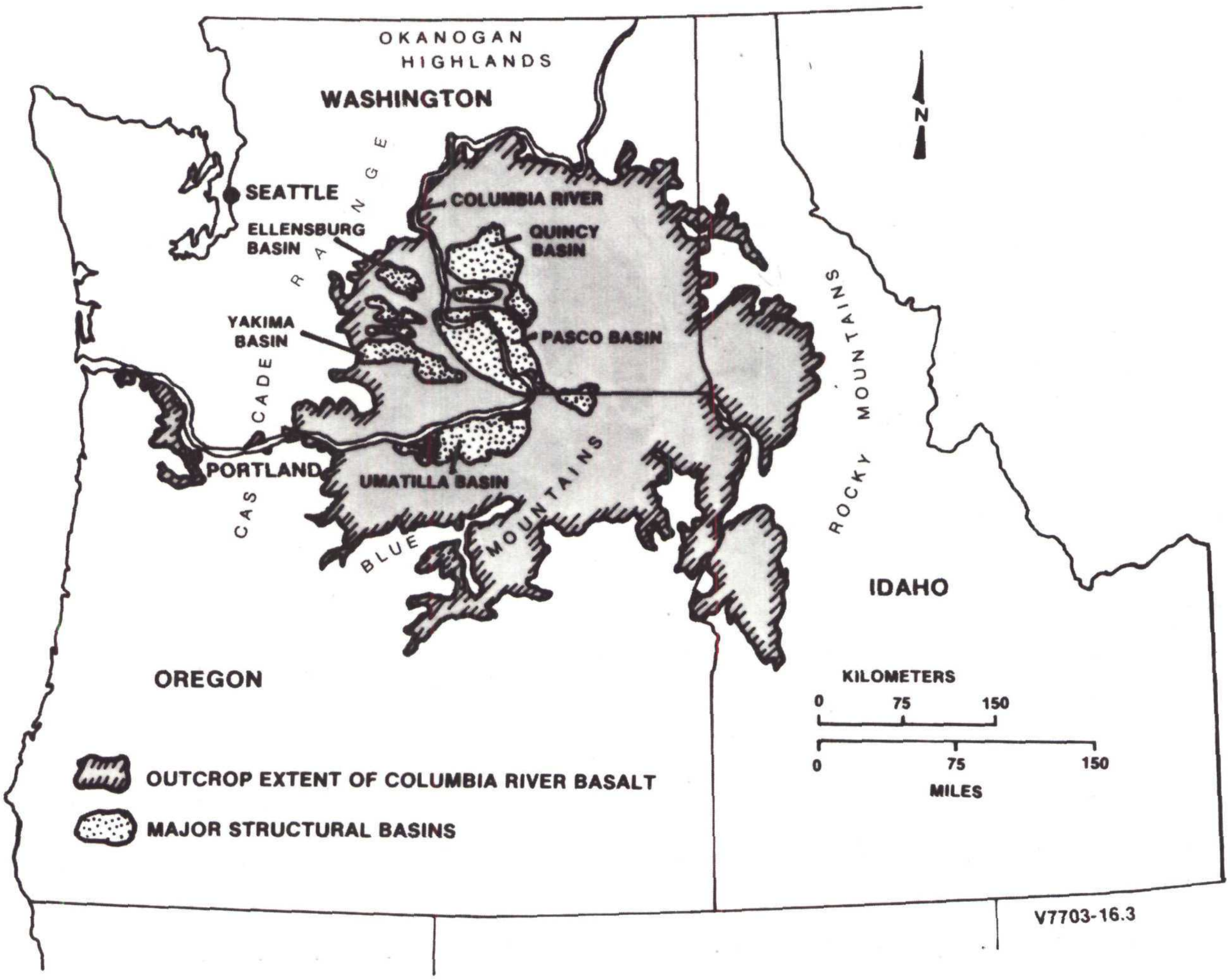
INTRODUCTION

The Columbia River Basalt is a layered mass of more than 48,000 cubic miles of tholeiitic lava covering an area of more than 58,000 square miles in parts of Washington, Oregon, and Idaho (Figure 1). This massive sequence of basalt flows represents an accumulation of repeated eruptions from middle to late Miocene (16 million years to 6 million years before present) that filled a slowly subsiding basin. In south-central Washington, the basalt was folded and locally faulted into a system of east-west-trending anticlinal ridges and synclinal valleys coeval with the eruptions of the younger flows. In the Pasco Basin, near the center of the area covered by the Columbia River Basalt, the total thickness is a minimum of 3,922 feet. There, the Columbia River Basalt apparently overlies a series of older basalts of Oligocene to Eocene age. Other aspects of Columbia River Basalt geology were recently summarized by Swanson and Wright (1978).

Previous paleomagnetic analyses of the Columbia River Basalt flows have resulted in valuable information for the correlation of these sequences. Paleomagnetic correlations have been reported by several researchers including Campbell and Runcorn (1956), Watkins (1965), Rietman (1966), and Watkins and Baski (1974). Rietman (1966) provided the most comprehensive evaluation of units throughout the Columbia Plateau.

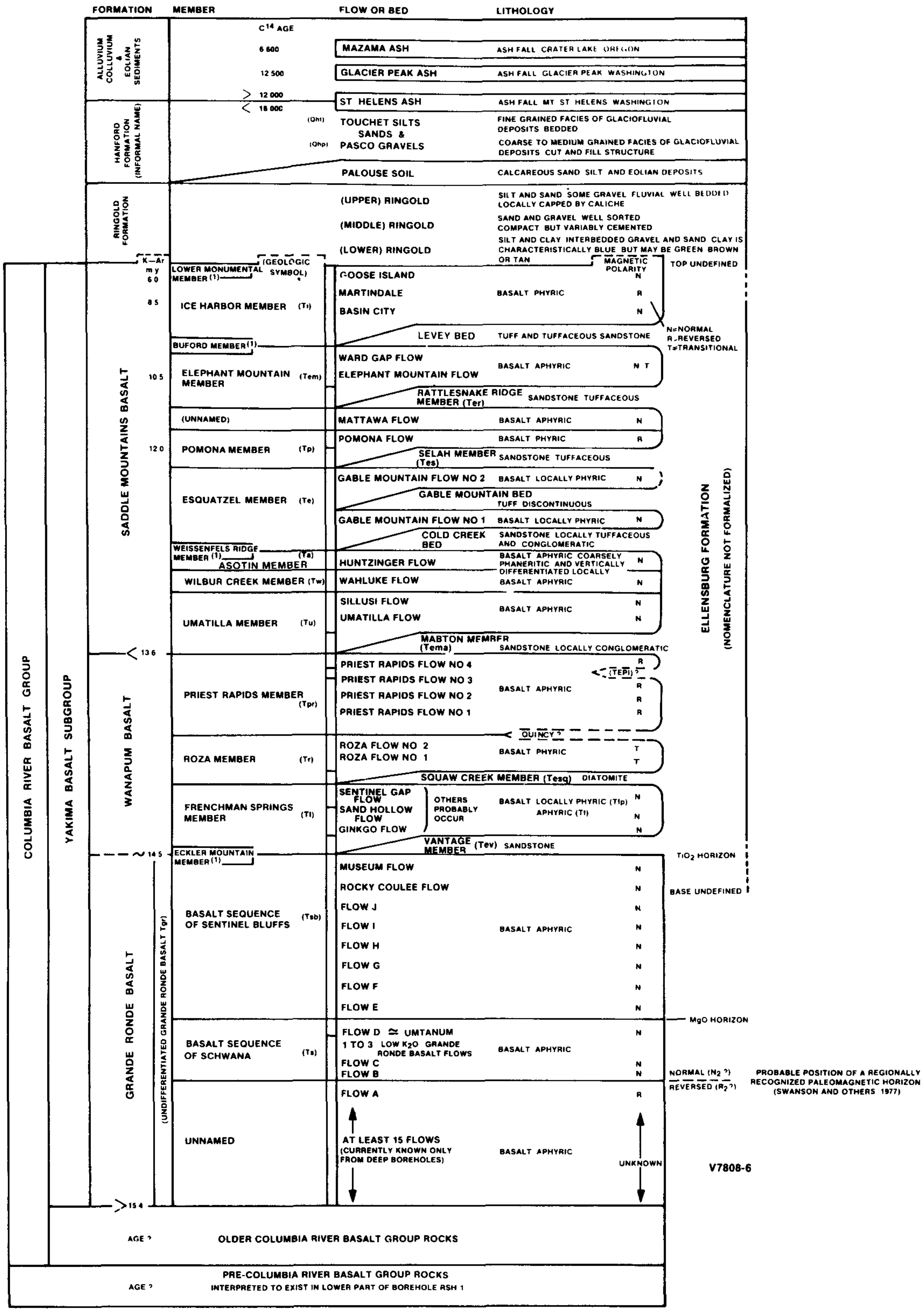
The Columbia Plateau



MAP OF THE EXTENT OF THE COLUMBIA PLATEAU BASALTS Grande Ronde Magnetostratigraphy Rockwell Basalt Project	
Project No. 14268A **Woodward-Clyde Consultants**	Figure 1 Page 2

The Basalt Waste Isolation Program within Rockwell Hanford Operations (a prime contractor to the U. S. Department of Energy) is investigating the feasibility of a nuclear waste terminal storage facility in the Columbia River Basalt. Current emphasis of the Basalt Waste Isolation Program is on the Columbia River Basalt underlying the Hanford Site located in the Pasco Basin of south-central Washington (Figure 1). Geologic studies is one of the areas of investigation within the Basalt Waste Isolation Program. A primary goal of the geologic studies is to evaluate the stratigraphic relations of the basalt flows in the upper Grande Ronde Basalt, a portion of the Columbia River Basalt, Figure 2. The upper Grande Ronde Basalt includes flows of the Sentinel Bluffs sequence, the Schwana sequence and the upper part of an unnamed sequence. Beck and others (1978) successfully applied magnetostratigraphy to correlating portions of the upper Grande Ronde Basalt which contains thick, internally dense flows that are currently being considered as potential repository host rock.

Prior to 1976, whole-rock, major-element chemical analyses had identified two sequences of basalt flows, the Sentinel Bluffs and the Schwana, in the upper Grande Ronde Basalt. These two sequences are distinguishable on the basis of pronounced differences in the concentrations of several major elements, mainly magnesium. The contact between the two sequences is shown as the MgO horizon on Figure 2. Identification of individual basalt units within the Sentinel Bluffs sequence above the MgO horizon and those in the Schwana sequence and the unnamed sequence below the MgO horizon was difficult because of the similar concentrations of major elements among the flows in each sequence.



(1) MEMBER KNOWN FROM AREAS OUTSIDE THE PASCO BASIN BUT NOT RECOGNIZED TO DATE WITHIN THE PASCO BASIN

COMPOSITE STRATIGRAPHIC SECTION OF PASCO BASIN Grande Ronde Magnetostratigraphy Rockwell Basalt Project	
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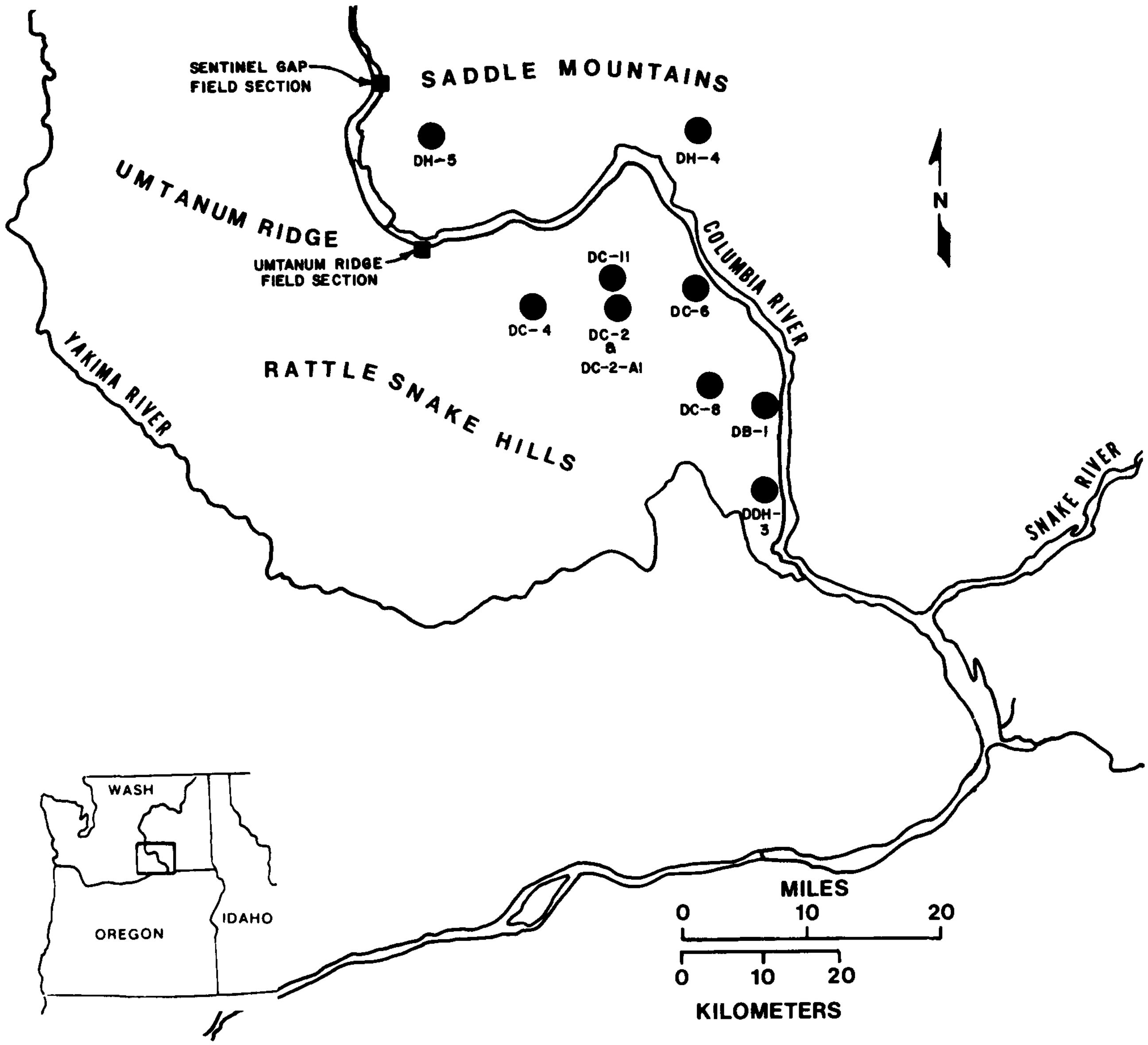
Coe and others (1978) conducted an examination of the paleomagnetic properties of the upper Grande Ronde Basalt flows exposed at Sentinel Gap (Figure 3). This study indicated that the upper Grande Ronde Basalt at Sentinel Gap (flows A through J, Rocky Coulee and Museum in Figure 2) contains at least one polarity reversal and possesses significant differences in the inclination of the natural remanent magnetization (NRM) direction between flows.

Beck and others (1978) extended the work on the Grande Ronde Basalt from surface exposures to samples obtained from drill cores as deep as several thousand feet. Their study included sampling of the upper Grande Ronde Basalt flows on Umtanum Ridge, south of Sentinel Gap, and in unoriented core from core holes DH-5, DC-2, and DDH-3, southeast of Sentinel Gap (Figure 3), forming a northwest-southeast traverse across the Pasco Basin. The study correlated three magnetostratigraphic units through the upper Grande Ronde Basalt of the Pasco Basin subsurface on the basis of inclination variations and located a polarity reversal in one core hole, DH-5. These studies by Coe and others (1978) and Beck and others (1978) thus established the feasibility of correlating flows of the Grande Ronde Basalt throughout the Pasco Basin using magnetostratigraphy, established preliminary magnetostratigraphic polarity boundaries, and identified units having distinctly different inclinations that could be used for correlation.

In late 1978, a third, considerably larger study was subcontracted by Rockwell Hanford Operations (Rockwell) to expand and better define these magnetostratigraphic correlations. The results of that study are the subject of this report.



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LOCATION MAP OF CORE HOLES Grande Ronde Magnetostratigraphy Rockwell Basalt Project	
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OBJECTIVES AND SCOPE

The first objective of the paleomagnetic studies presented in this report was to evaluate in greater detail the paleomagnetic characteristics and magnetostratigraphy of the Grande Ronde Basalt sequence and to correlate between selected core holes within the Pasco Basin. Core holes DC-4, DC-6, DC-8, and DH-4 were selected. A second objective of these paleomagnetic studies was to evaluate the paleomagnetic characteristics of selected portions of the Saddle Mountains Basalt and Wanapum Basalt sequences in the Pasco Basin, and to assess if they also possess variations in inclination and polarity that would make them suitable for magnetostratigraphic correlation using core hole samples in a manner similar to that for the Grande Ronde Basalt. Flows in core holes DB-1, DC-2, DC-11, DDH-3, and DH-4 were selected. Samples were also collected to evaluate, in a preliminary manner, the use of paleomagnetism in interpreting structural deformation within the basalt sequences. A preliminary comparison of fluxgate orientation of core relative to NRM direction orientation of core was also made.

The scope of these paleomagnetic studies was to collect, measure, and analyze the results from 940 samples using approximately seven samples per flow from 10 cores. The cores were oriented only with respect to up direction in all but a few cases. The numbers of samples and flows collected and the measurements completed for each core are listed in Table 1.

METHOD OF STUDY

The sampling was done from existing cores at the Hanford Site on two occasions, from October 23 through November 2 and December 11 through 13, 1978. The initial sampling consisted of taking seven samples per flow from flows selected by

TABLE 1

NUMBER OF FLOWS,
SAMPLES, AND MEASUREMENTS

Hole	Number of Flows/Samples/Measurements			Bedding Orientation Azimuth	Bedding Orientation Dip	Location Longitude (degrees East)	Location Latitude (degrees North)
DB-1	2	14	49	225	1	240.7	46.4
DC-2	13	90	340	190	.5	240.5	46.6
DC-2-Al	1	6	42	190	.5	240.5	46.6
DC-4	16	112	408	0	0	240.4	46.5
DC-6	15	147	478	30	1	240.6	46.6
DC-8	16	131	404	225	1	240.6	46.5
DC-11	2	14	55	4	8	240.5	46.6
DDH-3	11	77	288	315	.5	240.7	46.4
DH-4	35	328	1129	215	2	240.6	46.7
DH-5	3	21	86	190	9	240.6	46.6
TOTAL	114	940	3279				

Rockwell personnel. The samples were as evenly distributed throughout the flow as possible; emphasis was on sampling the freshest material possible, avoiding flow tops or bottoms and altered or fractured zones. Preliminary results from measurements of the samples from this collection showed areas of core where additional samples might clarify geologic correlation or lithologic flow boundary designations. These locations were selected by Dr. C. W. Myers of Rockwell, with the concurrence of Woodward-Clyde Consultants, and were sampled during the second sampling trip. New core from DC-4, which was unavailable during the first collection, was also sampled. Samples were also collected from DC-2-Al to evaluate a structural feature.

The up-direction, sample location, and depth were marked on each section of core prior to its removal from the core boxes. It was assumed that the core was in the correct up-down position. An azimuthal line was carefully drawn on each core section and arrows pointing up drawn right of this line (Figure 4). The core was drilled at the selected and marked locations using a totally non-magnetic diamond-tipped core barrel, using water as coolant. The accurate orientation of the samples as facilitated by the use of a sleeve-type orienting device, which results in the orientation of the sample relative to the core being accurate to within one degree.

Where two or more adjacent core sections were to be sampled, the sections were fitted together on a section of aluminum angle stock and a common axial line drawn on each section. The samples from these fitted core sections, therefore, have the same relative azimuth or declination. On some sections of the core, fluxgate magnetic north had previously been marked. This fluxgate north line was used as a guide to marking axial line to orient various sections of the core. On occasion,

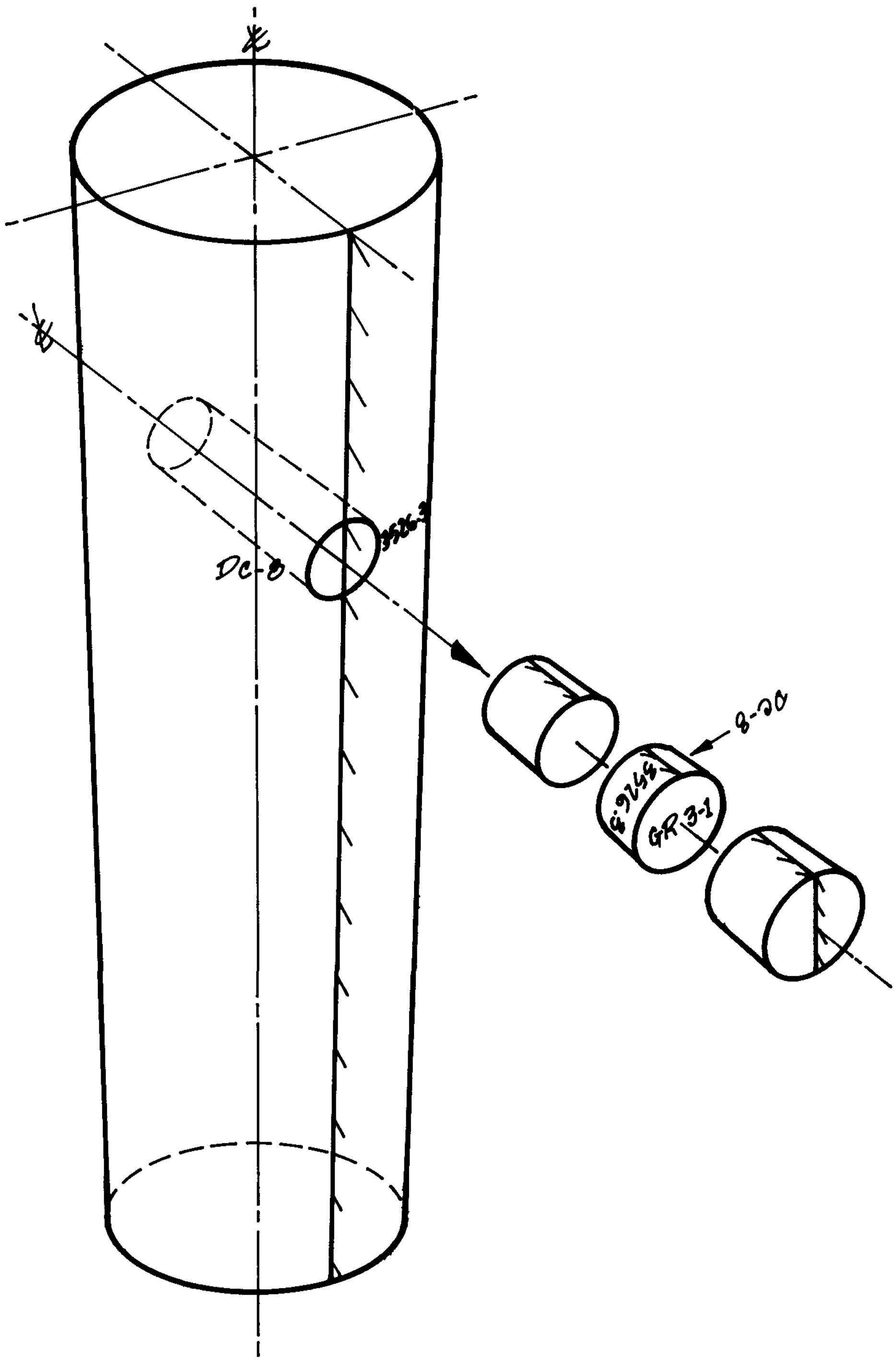

DIAGRAM OF SAMPLE ORIENTATION RELATIVE TO CORE SECTION ORIENTATION Grande Ronde Magnetostratigraphy Rockwell Basalt Project	
Project No. 14268A **Woodward-Clyde Consultants**	Figure 4 Page 10

discrepancies of approximately 30 degrees occurred between the actual physical fit of the sections of core and the marked fluxgate magnetic north line. In these cases, the physical fit was used to transfer a common relative declination. The use of the fluxgate north line allows a check, although imprecise, of the relative declination of the core sections. Each sample from the first collection, as it was cut, was given a unique sample identification number consisting of the flow number and a suffix of 1 through 7; 1 being the highest and 7 being the lowest sample in the flow. Subsequently, some of these sections and flows were resampled. These samples were given a suffix of 8 or higher. These numbers are also sequential stratigraphically from top to bottom.

All samples were measured at Woodward-Clyde Consultants paleomagnetic facility in Oakland, California. The magnetometer used was an ScT, 3-axis superconducting rock magnetometer with a 2-1/2-inch diameter access region. This instrument has a dynamic range of 10^{-8} to 1 emu and is directly interactive with a mini-computer that records and computes the precision of the measurement and calculates and stores the results on magnetic tape. The operator begins the interpretation process during measurement by using the simultaneous display of the data in tabular and plot forms.

The samples were demagnetized in a 400-hertz alternating field (AF) demagnetization unit. While demagnetized, the samples are magnetically shielded and spun about 3 axes. The general demagnetization scheme followed for these samples included the stepwise demagnetizing of two of the seven samples from each individual flow and, on the basis of the magnetic character of these samples, selecting a bulk demagnetization level for the remaining five samples. Use of the interactive system during measurement allowed additional measurements to be made when the selected levels were not appropriate for individual samples. Approximately 20 percent (580) more measurements were made over the number that had been estimated in the general demagnetization scheme.

RESULTS

The results of the paleomagnetic measurements for each of the 940 samples collected are presented by samples, one page per sample, in Data Volumes 1 through 4. The data volumes are on file in the Basalt Waste Isolation Program Library. Results are given as a list of magnetization directions and vector differences, a Zijderveld plot of the stratigraphic magnetization directions, a stereonet plot of the stratigraphic magnetization directions and vector differences, and a plot of normalized intensity versus demagnetization level. The samples are arranged stratigraphically by hole and the holes are arranged in alphabetical order. The stratigraphic inclinations (corrected for bedding orientation) of the directions selected as most representative of the original magnetization directions of individual samples are listed in the Appendix.

Bedding, in most cases, has a dip of less than 1 or 2 degrees. The dips do not significantly affect the inclinations except in two holes, DC-11 and DH-5, where bedding dips 8 and 9 degrees, respectively. These dips might be expected to increase scatter and possibly introduce error in inclinations when correcting unoriented core for a dip of this amount. This problem was discussed by Beck and others (1978). The holes involved in the present study had a small number of flows; and many of the samples had declination in a north-south direction. Since no particular scatter was observed, no measures to correct this potential problem were taken.

In general, the magnetic stability of the samples was good. The magnetic characteristics of the demagnetization level versus normalized intensity showed a range from very low coercivity spectrums (below 100 oersteds) to intermediate coercivity spectrums (below 800 oersteds). Results from these basalts typically reflect good magnetic stability and good agreement between the directions of samples from an individual flow. Very good results and stability for many of the flows collected in surface outcrop were demonstrated by Coe and others (1978). Samples from hole DC-4 show consistently good agreement and have standard deviations about the mean of the inclinations of the samples from one flow of typically less than 8 degrees. This comparatively better magnetic stability in DC-4 may reflect that it was recently drilled and has not been disturbed by other collections or stored for a significant period of time. The appendix lists the mean and standard deviations of the stratigraphic inclinations by flow. Flow mean and standard deviations of samples are not included where the standard deviation exceeded 16. Large standard deviations may represent a questionable distribution of inclinations of samples about the mean and certainly introduces suspicion regarding the validity of the mean as an approximation of the original direction of thermal remanent magnetization of the flow. In selecting data for inclusion in the mean, several guidelines were followed to ensure integrity of the data. The flow boundaries selected for collection of the samples were respected, although agreement between inclinations in a few cases was better across these flow boundaries than within the flow. This may reflect baked contact zones, magnetic alteration or instability, or selection of incorrect flow boundaries. Although any set of data needs to be corrected for possible errors, such as upside down core sections and the few magnetically unstable samples, care was taken to not distort data through this pruning process. No more than 30 percent, two out of seven, of the stratigraphic inclinations of the samples from an individual flow were discarded or inverted.

A number of samples in the cores had evidence indicating that a low coercivity component of magnetization, presumed to be secondary, had a negative inclination and may have formed in a reversed field direction. This secondary component may have been acquired during alteration of the flow when it was near the surface. An alternative is that it is the result of an anhysteretic remanent magnetization (ARM) moment acquired by low coercivity or viscous magnetic components of the samples. If ARM is responsible for this low-coercivity magnetization, many of the samples should have a horizontal vector difference direction similar to Sample 7-1 from hole DH-5. In addition, if low coercivity ARM were common in these samples, more would show the effects of possible low-coercivity magnetization by the drilling process, such as may be responsible for the behavior of Samples GR31-1, -2, and -3 from hole DH-4.

Although most of the measurements reflect the original magnetization direction, a few flows present insoluble problems given the available data. To aid in solving these problems, it is important to maintain the integrity of the paleomagnetic data and to check inconsistencies with the geologic data available in the core. There are many possible alternative interpretations of certain problems. The paleomagnetic data available are not sufficient to resolve between many of the alternatives. The alternatives caused by factors affecting magnetization direction may include partial or total remagnetization by heating from a flow above, chemical alteration by ground-water or weathering, remagnetization by the drilling process, or incorrect orientation of the core during collection, handling, inspection, and storage. Geologic alternatives that would have an effect on potential results include incorrect interpretation of flow boundaries, particularly by missing boundaries.

Flow GR16, from near the base of hole DC-6, appears to consist of a magnetically reversed section and a normal section and is a good example to illustrate some of the complexities involved in interpreting possible alternatives. The sampled portion of flow GR16 is 400 feet thick. The uppermost sample is at a depth of 3775 feet and the lowermost sample is at a depth of 4178 feet. Sample GR16-1, the uppermost sample, is three feet above GR16-8. Samples GR16-8, -2, -9, -10, and -11 span the next two feet; GR16-12 is one foot lower. These samples are probably from one or two core pieces. There are 40 feet between samples GR16-12 and -3, and 20 to 100 feet separate the remaining samples within the flow.

Samples GR16-1, -12, and -3 have negative inclinations (see Appendix). Samples GR16-8, -2, -9, -10, and -11, which are closely spaced, have inclinations that have low-coercivity magnetic components and negative inclinations. These negative inclination components are shown by shallow negative and positive NRM inclinations and vector difference directions having negative inclinations. It is difficult to assess from these results whether or not this low-coercivity negative-inclination component is due to: a) an original reversed direction and the core sections have been turned upside down or, b) a secondary component acquired during a time that the earth's field was reversed.

Sample GR16-1, which had a negative inclination, had a similar divergence of polarity between low and intermediate components of magnetization. A reasonable explanation for its secondary magnetization, assuming the core section is right side up, is that a low-coercivity component was acquired in the present earth's field. This is indicated by the vector difference inclination. Samples GR16-12 and -3, which also had negative inclinations, did not have significant visible secondary components of magnetization. The remaining samples all have steep positive inclinations on NRM directions, although a few shallow on demagnetization. This steep inclination and shallowing suggests that these samples may have been remagnetized in the drilling process along the axis of the core. Samples GR16-13, -3, -14, -15, -4, -5, -6, and -7, in contrast to samples higher in the flow, all have low coercivity magnetizations that had been reduced to 10 percent or less of their NRM intensity with coercive fields of 100 oersteds or less. The intensity of these lower samples was also higher by one to two orders of magnitude than the samples from high in the flow. These data suggest that the lower samples may have been remagnetized in a normal direction or that they could be from a different flow. This may be supported by the fact that this flow is unusually thick.

Given these conflicting lines of evidence, it is not possible to confidently resolve the problem on the basis of paleomagnetic data alone, as many other similar magnetic characteristics for samples from other flows yield what appear to be accurate and reliable results. As only 3 of 15 samples, less than 30 percent, needed to be inverted to compute a mean that had a reasonable, although not good, standard deviation of 12.5 degrees, flow GR16 was concluded to have a normal polarity and a mean inclination of 70.5 degrees. Another fact that suggests that the computed mean may be in error is that this portion of DC-6 appears to correlate with reversed polarity flows in holes DH-4 and DH-5. On the basis of the present paleomagnetic data alone, these alternatives cannot be satisfactorily resolved.

Similar dilemmas exist in several other flows including flows GR7 and GR13-15 in hole DC-6 and flow GR9 and several of the flows in the lower portion of hole DH-4. Where these alternatives were of particular importance for magneto-stratigraphic correlation, an attempt was made to explore the alternatives and carefully list the results in the appendix. These cases are plotted in a distinctive manner on Figure 5 (in pocket) and Figure 6.

In flows near the contact with the Vantage Sandstone, measurements showed that there was a single reversed flow, GR19(GR2) in hole DDH-3 and GR3 in hole DH-5. Flow GR3 in DH-5 has a negative inclination and a mean of 74 degrees after inverting sample 3-7. This same flow was sampled within the ranges of similar depth by Beck and others (1978); they concluded that the samples had a positive inclination of a similar amount. On the basis of demagnetization curves, it appears reasonable that the flow is reversed only if it is assumed that the secondary component is of normal polarity. This secondary component is present for nearly all the samples to some degree. The inclinations in flow GR3, being negative, are not in agreement with flow GR2 above, or in agreement with the inclinations of a few of the samples in flow GR4 below. Flow GR19(GR2) in hole DDH-3 also has a negative inclination of 74 degrees after inverting two of the eight samples, GR19-1 and GR19-8, which are the top and the bottom of the flow, respectively. As in flow GR3 of hole DH-5, it appears reasonable that this flow is reversed also, if it is assumed that a secondary component of magnetization is normal. This assumption may not be correct and these samples may have come from core sections that were upside down. Secondary components of magnetization in samples from upper portions of flows GR1 of hole DH-4 and GR1 of hole DC-8 suggest they were acquired in a reversed magnetic field. The polarity of these uppermost flows below the Vantage Sandstone is apparently

MEAN STRATIGRAPHIC INCLINATION BY FLOW AND MAGNETOSTRATIGRAPHIC CORRELATION

Grande Ronde [illegible]

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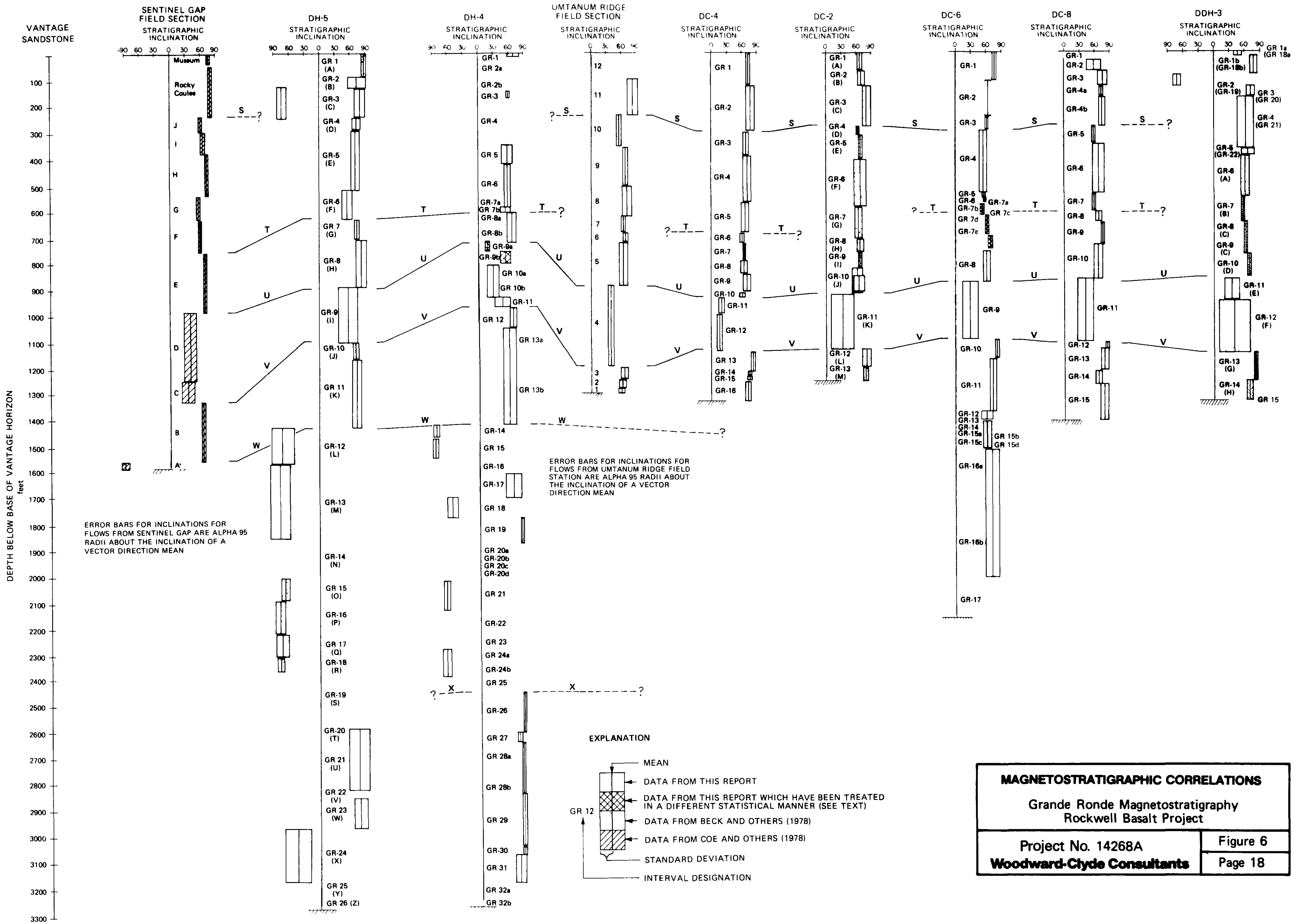
Figure 5



MAGNETOSTRATIGRAPHIC CORRELATIONS

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Rockwell Basalt Project

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Figure 6

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normal and these secondary components of magnetization may reflect a reversed earth's magnetic field during alteration, possibly while exposed near the surface.

Results from samples collected from hole DC-2-A1 for structural analysis are presented in the appendix. These measurements are from a core section in which all the samples have the same relative declination, and the directions of the samples show a reasonably coherent direction. There appears to be no significant difference in direction for samples from this hole.

During the field sampling, use was made of existing azimuthal lines to orient the core sections. These lines represented an approximate magnetic north as assessed using a fluxgate magnetometer. These lines are used in analysis of fracture orientations and the accuracy of these fluxgate orientation lines could be evaluated by comparing them against NRM declinations. Examples of the angular difference between fluxgate and NRM orientation are shown in Table 2. These examples, picked at random from the set, show a wide scatter and suggest little correspondence between NRM declination and fluxgate orientation. It appears that care is required in evaluating data dependent on just the fluxgate orientation.

DISCUSSION OF CORRELATION

Changes in the declination and inclination of the earth's magnetic field, called secular variations, take place on a continental scale and have durations of 10^2 to 10^3 years. The episodic emplacement of a sequence of lavas will describe a discrete sampling of these secular variations. Moreover, "...if the lavas span enough time for sufficient field variation, the sequence of directions...recorded in the flows will be a distinctive characteristic useful in correlating

TABLE 2

EXAMPLES OF ANGULAR DIFFERENCE
BETWEEN FLUXGATE ORIENTATION AND
NATURAL REMANENT MAGNETIZATION DIRECTION

Hole	Sample	Measured NRM Declination (degrees)	Angular Difference (degrees)
DC-2	3-4	260	100
	-5	303	57
	-6	306	54
	-7	151	151
DC-4	1-1	11	11
	-2	267	93
	-3	135	135
	-4	290	70
DC-6	GR 10-1	188	172
	-2	130	130
	-3	32	32
	-4	14	14
	-5	232	128
	-6	334	26
	-7	319	41
DC-8	GR5-1	332	28
	-2	312	48
	-3	340	20
	-4	343	17
	-5	14	14
	-6	23	23
	-7	340	20
DC-11	PO-1	237	123
	-2	17	17
	-3	287	73
	-4	280	80
	-5	114	114
	-6	256	104
	-7	160	160

isolated outcrops of the flows." (Coe and others, 1978). The upper Grande Ronde Basalt flows have been shown to have sufficiently different variations in the inclination that unoriented core samples could probably be correlated using unoriented core, even though declinations are not known.

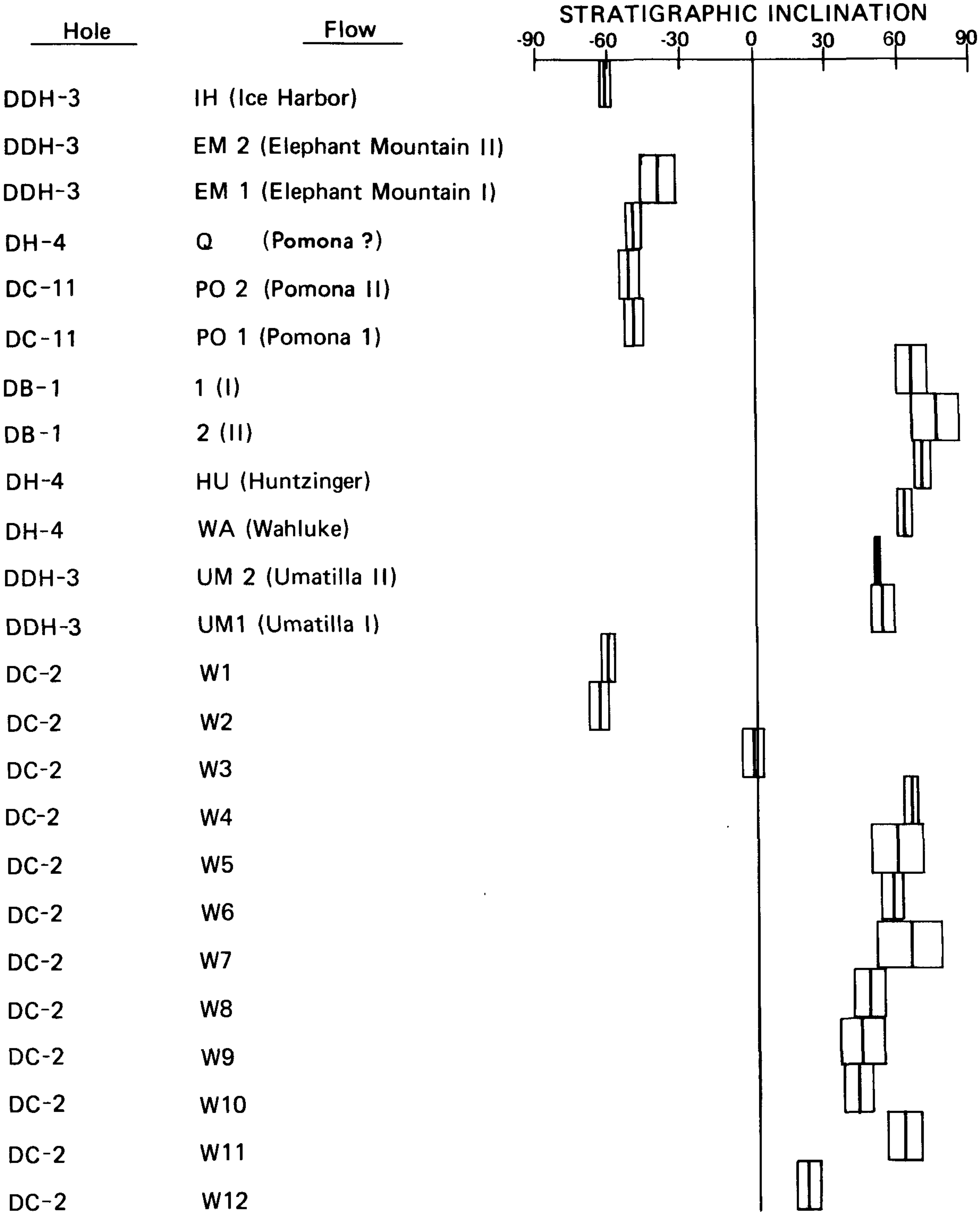
The results of the paleomagnetic measurements completed during this study make possible the correlation of horizons having distinctly different magnetic inclinations. The Grande Ronde Basalt has four such magnetic horizons and at least two polarity changes at various depths in two or more of the seven holes or two surface outcrops for which paleomagnetic data are comparable; this must be considered in correlation. The data from surface exposures, Sentinel Gap, from Coe and others (1978) and Umtanum Ridge, from Beck and others (1978) are from fully oriented samples for which alpha-95 could be calculated. The mean inclination and alpha-95 radius of confidence are plotted on Figure 6, rather than the mean of individual inclinations and their standard deviation, as these were not available. Paleomagnetic data from holes reported by Beck and others (1978) have not been selected to prevent possible misinterpretations due to large standard deviations as the inclinations of individual samples were not available in a form that could be confidently interpreted. These unselected data are plotted on Figure 6 and, in cases where the standard deviations are large, it must be recognized that the mean may not be a good representation of the original direction of magnetization.

In order to better evaluate whether or not the mean inclinations of two adjacent flows were significantly different, a Student t test at the 95 percent confidence level was used. The Student t test appears appropriate for the size and distribution of these data and was found to show significantly different means of inclinations from two adjacent flows, even though the standard deviations showed a slight overlap. The criteria used for magnetostratigraphic correlations between holes were that two adjacent flows from each of the holes to be correlated were significantly different, that the mean inclinations of the two respective potentially time-equivalent flows had approximately the same inclination, and that the sense of the difference in inclinations was the same and of approximately the same amount.

The magnetostratigraphic correlations between holes based on these criteria are shown on Figure 5 (in pocket) and Figure 6. There are four significant differences in mean inclinations between adjacent flows and two magnetic polarity boundaries that can be evaluated with a reasonable degree of confidence and that are at apparently different statigraphic horizons. Two of these magnetic correlation lines connecting flows having distinctly different inclinations can be observed in every core hole. They bound the flows having low inclination that Beck and others (1978) observed and correlated. The upper of these lines has been labeled U, and the lower V. The correlation lines above line U are less widespread, although the difference in inclination in adjacent flows for line T is observed in six of the nine sections. Magnetic correlation line T is below a line connecting flows, rather than boundaries between flows, that Beck and others (1978) drew as a tentative correlation. Their line cannot be used to correlate more than two or possibly three holes and is sandwiched by line S above and T below. The distinct magnetic inclinations in adjacent flows, which are the basis for magnetic correlation line S, can be observed in six of the nine sections. Magnetic correlation line S at the base of the Rocky Coulee flow in the Sentinel Gap section is at the base of the flows tentatively correlated by Beck and others (1978). In the case of magnetic correlation line T in hole DC-6 and correlation line V in hole DH-4, apparently two flows record different parts of the swing of the earth's magnetic direction inclination component, rather than the one flow, as observed in the other holes that have these inclination differences.

In the portions of DH-4 and DH-5 that contain the flows having inclinations of reversed magnetic fields, the magnetic stability is not good. This limits the detailed correlation of magnetically different inclinations in adjacent flows. The reversals in polarity observed are labeled magnetic correlation lines W and X. The reversal of the polarity observed, which forms the basis for correlation line W, is from a reversed to a normal field. The polarity change of correlation line W is observed in three sections and may be present in hole DC-6 between flows GR15 and GR16.

The results of measurements on samples from flows of the Wanapum and Saddle Mountains basalts are shown as mean inclinations and standard deviations on Figure 7. The relative magnetostratigraphic section of the Saddle Mountains Basalt and Wanapum Basalt is shown on Figure 7, as it is a composite stratigraphic section. The vertical scale does not represent the actual thickness of the flows studied. The mean flow inclination of adjacent flows shows that there are at least four places where the inclinations are distinctly different, and three magnetic reversal boundaries. One flow is transitional, flow W-3 from DC-2, and has a mean inclination of -1.2 degrees. Flow EM2-1 in hole DDH-3 is not plotted as it did not meet data selection criteria. It appears that the potential for magnetostratigraphic correlation in the Wanapum and Saddle Mountains basalts is as good as, or possibly better than, that in the Grande Ronde Basalt.



Note: Vertical dimension is not a scale of thickness.

PLOT OF MEAN STRATIGRAPHIC INCLINATION-SADDLE MOUNTAINS BASALT AND WANAPUM BASALT Grande Ronde Magnetostratigraphy Rockwell Basalt Project	
Project No. 14268A	Figure 7
[illegible]	Page 24

CONCLUSIONS

The paleomagnetic measurements of samples from the holes sampled have shown that there are four magnetic correlation lines, between adjacent flows in holes that have distinctly different mean stratigraphic inclinations, and two magnetic polarity boundaries that can be used for magnetic correlation in the Grande Ronde Basalt in the Pasco Basin. The results of paleomagnetic measurements of samples from the Wanapum Basalt and Saddle Mountains Basalt indicate that the potential for magnetostratigraphic correlation in these sequences is also good.

REFERENCES

Beck, M. E., Jr., Engebretson, D. C., and Plumley, P. W., 1978, Magnetostratigraphy of the Grande Ronde sequence: RHO-BWI-C-18, Rockwell Hanford Operations, Richland, Washington, 29 p.

Campbell, C. D., and Runcorn, S. K., 1956, Magnetization of the Columbia River basalts in Washington and northern Oregon: Journal of Geophysical Research, v. 61, p. 449-458.

Coe, R. S., Bogue, S., and Myers, C. W., 1978, Paleomagnetism of the Grande Ronde (Lower Yakima) Basalt exposed at Sentinel Gap: potential use for stratigraphic correlation: RHO-BWI-ST-2, Rockwell Hanford Operations, Richland, Washington, 24 p.

Reitman, J. D., 1966, Remanent magnetization of the late Yakima Basalt, Washington State: Ph.D. Dissertation submitted to Stanford University, Stanford, California 87 p.

Swanson, D. A., and Wright, T. L., 1978, "Bedrock Geology of the Northern Columbia Plateau and Adjacent Areas": in The Channeled Scabland, Baker and Nummendal, editors, National Aeronautics and Space Administration, Washington, D. C.,

Watkins, N. D., 1965, Paleomagnetism of the Columbia Plateau: Journal of Geophysical Research, v. 70, no. 6, p. 1379-1406.

Watkins, N. D., and Baski, A. K., 1974, Magnetostratigraphy and oroclinal folding of the Columbia River, Steens, and Owyhee basalts in Oregon, Washington, and Idaho: American Journal of Science, v. 274, no. 2, p. 148-189.

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APPENDIX

MEAN STRATIGRAPHIC

INCLINATION BY FLOW

APPENDIX

MEAN STRATIGRAPHIC INCLINATION BY FLOW

EXPLANATION

The data presented in this appendix are the selected demagnetization levels that are most representative of the original direction of magnetization of each individual sample. These data are explained, by column, from left to right.

Sample ID is sample identification.

Stratigraphic Inclination is the inclination after correction for bedding for the selected demagnetization level.

(I) indicates evidence from the inclination that the sample may have come from a core section that was upside down in the core box and that it should be inverted relative to the surrounding samples.

(?) queries whether or not the measurement direction reflects the original direction of magnetization.

Flow Mean is the mean stratigraphic inclination by flow.

Standard Deviation is the standard deviation about the flow mean. Footnotes cite places where the samples that have been included in the flow mean do not include all the samples from that particular flow. Flow mean and standard deviation were not included when the standard deviation was computed to be 16 or larger.

Percent NRM is the percent of the NRM intensity of the selected demagnetization level.

Selected Demagnetization Level is the demagnetization level, in oersteds, of the direction selected as most representative of the original magnetization direction of an individual sample and in relation to the samples from an individual flow. The asterisk indicates samples that were stepwise demagnetized as pilot samples.

APPENDIX

MEAN STRATIGRAPHIC INCLINATION BY FLOW

Hole DB-1

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
1-1	72			34	150
-2	72			8	100*
-3	65			27	100
-4	68	65.1	5.7[1]	24	100
-5	-60 (I)			11	100
-6	60			23	100*
-7	59			24	100
2-1	73			46	100
-2	73			75	100*
-3	59			53	100
-4	81	74.6	10.5[2]	45	100
-5	87			59	100
-6	-23 (?)			63	100*
-7	-34 (?)			41	100

---

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample 1-5 inverted.

2 Samples 2-1, -2, -3, -4 and -5.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DC-2

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
W1-1	-63			43	150
-2	-61			59	200*
-3	-57			83	200
-4	-64			30	150
-5	-58	-61.0	3.1	37	150
-6	-65			60	100*
-7	-59			34	150
W2-1	-70			23	150
-2	-61			56	100*
-3	-62			78	150
-4	-61	-65.4	4.4	69	150
-5	-71			93	200
-6	-64			105	100*
-7	-69			100	200
W3-1	-53 (?)			12	150
-2	- 6			35	100*
-3	42 (?)			6	100
-4	- 6			6	150
-5	2	- 1.2	4.7[1]	6	150
-6	- 4			15	100*
-7	5			16	150
-8	- 4			32	100
-9	4			20	100
W4-1	60			35	100
-2	59			31	100*
-3	63			50	100
-4	60	61.7	2.9	32	100
-5	59			43	100
-6	65			10	100*
-7	66			10	150

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Samples W3-1 and -3 not included.

(?) Queried inclination value.

Hole DC-2 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
W5-1	38			6	200
-2	57			30	200*
-3	63			26	200
-4	68	57.6	9.4	49	200
-5	60			36	200
-6	59			24	200*
-7	58			22	200
W6-1	56			59	200
-2	51			52	200*
-3	58			53	200
-4	58	56.3	4.3	69	200
-5	50			43	200
-6	61			39	200*
-7	60			19	200
W7-1	71			53	100
-2	64			69	100*
-3	80			31	100
-4	77	63.6	13.1	38	100
-5	57			46	100
-6	49			35	100*
-7	47			40	100
W8-1	48			21	100
-2	42			32	100*
-3	39			29	100
-4	58	46.9	6.4	48	100
-5	51			10	100
-6	47			10	100*
-7	43			31	100
W9-1	33			31	150
-2	41			20	200*
-3	54			38	150
-4	55	43.9	8.4	27	150
-5	47			33	150
-6	40			30	200*
-7	37			51	150

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-2 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
W10-1	44			14	75
-2	39			22	75*
-3	43			69	75
-4	50	41.0	13.4	23	75
-5	17 (?)	45.0	9.1[1]	13	75
-6	34	42.0	6.0[2]	19	100*
-7	60 (?)			7	75
W11-1	59			9	100
-2	72			124	100*
-3	61			66	100
-4	61	61.3	7.7	8	100
-5	67			29	100
-6	62			15	100*
-7	47			9	100
W12-1	20			59	300
-2	-21 (I)			48	200*
-3	18			49	300
-4	22	21.3	4.8[3]	30	200
-5	25			24	200
-6	14			21	200*
-7	29			7	200
Q-1	50			73	100
-2	70	65	10.3[4]	13	100
-3	67			20	100
-4	-73 (I)			40	150

---

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample W10-5 not included.

2 Samples W10-5 and -7 not included.

3 Sample W12-2 inverted.

4 Sample Q-4 inverted.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DC-2A-1

Sample ID	Stratigraphic Declination	Stratigraphic Inclination	alpha-95	Percent NRM	Selected Demagnetization Level (oersteds)
Q-1	330	29	16.2	77	300
-2	326	24		59	300
-3	12	38		30	300
-4	12	29	κ	70	300
-5	8	31	18.2	60	300
-6	3	30		59	300
Mean	355	31.7[1]			

---

1 These values represent the mean direction for which the alpha-95 and κ were computed. For comparison with other tables, the mean of only the inclinations is 30.2 and has a standard deviation of 4.5.

Hole DC-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR1-1	76			8	100
-2	71			6	200*
-3	77			74	100
-4	69	74.9	4.6	31	100
-5	75			17	200*
-6	73			53	100
-7	83			9	100
2-1	62			43	150
-2	82			11	100*
-3	82			8	75
-4	82	78.0	7.6	7	150
-5	84			3	200*
-6	78			52	150
-7	76			5	75
3-1	76			10	100
-2	72			28	100*
-3	63			14	100
-4	69	70.4	4.4	5	100
-5	68			6	100*
-6	70			27	100
-7	75			3	100
4-1	68			25	75
-2	84			8	100*
-3	67			7	75
-4	73	71.0	7.2	13	75
-5	63			8	100*
-6	76			4	75
-7	66			14	75
5-1	63			9	100
-2	68			43	100*
-3	69			6	100
-4	82	67.4	7.6	3	100
-5	66			7	100*
-6	67			8	100
-7	57			32	100

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR6-1	60			54	100
-2	59			75	100*
-3	60			30	100
-4	55	61.1	3.9	77	100
-5	67			8	100*
-6	63			14	100
-7	64			18	100
7-1	68			36	100
-2	67			12	100*
-3	69	66.1	2.6	37	100
-4	67			12	100
-5	65			19	100*
-6	66			36	100
-7	61			31	100
8-1	55			6	200
-2	68			29	200*
-3	68			22	100
-4	68	65.1	5.4	20	100
-5	60			21	100*
-6	68			9	400
-7	69			14	100
9-1	72			46	75
-2	69			7	100*
-3	78			11	75
-4	84	71.0	7.8	11	75
-5	68			17	50*
-6	61			12	75
-7	65			18	75
10-1	65			21	100
-2	58			25	100*
-3	65			28	150
-4	65	62.0	5.5	15	150
-5	64			15	200*
-6	66			13	150
-7	51			12	150

---

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR11-1	-14 (I)			15	150
-2	17			22	400*
-3	20	16.1	14.3	16	150
-4	22	20.1	5.9[1]*	71	150
-5	20			8	200*
-6	16			14	150
-7	32			6	150
12-1	13			16	150
-2	21			64	400*
-3	18			78	150
-4	10	16.3	4.5[2]	80	150
-5	71 (?)			7	100*
-6	15			32	150
-7	21			5	150
13-1	82			34	300
-2	80			28	400*
-3	77			12	300
-4	81	82.6	3.6	39	300
-5	86			23	400*
-6	87			37	300
-7	85			36	300
14-1	79			51	300
-2	75			29	400*
-3	79			46	300
-4	77	76.0	3.8	11	300
-5	77			16	300*
-6	77			40	150
-7	68			12	300

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR11-1 inverted.

2 Sample GR12-5 not included.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DC-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR15-1	82			15	300
-2	79			74	300*
-3	79			76	300
-4	74	76.4	4.9	23	300
-5	80			16	100*
-6	68			68	300
-7	73			9	100
16-1	74			9	100
-2	66			22	100*
-3	76			4	150
-4	81	72.7	5.6	4	150
-5	65			61	400*
-6	71			95	150
-7	76			13	100

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* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-6

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR1-1	75			54	50
-2	73			12	50*
-3	83			19	50
-4	77	76.9	4.1	55	50
-5	73			60	50
-6	75			54	50*
-7	82			38	50
GR2-1	65			23	150
-2	62			4	150*
-3	52			81	150
-4	58	63.7	7.2	84	150
-5	69			14	150
-6	66			21	200*
-7	74			36	150
GR3-1	58			17	150
-2	57			11	200*
-3	63			46	300
-4	63	61.9	3.1	30	300
-5	64			47	300
-6	63			84	200*
-7	65			69	300
GR4-1	44			76	200
-2	50			10	200*
-3	57			28	200
-4	59	53.6	6.2	26	150
-5	50			81	200
-6	53			84	200*
-7	62			69	150
GR5-1	52			8	150
-2	58			22	100*
-3	57			70	150
-4	56	55.4	2.1	22	150
-5	54			21	150
-6	54			19	100*
-7	57			14	150

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-6 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR6-1	63			37	200
-2	54			42	200*
-3	58			41	200
-4	58	57.4	2.9	28	200
-5	58			31	200
-6	56			35	200*
-7	55			17	200
GR7-8	-55 (I)			28	200
-1	58			33	200
-9	51			10	200
-2	50			33	200*
-10	59			34	200
-3	49			32	200
-11	61			29	100
-12	62			21	200
-13	64			40	200
-14	63	61.3	6.5[1]*	30	200
-15	61	54.0	4.3[2]	23	200
-16	59	62.0	1.7[3]	21	100
-4	18 (?)	67.6	1.9[4]	9	200
-17	39 (?)			8	200
-18	66			16	200
-19	71			29	200
-5	68			29	200
-20	69			52	200
-6	66			42	200*
-21	66			28	200
-7	67			10	200

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR7-8 inverted. Samples GR7-4 and -17 not included.

2 Samples GR7-8, -1, -9, -2, -10 and -3; with sample GR7-8 inverted.

3 Samples GR7-11, -12, -13, -14, -15 and -16.

4 Samples GR7-18, -19, -5, -20, -6, -21 and -7.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DC-6 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR8-1	56			12	200
-2	32 (?)			16	200*
-3	31 (?)			20	200
-4	59			44	200
-5	53	54.6	14.2	55	200
-8	67	61.1	6.5[1]*	48	200
-9	57			29	150
-6	70			5	100*
-7	66			9	200
GR9-1	39			9	150
-8	48			23	200
-2	50			5	200*
-3	13			43	200
-4	18	30.3	15.7[2]	60	200
-5	17			82	200
-6	16			69	200*
-9	70			6	200
-7	41			3	150
GR10-1	83			71	200
-2	84			80	200*
-3	83			62	200
-4	86	81.1	4.1	65	200
-5	74			27	200
-6	79			42	200*
-7	79			39	200
GR11-1	77			37	100
-2	83			21	100*
-3	68			47	100
-4	69	72.9	6.0	31	100
-5	71			5	100
-6	76			9	100*
-7	66			9	100

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Samples GR8-2 and -3 not included.

2 Sample GR9-9 not included.

(?) Queried inclination value.

Hole DC-6 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR12-1	-18 (?)			14	200
-2	47			12	200*
-3	-68 (I)			16	200
-8	68			40	25
-4	57	59.5	11.1[1]	7	150
-5	56			6	150
-6	79			4	75*
-9	-52 (I)			5	150
-7	49			10	85
GR13-15-1	33			19	100*
-8	62			16	100
-9	45			10	100
-10	54			6	100
-11	59			28	100
-12	69			13	100
-13	69			9	100
-2	70	61.4	11.0	12	100
-14	50	62.0	7.8[2]	40	100
-15	58			29	100
-3	54			29	100
-16	66			99	100
-4	67			94	100
-5	69			99	100*
-6	80			17	100
-17	66			13	100
-7	65			37	100
-18	69			19	100

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* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR12-1 not included. Samples GR12-3 and-9 inverted.

2 Samples GR13-15-1 and -6 not included.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DC-6 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR16-1	-75 (I)			113	100*
-8	56			33	100
-2	54			54	100
-9	50			34	100
-10	56			53	100
-11	69			71	100
-12	-77 (I)			50	100
-13	86	70.5	12.5[1]	16	100
-3	-74 (I)			15	75
-14	67			9	100
-15	71			42	50
-4	80			21	75
-5	86			35	75
-6	66			3	75*
-7	90			56	25
GR17-1	83			14	100*
-2	-86 (I)			23	85
-3	74			16	85
-4	89			13	85
-5	88			22	85
-8	21			34	100
-9	24			87	100
-6	-30 (?)			20	100*
-10	-35 (?)			17	100
-7	-37 (?)			18	100

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* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Samples GR16-1, -12 and -3 inverted.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DC-8

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR1-1	-8			48	100*
-2	-8			53	100
-3	-9			55	100
-4	18			36	100
-5	32			39	100
-6	38			25	100*
-7	50			16	100
GR2-1	29			34	150
-2	38			10	150
-3	21			7	150*
-4	66	59.2	12.9[1]	12	150*
-5	64			14	200*
-6	57			12	150
-7	71			8	150
GR3-1	62			51	75*
-2	75			36	75
-3	69			31	75
-4	78	73.1	8.7	6	75
-5	87			12	75
-6	77			12	75*
-7	64			46	75
GR4A-1	71			27	200*
-2	76			12	150
-3	74			26	150
-4	72	71.7	3.0	16	150
-5	66			11	200*
-6	72			19	150
-7	71			13	150
GR4B-1	70			51	40
-2	72			5	50
-3	74			6	40
-4	80			6	40
-5	72	74.4	5.4[2]	6	40
-6	74			5	50*
-7	64			9	40
-8	75			95	50*
-9	-76 (I)			44	50
-10	76			61	50
-11	85			20	50

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Samples GR2-1 and -3 not included.

2 Sample GR4B-9 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DC-8 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR5-1	55			26	200*
-2	56			29	200
-3	58			31	200
-4	59	57.1	2.5	43	200
-5	53			5	200
-6	60			44	200
-7	59			44	200*
GR6-8	79			15	50
-9	87			13	50
-1	-73 (I)			8	50
-2	59			11	50*
-3	55			32	50
-4	53	67.5	11.2[1]	35	50
-5	62			20	50
-6	65			19	50
-7	60			11	50*
-10	81			20	50
-11	69			7	50
GR7-1	55			30	150
-2	56			39	200*
-3	58			45	150
-4	59	58.6	2.7	23	150
-5	62			18	150
-6	62			21	150
-7	58			20	200*
GR8-1	64			32	100*
-2	78			28	100
-3	68			17	75
-4	69	68.4	5.0	37	75
-5	64			25	75
-6	71			18	75
-7	65			17	100*

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR6-1 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DC-8 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR9-1	65			34	100
-2	78			11	100*
-3	66			4	100
-4	67	75.6	7.0	9	100
-5	75			12	100
-6	84			8	100
-7	73			17	200*
GR10-8	72			24	75
-9	74			5	75
-1	76			20	50*
-2	68			4	75
-3	60			8	75
-4	62	66.7	8.2	21	75*
-5	51			9	75
-6	64			6	75
-7	66			90	75
-10	79			12	75
-11	61			30	75
GR11-8	65			13	100
-9	23			81	100
-1	52			10	100*
-2	30			207	100
-3	56			9	100
-4	56	43.1	14.9	5	100
-5	39			28	100
-6	38			29	100
-7	29			86	100*
-10	27			87	100
-11	59			2	100
GR12-1	88			18	50
-2	80			15	50*
-3	81			22	50
-4	89	85.1	3.4	17	50
-5	87			26	50
-6	85			28	50
-7	86			33	50*

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-8 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR13-1	66			54	75
-2	78			6	100*
-3	75			21	75
-4	84	79.9	7.4	20	75
-5	87			25	75
-6	84			11	100*
-7	85			15	75
GR14-1	73			25	100
-2	78			20	100*
-3	66			36	100
-4	62	68.3	5.7	79	100
-5	67			73	100*
-6	63			84	100
-7	69			79	100
GR15-1	81			17	100*
-2	85			13	75
-3	82			11	75
-4	78	79.4	7.8	9	75
-5	76			9	100*
-6	86			12	75
-7	89			7	75
-8	84			6	75
-9	69			18	75
-10	65			94	75

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DDH-3

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
IH-1	-61			48	125
-2	-60			16	75*
-3	-59			30	125
-4	-62	-60.6	2.2	65	75
-5	-64			26	125
-6	-61			38	75*
-7	-57			58	125
EM1-1	-35			23	200
-2	-35			16	300*
-3	-45			3	200
-4	-45	-39.4	7.3	3	200
-5	-42			1	200
-6	-27			3	150*
-7	-47			4	200
EM2-1	-26			63	125
-2	56			8	50*
-3	82			4	50
-4	66			9	50
-5	39			11	50
-6	46			7	75*
-7	-40			103	125
UMA2-1	50			14	150
-2	50			67	150*
-3	50			71	150
-4	52	50.1	1.1	76	150
-5	49			69	150
-6	49			60	150*
-7	51			16	150
UMA1-1	-49 (I)			50	150
-2	52			44	150*
-3	56			36	150
-4	57	53.3	5.1[1]	31	75
-5	54	39.3	39.2	24	75
-6	60			7	150*
-7	45			31	75

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample UMA1-1 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DDH-3 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
18A-1	42			31	150
-2	42			40	150*
-3	35			41	150
-4	43	47.4	9.5	35	150
-5	58			29	150
-6	54			32	150*
-7	58			28	150
18B-1	71			40	100
-2	86			18	150*
-3	84			28	100
-4	76	78.1	6.2	21	100
-5	76			24	100
-6	83			11	150*
-7	71			77	100
19-1	75 (I)			94	100
-2	-76			32	150*
-3	-74			24	100
-4	-76	-72.9	6.9[1]	27	100
-5	-67			36	100*
-6	-85			21	150
-7	-63			26	100
-8	67 (I)			88	100
20-1	82			21	300
-2	79			19	300*
-3	67			61	150
-4	71	71.6	6.6	24	300
-5	71			24	300
-6	67			17	300*
-7	64			13	300
21-1	41			6	200
-2	59			34	300*
-3	43			13	200
-4	76	62.3	15.1	69	200
-5	70			23	100
-6	70			9	300*
-7	77			22	100

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* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Samples 19-1 and -8 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DDH-3 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
22-1	66			39	100
-2	75			32	150*
-3	68			29	100
-4	70	66.1	4.4	35	100
-5	63			38	100
-6	59			29	150*
-7	72			28	100

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DC-11

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
PO2-1	-49			92	100
-2	-56			23	100*
-3	-54	-52.3	4.1	45	100
-4	-55			48	100
-5	-51			83	100
-6	-56			59	100*
-7	-45			51	100
PO1-1	-51			70	200
-2	-52			94	200*
-3	-54			71	200
-4	-49	-49.7	4.2	108	200
-5	-41			66	200
-6	-52			93	200*
-7	-49			72	200

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DH-4

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
Q-1	-47			33	200*
-2	-51			52	200
-3	-50			25	200
-4	-54	-50.3	2.6[1]	26	200
-5	-52			42	200
-6	-48			22	200
-7	61			73	200*
HU-1	68			75	400*
-2	73			18	400
-3	66			59	400
-4	-65 (I)	69.4	3.8[2]	8	400
-5	73			42	400
-6	67			34	400
-7	74			35	400*
WA-1	59			42	400*
-2	69			72	400
-3	61			53	400
-4	59	63.0	3.7[3]	27	400
-5	-63 (I)			16	400
-6	-66 (I)			48	400
-7	-64 (I)			44	400*
GR1-1	75			18	400
-2	55			20	300*
-3	58			16	400
-4	59	69.9	12.0	8	400
-5	79			10	300*
-6	82			26	400
-7	81			44	400

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample Q-7 not included.

2 Sample HU-4 inverted.

3 Sample WA-5, -6 and, -7 are from same core section and are inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR2-1	-54			16	300
-2	-51			28	300*
-8	58			26	300
-9	52			13	300
-10	59			21	300
-3	-66			8	300
-11	-69			14	300
-4	56			19	300
-12	-67			46	300
-13	54			43	300
-5	51			20	300*
-6	59			38	300
-14	63			38	300
-7	55			40	300
GR3-1	63			39	300
-2	61			46	300*
-3	59			43	300
-4	61	59.0	2.9	37	300
-5	54			36	300*
-6	56			21	300
-7	59			28	300
GR4-1	51			18	175
-8	-52			42	175
-2	-57			36	175*
-3	56			5	175
-4	60			13	175
-5	-49			17	175*
-9	-25			7	175
-6	42			24	175
-7	54			25	175
GR5-1	71			14	100
-2	68			4	100*
-3	48			65	100
-4	43	57.3	10.0	9	100
-5	59			18	125*
-6	57			21	100
-7	55			14	100

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR6-1	61			19	200
-2	56			17	300*
-3	-54 (I)			17	200
-8	59			18	200
-4	51	55.5	3.5[1]	31	200
-5	56			17	300*
-6	56			22	200
-7	51			43	200
GR7-1	61			15	300
-2	55			16	300*
-3	60			18	300
-4	57			25	300
-5	55			23	300*
-6	26			8	300
-8	49	53.3	8.8	6	300
-9	61			5	300
-7	47			25	300
-10	54			43	300
-11	57			37	300
-12	55			52	300
-13	53			44	300
-14	56			35	300
GR8-1	65			21	300
-2	71			44	300*
-3	48			7	300
-4	-76 (I)	65.3	8.9[2]	19	300
-8	-57 (I)			11	300
-5	66			17	300*
-6	69			16	300
-7	70			25	300

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR6-3 inverted.

2 Samples GR8-4 and -8 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR9-8	13			48	150
-1	18			65	300
-2	18			15	175*
-9	26			24	150
-3	16			24	150
-10	19			15	300
-4	11	17.3	4.8[1]	37	150
-11	31	51.0	10.2[2]	19	150
-5	46			15	300*
-12	62			26	150
-13	57			22	150
-6	54			13	150
-14	57			13	150
-7	50			12	150
GR10-1	-50 (I)			8	150
-8	40			10	175
-9	41			9	175
-10	19			16	175
-2	-28 (I)			19	175*
-11	24			11	175
-12	18			59	175
-13	23			39	175
-14	29			62	175
-3	3			64	150
-15	25	29.0	12.9[3]	25	175
-16	11			45	175
-4	12	25.7	11.3 (3)	65	150
-17	48			17	175
-5	36			28	175*
-18	11			46	175
-19	23			43	175
-6	14			78	150
-20	38			24	175
-7	42			12	150
-21	37			10	175

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Samples GR9-8, -1, -2, -9, -3, -10, and -4.

2 Samples GR9-11, -5, -12, -13, -6, -14, and -7.

3 Samples GR10-1 and -2 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DH-4(continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR11-8	61			19	150
-1	-19 (I)			42	150
-2	53			15	125*
-3	23	45.7	14.8[1]	14	150
-4	35			10	150
-5	35			25	125*
-6	51			18	150
-7	62			45	150
GR12-1	64			21	200
-2	58			45	175*
-3	71			20	200
-4	70	67.4	6.4	23	200
-5	77			31	175*
-6	70			24	200
-7	62			25	200
GR13-8	39			29	150
-9	57			19	150
-10	62			14	150
-1	41			52	200
-11	50			26	150
-12	48			24	150
-13	66	60.7	12.7[2]	10	150
-2	78			15	175*
-14	75			36	150
-3	71			37	200
-4	72			7	200
-5	65			10	125*
-6	65			40	200
-7	1 (?)			82	150
GR14-1	-76			50	300
-2	-72			9	300*
-3	-81			16	150
-4	-78	-75.1	5.7	35	150
-5	-81			42	300*
-6	-73			2	300
-7	-65			26	300

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* Samples selected as pilot samples for stepwise alternating field demagnetization.

[1] Sample GR11-1 not included.

[2] Sample GR13-7 not included.

(I) Samples that have been inverted as referred to in notes above.

(?) Queried inclination value.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selectd Demagnetization Level (oersteds)
GR15-8	-70			50	200
-1	-73			89	200
-2	-78			81	175*
-3	-80			80	200
-4	-76	-77.6	5.3[1]	24	200
-5	-75			55	175*
-6	-86			53	200
-7	83 (I)			46	200
GR16-1	68			10	150
-4	67			24	100
-5	-57			51	200
-2	-61			19	150
-6	-10			22	100
-7	-40			8	150
-3	-39			9	200
GR17-8	-67			104	200
-9	41			20	100
-10	-71			28	400*
-1	64			12	50
-2	-55	66.8	15.7[2]	2	250
-3	83			8	100*
-4	85			25	50
-5	45			2	250
-6	83			23	50
-7	74			9	50
GR18-1	-51			27	400
-2	73 (I)			8	100*
-8	68 (I)			9	100
-3	-57			38	400
-4	-57	-55.0	9.9[3]	37	400
-9	-51			31	400
-5	-45			33	400*
-6	-47			26	400
-7	-46			7	400

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR15-7 inverted.

2 Sample GR16-6 not included.

3 Samples GR18-2 and -8 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR19-1	85			32	50
-2	81			24	50*
-8	83			32	50
-3	- 7			35	50
-4	82	83.3	1.5[1]	22	50
-5	84			32	50*
-6	85			25	50
-7	83			39	50
GR20-1	84			43	50
-8	81			13	75
-9	53			13	75
-2	- 2			10	100*
-3	85			36	50
-4	76			28	50
-10	-55			12	75
-5	73			7	100*
-11	-65			62	400
-6	-73			105	50
-12	-76			115	75
-13	-66			104	75
-7	-66			101	100
-14	-62			107	75
GR21-1	-61			83	400
-2	-69			14	400*
-3	-78			26	400
-4	62 (I)	-67.4	5.6[2]	13	200
-8	-65			27	200
-5	-71			71	200*
-6	-69			5	200
-7	-64			114	200
GR22-1	83			47	50
-2	85			12	75*
-3	72			9	100
-4	-67			2	100
-5	-71			26	100*
-6	-62			14	100
-8	-88			26	50
-7	17			3	100

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR19-3 not included.

2 Sample GR21-4 inverted.

(I) Samples that have been inverted as referred to in notes above.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR23-1	-70			37	200
-8	77			37	50
-2	76			9	50*
-3	74			10	50
-4	73			26	50
-5	- 6			5	100*
-6	-63			11	200
-9	66			186	100
-7	-71			163	100
GR24-1	-70			45	300
-2	-43			38	200*
-8	-76			262	200
-3	-75			66	300
-4	-70			14	300
-5	-65			133	200*
-9	-62	-67.2	8.1	74	200
-6	-63			76	300
-10	-73			95	200
-11	-66			115	200
-12	-67			125	200
-13	-68			149	200
-7	-71			100	300
-14	-72			106	200
GR25-1	-72			87	300
-8	-57			121	
-2	-61			98	200*
-3	-19			4	300
-4	-20			5	300
-5	46			4	200*
-6	38			2	300
-9	-73			168	200
-7	-71			161	300
GR26-1	85			71	50
-2	86			59	50*
-3	87			52	50
-4	84	85.3	1.8	16	50
-5	82			16	50*
-6	87			27	50
-7	86			25	50

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR27-1	80			40	50
-2	72			31	50*
-3	75			40	50
-4	77	74.7	3.8	39	50
-5	85			10	100*
-6	76			34	50
-7	68			49	50
GR28-1	83			62	25
-8	84			45	50
-2	86			23	50*
-3	86			78	25
-4	51 (?)	79.3	10.3	111	100
-9	82	82.4	2.8[1]	26	50
-5	77			27	50*
-6	82			71	25
-10	81			22	50
-7	81			62	25
GR29-1	75			29	50
-2	84			27	50*
-3	85			34	50
-4	84	83.0	3.8	36	50
-5	83			36	50*
-6	83			36	50
-7	87			40	50
GR30-1	76			20	75
-2	82			12	75*
-3	83			20	75
-4	84	83.6	3.9	18	75
-5	86			19	75*
-6	86			16	75
-7	88			13	75

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample GR28-4 not included.

(?) Queried inclination value

Hole DH-4 (continued)

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization Level (oersteds)
GR31-1	64			32	50
-2	71			19	75*
-8	74			20	75
-3	69			21	50
-4	-79			19	50
-9	60			11	75
-5	82			10	75*
-6	-89			26	50
-7	-88			24	50
-10	79			31	75
GR32-1	-54			66	400
-8	-52			58	400
-2	-41			32	400*
-3	-41			15	400
-9	21			11	400
-4	87			27	50
-10	82			30	75
-11	63			13	75
-5	80			14	75*
-6	87			29	50
-7	87			29	50

* Samples selected as pilot samples for stepwise alternating field demagnetization.

Hole DH-5

Sample ID	Stratigraphic Inclination	Flow Mean	Standard Deviation	Percent NRM	Selected Demagnetization level (oersteds)
1-1	88			78	25
2-1	70			62	50
-2	84	77		52	50
3-1	-72			3	100
-2	-79			62	150*
-3	-79			35	175
-4	-86	-74.4	11.7[1]	92	175
-5	-87			85	175
-6	-58			8	400*
-7	60 (I)			1	100
4-1	-31			10	200
-2	-45			57	300*
-3	21			5	200
-4	21			5	200
-5	-50			91	200
-6	37			6	100*
-7	-65			26	200
5-1	-86			40	50
6-1	61			78	150
7-1	-74			80	150
8-1	-67			61	400

* Samples selected as pilot samples for stepwise alternating field demagnetization.

1 Sample 3-7 inverted.

(I) Samples that have been inverted as referred to in notes above.