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GEOCHEMICAL VARIATION OF COLUMBIA RIVER BASALTS
BENEATH THE HANFORD RESERVATION, WASHINGTON

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SUMMARY

Major element and trace element analyses of Columbia River basalts have been compiled to indicate where geochemical changes occur in the stratigraphy of the basalts. The analyses were averaged and plotted on petrologic variation diagrams to elucidate geochemical trends and correlations. More work needs to be performed on the trace element data since this report is concerned mainly with the major elements.

INTRODUCTION

In 1969 the Atlantic Richfield Hanford Company initiated a study of the basalt stratigraphy of the Pasco Basin, Washington. The objective of the present study is to describe the major and trace element data acquired to date to foster a better understanding of the geochemical variations in the Columbia River basalts. The available geochemical data was compiled and diagrams illustrating chemical trends in the basalts are presented in the report.

GEOLOGICAL SETTING

The Columbia River Plateau is an intermontane basin occupied by miocene to pliocene tholeiitic basalts of southeastern Washington, northern Oregon, and portions of western Idaho. The plateau is bounded by the Okanogan Highlands to the north, the Blue Mountains to the south, the Rocky Mountains to the east, and the Cascade Range to the west. The Columbia River basalts cover an area of 200,000 square kilometers, have a volume of 195,000 cubic kilometers, and are one kilometer in average thickness (Kuno, 1969).

Plateau basalts are characterized by unusual thickness and great lateral extent of individual flows, and a paucity of pyroclastic material. Plateau basalts are formed from magmas representing advanced stages of low pressure fractional crystallization of partial melts from upper mantle peridotite and are erupted through fissures formed by tensional stress in the crust.

The Pasco Basin is, and has been for some time, the central and lowest portion of the Columbia River Plateau. Early flows occur in an overlap relationship with the pre-existing topography due to the flooding action of the basalt and later thick fluid flows have been shown to have overcome regional slopes by onlap (Schminke, 1967a). Stratigraphic evidence indicates the latest basalt flows have an off-lap relationship with earlier flows and tend to be more restricted to the center of the basin than earlier flows. This offlap relationship is due to subsidence of the plateau and to decreasing volume and probably decreasing frequency of erupted basalts. The subsidence is in large part the result of adjustment to the migration of magma from beneath the plateau onto the surface of the plateau. On the basis of tectonic history, the thickest section of Columbia River basalts in the plateau would be expected to be in the Pasco Basin area and should provide excellent information on the changes in chemistry of the basalts through time. Figure 1 illustrates the geographical distribution of the Columbia River basalt and the boundaries of the Chief Joseph Dike Swarm to the southeast.

In order to obtain data on the subsurface stratigraphy, five core holes located on or near the United States Atomic Energy Commission Hanford reservation were drilled. Figure 2 shows the location of the holes, which vary in depth from 180 to 1,525 meters. These cores provide an unprecedented opportunity to study a continuous record of basaltic products, with good lateral control, in a thick pile of plateau basalts.

ANALYTICAL RESULTS

Approximately 750 drill core samples will be studied by the Atlantic Richfield Hanford Company to examine variations in the basalt stratigraphy (Brown, in press). Samples have been analyzed to determine the concentrations of major and trace elements, radiometric ages, isotopic concentrations of radionuclides, and mineralogic variation. The oxides (SiO_2 , TiO_2 , Al_2O_3 , FeO , MnO , MgO , CaO , Na_2O , K_2O) and minor elements (Ba, Sr, Rb, Ni, Zn, Cu, Sb, and Pb) were analyzed by atomic absorption spectrophotometry while the rare earth elements (La, Sm, Eu, and Tb) and other trace elements (Co, Sc, Cr, Hf, Th, and Ta) were analyzed by instrumental neutron activation analysis.

Five hundred and twenty-two whole rock major element analyses were recalculated to 100 percent anhydrous and have been compiled (Appendix A). The normalization of the analyses tended to eradicate variations in chemistry due to analytical error, which resulted in high or low totals, and reduced all analyses to a standard total. The normalization calculation changed the concentration of the individual oxides in proportion to their original concentration and in proportion to the difference between 100 and the actual analytical total. The relationships between the relative values of the oxides of an analysis are preserved by the normalization although the absolute values of the oxides are uncertain.

After recalculation to 100 percent, the analyses were listed in tables (Appendix A) with each analysis placed in its correct relative depth location within the drill hole. Significant changes in the proportion of two or more oxides between adjacent analyses were marked, persistent variations noted, and groups of similar analyses delineated. The tables of each drill hole were then compared. Groups of analyses, henceforth called units, which displayed similar distinctive concentrations of oxides were matched. Units which were unique or which could be correlated between two or more drill holes were given an alphabetical designation. "A" was assigned to the uppermost unit and "B", "C", etc., were assigned to stratigraphically lower units. The ranges in concentration and averages of each oxide were calculated for the unique and correlated units; these are listed in Table I. The number in parentheses above each set of ranges is the number of samples in that unit and in most cases is proportional to the stratigraphic thickness of the unit.

Trace elements can also be used to divide the basalt into units. Since in this study the trace element analyses are not as numerous as those for major elements, they have been used as a secondary system to verify the stratigraphic breaks based on major element chemistry. An examination of trace element data shows that a change in trace element abundances

usually occurs at the positions indicated by major element data. Certain units may be further subdivided on the basis of trace element data. The averages for each unit are listed in Table 2 and the data is tabulated in Appendix B, compiled to correspond in stratigraphic position to the major element data of Appendix A.

FACTORS INFLUENCING CHEMISTRY OF BASALTS

In studying the chemistry of basalts it is found that other than stating that a basalt has a specific composition it is difficult to draw conclusions as to why the basalt does in fact have that specific composition. If a series of basalts does not show definite compositional trends which can be ascribed to, the crystallization of a specific mineral of which the basalt is more fundamental has to be sought.

The composition of an erupted basalt is influenced by the composition of the original liquid, the nature and proportion of solid phases crystallizing from the liquid, and the distribution of elements between solid phases and the liquid. The composition of the original liquid is dependent upon the composition of the source rock, the type, proportion, and composition of minerals in the source rock, the degree of partial melting, and the temperature and pressure at the site of magma generation. The nature and proportion of solid phases crystallizing depends upon the composition of the liquid and the temperature and pressure at the site of crystallization. The density of the liquid and of the crystalline phases influences the gravitational settling of crystalline phases, and the viscosity of the magma influences the rate of upward migration of the magma. The volatile content of the magma influences the oxygen fugacity and the pressure and temperature of crystallization, and the composition of the country rock through which the magma passes may have a profound effect upon its chemistry. All of these factors play some part in influencing the composition of the erupted basalt.

PRESENTATION OF CHEMICAL DATA

Frequency Distribution

To show the frequency distribution of the averaged data from Tables I and II, 19 histograms were constructed for the oxides and trace elements of Columbia River basalts. A total of 36 whole rock major element analyses from Table I and 18 whole rock trace element analyses from Table II were utilized. Due to the small number of samples used, the type of distribution exhibited in many cases is often not distinct. However, from the diagrams constructed, SiO_2 , TiO_2 , FeO , Cr and Ba show notably bimodal mixed distributions while Al_2O_3 , Co , Hf and Th show normal distributions and K_2O and Ta show positively skewed normal distributions. The other oxides and trace elements have no discernible distinct distribution patterns. The process or processes which determine the creation of the observed frequency distributions have not been determined.

Correlation Coefficients

A correlation coefficient is a number between 1.0 and -1.0 which measures the dependency between two variables. A value of 1.0 indicates identity or absolute positive association while a value of -1.0 indicates absolute negative association. A value of 0.0 indicates neither an affinity nor a non-affinity. Coefficients of absolute magnitude smaller than unity indicate a degree of relative association depending upon their value; a value of -.20 indicates a weak negative correlation, while a value of .75 indicates a strong positive correlation.

From the correlation coefficients of the oxides it is observed that MgO has a positive correlation with Al_2O_3 and CaO and a negative correlation with SiO_2 , TiO_2 , FeO, Na₂O and K₂O; the same relationships which are observed for the oxides from the MgO variation diagram. The correlation coefficients express a more quantitative aspect of the associations, while the variation diagram expresses a more graphical aspect. Compared to variation diagrams, correlation coefficients are more versatile since they express relations between all the components to one another rather than to a standard component such as MgO. However, it is more difficult to grasp the relations since they are in numerical form.

It will be left to the reader to ascertain the various relations between oxides and elements other than noting an association between Sc, Cr, and Co and a strong association between Ba, La, Sm, Eu, Tb, Hf, Ta, and Th; there being a negative relation between the two groups.

TWO COMPONENT DIAGRAMS

MgO Variation Diagram

Variation diagrams are used to illustrate the change in elemental composition of a suite of rocks to infer the composition of the melt from which they were derived. In this study variation diagrams with MgO as the abscissa and the other oxides (SiO_2 , TiO_2 , Al_2O_3 , FeO, CaO, Na₂O and K₂O) as the ordinate have been constructed using the averages from the designated units of the five core holes listed in Table I. The lines connecting points on the diagrams are meant to identify average compositions belonging to the same unit and do not represent the field of compositions in which all the analyses from a specific unit lie. The MgO variation diagram was chosen as the method to illustrate single element variation of Columbia River basalts since the change in composition of the melt due to the influence of the crystallization of individual minerals (olivine, pyroxene, plagioclase, and iron-titanium oxide) is more readily discernible in this diagram than in other types of variation diagrams.

During the evolution of tholeiitic basalts large quantities of olivine may crystallize and settle out by gravitative differentiation (MacDonald, 1968). The crystallization of olivine alters the composition of the liquid phase

at higher temperature while pyroxene, plagioclase, and iron-titanium oxide alter it at lower temperature. The use of MgO variation diagrams permits a linear extrapolation of a liquid line of descent trend; controlled by olivine at the high MgO end and by pyroxene, plagioclase and iron-titanium oxide at the low MgO end.

When an individual phase crystallizes it preferentially concentrates certain elements into its structure, different phases concentrating different proportions of elements. If the concentrations of the elements incorporated into the crystal are less than the concentration in the liquid, they will increase in concentration in the liquid. If the concentrations of the elements in the crystal are more than that in the liquid, they will decrease in concentration in the liquid. For example, when a magnesium-rich olivine crystallizes from a liquid of basaltic composition, the liquid becomes depleted in MgO and enriched in SiO₂ and FeO. From the MgO variation diagram it is observed that as MgO decreases SiO₂, TiO₂, FeO, Na₂O and K₂O increase while Al₂O₃ and CaO decrease.

Alkali-Silica Diagram

The SiO₂-(Na₂O and K₂O) diagram delineates the fields of alkalic basalt and tholeiitic basalt as observed by MacDonald and Katsura (1964) from Hawaiian basalts (Figure 5). The insert is a diagram by Kuno (1965) illustrating the compositional trends of basalts from various localities. All the average compositions of units of the Columbia River basalts plot within the tholeiite field.

THREE COMPONENT DIAGRAMS

Silica-Iron-Magnesium Diagram

The SiO₂-FeO-MgO diagram describes the behavior of mafic and ultramafic rocks better than most ternary diagrams since the degree of explanation, indicated by the sum of the values of the three oxides before normalization to 100, is generally greater than 70 percent (Figure 6). The SiO₂-FeO-MgO diagram illustrates the compositional fields of rocks characteristic of the upper mantle (hercynite, websterite, and eclogite) and of rocks derived from them (basalt, basanite and nephelinite). The skaergaard trend is the path of liquids from a differentiated gabbroic intrusion. The Columbia River basalts lie in a distinct area between the fields of the Cascade Range basalts and the Snake River basalts, indicating they have relatively less silica than the Cascade basalts and relatively less iron than the Snake River basalts.

The minerals olivine, orthopyroxene, and clinopyroxene are located near the SiO₂-MgO edge at approximately 40, 60 and 73 percent, respectively. As the liquid changes in composition the crystals precipitated plot in a line extending from magnesian compositions to relatively more iron-rich and silica-poor compositions. Plagioclase lies at the SiO₂ apex and magnetite and ilmenite at the FeO apex. A partial melt derived from

Therzolite has a composition near the websterite and eclogite fields from which it may evolve towards basalt by crystallizing olivine and pyroxene. Plagioclase precipitation in Columbia River basalts does not seem to have influenced the composition of the liquid until late stage, near-surface crystallization.

Iron-Magnesium-Alkali Diagram

The FeO-MgO-(Na₂O and K₂O) diagram shows Columbia River basalts lie within the area characteristic of tholeiites (Figure 7). The Hawaiian tholeiite and skaergaard trends are after MacDonald and Katsura (1964). Plagioclase occupies the Na₂O-K₂O apex, while iron-titanium oxides occupy the FeO apex. Olivine and orthopyroxene are clustered very close together near the 75 to 85 percent MgO position along the FeO-MgO edge. Clinopyroxene lies near olivine and orthopyroxene but is displaced about 5 percent toward the Na₂O-K₂O apex. On this diagram it is difficult to evaluate the influence on the composition of the liquid by the separate crystallization of the individual major mafic minerals since they plot so close together. However, from their position on the diagram it can be observed that the crystallization of olivine and pyroxene is responsible for much of the compositional trend of the basalts.

Sodium-Calcium-Potassium Diagram

The Na₂O-CaO-K₂O diagram is frequently used to illustrate the fractionation trend for more differentiated rocks (trachytes, phonolytes and rhyolites) (Figure 8). The trend described by Columbia River basalts generally coincides with that for tholeiitic basalts. Plotted along the Na₂O-CaO edge is the mole percent anorthite content of plagioclase. Clinopyroxene plots near the CaO apex and the compositional trend of the analyses indicates CaO has produced the majority of the change. Plagioclase and/or clinopyroxene crystallization could, therefore, have produced much of the trend.

FOUR COMPONENT DIAGRAMS

The quaternary diagrams SiO₂-FeO-MgO-CaO and CaO-FeO-MgO-Al₂O₃ describe the chemical relations of Columbia River basalts within four component systems. The two diagrams illustrate an altered tetrahedron with three of the faces modified to coincide with the plane of the base of the tetrahedron. The position of the analyses of the basalts projected onto the four faces of the tetrahedron indicate their relative compositional trends.

The SiO₂-FeO-MgO-CaO diagram shows a compositional trend in which the basalts generally decrease in MgO and CaO and increase in FeO and SiO₂ with differentiation. The CaO-FeO-MgO-Al₂O₃ diagram shows a general decrease in MgO and increase in FeO. CaO decreases slightly in relative composition, while Al₂O₃ increases in the absence of FeO and decreases when it is present.

The degree to which the basalt compositions are explained is, as in ternary diagrams, the sum of the values of the oxides comprising the diagram. The manner in which compositions were projected onto the faces was by calculating three oxides at a time, in essence, constructing four ternary diagrams. Therefore the degree of explanation in this case does not equal the sum of the oxides since the four oxides are never simultaneously used to calculate the diagram. A better mode of representing compositions within a quaternary diagram would be by producing a three-dimensional, stereographic illustration of a tetrahedron in which compositions would be represented as one point instead of four. However, until such a diagram is made available the present system will have to suffice.

SOLIDIFICATION INDEX

The solidification index $[MgO \times 100 / (MgO + FeO + Fe_2O_3 + Na_2O + K_2O)]$ is the percentage of MgO of a composition plotted in the iron-magnesium-alkali diagram and can be employed as an approximation of the degree of solidification which primary magma underwent to produce the observed composition. Table IV is a listing of the solidification indices of the average compositions of units of Columbia River basalt.

The solidification index of a magma decreases as fractionation proceeds, and it is assumed the decrease is proportional with the amount of residual liquid. Primary magmas produced by partial melting in the upper mantle have solidification indices of 40 or higher. If 40 is taken as a general index for primary magmas, basalts with an index of 20 should correspond to magmas produced by 50 percent solidification (Kuno, 1969). Dr. A. C. Waters has also pointed out the usefulness of this method of correlating basalts in an unpublished report dated June 23, 1972 to the Atlantic Richfield Hanford Company.

IRON ENRICHMENT DISCONTINUITY

The iron enrichment $[FeO / (FeO + MgO)]$ diagram of Columbia River basalts illustrates a chemical discontinuity between .62 and .68 of the iron-magnesium ratio (Figure 11). Experimental evidence (Tilley and Thompson, 1970) indicates that at one atmosphere pressure the liquidus temperature of basalts decreases as iron enrichment increases. In order to explain such a gap exhibited by many volcanic suites, Thompson (1972) used the conclusions of Wright and Fiske (1971) from their study of lavas from Kilauea, Hawaii. Thompson believes the chemical discontinuity is generated as follows: basaltic magma is formed by partial melting of the upper mantle. Some of this magma is erupted unmodified except for the chemical variation resulting from high pressure partial melting trends and low pressure olivine subtraction or addition. Some batches of magma stagnate on the way to the surface and form irregular and sill like bodies which crystallize until they are approximately 50 to 60 percent solidified. At this point the crystal meshwork of the magma batch is sufficiently rigid to fracture without disaggregation when stressed, allowing the differentiated, low liquidus temperature liquid to migrate to lower pressure and be erupted with little further modification.

This model explains the chemical discontinuity as the result of a repetitive, reproducible, discontinuous sampling process superimposed on other differentiation processes. This process allows only relatively unevolved basalts and basalts from highly evolved interstitial liquids to be erupted (Thompson, 1972). Basalts of Units B and D would, therefore, belong to the first group while all the other basalts of the other units would belong to the second group, except Unit K of DH-3 which is transitional.

STRATIGRAPHY OF BASALTS

The stratigraphic section of the Columbia River basalt is presently divided into two major sections, the younger Yakima basalts and the older Picture Gorge basalts. Table V is the nomenclature of Columbia River basalt stratigraphy as defined by Schminke (1976b) and Wright, Grolier, and Swanson (in press), with minor modifications.

The chemistry of subsurface basalt units from the cored holes has been compared with analyses from type localities. The uppermost portion of Unit A from core hole DH-3 corresponds to Ice Harbor, while Unit A itself is equivalent to Elephant Mountain. Unit B corresponds to Pomona, Unit C to the lower flow exposed on Gable Mountain, Unit D to Huntzinger, and Unit E is equivalent to Umatilla. Unit F is correlated with Priest Rapids and Roza, Unit G with Frenchman Springs, and Unit H corresponds to Museum and Rocky Coulee.

Units G, H and I are quite thick, indicating minor change in chemistry with massive eruption of basalt. This is in contrast to the variability of basalt chemistry above and below these thick units. Basalts of Units J and K from DH-3 are not correlated with those from core holes DH-4 and DH-5. They are grouped together for convenience and this should be taken into consideration. Instead of the 12 units listed in the table, there should actually be three more due to the uniqueness in DH-3 of Units J, K and upper A. This study has, therefore, defined 15 different geochemical-stratigraphic units.

The basalt units defined in this study are frequently comprised of more than one flow unit as indicated by lithologic contact indicating the top or bottom of a flow. This indicates that a geochemical basalt unit does correspond to a distinct sequence of basalt flow units.

Figure 12 is an illustration of the geochemical variation of Columbia River basalt through time; Unit A is the youngest and Unit L is the oldest basalt unit studied. With decreasing age the composition of the basalts generally decreases in SiO_2 , Al_2O_3 , Na_2O , K_2O and increases in TiO_2 , FeO , CaO and MgO .

CONCLUSIONS

The problem of correlating basalts over extended areas is greatly facilitated by chemical data and promises to be the most definitive method of correlation.

The data of this study indicate the Pomona magma type (Units B and D) is more primitive in chemical composition than other Yakima basalt units, while the Umatilla magma type (Unit E) is the most differentiated basalt studied.

The key to understanding the chemistry of basalts seems to be in the process of the generation of magma from source material rather than the process of fractional crystallization. The crystallization process does play an important role in understanding the chemistry of the basalts but it does not fully explain the compositional variability of basalts. Therefore a more fundamental cause must be sought and it seems to be in the process of melting.

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REFERENCES

- Brown, D. J., "Identifiable Basalt Flows in the Pasco Basin, Washington," (in press).
- Frey, F. A., M. A. Haskin, J. A. Poetz and L. A. Haskin, "Rare Earth Abundances in Some Basic Rocks," Jour. Geoph. Res., 73, pp. 6085-7003.
- Goles, G. G. and M. Osawa, "Petrogenesis of Columbia River Basalts," Trans. Am. Geoph. Un., 52, p. 375, (1971).
- Hill, D. P., "Crustal and Upper Mantle Structure of the Columbia River Plateau from Long-Range Seismic-Refraction Measurements," Bull. Geol. Soc. Am., 83, pp. 1639-1648, (1972).
- Hubbard, N. J., "A Chemical Comparison of Oceanic Ridge, Hawaiian Tholeiitic and Hawaiian Alkalic Basalts," Earth Planet Sci. Lett., 5, pp. 346-352, (1969).

REFERENCES (Continued)

- Kuno, H., "Fractionation Trends of Basalt Magmas in Lava Flows," Jour. Petrol., 6, pp. 302-321, (1965).
- , "Plateau Basalts in the Earth's Crust and Upper Mantle," Am. Geoph. Un. Mono., 13, pp. 495-501, (1969).
- MacDonald, G. A., "Composition and Origin of Hawaiian Lavas," In Studies in Volcanology, Geol. Soc. Am. Mem., 116, pp. 477-522, (1968).
- MacDonald, G. A. and T. Katsura, "Chemical Composition of Hawaiian Lavas," Jour. Petrol., 5, pp. 82-133, (1964).
- Osawa, M. and G. G. Goles, "Trace Element Abundances in Columbia River Basalts," Proc. Second Columbia River Basalt Symposium, Eastern Washington State College Press, pp. 73-96, (1970).
- Powers, H. A., "A Distinctive Chemical Characteristic of Snake River Basalts of Idaho," U. S. Geol. Surv. Prof. Paper 400B, 298, (1960).
- Schmincke, H. U., "Flow Directions in Columbia River Basalt Flows and Paleocurrents of Interbedded Sedimentary Rocks of South-Central Washington," Geol. Rundschau, 56, pp. 992-1020, (1967a).
- , "Stratigraphy and Petrology of Four Upper Yakima Basalt Flows in South-Central Washington," Bull. Geol. Soc. Am., 78, pp. 106-110, (1967b).
- Taubeneck, W. H., "Dikes of Columbia River Basalt in Northeastern Oregon, Western Idaho, and Southeastern Washington," Proc. Second Columbia River Basalt Symposium, Eastern Washington State College Press, pp. 73-96, (1970).
- Thompson, R. N., "Evidence for a Chemical Discontinuity Near the Basalt-Andesite Transition in Many Anorogenic Volcanic Suites," Nature, 236, pp. 106-110, (1972).
- Tilley, C. E. and R. N. Thompson, "Melting and Crystallization Relations of the Snake River Basalts of Southern Idaho," Earth Planet. Sci. Lett., 8, pp. 79-92, (1970).
- Waters, A. C., "Stratigraphic and Lithologic Variations in the Columbia River Basalt," Am. Jour. Sci., 259, pp. 593-611, (1961).
- , unpublished to Atlantic Richfield Hanford Company, (1972).
- Wright, T. L., M. J. Grolier and D. A. Swanson, "Chemical Variation Related to the Stratigraphy of the Columbia River Basalt," Bull. Geol. Soc. Am., 84, pp. 371-386, (1972).

APPENDIX A

Data in parts per million

DH-1

	SiO2	TiO2	Al2O3	CR2O3	FE2O3	FeO	MNO	MGO	CaO	Na2O	K2O
CA1	53.3	3.2	12.6			14.4	.2	4.4	8.1	2.4	1.4
2 A	53.3	3.3	13.3			13.0	.2	4.8	8.2	2.6	1.3
3	—										
4	—										
5	—										
6	54.6	2.0	14.9			11.1	.2	5.5	9.4	1.8	.5
1030	55.6	1.6	14.8			10.2		5.6	9.7	2.1	.4
7	54.6	2.0	14.3			11.0	.2	5.9	9.5	2.0	.4
8 B	54.1	1.8	14.8			10.6	.2	6.0	9.5	2.4	.6
1031	54.0	1.7	14.7			10.6		6.0	10.1	2.4	.4
9	52.4	1.8	14.5			10.6	.2	7.2	10.6	2.3	.5
1033	53.4	1.6	13.8			11.0		7.5	10.3	2.3	.3
10	51.7	2.0	14.1			11.9	.2	7.0	10.3	2.3	.6
1034	52.1	1.6	14.8			10.9		8.0	9.6	2.5	.5
11	51.7	1.9	14.6			10.6	.3	6.8	11.0	2.5	.6
12	51.8	1.9	14.3			11.7	.2	7.3	9.9	2.5	.5
1035	51.7	1.5	14.5			11.0		8.7	9.8	2.3	.4
13	51.9	1.8	14.7			11.5	.2	7.0	10.1	2.3	.4
14	—										
15	—										
16	—										
17	55.9	2.9	13.3			12.1	.2	3.7	7.2	2.9	1.7
1036 C	54.1	2.7	13.6			14.1		4.2	7.5	2.5	1.3
1037	53.9	2.5	13.7			13.5		4.2	7.4	2.8	2.1
18	54.0	2.8	13.2			13.4	.2	4.1	7.5	2.9	2.0
1038	53.2	2.7	13.2			13.9		4.1	8.8	2.7	1.5
19	53.8	2.8	13.2			14.2	.2	3.9	7.3	2.9	1.6
1039	54.2	2.7	13.3			13.9		4.3	8.2	2.8	1.6
20	53.2	2.8	13.2			14.7	.2	3.9	7.3	2.9	1.7
21	52.6	1.6	14.9			11.8	.1	6.2	9.7	2.3	.7
1040	52.1	1.5	15.1			10.8		7.7	9.8	2.4	.5
22 D	51.8	1.6	14.8			11.8	.2	7.0	9.2	2.4	1.1
1041	51.1	1.5	15.2			11.0		8.7	9.4	2.4	.7
1042	52.5	1.4	14.8			10.6		8.3	9.1	2.3	.9
23	52.2	1.8	14.7			12.0	.2	6.5	9.0	2.5	.9
24	54.4	3.5	16.0			14.4	.1	2.0	5.3	2.8	1.6
25	56.8	2.8	14.2			11.7	.2	2.5	6.3	3.0	2.5
1043	56.5	2.3	13.7			12.4		2.8	6.1	3.3	2.8

DH-1

	SiO ₂	TiO ₂	Al ₂ O ₃	CR ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O
26	55.8	2.6	13.7			12.9	.2	3.1	6.1	3.2	25
1044											
27	54.9	2.9	13.5			13.0	.2	3.0	6.4	3.4	26
28 E	54.4	3.1	13.7			13.3	.3	3.5	7.0	3.0	1.7
1045											
29	54.9	2.7	13.4			13.8	.2	3.3	6.1	3.1	25
30	54.2	2.9	13.1			14.2	.2	3.4	6.6	3.2	2.2
1046											
31	53.0	2.9	13.2			15.8	.3	2.9	6.6	3.2	2.1
1047											
32	—										
33	—										
34	—										
1048	52.6	2.6	14.3			12.7		5.2	8.9	2.8	.9
1049	52.5	2.7	13.8			13.1		5.6	9.0	2.7	.7
1050	51.9	2.8	14.1			12.8		5.7	9.2	2.8	.7
35	51.5	3.0	13.6			13.4	.2	5.5	9.3	2.8	.7
1051	52.2	2.6	13.6			13.3		5.4	9.4	2.7	.9
36	51.9	2.9	13.9			13.6	.2	4.9	8.8	2.8	1.0
37	51.5	3.1	13.3			13.4	.3	5.1	9.2	2.9	1.1
1052	51.1	2.8	13.3			14.5		5.8	9.0	2.4	1.0
38 F	50.9	3.2	13.5			14.2	.2	5.1	9.2	2.7	1.0
39	51.0	3.0	13.4			14.3	.2	5.8	8.7	2.7	.8
40	51.9	3.1	13.2			14.0	.2	5.5	8.4	2.7	1.0
1053	51.6	2.6	13.2			13.9		6.3	8.6	2.6	1.1
41	51.5	3.1	13.0			14.2	.2	5.6	8.7	2.7	1.1
42	52.6	3.3	12.6			14.7	.2	4.7	8.1	2.8	.9
43	54.1	3.1	12.2			14.3	.3	4.2	7.7	2.8	1.2
44	56.3	3.5	12.9			15.4	.2	4.7	8.5	3.0	1.4
45	52.9	3.0	13.6			13.6	.2	4.5	8.1	2.9	1.3
46	58.8										
47	55.2	3.2	13.6			11.9	.2	4.0	7.5	2.7	1.6
48	52.0	3.2	13.3			13.6	.2	4.9	8.8	2.8	1.0

DH-2

	102	7.02	10203	02203	FE203	FL2	0410	160	260	1000	100
49	51.3	3.1	10.9			17.2	.2	3.9	9.9	2.1	1.4
50	52.5	3.2	10.7			17.3	.2	2.7	9.4	2.3	1.1
10541	52.6	3.2	13.2			14.9		4.1	8.5	2.3	1.1
51	52.8	3.2	11.0			16.9	.2	3.7	9.1	2.2	1.0
1055	53.0	3.3	13.1			14.8		4.3	8.2	2.3	1.0
52	-										
53	53.5	1.8	12.9			12.4	.2	5.9	10.2	2.3	.7
54	51.8	1.7	13.7			12.7	.2	6.5	10.4	2.2	.7
1057	52.5	1.5	14.1			11.1		8.0	10.1	2.3	.4
558	52.3	1.5	14.7			10.6		7.9	10.4	2.4	.3
56	-										
56	55.6	3.5	13.4			12.6	.2	2.6	7.4	2.6	2.2
57	57.3	3.6	12.2			14.7	.2	2.5	7.7	2.3	3.1
58	56.6	3.2	11.6			12.7	.2	2.7	6.9	2.9	2.3
59	52.6	2.6	12.3			16.4	.2	2.6	7.4	2.9	2.2
60	54.4	2.5	11.1			15.0	.2	2.8	7.8	3.1	3.2
61	55.1	2.4	11.9			15.4	.2	2.7	6.2	3.0	3.0
62	56.4	2.4	12.2			13.8	.2	2.4	6.3	3.2	3.0
63	55.4	2.5	12.5			14.8	.2	2.9	5.9	3.1	2.7
64	55.6	2.4	12.0			15.0	.2	2.5	6.7	3.0	2.6
65	55.0	2.7	12.4			14.9	.2	2.8	6.5	3.1	2.8
67	-										
70	49.1	3.1	12.1			16.0	.3	7.8	9.2	2.3	.9
71	50.1	3.3	12.1			16.5	.2	4.8	9.8	2.3	1.0
72	51.5	3.2	11.3			16.6	.2	4.3	9.2	2.7	.4
73	52.6	3.2	11.4			15.4	.2	4.5	9.0	2.5	.9

	SiO2	TiO2	Al2O3	Fe2O3	Fe2O3	FLD	MNO	MGO	CaO	Na2O	K2O
2001	50.5	31	13.6			13.6		5.9	10.6	2.3	.7
2	50.8	33	13.2			13.1		6.5	10.1	2.2	.7
3	51.8	3.2	12.9			13.1		6.0	10.1	2.4	.6
152	52.0	3.2	12.9			15.3		5.0	8.2	2.7	.7
6 A	52.9	31	12.2			14.1		5.2	8.7	2.4	.4
153	52.3	32	12.8			15.5		4.9	7.9	2.6	.8
8	53.2	33	12.6			14.1		4.4	8.8	2.4	1.0
9	52.7	34	11.8			15.3		4.4	7.8	2.2	2.2
154	52.1	3.1	13.1			15.3		4.8	7.9	2.8	.8
11	54.2	17	13.3			11.1		7.1	10.1	2.1	.4
12 B	55.3	1.6	13.4			11.0		7.1	8.8	2.2	.6
13	54.8	1.6	13.6			10.9		7.2	9.1	2.3	.5
14	55.5	1.7	13.4			10.6		7.3	8.7	2.3	.6
16	57.1	2.7	13.3			13.9		3.6	6.0	2.0	1.3
17	55.1	2.7	12.3			14.4		4.1	7.2	2.5	1.7
18 C	55.4	2.4	12.9			13.6		3.9	7.6	2.1	1.5
19	55.0	2.6	12.9			14.4		3.7	7.2	2.6	1.7
22	56.4	2.8	12.6			13.2		3.7	6.1	2.9	2.2
24	57.4	2.4	13.8			11.8		2.9	5.7	2.3	2.5
25	57.4	2.3	13.4			12.1		2.9	6.0	2.2	2.7
26 E	57.9	2.3	13.7			12.1		2.6	5.6	3.1	2.6
27	57.3	2.3	13.1			12.7		2.9	5.7	3.4	2.6
28	57.4	2.2	12.8			12.7		3.0	5.8	3.4	2.6
29	56.3	2.3	12.6			12.5		4.4	6.0	3.3	2.5
31	54.1	2.6	12.8			14.7		4.6	8.0	2.4	.8
32	53.1	2.6	12.3			14.5		5.2	8.8	2.5	.9
33	53.8	2.6	13.1			13.6		5.0	8.7	2.4	.9
34	53.2	2.7	13.1			13.6		5.2	8.4	2.7	1.1
155	50.5	3.2	15.3			14.1		4.7	8.5	3.1	.6
36	53.6	2.6	13.2			14.1		4.4	8.6	2.5	.9
37	53.1	2.6	13.2			14.2		4.8	8.5	2.6	1.0
38 G	53.7	2.5	13.3			13.9		4.4	8.4	2.7	1.1
39	53.4	2.7	12.8			14.4		4.7	8.1	2.7	1.2
40	54.2	2.5	12.9			13.8		4.4	8.4	2.6	1.2
41	55.2	2.7	12.6			14.1		4.1	7.8	2.5	1.1
42	54.5	2.4	12.6			14.6		4.4	7.6	2.7	1.2
41	54.1	3.0	12.4			14.4		4.4	7.7	2.9	1.2
43	53.8	2.6	12.9			14.1		4.4	7.6	2.8	1.1

	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	Fe2	MnO	MgO	CaO	Na2O	K2O
44	53.8	2.5	13.0			14.1		4.4	7.9	2.9	1.4
45	54.6	2.6	13.2			14.1		3.8	7.7	3.0	1.2
46	54.7	2.6	12.7			13.7		4.2	8.0	2.8	1.4
47	53.7	2.6	13.2			14.9		4.4	7.4	2.5	1.2
48	53.8	2.6	12.9			14.1		4.8	8.0	2.6	1.2
49	53.9	2.5	12.9			13.9		4.7	8.1	2.7	1.3
50	54.6	2.6	12.8			13.7		4.7	8.0	2.6	1.1
51	54.6	2.5	12.7			14.2		4.4	7.6	2.7	1.2
52	54.1	2.4	12.6			14.4		4.5	7.9	2.8	1.2
53	54.4	2.5	13.0			13.8		4.2	7.9	2.9	1.4
54	53.2	2.4	13.1			14.5		5.2	8.1	2.5	1.0
55	53.4	2.3	12.8			14.8		4.9	7.9	2.7	1.3
56	53.8	2.4	13.0			14.3		4.6	7.8	2.7	1.3
57	54.8	2.3	12.5			14.1		4.6	7.6	2.8	1.2
58	55.1	2.3	12.7			14.4		3.7	7.7	2.8	1.2
59	57.1	2.5	12.8			11.5		4.4	7.6	2.9	1.2
60	55.4	2.3	12.2			14.4		4.3	7.5	2.8	1.1
156	52.2	2.7	13.4			15.3		4.6	7.7	3.0	1.0
61	55.1	2.4	12.4			14.4		4.3	7.6	2.7	1.1
62	55.6	2.4	12.7			14.0		3.7	7.6	3.0	1.0
63	55.4	2.4	12.3			14.6		4.0	7.5	2.7	1.1
64	56.6	2.3	12.0			14.8		4.2	7.3	1.9	1.0
65	54.7	2.3	12.0			15.7		4.3	7.3	2.5	1.1
66	55.1	2.3	12.1			15.7		4.3	7.3	2.3	.9
157	52.6										
67	55.0	2.4	12.1			14.9		3.8	8.0	2.8	1.0
68	56.4	1.7	12.6			12.5		5.1	7.8	3.0	1.0
158	53.1	2.8	13.2			15.0		4.7	7.3	2.8	.9
69	57.7	1.7	12.2			14.5		2.8	3.7	2.5	4.9
159	55.1	2.0	16.3			10.8		3.8	7.0	3.1	1.9
70	56.2	1.6	12.7			13.1		4.5	7.9	3.1	.9
71	56.4	1.6	12.1			13.5		4.7	7.6	3.0	1.1
72	55.9	1.6	12.9			12.5		5.1	8.2	2.8	1.0
73	55.8	1.6	13.0			13.2		5.2	7.9	2.6	.7
74	56.4	1.7	12.5			13.4		4.8	7.6	2.6	.9
75	56.7	1.7	12.7			13.0		4.7	7.6	2.8	.9
76	57.4	1.7	12.4			12.8		4.5	7.3	2.7	1.0
77	57.6	1.6	12.4			12.6		4.7	7.2	2.6	1.1

	SiO2	TiO2	Al2O3	CR2O3	Fe2O3	FeO	MNO	MGO	CAO	NA2O	K2O
78	57.2	1.7	12.7			12.0		4.9	7.5	2.8	1.1
79	57.4	1.6	12.7			11.9		4.9	7.6	2.7	1.1
80	57.7	1.6	12.5			11.8		5.0	7.5	2.7	1.1
81	58.0	1.6	12.6			11.5		4.9	7.6	2.7	1.1
82	55.9	1.8	12.9			12.7		5.1	8.0	2.4	1.1
161	54.1	1.9	14.0			12.2		5.6	8.1	3.1	.9
83	54.4	1.6	12.9			14.3		5.3	8.1	2.8	.6
84	54.9	1.5	12.7			14.0		5.5	8.0	2.8	.7
85	55.8	1.6	12.6			13.1		5.4	8.1	2.7	.7
86 H	55.6	1.7	13.0			13.0		5.6	7.6	2.7	.8
87	55.8	1.7	12.9			12.9		5.6	7.8	2.6	.8
88	55.4	1.7	13.1			12.9		5.4	7.6	2.9	1.0
89	55.0	1.8	12.9			13.5		5.7	7.9	2.7	.7
92	54.3	1.7	13.2			13.2		5.5	8.3	2.9	.9
93	53.5	1.8	13.9			13.0		5.5	8.5	2.7	1.0
94	55.7	1.7	13.1			12.6		5.1	8.3	2.9	.7
95	54.4	1.8	13.6			13.1		5.2	8.2	3.0	.6
96	53.7	1.8	13.4			12.9		5.4	9.1	2.7	1.0
97	54.1	1.7	13.5			13.3		5.5	8.6	2.7	.6
98	53.7	1.9	13.9			13.0		5.4	8.5	3.0	.7
99	55.7	1.7	13.3			12.3		5.3	8.3	2.9	.7
100	54.7	1.8	13.8			12.2		5.5	8.1	2.7	1.3
101	51.8	1.9	14.7			12.8		6.7	8.5	2.8	.8
102	54.1	1.8	13.6			12.5		6.2	8.1	3.0	.7
103	53.5	1.8	13.9			13.2		5.8	7.9	2.8	1.2
104	52.9	1.8	13.9			13.3		5.4	8.7	2.8	1.2
105	53.9	1.9	14.3			12.8		5.2	8.1	3.0	.8
106	56.0	1.8	13.3			12.2		4.9	7.7	3.2	.9
108	58.6	2.0	12.7			12.0		3.4	6.3	3.0	2.5
109	58.9	1.9	12.5			12.3		3.4	6.9	2.9	1.3
110	57.1	2.0	13.2			11.8		3.7	7.0	2.8	2.3
111	56.5	2.1	12.9			13.1		3.6	7.0	3.1	1.7
112 I	56.5	2.0	13.1			12.7		3.7	6.8	3.2	2.1
113	56.1	2.1	13.0			13.4		3.8	6.9	3.2	1.4
114	55.3	2.2	13.3			13.4		3.9	6.9	3.5	1.5
115	55.1	2.2	13.3			14.1		3.8	6.9	3.2	1.4
116	56.1	2.0	13.5			13.3		3.7	6.8	3.4	1.3
117	55.8	2.0	13.4			13.1		3.9	7.0	3.4	1.4

DH-3

	SiO2	TiO2	AL2O3	CR2O3	FE2O3	FeO	MNO	MGO	CAO	NA2O	K2O
119	56.0	2.1	13.7			12.7		3.8	7.0	3.3	1.4
120	57.2	2.1	12.9			12.6		3.5	6.8	3.3	1.6
121	57.3	2.1	12.0			13.6		3.6	6.7	3.1	1.5
122	53.9	2.0	12.7			13.3		5.4	8.5	3.1	1.1
129	52.5	2.0	14.5			13.4		5.0	8.8	2.9	.9
136 J	54.0	1.7	13.9			12.2		5.7	8.5	3.1	.9
123	55.1	1.8	12.7			12.4		5.8	8.0	3.2	1.0
124	55.6	1.9	12.8			12.4		5.3	7.9	3.1	1.0
125	50.8	1.8	15.1			12.3		6.6	9.8	3.2	.4
126 K	52.2	1.8	14.6			11.8		6.4	9.4	3.3	.5
128	53.1	1.8	14.2			11.5		6.3	9.0	3.3	.7
127	53.2	1.7	14.3			11.5		6.0	9.3	3.2	.8
133 L	56.1	1.8	13.9			13.4		4.5	5.4	2.8	2.0

		SiO2	TiO2	Al2O3	CR2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O
4001		51.2	3.2	12.7			15.8	.2	4.5	9.0	2.5	.8
2	A	51.7	3.2	12.7			15.8	.2	4.5	8.6	2.3	.9
3		51.9	3.3	12.8			15.1	.2	4.8	8.6	2.5	.9
4		52.2	1.7	14.2			11.4	.2	7.4	10.6	2.3	.1
5		52.0	1.6	13.9			11.6	.2	7.7	10.6	2.2	.2
6		52.4	1.6	14.0			11.1	.2	7.7	10.5	2.4	.2
7		52.5	1.6	13.9			11.2	.2	7.5	10.4	2.4	.2
8		52.3	1.6	13.8			11.2	.2	7.8	10.5	2.4	.3
9	B	52.4	1.7	13.7			11.1	.2	7.6	10.5	2.5	.3
10		53.9	1.9	14.1			11.2	.2	6.0	9.3	2.5	.9
11		52.5	1.7	14.8			11.7	.2	6.4	9.4	2.4	.9
12		50.2	1.3	16.0			10.0	.2	9.4	10.5	2.3	.1
13		50.3	1.4	15.8			10.2	.2	9.0	10.7	2.2	.3
14		51.5	1.6	15.2			10.8	.2	7.7	9.8	2.4	.8
15		52.6	1.8	14.3			11.9	.2	6.2	9.1	2.5	1.4
16		53.8	1.8	14.1			11.8	.2	5.2	8.2	2.8	2.0
17		53.6	1.8	13.8			12.3	.2	5.4	8.2	2.8	1.9
18		49.9	3.1	13.5			15.6	.2	5.8	7.9	2.7	1.2
19		49.8	3.0	13.2			15.0	.2	6.1	9.0	2.6	1.0
20		50.3	3.1	13.2			14.4	.2	6.0	9.1	2.6	1.0
21		51.0	3.0	13.0			14.8	.3	5.4	8.5	2.7	.9
22	F	49.0	2.8	12.5			18.5	.4	4.7	8.6	2.5	.9
23		50.8	2.9	12.3			15.5	.3	5.2	8.3	2.5	1.1
24		51.8	3.0	12.5			15.7	.3	4.8	8.3	2.6	1.0
25		50.7	3.1	12.8			16.0	.3	5.2	8.5	2.5	1.0
26		50.0	3.1	12.8			16.4	.3	5.4	8.5	2.6	1.1
27		50.8	3.1	12.6			16.1	.3	5.1	8.2	2.8	1.0
28		51.5	2.7	13.4			14.9	.2	4.9	8.7	2.6	1.0
29		51.5	2.7	13.4			14.5	.2	5.3	9.5	2.9	1.0
30		51.7	2.7	13.1			14.7	.2	5.1	8.4	3.0	1.0
31		51.9	2.7	13.2			14.3	.2	5.3	8.3	3.0	1.0
32		51.8	2.7	13.1			14.9	.2	5.2	8.7	2.5	.8
33	G	51.6	2.8	12.9			14.9	.2	5.3	8.5	2.8	1.0
34		52.5	2.8	12.9			14.9	.2	4.8	8.1	2.6	1.0
35		52.8	2.8	12.9			14.7	.2	4.8	7.9	2.8	1.1
36		52.7	2.8	12.7			15.0	.2	4.9	7.7	2.9	1.1
37		53.1	2.7	13.1			14.8	.2	4.6	7.6	3.0	.8
38		53.7	2.5	13.0			14.1	.2	4.2	7.5	2.9	1.0

	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O
39	52.9	2.6	13.0			15.5	.2	4.4	7.3	2.9	1.1
40	54.5	2.6	13.0			13.7	.2	3.9	7.2	3.1	1.7
41	53.6	2.6	13.0			14.8	.2	4.6	7.2	2.9	1.0
42	53.5	2.8	13.3			14.4	.2	4.3	7.8	2.7	1.0
43	52.2	2.7	13.5			15.3	.2	4.8	7.8	2.8	.7
44	52.5	3.0	13.2			15.1	.2	4.7	7.7	2.8	.8
45	52.1	2.9	13.1			16.2	.2	4.2	7.5	2.9	.7
46	53.5	2.7	12.6			15.6	.2	4.9	7.1	2.5	.7
47	53.2	2.7	13.2			14.8	.2	4.6	7.3	2.9	1.0
48	G 53.3	2.8	12.8			15.1	.2	4.7	7.2	3.0	.9
49	52.8	2.9	13.5			14.8	.2	4.6	7.2	3.2	.7
50	53.2	2.8	13.3			14.9	.2	4.7	7.1	3.1	.7
51	51.3	2.7	13.3			15.4	.3	4.9	8.5	2.8	.7
52	53.3	2.8	13.2			15.0	.2	4.8	7.3	2.8	.5
53	53.4	2.8	13.2			15.2	.3	4.6	7.0	2.8	.7
54	53.2	2.7	13.3			14.9	.2	4.8	7.1	3.0	.7
55	52.8	2.6	13.0			15.6	.2	5.0	7.2	3.0	.6
56	52.1	2.8	12.8			14.5	.2	4.1	10.0	2.6	1.0
57	52.9	2.8	13.0			14.3	.2	4.7	8.2	2.8	1.1
58	52.6	2.7	12.8			15.2	.3	4.6	8.0	2.8	1.0
59	52.6	2.7	13.3			14.8	.3	4.2	8.1	2.8	1.2
60	52.5	2.6	13.2			14.6	.2	4.6	8.0	3.1	1.2
61	52.6	2.7	13.1			14.7	.3	4.5	8.1	3.0	.9
62	52.1	2.7	13.0			15.0	.3	4.7	8.2	3.1	.9
63	52.5	2.6	12.9			15.1	.2	4.8	7.7	3.1	1.0
64	54.2	1.6	14.4			11.8	.2	5.6	8.5	3.0	.7
65	-										
66	54.2	1.7	14.1			11.6	.2	5.1	8.1	3.0	.9
67	54.5	1.7	14.3			11.3	.2	5.5	8.5	3.1	.8
68	54.5	1.8	14.5			11.5	.2	5.4	8.5	3.0	.6
69	54.3	1.7	13.9			12.1	.2	5.4	8.7	3.1	.5
70	H 53.0	1.7	14.2			12.1	.2	5.6	9.9	3.0	.3
71	53.2	1.7	14.5			12.2	.2	5.9	8.8	3.0	.5
72	54.5	1.8	14.3			11.8	.2	5.3	8.5	3.0	.5
73	53.3	1.8	14.1			12.4	.2	5.8	8.1	3.1	1.1
74	54.2	1.7	14.2			11.9	.2	5.4	8.4	2.9	1.0
75	53.3	1.8	14.1			12.4	.2	5.8	8.1	3.1	1.1
76	55.2	1.7	13.5			11.7	.2	5.4	8.3	3.0	1.0

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	SiO2	TiO2	Al2O3	CR2O3	Fe2O3	FeO	MNO	MGO	CAO	NA2O	K2O
77	54.5	1.8	13.6			12.2		5.6	8.3	2.9	1.0
78	54.6	1.8	13.7			12.0		5.6	8.4	2.9	1.0
79	56.5	1.8	12.9			11.9		4.8	7.9	3.0	1.1
80	55.8	1.8	13.2			11.8		5.3	8.2	2.9	1.1
81	54.6	1.9	14.0			12.0		5.4	8.2	3.0	.9
82	54.3	2.0	13.8			12.0		5.5	8.4	3.0	.9
83	—										
84	55.6	1.8	13.6			11.6		5.4	8.3	2.9	.9
85	—										
86	55.4	1.8	13.6			11.7	.2	5.3	8.0	2.9	1.0
87	55.4	1.8	13.6			11.8	.2	5.4	8.0	2.9	.9
88	55.2	1.9	13.6			11.8	.2	5.4	8.0	2.9	.9
89	H 54.3	2.0	13.7			12.3	.2	5.5	8.1	2.9	.9
90	55.6	1.9	13.5			11.6	.2	5.4	8.0	2.9	.9
91	54.8	1.8	13.4			12.5	.2	5.1	7.8	3.5	.9
92	55.9	1.9	13.3			12.1	.2	5.0	7.6	2.9	.9
93	55.2	2.0	13.4			12.4	.2	5.2	7.8	2.9	.9
94	55.6	2.2	13.3			12.0	.2	4.9	7.7	3.0	1.0
95	55.4	2.0	14.0			13.1	.2	4.9	8.3	2.9	1.1
96	55.9	1.9	13.2			12.5	.2	4.2	7.6	3.2	1.2
97	55.8	1.9	13.2			12.6	.2	4.3	7.5	3.2	1.2
98	56.7	1.9	12.9			12.5	.2	4.2	7.3	3.1	1.1
99	56.0	2.0	13.7			11.9	.2	4.2	7.5	3.3	1.2
100	53.4	2.2	14.1			13.3	.3	4.9	7.6	2.9	1.3
101	54.9	2.2	14.1			12.1	.3	4.3	7.5	3.3	1.3
102	55.5	2.1	13.4			13.0	.2	4.0	7.1	3.2	1.4
103	55.8	2.1	13.4			12.7	.2	3.9	7.1	3.3	1.3
104	55.7	2.1	13.2			13.5	.2	3.5	7.1	3.2	1.4
105	56.0	2.1	13.1			13.2	.2	3.5	7.2	3.3	1.4
106	56.8	2.1	13.0			12.7	.2	3.5	7.0	3.4	1.3
107	57.3	1.8	13.5			12.1	.2	3.6	6.8	3.4	1.3
108	I 57.4	1.9	13.1			12.2	.2	3.1	6.7	2.7	2.7
109	56.1	1.9	13.7			12.4	.2	3.7	7.4	3.4	1.2
110	58.0	1.9	13.2			11.6	.2	3.5	6.9	3.3	1.5
111	55.8	1.8	12.6			14.8	.2	3.4	6.7	3.4	1.5
112	57.2	2.3	13.8			11.9	.2	3.4	6.7	3.2	1.4
113	56.5	2.0	13.8			11.9	.2	3.6	7.2	3.2	1.6
114	56.7	2.1	13.6			12.0	.2	3.3	7.2	3.3	1.5

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	SiO2	TiO2	AL2O3	CR2O3	FE2O3	FeO	MNO	MGO	CAO	NA2O	K2O
115	56.8	2.0	13.6			11.9	.2	3.4	7.3	3.3	1.4
116	56.8	1.9	13.6			12.1	.2	3.2	7.4	3.2	1.4
117	56.4	2.0	13.7			12.1	.2	3.5	7.1	3.3	1.7
118	56.9	1.9	13.7			11.9	.2	3.6	7.0	3.4	1.5
119	57.0	1.8	14.5			11.7	.2	3.4	7.1	3.3	1.5
120	56.2	1.7	15.0			11.6	.2	3.4	6.9	3.2	1.7
121	57.8	2.0	13.2			11.2	.2	3.4	7.1	3.5	1.7
122	57.0	1.9	13.2			12.2	.2	3.5	6.9	3.6	1.4
123	58.1	1.9	12.8			11.7	.2	3.4	6.8	3.4	1.6
124	57.3	1.8	13.5			11.7	.2	3.5	7.0	3.4	1.7
125	57.6	1.8	13.3			12.0	.2	3.4	6.9	3.4	1.5
126 I	57.8	1.8	13.3			11.6	.2	3.4	7.1	3.4	1.5
127	57.7	1.8	13.2			12.0	.2	3.2	6.9	3.4	1.5
128	57.3	1.9	13.0			12.2	.2	3.4	7.1	3.5	1.4
129	56.7	2.1	13.3			12.7	.2	3.2	6.8	3.4	1.5
130	55.8	2.3	13.8			12.8	.2	3.3	6.9	3.5	1.4
131	57.0	1.9	13.8			12.0	.2	3.5	7.1	3.4	1.2
132	55.5	1.9	14.3			12.3	.2	3.6	7.3	3.4	1.5
133	56.0	1.9	13.3			12.6	.2	4.0	7.3	3.6	1.6
134	55.2	1.9	14.1			12.9	.2	3.4	7.3	3.2	1.3
135	54.7	2.2	13.7			12.8	.2	4.0	7.6	3.2	1.6
136	55.1	2.2	14.1			12.5	.2	4.1	7.1	3.1	1.0
137	56.8	2.1	12.5			12.6	.2	4.1	7.0	3.2	1.4
138	56.3	2.1	13.6			12.6	.2	3.9	6.8	3.2	1.1
139	55.7	2.2	13.6			12.2	.2	4.0	7.1	3.2	1.4
140	58.2	1.8	12.9			10.8	.2	4.3	7.3	3.3	1.2
141	56.2	1.9	14.1			11.2	.2	4.2	7.7	3.2	1.3
142	55.6	1.9	14.0			11.4	.2	4.4	8.0	3.3	1.3
143	56.3	1.9	13.5			12.1	.2	3.6	7.7	3.4	1.3
144	56.6	2.0	13.5			11.6	.2	4.0	7.6	3.4	1.1
145	56.5	2.0	13.5			11.8	.2	3.9	7.2	3.4	1.5
146 J	56.0	1.9	13.4			12.7	.2	3.6	7.3	3.5	1.5
147	56.4	1.8	13.6			12.1	.2	3.6	7.6	3.5	1.1
148	56.3	2.0	13.3			12.5	.2	3.9	7.3	3.3	1.4
149	57.4	1.8	13.2			11.6	.2	3.6	7.4	3.5	1.2
150	56.9	1.7	13.5			11.4	.2	3.7	7.8	3.4	1.5
151	57.8	1.7	13.5			11.5	.2	3.4	7.1	3.4	1.4
152	57.0	1.8	13.4			11.8	.2	3.5	7.1	3.4	1.8

	SiO2	TiO2	Al2O3	CR2O3	FE2O3	FeO	MNO	MGO	CAO	NA2O	K2O
153	<u>57.0</u>	1.9	<u>13.7</u>			11.7	.2	3.6	7.3	3.3	1.3
154	- 59.0	1.8	12.7			11.1	.2	3.3	6.6	3.5	1.8
155	58.1	1.8	13.0			11.6	.2	3.5	7.1	3.4	1.3
156	59.0	1.9	13.0			11.2	.2	3.3	6.9	3.4	1.2
157 J	58.7	1.8	13.0			11.5	.2	3.4	6.4	3.3	1.9
158	58.3	1.8	13.2			11.4	.2	3.5	6.4	3.4	1.8
159	58.3	1.8	13.1			11.7	.2	3.5	7.1	3.5	.9
160	57.8	1.9	13.4			11.5	.2	3.4	7.2	3.6	1.1
161	57.6	1.8	13.2			11.8	.2	3.4	7.3	3.7	1.0
162	57.3	1.8	13.5			11.7	.2	3.4	7.4	3.6	1.1
163	58.4	1.7	12.5			11.0	.2	3.2	8.6	3.5	1.0
164	53.7	1.9	13.7			12.6	.2	3.6	10.0	3.3	.9
165	53.7	2.2	14.1			13.2	.2	3.7	7.5	3.3	2.0
166	55.1	2.2	14.1			12.1	.2	3.7	8.1	3.5	1.0
167	55.7	2.1	13.5			12.7	.2	3.8	7.4	3.4	1.2
168 K	55.0	2.2	13.2			12.3	.2	3.9	8.2	3.4	1.6
169	55.1	2.1	13.6			12.1	.2	3.8	8.0	3.4	1.7
170	56.4	2.1	13.0			12.5	.2	3.8	7.6	3.6	.8
171	56.0	2.0	13.2			12.5	.2	3.9	7.7	3.6	.8
172	56.2	2.0	13.5			12.1	.2	3.9	7.7	3.5	.9
173	56.7	2.1	13.1			12.3	.2	3.7	7.4	3.5	1.3

		SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O
5001		52.9	3.1	13.1			16.4		4.0	7.7	2.3	.4
2		53.9	2.9	12.9			15.9		3.9	7.6	2.5	.4
3	A	54.1	2.9	12.7			14.9		4.5	7.7	2.6	.8
4		54.0	3.1	12.7			14.9		4.1	7.8	2.4	.8
5		54.1	3.1	12.8			14.2		4.3	8.1	2.6	1.0
6		53.6	1.6	14.2			10.9		7.2	9.8	2.4	.3
7		53.5	1.7	14.0			10.9		7.5	9.8	2.2	.3
8		53.0	1.6	14.5			11.2		7.7	8.8	2.4	.7
9		52.2	1.6	14.3			11.4		7.7	9.6	2.4	.7
10		52.5	1.6	14.3			11.1		7.9	9.6	2.4	.5
11	B	52.7	1.7	14.3			11.0		7.6	9.7	2.5	.6
12		51.2	1.6	14.6			11.8		8.4	9.9	2.1	.3
13		51.9	1.6	15.8			10.1		8.5	9.6	2.3	.3
14		53.3	1.6	15.4			9.7		7.4	9.2	2.6	.8
15		51.7	1.6	15.5			10.5		7.5	10.2	2.3	.6
16		52.4	1.7	15.4			10.6		7.2	9.5	2.3	.8
17		52.7	1.7	15.5			10.8		6.7	9.2	2.5	.9
18		51.7	2.8	13.6			14.5		5.3	8.6	2.6	.9
19		50.9	2.8	13.9			14.3		6.1	8.5	2.6	1.0
20		51.7	3.0	12.9			15.8		5.0	7.9	2.7	1.1
21		52.9	3.0	12.2			15.2		5.0	8.0	2.7	1.1
22	F	53.1	3.0	12.7			15.3		4.1	7.8	2.9	1.1
23		51.4	3.1	13.0			15.6		4.5	8.5	2.8	1.1
24		52.3	3.1	12.8			14.7		5.1	8.2	2.7	1.1
25		54.6	2.8	12.1			14.2		4.6	7.9	2.7	1.2
26		51.8	3.1	12.9			15.4		4.9	8.1	2.8	1.1
27		50.0	3.5	13.6			14.9		5.5	8.3	3.0	1.2
28		52.7	2.6	14.5			13.4		4.9	8.4	2.7	.8
29		53.0	2.4	13.7			13.9		5.2	8.4	2.7	.7
30		52.4	2.9	13.5			14.1		4.6	8.6	2.9	1.1
31		51.8	2.7	13.2			15.0		5.0	8.5	2.8	1.0
32		52.2	2.7	13.3			14.5		5.1	8.5	2.7	1.0
33	G	52.3	2.7	13.1			14.9		5.0	8.0	2.9	1.2
34		52.4	3.0	13.3			14.2		4.5	8.3	2.8	1.5
35		53.2	2.7	12.8			15.2		4.8	7.8	2.6	.9
36		53.9	2.7	12.4			15.1		4.5	7.8	2.6	1.1
37		53.2	2.9	12.7			14.9		4.6	7.8	2.7	1.2
38		53.0	2.9	12.6			14.7		4.6	8.0	2.7	1.5

	SI02	TI02	AL203	CR203	FE203	FED	MNO	UGO	CAO	NA2O	K2O
39	53.1	2.5	13.2			14.5	.2	4.5	8.0	2.8	1.2
40	51.8	3.0	13.3			14.8	.2	4.7	7.8	2.6	1.6
41	53.9	2.6	12.8			14.5	.2	4.5	7.2	2.8	1.3
42	54.0	2.9	12.7			14.2	.2	4.5	7.3	2.9	1.4
43	54.3	2.6	12.6			14.2	.2	4.5	7.2	2.8	1.4
44	53.9	2.5	12.8			14.4	.2	4.6	7.4	2.8	1.5
45	54.0	2.6	12.9			14.2	.2	4.7	7.5	2.6	1.2
46	53.4	2.9	12.9			14.3	.2	4.7	7.6	2.6	1.3
47 G	53.1	3.2	13.2			14.1	.2	4.8	7.7	2.6	1.3
48	53.2	3.0	13.1			14.0	.2	4.8	7.6	2.7	1.3
49	51.5	2.9	13.1			14.8	.2	5.1	8.2	3.0	1.3
50	55.0	2.7	12.9			12.0	.3	4.6	8.4	3.1	1.1
51	53.5	2.7	12.5			14.6	.3	4.3	8.4	2.7	1.0
52	53.4	2.8	12.9			14.5	.3	4.1	8.2	2.8	1.0
53	53.5	3.0	12.2			14.9	.3	4.5	8.1	2.7	1.0
54	52.8	2.9	12.8			14.6	.2	4.3	8.2	2.9	1.0
55	52.2	3.0	13.3			14.8	.2	4.2	8.5	2.8	1.0
56	52.9	3.1	12.8			14.7	.2	4.1	8.1	2.9	1.2
57	51.0	3.0	14.0			15.5	.2	4.4	7.9	2.9	1.0
58	52.5	3.1	12.3			14.9	.2	4.4	8.0	3.1	1.3
59	51.7	3.2	13.1			14.7	.2	4.4	8.6	3.0	1.2
60	51.7	3.0	13.2			14.4	.2	4.9	8.6	3.1	1.1
61	52.4	3.0	13.3			14.4	.2	4.4	8.3	3.0	1.0
62	54.5	2.8	12.5			13.6	.2	4.1	8.0	3.1	1.2
63	52.9	2.9	13.0			14.2	.2	4.2	8.2	3.1	1.2
64	54.7	1.6	13.8			11.8	.2	5.2	9.0	2.9	.6
65	55.4	1.7	13.6			11.4	.2	4.8	8.3	3.2	1.3
66	55.3	1.6	14.2			10.9	.2	5.0	8.8	3.0	.9
67	55.2	1.6	14.3			11.0	.2	4.9	8.6	3.1	1.0
68	55.5	1.5	14.4			10.7	.2	4.8	8.6	3.2	1.0
69 H	55.4	1.5	14.3			11.3	.2	4.8	8.4	3.1	1.0
70	55.0	1.8	14.2			11.2	.2	4.8	8.9	3.0	1.1
71	54.9	1.8	13.9			11.4	.2	4.8	8.7	3.1	1.2
72	54.6	1.6	14.2			11.4	.2	5.1	8.7	3.1	1.0
73	54.9	1.6	13.9			11.3	.2	5.1	8.6	3.3	1.2
74	54.2	1.9	14.0			11.7		5.3	9.0	2.8	1.0
75	54.1	1.7	13.9			11.8		5.8	9.4	3.0	.9
76	53.9	1.8	13.7			11.6		5.9	9.2	3.0	.9

DH-5

	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O
77	54.0	1.8	13.6			11.6		5.9	9.2	2.9	1.0
78	53.8	1.8	13.9			11.7		5.9	9.0	2.8	1.1
80	51.8	1.8	13.4			11.5		5.6	8.8	2.9	4.1
81	53.0	1.9	13.7			11.9		5.8	8.9	3.0	1.8
83	52.8	1.9	13.9			11.9		6.0	9.1	3.0	1.4
126	57.1	1.9	13.6			11.5		3.7	7.1	3.3	1.9
127	57.5	1.9	13.7			11.6		3.9	6.9	3.2	1.4
128	56.2	1.9	13.7			12.0		4.4	7.4	3.2	1.2
129	55.7	1.8	13.5			11.4		3.9	8.7	3.2	1.7
130	56.0	2.0	14.4			11.7		4.0	7.0	3.2	1.7
134	56.1	2.0	13.3			12.8		3.8	7.0	3.4	1.6
135	56.7	2.1	13.3			11.9		3.7	7.2	3.3	1.9
136	56.4	2.2	13.4			12.0		3.9	7.1	3.3	1.8
137	56.7	2.1	13.4			11.9		3.7	7.0	3.3	2.0
138 I	56.0	2.0	13.5			12.3		3.9	7.1	3.5	1.6
139	56.2	2.0	13.6			12.1		4.0	7.2	3.3	1.7
140	55.6	2.1	13.4			12.5		4.1	7.2	3.2	1.8
141	55.1	2.1	13.7			12.8		4.3	7.4	3.3	1.3
142	55.2	2.1	13.7			12.7		4.3	7.6	3.2	1.3
143	55.4	1.9	14.0			11.3		4.7	7.9	3.0	1.8
144	53.1	2.2	14.1			12.6		5.1	7.5	3.5	1.7
145	56.2	2.0	13.5			12.0		4.1	7.4	3.3	1.4
146	55.8	2.1	13.7			12.2		4.1	7.3	3.3	1.5
147	55.9	2.0	13.5			12.2		4.1	6.9	3.3	2.1
148	55.4	2.1	13.4			12.0		3.9	7.0	3.2	2.9
149	56.0	2.1	13.6			12.3		3.8	7.1	3.4	1.7
150	56.4	2.1	14.2			12.3		3.1	7.3	3.3	1.1
151	56.9	1.9	13.8			11.5		3.9	7.0	3.4	1.6
152 J	56.7	1.9	13.6			11.4		4.1	7.2	3.4	1.6
153	56.2	1.9	13.6			11.6		3.9	7.0	3.3	2.6
154	54.9	1.9	13.7			11.5		4.3	7.9	3.3	2.5
155	55.7	2.1	14.1			12.0		3.9	6.7	3.4	2.2
156 K	56.3	2.1	13.9			12.0		3.8	6.9	3.2	1.9
157	56.5	2.2	13.6			11.9		3.8	7.2	3.5	1.4
158	56.5	2.2	13.5			11.8		3.7	7.2	3.3	1.2
159	55.7	2.2	13.8			12.3		3.8	7.0	3.4	1.9
160	55.4	2.2	14.2			12.6		3.5	6.8	3.5	1.9
161	56.7	2.0	13.4			12.0		3.5	6.7	3.1	2.5

	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O
162	57.1	2.0	13.5			12.1		3.5	6.6	3.4	1.7
163	56.4	2.2	13.5			12.3		3.8	7.3	3.4	1.2
164	56.6	2.4	13.6			12.2		3.7	6.7	3.3	1.5
165	56.8	2.2	13.3			12.1		3.8	7.2	3.3	1.2
166	56.1	2.4	13.3			12.6		3.7	7.0	3.2	1.8
167	56.0	2.3	13.7			12.2		3.7	6.9	3.4	1.8
168	55.2	2.3	13.6			12.7		4.0	6.7	3.3	2.2
169	55.5	2.3	13.1			13.2		4.3	7.3	3.5	.9
170	55.8	2.2	13.2			12.7		4.0	7.1	3.4	1.6
171	53.6	2.3	13.4			12.2		4.0	7.5	3.3	3.5
174	54.2	2.3	13.9			12.4		4.4	7.9	3.1	1.8
175 K	55.6	2.3	13.3			13.0		4.2	7.3	3.2	1.1
181	54.6	2.3	13.3			12.5		4.3	8.0	3.2	1.9
182	55.2	2.2	13.4			12.5		4.5	7.3	3.4	1.6
183	56.9	2.2	12.6			12.2		3.9	7.2	3.3	1.7
184	55.5	2.3	13.3			12.5		4.0	7.4	3.4	1.6
185	54.5	2.4	13.5			12.9		3.8	7.2	2.9	2.9
186	56.2	2.2	13.6			12.6		3.6	7.1	3.3	1.4
187	55.9	2.2	13.5			12.5		3.9	7.2	3.3	1.5
188	55.6	2.3	13.6			12.7		3.7	7.1	3.3	1.8
189	55.8	2.2	13.3			12.5		3.5	6.6	3.4	2.7
190	55.3	2.3	13.3			12.6		3.4	6.9	3.2	3.0
191	55.7	2.4	13.4			12.8		3.5	6.8	3.3	2.2
192	56.0	2.3	13.3			12.6		3.5	6.6	3.5	2.1
193	54.6	2.4	13.5			13.2		3.6	7.0	3.4	2.3
194	55.8	2.2	13.2			13.1		3.4	6.8	3.4	2.0
195	56.1	2.2	13.3			12.9		3.5	6.7	3.4	1.9
196	56.2	2.2	13.4			12.8		3.5	6.7	3.3	1.8
197	55.8	2.3	13.5			13.1		3.5	6.7	3.3	1.8
198	56.1	2.2	13.3			12.5		3.5	6.6	3.2	2.7
199	55.1	2.2	13.4			13.3		3.5	6.6	3.3	2.7
201	54.8	2.3	13.7			12.8		4.1	7.6	3.2	1.4
202	55.5	2.1	13.7			12.4		3.9	7.7	3.3	1.4
203	55.7	2.3	12.6			12.9		3.9	7.3	3.5	1.8
204	52.6	2.4	14.3			13.2		4.4	7.0	3.5	2.5

APPENDIX B

Data in parts per million

DH-1

		SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
A	1		20	60	580							
	2		60	40	650							
	3		40	40	825							
	4		40	40	570							
	5		40	40	525							
	6		120	40	410							
	7		80	40	350							
	8		100	40	400							
B	9		120	40	340							
	10		100	40	370							
	11		100	40	370							
	12		100	40	375							
	13		120	40	350							
	14		80	40	375							
	15		60	40	825							
	16		60	40	725							
C	17		20	40	750							
	18		40	40	725							
	19		20	40	650							
	20		40	40	710							
	21		20	40	500							
	22		180	40	540							
	23		160	40	615							
	24		420	40	3800							
E	25		420	40	3405							

DH-1

	SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
26		220	240	3300							

27		220	240	3190							

28		20	240	2740							

E 29		20	240	2830							

30		220	240	2850							

31		20	240	2700							

32		20	240	1710							

(1) 33		220	240	600							

34		20	240	790							

35		80	240	630							

F

(2) 36		80	240	690							

37		80	40	660							

38		100	240	680							

39		100	40	580							

40		100	40	595							

41		80	40	595							

42		220	240	615							

43		220	40	615							

(3) 44		40	240	665							

45		40	240	820							

46		40	240	730							

47		40	240	640							

48		40	240	735							

DH-2

	SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH

49		190	84	920							

50		320	74	840							

A

51		295	55	680							

52		460	35	635							

53		200	61	445							

B 54		300	94	390							

55		240	427	930							

56		450	87	3200							

57		450	55	3130							

58		90	55	3125							

59		110	422	3030							

E 60		180	47	3465							

61		450	427	3510							

62		80	75	3650							

63		60	83	3450							

64		100	39	3360							

65		60	427	3135							

67		450	419	500							

70		170	82	605							

F 71		160	66	640							

72		170	62	550							

73		130	71	590							

DH-3

		SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
	2001	43	190	60	602	36	9.1	2.8	1.4	6.1	2.5	1.7
	2	43	238	46	632	32	8.5	2.9	1.6	6.0	2.4	1.6
	(1) 3	45	185	49	626	39	9.9	3.3	1.7	7.5	2.6	1.9
A	6	32	13	45	590	41	10.6	3.0	1.3	7.5	2.8	6.6
	(2)											
	8	30	21	48	525	37	9.6	2.8	1.3	6.5	2.7	5.4
	9	20	19	46	500	33	9.3	2.7	1.4	6.8	2.6	5.9
	11	34	114	44	300	17	4.7	1.5	.78	2.8	1.1	2.1
B	12	32	101	41	260	18	4.5	1.4	.79	3.5	.91	1.7
	13	32	111	42	250	17	4.9	1.5	.71	3.3	1.0	2.3
	14	34	94	42	275	16	4.7	1.5	.49	3.1	1.1	2.6
	16	28	90	39	620	43	10.5	2.2	1.3	6.3	2.2	9.8
C	17	31	83	45	580	38	11.4	2.3	1.0	5.8	2.2	8.6
	18	27	9.1	42	600	37	8.4	2.3	1.2	6.2	2.2	9.0
	19	28	50	42	670	38	8.2	2.5	1.1	5.0	2.0	8.2
	22	27	20	29	3048	43	9.0	3.9	1.3	9.5	2.0	6.5
	24	25	15	27	3190	46	10.6	4.7	1.4	11.0	1.9	7.5
	25	25	10	28	3350	46	10.0	4.3	1.2	10.1	2.1	7.1
E	26	24	88	25	3280	47	10.3	4.1	1.6	10.4	1.8	6.7
	27	24	<1	25	3370	46	10.5	4.5	1.4	10.0	2.0	7.1
	28	26	<1	27	3470	45	10.0	4.6	1.7	11.0	2.4	7.7
	29	24	13	24	3070	45	9.0	4.2	1.9	13	2.0	7.5
	31	36	100	36	670	26	7.3	2.5	1.1	5.5	1.6	2.9
	(1) 32	36	106	28	580	31	7.7	4.9	1.3	3.9	1.5	3.6
	33	40	111	43	560	28	7.9	3.6	2.2	4.8	1.3	3.2
	34	36	100	38	540	26	7.8	2.6	1.5	4.8	1.3	3.8
	36	39	63	42	450	27	7.2	2.3	1.8	5.9	1.7	5.4
G	37	38	67	38	500	31	7.4	2.8	1.5	4.7	1.5	4.8
	38	38	63	37	560	29	7.5	3.2	1.7	5.6	1.2	5.0
	(2) 39	34	66	35	510	31	6.7	2.8	.81	5.2	1.1	5.8
	40	37	57	39	580	27	7.0	2.8	1.6	5.4	1.2	3.5
	41	37	31	40	580	25	7.2	2.2	1.6	6.6	1.8	6.1
	90											
	(3) 91											
	43	33	18	35	715	27	7.0	2.0	.94	5.0	1.4	4.9

		SC	CR	CO	BA	LA	SM	EA	TB	HF	TA	TH
	44	36	24	38	680	31	7.5	2.6	1.8	6.4	1.7	5.3
(3)	45	39	23	39	650	29	8.3	2.6	1.8	6.5	1.6	6.2
	46	36	29	35	635	39	9.3	3.2	1.3	5.4	1.4	6.2
	47	43	58	39	550	35	8.7	3.5	2.0	6.6	1.5	5.0
	48	39	56	40	550	31	7.9	3.2	1.2	5.0	1.4	6.0
	49	41	52	42	540	28	9.1	3.4	1.2	6.1	1.3	4.0
	50	38	50	42	560	29	7.3	2.7	2.0	5.3	1.3	4.4
(4)	51	38	50	43	580	29	6.8	2.4	1.7	5.8	1.2	4.4
	52	39	72	44	575	29	7.4	2.3	1.9	5.4	1.3	4.3
	53	39	58	44	635	26	6.8	2.3	1.5	5.3	1.2	5.1
	54	38	60	39	460	20	5.7	2.1	1.9	5.4	1.1	4.2
	55	37	63	42	600	25	6.5	2.0	1.7	4.5	1.1	3.3
G ₁	56	38	53	43	440	30	6.9	2.3	1.8	5.4	1.2	4.2
	57	39	68	44	680	23	6.2	2.0	1.7	5.3	1.3	3.8
	58	40	27	42	580	29	8.3	2.6	1.9	4.7	1.3	4.8
	59	39	24	43	660	27	7.3	2.3	1.9	4.9	1.3	4.2
	60	37	20	45	620	27	9.1	2.9	2.3	6.2	1.5	6.1
(5)	61	39	26	42	650	29	7.7	2.3	1.7	5.3	1.3	4.5
	62	40	32	44	700	27	7.8	2.4	1.8	5.6	1.4	4.5
	63	39	32	39	590	30	8.2	2.3	2.3	5.8	1.4	4.8
	64	36	22	42	725	29	7.7	2.3	1.8	5.3	1.1	4.5
	65	40	24	44	547	30	8.3	2.5	2.0	5.6	1.2	5.3
	66	39	27	44	588	29	7.6	2.2	1.8	5.1	1.3	5.5
	67	45	51	42	551	28	7.4	2.4	2.7	5.4	1.2	4.1
(5)	68	35	54	40	656	23	5.6	1.9	1.7	5.5	1.1	5.4
	69	37	59	23	553	46	11.2	3.0	2.7	6.4	1.5	7.1
	70	35	52	40	630	24	5.5	1.8	1.6	3.7	1.0	3.5
	71	36	52	39	565	27	6.2	1.8	1.7	6.3	1.2	5.4
	72	37	61	44	593	23	5.7	1.8	1.8	5.1	1.4	4.0
H	73	39	53	40	585	23	6.2	1.9	1.4	5.1	1.1	5.4
	74	37	53	38	650	26	6.0	1.8	1.4	4.6	1.1	4.5
(1)	75	39	48	45	715	27	6.2	2.0	1.6	5.1	1.2	4.9
	76	35	42	39	765	28	6.6	2.0	1.5	5.0	1.1	5.0
	77	39	54	44	715	26	6.2	2.0	1.2	5.5	1.0	5.8

DH-3

		SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
	78	35	40	37	616	25	5.2	1.9	.91	5.2	.91	2.8
	79	40	48	42	591	22	6.0	2.0	1.1	5.4	1.1	3.5
(2)	80	38	49	40	571	23	5.5	2.1	1.0	5.4	1.1	3.1
	81	40	51	43	591	22	5.3	2.3	1.1	5.0	1.3	3.6
	82	42	61	37	434	19	5.1	2.1	1.2	4.8	1.0	3.1
	83	40	49	45	475	19	5.1	2.0	1.0	5.7	1.0	2.9
	84	39	51	41	525	19	5.3	2.1	.78	5.0	1.0	2.3
	85	43	58	55	567	22	5.4	2.1	1.2	5.9	1.0	2.9
	86	41	50	43	550	19	5.5	1.7	.91	6.4	1.1	2.9
	87	41	60	44	480	19	5.2	2.1	.89	5.3	1.1	2.8
	88	30	41	32	570	15	4.1	1.5	.77	3.6	.77	1.9
H	> 89	33	33	35	525	16	4.4	1.8	1.0	4.4	.77	2.4
	92	38	52	40	525	20	5.0	2.1	.89	5.0	.89	2.7
	93	43	44	49	525	22	5.9	2.3	1.2	5.4	1.0	2.7
(3)	94	38	44	41	639	19	5.3	2.2	.91	5.4	1.1	2.0
	95	36	40	40	716	20	5.2	1.9	1.0	5.0	1.0	2.7
	96	38	40	44	867	18	5.0	1.8	.89	4.7	1.0	2.4
	97	42	47	46	472	17	5.0	1.9	.93	5.1	.87	2.5
	98	38	40	40	835	18	5.0	2.0	1.1	5.2	.94	2.9
	99	43	39	49	525	18	5.1	2.1	1.0	6.1	1.0	2.4
	100	38	33	43	765	20	5.1	1.9	1.0	5.8	.91	2.2
	101	42	33	49	570	21	5.5	2.0	1.0	6.4	1.1	2.7
	102	37	39	41	620	17	5.1	1.8	1.0	4.8	.82	2.4
	103	42	28	41	570	23	6.5	2.2	1.0	6.2	1.1	3.6
	104	36	28	42	825	23	5.1	1.9	1.0	5.6	.82	2.7
	105	40	30	44	950	24	5.7	2.1	1.1	6.5	1.1	3.2
	106	37	23	39	955	20	5.3	2.0	1.0	5.1	1.0	3.1
	108	38	22	36	980	29	7.0	2.7	1.4	7.9	1.1	5.6
I	109	35	5.1	38	1190	23	5.9	2.2	1.3	7.1	1.2	4.1
	110	38	13	41	760	28	6.7	2.4	1.1	5.6	1.2	4.2

DH-4

		SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
	4001				591							
A	2				1280							
	3	32	29	42	613	36	8.3	2.4	1.4	7.6	3.7	5.0
	4				565							
	5	33	121	40	406	18	3.6	1.4	.70	2.3	1.0	1.9
	6				467							
	7	34	108	41	453	20	4.3	1.3	1.0	4.2	1.3	1.6
	8				467							
	9	33	92	42	467	18	4.2	1.6	1.3	5.1	1.4	1.6
B	10	27	111	38	772	35	5.8	1.5	1.3	5.6	1.6	5.1
	11	26	125	40	642	33	5.5	1.7	1.1	5.6	1.6	2.2
	12	30	215	42	459	13	3.0	1.1	.84	3.5	.82	4.3
	13	28	269	45	371	13	3.2	1.0	.45	2.8	1.0	.90
	14	26	173	39	525	26	4.7	1.4	.88	5.0	1.2	1.3
	15	26	97	37	775	35	5.9	1.7	1.2	7.1	1.7	2.8
	16	25	31	37	1079	45	7.2	1.7	1.1	7.9	1.7	3.0
	17	26	41	38	998	42	6.3	2.1	1.4	8.1	1.9	3.4
	18	34	92	38	1733	26	6.6	2.2	1.3	4.4	1.7	1.8
	19	36	101	40	656	26	7.1	2.5	1.9	5.5	1.9	1.8
(1)	20	35	94	37	583	28	7.1	2.4	1.2	5.4	2.0	1.3
	21	35	103	40	525	27	6.6	2.1	.95	4.6	1.1	2.8
F	22	35	11	38	565	33	7.8	2.5	1.7	5.5	1.6	3.7
	23	35	19	38	708	31	7.7	2.3	1.1	5.4	1.2	3.3
(2)	24	36	16	38	620	35	8.3	2.7	1.6	5.0	1.6	3.3
	25	35	17	37	642	31	7.7	2.3	1.2	5.1	1.2	2.7
	26	38	20	37	727	33	7.7	2.5	1.4	3.9	1.6	3.5
	27	35	18	38	731	30	7.7	2.4	.78	5.1	1.2	2.6
	28	34	48	36	607	33	7.0	2.2	1.3	4.0	1.5	3.5
	29	34	52	38	700	28	7.1	1.9	1.0	4.2	1.1	2.8
(1)	30	34	55	38	673	30	6.5	2.1	1.3	4.6	1.4	3.3
	31	34	51	37	700	29	6.8	1.9	1.1	4.5	1.0	2.6
	32	37	38	39	597	33	7.0	2.2	1.3	5.4	1.4	4.1
G	33	35	40	36	662	29	6.6	2.2	1.5	3.6	1.3	3.5
	34	34	28	37	581	29	7.2	1.9	1.2	6.0	1.4	5.2
	35	33	28	38	710	29	6.4	2.2	1.3	4.1	1.2	3.7
(2)	36											
	37	34	29	35	765	30	7.9	2.0	1.6	6.1	1.4	5.4
	38	33	29	32	716	32	7.5	2.4	1.1	5.2	1.3	4.7

DH-4

	SC	CR	CO	PA	LA	SM	EU	TB	HF	TA	TH
39				753							
40	31	25	37	722	35	8.3	1.9	1.5	6.9	1.4	4.8
41	35	18	39	700	29	7.1	2.6	1.7	4.8	1.4	4.4
42				639							
43	33	17	35	616	28	6.8	1.8	1.5	5.8	1.2	4.7
44	36	20	36	677	28	6.0	2.4	1.4	4.1	1.3	3.4
45	33	24	35	665	29	7.4	2.0	1.2	5.1	1.3	5.1
46				610							
47				683							
48				767							
49				758							
50				639							
51				729							
52				656							
53				758							
54				700							
55				642							
56				606							
57				709							
58				687							
59				713							
60				619							
61				801							
62				683							
63				675							
64				638							
65				600							
66	32	42	35	668	25	4.9	1.8	1.4	3.3	1.0	2.7
67	33	44	36	646	22	5.0	1.7	1.1	4.1	1.7	3.5
68	33	48	38	613	24	4.5	1.7	1.0	3.4	.89	4.0
69	34	55	39	591	20	4.6	1.6	1.0	3.9	1.0	2.9
70	34	52	38	563	22	4.8	1.5	1.1	3.4	1.0	3.2
71	33	57	36	630	20	4.6	1.4	1.0	3.3	.93	2.7
72				600							
73				692							
74	35	53	37	656	23	5.0	1.6	.91	3.2	1.0	3.4
75				700							
76				565							

DH-4

	SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
77				632							
78	36	69	39	667	20	5.2	1.7	1.4	4.0	1.1	1.0
79				692							
80				640							
81	34	50	36		25	5.2	1.8	1.2	3.6	1.1	3.2
82											
83											
84	33	41	36		19	4.8	1.4	.89	4.2	.93	2.5
85				622							
H 86	29	16	34	610	31	6.5	2.0	1.2	5.4	1.1	5.6
87				621							
88	35	42	38	612	20	4.8	1.6	1.1	3.9	1.3	3.4
89				563							
90	36	45	39	578	19	4.8	1.5	.91	4.1	.76	2.9
91	35	45	38	591	21	5.2	1.7	.91	4.3	1.2	4.0
92				578							
93	35	28	38	569	21	4.9	1.6	.79	4.3	.78	3.3
94	35	40	39	691	20	5.1	1.7	.91	3.7	1.3	2.8
95	37	24	40	760	22	5.2	1.7	1.2	5.0	1.1	3.2
96				735							
97	33	15	39	758	25	5.6	1.9	.78	5.3	1.4	5.6
98	33	17	39	622	24	5.4	1.8	1.0	4.7	1.0	3.7
99	33	15	37	678	28	5.7	1.9	.92	5.5	1.3	4.3
100				623							
101				803							
102	32	13	35	716	28	6.0	1.7	.89	5.3	1.1	4.4
103	32	22	36	788	28	6.0	1.8	1.1	3.9	1.0	3.9
104	32	11	35	830	27	6.1	1.9	.87	5.0	1.3	4.9
105				810							
106				720							
I 107	30	26	35	740	27	5.9	1.6	1.0	4.3	1.1	5.0
108				500							
109	30	7.3	34	670	30	5.9	1.9	.76	5.0	1.3	5.1
110	29	28	35	680	28	6.0	1.8	.85	5.3	1.1	4.8
111	29	12	33	710	30	5.8	1.8	.84	5.3	1.3	4.4
112	29	8.6	35	770	28	5.9	1.7	.92	4.7	1.2	4.9
113				690							
114				600							

DH-4

	SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH	
	115			750								
	116	30	13	34	680	29	5.9	1.8	.91	5.5	1.2	5.4
	117			810								
	118			850								
	119	31	21	36	750	29	6.1	1.8	1.0	5.7	1.2	4.7
	120			780								
	121	29	24	34	780	30	6.0	1.9	1.0	5.4	1.2	5.8
	122	30	42	36	730	30	6.0	1.8	1.1	5.5	1.2	5.0
(1)	123			780								
	124	31	16	35	800	28	5.9	1.9	1.0	5.1	1.3	5.1
I	125			630								
	126	29	78	34	800	29	6.2	1.7	.75	4.2	1.0	5.2
	127			770								
	128	30	16	34	810	33	6.3	1.9	1.0	5.1	1.3	7.0
	129			810								
	130	31	13	34	650	31	6.3	2.1	.93	5.2	1.3	5.1
	131	29	24	35	620	28	5.6	1.9	1.0	4.9	1.1	7.5
	132	29	9	34	610	28	5.7	1.8	1.0	5.2	1.2	3.8
	133	29	11	34	620	29	5.8	1.9	1.0	5.2	1.2	7.2
(2)	134	29	18	34	600	28	5.9	1.8	1.4	5.6	1.3	4.9
	135	34	16	40	600	29	6.6	2.2	1.2	6.2	1.5	5.9
	136	33	42	37	600	27	6.2	1.9	1.7	4.9	1.3	2.9
	137	32	37	37	600	28	6.1	1.9	1.0	4.9	1.4	4.6
	138	32	19	36	640	25	6.1	2.0	1.3	5.0	1.3	4.4
	139			630								
	140	31	36	37	570	25	5.4	1.7	.72	3.7	1.1	5.2
	141	31	27	35	680	21	5.1	1.5	1.0	3.9	1.1	3.9
	142	31	30	36	640	22	4.9	1.5	1.6	3.3	1.3	2.2
	143	30	24	34	640	26	5.3	1.7	1.5	4.5	1.5	2.7
	144			660								
J	145	30	9	35	630	26	5.5	1.5	2.5	4.5	1.4	1.3
	146	30	23	34	580	27	5.4	1.6	1.5	4.5	1.5	3.0
	147	31	30	35	500	26	5.7	1.5	2.3	5.3	1.5	2.3
	148	31	13	36	860	26	5.6	1.8	1.4	4.7	1.8	3.3
	149	30	17	33	700	26	5.4	1.5	1.2	5.6	1.6	2.9
	150			690								
	151	29	13	34	720	26	5.2	1.5	.93	4.1	1.5	3.1
	152	30	15	33	700	26	5.4	1.7	1.3	3.9	1.8	4.6

DH-4

	SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH	
J	153	29	18	33	670	26	5.4	1.5	.87	4.7	1.4	3.3
	154	29	26	32	740	27	5.6	1.6	.77	4.6	1.8	4.4
	155	28	8.6	33	620	25	5.2	1.3	.93	4.6	1.4	3.1
	156				780							
	157	29	11	33	790	25	5.3	1.4	.69	4.3	1.4	4.7
	158	28	12	33	720	25	5.1	1.4	1.2	4.5	1.3	3.3
	159	30	13	34	740	28	5.5	1.6	1.3	5.0	2.1	4.5
	160	28	12	33	570	26	5.1	1.4	.87	4.5	1.6	3.3
	161	30	44	34	590	28	5.5	1.7	.81	3.9	2.0	4.7
	162	29	19	34	640	26	5.3	1.9	1.4	5.2	1.8	3.1
K	163	30	8.3	34	610	25	5.8	2.0	1.0	6.5	1.9	3.2
	164				850							
	165	32	10	36	740	28	6.2	2.1	1.4	6.3	1.7	3.1
	166	31	16	35	900	27	6.4	2.1	1.5	6.4	1.8	3.0
	167				650							
	168	31	23	36	640	26	5.8	2.1	1.1	6.3	2.2	2.5
	169	32	10	36	650	26	6.7	2.3	1.6	6.1	2.1	2.7
	170	33	17	38	650	27	5.9	1.9	1.2	5.8	2.1	3.0
	171	31	21	35	620	25	6.2	2.2	1.3	7.5	1.7	2.6
	172				560							
173	32	19	37	570	26	5.8	2.0	1.0	5.8	2.2	2.9	

DH-5

	SC	CR	CO	BA	LA	SM	EL	TB	HF	TA	TH	
	5001			586								
A	2	28	23	34	687	45	8.4	2.6	1.5	5.3	2.2	5.9
	3	30	29	45	551	38	8.2	2.6	1.7	6.9	2.2	5.2
	4	30	22	45	616	40	8.7	2.3	1.4	6.7	2.2	5.6
	5	29	26	47	1176	38	8.3	2.4	1.4	7.4	2.1	4.6
	6			453								
	7	32	96	40	389	19	4.2	1.4	1.1	3.2	1.0	2.7
	8			420								
	9	32	106	41	385	18	4.0	1.4	1.0	3.1	1.0	2.3
	10			416								
B	11	33	104	43	414	21	4.3	1.4	.89	3.3	1.0	3.0
	12			350								
	13	26	217	43	411	16	3.6	1.4	.78	3.2	.69	1.7
	14	27	202	42	490	25	4.5	1.3	1.0	3.2	.77	2.6
	15	29	198	42	525	26	4.9	1.4	1.1	4.4	.94	3.6
	16			485								
	17	27	167	41	551	27	5.0	1.3	1.2	3.3	.93	3.0
(1)	18	34	95	37	600	26	6.9	2.3	1.0	4.7	1.2	2.9
	19	35	105	38	554	24	6.3	2.1	1.5	3.2	1.2	2.1
	20	37	21	38	636	30	7.6	2.4	1.5	5.5	1.6	4.3
	21	36	15	37	689	29	7.8	2.3	1.7	4.0	1.5	3.4
	22	36	20	39	642	33	8.4	2.5	1.2	5.8	1.7	3.4
F	23			788								
	(2) 24	36	16	39	642	31	7.6	2.4	1.7	4.3	1.4	3.6
	25			700								
	26	37	21	38	700	32	8.5	2.5	1.4	6.1	1.6	4.2
	27	29	55	33	710	23	5.3	1.7	1.4	3.0	1.0	2.5
	28			656								
	29	40	21	41	750	33	8.3	2.5	1.6	6.1	1.7	4.6
	30	34	61	37	755	27	6.4	2.2	1.2	4.6	1.2	2.7
	31	35	44	37	744	27	6.3	2.1	1.1	4.2	1.3	1.8
G	32			671								
	33	31	26	34	805	26	6.3	2.2	1.2	4.6	1.0	3.3
	34			670								
	35			683								
	36			625								
	37	40	36	43	687	31	8.0	2.5	1.0	5.3	1.6	4.5
	38			680								

DH-5

	SC	CR	CO	BA	LA	SM	EA	TB	HF	TA	TH
39				718							
40				735							
41				788							
42	35	36	39	815	31	7.1	1.9	1.6	4.9	2.1	3.1
43				805							
44				675							
45				710							
46	37	60	39	712	28	6.5	1.9	1.6	6.0	2.0	2.8
47	35	49	39	755	29	6.3	2.1	1.4	5.2	1.9	3.1
G 48				770							
49	36	56	39	805	28	6.4	1.9	1.5	5.4	2.1	2.7
50				540							
51	34	86	39	500	25	6.1	2.1	1.4	7.7	2.0	3.0
52				530							
53	35	35	37	470	29	6.9	2.0	1.4	4.4	1.9	3.7
54				550							
55				510							
56	36	29	38	710	25	6.2	2.1	1.7	6.1	2.2	2.2
57				530							
58				520							
59				460							
60	35	29	40	480	27	6.4	2.0	1.5	3.5	1.6	3.0
61				500							
62	35	26	37	520	27	6.5	1.9	1.4	5.8	2.0	3.4
63				640							
64	34	72	37	520	22	4.5	1.3	1.2	3.6	1.0	1.7
65	33	35	34	650	23	5.0	1.6	1.2	5.0	1.7	2.3
66	33	57	36	520	22	5.0	1.4	.75	3.5	1.3	2.8
67	34	49	35	510	20	4.6	1.5	.88	4.1	1.2	2.6
68	34	55	36	480	25	5.2	1.6	1.3	4.0	1.6	2.9
69				530							
H 70	33	44	34	560	22	4.7	1.4	.82	6.2	1.5	2.9
71				540							
72	33	55	35	500	23	5.1	1.5	1.2	4.6	1.2	2.1
73				500							
74	33	41	36		19	4.4	1.5	1.2	5.4	1.4	1.7
75	35	50	38		22	4.8	1.5	1.3	3.5	1.3	3.6
76											
77	34	51	36		20	4.6	1.5	1.5	4.4	1.2	1.9

TABLE I

MAJOR ELEMENT AVERAGES AND RANGES OF UNITS A-L

Averages and Ranges of Units

Units Oxides

Core Holes

		DH-1		DH-2		DH-3		DH-4		DH-5	
		(2)*		(5)		(9)		(3)		(5)	
	SiO2	53.3	53.3-53.3	52.4	51.3-53.0	52.0	50.5-53.2	51.6	51.2-51.9	53.8	52.9-54.1
	TiO2	3.3	3.2- 3.3	3.2	3.1- 3.3	3.2	3.1- 3.4	3.2	3.2- 3.3	3.0	2.9- 3.1
	Al2O3	13.0	12.6-13.3	11.8	10.7-13.2	12.8	11.8-13.6	12.7	12.7-12.8	12.8	12.7-13.1
	FeO	13.7	13.0-14.4	16.2	14.8-17.3	14.4	13.1-15.5	15.6	15.1-15.8	15.3	14.2-16.4
A	MNO	.2	.2- .2	.2	.2- .2			.2	.2- .2		
	MGO	4.4	4.4- 4.8	3.9	3.7- 4.3	5.2	4.4- 6.5	4.6	4.5- 4.8	4.2	3.9- 4.5
	CAO	8.2	8.1- 8.2	9.0	8.2- 9.9	8.8	7.9-10.6	8.7	8.6- 9.0	7.8	7.6- 8.1
	NA2O	2.5	2.4- 2.6	2.2	2.1- 2.3	2.4	2.0- 2.8	2.4	2.3- 2.5	2.5	2.3- 2.6
	K2O	1.4	1.3- 1.4	1.1	1.0- 1.4	1.0	.6- 2.2	.9	.8- .9	.7	.4- 1.0
		(13)		(4)		(4)		(14)		(12)	
	SiO2	53.0	51.7-55.6	52.5	51.8-53.5	55.0	54.2-55.5	52.3	50.2-53.9	52.6	51.2-53.5
	TiO2	1.8	1.5- 2.0	1.6	1.5- 1.8	1.7	1.6- 1.7	1.7	1.3- 1.9	1.6	1.6- 1.7
	Al2O3	14.5	13.8-14.9	13.9	12.9-14.7	13.4	13.3-13.6	14.4	13.7-16.0	14.8	14.0-15.8
	FeO	11.0	10.2-11.9	11.7	10.6-12.7	10.9	10.6-11.1	11.3	10.0-12.3	10.8	9.7-11.4
B	MNO	.2	.2- .2	.2	.2- .2			.2	.2- .2		
	MGO	6.8	5.5- 8.7	7.1	5.9- 8.0	7.2	7.1- 7.3	7.2	5.2- 9.4	7.6	6.7- 8.5
	CAO	10.0	9.4-11.0	10.3	10.1-10.4	9.2	8.7-10.1	9.9	8.2-10.6	9.6	8.8-10.2
	NA2O	2.3	1.8- 2.5	2.3	2.2- 2.4	2.2	2.1- 2.3	2.4	2.2- 2.8	2.4	2.1- 2.6
	K2O	.5	.3- .6	.5	.3- .7	.5	.4- .6	.6	.1- 2.0	.6	.3- .9
		(8)				(4)					
	SiO2	54.0	53.2-55.9			55.7	55.0-57.1				
	TiO2	2.7	2.5- 2.9			2.6	2.4- 2.7				
	Al2O3	13.3	13.2-13.7			12.9	12.3-13.3				
	FeO	13.7	12.1-14.7			14.1	13.6-14.4				
C	MNO	.2	.2- .2								
	MGO	4.1	3.7- 4.3			3.8	3.6- 4.1				
	CAO	7.7	7.2- 8.8			7.0	6.0- 7.6				
	NA2O	2.8	2.5- 2.9			2.5	2.0- 2.7				
	K2O	1.7	1.3- 2.1			1.6	1.3- 1.7				
		(6)									
	SiO2	52.1	51.1-52.6								
	TiO2	1.6	1.4- 1.8								
	Al2O3	14.0	14.7-15.2								
	FeO	11.3	10.6-12.0								
D	MNO	.2	.1- .2								
	MGO	7.4	6.2- 8.7								
	CAO	9.4	9.0- 9.8								
	NA2O	2.4	2.3- 2.5								
	K2O	.8	.5- 1.1								
		(9)		(10)		(7)					
	SiO2	55.0	53.0-56.8	55.4	52.6-57.3	57.2	56.3-57.9				
	TiO2	2.9	2.3- 3.5	2.8	2.4- 3.6	2.4	2.2- 2.8				
	Al2O3	13.8	13.1-16.0	12.5	11.1-13.4	13.1	12.6-13.8				
	FeO	13.5	11.7-15.8	14.6	12.6-16.4	12.4	11.8-13.2				
E	MNO	.2	.2- .3	.2	.2- .2						
	MGO	2.9	2.0- 3.5	2.7	2.4- 2.9	3.2	2.6- 4.4				
	CAO	6.3	5.3- 7.0	6.9	5.9- 7.8	5.9	5.6- 6.1				
	NA2O	3.1	2.8- 3.4	3.0	2.6- 3.2	3.2	2.9- 3.4				
	K2O	2.3	1.6- 2.8	2.8	2.2- 3.2	2.5	2.2- 2.7				

* Number in parenthesis is the number of averaged samples in the unit

Weight Percent

TABLE I (Continued)

CORE HOLES

	DH-1		DH-2		DH-3		DH-4		DH-5	
	(18)		(4)				(10)		(10)	
SI02	51.9	50.3-54.1	50.8	49.1-52.6			50.4	49.8-51.8	52.0	50.9-54.6
TI02	3.0	2.6- 3.5	3.2	3.1- 3.3			3.0	2.8- 3.1	3.0	2.8- 3.5
AL2O3	13.4	12.2-14.3	11.7	11.3-12.1			12.6	12.3-13.5	13.0	12.1-13.9
FEO	13.8	12.7-15.4	16.1	15.4-16.6			15.8	14.4-18.5	15.0	14.2-15.6
F MNO	.2	.2- .3	.2	.2- .3			.3	.2- .4		
MGO	5.3	4.0- 6.3	4.6	4.3- 4.8			5.4	4.7- 6.1	5.0	4.1- 6.1
CAO	8.8	7.5- 9.4	9.3	9.0- 9.8			8.5	7.9- 9.1	8.1	7.8- 8.6
NA2O	2.8	2.4- 3.0	2.5	2.3- 2.7			2.6	2.5- 2.8	2.8	2.6- 3.0
K2O	1.0	.7- 1.6	.9	.9- 1.0			1.0	.9- 1.2	1.1	.9- 1.2
						(41)		(36)		(36)
SI02					54.3	52.2-57.1	52.7	51.3-54.5	53.0	51.0-55.0
TI02					2.5	1.7- 3.0	2.7	2.5- 3.0	2.8	2.4- 3.2
AL2O3					12.7	12.0-16.3	13.1	12.6-13.5	13.0	12.2-14.5
FEO					14.2	10.8-15.7	15.0	13.7-16.2	14.4	12.0-15.5
G MNO							.2	.2- .3	.2	.2- .3
MGO					4.4	3.7- 5.2	4.7	3.9- 5.3	4.6	4.1- 5.2
CAO					7.8	7.0- 8.8	7.8	7.0-10.0	8.0	7.2- 8.6
NA2O					2.7	1.9- 3.0	2.9	2.5- 3.2	2.8	2.6- 3.1
K2O					1.1	.8- 1.4	.9	.5- 1.8	1.2	.7- 1.6
						(36)		(35)		(18)
SI02					55.3	51.8-58.0	54.9	53.0-56.7	54.4	51.8-55.5
TI02					1.7	1.5- 1.9	1.9	1.6- 2.2	1.7	1.5- 1.9
AL2O3					13.2	12.1-14.7	13.8	12.9-14.5	13.9	13.4-14.4
FEO					12.8	11.5-14.3	12.1	11.3-13.3	11.5	10.9-11.9
H MNO							.2	.2- .3	.2	.2- .2
MGO					5.3	4.5- 6.7	5.2	4.2- 5.9	5.3	4.8- 6.0
CAO					8.0	7.2- 9.1	8.1	7.3- 9.9	8.8	8.3- 9.2
NA2O					2.8	2.4- 3.2	3.0	2.9- 3.5	3.0	2.8- 3.3
K2O					.9	.6- 1.3	.9	.3- 1.3	1.3	.6- 4.1
						(13)		(38)		(22)
SI02					56.7	55.1-58.9	56.6	55.1-58.1	55.9	53.1-57.5
TI02					2.1	1.9- 2.2	2.0	1.7- 2.3	2.0	1.8- 2.2
AL2O3					13.0	12.0-13.7	13.5	12.5-15.0	13.6	13.3-14.4
FEO					12.9	11.8-14.1	12.3	11.2-14.8	12.1	11.3-12.8
I MNO							.2	.2- .2		
MGO					3.7	3.4- 3.9	3.5	3.1- 4.1	4.0	3.1- 5.1
CAO					6.8	6.3- 7.0	7.1	6.7- 7.6	7.3	6.9- 8.7
NA2O					3.2	2.8- 3.5	3.4	2.7- 3.8	3.3	3.0- 3.5
K2O					1.6	1.3- 2.5	1.5	1.0- 2.7	1.6	1.1- 2.9
						(5)		(24)		(4)
SI02					54.2	52.5-55.6	57.4	55.6-59.0	56.1	54.9-56.9
TI02					1.9	1.7- 2.0	1.8	1.7- 2.0	1.9	1.9- 1.9
AL2O3					13.3	12.7-14.5	13.3	12.5-14.1	13.7	13.6-13.8
FEO					12.7	12.2-13.4	11.6	10.8-12.7	11.5	11.4-11.6
J MNO							.2	.2- .2		
MGO					5.4	5.0- 5.8	3.6	3.2- 4.3	4.1	3.9- 4.3
CAO					8.3	7.9- 8.8	7.3	6.4- 8.6	7.3	7.0- 7.9
NA2O					3.1	2.9- 3.2	3.4	3.2- 3.7	3.4	3.3- 3.4
K2O					1.0	.9- 1.1	1.3	.9- 1.9	2.1	1.6- 2.6

TABLE I (Continued)

CORE HOLES

	DH-3	DH-4	DH-5
	(4)	(10)	(42)
SiO ₂	52.3 50.8-53.2	55.4 53.7-56.7	55.6 52.6-57.1
TiO ₂	1.8 1.7- 1.8	2.1 1.9- 2.2	2.2 2.0- 2.4
Al ₂ O ₃	14.6 14.2-15.1	13.5 13.0-14.1	13.5 12.6-14.3
FeO	11.8 11.5-12.3	12.4 12.1-13.2	12.6 11.8-13.3
K MnO		.2 .2- .2	
MgO	6.3 6.0- 6.6	3.8 3.6- 3.9	3.8 3.4- 4.4
CaO	9.4 9.0- 9.8	8.0 7.4-10.0	7.1 6.6- 8.0
Na ₂ O	3.3 3.2- 3.3	3.5 3.3- 3.6	3.2 2.9- 3.5
K ₂ O	.6 .4- .8	1.2 .8- 2.0	1.9 .5- 3.5
	(1)		
SiO ₂	56.1		
TiO ₂	1.8		
Al ₂ O ₃	13.9		
FeO	13.4		
L MnO			
MgO	4.5		
CaO	5.4		
Na ₂ O	2.8		
K ₂ O	2.0		

Table II

TRACE ELEMENT AVERAGES OF UNITS A-I

		Averages of Units									
Units	Elements	Core Holes					Core Holes				
		DH-1	DH-2	DH-3	DH-4	DH-5	DH-1	DH-2	DH-3	DH-4	DH-5
		(2) *	(3)	(6)	(3)	(4)	(16)	(5)		(10)	(8)
	SC			36	22	29				35	35
	CR	40	268	111	25	25	< 56	136		45	44
	CO	50	74	40	42	43	< 40	60		38	37
	PA	615	813	570	828	504	887	577		749	666
	LA			36	36	40				30	29
F	SM			9.5	8.3	8.4				7.4	7.3
	FU			2.9	2.4	2.5				2.4	2.3
	TP			1.5	1.4	1.5				1.3	1.4
	HF			6.7	7.6	6.6				5.0	4.6
	TA			2.6	3.7	2.2				1.5	1.4
	TH			3.9	5.0	5.3				2.7	3.3
		(12)	(3)	(4)	(11)	(7)			(37)	(15)	(14)
	SC			33	29	29			38	34	36
	CR	86	186	105	133	156			51	33	42
	CO	< 40	63	42	40	42			40	37	39
	PA	438	490	271	603	441			589	683	653
	LA			17	27	22			29	30	28
G	SM			4.7	4.9	4.4			7.6	7.0	6.7
	FU			1.5	1.5	1.4			2.6	2.1	2.1
	TP			.7	1.0	.8			1.7	1.3	1.4
	HF			3.2	5.2	3.4			4.9	5.0	5.3
	TA			1.0	1.4	.9			1.3	1.3	1.8
	TH			2.2	2.2	2.7			4.7	4.1	3.2
		(6)		(4)					(35)	(20)	(10)
	SC			29					38	34	34
	CR	40		7.9					45	40	51
	CO	< 40		42					42	38	36
	PA	731		618					631	641	531
	LA			30					21	23	22
H	SM			8.9					5.4	5.1	4.8
	FU			2.3					2.0	1.7	1.5
	TP			1.2					1.1	1.0	1.1
	HF			5.8					5.3	4.1	4.4
	TA			2.2					1.1	1.1	1.3
	TH			8.9					3.3	3.4	2.5
		(9)	(10)	(7)					(3)	(24)	
	SC			25					37	30	
	CR	< 20	83	7.7					13	22	
	CO	< 40	51	26					38	35	
	BA	2047	3306	2254					977	709	
	LA			45					27	29	
I	SM			9.9					6.5	6.0	
	FU			4.3					2.4	1.9	
	TP			1.5					1.3	1.0	
	HF			9.0					6.9	5.1	
	TA			2.0					1.2	1.2	
	TH			7.2					4.6	5.1	

D CR 120 CO <40 BA 552

* Number in parenthesis is the number of averaged samples in the unit

TABLE III

CORRELATION COEFFICIENTS FOR MAJOR AND TRACE ELEMENTS

	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O
SiO2	1.00	-.40	.08	-.41	-.37	-.54	-.74	.64	.62
TiO2	-.40	1.00	-.76	.89	.23	-.47	-.13	-.24	.18
Al2O3	.08	-.76	1.00	-.84	-.07	.58	.24	.11	-.21
FeO	-.41	.89	-.84	1.00	.18	-.45	-.17	-.24	.11
MnO	-.37	.23	-.07	.18	1.00	.01	.29	-.14	-.10
MgO	-.54	-.47	.58	-.45	.01	1.00	.81	-.56	-.79
CaO	-.74	-.13	.24	-.17	.29	.81	1.00	-.60	-.84
Na2O	.64	-.24	.11	-.24	-.14	-.56	-.60	1.00	.54
K2O	.62	.18	-.21	.11	-.10	-.79	-.84	.54	1.00

	SC	CR	CO	BA	LA	SM	EU	TB	HF	TA	TH
SC	1.00	-.03	.35	-.50	-.53	-.18	-.21	.21	-.29	-.20	-.44
CR	-.03	1.00	.47	-.42	-.36	-.48	-.47	-.48	-.50	-.25	-.64
CO	.35	.47	1.00	-.72	-.14	-.04	-.38	-.07	-.25	.25	-.22
BA	-.50	-.42	-.72	1.00	.57	.54	.84	.38	.74	.22	.51
LA	-.53	-.36	-.14	.57	1.00	.87	.73	.63	.70	.71	.71
SM	-.18	-.48	-.04	.54	.87	1.00	.87	.80	.78	.72	.72
EU	-.21	-.47	-.38	.84	.73	.87	1.00	.74	.84	.47	.62
TB	.21	-.48	-.07	.38	.63	.80	.74	1.00	.65	.52	.42
HF	-.29	-.50	-.25	.74	.70	.78	.84	.65	1.00	.69	.63
TA	-.20	-.25	.25	.22	.71	.72	.47	.52	.69	1.00	.46
TH	-.44	-.64	-.22	.51	.71	.72	.62	.42	.63	.46	1.00

TABLE IV

SOLIDIFICATION INDICES OF UNITS A-L

<u>Units</u>	<u>DH-1</u>	<u>DH-2</u>	<u>DH-3</u>	<u>DH-4</u>	<u>DH-5</u>
A	20.0	16.7	22.6	19.6	18.5
B	33.0	32.9	34.6	33.5	35.5
C	18.4		17.3		
D	33.8				
E	13.3	11.7	15.0		
F	23.1	19.1		21.8	20.9
G			19.6	20.0	20.0
H			24.3	24.5	25.1
I			17.1	16.9	19.0
J			24.3	18.1	19.4
K			28.6	18.2	17.7
L			19.8		

TABLE V

STRATIGRAPHIC SECTION OF COLUMBIA RIVER BASALTS

YAKIMA	Upper	Ice Harbor	}	. . . . .	A
		Elephant Mountain			
		Pomona			B
		Gable Mountain			C
		Huntzinger			D
	Middle	Umatilla	}	. . . . .	E
		Priest Rapids			
		Roza			F
		Frenchman Springs			G
	Lower	Museum			
		Rocky Coolee			H
		Yakima Undifferentiated			

Picture Gorge and Lower Basalt

- Upper Yakima basalt
- Middle Yakima basalt
- Lower Yakima basalt
- Picture Gorge and Lower basalt

FIGURE 1

AREAL DISTRIBUTION OF COLUMBIA RIVER BASALT
 [After Waters (1961), Wright, Grolier and Swanson (1973)
 and Taubeneck (1970).]

FIGURE 2

CORE HOLE LOCATION MAP
[After Brown (in press)]

* Note- decimal point is displaced one unit to the right of the true value.

(Weight Percent)

FIGURE 3

HISTOGRAMS OF AVERAGED GEOCHEMICAL DATA

(Parts per million)

FIGURE 3 (Continued)

HISTOGRAMS OF AVERAGED GEOCHEMICAL DATA

(Weight Percent)

FIGURE 4

MgO VARIATION DIAGRAM

(Weight Percent)

FIGURE 4 (Continued)

MgO VARIATION DIAGRAM

FIGURE 5
ALKALI-SILICA DIAGRAM

FIGURE 6
SiO₂-FeO-MgO DIAGRAM

FIGURE 7
FeO-MgO-(Na₂O and K₂O) DIAGRAM

FIGURE 8
Na₂O-CaO-K₂O DIAGRAM

COLUMBIA RIVER BASALT

FIGURE 9

SiO₂-FeO-MgO-CaO DIAGRAM

COLUMBIA RIVER BASALT

FIGURE 10

CaO-FeO-MgO-Al₂O₃ DIAGRAM

FIGURE 11
IRON ENRICHMENT DIAGRAM

FIGURE 12
GEOCHEMICAL VARIATION OF COLUMBIA RIVER BASALT THROUGH TIME