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Preliminary chemical and mineralogical analyses of the major volcanic ash beds in the Oligocene Brule Formation, Northwestern Nebraska

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INTRODUCTION

In ascending stratigraphic order the three most prominent volcanic ash beds in the Oligocene Brule Formation, which is part of the White River Group in northwestern Nebraska, are the Lower Whitney, the Upper Whitney, and the Nonpareil. These volcanic ash beds were sampled in four areas, Scottsbluff National Monument, Round Top, Chadron, and Beaver Wall (fig. 1). The purpose of this report is to present data and preliminary interpretations on the chemical and mineralogical composition of the Brule ash beds. Factor analysis was used to relate chemical compositions to mineralogy and to reduce the number of variables to be interpreted (Dickinson, 1988, 1988).

Methods

Thirty samples, collected from measured sections at four localities, were analyzed chemically and mineralogically. Major elements were measured as oxides by X-ray fluorescence (XRF) (Taggart and others, 1987). Uranium, thorium and the rare earth elements were done by instrumental neutron activation analysis (INAA) (Baedecker and Mckown, 1987). Other elements were determined by inductively coupled plasma spectroscopy (ICP) (Lichte and others, 1987). Mineralogical determinations were by X-ray diffraction (XRD) of whole-rock powder mounts and oriented clay mineral mounts.

The mineral values are represented by the areas in square inches of the area under selected XRD peaks. The XRD data was obtained under conditions made as uniform as possible for all the XRD runs. The same mount preparation procedures, the same instrument, and the same instrument settings

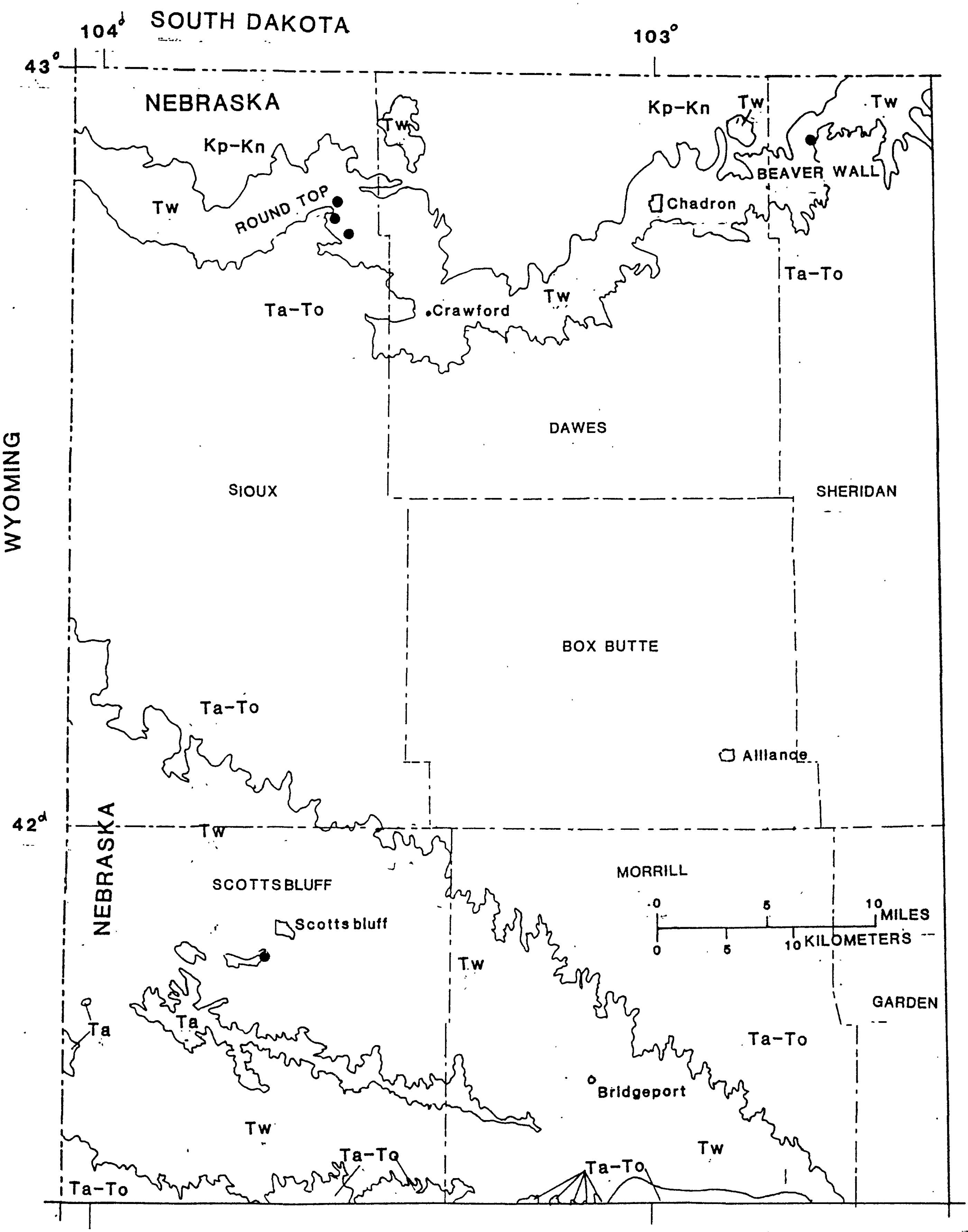

Figure 1.--Geologic map of study area showing sample localities (●), White River Group (Tw), Rocks older than White River Group including Cretaceous Pierre Shale and Niobrara Formation (Kp-Kn), rocks younger than White River Group including Arikaree Group and Ogalala Group (Ta-To). Geology is from Burchett (1986).

were used for all samples, and all the runs were made continuously from start to finish insofar as the length of the work day allowed. The exact species of some of the minerals could not be determined from the whole-rock XRD patterns. For instance, several of the amphiboles could have contributed to the only observed amphibole peak. Therefore, without further work hornblende and for similar reasons, biotite was not differentiated.

Three databases, each containing thirty samples, from the mineralogical and chemical data were assembled and analyzed (tables 1-3). Correlation coefficients and R-mode factor analyses (Harmon, 1960) were calculated from the databases using commercially available software (Number Cruncher Statistical System, Hintze, 1992) and a personal computer. A value of three fourths of the lower detection limit was substituted for ICP values reported as less-than values. Variables containing INAA values reported as zero because the concentration was low or because interference prevented accurate measurement were excluded from the calculations.

Sample localities

Samples were collected from the Scottsbluff National Monument, Round Top about six miles northwest of Crawford, Nebraska, the Campus of Chadron State University, just above the large "C" on the hill, and Beaver Wall, a prominent north-south trending escarpment about 15 miles east of Chadron (fig. 1). Table 4 shows the distribution of the samples.

GEOLOGY

The White River Group comprises the Chadron and the overlying Brule Formations. The Group covers or underlies much of northwestern Nebraska (Schultz and Stout, 1955). The Brule consists of the Orella, Whitney and Brown Siltstone Members. The Whitney contains numerous volcanic ash beds, the most prominent of which are the Lower and Upper Whitney beds. The Brown Siltstone beds contain the Nonpareil ash bed (Swinehart and others, 1985).

The Chadron and Brule Formations consist mostly of colluvial and alluvial claystone, and mudstone. Some lacustrine gypsum and limestone are also present. Paleosols were developed on some of the flood plain surfaces (Schultz and others, 1955). The ultimate sediment sources for the White River Group were sedimentary and crystalline rocks in the mountains to the west, and contemporaneous volcanos from the west or southwest. The Chadron unconformably overlies the Cretaceous Pierre Shale, although in some areas they are separated by the Eocene interior paleosol or by younger Cretaceous sedimentary rocks. In the study area the Brule Formation is overlain by the Miocene Gering Formation of the Arikaree Group.

Brule Formation

In northwestern Nebraska the Brule Formation contains the Orella and overlying Whitney Members. An additional informal member called the Brown Siltstone beds was recognized above the Whitney by Swinehart and others (1985). The Brown Siltstone beds and the Whitney Member contain soft siltstone and fine-grained sandstone that are partly eolian and partly fluvial in origin, and interbedded largely air-fall ash layers. The Orella consists mostly of light-pink to brown pelletal mudstone, together with a playa facies characterized by gypsum, dolomite, and limestone (Dunham, 1955; Dickinson, 1991). Swinehart and others (1985) described a regional unconformity within the Brule.

At the Scottsbluff and Round Top localities the ash beds were deposited primarily by air-fall and are relatively pure, consisting of perhaps as much as 95 percent volcanic shards (Swinehart, and others 1985). Toward the east, the ash beds have been increasingly mixed with non-volcanic detrital material (NVDM) and may consist of 50 percent or less volcanic ash in the Chadron and Beaver Wall localities (fig. 1). The ash beds are made up of four basic components: (1) volcanic ash, deposited mostly by air-fall, (2) NVDM deposited by eolian and fluvial deposition, (3) alteration products of the volcanic glass consisting mostly of smectite, opal, and in some areas clinoptilolite, and (4) other diagenetic minerals such as calcite that were deposited from percolating ground-water. Clinoptilolite is a common alteration product of volcanic glass in the White River Group in Wyoming and South Dakota, but little or none has been found in Nebraska (Stanley and Benson, 1979). Quartz and feldspar are the most common non-volcanic sedimentary minerals, and calcite is the most common mineral deposited from circulating pore waters.

The mineral contents of the ash samples as indicated by whole-rock XRD analyses are calcite, feldspar, quartz, amphibole, mica (mostly biotite), and smectite. The biotite is included in the fresh ash, but is not separated from muscovite or illite in the XRD analyses, and part of the XRD mica response may result from these other minerals. Nevertheless, mica is positively correlated with U (+0.57) and Th (+0.69)) and negatively correlated with quartz (-0.51) and feldspar (-0.62) suggesting that most of the XRD 10 angstrom response is produced by a mineral (biotite) in the volcanic ash. In some samples the origin of the smectite was not determined, but much of the smectite formed as an alteration product of the ash, and some is part of the NVDM. The latter probably having formed as an alteration product of volcanic glass, but having been subsequently redistributed as fluvial sediment after penecontemporaneous erosion. The quartz and feldspar are the primary constituents of the NVDM. Amphibole (hornblende ?) is also mostly a part of the NVDM.

The average SiO_2 content of the all the ash samples is 65.8 percent (Table 6). If the SiO_2 content is re-calculated after removing the loss on ignition (LOI), which mainly results from calcite, water and hydrous minerals in the sample, together with CAO, MnO, and P_2O_5, which were also probably introduced by ground water, the SiO_2 content of the samples in the proximal areas averages 74 percent. The latter figure is probably closer to the original SiO_2 content of the pure volcanic ash.

Lower Whitney Ash.--The lower Whitney ash averages about 20 ft in thickness throughout most of the study area but thins sharply and may be absent along the northeastern margin of the study area (Swinehart and others, 1985). At the Beaver Wall locality, the lower ash is only about 4 ft thick. Amphibole (probably hornblende) was found in only one sample of the Lower Whitney ash (table 7). The contents of quartz and feldspar increase northeastward in the study area reflecting the increasingly greater proportion of NVDM in the ash. Mica (mostly biotite?) decreases in a northeasterly direction. The four relatively pure samples from the Scottsbluff and Round Top areas, averaged 64.3 percent SiO_2 (table 3).

Upper Whitney Ash.--The upper Whitney ash is 22 ft thick in the southwestern part of the study area in Kimball County, and it thins slightly to the northeast where it is 17 ft thick in Dawes County, Nebraska. From Dawes County it thins rapidly to the Beaver Wall locality in western Sheridan County area where it is only about 4 ft thick. It is absent in north central Sheridan County (Swinehart, and others 1985). Judging from the size of the XRD peaks the upper ash has more calcite than the lower ash. Quartz and feldspar increase northeastward due to the increased mixing with NVDM.

The four relatively fresh samples of the upper Whitney ash from the Scottsbluff and Round Top areas, averaged 57.9 percent SiO_2 (table 6). This value, lower than that of the lower ash, results from the greater amount of calcite in the upper ash as indicated by the XRD data (table 7).

Nonpareil Ash.--The Nonpareil ash ranges in thickness from about 40 ft in the western and central parts of the study area to 20 ft in southeastern Dawes County and at the Beaver Wall. The mineral contents of the Nonpareil ash are about the same as the Whitney ashes. Two samples from Round Top contain calcite, feldspar, quartz, amphibole, mica, and smectite. Based on the limited data, the amount of mica decreased toward the east. Some beds of the Nonpareil ash were deposited by streams at the Beaver Wall locality.

Source of sediments for the ash beds.--The source of the primary constituent of the ash beds (silt-sized glass shards) was probably the Thirty-nine mile or San Juan volcanic fields in central and southern Colorado. The most likely source based on distance from northwestern Nebraska, composition, and age is the Thorn Ranch Tuff. According to Wobus and others (1979), the Thorn Ranch Tuff originated in the San Juan volcanic field, south-central Colorado. Thorn Ranch Tuff contains phenocrysts of sanidine, plagioclase, quartz and biotite (Epis and Chapin, 1974). The Thorn Ranch contains about 21 ppm Th (Dickinson, 1987), which is very close to the Brule ashes. The age of the Brule ashes is about 30 ma, which is approximately the same as the Thorn Ranch Tuff (Swinehart and others, 1985; Epis and Chapin, 1974).

STATISTICAL ANALYSIS

Chemical and mineralogical data for the 30 samples are listed in tables 5-8. Three databases were assembled from these data. They are data base I, compiled from the mineral and ICP chemical data (tables 5 and 7), database II, compiled from the mineral and XRF data (tables 6 and 7) and database III, compiled from the mineral and rare-earth element data (tables 7 and 8). The factor analyses were performed to reduce the number of variables to be interpreted by grouping them into related sets. A four-factor model was chosen after examining models with 3-7 factors as the best compromise between high communalities and the simplest model that would explain the observed relationships. In addition, a scatter diagram was prepared to examine regional differences in the uranium to thorium ratio (fig. 2). The results of these studies suggest many interesting relationships and the data can be interpreted to reflect sedimentologic and diagenetic processes and to indicate sediment sources. The R-mode factor analyses for these databases are presented below:

Database I.--Factor one contains variables with both positive and negative loadings (table 1). The variables with positive loadings, U, K, Pb, Th, Be, P, and mica, are believed to represent the content of the air fall ash fraction of the beds, and the variables with negative loadings, Sr, feldspar, quartz, and Cr probably represent the non-volcanic detrital fraction (NVDM). Thorium is high in beds that consist mostly of volcanic ash and low in beds with a greater amount of NVDM. Uranium and Pb, which is a decay product of both U and Th, are positively correlated with thorium in the relatively pure ash beds. Biotite is a constituent of the nearly pure ashes (Swinehart and others, 1985 and Evanoff, 1990). The quartz and feldspar represent NVDM and strontium probably substitutes for one of the cations in the feldspar.

Factor two contains Ti, Nd, Fe, Ce, and V. Iron and Ti frequently occur together and are components of ilmenite ($FeTiO_3$). Ilmenite is commonly high in resistate sediment concentrations.

Factor three contains Ca, calcite, and Mn with positive loadings and Ba with a negative loading. Calcite is precipitated in the ash beds from ground-water and as such is an allocthonous component. Calcite explains the presence of both Ca, which of course is a major constituent of calcite, and Mn, which substitutes for Ca in the calcite structure. The presence of barium with its negative loading is probably insignificant as indicated by its very low communality (.21, table 1).

Factor four contains Mg, Li, Zn, smectite, Al, Cu, and amphibole. Smectite is an alteration product of the ash (Dickinson, 1991), but also occurs in the NVDM. Nevertheless, its occurrence here suggests that this factor represents alteration of the ash. Aluminum is a component of the smectite and Mg substitutes for Al in the structure. Both Al and Mg are found in amphiboles along with iron, which has its second high loading in this factor. Lithium, Zn, and Cu are mobile during weathering and may be absorbed by the clays.

Table 1. Varimax factor analysis of database I containing elements determined by ICP, common minerals determined by XRD, and U and Th by INAA.

Rotated Factor Loadings

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
URANIUM	<u>0.96</u>	-.054	0.12	-.20	0.98
THORIUM	<u>0.83</u>	-.30	0.15	-.23	0.85
ALUMINUM	0.56	0.02	-.57	<u>0.57</u>	0.96
CALCIUM	-.01	0.06	<u>0.97</u>	-.0359	0.94
IRON	-.22	<u>-.81</u>	-.28	0.41	0.95
POTASSIUM	<u>0.95</u>	0.17	0.02	-.16	0.95
MAGNESIUM	-.07	-.19	0.01	<u>0.96</u>	0.97
SODIUM	-.10	0.05	-.67	<u>-.71</u>	0.97
PHOSPHOROUS	<u>0.61</u>	-.17	0.52	0.25	0.73
TITANIUM	-.18	<u>-.85</u>	-.27	0.32	0.93
MANGANESE	0.23	-.06	<u>0.93</u>	0.13	0.93
BARIUM	-.29	0.05	<u>-.30</u>	0.17	0.21
BERYLLIUM	<u>0.82</u>	0.12	-.10	0.35	0.82
CERIUM	0.49	<u>-.81</u>	0.19	-.03	0.93
CHROMIUM	<u>-.68</u>	-.55	-.30	0.28	0.94
COPPER	0.42	-.11	0.38	<u>0.53</u>	0.61
LANTHANUM	0.32	<u>-.73</u>	0.49	-.19	0.91
LITHIUM	-.19	-.10	0.02	<u>0.92</u>	0.89
NEODYMIUM	0.11	<u>-.82</u>	0.42	0.11	0.88
LEAD	<u>0.92</u>	0.03	-.24	0.04	0.91
STRONTIUM	<u>-.82</u>	-.05	-.49	-.07	0.91
VANADIUM	-.43	<u>-.79</u>	0.13	0.30	0.91
YTTRIUM	<u>0.83</u>	-.10	0.29	0.22	0.83
ZINC	0.49	-.32	-.02	<u>0.76</u>	0.93
CALCITE	0.15	-.12	<u>0.93</u>	0.03	0.90
FELDSPAR	<u>-.75</u>	-.15	-.48	-.25	0.87
QUARTZ	<u>-.80</u>	-.20	-.45	-.21	0.92
AMPHIBOLE	-.36	-.10	-.22	<u>-.43</u>	0.38
MICA	<u>0.51</u>	-.19	0.44	-.23	0.55
SMECTITE	-.10	-.20	-.11	<u>0.65</u>	0.83

Database II.--Factor one consists of CaO, MnO, calcite, and P_2O_5 with positive loadings and SiO_2 and Na_2O with negative loadings. As with factor three in database I, calcite, Ca, and Mn, are closely related and represent an allocthonous source material. The SiO_2 and Na_2O probably represent both volcanic and non-volcanic materials, because they are as concentrated in the samples that are nearly all volcanic ash as in the samples containing large amounts of NVDM.

Factor two contains Fe_2O_3, TiO_2, MgO, and smectite. The strong correlation between Fe and Ti (r =.97) again suggests their concentration is controlled by the mineral ilmenite ($FeTiO_3$), which is a common resistate mineral in detrital sediments. The association with smectite is somewhat puzzling because smectite is known to occur as an alteration of the ash shards (Dickinson, 1991). Smectite also occurs as a detrital component of the White River sediments, perhaps having been derived from upstream erosion of volcanic beds. The occurrence of detrital smectite is apparently more prominent in ash beds that are substantially diluted with NVDM. Magnesium substitutes for aluminum in the smectite structure. Aluminum (Al_2O_3) has its highest loading in factor three, but it is, nevertheless, positively correlated with both smectite (r= +0.32) and Mg (MgO) (r= +0.43).

Factor three contains K_2O and Al_2O_3 with positive loadings and quartz and feldspar with negative loadings. Potassium is most closely related to mica and Al_2O_3 to smectite. Quartz and feldspar, as in database I, factor one, are predominantly derived from non-volcanic detrital material.

Factor four consists of amphibole and mica. Biotite was reported from White River ash beds in southeastern Wyoming by Evanoff (1990) and biotite was reported from the lower Whitney ash in northwestern Nebraska by Swinehart and others, (1985). Although the amphibole is primarily related to the NVDM some may also have occurred in the volcanic fraction. In addition, sorting during eolian or fluvial activity may have brought the two minerals together.

Table 2 Varimax factor analysis of database II containing common minerals determined by XRD and major elements determined by XRF.

Rotated Factor Loadings

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
CALCITE	0.93	0.09	0.09	0.07	0.88
FELDSPAR	-.52	-.06	-.80	0.08	0.91
QUARTZ	-.47	-.16	-.78	0.25	0.92
AMPHIBOLE	-.25	0.04	-.27	0.76	0.72
MICA	0.45	0.08	0.56	0.63	0.92
SMECTITE	0.01	-.71	-.00	-.20	0.54
SIO_2	-.92	-.03	-.32	0.13	0.97
AL_2O_3	-.51	-.36	0.69	-.30	0.96
$FE2O_3$	-.15	-.87	-.21	0.18	0.86
MGO	0.12	-.83	0.10	-.39	0.8
CAO	0.95	0.22	-.07	0.02	0.96
NA_2O	-.81	0.33	-.12	0.36	0.92
K_2O	-.11	0.38	0.74	0.09	0.71
TIO_2	-.19	-.85	-.15	0.20	0.81
$P2O_5$	0.59	-.16	0.57	-.19	0.73
MNO	0.94	0.12	0.15	-.04	0.91

Database III.--Database three contains minerals determined by XRD and elements determined by the delayed neutron method that includes the rare earth elements. Elements Fe, Na, Gd, Tb, W, and Au were not included in the factor analysis because of the limited number of variables that could be used and because some of the results were either below the detection level or were made unreliable by interference.

Factor one consists of Cs, As, Rb, U, Ta, U, Sb, and Th with positive loadings and quartz, feldspar, Sr, Eu, Cr, Zr, Hf, Sc, and amphibole with negative loadings. The positive group is composed of elements concentrated in the volcanic part of the sediment and the negative group is concentrated in the NVDM. Both Th and U, generally concentrated in the purer ashes, are in the positive group. The negative group contains quartz and feldspar which are high in the NVDM. Strontium substitutes for a cation in feldspar and Eu follows Sr ($r = +0.76$) in the negative group. Hafnium follows Zr ($r = 0.98$), which is common in resistate sediments as zircon. Scandium is generally concentrated in the silicate phases. The occurrence of amphibole here may have little significance because of its low communality (0.45, table 3).

Factor two consists entirely of the light rare earth elements, Nd, Sm, Ce, La, Lu, and Yb, which are generally equally distributed in all rocks. They are neither correlated with the NVDM or volcanic fractions.

Factor three consists of Zn, smectite, Tm and Ho. Zinc can be held in the smectite structure. The heavy rare earths Tm and Ho may have been absorbed on the clay.

Factor four consists of mica, Ni, and calcite. Biotite is known to occur in the ashes, but mica is not in the volcanic component (in factor one), which probably means that illite also contributes substantially to the measured XRD peak (table 7), and the illite may be diagenetic, part of the NVDM, or both. Calcite, as mentioned above is allocthonous. Nickel may be introduced with the calcite in ground water, but its communality (0.47, table 3) is low and its occurrence here lacks significance.

Table 3.--Factor analysis of database III containing common minerals determined by XRD and RE elements determined by delayed neutron.

Rotated Factor Loadings

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
CALCITE	0.41	0.10	0.05	0.45	0.38
FELDSPAR	-.91	-.0064	0.18	-.20	0.90
QUARTZ	-.95	0.0082	0.11	-.12	0.93
AMPHIBOLE	-.49	0.0065	0.27	0.38	0.45
MICA	0.53	0.23	0.15	0.68	0.81
SMECTITE	-.13	0.10	-.67	-.015	0.48
RB	0.90	0.26	0.17	-.041	0.91
SR	-.90	-.17	0.033	-.19	0.87
CS	0.95	0.22	0.010	-.10	0.95
BA	0.043	-.040	-.41	0.20	0.21
TH	0.71	0.51	0.24	0.24	0.88
U	0.85	0.37	0.24	-.028	0.93
LA	0.14	0.81	0.07	0.43	0.87
CE	0.17	0.90	-.16	0.26	0.93
ND	-.078	0.93	-.23	0.07	0.93
SM	0.042	0.92	-.28	-.15	0.94
EU	-.86	0.20	-.35	0.071	0.91
TM	-.075	0.10	-.62	-.10	0.41
YB	0.61	0.64	-.18	-.34	0.92
LU	0.57	0.68	-.14	-.30	0.90
ZR	-.78	0.53	-.056	-.23	0.95
HF	-.75	0.57	-.087	-.20	0.94
TA	0.83	0.39	0.10	-.17	0.89
SC	-.66	0.12	-.67	-.029	0.90
CR	-.84	0.24	-.35	-.058	0.89
CO	-.22	0.28	-.65	0.42	0.73
NI	-.16	-.049	-.24	0.62	0.47
ZN	0.33	0.26	-.86	-.13	0.94
AS	0.90	0.22	0.078	-.045	0.88
SB	0.77	-.011	-.40	-.17	0.78

THE ASHES AS A POSSIBLE URANIUM SOURCE FOR COMMERCIAL DEPOSITS

Uranium averages 7.8 ppm U in the ashes in the proximal areas (Scottsbluff and Round Top) and 3.2 in the distal areas (Chadron and Beaver Wall). The proximal area value (7.8) is very close to the 8 ppm Zielinski (1983) determined from White River volcanic glass separates. Considering that even the relatively fresh glass analyzed here is diluted with an estimated 5 to 10 percent NVDM, the values are compatible. Hence, it seems unlikely that the ashes studied in this report could have produced a significant proportion of the uranium found in deposits such as Crow Butte which are in basal sandstone beds of the Chadron Formation. Water that carried uranium for those deposits probably originated much further updip to the northwest. A greater degree of alteration occurred in other areas, especially in parts of Wyoming and South Dakota (Evanoff, 1990; Stanley and Benson, 1979). This alteration, which produced clinoptilolite as well as smectite and opal, probably also put greater amounts of uranium into the ground-water that entered these basal sandstone aquifers (Dickinson, 1993). Lander and Hay (1993) related the areas of zeolitic alteration to hydrologic regimes.

Thorium is resistant to leaching and the relatively constant Th/U ratio (fig. 2) suggests that the lower U in the samples from the northeastern localities is not because of uranium leaching. The ratio remains relatively constant throughout the study area, even where the volcanic sediments are strongly diluted by non-volcanic sediments. Areas of strong uranium leaching or alteration were not found in the study area.

REGIONAL VARIATIONS

Thorium and uranium are lower in all three ash beds in the northeastern part of the area. Uranium decreases from about 8 ppm in the Scottsbluff and Round Top localities to about 3 ppm at the Chadron and Beaver Wall localities. Thorium decreases from about 22 ppm to 12 ppm in the same samples. The decrease is because of the the mixing with and dilution by the non-volcanic sediment (NVDM) that contains less uranium and thorium. The mixing resulted from eolian, fluvial, and biologic activity. The Th/U ratio remains about the same at all the sample sites (fig. 2). Antimony and arsenic follow dilution patterns to the northeast similar to those of uranium and thorium. Feldspar and quartz, a part of the NVDM, increase to the northeast in an inverse trend to that of uranium and thorium. Strontium, which is probably in the feldspar, and scandium which is probably in the amphibole also increase northeastward. Mica is lower at the northeastern sites. Available data, however, do not provide definitive conclusions for the amphibole, which may have occurred both in the volcanic and NVDM fractions.

SUMMARY

In ascending order three major volcanic ash beds of the Brule Formation in northwestern Nebraska are the Lower Whitney, the Upper Whitney and the Nonpareil. These beds are mixed with increasingly large amounts of NVDM northeastward away from the volcanic source, which probably is the San Juan volcanic field in south-central Colorado. The chemical and mineralogical contents of the sediment can be divided into general groups of related values. These groups (factors) are interpreted to generally represent the four compositional components of the ash beds. These are: (1) volcanic ash, deposited mostly by air-fall, but partly redistributed by fluvial and eolian processes, (2) NVDM deposited by eolian and fluvial processes, (3) alteration products of the volcanic glass consisting mostly of smectite, opal, and in some areas clinoptilolite, and (4) diagenetic minerals such as calcite that are high in Mn as well as Ca and that were deposited from percolating ground-water. The Brule ash beds are probably not the source of much of the uranium in commercial uranium deposits in northwestern Nebraska.

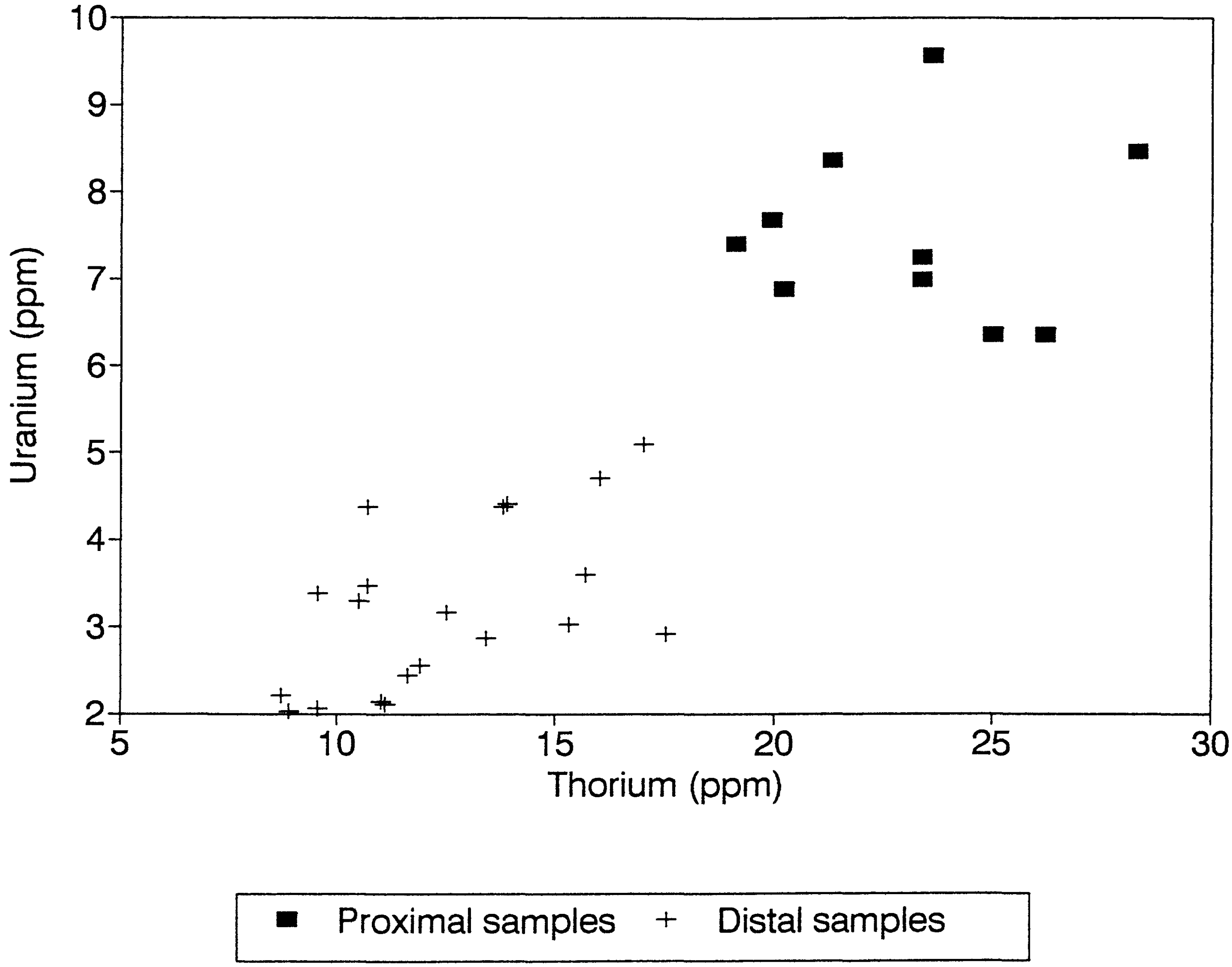

Figure 2.--Scatterplot showing relation of uranium to thorium in samples from proximal (Round Top and Scottsbluff) and distal (Chadron and Beaver Wall) areas.

Table 4. Sample stratigraphy, locality, and lithology and location

	Lab. No.	Field No.	Stratigraphic unit	Locality	Lithology
1	D-387970	f82885-1	Lower Whitney	Round Top	Ash
2	D-387972	f82885-4	Lower Whitney	Round Top	Ash
3	D-387974	f71991-1	Lower Whitney	Scottsbluff	Ash
4	D-387975	f71991-2	Lower Whitney	Scottsbluff	Ash
5	D-387971	f82885-2	Upper Whitney	Round Top	Ash
6	D-387973	f82885-5	Upper Whitney	Round Top	Ash
7	D-387976	f71991-3	Upper Whitney	Scottsbluff	Ash
8	D-387977	f71991-4	Upper Whitney	Scottsbluff	Ash
9	D-387982	f72786-1	Nonpareil	Round Top	Ash
10	D-387983	f72786-2	Nonpareil	Round Top	Ash
11	D-387984	f70991-1	Nonpareil	Chadron"C"	Ash
12	D-387985	f70991-2	Nonpareil	Chadron"C"	Ash
13	D-387986	f70991-3	Nonpareil	Chadron"C"	Ash
14	D-387987	f70991-4	Nonpareil	Chadron"C"	Ash
15	D-387988	f70991-5	Nonpareil	Chadron"C"	Ash
16	D-387989	f70991-6	Nonpareil	Chadron"C"	Ash
17	D-387990	f70991-7c	Nonpareil	Chadron"C"	Ash
18	D-387991	f70991-7bw	Nonpareil	Beaver Wall	Ash
19	D-387992	f70991-8	Nonpareil	Beaver Wall	Ash
20	D-387993	f70991-9	Nonpareil	Beaver Wall	Ash
21	D-387994	f70991-10	Nonpareil	Beaver Wall	Ash
22	D-387995	f70991-11	Nonpareil	Beaver Wall	Ash
23	D-387996	f70991-12	Nonpareil	Beaver Wall	Ash
24	D-387997	f70991-13	Nonpareil	Beaver Wall	Ash
25	D-387998	f70991-14	Nonpareil	Beaver Wall	Ash
26	D-387999	f70991-15	Nonpareil	Beaver Wall	Ash
27	D-387978	f71791-7	Lower Whitney	Beaver Wall	Ash
28	D-387979	f71791-8	Lower Whitney	Beaver Wall	Ash
29	D-387980	f71791-11	Upper Whitney	Beaver Wall	Ash
30	D-387981	f71791-12	Upper Whitney	Beaver Wall	Ash

Table 4 continued:

Field No.	Longitude West deg./min./sec.	Latitude North deg./min./sec.
f82885-1	103 / 33/ 12	42 / 47/ 14
f82885-4	103 / 34/ 37	42 / 48/ 25
f71991-1	103 / 42 / 30	41 / 49 / 56
f71991-2	103 / 42 / 30	41 / 49 / 56
f82885-2	103 / 34/ 15	42 / 49/ 09
f82885-5	103 / 34/ 07	42 / 48/ 25
f71991-3	103 / 42 / 30	41 / 49 / 56
f71991-4	103 / 42 / 30	41 / 49 / 56
f72786-1	103 / 34/ 34	42 / 49/ 40
f72786-2	103 / 34/ 34	42 / 49/ 40
f70991-1	103 / 00 / 18	42 / 48 / 51
f70991-2	103 / 00 / 18	42 / 48 / 51
f70991-3	103 / 00 / 18	42 / 48 / 51
f70991-4	103 / 00 / 18	42 / 48 / 51
f70991-5	103 / 00 / 18	42 / 48 / 51
f70991-6	103 / 00 / 18	42 / 48 / 51
f70991-7c	103 / 00 / 18	42 / 48 / 51
f70991-7b	102 / 42 / 55	42 / 55 / 00
f70991-8	102 / 42 / 55	42 / 55 / 00
f70991-9	102 / 42 / 55	42 / 55 / 00
f70991-10	102 / 42 / 55	42 / 55 / 00
f70991-11	102 / 42 / 55	42 / 55 / 00
f70991-12	102 / 42 / 55	42 / 55 / 00
f70991-13	102 / 42 / 55	42 / 55 / 00
f70991-14	102 / 42 / 55	42 / 55 / 00
f70991-15	102 / 42 / 55	42 / 55 / 00
f71791-7	102 / 42 / 55	42 / 55 / 00
f71791-8	102 / 42 / 55	42 / 55 / 00
f71791-11	102 / 42 / 55	42 / 55 / 00
f71791-12	102 / 42 / 55	42 / 55 / 00

Table 5. Chemical data determined by inductively coupled plasma spectroscopy. Numbers one through eight are given in percent and the remainder are given in parts per million.

A.--Summary statistics

No.	Variable	Minimum	Maximum	Mean	Std. Dev.
1	ALUMINUM	5	7.1	6.4	.588
2	CALCIUM	1.2	13	3.66	2.97
3	IRON	1.5	3	1.91	.305
4	POTASSIUM	1.6	3.6	2.47	.618
5	MAGNESIUM	.67	1.7	.970	.272
6	SODIUM	.68	1.7	1.44	.217
7	PHOSPHOROUS	.02	.08	.048	.0161
8	TITANIUM	.15	.32	.203	.0326
9	MANGANESE	310	1600	568	268
10	BARIUM	500	920	708	99.1
11	BERYLIUM	1	3	1.80	.606
12	CESIUM	46	80	63.0	8.14
13	CHROMIUM	11	39	20.8	6.29
14	COPPER	2	15	8.73	3.70
15	LANTHANUM	28	45	36.2	4.73
16	LITHIUM	22	120	46.9	25.6
17	NEODYMIUM	23	38	28.6	3.40
18	LEAD	16	30	20.4	3.69
19	STRONTIUM	220	430	313	62.9
20	VANADIUM	25	79	44.0	12.0
21	YTTRIUM	12	26	18.3	3.59
22	ZINC	36	62	49.2	8.51

Table 5 continued:

B.--Data

Field No.	Al	Ca	Fe	K	Mg	Na
f82885-1	7.0	3.0	2.0	2.9	0.99	1.4
f82885-4	6.3	6.4	1.9	2.9	0.86	1.3
f71991-1	6.9	1.2	1.5	3.6	0.67	1.7
f71991-2	7.1	1.3	2.0	3.1	1.0	1.5
Mean	6.8	3.0	1.9	3.1.	0.88	1.5
f82885-2	5.0	9.6	1.7	2.8	0.70	1.3
f82885-5	6.3	7.7	1.8	2.8	0.82	1.3
f71991-3	6.2	6.0	1.7	3.2	0.76	1.5
f71991-4	6.6	4.7	2.2	3.1	0.97	1.4
Mean	6.0	7.0	1.9	3.0	0.81	1.4
f72786-1	6.9	1.7	1.6	3.5	0.76	1.6
f72786-2	6.6	4.3	1.6	3.3	0.75	1.5
Mean	6.8	3.0	1.6	3.4	0.76	1.6
f70991-1	5.8	1.8	1.9	1.7	0.69	1.7
f70991-2	6.5	1.7	1.7	2.1	0.96	1.6
f70991-3	5.3	9.4	1.5	1.7	0.77	1.4
f70991-4	7.0	1.7	2.2	2.0	1.4	1.3
f70991-5	6.7	1.8	2.0	2.1	1.2	1.5
f70991-6	7.0	1.8	2.3	2.1	1.3	1.4
f70991-7c	7.0	1.6	2	2.4	1.3	1.3
Mean	6.5	2.8	1.9	2.0	1.1	1.5
f70991-7b	7.0	2.3	1.8	3.1	0.95	1.4
f70991-8	6.4	5	1.6	2.8	0.91	1.3
f70991-9	6.0	1.8	1.9	2.0	0.73	1.7
f70991-10	5.6	13	1.9	1.8	1.5	0.68
f70991-11	5.8	1.9	1.8	1.8	0.76	1.7
f70991-12	5.6	1.6	1.9	1.7	0.73	1.7
f70991-13	5.7	1.7	1.9	1.7	0.7	1.7
f70991-14	7.0	1.9	2.4	1.8	1.7	1.1
f70991-15	6.1	2.1	3.0	1.6	1.0	1.6
Mean	6.1	3.5	2.0	2.0	1.0	1.4
f71791-7	6.1	5.4	1.6	2.5	0.73	1.5
f71791-8	6.6	3.1	2.0	2.3	1.1	1.4
Mean	6.4	4.0	1.8	2.4	0.92	1.5
f71791-11	7.0	2.0	2.0	2.9	1.2	1.3
f71791-12	6.9	2.4	2.0	2.7	1.2	1.3
Mean	7.0	2.2	2.0	2.8	1.2	1.3

Table 5--continued

Field No.	P	Ti	Mn	Ba	Be	Ce
f82885-1	0.08	0.20	510	500	2.0	68
f82885-4	0.06	0.20	820	610	2.0	74
f71991-1	0.06	0.15	660	540	3.0	67
f71991-2	0.06	0.21	510	650	3.0	72
Mean	0.07	0.19	630	580	2.5	70
f82885-2	0.05	0.18	1100	580	1.0	71
f82885-5	0.08	0.19	920	520	2.0	65
f71991-3	0.07	0.20	680	670	2.0	71
f71991-4	0.05	0.24	620	920	2.0	72
Mean	0.06	0.20	830	670	1.8	70
f72786-1	0.04	0.19	530	740	3.0	64
f72786-2	0.04	0.18	500	770	2.0	64
Mean	0.04	0.19	520	760	2.5	64
f70991-1	0.03	0.2	310	740	1.1	57
f70991-2	0.03	0.18	330	820	1.0	48
f70991-3	0.03	0.15	640	670	1.0	46
f70991-4	0.04	0.23	390	760	2.0	55
f70991-5	0.05	0.21	350	750	2.0	56
f70991-6	0.03	0.24	350	740	2.0	68
f70991-7c	0.04	0.20	470	770	2.0	58
Mean	0.04	0.20	410	750	1.6	55
f70991-7b	0.06	0.20	530	910	2.0	66
f70991-8	0.05	0.18	660	760	2.0	62
f70991-9	0.04	0.21	340	750	1.0	57
f70991-10	0.08	0.20	1600	710	2.0	69
f70991-11	0.03	0.19	340	730	1.0	50
f70991-12	0.03	0.20	340	710	1.0	64
f70991-13	0.02	0.21	340	670	1.0	65
f70991-14	0.05	0.26	540	680	2.0	67
f70991-15	0.04	0.32	460	700	1.0	80
Mean	0.04	0.22	570	740	1.4	64
f71791-7	0.04	0.16	660	660	2.0	50
f71791-8	0.06	0.20	490	630	2.0	59
Mean	0.05	0.18	580	650	2.0	55
f71791-11	0.05	0.21	540	820	2.0	63
f71791-12	0.05	0.20	500	770	2.0	61
Mean	0.05	0.21	520	800	2.0	62

Table 5--continued

Field No.	Co	Cr	Cu	Ga	La	Li
f82885-1	7.0	18	15	28	37	39
f82885-4	8.0	16	12	15	43	28
f71991-1	5.0	11	6.0	18	38	30
f71991-2	7.0	19	12	18	36	39
Mean	6.8	16	11	20	39	34
f82885-2	7.0	15	15	14	42	26
f82885-5	6.0	17	11	17	37	33
f71991-3	8.0	14	9.0	15	44	22
f71991-4	10	20	14	17	42	30
Mean	7.8	17	12	16	41	28
f72786-1	6.0	11	5.0	17	36	28
f72786-2	5.0	11	6.0	16	37	28
Mean	5.5	11	5.5	18	37	28
f70991-1	6.0	26	4.0	13	34	24
f70991-2	6.0	19	6.0	15	28	47
f70991-3	6.0	19	8.0	12	32	36
f70991-4	9.0	28	13	17	28	95
f70991-5	7.0	25	10	16	33	66
f70991-6	8.0	30	11	17	36	83
f70991-7c	8.0	23	13	18	31	85
Mean	7.1	24	9.3	15	32	62
f70991-7b	6.0	15	8.0	17	39	50
f70991-8	6.0	14	7.0	16	35	48
f70991-9	7.0	26	4.0	14	34	27
f70991-10	9.0	22	12	16	45	100
f70991-11	6.0	23	2.0	12	30	26
f70991-12	6.0	26	3.0	13	37	33
f70991-13	6.0	26	4.0	12	38	38
f70991-14	10	25	9.0	17	37	120
f70991-15	9.0	39	5.0	15	45	44
Mean	7.2	24	6.0	15	38	54
f71791-7	5.0	18	7	14	29	27
f71791-8	8.0	24	11	16	34	40
f71791-11	7.0	21	10	17	35	59
f71791-12	8.0	22	10	16	34	57
Mean	7.0	21	10	16	33	46

Table 5--continued

Field No.	Nd	Ni	Pb	Sc	Sr	V
f82885-1	30	8.0	26	6.0	270	49
f82885-4	30	8.0	23	6.0	250	52
f71991-1	28	5.0	30	5.0	240	26
f71991-2	30	7.0	27	6.0	300	42
Mean	30	7.0	27	5.8	270	42
f82885-2	30	7.0	19	6.0	240	43
f82885-5	31	7.0	21	6.0	260	40
f71991-3	30	7.0	22	6.0	230	39
f71991-4	30	9.0	21	7.0	260	53
Mean	30	7.5	21	6.3	250	44
f72786-1	27	5.0	27	6.0	220	26
f72786-2	29	5.0	24	6.0	250	25
Mean	28	5.0	26	6.0	240	26
f70991-1	28	6.0	16	7.0	430	48
f70991-2	23	7.0	19	6.0	410	40
f70991-3	25	7.0	16	6.0	350	36
f70991-4	25	11	19	8.0	350	54
f70991-5	28	9.0	19	7.0	370	47
f70991-6	29	10	20	8.0	360	58
f70991-7	26	10	22	7.0	310	45
Mean	26	8.6	19	7.0	370	47
f70991-7b	30	6.0	23	7.0	270	32
f70991-8	27	6.0	21	6.0	270	29
f70991-9	27	7.0	18	7.0	380	47
f70991-10	38	10	16	6.0	240	68
f70991-11	24	7.0	16	7.0	410	44
f70991-12	30	8.0	17	7.0	360	49
f70991-13	28	7.0	17	7.0	380	47
f70991-14	31	10	21	8.0	300	52
f70991-15	38	9.0	17	9.0	410	79
Mean	30	7.8	18	7.1	340	50
f71791-7	23	7.0	16	6.0	330	30
f71791-8	28	10	18	7.0	350	39
mean	26	9.0	17	6.5	340	35
f71791-11	27	9.0	21	8.0	290	39
f71791-12	27	9.0	21	7.0	300	41
Mean	27	9.0	21	7.5	300	40

Table 5--Continued:

Field No.	Y	Yb	Zn
f82885-1	25	3.0	57
f82885-4	19	2.0	48
f71991-1	26	3.0	50
f71991-2	22	2.0	60
Mean	23	2.5	53
f82885-2	19	2.0	44
f82885-5	23	2.0	52
f71991-3	20	2.0	43
f71991-4	18	2.0	53
Mean	20	2.0	48
f72786-1	21	2.0	50
f72786-2	21	2.0	50
Mean	21	2.0	50
f70991-1	14	1.0	36
f70991-2	14	1.0	41
f70991-3	15	2.0	36
f70991-4	14	2.0	56
f70991-5	18	2.0	48
f70991-6	18	2.0	56
f70991-7c	19	2.0	56
Mean	16	1.7	47
f70991-7b	21	2.0	55
f70991-8	19	2.0	48
f70991-9	14	1.0	39
f70991-10	23	3.0	58
f70991-11	13	1.0	36
f70991-12	14	1.0	36
f70991-13	12	1.0	36
f70991-14	18	2.0	62
f70991-15	17	2.0	56
Mean	17	1.7	47
f71791-7	15	2.0	41
f71791-8	19	2.0	54
Mean	17	2.0	48
f71791-11	19	2.0	61
f71791-12	19	2.0	59
Mean	19	2.0	60

Table 6 Oxides Measured by X-ray Fluorescence. All values are given in percent.

A.--Summary Statistics

No.	Variable	Minimum	Maximum	Mean	Std. Dev.
1	SIO_2	43	76	65.8	7.29
2	AL_2O_3	9.4	13.1	11.7	1.07
3	FE_2O_3	2.14	4.21	2.69	.420
4	MGO	1.02	2.78	1.50	.448
5	CAO	1.56	18.1	4.91	4.08
6	NA_2O	.73	2.26	1.82	.302
7	K_2O	.52	4.38	2.88	.848
8	TIO_2	.29	.61	.385	.0620
9	P_2O_5	.05	.2	.122	.0372
10	MNO	.05	.21	.763	.0334
11	LOI	2.05	20.4	7.58	3.94

Table 6 continued

B.--Data

Field No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O
f82885-1	63	13	2.8	1.5	4.1	1.7
f82885-4	59	11	2.6	1.3	8.5	1.7
f71991-1	68	13	2.1	1.0	1.6	2.2
f71991-2	67	13	2.9	1.7	1.7	2.0
Mean	64	13	2.6	1.4	4.0	1.9
f82885-2	53	10	2.5	1.1	13	1.6
f82885-5	56	11	2.4	1.2	10	1.6
f71991-3	61	11	2.3	1.1	8.0	1.9
f71991-4	62	12	3.0	1.5	6.3	1.8
Mean	58	11	2.6	1.2	9.4	1.7
f72786-1	68	13	2.3	1.2	2.2	2.0
f72786-2	63	12	2.2	1.1	5.7	1.8
Mean	66	12	2.2	1.2	4.0	1.9
f70991-1	75	11	2.8	1.1	2.4	2.3
f70991-2	72	12	2.3	1.5	2.3	2.1
f70991-3	59	9.4	2.2	1.1	13	1.7
f70991-4	68	13	3.0	2.3	2.3	1.7
f70991-5	70	12	2.8	1.8	2.4	1.8
f70991-6	68	13	3.2	2.1	2.3	1.7
f70991-7c	68	13	2.8	2.1	2.2	1.7
Mean	68	12	2.7	1.7	3.8	1.8
f70991-7b	67	13	2.6	1.5	3.0	1.8
f70991-8	63	12	2.3	1.4	6.8	1.7
f70991-9	75	11	2.7	1.1	2.4	2.2
f70991-10	43	9.7	2.6	2.2	18	0.73
f70991-11	76	11	2.5	1.2	2.4	2.2
f70991-12	76	10	2.7	1.1	2.1	2.1
f70991-13	76	11	2.7	1.1	2.2	2.1
f70991-14	66	13	3.3	2.8	2.5	1.4
f70991-15	72	11	4.2	1.6	2.7	2.1
Mean	68	11	2.9	1.6	4.7	1.8
f71791-7	65	11	2.2	1.1	7.1	1.8
f71791-8	66	12	2.9	1.6	4.1	1.7
Mean	66	12	2.6	1.4	5.6	1.8
f71791-11	66	13	2.8	1.8	2.7	1.7
f71791-12	66	13	2.8	1.8	3.2	1.7
Mean	66	13	2.8	1.8	3.0	1.7

Table 6. continued:

Field No.	K_2O	TiO_2	P_2OP_5	MnO	LOI
f82885-1	3.5	0.36	0.19	0.07	9.0
f82885-4	3.4	0.39	0.15	0.10	11
f71991-1	4.4	0.29	0.15	0.09	6.3
f71991-2	3.8	0.39	0.15	0.07	6.6
Mean	3.8	0.36	0.16	0.08	8.3
f82885-2	3.2	0.35	0.13	0.14	14
f82885-5	3.2	0.33	0.18	0.12	13
f71991-3	3.8	0.36	0.17	0.09	9.8
f71991-4	3.6	0.45	0.13	0.08	9.0
Mean	3.5	0.37	0.15	0.11	11
f72786-1	4.3	0.35	0.11	0.07	6.7
f72786-2	3.9	0.33	0.10	0.07	9.3
Mean	4.1	0.34	0.11	0.07	8.0
f70991-1	2.2	0.38	0.08	0.05	2.1
f70991-2	2.6	0.34	0.09	0.05	4.1
f70991-3	2.0	0.31	0.08	0.08	11
f70991-4	2.5	0.44	0.1	0.05	6.8
f70991-5	2.5	0.42	0.12	0.05	5.5
f70991-6	2.5	0.47	0.09	0.05	6.3
f70991-7c	2.9	0.39	0.11	0.06	7.1
Mean	2.5	0.39	0.10	0.06	6.2
f70991-7b	3.8	0.39	0.15	0.07	7.1
f70991-8	3.3	0.34	0.14	0.09	9.4
f70991-9	2.4	0.39	0.09	0.05	2.6
f70991-10	2.0	0.36	0.20	0.21	20
f70991-11	2.3	0.36	0.08	0.05	2.4
f70991-12	2.2	0.38	0.07	0.05	2.3
f70991-13	2.1	0.39	0.05	0.05	2.5
f70991-14	2.2	0.48	0.14	0.07	8.3
f70991-15	2.0	0.61	0.10	0.06	3.1
Mean	2.5	0.41	0.11	0.08	6.5
f71791-7	2.9	0.31	0.10	0.09	8.3
f71791-8	2.8	0.41	0.16	0.07	7.5
Mean	2.9	0.36	0.13	0.08	7.9
f71791-11	3.6	0.40	0.12	0.07	8.1
f71791-12	3.3	0.39	0.12	0.07	7.9
Mean	3.5	0.40	0.12	0.07	8.0

Table 7. X-ray diffractogram peaks and areas measured for those peaks for the common minerals.

A.--X-ray diffractogram peaks (Cu, K-alpha radiation) measured for the common minerals in the Brule ash samples.

Mineral	X-ray diffraction peak (degrees 2-theta)	Crystallographic index
Calcite	29.4	104
Feldspar	26.9-27.9	002
Quartz	26.7	101
Amphibole	10.8	110
Mica[1]	8.8	001
Smectite	5.9	001

1 The term "mica" is used for minerals that contributed to the 10 angstrom XRD peak. These included biotite, illite, and possibly muscovite.

B.--Summary Statistics

No.	Variable	Minimum	Maximum	Mean	Std. Dev.
1	CALCITE	0.0	1.53	.21	.383
2	FELDSPAR	.2	2.58	.100	.689
3	QUARTZ	.05	.7	.263	.186
4	AMPHIBOL	0.0	.2	.0213	.0408
5	ILLITE	0.0	.14	.052	.036
6	SMECTITE	.08	.73	.296	.161

Table 7 continued

C.--Data

Field No.	Calcite	Feldspar	Quartz	Amphibole	Mica	Smectite
f82885-1	0.17	0.38	0.1	0	0.05	0.52
f82885-4	0.67	0.3	0.09	0	0.09	0.29
f71991-1	0	0.45	0.1	0	0.04	0.08
f71991-2	0	0.44	0.15	0.03	0.05	0.30
Mean	0.21	0.39	0.11	0.01	0.06	0.30
f82885-2	1.15	0.29	0.06	0.00	0.11	0.14
f82885-5	0.80	0.37	0.15	0.00	0.10	0.20
f71991-3	0.48	0.40	0.08	0.00	0.13	0.11
f71991-4	0.25	0.21	0.10	0.08	0.14	0.10
Mean	0.67	0.32	0.10	0.02	0.12	0.14
f72786-1	0.00	0.69	0.05	0.03	0.09	0.35
f72786-2	0.29	0.71	0.06	0.00	0.06	0.19
Mean	0.15	0.70	0.06	0.02	0.08	0.27
f70991-1	0.00	1.50	0.65	0.20	0.10	0.50
f70991-2	0.00	2.00	0.45	0.02	0.02	0.30
f70991-3	0.00	1.02	0.32	0.03	0.03	0.20
f70991-4	0.00	1.20	0.32	0.00	0.03	0.20
f70991-5	0.00	1.10	0.28	0.00	0.02	0.50
f70991-6	0.00	1.23	0.36	0.03	0.02	0.41
f70991-7c	0.00	1.00	0.34	0.00	0.05	0.57
Mean	0.00	1.3	0.39	0.04	0.04	0.38
f70991-7bw	0.00	0.50	0.17	0.00	0.03	0.37
f70991-8	0.60	0.95	0.25	0.01	0.04	0.33
f70991-9	0.00	1.9.	0.45	0.05	0.02	0.13
f70991-10	1.5	0.20	0.05	0.00	0.07	0.45
f70991-11	0.00	1.8.	0.53	0.04	0.02	0.10
f70991-12	0.00	2.6.	0.55	0.06	0.03	0.18
f70991-13	0.00	2.1.	0.45	0.06	0.00	0.34
f70991-14	0.00	0.90	0.20	0.00	0.04	0.73
f70991-15	0.00	2.5.	0.70	0.00	0.02	0.30
Mean	0.27	1.5.	0.37	0.02	0.03	0.33
f71791-7	0.00	1.1	0.28	0.00	0.02	0.08
f71791-8	0.19	1.1	0.25	0.00	0.02	0.30
Mean	0.10	1.1	0.27	0.00	0.02	0.19
f71791-11	0.00	0.36	0.12	0.00	0.06	0.28
f71791-12	0.15	0.69	0.23	0.00	0.06	0.32
Mean	0.08	0.53	0.18	0.00	0.06	0.30

Table 8. Chemical analysis by instrumental neutron activation analysis (INAA). Values are given in parts per million (ppm). i* indicates values below detection limit or where interference did not permit accurate determination; Arithmetic means were not calculated for columns containing i* values.

A.--Summary Statistics

No.	Variable	Minimum	Maximum	Mean	Std. Dev.
1	FE	14400	29600	18700	2950
2	NA	5640	16900	13400	2250
3	RB	55.2	189	105	38.3
4	SR	203	471	312	74.1
5	CS	1.27	9.07	4.55	2.21
6	BA	7.27	906	673	162
7	TH	7.8	27.1	15.1	5.41
8	U	2.09	10.3	4.79	2.42
9	LA	25.9	42.8	33.4	4.07
10	CE	49.7	88.8	66.1	8.05
11	ND	21.5	37.8	27.9	3.01
12	SM	4.3	7.4	5.48	.615
13	EU	.683	1.23	.914	.121
14	TB	.477	.766	.600	.0751
15	YB	1.66	2.79	2.20	.300
16	LU	.244	.405	.323	.0436
17	ZR	127	501	202	70.7
18	HF	3.64	13.9	5.84	1.92
19	TA	.587	2.14	1.15	.431
20	SC	4.14	8.55	6.21	.967
21	CR	10.4	37.5	18.9	5.82
22	CO	3.58	7.89	5.40	1.13
23	ZN	35.3	61.8	48.5	8.00
24	AS	1.95	10.6	5.56	2.66
25	SB	.266	.945	.559	.158
26	AU	.186	2.87	1.08	.662

Table 8 continued

B.--Data

Field No.	Fe	Na	Rb	Sr	Cs	Ba
f82885-1	19000	13000	150	260	7.6	490
f82885-4	18000	12000	130	250	5.7	590
f71991-1	14000	16000	190	220	9.1	530
f71991-2	20000	15000	170	300	8.1	650
Mean	17800	14000	160	258	7.63	565
f82885-2	17000	12000	130	220	5.6	560
f82885-5	17000	12000	130	240	6.9	490
f71991-3	16000	14000	150	220	6.5	670
f71991-4	21000	13000	140	240	6.3	890
Mean	18000	13000	140	230	6.3	650
f72786-1	16000	15000	170	230	7.5	750
f72786-2	15000	13900	150	250	6.7	760
Mean	16000	15000	160	240	7.10	760
f70991-1	20000	17000	61	470	1.4	760
f70991-2	17000	15000	75	430	2.6	830
f70991-3	16000	13000	61	370	2.1	660
f70991-4	21000	12000	81	330	3.5	730
f70991-5	20000	14000	79	370	3.2	750
f70991-6	22000	13000	88	370	3.9	730
f70991-7c	19000	12000	95	290	4.3	750
Mean	19000	14000	77.0	380	3.0	740
f70991-7b	18000	13000	120	270	5.5	910
f70991-8	15800	12000	110	260	4.6	750
f70991-9	19000	16000	68	390	2.0	720
f70991-10	18000	5600	80	200	4.4	650
f70991-11	18000	16000	64	420	1.7	730
f70991-12	19000	16000	58	360	1.7	700
f70991-13	19000	16000	58	400	1.5	670
f70991-14	23000	11000	77	290	3.5	660
f70991-15	30000	16000	55	410	1.5	680
Mean	20000	14000	77	33	2.9	640
f71791-7	15000	13000	90	320	3.9	640
f71791-8	20000	12000	93	350	4.5	610
Mean	18000	12500	92	340	4.2	630
f71791-11	20000	13000	120	300	5.9	830
f71791-12	19000	12000	110	300	5.4	760
Mean	20000....	13000	120	300	5.7	800

Table 8 . Continued

	Th	U	La	Ce	Nd	Sm
f82885-1	20	7.5	34	70	29	6.1
f82885-4	25	6.7	38	74	28	5.3
f71991-1	22	10	34	67	28	6.0
f71991-2	20	9.1	33	75	31	6.4
Mean	22	8.4	35	72	29	6.0
f82885-2	23	6.7	39	73	28	5.3
f82885-5	17	6.8	33	67	28	5.8
f71991-3	27	8.5	40	73	28	5.2
f71991-4	22	7.4	39	75	30	5.6
Mean	22	7.3	38	72	28	5.5
f72786-1	22	8.2	35	70	30	5.7
f72786-2	19	7.3	34	64	26	5.5
Mean	21	7.8	34	67	28	5.6
f70991-1	9.6	2.2	33	62	28	5.5
f70991-2	9.2	2.7	26	52	23	4.4
f70991-3	7.8	2.3	30	50	24	4.5
f70991-4	12	3.0	26	57	22	4.5
f70991-5	11	3.2	32	63	28	5.7
f70991-6	12	3.1	33	66	29	5.8
f70991-7c	13	3.8	30	63	26	5.2
Mean	11	2.9	30	59	26	5.1
f70991-7bw	15	4.8	35	71	29	5.8
f70991-8	14	4.6	33	64	27	5.2
f70991-9	9.9	2.6	31	61	28	5.3
f70991-10	11	3.3	39	70	31	5.8
f70991-11	9.3	2.1	29	57	26	5.1
f70991-12	11	2.2	34	66	29	5.5
f70991-13	11	2.2	36	70	28	5.3
f70991-14	14	2.9	33	69	29	5.8
f70991-15	15	3.0	43	89	38	7.4
Mean	12	3.1	35	69	30	5.7
f71791-7	9.8	3.6	27	52	22	4.3
f71791-8	12	4.4	31	63	29	5.6
Mean	11	4.0	29	58	26	5.0
f71791-11	14	5.0	33	67	29	5.6
f71791-12	13	4.4	31	64	27	5.5
Mean	14	4.7	32	66	28	5.6

Table 8. Continued

Field No.	Gd	Tb	Ho	Tm	Yb	Lu
f82885-1	5.7	0.72	0.97	0.42	2.7	0.40
f82885-4	i*	0.60	i*	0.37	2.3	0.33
f71991-1	i*	0.72	i*	0.0	2.8	0.41
f71991-2	5.9	0.71	i*	0.41	2.5	0.36
Mean		0.69		0.30	2.6	0.37
f82885-2	5.2	0.58	i*	0.34	2.2	0.34
f82885-5	4.9	0.67	i*	0.41	2.6	0.38
f71991-3	i*	0.56	i*	0.0	2.1	0.33
f71991-4	i*	0.60	i*	0.34	2.2	0.32
Mean		0.60		0.27	2.3	0.34
f72786-1	i*	0.64	0.96	0.41	2.5	0.37
f72786-2	i*	0.62	i*	0.39	2.4	0.36
Mean		0.63		0.40	2.5	0.36
f70991-1	i*	0.54	i*	0.30	1.9	0.28
f70991-2	3.9	0.49	0.69	0.29	1.8	0.27
f70991-3	3.7	0.51	0.76	0.35	2.1	0.32
f70991-4	3.5	0.50	0.70	0.30	1.9	0.27
f70991-5	4.6	0.63	0.86	0.37	2.3	0.33
f70991-6	4.7	0.6	0.87	0.34	2.2	0.32
f70991-7c	4.4	0.59	0.77	0.34	2.2	0.31
Mean		0.56		0.33	2.0	0.30
f70991-7b	4.9	0.66	0.94	0.38	2.4	0.34
f70991-8	4.3	0.57	0.81	0.36	2.2	0.31
f70991-9	4.3	0.54	0.74	0.29	1.8	0.27
f70991-10	4.7	0.65	0.93	0.38	2.4	0.35
f70991-11	4.4	0.50	0.67	0.27	1.7	0.25
f70991-12	4.3	0.57	0.75	0.31	1.9	0.28
f70991-13	4.0	0.51	0.66	0.26	1.7	0.24
f70991-14	4.5	0.62	0.89	0.37	2.3	0.34
f70991-15	5.8	0.77	0.98	0.42	2.6	0.41
Mean	4.6	0.60	0.82	0.34	2.1	0.31
f71791-7	3.3	0.48	0.67	0.29	1.8	0.28
f71791-8	i*	0.62	0.81	0.35	2.2	0.31
Mean		0.55	0.74	0.32	2.0	0.30
f71791-11	i*	0.61	i*	0.34	2.3	0.33
f71791-12	4.5	0.60	0.78	0.35	2.1	0.32
Mean		0.61		0.35	2.2	0.33

Table 8. Continued

Field No.	Zr	Hf	Tf	W	Sc	CR
f82885-1	170	5.3	1.9	3.3	5.6	16
f82885-4	160	4.4	1.5	2.4	5.8	14
f71991-1	160	4.9	2.1	2.3	4.1	11
f71991-2	180	5.8	1.9	3.1	6.0	18
Mean	170	5.1	1.8	2.8	5.4	15
f82885-2	130	4.0	1.3	1.3	5.4	14
f82885-5	150	4.6	1.6	0.87	5.0	15
f71991-3	140	4.2	1.5	2.8	4.2	12
f71991-4	160	4.8	1.4	1.8	6.6	18
Mean	140	4.4	1.5	1.7	5.3	15
f72786-1	190	5.7	1.9	2.3	5.5	11
f72786-2	200	5.2	1.6	2.3	5.4	10
Mean	195	5.5	1.8	2.3	5.5	11
f70991-1	280	7.3	0.67	0.62	6.7	26
f70991-2	170	5.1	0.81	1.7	6.1	18
f70991-3	190	5.1	0.66	0.47	5.6	18
f70991-4	190	5.5	0.98	1.0	7.2	24
f70991-5	250	6.4	0.65	2.0	7.0	23
f70991-6	220	6.4	1.0	1.9	7.7	26
f70991-7c	170	5.1	1.1	1.6	6.7	20
Mean	210	5.8	0.88	1.3	6.7	22
f70991-7b	190	5.5	1.2	2.2	6.3	14
f70991-8	170	5.3	1.1	2.1	5.7	13
f70991-9	240	7.3	0.70	0.78	6.7	23
f70991-10	130	3.6	0.87	1.4	5.6	18
f70991-11	230	6.9	0.65	i*	6.6	21
f70991-12	280	7.8	0.59	0.70	6.3	23
f70991-13	280	8.1	0.64	0.90	6.3	23
f70991-14	230	7.7	1.1	i*	7.4	23
f70991-15	500	14	0.88	0.99	8.6	38
Mean	250	7.3	.86		6.6	22
f71791-7	160	4.1	0.81	1.8	5.5	17
f71791-8	210	5.6	0.96	i*	7.0	22
Mean	190	4.9	0.89		6.3	20
71791-11	170	5.1	1.1	1.6	7.1	19
f71791-12	170	4.8	1.0	1.2	6.8	20
Mean	170	5.0	1.1	1.4	7.0	20

Table 8. Continued:

Field No.	Co	Ni	Zn	As	Sb	Au
f82885-1	5.3	2.4	54	9.4	0.64	1.1
f82885-4	5.7	2.8	46	6.5	0.59	0.98
f71991-1	3.6	0.78	46	11	0.74	0.19
f71991-2	5.5	8.2	59	9.6	0.71	0.96
Mean	5.0	.56	51	9.0	0.67	0.81
f82885-2	5.4	8.1	42	6.6	0.56	2.9
f82885-5	4.4	4.7	50	9.5	0.58	1.0
f71991-3	5.7	9.8	39	9.6	0.55	1.4
f71991-4	7.6	12	52	7.5	0.61	1.6
Mean	5.8	8.5	46	8.3	0.57	1.7
f72786-1	3.8	5.8	49	7.1	0.66	0.73
f72786-2	3.8	5.3	46	6.9	0.65	1.4
Mean	3.8	5.6	48	7.0	0.66	1.1
f70991-1	4.8	8.5	38	2.4	0.27	1.7
f70991-2	4.8	7.0	43	3.1	0.42	0.31
f70991-3	4.4	0.67	39	2.6	0.35	0.23
f70991-4	6.6	6.3	55	3.0	0.54	0.57
f70991-5	5.8	5.0	50	3.1	0.54	0.48
f70991-6	6.4	7.3	54	4.3	0.54	0.64
f70991-7c	6.6	7.5	55	4.7	0.57	0.31
Mean	5.6	6.0	47	3.3	0.46	0.63
f70991-7b	4.5	9.1	54	6.1	0.69	1.4
f70991-8	4.4	5.2	47	5.9	0.58	1.6
f70991-9	5.0	5.2	42	2.8	0.39	1.9
f70991-10	6.6	3.6	57	5.1	0.55	2.2
f70991-11	4.9	9.8	38	2.5	0.36	1.2
f70991-12	5.2	7.4	35	2.2	0.28	0.29
f70991-13	5.0	10	37	2.0	0.34	1.4
f70991-14	7.9	12	62	3.8	0.56	0.78
f70991-15	7.4	4.1	56	2.3	0.40	2.0
Mean	5.6	7.4	47	3.6	0.46	1.4
f71791-7	3.8	4.6	39	5.8	0.65	0.22
f71791-8	5.7	0.0	54	6.4	0.71	0.72
Mean	4.8	2.3	47	6.1	0.68	0.47
f71791-11	5.7	11	62	8.3	0.95	1.3
f71791-12	5.9	8.5	58	7.1	0.82	0.91
Mean	5.3	6.0	53	6.9	0.78	0.78

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