Appendix F

Inductively Coupled Plasma Mass Spectrometry Data

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The samples were ground into powders by Brent Miller at the University of North Carolina at Chapel Hill using an aluminum-oxide shatter box and sent to MURR in powdered form. Aliquots of 150 mg were set aside for inductively coupled plasma mass spectrometry (ICP-MS).

The rock samples from Fort Bragg were analyzed by ICP-MS to determine the rare-earth elements present in the rocks with high precision. The aliquot was weighed whole into a precleaned Teflon digestion vessel. Fisher brand Optima grade nitric acid (1 ml) and Fisher brand TraceMetal grade hydrofluouric acid (3 ml) were added. The vessels were sealed and samples were heated in a microwave digestion system. After digestion, the vessels were cooled to room temperature before opening. A second microwave cycle was then performed in which a solution of Aldrich brand 99.999% boric acid (4%, 30 ml) was added to the vessels. The vessels were resealed and heated again in the microwave. Vessel blanks containing only the digestion reagents were similarly prepared in order to check for analyte backgrounds. Quality control samples made from USGS RGM-1 rhyolite and NIST SRM-278 obsidian rock were also digested along with the unknown samples to provide accuracy checks.

The digested samples were transferred with rinsing (18.2 MΩ DI H_2O) to precleaned Nalgene bottles. These digestates were then diluted by a factor of 10 for ICP analysis, and an internal standard of Indium (In) was added to the diluted samples. Linearity standards made from diluted commercial High-Purity Standard stock solutions were prepared to calibrate the ICP-MS. The internal standard of In was also added to all linearity standards. Standards were re-analyzed repeatedly throughout the analytical run to ensure continuous correct instrument response.

Vessel backgrounds were found to be insignificant in comparison to the analyte levels in the samples. Table F.1 lists the results for the 14 rare-earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) along with the data for Hf, Ta, and Th with all values reported in parts per million. Note that some elements are reported by measurement of more than one isotope (^{143}Nd and ^{146}Nd, ^{156}Gd and ^{157}Gd); in these cases, the values given in the table are for the element, not for the individual isotope. The agreement between element concentrations extrapolated from the measurement of different isotopes is excellent.

Table F.1. Element Concentrations as Measured by Inductively Coupled Plasma Mass Spectrometry.

Sample [a]	^{139}La (ppm)	^{140}Ce (ppm)	^{141}Pr (ppm)	^{143}Nd (ppm)	^{146}Nd (ppm)	^{147}Sm (ppm)	^{153}Eu (ppm)	^{156}Gd (ppm)	^{157}Gd (ppm)	^{159}Tb (ppm)	^{163}Dy (ppm)	^{165}Ho (ppm)	^{166}Er (ppm)	^{169}Tm (ppm)	^{172}Yb (ppm)	^{175}Lu (ppm)	^{178}Hf (ppm)	^{181}Ta (ppm)	^{232}Th (ppm)
FBL001	34.4	66.3	8.31	32.5	32.6	7.72	1.180	8.73	8.39	1.44	9.16	1.96	5.87	0.906	6.12	0.951	5.60	0.670	10.26
FBL002	33.0	67.7	8.62	33.5	34.0	8.22	1.241	9.99	9.19	1.69	10.90	2.42	7.45	1.239	8.35	1.373	7.26	0.886	12.99
FBL003	36.4	73.3	9.19	36.3	36.4	9.05	1.277	10.93	10.14	1.83	11.92	2.59	7.91	1.196	7.91	1.224	5.74	0.708	9.74
FBL004	24.2	52.5	6.62	26.7	26.3	6.96	0.970	8.29	8.07	1.46	9.49	2.06	6.20	0.998	6.57	1.063	7.21	0.869	12.59
FBL005	35.0	73.5	9.44	38.0	38.0	9.06	0.699	10.45	9.58	1.73	11.05	2.39	7.15	1.094	7.29	1.137	5.56	0.754	12.76
FBL006	34.4	71.7	9.16	36.1	36.5	9.09	1.164	10.54	9.86	1.84	11.96	2.71	8.31	1.348	8.86	1.457	7.46	0.931	13.75
FBL007	27.8	46.4	7.39	28.4	28.1	6.30	0.830	6.43	5.95	1.05	6.24	1.46	4.51	0.724	5.05	0.802	5.66	0.694	10.00
FBL008	27.9	60.5	7.81	32.8	32.2	8.14	1.321	9.74	9.22	1.63	10.83	2.39	7.21	1.138	7.31	1.148	6.97	0.669	10.15
FBL009	27.6	59.4	7.70	31.5	31.4	8.07	1.281	9.59	9.16	1.66	10.91	2.40	7.36	1.146	7.44	1.161	6.87	0.663	10.70
FBL010	24.2	53.1	6.90	28.7	28.2	7.25	1.043	8.32	7.91	1.42	9.16	2.09	6.53	1.018	6.80	1.086	6.25	0.593	8.87
FBL011	29.3	64.0	8.42	33.9	34.1	8.58	1.258	10.31	9.84	1.81	11.74	2.61	7.94	1.261	8.41	1.338	8.31	0.851	13.59
FBL012	28.8	62.1	8.03	33.0	32.6	8.25	1.182	9.86	9.26	1.68	10.99	2.43	7.36	1.130	7.41	1.158	7.07	0.724	11.11
FBL013	23.5	52.3	6.87	28.2	28.0	7.15	1.033	7.91	7.88	1.40	9.16	2.01	6.16	0.989	6.57	1.024	6.14	0.582	9.45
FBL014	25.4	53.4	6.87	28.5	28.3	6.73	1.623	7.60	7.04	1.23	7.46	1.71	5.18	0.798	5.17	0.801	5.89	0.515	7.73
FBL015	30.0	62.4	7.78	30.2	30.5	7.13	0.896	8.52	7.66	1.36	8.62	1.87	5.72	0.907	6.04	0.977	6.47	0.860	13.86
FBL016	27.0	55.7	6.81	26.7	26.7	6.40	0.859	7.65	7.06	1.27	8.46	1.90	5.83	0.914	5.99	0.949	5.37	0.695	11.43
FBL017	29.1	60.3	7.47	29.4	29.1	7.00	0.876	8.05	7.46	1.33	8.81	1.97	5.93	0.930	6.23	1.001	6.08	0.809	13.18
FBL018	26.9	55.4	6.83	26.8	26.4	6.23	0.790	7.25	7.09	1.24	8.33	1.87	5.73	0.904	6.09	0.952	5.19	0.638	11.41
FBL019	27.8	57.6	7.08	27.6	27.5	6.65	0.888	7.68	7.07	1.27	8.11	1.80	5.41	0.831	5.60	0.877	5.52	0.745	12.19
FBL020	19.5	39.6	4.91	19.3	19.3	4.32	0.914	4.74	4.32	0.73	4.62	0.99	2.97	0.453	2.91	0.464	3.11	0.428	5.42
FBL021	18.9	41.3	5.43	22.7	22.4	5.55	1.328	6.45	5.95	1.09	7.06	1.60	4.91	0.820	5.42	0.895	5.88	0.234	5.25
FBL022	19.9	42.8	5.57	23.1	23.2	5.28	1.238	6.01	5.59	0.99	5.95	1.41	4.45	0.698	4.80	0.778	5.05	0.227	4.50
FBL023	15.3	31.1	3.99	16.7	16.3	3.94	0.860	4.41	4.08	0.71	4.60	1.03	3.14	0.486	3.23	0.487	2.49	0.235	3.87
FBL024	18.9	40.8	5.35	22.3	22.1	5.07	1.094	5.53	5.10	0.88	5.47	1.21	3.55	0.548	3.59	0.537	3.56	0.383	5.43
FBL025	31.6	63.7	7.75	29.0	28.7	6.10	0.809	6.70	6.23	1.07	6.64	1.50	4.62	0.724	4.96	0.820	4.79	0.857	12.49
FBL026 (1)	28.1	55.8	6.64	25.0	24.5	5.41	0.748	5.79	5.26	0.88	5.61	1.22	3.74	0.575	3.82	0.598	3.65	0.661	9.06
FBL026 (2)	28.3	56.1	6.63	25.1	24.9	5.31	0.743	5.98	5.25	0.88	5.55	1.23	3.77	0.577	3.83	0.601	3.64	0.647	9.13
FBL027	18.2	60.8	7.06	29.0	28.3	7.24	1.387	7.96	7.34	1.23	7.79	1.71	5.10	0.755	4.63	0.688	4.45	1.110	15.17
FBL028	47.0	94.6	11.74	44.7	44.8	9.89	1.715	9.75	9.08	1.46	8.36	1.67	4.56	0.634	3.86	0.567	5.94	1.412	19.32
FBL029	35.2	74.2	9.27	35.2	35.3	7.27	1.428	6.85	6.68	1.11	6.70	1.37	4.05	0.604	3.81	0.565	3.95	0.865	12.74
FBL030	174.2	240.0	22.98	86.8	86.6	17.31	3.351	16.95	17.11	2.68	14.97	2.90	7.67	1.035	6.06	0.857	4.85	1.129	16.27
FBL031	57.3	209.7	16.10	62.8	62.5	13.65	0.529	12.64	12.72	2.14	12.94	2.71	8.08	1.248	8.18	1.262	15.46	1.536	14.75
FBL032	58.5	268.9	17.14	65.7	66.4	14.66	0.465	13.12	13.54	2.36	14.41	3.08	9.07	1.420	9.03	1.461	18.17	1.752	17.17
FBL033	63.4	266.0	17.60	68.1	67.6	14.40	0.422	13.38	13.95	2.35	14.35	3.06	9.22	1.452	9.26	1.473	17.72	1.673	16.39
FBL034	58.7	211.9	16.36	64.0	63.9	13.82	0.500	12.98	13.00	2.18	13.14	2.77	8.17	1.244	8.04	1.226	14.69	1.438	13.55

Table F.1. Element Concentrations as Measured by Inductively Coupled Plasma Mass Spectrometry (continued).

Sample [a]	^{139}La (ppm)	^{140}Ce (ppm)	^{141}Pr (ppm)	^{143}Nd (ppm)	^{146}Nd (ppm)	^{147}Sm (ppm)	^{153}Eu (ppm)	^{156}Gd (ppm)	^{157}Gd (ppm)	^{159}Tb (ppm)	^{163}Dy (ppm)	^{165}Ho (ppm)	^{166}Er (ppm)	^{169}Tm (ppm)	^{172}Yb (ppm)	^{175}Lu (ppm)	^{178}Hf (ppm)	^{181}Ta (ppm)	^{232}Th (ppm)
FBL035	22.1	48.4	6.21	24.9	25.0	5.44	1.334	5.56	5.21	0.81	4.43	0.99	2.89	0.430	2.74	0.412	4.16	0.500	6.54
FBL036	25.8	51.8	6.15	23.1	22.8	4.48	0.798	3.97	3.98	0.63	3.79	0.81	2.49	0.378	2.67	0.412	5.24	0.443	8.47
FBL037	35.4	73.4	9.18	36.5	36.3	7.34	1.463	7.49	6.86	1.02	5.96	1.26	3.63	0.540	3.61	0.580	5.50	0.581	8.90
FBL038	18.7	36.5	4.85	21.0	21.0	4.57	1.223	4.46	4.24	0.60	3.40	0.67	1.93	0.265	1.62	0.258	2.47	0.162	2.16
FBL039 (1)	12.9	33.8	4.17	15.9	15.7	3.98	0.494	3.99	3.79	0.71	4.65	1.03	3.30	0.522	3.58	0.557	6.45	0.828	11.82
FBL039 (2)	13.6	35.5	4.47	16.8	16.5	4.13	0.500	3.85	3.42	0.62	3.79	0.82	2.66	0.453	3.09	0.503	6.69	0.845	12.37
FBL040	11.9	31.7	4.92	23.6	23.3	6.23	2.081	6.63	6.38	1.02	6.26	1.29	3.55	0.513	3.27	0.483	1.92	0.106	0.35
FBL041	10.8	27.0	3.88	17.7	17.4	4.24	1.327	4.33	4.06	0.63	3.57	0.71	1.92	0.274	1.66	0.217	0.85	0.085	0.54
FBL042	7.9	18.9	2.64	12.1	11.8	3.07	1.004	3.60	3.53	0.59	3.69	0.79	2.31	0.330	2.22	0.319	1.27	0.045	0.45
FBL043	38.9	70.2	8.65	33.7	33.6	6.76	1.678	6.83	6.19	0.92	5.27	1.12	3.27	0.494	3.28	0.521	6.34	0.430	10.50
FBL044	26.0	65.1	9.18	37.8	37.5	8.76	1.943	8.96	8.12	1.31	7.57	1.59	4.66	0.737	4.94	0.807	7.19	0.614	7.38
FBL045	30.2	58.1	6.96	27.3	27.0	5.53	1.308	5.31	4.88	0.76	4.40	0.93	2.81	0.432	2.81	0.470	5.84	0.403	9.65
FBL046	21.3	43.0	5.38	21.2	21.2	4.61	1.091	4.26	3.98	0.64	3.76	0.78	2.30	0.344	2.41	0.369	4.31	0.298	6.17
FBL047	19.9	42.0	5.29	20.4	20.2	3.96	0.883	3.90	3.62	0.57	3.43	0.75	2.27	0.358	2.56	0.412	5.11	0.317	3.16
FBL048	27.6	59.0	7.67	29.5	29.3	5.88	1.320	5.90	5.23	0.84	5.11	1.09	3.34	0.528	3.58	0.599	7.12	0.419	4.43
FBL049 (1)	28.3	60.2	7.57	29.1	29.0	5.63	1.214	5.46	4.89	0.78	4.65	1.00	3.10	0.491	3.44	0.568	7.49	0.449	4.46
FBL049 (2)	28.1	60.7	7.58	29.2	29.3	5.74	1.212	5.35	4.81	0.76	4.73	1.01	3.13	0.493	3.44	0.565	7.29	0.428	4.36
FBL050	26.4	55.9	7.04	27.0	26.8	5.25	1.096	4.65	4.62	0.74	4.30	0.92	2.83	0.440	3.01	0.487	5.92	0.343	3.59
FBL051	21.8	43.5	5.13	19.2	18.9	4.16	0.632	4.63	4.18	0.73	4.65	1.02	3.15	0.505	3.45	0.554	3.80	0.653	9.89
FBL052	20.8	39.6	4.49	16.3	16.4	3.33	0.499	3.55	3.36	0.55	3.66	0.76	2.34	0.368	2.52	0.400	2.71	0.441	6.56
FBL053	24.6	48.4	5.60	20.6	20.9	4.48	0.786	4.82	4.34	0.73	4.32	1.04	3.26	0.522	3.41	0.562	3.75	0.637	9.46
FBL054	26.1	51.3	6.05	22.8	22.5	4.73	0.680	4.88	4.65	0.79	4.95	1.12	3.37	0.551	3.64	0.590	3.75	0.561	10.42
FBL055	17.4	36.9	4.71	19.2	19.2	4.33	1.036	4.84	4.46	0.71	4.35	0.94	2.78	0.410	2.60	0.392	2.57	0.340	4.55
FBL056	20.6	43.8	5.61	20.7	20.5	4.46	0.796	4.49	4.16	0.71	4.31	0.98	3.18	0.535	3.58	0.599	4.37	0.725	9.53
FBL057	46.8	93.3	11.54	43.6	43.6	9.32	1.559	9.69	8.56	1.51	10.17	2.41	8.36	1.445	8.93	1.365	5.00	1.219	16.84
FBL058	59.1	136.6	16.63	64.5	64.3	13.75	0.416	12.57	12.72	2.16	13.12	2.76	8.16	1.246	8.25	1.254	14.99	1.449	14.44
FBL059	51.3	191.6	15.03	58.9	58.8	13.00	0.472	11.99	12.15	2.08	12.36	2.61	7.61	1.174	7.69	1.192	14.98	1.471	14.19
FBL060	26.8	60.2	7.19	28.7	28.6	6.38	0.585	6.75	6.18	1.06	6.85	1.41	4.14	0.637	4.26	0.668	4.87	0.705	8.64
FBL061	25.7	55.7	6.86	27.5	27.3	6.21	0.644	6.77	6.30	1.07	6.78	1.44	4.34	0.671	4.39	0.694	4.56	0.660	7.95
FBL062	28.0	58.5	7.61	30.0	29.9	6.68	0.665	7.20	6.60	1.14	7.16	1.57	4.67	0.745	4.82	0.788	5.24	0.748	9.57
FBL063	28.8	61.2	7.68	30.2	30.0	6.60	0.546	7.04	6.40	1.11	6.99	1.47	4.50	0.702	4.65	0.722	4.58	0.682	8.12
FBL064	29.6	64.0	8.18	32.0	32.4	7.28	0.583	7.43	6.83	1.14	7.08	1.62	4.78	0.748	5.00	0.813	5.90	0.844	10.77
FBL065	33.7	73.3	9.22	36.8	37.0	8.27	0.702	9.02	8.25	1.39	8.62	1.85	5.43	0.839	5.58	0.880	5.42	0.800	9.93
FBL066	27.4	58.9	7.37	28.3	28.1	5.43	1.181	5.36	4.81	0.78	4.72	1.03	3.18	0.511	3.61	0.596	7.61	0.431	4.65
FBL067	23.9	50.9	6.60	26.9	27.3	5.57	1.633	5.74	5.22	0.81	4.90	1.04	3.05	0.458	2.95	0.471	4.41	0.308	2.97

Table F.1. Element Concentrations as Measured by Inductively Coupled Plasma Mass Spectrometry (continued).

Sample [a]	^{139}La (ppm)	^{140}Ce (ppm)	^{141}Pr (ppm)	^{143}Nd (ppm)	^{146}Nd (ppm)	^{147}Sm (ppm)	^{153}Eu (ppm)	^{156}Gd (ppm)	^{157}Gd (ppm)	^{159}Tb (ppm)	^{163}Dy (ppm)	^{165}Ho (ppm)	^{166}Er (ppm)	^{169}Tm (ppm)	^{172}Yb (ppm)	^{175}Lu (ppm)	^{178}Hf (ppm)	^{181}Ta (ppm)	^{232}Th (ppm)
FBL068 (1)	31.5	70.2	9.14	35.7	35.7	7.35	1.593	7.11	6.42	1.05	6.16	1.49	4.65	0.715	4.82	0.759	6.79	0.698	7.33
FBL068 (2)	31.0	69.3	9.03	35.6	35.4	7.33	1.559	7.09	6.46	1.06	6.23	1.47	4.62	0.717	4.85	0.758	6.82	0.716	7.37
FBL069	25.7	46.8	5.56	21.3	20.9	4.23	1.015	3.74	3.78	0.57	3.41	0.70	2.12	0.331	2.23	0.349	4.40	0.278	7.40
FBL070	8.0	19.1	2.66	11.9	12.1	2.80	1.038	2.55	2.44	0.36	2.02	0.39	1.12	0.154	0.97	0.155	0.75	0.075	1.42
FBL071	6.6	15.6	2.13	9.8	9.6	2.50	0.949	2.83	2.66	0.42	2.49	0.52	1.46	0.207	1.24	0.184	0.75	0.039	0.26
FBL072	27.8	59.8	7.92	32.3	32.4	8.17	1.549	9.68	8.95	1.65	10.71	2.35	7.13	1.102	7.06	1.097	6.09	0.726	9.19
FBL073	28.4	57.2	9.37	42.2	42.0	10.49	2.418	11.51	10.89	1.82	11.03	2.34	6.74	0.990	6.55	1.033	5.21	0.430	6.82
FBL074	28.7	59.3	7.26	27.8	27.3	5.85	1.136	6.37	5.72	0.96	5.81	1.23	3.72	0.572	3.60	0.541	4.29	0.803	9.99
FBL075	16.4	38.1	5.47	24.5	24.6	6.00	1.887	6.49	6.15	0.98	5.93	1.28	3.64	0.533	3.46	0.525	3.98	0.259	3.25
FBL076	33.1	66.2	8.10	30.1	29.9	6.55	0.867	7.16	6.58	1.17	7.48	1.65	5.01	0.819	5.47	0.869	10.24	1.663	16.37
FBL077	22.6	47.3	5.81	22.7	22.9	4.95	0.918	4.89	4.38	0.71	4.29	0.96	3.26	0.536	3.88	0.652	5.45	0.713	8.83
FBL078	25.7	54.1	6.55	25.2	25.2	5.69	1.214	6.25	5.82	0.98	6.06	1.34	4.01	0.625	4.11	0.642	7.22	0.789	9.82
FBL079	24.8	53.5	6.80	27.5	27.4	6.34	1.570	7.36	6.84	1.18	7.60	1.70	5.04	0.765	5.07	0.786	6.24	0.686	8.78
FBL080	25.5	54.2	6.94	29.0	28.9	6.97	1.242	8.28	7.82	1.37	8.73	1.93	5.82	0.899	5.83	0.908	5.41	0.587	6.93

[a] Samples FBL026, FBL039, FBL049, and FBL068 were each measured twice; the concentration values for each measurement are listed separately.