UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Neutron-activation analytical results and sample locality map of drill-cuttings from wells in northwestern Minnesota

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Open-File Report 91-44

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1991

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STUDIES RELATED TO CUSMAP

This report presents part of the results of a geochemical survey of the Roseau 1° x 2° quadrangle, Minnesota. Geochemical samples were collected as one of several multidisciplinary studies associated with the Conterminous United States Mineral Appraisal Program (CUSMAP).

INTRODUCTION

From 1985 to 1987, the U.S. Geological Survey conducted a reconnaissance geochemical survey of the Roseau 1° x 2° quadrangle, Minnesota. Glacially derived overburden covers all of the bedrock in this area of northwestern Minnesota. Basal till, saprolite, and bedrock in the Roseau 1° x 2° quadrangle could only be directly sampled in drill cuttings stored at the Minnesota Geological Survey in St. Paul, Minnesota. Cuttings were available from eleven wells that had been drilled in the western part of the Roseau 1° x 2° quadrangle and the eastern half of the Thief River Falls 1° x 2° quadrangle. Drill-cutting samples were collected from all 11 wells.

Metavolcanic rocks, metasediments, and granitic plutons of the Archean Wabigoon belt underlie the area in which these wells were drilled (Day and others, in review). Proterozoic mafic dikes cut the Archean basement (Southwick and Day, 1983). Ordovician sedimentary rocks were deposited over the Precambrian basement in western Kittson County (Webers, 1972). Saprolite as much as 50 meters thick formed on the Precambrian and Paleozoic rocks in this area during the Cretaceous (D.L. Southwick, Minnesota Geological Survey, personal commun.). Cretaceous sedimentary rocks overly this regolith in western Marshall and southern Kittson Counties (Austin, 1972). Extensive glacial and glaciolacustrine deposits cover northwestern Minnesota to depths sometimes in excess of 100 meters Robert J. Horton, U.S. Geological Survey, personal commun.). This corner of Minnesota is part of a largely featureless, poorly dissected, lake bed resulting from Glacial Lake Agassiz (Wright, 1972).

METHODS OF STUDY

Sample Media

Well cuttings are coarsely pulverized rock material produced as the result of drilling a well. As the drill penetrates rock, cuttings are flushed from the hole in the drilling mud or circulating water that is pumped down the drill stem. The cuttings are collected over intervals in depth, and they are largely representative of the rock through which the drill penetrated in the specified drilling interval. As the drilling fluid circulates up the hole, there is some mixing of cuttings between intervals and contamination with material sloughing off the sides of the hole. In spite of this contamination, well cuttings are representative of a particular rock interval.

Sample Collection

Splits of cuttings were collected at the Minnesota Geological Survey. The locations of wells from which the splits were collected are shown in figure 1. Information about each well is listed in Table 1.

Sample Preparation

Well-cutting samples were crushed and then pulverized to minus-0.15 mm with ceramic plates.

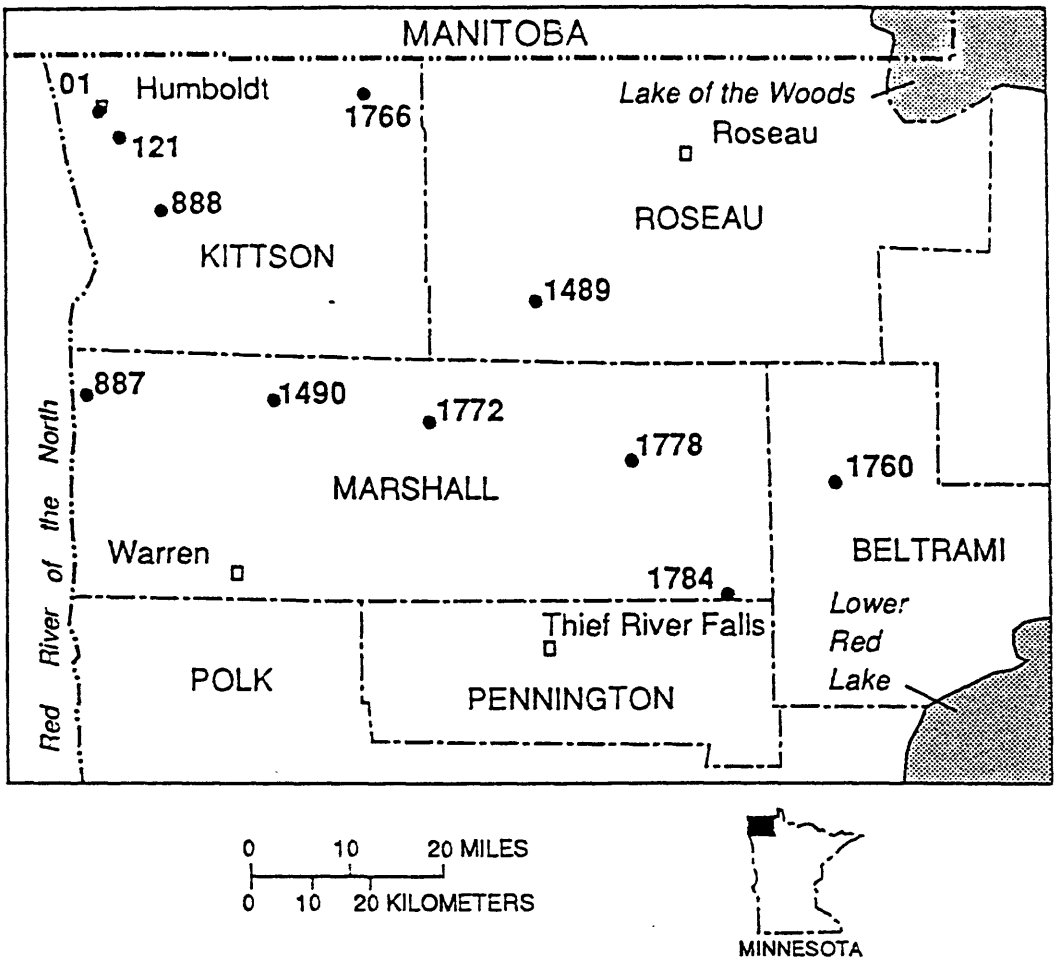

Figure 1. Localities of sampled wells in northwestern Minnesota.

Table 1. Description of sampled wells in northwestern Minnesota.

MGS no.	Well	County	Total depth (in ft)	Bottom unit
01	Humboldt City	Kittson	610	schist
121	Florence #1	Kittson	625	granitic gneiss
887	Thibidaux #1	Marshall	322.5	Red River fm.
888	Hallock "A"	Kittson	520	Winnipeg fm.
1489	DOE RRVD-29	Roseau	320	mylonitic schist
1490	DOE RRVD-30	Marshall	367	schist
1760	USGS B-PL-1D2	Beltrami	355	saprolite on Precambrian rock
1766	USGS K-PL-1B2	Kittson	395	granodiorite
1772	USGS M-PL-1B2	Marshall	454.5	granofels
1778	USGS M-PL-2B2	Marshall	248.5	metabasalt
1784	USGS M-PL-3B2	Marshall	171.5	granite

Sample Analysis

Activation analysis method

The stream-sediment, heavy-mineral-concentrate, and rock samples were analyzed for 23-28 elements using a slight modification of the instrumental activation analysis (INAA) method from Baedecker and McKown, 1987. The samples were irradiated in the USGS TRIGA reactor for 8 hours at a flux of approximately 2 X 10^{12}. The gamma-ray spectra of the samples were obtained in the USGS Denver facilities at approximately 9 and 23 days after irradiation on both a high resolution coaxial Ge and a low-energy photon (LEPD) detector. Results were obtained by computer comparison of spectra derived from the sample against spectra obtained from standards made from a combined quartz standard (CQS) that has been standardized against Geological Survey reference samples. Data analysis in the Denver laboratory was carried out using slightly modified software for the iterative least-squares analysis of complex peaks (SAMPO written by J.T. Routti, Lawrence Radiation Laboratory, Berkeley, California) and software for data management and report form generation written by USGS. The elements analyzed and their lower limits of determination vary with the matrix of the sample. Estimates of the concentration levels that have a 10 percent error due to counting statistics are listed in table 2. The estimates were determined under idealized conditions and will improve or degrade with differences in matrix.

ROCK ANALYSIS STORAGE SYSTEM

Upon completion of all analytical work, the analytical results were entered into a computer-based file called Rock Analysis Storage System (RASS). This data base contains both descriptive geological information and analytical data. Any or all of this information may be retrieved and converted to a binary form (STATPAC) for computerized statistical analysis or publication (VanTrump and Miesch, 1977).

DESCRIPTION OF DATA TABLES

Analytical data for well-cutting samples from northwestern Minnesota are listed in table 3. The Minnesota Geological Survey (MGS) number contains three numbers separated by dashes (-). The first number is the well number. The second and third numbers indicate the depth interval in feet over which the cuttings in that sample were collected. Latitude and longitude are given in degrees, minutes, and seconds. In general, the within-run precision of each element is given by the percent-coefficient of variation (cv%) determined by comparing the abundances obtained from each gamma-ray line determined for the specific sample. The exceptions are Sr, Zr, and Ni, for which there is only one determination, and a counting statistic error is reported. Values determined for the major elements (iron, sodium) are given in weight percent; gold is given in parts per billion (nanograms/gram); all others are given in parts per million (micrograms/gram). If there was a significant interference on the determination of an element (>30%), the value obtained by the interference calculation is reported and is given a cv = 60%, and a "less than" symbol (<) is entered in front of the value. If an element was not detected because of spectral interferences of low abundance in a sample, a dash (-) is entered in table 3 in place of an analytical value. In the three cases where detectable gold was found in a sample, the cv is less than 10 percent.

Table 2. Instrumental neutron-activation analysis detection limits: approximate concentrates at 10% error (matrix dependent).

Element	Concentration
Fe	.0402 %
Na	0.0125
Cs	0.26 ppm
Ba	73.0
Rb	12.0
Sr	98.
Th	0.11
U	0.58
La	0.43
Ce	3.9
Nd	10.0
Sm	0.07
Eu	0.1
Tb	0.25
Yb	0.15
Lu	0.03
Ta	0.30
Zr	126.
Hf	0.18
Sb	0.21
Sc	0.07
Cr	2.7
Co	0.13
Ni	22.
Zn	2.20
As	1.12
W	1.12
Au	5.0 ppb

Table 3.--Major-element, trace-element, and rare-earth-element concentrations for drill cutting samples from test wells in northwestern Minnesota.

MGS no.	Lab. no.	Lat	Long	Fe	cv %	Na	cv %	Rb	cv %	Sr	cv %	Cs	cv %	Be	cv %	Zr	cv %	Hf	cv %	Te	cv %	Sc	cv %	Cr	cv %	Co	cv %	Ni	cv %	Zn	cv %
01-550-556	D-275065	485514	0970556	3.27	1	0.775	1	138	1	129	6	6.28	1	210	2	99.9	8	3.57	1	0.824	1	12.0	1	91.8	2	14.7	1	42.5	4	61.1	3
01-556-560	D-275066	485514	0970556	3.88	1	1.08	1	109	2	162	7	4.51	1	280	1	144	8	3.65	1	0.809	1	14.9	1	93.2	2	12.7	1	41.8	7	57.1	3
01-560-571	D-275067	485514	0970556	3.76	1	0.922	1	129	1	215	4	5.71	1	286	2	143	10	3.62	1	0.947	1	17.2	1	105	2	14.8	1	45.4	6	--	--
01-571-592	D-275068	485514	0970556	3.54	1	2.14	1	163	1	218	7	6.51	1	440	1	205	5	5.05	1	1.07	1	15.0	1	108	2	15.1	1	46.8	9	58.6	3
01-592-610A	D-275069	485514	0970556	4.42	1	0.670	1	156	1	145	8	6.91	1	427	2	170	7	4.56	1	0.980	2	16.9	1	111	2	22.9	1	54.9	3	64.5	3
01-592-610B	D-275070	485514	0970556	4.33	1	0.705	1	--	--	157	9	7.45	2	422	2	155	10	4.63	1	1.01	1	17.5	1	119	2	22.4	1	60.2	7	65.6	3
121-470-475	D-275071	485237	0970234	2.48	1	0.0422	1	31.9	2	74.4	5	1.51	1	160	1	56.2	9	2.02	3	0.210	1	4.07	1	26.9	2	4.40	1	10.3	12	12.3	5
121-480-485	D-275072	485237	0970234	1.13	1	0.0355	3	20.6	1	76.5	6	0.955	1	83.9	1	32.1	5	1.34	1	0.132	1	2.75	1	16.9	1	3.12	1	7.1	18	8.79	5
121-485-490	D-275073	485237	0970234	1.83	1	0.144	1	57.8	1	116	6	2.83	1	211	2	98.8	7	3.15	1	0.419	1	6.55	1	37.6	4	5.60	1	12.6	5	37.0	3
121-490-495	D-275074	485237	0970234	3.31	1	0.360	1	61.2	1	153	6	2.94	1	199	2	91.0	9	2.63	3	0.509	2	11.1	1	54.0	2	12.3	1	29.1	9	60.5	3
121-500-505	D-275075	485237	0970234	4.01	1	0.479	1	176	1	211	3	8.25	1	391	1	173	3	3.87	2	0.978	1	16.8	1	114	2	16.6	1	53.9	6	--	--
121-505-510	D-275076	485237	0970234	4.08	1	0.454	2	174	1	198	3	7.96	1	407	1	149	6	3.75	3	0.955	2	17.0	1	110	2	17.5	1	54.0	6	75.4	3
121-510-515	D-275077	485237	0970234	4.09	1	0.444	1	183	1	188	4	8.15	1	579	3	141	9	4.04	2	0.965	1	16.8	1	117	2	18.1	1	55.4	4	85.1	3
121-520-525	D-275078	485237	0970234	4.27	1	0.391	1	164	1	203	7	7.70	1	691	1	130	6	3.66	1	0.912	1	16.5	1	100	7	21.1	1	42.2	6	--	--
121-530-535	D-275079	485237	0970234	3.82	1	0.469	1	168	2	250	6	7.03	1	828	1	156	8	4.46	3	0.985	1	15.3	1	110	2	19.5	1	50.8	6	71.6	3
121-540-545	D-275080	485237	0970234	4.25	1	0.275	2	130	1	209	3	5.23	1	717	2	--	--	4.12	2	0.775	2	17.4	2	103	2	24.5	1	59.2	5	80.1	3
121-545-550	D-275081	485237	0970234	4.83	1	0.331	1	84.4	1	160	7	2.87	1	605	1	185	9	4.13	4	0.597	1	20.6	1	118	5	26.4	1	49.5	7	85.9	3
121-550-555	D-275082	485237	0970234	4.26	1	0.328	1	87.8	2	166	7	3.31	1	579	1	151	8	3.68	7	0.517	1	16.6	2	104	2	22.1	1	47.9	5	68.9	3
121-555-560	D-275083	485237	0970234	7.13	1	0.257	1	84.8	1	150	3	3.08	1	555	1	237	5	4.60	5	0.608	3	19.4	3	114	2	30.8	2	71.8	3	95.7	3
121-560-565	D-275084	485237	0970234	4.65	1	0.286	2	94.4	1	142	6	3.27	2	848	1	181	2	3.95	2	0.578	2	17.7	1	131	2	26.4	1	98.2	6	64.0	4
121-565-570	D-275085	485237	0970234	4.44	1	0.576	1	81.1	1	170	5	3.58	1	570	2	201	5	5.21	3	0.532	3	16.4	3	110	2	25.5	1	132	2	96.4	3
121-570-575	D-275086	485237	0970234	5.33	1	1.06	1	58.5	3	334	2	1.96	3	1030	3	129	9	2.69	3	0.303	1	16.1	2	116	4	23.8	1	179	2	66.8	3
887-195-200	D-275087	482930	0970741	2.48	1	0.886	1	68.3	1	210	5	3.46	1	427	2	89.7	8	2.86	1	0.601	1	8.28	2	52.6	2	9.37	1	27.8	9	71.3	3
887-320-325	D-275088	482930	0970741	0.546	1	0.0593	4	10.9	3	173	2	0.527	2	36.6	1	--	--	0.373	2	0.0934	1	1.30	1	7.63	1	1.70	2	2.8	21	7.78	5
888-425-430	D-275089	484606	0965651	3.00	1	0.524	1	85.9	1	188	4	4.77	2	399	1	118	5	3.29	3	0.728	1	10.8	1	67.2	2	11.0	1	31.5	11	84.7	3
888-450-455	D-275090	484606	0965651	2.70	1	0.350	1	94.4	1	194	5	4.43	2	312	1	139	4	3.76	1	0.652	1	9.67	1	65.4	3	10.5	1	34.5	5	59.4	3
888-475-480	D-275091	484606	0965651	3.37	1	0.238	6	93.6	2	208	5	4.65	1	301	2	160	4	4.48	1	0.849	1	12.4	1	87.3	2	13.5	1	43.3	4	--	--
888-485-490	D-275092	484606	0965651	2.43	1	0.224	2	67.8	1	213	3	3.37	1	262	2	135	4	3.75	1	0.624	1	8.30	1	54.4	2	8.55	1	31.4	7	50.5	3
888-495-500	D-275093	484606	0965651	5.54	1	0.329	1	66.9	1	134	7	3.05	1	180	2	162	9	3.44	2	0.487	1	20.9	1	145	2	19.6	1	55.9	5	--	--
888-505-510	D-275094	484606	0965651	5.61	1	0.368	2	74.6	1	130	8	3.47	1	228	2	122	6	3.15	2	0.484	3	19.5	1	170	2	22.3	1	68.3	4	--	--
888-515-520	D-275095	484606	0965651	5.06	1	0.594	4	50.0	1	128	9	2.56	1	179	2	78.6	14	2.61	3	0.375	1	19.4	1	220	2	25.8	1	83.7	1	--	--

Table 3.--Major-element, trace-element, and rare-earth-element concentrations from drill cutting samples for test wells in northwestern Minnesota--(continued).

MGS no.	Lab. no.	Lat	Long	Fe	cv %	Na	cv %	Rb	cv %	Sr	cv %	Cs	cv %	Be	cv %	Zr	cv %	Hf	cv %	Te	cv %	Sc	cv %	Cr	cv %	Co	cv %	Ni	cv %	Zn	cv %
1489-265-270	D-275059	483830	0960521	5.73	1	3.04	1	82.6	1	64	16	1.16	1	374	1	156	12	3.77	2	1.09	2	14.6	1	462	6	31.5	1	150	2	144	6
1489-275-280	D-275060	483830	0960521	4.13	1	3.30	1	87.0	1	69.1	10	1.18	1	380	2	108	6	3.38	1	1.15	1	10.9	1	219	5	21.6	1	89.8	4	116	5
1489-285-290	D-275061	483830	0960521	9.54	1	2.15	2	40.7	3	--	--	0.705	5	185	3	112	13	3.90	3	1.69	2	28.9	1	479	6	45.5	1	196	5	198	7
1489-295-300	D-275062	483830	0960521	5.67	1	2.15	1	83.9	1	48	19	1.17	4	260	2	82.8	11	3.29	1	1.07	1	17.0	1	348	7	28.7	1	126	3	125	5
1489-305-310	D-275063	483830	0960521	3.19	1	2.38	1	133	1	43	16	1.41	1	394	2	83.2	12	2.96	1	0.979	1	9.73	1	164	4	15.6	1	54.6	5	76.2	7
1489-315-320	D-275064	483830	0960521	2.79	1	2.62	1	160	1	30	28	1.75	1	273	3	107	10	3.37	1	1.70	1	8.55	1	165	4	14.1	1	65.2	5	61.7	5
1490-350-355	D-275096	482928	0964100	1.17	1	0.436	4	24.7	1	85.4	3	0.767	1	905	1	61.4	6	1.99	1	0.244	2	2.48	1	15.7	2	6.27	1	21.7	5	28.7	3
1490-360-365	D-275097	482928	0964100	1.88	1	--	--	41.7	1	179	4	1.68	1	471	1	117	3	2.99	1	0.462	1	6.06	1	31.4	4	9.13	1	23.6	8	52.3	3
1490-365-367	D-275098	482928	0964100	1.81	1	--	--	40.0	3	128	7	1.89	3	480	1	131	4	3.49	1	0.479	1	5.39	1	32.6	2	17.4	1	35.9	5	69.6	3
1760-270-275	D-275029	482236	0952432	1.80	1	1.60	1	45.5	2	250	3	1.06	4	441	1	106	11	2.43	1	0.318	3	5.28	2	41.9	3	7.17	1	27.6	11	31.2	5
1760-275-280	D-275030	482236	0952432	2.50	1	1.51	1	47.2	1	211	8	1.06	1	492	1	109.8	9	2.26	2	0.303	2	6.61	2	66.2	3	10.7	1	33.6	8	43.8	3
1760-285-290	D-275031	482236	0952432	2.72	1	1.21	1	55.0	3	168	3	1.70	1	420	1	81.6	13	2.59	1	0.311	2	8.93	1	58.6	4	10.6	1	38.3	6	58.4	6
1760-295-300	D-275032	482236	0952432	2.90	1	1.28	1	56.8	2	196	2	1.59	3	430	1	147	6	3.88	1	0.400	1	6.09	1	41.1	4	9.35	1	25.3	9	61.5	6
1760-305-310	D-275033	482236	0952432	5.96	1	1.06	1	--	--	152	8	1.57	2	422	1	188	4	4.29	2	2.43	2	6.96	1	47.0	3	16.2	1	27.2	15	103	5
1760-315-320	D-275034	482236	0952432	4.81	1	1.01	3	48.7	1	150	7	1.20	3	351	1	142	5	3.71	1	0.351	1	8.23	2	46.0	6	15.1	1	34.2	8	111	5
1760-325-330	D-275035	482236	0952432	4.97	1	1.07	1	52.7	2	162	5	1.40	2	382	1	105	10	3.54	1	0.425	3	7.92	2	42.4	7	16.2	1	39.8	6	108	6
1760-335-340	D-275036	482236	0952432	4.31	1	1.14	1	53.4	1	214	4	1.40	1	380	1	156	4	3.95	1	0.409	1	7.89	1	51.2	5	14.3	1	37.0	7	116	3
1760-350-355	D-275037	482236	0952432	3.54	1	1.85	1	58.3	1	261	5	1.62	1	424	1	141	3	3.64	1	0.396	2	7.24	2	45.0	6	12.4	1	32.5	8	91.1	4
1766-355-357	D-275038	485658	0962918	3.01	1	0.916	1	78.2	1	253	4	3.24	2	372	1	153	6	3.30	1	0.659	1	11.2	1	76.5	4	13.9	1	33.4	9	53.5	6
1766-357-360	D-275039	485658	0962918	2.24	1	0.421	1	109	5	385	5	3.93	1	809	2	325	5	9.63	5	1.58	2	17.0	2	112	8	253	1	351	1	173	8
1766-360-365	D-275040	485658	0962918	2.49	1	0.986	1	63.1	2	262	5	2.40	2	1050	1	97.9	10	3.40	3	0.620	1	10.2	1	62.3	5	28.2	1	58.5	9	54.6	6
1766-365-370	D-275041	485658	0962918	1.45	1	0.417	2	42.1	1	102	8	1.72	1	332	1	146	4	4.32	1	0.444	2	7.08	1	81.3	4	21.8	1	38.2	6	129	4
1766-370-375	D-275042	485658	0962918	1.62	1	0.324	3	48.2	1	79.6	8	0.920	3	339	1	125	5	3.56	1	0.326	3	6.31	1	35.4	3	9.82	1	21.2	9	36.2	6
1766-375-379	D-275043	485658	0962918	2.24	1	1.31	2	46.5	1	196	6	1.15	1	311	2	145	7	3.32	1	0.409	2	8.02	1	47.1	4	11.9	1	25.1	9	41.3	6
1766-379-383	D-275044	485658	0962918	2.39	1	1.92	1	47.0	2	288	2	1.10	2	330	1	124	7	2.96	1	0.336	1	6.55	1	39.3	5	10.5	1	18.2	13	49.0	7
1766-390-394	D-275045	485658	0962918	2.53	1	1.95	1	43.9	1	292	3	1.12	1	382	1	92.0	13	3.14	1	0.370	2	6.99	1	43.9	4	11.1	1	38.7	5	57.5	7
1772-400-405	D-275046	482813	0961955	1.94	1	1.63	1	44.6	3	237	3	1.01	1	392	1	124	4	3.10	1	0.377	1	5.35	1	68.2	4	12.3	1	35.0	4	370	2
1772-410-412	D-275047	482813	0961955	6.62	1	1.60	1	42.6	3	239	3	0.947	1	359	1	85	15	1.86	5	0.237	2	9.05	1	32.6	5	22.5	1	32.4	8	--	--
1772-420-425	D-275048	482813	0961955	12.2	1	0.768	1	30.5	3	91.3	13	0.684	1	231	4	88	18	2.93	7	0.279	2	20.9	3	35.9	7	46.6	2	47.8	9	26.4	9
1772-430-436	D-275049	482813	0961955	17.2	1	0.564	1	22.6	6	98.3	13	0.441	9	166	3	114	12	2.38	2	0.245	2	23.8	3	45.5	3	33.6	2	75.3	8	99.3	9
1772-440-445	D-275050	482813	0961955	7.36	1	0.981	2	38.7	4	130	9	1.74	1	252	3	144	12	3.24	2	0.373	2	14.1	1	58.6	6	24.5	1	88.1	3	88.3	6
1772-450-453	D-275051	482813	0961955	5.82	1	1.78	1	42.8	2	192	5	1.10	4	285	2	119	10	3.30	2	0.405	3	13.3	2	91.7	2	21.9	1	92.4	4	87.4	7

Table 3.--Major element, trace-element, and rare-earth-element concentrations for drill cutting samples from test wells in northwestern Minnesota--(continued).

MGS no.	Th	cv %	U	cv %	La	cv %	Ce	cv %	Nd	cv %	Sm	cv %	Eu	cv %	Tb	cv %	Yb	cv %	Lu	cv %	As	cv %	Sb	cv %	W	cv %	Au
1778-230-235	4.19	1	1.36	2	15.2	1	31.7	2	12.3	1	2.15	1	0.484	1	0.230	4	0.704	1	0.105	3	1.84	5	0.13	10	--	--	<0.9
1778-240-245	3.64	1	0.993	2	12.9	1	26.2	1	10.3	3	1.92	1	0.439	4	0.206	2	0.620	6	0.0953	5	1.56	6	0.12	6	0.862	17	<0.3
1778-248-248.5	4.67	1	1.12	1	15.1	1	31.3	1	12.2	1	2.36	1	0.561	1	0.270	1	0.801	2	0.116	4	2.34	5	0.167	7	32.8	2	<0.6
1784-160-165	4.47	1	1.25	5	16.3	1	34.2	2	13.5	1	2.68	1	0.576	5	0.288	3	0.995	2	0.152	4	2.22	7	0.184	9	1.18	25	<0.7
1784-165-168	3.96	1	1.04	3	13.5	1	28.2	1	12.0	2	2.37	1	0.541	6	0.283	1	0.978	1	0.144	1	1.87	8	0.192	11	7.12	7	<2.3
1784-168-170	3.63	1	0.964	3	14.0	1	29.9	1	12.8	2	2.66	1	0.653	1	0.337	4	1.06	3	0.161	1	1.95	8	0.089	11	18.1	2	<0.3
1784-170-171.5	3.48	2	0.932	2	13.6	1	28.0	1	12.7	4	2.64	1	0.668	1	0.323	1	0.974	2	0.146	1	1.64	7	0.135	8	10.9	7	<0.2

Table 3.--Major element, trace-element, and rare-earth-element concentrations for drill cutting samples from test wells in northwestern Minnesota--(continued).

MGS no.	Th	cv %	U	cv %	La	cv %	Ce	cv %	Nd	cv %	Sm	cv %	Eu	cv %	Tb	cv %	Yb	cv %	Lu	cv %	As	cv %	Sb	cv %	W	cv %	Au
1489-265-270	15.2	1	3.76	5	16.5	1	35.6	4	12.5	4	2.78	1	0.738	2	0.416	6	1.53	1	0.249	2	--	--	--	--	--	--	<2.5
1489-275-280	16.8	1	4.22	2	12.1	1	28.4	2	10.9	3	2.38	1	0.567	1	0.335	7	1.21	2	0.207	1	--	--	0.073	24	2	18	<2.0
1489-285-290	9.34	2	2.74	3	15.6	3	29.4	3	13.8	2	2.66	1	0.671	4	0.418	3	1.77	4	0.296	11	--	--	--	--	3.26	20	30.7
1489-295-300	12.1	1	4.66	3	17.4	1	37.0	4	13.5	1	2.88	1	0.714	2	0.417	6	1.45	1	0.232	1	0.956	19	--	--	7.48	4	35.6
1489-305-310	14.7	1	3.29	1	16.4	1	36.9	1	13.8	2	2.72	1	0.648	4	0.383	5	1.35	1	0.205	1	--	--	--	--	--	--	<0.4
1489-315-320	14.7	1	2.74	1	11.5	1	26.6	1	9.17	1	2.07	1	0.421	7	0.298	5	1.20	1	0.196	1	--	--	<.02	60	2.26	20	<2.1
1490-350-355	2.40	1	1.17	1	8.35	1	16.9	1	7.40	4	1.47	1	0.275	3	0.173	2	0.554	5	0.0810	4	2.91	8	0.161	6	--	--	<0.2
1490-360-365	4.07	1	2.18	1	15.4	1	31.9	1	13.0	1	2.87	1	0.586	2	0.340	2	1.04	1	0.152	6	5.47	8	0.544	3	1.9	21	<0.1
1490-365-367	4.60	1	2.27	1	16.0	1	33.1	1	13.9	1	2.78	1	0.562	2	0.328	3	1.04	1	0.151	5	6.18	6	0.434	6	--	--	<1.0
1760-270-275	4.50	2	1.01	2	16.1	1	33.7	4	12.8	2	2.36	1	0.561	1	0.275	1	0.895	1	0.131	1	2.38	3	0.19	10	3.38	9	<1.1
1760-275-280	4.13	2	1.14	2	19.5	1	42.4	1	15.6	3	2.97	1	0.714	1	0.342	1	1.01	2	0.140	1	3.85	5	0.198	8	--		<0.4
1760-285-290	4.57	1	1.10	1	23.8	1	53.2	1	21.3	2	3.89	1	0.830	2	0.411	5	1.14	1	0.160	1	5.46	5	0.207	10	1.41	20	<1.6
1760-295-300	4.54	1	1.13	2	23.2	1	54.1	2	22.3	1	4.04	1	0.871	1	0.399	1	1.22	1	0.186	4	3.2	8	0.193	11	8.5	8	<0.8
1760-305-310	4.51	1	1.13	4	24.8	1	57.1	2	23.0	3	4.10	1	0.908	2	0.455	7	1.21	3	0.190	2	3.3	8	0.171	12	6.35	8	<1.2
1760-315-320	4.22	1	1.06	2	21.2	1	49.9	1	21.3	1	3.87	1	0.866	2	0.412	7	1.21	4	0.181	1	2.36	9	0.19	8	8.34	13	<2.4
1760-325-330	3.72	2	1.05	2	21.6	1	54.2	1	21.5	1	3.83	1	0.887	2	0.441	4	1.21	2	0.173	6	2.19	8	0.22	5	20.7	6	<0.8
1760-335-340	3.94	1	1.08	2	22.2	1	54.7	1	21.9	2	4.06	1	0.871	2	0.410	4	1.23	3	0.183	1	3.04	8	0.215	8	6.16	11	<1.0
1760-350-355	4.24	1	1.05	2	24.6	1	55.6	1	23.1	1	4.14	1	0.922	1	0.407	5	1.20	1	0.177	3	2.83	10	0.207	5	2.49	16	<0.8
1766-355-357	9.48	1	1.78	2	34.2	1	69.3	1	26.0	1	4.78	1	1.04	1	0.539	2	1.59	1	0.226	1	2.38	14	0.165	12	<1.4	60	<0.082
1766-357-360	22.9	2	14.6	1	85.8	1	180	2	66.1	2	11.3	1	2.31	2	1.25	2	3.94	2	0.612	1	1.71	22	0.212	9	<2.0	60	--
1766-360-365	8.99	1	2.63	1	34.1	1	70.4	1	27.2	2	4.86	1	1.05	1	0.547	1	1.72	1	0.246	1	3.44	9	0.179	6	--	--	<0.07
1766-365-370	8.55	1	1.88	1	26.0	1	52.8	1	19.6	1	3.52	1	0.705	2	0.406	1	1.21	4	0.184	1	5.79	4	0.129	11	14.4	3	<0.08
1766-370-375	4.31	1	0.999	2	21.1	1	45.4	1	19.5	1	3.82	1	0.816	1	0.394	1	0.921	2	0.134	1	1.56	15	0.093	10	11.6	9	<1.2
1766-375-379	4.54	1	1.07	2	20.6	1	42.6	1	17.8	1	3.47	1	0.819	1	0.367	2	0.933	4	0.141	2	2.13	9	0.065	16	3.04	18	<4.0
1766-379-383	4.20	1	1.14	2	21.6	1	44.9	1	17.8	1	3.51	1	0.803	3	0.404	1	0.955	1	0.140	3	3.7	8	0.104	10	--	--	<3.4
1766-390-394	4.59	1	1.20	2	21.9	1	45.5	2	17.4	1	3.38	1	0.776	4	0.380	2	1.02	2	0.153	3	2.29	9	0.111	11	8.87	9	<1.3
1772-400-405	4.53	1	1.35	5	13.3	1	29.1	1	10.9	1	2.12	1	0.468	1	0.238	3	0.839	1	0.124	1	3.55	10	0.266	2	1.79	21	10.1
1772-410-412	4.02	2	1.06	1	12.5	1	35.2	5	9.95	5	1.89	2	0.527	5	0.232	4	0.730	2	0.111	5	2.45	2	0.176	10	1.01	22	<1.7
1772-420-425	5.11	5	1.04	2	10.9	2	49.0	4	9.06	5	1.81	2	0.535	5	0.262	5	0.951	2	0.144	4	1.74	10	0.112	19	2.34	18	<1.5
1772-430-436	6.03	5	0.936	2	12.9	2	80.0	6	11.0	2	2.16	3	0.660	3	0.292	4	0.924	5	0.140	5	1.37	15	0.172	16	3.47	15	<1.9
1772-440-445	4.33	3	0.950	3	19.9	1	46.0	5	16.1	2	3.33	1	0.958	3	0.433	5	1.44	1	0.219	1	1.39	9	0.157	13	4.98	2	<0.4
1772-450-453	4.38	2	0.907	3	17.0	1	46.6	3	14.5	1	2.64	1	0.770	1	0.327	6	1.11	5	0.189	6	1.03	12	0.136	23	1.32	17	<0.6

Table 3.--Major element, trace-element, and rare-earth-element concentrations for drill cutting samfples from test wells in northwestern Minnesota--(continued).

MGS no.	Th	cv %	U	cv %	La	cv %	Ce	cv %	Nd	cv %	Sm	cv %	Eu	cv %	Tb	cv %	Yb	cv %	Lu	cv %	As	cv %	Sb	cv %	W	cv %	Au
01-550-556	8.97	1	1.33	2	30.3	1	60.5	1	21.1	2	3.86	1	0.769	3	0.420	2	1.35	2	0.201	1	4.24	5	0.057	22	2	13	<1.2
01-556-560	11.9	2	1.73	3	39.5	1	86.2	1	31.0	3	5.78	1	1.15	2	0.609	2	1.62	3	0.241	3	5.71	4	0.127	15	3	17	<1.0
01-560-571	18.5	1	1.66	2	45.5	1	99.4	1	38.4	3	7.36	1	1.50	1	0.745	4	1.91	2	0.276	4	6	5	0.105	17	1.95	16	<0.2
01-571-592	15.4	2	2.50	4	48.9	1	109	1	39.1	1	7.30	1	1.43	1	0.793	3	2.16	2	0.316	5	9.16	4	2.29	1	<1.1	60	<3.0
01-592-610A	15.5	1	2.13	2	43.9	1	91.5	1	34.6	2	6.33	1	1.24	2	0.604	1	1.96	1	0.294	5	4.5	7	0.17	14	<1.0	60	<4.4
01-592-610B	14.4	1	2.16	1	45.2	1	94.3	1	33.6	3	5.77	1	1.13	1	0.586	4	1.96	3	0.291	5	3.62	6	0.17	14	--	--	<2.1
121-470-475	2.78	1	1.44	1	11.1	1	21.9	1	7.92	3	1.36	1	0.228	1	0.123	4	0.409	4	0.0595	4	7.69	3	0.081	6	<0.30	60	<0.2
121-480-485	1.89	2	0.896	1	8.18	1	16.3	1	5.71	2	1.01	1	0.174	2	0.0908	3	0.278	3	0.0425	4	3.39	4	0.065	9	0.445	23	<0.5
121-485-490	5.12	1	2.99	1	22.0	1	46.9	1	17.2	2	2.97	1	0.527	2	0.304	1	0.928	3	0.138	6	4.76	4	0.034	22	1.52	19	<0.9
121-490-495	7.00	2	2.84	1	28.3	1	65.3	1	24.7	1	4.82	1	0.944	1	0.509	1	1.36	3	0.196	2	9.74	3	0.1	16	1.9	21	<0.9
121-500-505	20.3	2	1.77	1	50.3	1	111	1	44.2	1	8.99	1	1.72	1	0.943	2	2.33	3	0.355	1	4.72	6	0.102	15	<0.9	60	--
121-505-510	16.9	1	1.94	3	47.4	1	103	1	40.2	1	7.79	1	1.47	1	0.838	1	2.18	1	0.333	6	5.76	6	0.137	9	2.06	0	--
121-510-515	14.5	2	1.86	1	49.8	1	106	2	38.4	1	6.99	1	1.41	1	0.731	2	2.18	1	0.312	3	8.37	5	0.117	17	2.59	16	<1.5
121-520-525	14.4	2	1.95	3	44.3	1	96.2	1	33.4	1	6.29	1	1.31	2	0.673	2	1.92	1	0.327	2	5.39	6	--	--	2.85	16	<0.9
121-530-535	14.2	2	3.15	2	47.1	1	105	2	41.2	1	8.08	1	1.62	1	0.880	4	2.27	4	0.325	4	4.75	8	0.137	15	3.28	15	<1.5
121-540-545	15.4	2	14.2	1	46.4	1	123	1	62.6	2	14.5	1	3.01	1	1.55	1	2.94	4	0.432	4	4.45	8	0.186	15	--		<0.4
121-545-550	9.94	2	2.48	2	41.1	2	97.2	4	44.3	5	7.95	1	1.99	1	0.958	2	2.14	2	0.298	3	7.85	5	0.181	15	<1.77	60	<0.6
121-550-555	10.3	2	2.36	2	44.1	1	102	1	42.5	3	8.03	1	1.90	2	0.848	2	1.96	1	0.289	9	5.06	6	0.16	10	3.51	15	<0.5
121-555-560	11.8	5	3.00	2	43.3	1	106	2	45.4	4	8.91	1	2.21	2	1.06	2	2.21	3	0.308	9	8.7	5	0.251	11	<2.20	60	--
121-560-565	10.4	2	3.51	1	39.3	1	97.1	3	42.4	1	8.32	1	1.93	1	0.899	2	1.90	1	0.283	1	5.86	7	0.23	6	<2.16	60	<1.2
121-565-570	11.1	2	3.97	2	50.3	1	132	2	56.4	3	10.7	1	2.46	1	1.08	2	2.13	3	0.287	5	6.53	6	0.199	15	981.01	2	<1.0
121-570-575	5.38	3	1.68	2	27.6	1	70.1	2	32.6	2	6.69	3	1.61	1	0.660	2	1.43	3	0.194	3	5.22	8	0.233	11	426.01	1	--
887-195-200	6.82	2	2.21	1	21.3	1	45.4	1	17.7	1	3.70	2	0.723	2	0.408	2	1.28	2	0.186	5	6.64	5	--	--	9.95	1	<0.5
887-320-325	0.885	1	0.678	2	4.08	1	8.21	2	3.612	2	0.707	1	0.136	4	0.0833	2	0.297	1	0.0457	2	2.18	6	0.046	14	--	--	--
888-425-430	8.51	2	2.37	1	25.6	1	54.6	1	22.4	1	4.64	1	0.866	3	0.547	3	1.65	2	0.242	4	6.42	5	0.599	3	7.66	13	<2.2
888-450-455	8.69	1	1.81	1	27.4	1	57.1	2	22.3	2	4.50	1	0.915	1	0.520	2	1.55	2	0.225	4	5.03	6	0.269	7	4.25	13	<1.2
888-495-500	5.52	2	1.41	2	20.3	1	46.2	2	19.6	2	4.25	1	0.958	1	0.591	2	1.77	6	0.251	3	3.6	12	0.257	11	6.38	6	<1.6
888-505-510	5.29	2	1.42	3	18.5	1	43.1	1	17.3	3	3.92	1	0.890	2	0.567	4	1.83	5	0.278	2	4.5	9	0.307	6	8.91	14	--
888-515-520	4.09	1	1.17	2	13.8	1	30.7	1	13.3	2	3.02	1	0.716	2	0.469	3	1.55	3	0.243	5	3.73	12	0.309	11	4.89	16	<0.8

Table 3.--Major element, trace-element, and rare-earth-element concentrations for drill cutting samples from test wells in northwestern Minnesota--(continued).

MGS no.	Lab. no.	Lat	Long	Fe	cv %	Na	cv %	Rb	cv %	Sr	cv %	Cs	cv %	Be	cv %	Zr	cv %	Hf	cv %	Te	cv %	Sc	cv %	Cr	cv %	Co	cv %	Ni	cv %	Zn	cv %
1778-230-235	D-275052	482357	0955250	1.34	1	1.37	1	40.9	1	248	2	1.12	1	363	2	90.0	5	2.37	1	0.319	2	3.65	1	25.3	5	4.71	1	11.5	12	27.6	5
1778-240-245	D-275053	482357	0955250	1.28	1	1.46	1	41.0	2	244	5	0.919	2	382	1	90.1	4	2.27	1	0.266	2	3.40	1	27.5	4	4.20	1	12.2	11	23.5	5
1778-248-248.5	D-275054	482357	0955250	2.21	1	1.86	1	46.6	2	292	2	1.10	1	443	1	78.7	4	2.29	3	0.291	3	6.43	1	61.2	4	8.02	1	16.9	11	36.6	6
1784-160-165	D-275055	481224	0953832	1.66	1	1.81	1	--	--	264	4	1.03	5	454	2	123	5	3.19	1	0.349	2	5.28	1	43.4	3	6.55	1	13.7	14	32.9	6
1784-165-168	D-275056	481224	0953832	1.96	1	1.91	3	44.8	1	264	3	1.09	1	460	1	111	10	2.93	1	0.310	1	6.25	1	48.5	4	8.25	1	28.3	7	35.1	7
1784-168-170	D-275057	481224	0953832	2.11	1	2.09	1	41.6	2	252	2	0.835	2	450	1	98.1	7	3.26	1	0.328	2	6.45	1	42.3	3	7.86	1	19.3	12	38.5	8
1784-170-171.5	D-275058	481224	0953832	1.51	1	2.20	1	41.8	1	265	3	0.784	1	495	1	105	4	3.00	1	0.303	1	4.55	1	30.7	1	5.57	1	17.5	10	30.5	8

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