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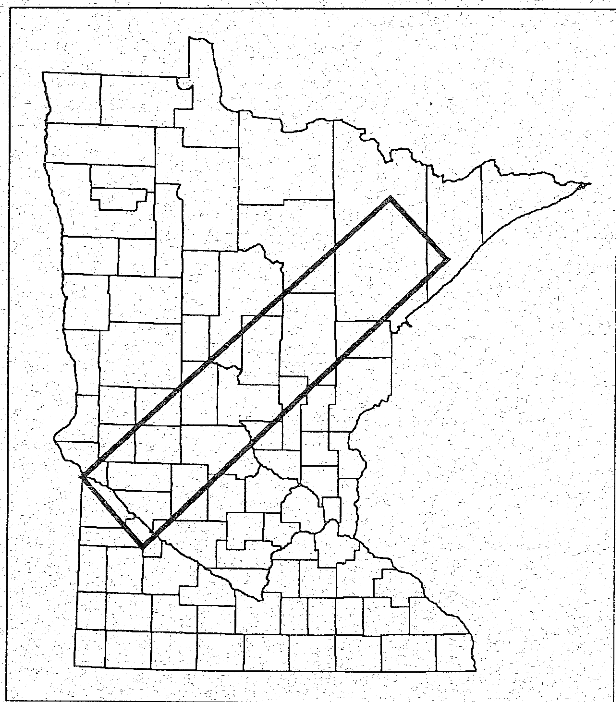
TEST AND PILOT STUDY DATA



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A COOPERATIVE PROJECT
WITH THE UNITED STATES GEOLOGICAL SURVEY

MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINERALS

Consultant's Report

CHEMICAL AND MINERALOGICAL ANALYSES AND GEOLOGICAL CHARACTERISTICS OF HEAVY MINERALS FROM GLACIOFLUVIAL SEDIMENTS IN MINNESOTA

TEST AND PILOT STUDY DATA

By

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A Cooperative Project
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INTRODUCTION

A pilot study which analyzed the heavy-mineral fraction of glaciofluvial sediments was conducted over a broad area of Minnesota by the Minnesota Department of Natural Resources (MDNR), Division of Minerals, in cooperation with the U.S. Geological Survey (USGS), Branch of Geochemistry in Denver, Colorado. This study examined the heavy-mineral concentrates of eighty glaciofluvial samples collected from a number of geologically distinct areas of the state. It evolved from a similar eight-sample test study, completed in the previous year, which showed variations in the heavy-mineral content of glaciofluvial sediments across the state.

The primary goals of this study were to develop heavy-mineral baseline data for Quaternary sediments in a portion of the state and to educate MDNR staff in heavy-mineral investigative techniques that have been developed and refined by the USGS. The specific pilot study objectives were threefold: 1) to determine the presence of heavy minerals of economic value, either precious or semi-precious metals or industrial minerals, in glaciofluvial deposits that are currently being mined for sand and gravel; 2) to determine if pathfinders are present in the heavy-mineral fraction of surficial glaciogenic sediments; and 3) to determine reliable, cost-effective sampling methods, concentration techniques, and analytical methods to use in future heavy-mineral studies.

This report summarizes the sampling strategy, the methods of sample preparation and analysis, the geological characteristics of the samples, and the heavy-mineral chemical and mineralogical data for the eighty-eight test and pilot study samples.

STUDY AREA

The study area consists of a broad rectilinear area that traverses the state from northeast to southwest (Figure 1). The general boundaries of the study area are delimited by Tower and Norshore Railroad Junction in the north and Ortonville and Granite Falls in the south.

The orientation of the study area was chosen to parallel the southwesterly glacial flow and to encompass several of the state's major bedrock terranes. The presence or dearth of heavy-mineral suites along the flow path could be used to indicate areas of higher mineral potential. Appendix A contains a generalized map of the geologic terranes of Minnesota.

A number of additional sites were selected outside the main study area. Four samples were collected from an area underlain by Paleozoic sedimentary rocks in east-central Minnesota. The intent of selecting these sample sites was to determine if the composition of heavy-mineral concentrates varies from the main study area which is underlain by Precambrian rocks. In addition, four of the eight test study sites are located outside the pilot study area.

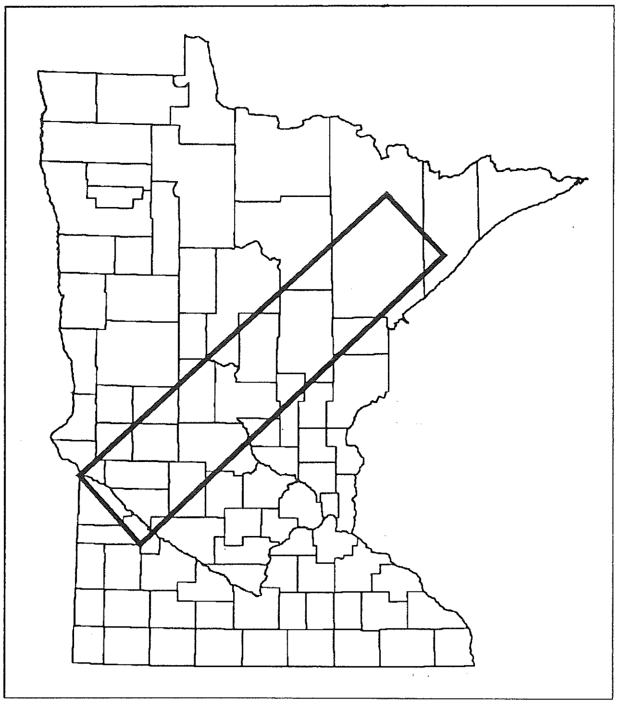


Figure 1. Study area location, Minnesota

METHODOLOGY

Sample Medium and Sampling Strategy

The sample medium and sampling strategy for the pilot study were dictated by the goals of the study as well as budgetary limitations. The sample medium was determined primarily by study objectives one and two. Because of the somewhat divergent objectives of the study, glaciofluvial sediments were chosen for the sample medium for this initial study. The primary sampling strategy was to collect samples from sediments of northeastern provenance, specifically the late Wisconsin deposits of the Superior, Rainy, and Wadena lobes (Figure 2). The sediments deposited by these glacial lobes tend to be locally or regionally derived.

Secondary sampling strategies were based on preference toward these criteria: 1) to collect samples in areas where the drift thickness was less than 100 feet because this would increase the probability that the sediment sampled would reflect regional bedrock (see Appendix B for a depth to bedrock map of the state); 2) to collect samples from ice-contact sediments over outwash sediments because the transport distances for these sediments tend to be shorter; and 3) to collect samples from active gravel pit operations. The final selection of sample sites was governed by the ability to obtain authorization from the gravel pit owner to collect a sample.

Because of the above sampling strategies, sample site locations were not equally distributed within the study area. Figure 3 shows the location of the pilot and test study sample sites. The pilot study samples are numbered 23901 through 23975; and the test study samples are numbered 20431 and 22631 through 22637.

Seventy-seven of the eighty samples in the pilot study were collected from gravel pits. Exceptions include an active stream-sediment sample collected in central Minnesota, a pre-glacial alluvium sample collected in southwestern Minnesota, and a heavy-mineral-concentrate sample provided by a gravel pit operator. Seven of the eight test study samples were collected from gravel pits and one sample was collected just off a roadway with an auger.

Sample Collection

The test study samples were collected in October of 1989 and the pilot study samples were collected during August and September of 1990.

To maximize the amount of heavy-mineral baseline data collected, sampling was not random in the pit but was biased to optimize the heavy-mineral content of a sample. Therefore, samples are not necessarily characteristic of the gravel pit as a whole. The preferred sediment was sandy pebble-gravel with streaks of heavy minerals. Otherwise, sandy pebble-gravel without heavy-mineral streaks or poorly sorted pebbly sand was sampled if available.

A geologic description of the gravel pit and the sediments sampled was completed at each site. The description includes the glacial lobe, landform, sediment type and variability, stratigraphy, pebble lithology, grain size, sample location, and size of the gravel pit.

At each sample location, approximately 6 liters of minus-10-mesh (2 mm) material was collected for analysis. Prior to the sampling, approximately one foot of sediment was cleared from the pit face before the bulk samples were collected with a plastic scoop. The amount of bulk sample collected at each site varied according to the amount of oversize (>2 mm) material present. The bulk sample was sieved through a stainless-steel 10-mesh screen to acquire the 6 liter study sample. The sieving was done in the field if the sample was dry enough to be sieved without sample clumping; if not, the sample was oven dried in the laboratory and then sieved.

Archive samples were collected at the same location as the study sample and in the same manner; they are not a split of the study sample. Five archive samples were used as replicate samples in the analyses to check site variability.

Sample Preparation

The procedure used to reduce the bulk samples to a heavy-mineral concentrate is illustrated by the flow chart in Figure 4. In the laboratory, the plus-20-mesh (0.83 mm) material was removed and archived; a rough concentrate of the minus-20-mesh fraction was prepared using a Wilfley table or hand panning, separately or in combination. For the test study samples the rough concentrate was prepared using the minus-10-mesh fraction.

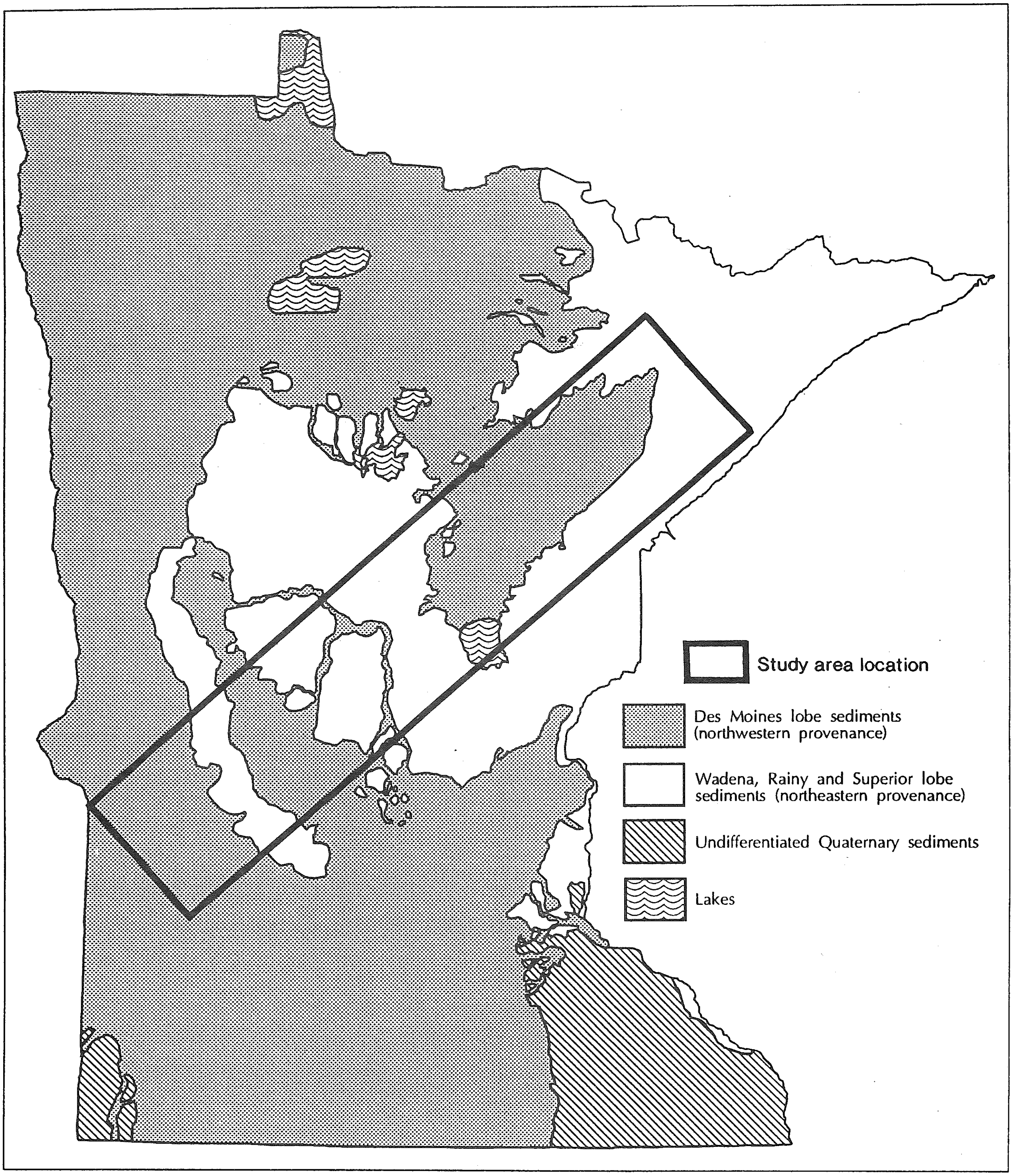


Figure 2. Generalized Quaternary geology of Minnesota
Adapted from the Minnesota Land Management Information Center's MLMIS40 data base, filename QUATGEO.EPP. LMIC created this file by scanning the Quaternary geologic map of Minnesota (Hobbs and Goebel, 1982), converting this file to ARC/INFO polygon coverage, then converting the ARC/INFO coverage to a 40-acre grid-cell EPPL7 file.

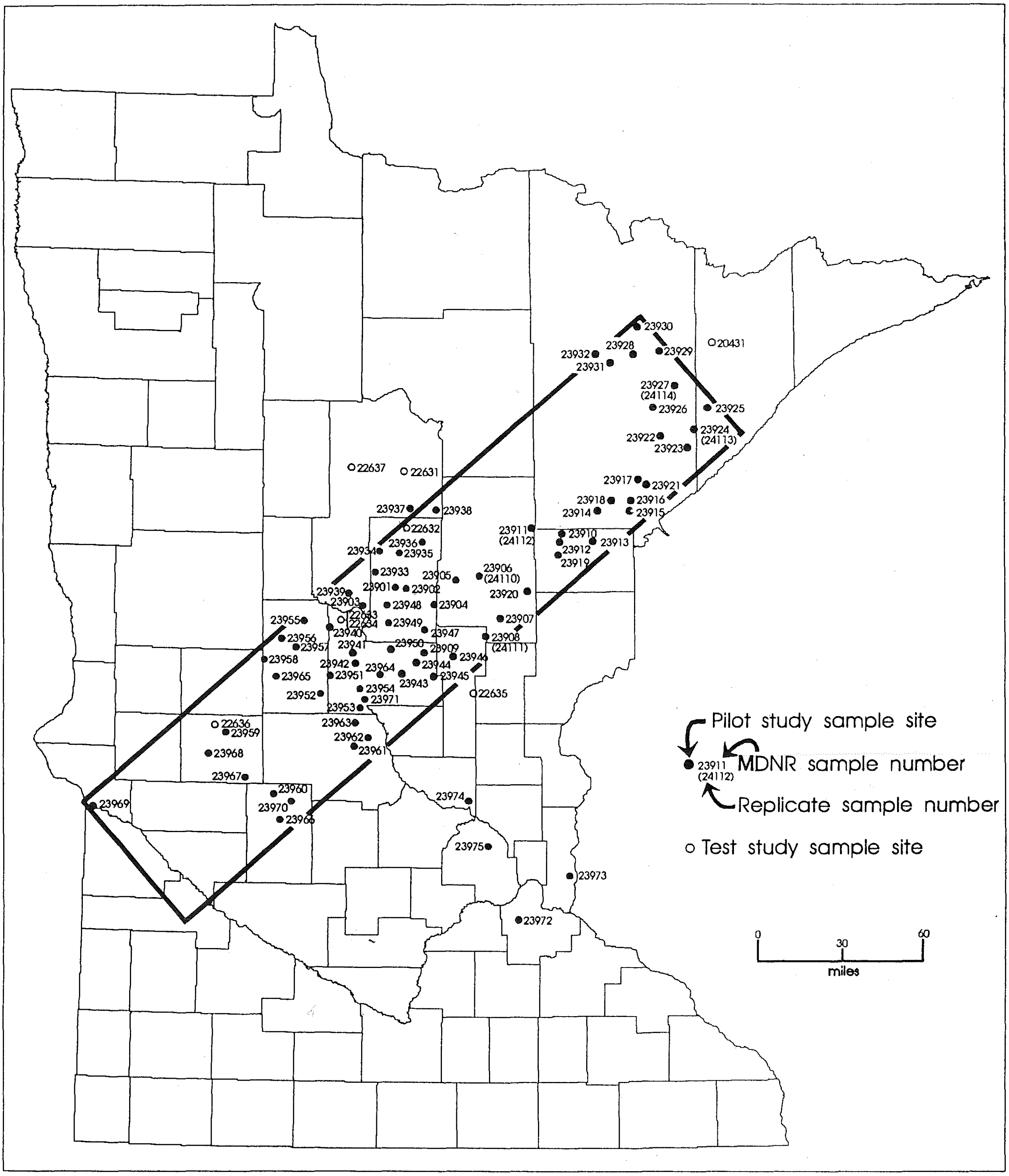
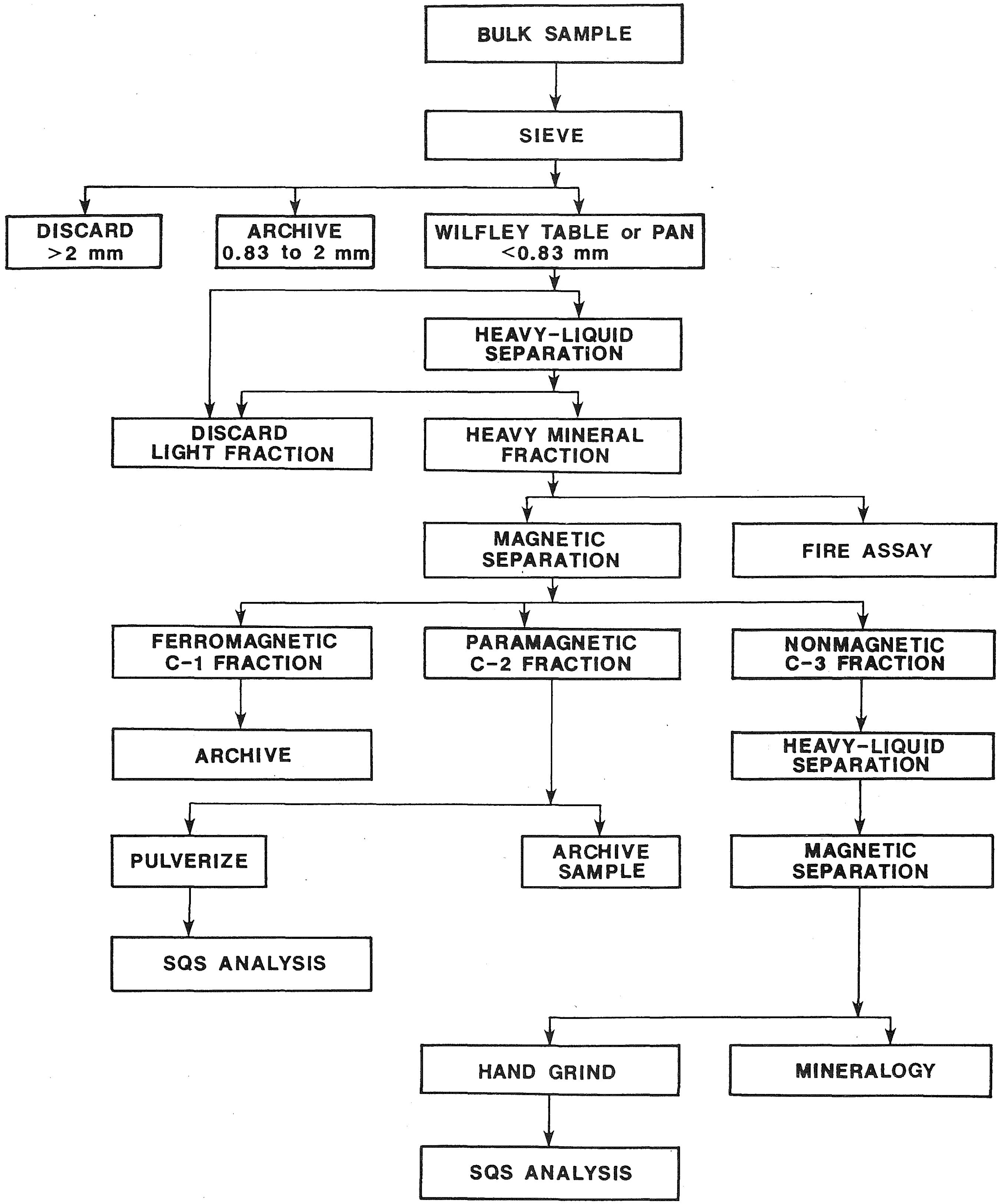


Figure 3. Test and pilot study sample locations, Minnesota



Note: SQS = Semiquantitative emission spectroscopy

Figure 4. Flow chart of procedures used to prepare the heavy-mineral-concentrate samples

These methods removed most of the quartz, feldspar, clay-sized material, and organic material from the sample.

After the rough concentrate was oven dried, the remaining light minerals were separated by flotation in bromoform ($CHBr_3$, specific gravity ~2.85). The resulting heavy-mineral concentrate was washed with acetone, air dried, and then divided using a Jones Splitter. One portion of the heavy-mineral concentrate was used for fire assay; the remaining portion was separated into three fractions using a modified Frantz Isodynamic Magnetic Separator.

The modified magnetic separator, in which the magnetic pole pieces are mounted horizontally, uses a current of 0.25 amperes to remove the strongly magnetic (C-1) fraction consisting of ferromagnetic minerals such as magnetite and ilmenite. A current of 1.75 amperes is then used to separate the paramagnetic (C-2) fraction, consisting of most iron and manganese oxides and ferromagnesian silicates, from the nonmagnetic (C-3) fraction which consists of most remaining oxides, sulfides, native metals, and other nonmagnetic ore minerals.

These magnetic fractions are the same fractions that would be produced by using a Frantz Isodynamic Magnetic Separator set at a slope of 15° and a tilt of 10° with a current of 0.2 ampere to remove the C-1 fraction and a current of 0.6 ampere to separate the C-2 and C-3 fractions.

The C-1 fraction was archived. The C-2 fraction was divided into two splits with a Jones Splitter; one split was pulverized to minus-100-mesh (0.15 mm) in a Braun vertical pulverizer for spectrographic analysis, and the other split was archived. The C-3 fraction was put through a second bromoform and magnetic separation clean-up step to remove any remaining light minerals. Following clean-up, the C-3 fraction was divided into two splits with a Jones Splitter; one split was hand ground, using an agate mortar and pestle, for spectrographic analysis, and the other split was used for mineralogical determinations.

Chemical Analyses

Three methods of elemental analysis were used to determine the chemistry of the heavy-mineral concentrates: fire assay, semiquantitative emission spectroscopy, and cyanide leach assay.

Fire Assay

Fire assay was used to determine low levels (parts per billion) of gold and platinum group elements (PGE) in the heavy-mineral-concentrate samples. The elements and their lower limits of determination are listed in Table 1.

Table 1. Lower limits of determination for the fire assay of the heavy-mineral-concentrate samples

Element	Nickel-Sulfide Flux[1] Lower Determination Limit parts per billion	Lead-Oxide Flux[2] Lower Determination Limit parts per billion
Ruthenium (Ru)	0.6	100
Rhodium (Rh)	0.5	10
Palladium (Pd)	0.5	1
Iridium (Ir)	0.5	20
Platinum (Pt)	0.5	10
Osmium (Os)	2	200
Gold (Au)	7	1

[1]10 g sub-sample
[2]15 g sub-sample

For the test study samples, one-half of the heavy-mineral concentrate was pulverized, with a 15 g sub-sample analyzed. These samples were analyzed for gold and PGE using the classical fire assay lead-oxide flux/silver doré bead method, followed by emission spectroscopic determination of the noble elements in the doré bead (Adrian and Carlson, 1990).

For the pilot study samples, 15 grams of the heavy-mineral concentrate was pulverized, with a 10 g sub-sample analyzed. These samples were analyzed for gold and PGE by the newer fire-assay nickel-sulfide flux/acid digestion method, followed by inductively-coupled-plasma/mass spectrographic determination of the noble elements using an isotope-dilution procedure (Meier and others, 1991).

Semiquantitative Emission Spectroscopy

Semiquantitative emission spectroscopy (SQS) was used to determine the concentrations (parts per million) of 35 elements in the nonmagnetic and paramagnetic concentrate samples. Table 2 lists the elements and their lower limits of determination based on a 5 mg sub-sample.

A six-step semiquantitative direct-current arc emission spectrographic method was used (Grimes and Marranzino, 1968). The SQS method is a solid-sample analysis in which the results are obtained by a visual comparison of spectra derived from the sample against spectra obtained from standards made from pure oxides and carbonates. Standard concentrations are geometrically spaced over any given order of magnitude of concentration as follows: 100, 50, 20, 10, and so forth. Samples whose concentrations are estimated to fall between those values are assigned values of 70, 30, 15, and so forth. The precision of the analytical method is approximately plus or minus one reporting interval at the 83% confidence level and plus or minus two reporting intervals at the 96% confidence level (Motooka and Grimes, 1976).

Cyanide Leach Assay

Cyanide leach assay was used to determine the cyanide-soluble gold recovery in three archive samples. The archive samples were collected at pilot study sample sites 23932, 23935, and 23960.

The sample preparation and analyses were performed at Bondar-Clegg's Metallurgical Laboratory in Sparks, Nevada. The minus-20-mesh (0.85 mm) fraction of each archive sample was crushed to 100% passing 48-mesh (0.414 mm). A 250 gram split from each crushed sample was pulverized to pass 150-mesh (0.1041 mm). Preg-rob tests were then performed on 30 gram portions of the pulverized material to determine if there were constituents in the sample which would adsorb gold out of a cyanide solution.

Cyanide leach assays were then performed on the remaining minus-48-mesh material following a method developed from Lenahan and Murray-Smith, 1986. The leaches were conducted for 48 hours with 10 lb/ton NaCN solution at 50% solids; with the pH adjusted to greater than 10.

Following leaching, the tailings were filtered, washed and dried. A 250 gram split was pulverized and then fire assayed to determine if any gold remained in the tailings.

Mineralogical Techniques

Four techniques were used to determine the mineralogy of the heavy-mineral concentrates: binocular microscopy, x-ray diffraction, point count analysis, and electron microprobe analysis.

Binocular Microscopy

Binocular microscopy techniques were used to determine the mineralogy of the nonmagnetic (C-3) concentrate samples. The samples were scanned visually using a binocular microscope and a shortwave ultraviolet light to identify mineral grains by their physical properties. Emphasis is placed on mineralogical identification of the ore-related and gemstone minerals.

This visual examination is also utilized as an important supplement to the spectrographic analyses, identifying both minerals poorly represented in the SQS sample split as well as man-made contaminants.

Table 2. Lower limits of determination for the spectrographic analysis of the heavy-mineral-concentrate samples, based on a 5 mg sub-sample

Element	Lower Determination Limit
	Percent
Calcium (Ca)	0.1
Iron (Fe)	0.1
Magnesium (Mg)	0.05
Sodium (Na)	0.5
Phosphorus (P)	0.5
Titanium (Ti)	0.005
	Parts per million
Silver (Ag)	1
Arsenic (As)	500
Gold (Au)	20
Boron (B)	20
Barium (Ba)	50
Beryllium (Be)	2
Bismuth (Bi)	20
Cadmium (Cd)	50
Cobalt (Co)	20
Chromium (Cr)	20
Copper (Cu)	10
Gallium (Ga)	10
Germanium (Ge)	20
Lanthanum (La)	100
Manganese (Mn)	20
Molybdenum (Mo)	10
Niobium (Nb)	50
Nickel (Ni)	10
Lead (Pb)	20
Antimony (Sb)	200
Scandium (Sc)	10
Tin (Sn)	20
Strontium (Sr)	200
Thorium (Th)	200
Vanadium (V)	20
Tungsten (W)	50
Yttrium (Y)	20
Zinc (Zn)	500
Zirconium (Zr)	20

X-Ray Diffraction

X-ray diffraction techniques were used to identify minerals that were difficult to determine visually or to confirm identifications made by visual examination. Several x-ray diffraction techniques were used: single grain mounts using a Gandolfi Camera, powder mounts using a Debye-Scherrer Camera, and glass slide mounts using a manual x-ray powder diffractometer. Powder diffractometry is mainly used for the identification of crystalline compounds by their diffraction patterns (Klug and Alexander, 1974).

Point Count Analysis

Point count analyses were used to determine the quantitative mineralogy of the paramagnetic (C-2) concentrate test study samples. Grain mounts were prepared from a portion of the C-2 archive sample and 500-600 points were counted on each slide to determine the percentage of each mineral. Voids on the slides were counted along with the mineral grains and then subtracted from the total count before percentages were taken.

Electron Microprobe Analysis

Electron microprobe analyses were performed on the magnetic, paramagnetic, and nonmagnetic fractions of the heavy-mineral-concentrate test study samples to determine the chemical composition and identification of various mineral grains. The analyses were performed at the Institute of Electron Optics, University of Oulu, in Finland, using a JEOL JCXA 733 electron microprobe equipped with a LINK AN10000 energy dispersive spectrometer, following the method described by Alapieti and Sivonen (1983).

DESCRIPTION OF THE DATA TABLES

General site information, geologic descriptions, and heavy-mineral chemical and mineralogical data were input into a relational database manager, at the Minerals Division office in Hibbing, Minnesota. The information presented in tables 3 through 16 and appendices C and D are output from the database.

All tables are related to each other by the MDNR sample number. The test study samples are numbered 20431 and 22631 through 22637. The pilot study samples are numbered 23901 through 23975. The five-samples which represent replicate samples are numbered 24110 through 24114; these samples relate to pilot study samples 23906, 23908, 23911, 23924, and 23927, respectively.

All samples were collected from glaciofluvial sediments and processed in the same manner, except for three samples: 1) sample number 23967 is a heavy-mineral-concentrate sample provided by a gravel pit operator, 2) sample number 23969 is possibly a pre-glacial alluvium sample, and 3) sample number 23971 is an active stream-sediment sample. The grain morphology observed in these samples by visual examination of the nonmagnetic-concentrate fraction suggests that they are not normal glaciofluvial sediments. Because of the difference in the sample mediums, any anomalous values indicated in the analytical data for these samples should be considered independently of the analytical data for the glaciofluvial samples.

Visual examination of the nonmagnetic concentrate fraction identified man-made contaminants in some of the samples. Fragments of lead shot, brass and copper shell casings, or aluminum shavings were observed in sample numbers 22632, 22635, 23901, 23918, 23922, 23931, 23941, 23943, 23944, 23945, 23949, 23950, 23951, 23954, 23968, and 23975. Table 12 lists the specific contaminants seen in individual samples. In some cases these contaminants are also reflected by inflated values in the analytical data. Therefore, interpretation of the analytical data is best utilized in conjunction with the mineralogical data presented in Table 12.

Tables 3 through 5 contain descriptive information for the test and pilot study sample sites. Table 3 lists site location information, surface ownership, and gravel pit activity status. Table 4 rearranges the sample numbers by ascending township, range, and section locations. Table 5 presents geologic descriptions of the gravel pit sampling sites and the sediments sampled.

Table 6 lists volume and weight measurements of the various sample fractions for the test and pilot study samples.

Tables 7 through 9 present the analytical data for the heavy-mineral-concentrate samples. Table 7 displays the gold and platinum group element data for the heavy-mineral concentrates as determined by fire assay. Tables 8 and 9 present the analytical data for the paramagnetic fraction and the nonmagnetic fraction, respectively, as determined by semiquantitative emission spectroscopy.

Table 10 presents the cyanide-soluble gold recovery data for three pilot study archive samples as determined by cyanide leach assay. The results of the preg-rob tests on the pulverized samples and the gold fire assays on the tailings are also shown.

Tables 11 through 16 present the mineralogical data for the heavy-mineral-concentrate samples. Table 11 provides a visual description of the ore-related, rock forming, and accessory minerals observed in the nonmagnetic fraction. Table 12 displays the mineralogical data for the nonmagnetic fraction as determined by binocular microscopy and x-ray diffraction techniques. Table 13 lists the quantitative mineralogical data for the paramagnetic fraction of the test study samples as determined by point count analysis. Tables 14 through 16 present mineralogical remarks and chemical composition data for various mineral grains identified in the heavy-mineral-concentrate fractions of the eight test study samples by electron microprobe analysis. This data is displayed in Table 14 for apatite minerals, in Table 15 for monazite minerals, and in Table 16 for miscellaneous minerals.

Appendices C and D present an interpretation of the underlying bedrock for the test and pilot study sample sites. Appendix C lists the underlying bedrock map unit symbol and depth to bedrock for the study sites as derived from various maps and well log data. Appendix D provides an explanation of the bedrock map unit symbols utilized in Appendix C.

ACKNOWLEDGEMENTS

We are grateful to Mr. Paul Theobald, U.S. Geological Survey, who was instrumental in providing direction to the study and for coordinating the U.S. Geological Survey involvement, making this cooperative project possible.

Special thanks are due to Mr. J.D. Lehr, Minnesota Department of Natural Resources, for his assistance with the Quaternary geology of Minnesota and the broad direction he provided for the field work.

We would also like to express our appreciation to the many private landowners and gravel pit operators who allowed us access to their property to collect the samples for this study.

In addition, the following individuals and public agencies are acknowledged for their valuable contributions to this study: Mr. Tim Cowdery, for providing the geologic descriptions at many of the sample sites. Mr. Bob Carlson, Ms. Betty Adrian, and Mr. Al Meier, U.S. Geological Survey, for providing the fire assay analyses. Mr. Tuomo T. Alapieti, Department of Geology, and Mr. Seppo J. Sivonen, Institute of Electron Optics, both at the University of Oulu in Finland, for providing the electron microprobe analyses. Ms. Jane Cleland, Minnesota Geological Survey, for providing the mineralogical point count analyses. The Natural Resources Research Institute, Coleraine, Minnesota, for providing the use of their Wilfley table.

Finally, we would like to thank the many other individuals who offered suggestions and assistance throughout the course of this study.

DATA TABLES

Table 3. Location information, surface ownership, and gravel pit activity status for the test and pilot study sample sites

MDNR Sample Number	USGS Sample Number	County	USGS Quadrangle	Latitude	Longitude	TWP	RNG	SEC	Location	Surface Ownership	Gravel Pit Activity Status	Remarks
20431	D-349932	Lake	Slate Lake West	47 42 40	91 41 50	60	11W	3	SE NE NE SE	Federal	N/A	Test study sample.
22631	D-349925	Cass	Tobique	47 2 28	94 5 23	141	27W	10	NW SE NW SW	County	Active	Test study sample.
22632	D-349926	Crow Wing	Cross Lake	46 44 33	94 3 56	138	27W	26	SW SW NE NW	Private	Active	Test study sample.
22633	D-349927	Morrison	Motley SE	46 15 38	94 33 30	132	31W	11	NW SW SW NW	Private	Active	Test study sample; same site as 22634.
22634	D-349928	Morrison	Motley SE	46 15 38	94 33 30	132	31W	11	NW SW SW NW	Private	Active	Test study sample; same site as 22633.
22635	D-349929	Mille Lacs	Milaca NE	45 52 49	93 32 21	39	26W	11	NE SE SE SE	County	Active	Test study sample.
22636	D-349930	Pope	Glenwood	45 41 40	95 29 16	126	38W	29	SE SW SW NW	Private	Active	Test study sample.
22637	D-349931	Cass	Jack Lake	47 3 12	94 29 53	141	30W	5	SE SW SE	Federal	Active	Test study sample.
23901	D-372285	Crow Wing	Merrifield	46 25 59	94 8 53	134	28W	12	NE SW NW SE	Private	Inactive	
23902	D-372290	Crow Wing	Riverton	46 25 43	94 3 55	46	30W	36	SE SW NE NE	Private	Active	
23903	D-372295	Cass	Pillager	46 20 17	94 23 34	133	30W	13	NW SE NE NE	Private	Intermittently active	
23904	D-372300	Crow Wing	Garrison	46 20 44	93 50 52	45	28W	26	SE SE SW SW	Private	Active	
23905	D-372305	Aitkin	Spirit Lake	46 28 29	93 41 6	46	26W	18	NW NW NW NW	Private	Active	
23906	D-372310	Aitkin	Glen	46 29 47	93 30 38	46	25W	4	SW NE NW SW	Private	Active	Archive sample was used for replicate sample 24110.
23907	D-372315	Aitkin	Thor SE	46 16 40	93 20 42	44	24W	23	SE NW SW SW	County	Inactive	
23908	D-372320	Mille Lacs	Isle	46 11 4	93 27 33	43	25W	23	NE SW SW SE	Private	Active	Archive sample was used for replicate sample 24111.
23909	D-372325	Morrison	Hillman	46 5 42	93 55 28	42	28W	30	NW NW SW NE	Private	Inactive	
23910	D-372330	Carlton	Cromwell East	46 43 21	92 52 9	49	19W	22	NW NE NW NW	Private	Inactive	
23911	D-372286	Aitkin	Wright	46 44 49	93 5 1	49	22W	11	NE SE SE NE	State	Intermittently active	Archive sample was used for replicate sample 24112.
23912	D-372291	Carlton	Cromwell West	46 40 41	92 53 15	48	20W	4	SE NW NE NW	Private	Intermittently active	
23913	D-372296	Carlton	Sawyer	46 40 36	92 37 59	48	18W	4	NW SW NE NW	County	Abandoned	
23914	D-372301	St. Louis	Brookston	46 50 17	92 35 47	50	18W	11	NW NW NW NW	State	Active	
23915	D-372306	St. Louis	Adolph	46 50 10	92 20 39	50	16W	10	NE NE NE NE	Private	Active	
23916	D-372311	St. Louis	Twig	46 53 34	92 20 30	51	16W	23	SE NW NW NW	County	Active	

Table 3. Location information, surface ownership, and gravel pit activity status for the test and pilot study sample sites ...continued

MDNR Sample Number	USGS Sample Number	County	USGS Quadrangle	Latitude	Longitude	TWP	RNG	SEC	Location	Surface Ownership	Gravel Pit Activity Status	Remarks
23917	D-372316	St. Louis	Shaw	47 0 19	92 16 52	52	15W	7	SE NE SE NE	County	Abandoned	
23918	D-372321	St. Louis	Independence	46 53 43	92 29 17	51	17W	15	SW SE SW SW	Private	Intermittently active	
23919	D-372326	Carlton	Heikkila Creek	46 36 26	92 53 53	48	20W	32	NW NW NE NE	State	Intermittently active	
23920	D-372331	Aitkin	Split Rock Lake	46 25 9	93 7 55	45	22W	4	NW NW NE NW	State	Intermittently active	
23921	D-372287	St. Louis	Fredenburg	46 58 23	92 13 5	52	15W	27	SE NE NE NE	Private	Active	
23922	D-372292	St. Louis	Boulder Lake	47 13 27	92 6 5	55	14W	27	SE SE NE NW	State	Inactive	
23923	D-372297	St. Louis	Pequaywan Lake	47 9 41	91 53 57	54	12W	18	SE NE NE SE	County	Active	
23924	D-372302	St. Louis	Brimson	47 15 21	91 50 48	55	12W	15	NW NE NW NE	Private	Intermittently active	Archive sample was used for replicate sample 24113.
23925	D-372307	Lake	Whyte	47 21 55	91 44 28	56	11W	4	SE NE NW	Private	Active	
23926	D-372312	St. Louis	Whiteface Reservoir	47 22 23	92 9 34	57	14W	31	NE SE SW SE	Federal	Intermittently active	
23927	D-372317	St. Louis	Skibo	47 29 20	91 59 31	58	13W	21	SE SW SW SE	County	Inactive	Archive sample was used for replicate sample 24114.
23928	D-372322	St. Louis	Biwabik NE	47 39 19	92 18 26	60	16W	25	SE SW SE NE	Private	Active	
23929	D-372327	St. Louis	Isaac Lake	47 40 13	92 6 25	60	14W	22	SW SW NW NE	Private	Inactive	
23930	D-372332	St. Louis	Tower	47 46 58	92 17 9	61	15W	8	NW NW SW NW	Private	Intermittently active	
23931	D-372288	St. Louis	McKinley	47 36 47	92 29 49	59	17W	10	SW NE SW NW	Private	Abandoned	
23932	D-372293	St. Louis	Britt	47 39 36	92 36 24	60	18W	27	NE SW NE NE	Private	Active	
23933	D-372298	Crow Wing	Nisswa	46 30 46	94 18 27	135	29W	14	SW NW NW NW	State	Active	
23934	D-372303	Crow Wing	Nisswa	46 37 15	94 16 14	136	29W	1	SE SW NE SE	Private	Active	
23935	D-372308	Crow Wing	Trommald	46 36 35	94 7 9	136	27W	8	NE NW NW SW	County	Inactive	
23936	D-372313	Crow Wing	Emily	46 40 8	93 56 60	137	26W	22	NW NW SE NE	Private	Active	
23937	D-372318	Cass	Mitchell Lake	46 50 52	94 2 24	139	27W	13	NE SE SE SW	State	Inactive	
23938	D-372323	Cass	Edna Lake	46 50 22	93 50 20	139	25W	21	SE SE SE NE	State	Inactive	
23939	D-372328	Cass	Casino	46 23 56	94 30 26	134	30W	19	SE SE SE SW	Private	Abandoned	
23940	D-372333	Morrison	Lincoln	46 13 8	94 38 20	132	31W	30	SE NW SE NW	Private	Inactive	
23941	D-372289	Morrison	Randall East	46 5 4	94 27 52	130	30W	9	SW NE NE SW	Private	Active	
23942	D-372294	Morrison	Randall East	46 1 54	94 26 32	130	30W	34	SE SE NE NW	Private	Intermittently active	
23943	D-372299	Morrison	Pierz	45 58 44	94 5 29	40	30W	9	SE NW SW NW	Private	Active	
23944	D-372304	Morrison	Hillman	46 2 23	93 58 37	41	29W	14	SW NW NW NW	Private	Inactive	
23945	D-372309	Morrison	Ramey NE	45 58 4	93 50 52	40	28W	16	NW NE NW NW	Private	Inactive	
23946	D-372314	Mille Lacs	Onamia	46 4 28	93 42 15	42	27W	36	SW SW NW SW	State	Intermittently active	

Table 3. Location information, surface ownership, and gravel pit activity status for the test and pilot study sample sites ...continued

MDNR Sample Number	USGS Sample Number	County	USGS Quadrangle	Latitude	Longitude	TWP	RNG	SEC	Location	Surface Ownership	Gravel Pit Activity Status	Remarks
23947	D-372319	Crow Wing	Platte Lake	46 12 54	93 55 16	43	28W	7	SW SE SW SE	Private	Active	
23948	D-372324	Crow Wing	Brainerd	46 20 21	94 12 28	45	31W	36	SW SW NW	Private	Active	
23949	D-372329	Crow Wing	Lastrup NW	46 14 45	94 11 44	44	31W	36	SW NE SW SE	Private	Active	
23950	D-372334	Morrison	Freedhem	46 6 17	94 10 31	42	30W	19	NW SW NW SE	Private	Intermittently active	
23951	D-372335	Morrison	Swanville	45 57 47	94 37 51	129	31W	19	SE SW	Private	Active	
23952	D-372339	Todd	Burtrum	45 51 52	94 42 7	128	32W	27	SW SE NE SW	Private	Inactive	
23953	D-372343	Morrison	Bowlus	45 47 57	94 24 21	127	30W	24	SW NE SW NW	Private	Active	
23954	D-372347	Morrison	Little Falls West	45 53 45	94 24 10	128	30W	13	SE SW NE SW	Private	Active	
23955	D-372351	Todd	Staples	46 15 11	94 50 12	132	33W	9	SE SW SE SE	Private	Active	
23956	D-372355	Todd	Eagle Bend	46 9 16	95 0 16	131	34W	18	SW SW NE SE	Private	Abandoned	
23957	D-372359	Todd	Browerville SW	46 6 36	94 53 53	131	34W	36	NW NE SE SE	Private	Inactive	
23958	D-372336	Todd	Rose City	46 2 35	95 8 0	130	35W	30	NE SW SW NE	Private	Abandoned	
23959	D-372340	Pope	Glenwood	45 39 23	95 24 34	125	38W	2	NW SE SE SE	State	Abandoned	
23960	D-372344	Kandiyohi	Mount Tom	45 20 32	95 2 30	122	35W	26	SW NE SE SW	Private	Active	
23961	D-372348	Stearns	Avon	45 35 45	94 26 40	125	30W	34	SE NE SW NW	Private	Inactive	
23962	D-372352	Stearns	St. Stephen	45 38 38	94 20 28	125	29W	16	NE NE NW NW	Private	Inactive	
23963	D-372356	Stearns	Holdingford	45 42 59	94 26 20	126	30W	22	NW NW NW NE	Private	Intermittently active	
23964	D-372360	Morrison	Little Falls East	45 58 26	94 15 27	40	31W	7	SW SE NW SW	Private	Active	
23965	D-372337	Todd	Lake Osakis	45 57 7	95 2 26	129	35W	25	NE SW NW SW	Private	Abandoned	
23966	D-372341	Kandiyohi	Spicer	45 12 24	94 59 25	120	34W	18	SE NW SW NE	Private	Active	
23967	D-372345	Pope	Lake Simon	45 25 20	95 15 24	123	37W	36	SW NE SE NE	Private	Active	Concentrate sample provided.
23968	D-372349	Pope	Starbuck	45 32 33	95 31 58	124	39W	14	SW SE SE SW	State	Inactive	
23969	D-372353	Big Stone	Ortonville	45 15 50	96 24 7	121	46W	26	SE NW	Private	N/A	Pre-glacial alluvium.
23970	D-372357	Kandiyohi	New London	45 18 10	94 54 36	121	34W	11	NE NW NE SE	State	Inactive	
23971	D-372361	Morrison	Royalton	45 50 41	94 21 54	127	29W	5	SW SE NW NW	Private	N/A	Active stream sediment.
23972	D-372338	Dakota	Farmington	44 43 33	93 11 26	115	20W	35	SW SE NW	Private	Active	
23973	D-372342	Washington	Hudson	44 57 19	92 48 39	29	20W	33	NW NW SE	Private	Active	
23974	D-372346	Sherburne	Elk River	45 20 33	93 34 4	33	26W	22	NE NW NW	Private	Active	
23975	D-372350	Hennepin	Osseo	45 6 25	93 25 11	119	22W	24	NE SW NW NW	Private	Active	
24110	D-372354	Aitkin	Glen	46 29 47	93 30 38	46	25W	4	SW NE NW SW	Private	Active	Replicate sample of 23906.

Table 3. Location information, surface ownership, and gravel pit activity status for the test and pilot study sample sites ...continued

MDNR Sample Number	USGS Sample Number	County	USGS Quadrangle	Latitude	Longitude	TWP RNG SEC	Location	Surface Ownership	Gravel Pit Activity Status	Remarks
24111	D-372358	Mille Lacs	Isle	46 11 4	93 27 33	43 25W 23	NE SW SW SE	Private	Active	Replicate sample of 23908.
24112	D-372362	Aitkin	Wright	46 44 49	93 5 1	49 22W 11	NE SE SE NE	State	Intermittently active	Replicate sample of 23911.
24113	D-372364	Lake	Brimson	47 15 21	91 50 48	55 12W 15	NW NE NW NE	Private	Intermittently active	Replicate sample of 23924.
24114	D-372363	St. Louis	Skibo	47 29 20	91 59 31	58 13W 21	SE SW SW SE	County	Inactive	Replicate sample of 23927.

Table 4. Sample numbers arranged by ascending township, range, and section locations

TWP	RNG	SEC	Location	MDNR Sample Number	USGS Sample Number
29	20W	33	NW NW SE	23973	D-372342
33	26W	22	NE NW NW	23974	D-372346
39	26W	11	NE SE SE SE	22635	D-349929
40	28W	16	NW NE NW NW	23945	D-372309
40	30W	9	SE NW SW NW	23943	D-372299
40	31W	7	SW SE NW SW	23964	D-372360
41	29W	14	SW NW NW NW	23944	D-372304
42	27W	36	SW SW NW SW	23946	D-372314
42	28W	30	NW NW SW NE	23909	D-372325
42	30W	19	NW SW NW SE	23950	D-372334
43	25W	23	NE SW SW SE	24111	D-372358
43	25W	23	NE SW SW SE	23908	D-372320
43	28W	7	SW SE SW SE	23947	D-372319
44	24W	23	SE NW SW SW	23907	D-372315
44	31W	36	SW NE SW SE	23949	D-372329
45	22W	4	NW NW NE NW	23920	D-372331
45	28W	26	SE SE SW SW	23904	D-372300
45	31W	36	SW SW NW	23948	D-372324
46	25W	4	SW NE NW SW	24110	D-372354
46	25W	4	SW NE NW SW	23906	D-372310
46	26W	18	NW NW NW NW	23905	D-372305
46	30W	36	SE SW NE NE	23902	D-372290
48	18W	4	NW SW NE NW	23913	D-372296
48	20W	4	SE NW NE NW	23912	D-372291
48	20W	32	NW NW NE NE	23919	D-372326
49	19W	22	NW NE NW NW	23910	D-372330
49	22W	11	NE SE SE NE	23911	D-372286
49	22W	11	NE SE SE NE	24112	D-372362
50	16W	10	NE NE NE NE	23915	D-372306
50	18W	11	NW NW NW NW	23914	D-372301
51	16W	23	SE NW NW NW	23916	D-372311
51	17W	15	SW SE SW SW	23918	D-372321
52	15W	7	SE NE SE NE	23917	D-372316

Table 4. Sample numbers arranged by ascending township, range, and section locations ...continued

TWP	RNG	SEC	Location	MDNR Sample Number	USGS Sample Number
52	15W	27	SE NE NE NE	23921	D-372287
54	12W	18	SE NE NE SE	23923	D-372297
55	12W	15	NW NE NW NE	24113	D-372364
55	12W	15	NW NE NW NE	23924	D-372302
55	14W	27	SE SE NE NW	23922	D-372292
56	11W	4	SE NE NW	23925	D-372307
57	14W	31	NE SE SW SE	23926	D-372312
58	13W	21	SE SW SW SE	24114	D-372363
58	13W	21	SE SW SW SE	23927	D-372317
59	17W	10	SW NE SW NW	23931	D-372288
60	11W	3	SE NE NE SE	20431	D-349932
60	14W	22	SW SW NW NE	23929	D-372327
60	16W	25	SE SW SE NE	23928	D-372322
60	18W	27	NE SW NE NE	23932	D-372293
61	15W	8	NW NW SW NW	23930	D-372332
115	20W	35	SW SE NW	23972	D-372338
119	22W	24	NE SW NW NW	23975	D-372350
120	34W	18	SE NW SW NE	23966	D-372341
121	34W	11	NE NW NE SE	23970	D-372357
121	46W	26	SE NW	23969	D-372353
122	35W	26	SW NE SE SW	23960	D-372344
123	37W	36	SW NE SE NE	23967	D-372345
124	39W	14	SW SE SE SW	23968	D-372349
125	29W	16	NE NE NW NW	23962	D-372352
125	30W	34	SE NE SW NW	23961	D-372348
125	38W	2	NW SE SE SE	23959	D-372340
126	30W	22	NW NW NW NE	23963	D-372356
126	38W	29	SE SW SW NW	22636	D-349930
127	29W	5	SW SE NW NW	23971	D-372361
127	30W	24	SW NE SW NW	23953	D-372343
128	30W	13	SE SW NE SW	23954	D-372347
128	32W	27	SW SE NE SW	23952	D-372339
129	31W	19	SE SW	23951	D-372335

Table 4. Sample numbers arranged by ascending township, range, and section locations ...continued

TWP	RNG	SEC	Location	MDNR Sample Number	USGS Sample Number
129	35W	25	NE SW NW SW	23965	D-372337
130	30W	9	SW NE NE SW	23941	D-372289
130	30W	34	SE SE NE NW	23942	D-372294
130	35W	30	NE SW SW NE	23958	D-372336
131	34W	18	SW SW NE SE	23956	D-372355
131	34W	36	NW NE SE SE	23957	D-372359
132	31W	11	NW SW SW NW	22634	D-349928
132	31W	11	NW SW SW NW	22633	D-349927
132	31W	30	SE NW SE NW	23940	D-372333
132	33W	9	SE SW SE SE	23955	D-372351
133	30W	13	NW SE NE NE	23903	D-372295
134	28W	12	NE SW NW SE	23901	D-372285
134	30W	19	SE SE SE SW	23939	D-372328
135	29W	14	SW NW NW NW	23933	D-372298
136	27W	8	NE NW NW SW	23935	D-372308
136	29W	1	SE SW NE SE	23934	D-372303
137	26W	22	NW NW SE NE	23936	D-372313
138	27W	26	SW SW NE NW	22632	D-349926
139	25W	21	SE SE SE NE	23938	D-372323
139	27W	13	NE SE SE SW	23937	D-372318
141	27W	10	NW SE NW SW	22631	D-349925
141	30W	5	SE SW SE	22637	D-349931

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
20431	Rainy	Esker	Ice-contact	No gravel pit at site.	Sample collected just off roadway with an auger; from surface to 5 foot depth collected.		Sample collected during glacial drift geochemistry study (Buchheit and others, 1989).
22631	Wadena	Outwash plain	Outwash	Pebbly sand, well stratified. Granite and greenstone pebbles dominant. Some limestone, red rhyolite and red sandstone present.	Sample taken 10 feet down pit face, 1 foot below the Fe-oxide-rich zone	Pebbly sand	
22632	Rainy	Outwash plain	Outwash	Poorly sorted pebbly sand, dark brown. No bedding observed. Abundant Superior lobe lithologies present, i.e. red sandstone and some agates. No shale or limestone.		Poorly sorted pebbly sand	Looks like Rainy lobe deposit with a strong Superior lobe component.
22633	Superior	Esker	Ice-contact	Sandy pebble-gravel most common sediment present. Some sorted sand also present. Generally a fairly coarse deposit. Abundant Superior lobe lithologies present. Also, abundant pinkish argillite present (locally derived?).		Pebble gravel	Same site as 22634; supraglacial esker.
22634	Superior	Esker	Ice-contact	Sandy pebble-gravel most common sediment present. Some sorted sand also present. Generally a fairly coarse deposit. Abundant Superior lobe lithologies present. Also, abundant pinkish argillite present (locally derived?).		Sand	Same site as 22633; supraglacial esker.

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
22635	Superior	Esker	Ice-contact	Poorly sorted sandy pebble and cobble gravel. Some sorted sand also present. Cobble gravel appears to form core of esker. Abundant Superior lobe lithologies present. No shale or limestone. Some iron-formation (local?).		Sandy pebble gravel?	Tunnel valley esker.
22636	Wadena	Stagnation moraine	Ice-contact	5 to 12 feet of yellowish-brown loamy till containing shale (Des Moines lobe till) overlying stratified sand and pebbly sand, moderately to poorly sorted. Pebble lithologies include granite, red sandstone, agate, gabbro and dolomite. No shale.	Sample taken 5 feet below Des Moines till	Pebbly sand?	
22637	Wadena	Stagnation moraine	Ice-contact	Poorly sorted sand and pebbly sand. Contains approximately 40% supracrustals, 50% granite and 5% carbonate, agates, red sandstone and felsite. No shale.		Pebbly sand?	
23901	Rainy	Kame	Ice-contact	Moderately to well sorted sand and gravel. Flanks of kame overlain by dark brown sandy diamicton. Many Superior lobe lithologies present (agate, rhyolite). Also, pinkish-tan phyllite common. No large boulders present.	2 meters above pit floor		
23902	Rainy	Collapsed outwash plain	Outwash	0.5 to 1.5 meters sandy diamicton, dark reddish-brown overlying	South pit - west exposure, 7 meter	Coarse sand, cross-bedded	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				moderately to well sorted sand and gravel, stratified and cross-bedded, uncollapsed bedding.	high section		
23903	Rainy	Outwash plain	Outwash	Large (160 acre) pit. Well sorted medium sand fining upward, overlying, with sharp contact, sand and gravel, poorly to well sorted. Common pebble lithologies include red sandstone, basalt, limestone. Iron-formation, pinkish phyllite, shale and graywacke also present. Generally a lithologically mixed deposit. Interpretation: Rainy lobe outwash plain overlain by near-shore lacustrine deposits.	From stockpile of crushed gravel	1/4 inch to 100-mesh crushed product	
23904	Superior	Stagnation moraine	Ice-contact	1.5 to 2 meters reddish-brown sandy diamicton (Superior lobe till) overlying poorly sorted sand and gravel with interbedded sand, silt and clay, well to poorly sorted.	Immediately below till (approximately 2 meters below surface)	Sand and gravel	
23905	Superior	Stagnation moraine	Ice-contact	Tan, fine-grained diamicton, non-calcareous, overlying stratified sand and gravel, with interbedded silt and clay, well sorted. Pebble lithologies include rhyolite, agate, red sandstone, granophyre and metasedimentary rocks.	Lower pit, SW face of SE main pit. Face 3.5 meters high. Sample taken 1 meter above pit bottom, 30cm in from disturbed face.	Medium sand and fine gravel, cross-bedded	
23906	Superior	Kame	Ice-contact	Interbedded poorly to well sorted	3 meters above pit	Sand and gravel,	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				gravel, sand, silt, clay and reddish to yellow diamicton. Collapsed bedding. Abundant Superior lobe lithologies present.	floor, 12 meters below surface	moderately to poorly sorted, stratified, with interbedded diamicton (avoided in sampling)	
23907	Superior	Esker	Ice-contact	0.3 meters tan, loamy diamicton, non-calcareous overlying moderately sorted gravel and well sorted sand with some interbedded sandy diamicton, red.	3 meter high face in SW corner of pit	Sand and gravel	
23908	Superior	Stagnation moraine	Ice-contact	5 meter high exposure of interbedded sand, gravel, silt, clay and red, sandy diamicton ranging from well sorted clay, silt and sand to very poorly sorted sandy, cobble- and boulder-gravel. Collapsed bedding.	SE pit, south face	Very well sorted medium sand with fine gravel layers	
23909	Superior	Esker	Ice-contact	East face, closest to road, 2 meters high. Reddish-brown sandy diamicton, 0.5 to 0.7 meters thick, overlying poorly sorted medium gravel, cross-bedded; fine to medium sand, well sorted; and sandy gravel, moderately sorted.	East face, closest to road approximately 1.5 meters below surface	Moderately sorted sandy gravel	
23910	Superior	Kame	Ice-contact	North face 9 meters high. Red, sandy diamicton, 1 to 1.5 meters thick, overlying poorly sorted, medium gravel and well sorted sand.	North face	Very poorly sorted coarse gravel	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23911	Superior	Esker	Ice-contact	SW face, 4 meters high. Poorly sorted sandy gravel. Stratified and fine to medium gravel, cross-bedded. Granophyre, felsite and agate present.	SW face, approximately 3.5 meters below surface	Fine to medium gravel	
23912	Superior	Stagnation moraine	Ice-contact	Red sandy diamicton, 0 to 2 meters thick, overlying fine to medium, well sorted sand with fine gravel; very-coarse gravel, very poorly sorted; and fine to medium sand, very-well sorted. Collapsed bedding. Abundant Superior lobe lithologies, including red sandstone, also abundant light gray phyllite.	SW face	Fine to medium sand, with fine gravel, well sorted	
23913	Superior	Outwash plain	Outwash	Medium gravel, moderately to poorly sorted, stratified overlying well sorted, medium sand. Abundant granophyre, also porphyritic rhyolite.	West face, north side of pit	Medium gravel, moderately to poorly sorted	Very poor exposure
23914	Superior	Esker	Ice-contact	10 meter high exposure. Very coarse gravel, very poorly sorted; overlying medium gravel; overlying interbedded sand (medium, well sorted) and medium gravel, moderately to poorly sorted. Horizontal stratification. Red sandy diamicton present in west face. Superior lobe lithologies,			

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				especially agate, abundant. Red sandstone present. NE corner, north face, within upper 2 meters.			
23915	Superior	Stagnation moraine	Ice-contact	Red sandy diamicton, 1 to 2 meters thick overlying very coarse gravel, poorly sorted and fine gravel, well sorted, with lenses of well sorted fine sand. Collapsed bedding. Abundant agate, granophyre, porphyritic felsite and some red sandstone.	Lowest part of pit, 20 feet (?) below land surface	Fine gravel, well sorted, with lenses of well sorted fine sand	
23916	Superior	Stagnation moraine	Ice-contact	Diamicton, 1 to 1.5 meters thick, overlying very-fine to coarse gravel, sand and silt, stratified.	South central wall of pit	Fine to medium pebble gravel	
23917	Superior	Outwash plain	Outwash	Interbedded sand and gravel, ranging from fine sand to medium gravel, poorly to well sorted, horizontal stratification and cross-bedding. Granophyre, agate, porphyritic felsite abundant. No metasediments or red sandstone.	East face	Fine gravel	
23918	Superior	Stagnation moraine	Ice-contact	Stratified sand and gravel ranging from coarse gravel, very-poorly sorted to fine sand, well sorted. Total thickness 15 meters.	Lowest face, 5 meters high	Medium gravel, stratified	
23919	Superior	Drumlin	Ice-contact	Red, sandy diamicton, 1 meter thick, overlying interbedded medium to fine gravel, sand and silt.		Medium to fine gravel, stratified	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23920	Superior	Esker	Ice-contact	Red, sandy diamicton overlying interbedded gravel and sand, cross-bedded to stratified. Agate, red sandstone, granophyre, porphyritic felsite present.	South face 2 meters below land surface, 2 meters above pit floor	Medium gravel	
23921	Superior	Stagnation moraine	Ice-contact	Exposure 16 meters high. Yellow-brown sandy diamicton, 0.75 meters thick, overlying sand and gravel, poorly to well sorted, stratified and collapsed bedding. Abundant porphyritic felsite and red sandstone.	Main pit, south face	Fine to medium gravel, cross-bedded	
23922	Rainy	Outwash plain	Outwash	4 meter high exposure. Yellow-brown sandy diamicton, 1 meter thick, overlying medium to fine gravel, poorly sorted. Faintly stratified. Granophyre, porphyritic felsite, basalt, slate and granite present.	East face, left side	Medium to fine gravel, poorly sorted	
23923	Superior	Outwash plain	Outwash	Moderately coarse to fine gravel and coarse sand, moderately to poorly sorted. Mostly basalt, felsite, gabbro; few porphyritic felsite pebbles, rare agate.	NW face	Coarse sand and fine gravel	Outwash plain is collapsed.
23924	Superior	Outwash plain	Outwash	3 meter high exposure. Brown, sandy diamicton, 0 to 0.3 meters thick, overlying fine to medium gravel, poorly sorted, stratified.	West face, near surface	Fine pebbly gravel	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				Felsite, basalt, granite, some red sandstone and granophyre.			
23925	Rainy	Stagnation moraine	Ice-contact	Yellow-brown sandy diamicton, 1.5 meters thick, overlying fine to coarse gravel, poorly to well sorted, with lenses of coarse sand. Boulders are gabbro. Other lithologies: granophyre, red sandstone, porphyritic felsite, basalt, granite, slate and some agate.	SE pit, south face	Fine gravel	
23926	Rainy	Valley train	Outwash	Sand and gravel, ranging from fine sand to coarse gravel, poorly to moderately well sorted. Basalt, gabbro, felsite, granite present.	North pit, NW face	Fine gravel and coarse sand, moderately sorted	
23927	Rainy	Outwash plain	Outwash	Yellow-brown, sandy diamicton, 0.5 to 1.5 feet thick overlying stratified sand and gravel, ranging from medium sand, well sorted, to coarse gravel moderately sorted. Lithologies include: basalt, gabbro, granite, gneiss, felsite.	South end of pit, east face	Medium sand, well sorted and fine gravel, moderately well sorted	
23928	Rainy	Outwash fan	Ice-contact	4 meter high exposure. Yellow-brown, sandy diamicton, 0.5 meters thick overlying very coarse gravel, poorly sorted, with interbedded sand, very fine to coarse, well sorted. Lithologies present: granite, greenstone,	North pit, east side, south face	Interbedded coarse sand, very well sorted and coarse sandy gravel, poorly sorted	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				gneiss, schist, metasediments, gabbro and iron formation.			
23929	Rainy	Outwash plain	Outwash	3-meter-high exposure. Medium sand to medium gravel, well sorted. Lithologies present: granite, schist, metasediments, porphyritic felsite, greenstone, gabbro, gneiss.	North face	Medium gravel, well sorted	
23930	Rainy	Outwash fan	Ice-contact	12-meter-high exposure. Interbedded medium to coarse gravel, poorly sorted, and fine sand to fine gravel, well sorted. Lithologies include: gabbro, metasediments, basalt, iron formation, schist and granite.	SW pit, center of north face	Fine gravel	
23931	Rainy	Outwash fan	Ice-contact	Interbedded fine sand, very-well sorted; fine gravel; and coarse gravel, poorly sorted, with fine sand lenses. Collapsed bedding. Lithologies include: granite, greenstone, gneiss, gabbro, iron formation and metasediments.	NW pit, north face	Medium gravel, very well sorted	
23932	Rainy	Stagnation moraine	Ice-contact	Interbedded medium to coarse gravel and medium sand, moderately to well sorted. Lithologies include: granite, gabbro, gneiss, metasediments, greenstone, schist, felsite.	West side of pit, north face	Fine gravel with pebbles and cobbles, well sorted	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23933	Rainy	Outwash plain	Outwash	Medium to fine gravel, very-poorly sorted and medium sand, moderately well sorted, cross-bedded, collapsed. Lithologies include: agate, red sandstone, granite, gabbro, metasediments, porphyritic felsite, basalt.	NE pit, south face	Fine gravel and coarse sand, well sorted, cross-bedded	
23934	Rainy	Outwash plain	Outwash	Interbedded medium gravel to medium sand, moderately well sorted, horizontal stratification. Lithologies include: granite, gabbro, schist, greenstone, porphyritic felsite, some red sandstone, agate and granophyre.	SW pit, east face	Medium sand with heavy mineral bands, well sorted	
23935	Rainy	Outwash plain	Outwash	Medium sand, with pebbly beds, very well sorted, cross-bedded. Lithologies include: metasediments, schist, granite, gabbro, felsite, basalt.	Main pit, south face	Pebbly, medium sand, cross-bedded	
23936	Rainy	Stagnation moraine	Ice-contact	Interbedded fine gravel to fine sand, moderately well sorted. Some interbedded clay. Collapsed bedding. Lithologies include: granite, slate, basalt, red sandstone, granophyre, felsite, gabbro, vein quartz.	South pit, NE face	Interbedded medium sand and fine gravel, collapsed bedding	
23937	Rainy	Outwash plain	Outwash	Interbedded medium gravel, poorly sorted, massive and coarse sand, well sorted. Lithologies include:	North part of pit, NW face	Coarse sand, well sorted	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				granite, gabbro, metasediments, felsite, basalt, schist, gneiss.			
23938	Rainy	Stagnation moraine	Ice-contact	Fine to coarse sand, pebbly, well sorted, cross-bedded. Lithologies include: granite, gabbro, felsite, granophyre, schist, basalt.	West face	Coarse pebbly sand, moderately to poorly sorted, iron cemented	
23939	Rainy	Outwash plain	Outwash	Interbedded poorly sorted pebbly sand, and well sorted medium sand with pebble layers. Massive. Lithologies include: red sandstone, granite, gabbro, basalt, porphyritic rhyolite, gneiss, slate.	West face	Pebbly coarse sand, moderately to poorly sorted, massive	
23940	Superior	Stagnation moraine	Ice-contact	Sandy loam diamicton, 0.5 to 1 meter thick, overlying a generally fining downward sequence of interbedded gravel, sand, silt, clay and diamicton. Lithologies include: gneiss, granite, gabbro, basalt, rhyolite, red sandstone, metasediments, schist.	North side, NW face	Pebbly sand	
23941	Rainy	Outwash fan	Ice-contact	Interbedded fine sand, moderately to very-well sorted and gravel.	SW pit, SW face, 3 meters above pit floor	Coarse gravel, moderately sorted	
23942	Superior	Esker	Ice-contact	Interbedded sequence of fine to coarse gravel, fine to medium sand, silt and clay. Stratified, cross-bedded and massive.	SE pit, NW end, north face	Fine gravel, well sorted, cross-bedded	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23943	Superior	Valley train	Outwash	Interbedded and stratified. Sandy pebble gravel and pebbly sand, ranging from very poorly to moderately well sorted. A few cobbles and boulders interspersed in more poorly sorted beds; 10 to 15 feet thick, overlying sand, fine to coarse, moderately to well sorted, cross-bedded, >5 feet thick. Pebble lithologies: basalt, felsite, red sandstone. Also some granite, gabbro, gneiss and greenstone.	South end of pit, 15 to 20 feet high face, 8 feet below disturbed land surface	Interbedded sandy pebble gravel and pebbly sand, very poorly to moderately well sorted	
23944	Superior	Esker	Ice-contact	10 feet high exposure of sandy, cobbly pebble-gravel, poorly to very poorly sorted. Sand matrix ranges from very fine to very coarse, slightly silty, coarse skewed. Massive. Pebble lithologies: basalt, felsite, red sandstone, granite, gneiss, and greenstone.	North part of pit, approximately 5 feet below land surface.	Sandy, cobbly pebble-gravel, poorly to very poorly sorted.	
23945	Superior	Outwash fan	Ice-contact	Sandy pebble gravel, very poorly sorted, 3 feet thick, overlying sand, very fine to very coarse, poorly sorted, 3 feet exposed. Pebble lithologies: basalt, felsite, granite, greenstone, and gneiss.	South end of pit, approximately 3 feet below land surface	Sandy pebble gravel, very poorly sorted	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23946	Rainy	Unknown	Outwash	Yellowish-brown (Alborn) till overlying reddish-brown (Pierz) till overlying sandy pebble gravel, poorly to very poorly sorted, massive to stratified, 12 to 24 inches thick; overlying very fine to very coarse sand, slightly pebbly, poorly to well sorted, cross-bedded, 6 to 8 feet thick. Pebble lithologies in interval sampled: basalt, greenstone, gabbro, granite, gneiss, graywacke, limestone, red sandstone and felsite also present, but not common.	South end of pit	Sandy pebble gravel, poorly to very poorly sorted, massive to stratified	
23947	Rainy	Outwash plain	Outwash	Interbedded sandy pebble gravel, poorly to very poorly sorted, weakly stratified and very-fine to very-coarse sand, moderately to poorly sorted. Pebble lithologies: greenstone, granite, gneiss, slate, iron formation.	NW portion of pit, 4 feet below land surface	Sandy pebble gravel, poorly to very poorly sorted, weakly stratified	
23948	Rainy	Outwash plain	Outwash	Pebbly sand, very-fine to very-coarse, poorly sorted, overlying very-fine to fine silty sand, well sorted. In general, very sandy pit. Bedding slightly collapsed. Pebble lighologies: granite, gneiss, greenstone, red sandstone, basalt, graywacke, iron formation and granophyre.	In upper portion of pit approximately 8 feet below land surface	Pebbly sand, very fine to very coarse, poorly sorted, weakly stratified	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23949	Rainy	Outwash fan	Ice-contact	12 to 36 inches of silty sand, very fine to fine (eolian), overlying sandy fine pebble gravel, poorly sorted, massive with thinly bedded fine to very coarse sand, 8 to 10 feet thick; overlying very compact rainy lobe till, 8 feet thick; overlying rainy lobe sand and gravel, 6 to 8 feet thick. Pebble lithologies: granite, gneiss, greenstone, basalt, graywacke, iron formation, felsite, red sandstone.	Approximately 5 feet below land surface in north portion of pit	Sandy, fine pebble gravel, poorly sorted, massive	
23950	Rainy	Kame	Ice-contact	50 foot high exposure of interbedded sand and sandy pebble gravel. Pebble lithologies: granite, iron formation (very common), greenstone, basalt, graywacke, gneiss, red sandstone and felsite present, but not common.	South end of pit, approximately 15 feet below land surface	Fine pebbly sand, medium to very coarse, poorly sorted, massive	
23951	Rainy	End moraine	Ice-contact	Interbedded coarse to very coarse sandy pebble gravel, poorly sorted; and fine to coarse sand, moderately to well sorted, stratified. Bedding slightly collapsed. Pebble lithologies: granite, gneiss, greenstone, graywacke, red sandstone, basalt. Limestone present, but not abundant.	East end of pit	Coarse to very coarse sandy fine pebble gravel, poorly sorted, weakly stratified	

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23952	Superior	Stagnation moraine	Ice-contact	Pebbly sand, very fine to very coarse, poorly to very poorly sorted, weakly stratified. Very fine to very coarse pebbles and some cobbles present. Pebble lithologies: granite, gneiss, basalt, felsite, graywacke, limestone, dolomite, granophyre, agate.	4 feet below land surface	Pebbly sand, very fine to very coarse, poorly to very poorly sorted	
23953	Wadena	Unknown	Ice-contact	Interbedded sandy pebble gravel, very poorly sorted; pebbly sand, poorly sorted and sand. Stratified-pebble lithologies: granite, limestone, dolomite (quite common), gneiss, greenstone, basalt, graywacke.	East side of pit, approximately 4 feet below land surface	Very fine to fine pebbly sand, ranging from very fine to coarse, poorly sorted, weakly stratified	
23954	Wadena	Unknown	Outwash	3 to 3.5 feet of Pierz till overlying crudely interbedded sandy, very-fine to medium pebble gravel and very-fine to medium pebbly sand, medium to very coarse, moderately to poorly sorted. Pebble lithologies: limestone and dolomite (common), granite, gneiss, greenstone, basalt, graywacke.	North end of pit, approximately 7 feet below land surface and 4 feet below contact with overlying till	Sandy, very-fine to medium pebble gravel and very-fine to medium pebbly sand, medium to very coarse, moderately to poorly sorted	
23955	Wadena	Valley train	Outwash	Interbedded silt, sand and gravel, well to poorly sorted, horizontal stratification. Lithologies include: abundant limestone. Also, basalt, phyllite, porphyritic	Central pit, south face	Sandy, pebble, medium gravel, poorly sorted, massive	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				felsite.			
23956	Wadena	Valley train	Outwash	0.6 meters loamy sand, reddish color, overlying pebbly gravelly sand, poorly sorted, weakly stratified. Lithologies include: abundant limestone. Also, gneiss, granite, basalt, schist, felsite.		Pebbly, gravelly sand, poorly sorted	
23957	Wadena	Valley train	Outwash	Interbedded sandy gravel, fine to medium, moderately to poorly sorted, cross-bedded, stratified; and sand, medium to coarse, pebbly, moderately to well sorted, massive, cross-bedded. Lithologies include: abundant limestone. Also granite, gabbro, gneiss, felsite, basalt.	East central face	Fine gravel, moderately sorted, cross-bedded	
23958	Wadena	Outwash plain	Outwash	Medium sand, pebbly, moderately poorly sorted overlying fine to coarse pebbly sand and sandy fine gravel, moderately poorly sorted, stratified. Lithologies include: limestone, gneiss, granite, greenstone, gabbro.	South face	Fine sandy gravel, 1.2 meters below land surface	
23959	Wadena	Stagnation moraine	Ice-contact	Medium sandy gravel, cobbly and coarse sand. Poorly to moderately well sorted. Lithologies include: abundant limestone. Also, gneiss, phyllite, schist, granite, basalt, gabbro.	North face, 8 meters from pit floor	Sandy, cobbly gravel, poorly sorted	West side of pit at lower (approximately 6 meters) elevation is Des Moines lobe outwash. Abundant Pierre Shale.

Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
23960	Wadena	Stagnation moraine	Ice-contact	Brown, clayey diamicton, 0.4 meters thick, overlying sandy, pebbly, cobbly, bouldery gravel, very poorly sorted, horizontal stratification. Lithologies include: abundant limestone. Also, granite, gabbro, schist, gneiss, 2 pieces Pierre Shale.	South face	Very coarse gravel	
23961	Wadena	Unknown	Outwash	Red, sandy diamicton, 1 meter thick overlying stratified sand and gravel. Lithologies include: granite, limestone, gabbro, felsite, red sandstone, greenstone, iron formation.	East face, south end of settling pond	Fine gravel	
23962	Wadena	Unknown	Ice-contact	Yellowish-brown, sandy diamicton, 0 to 2 meters thick, overlying very-poorly sorted gravel and well sorted fine sand and silt. Stratified. Lithologies include: limestone, granite.		Gravel, very poorly sorted, weakly stratified	
23963	Superior	Valley train	Outwash	Sandy, pebbly gravel, very poorly sorted. Lithologies include: abundant limestone. Also, granite, gneiss, sandstone, porphyritic felsite, basalt.	South face	Sandy, pebbly gravel, very poorly sorted	Described as mixed Superior/Wadena lobe by T. Cowdery.
23964	Superior	Stagnation moraine	Ice-contact	Interbedded fine sand to gravel, moderately sorted, cross-bedded, stratified, collapsed. Lithologies include: red sandstone, agate,	East pit, east side	Medium to fine gravel, moderately sorted, massive	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				granophyre, iron formation, granite, gabbro, basalt, felsite.			
23965	Wadena	Stagnation moraine	Ice-contact	Interbedded very-fine sand, well sorted, cross-bedded; and fine gravel, moderately sorted; overlying clay loam diamicton with no shale. Lithologies include: graywacke, basalt, granite, gabbro, iron formation, felsite and abundant limestone.	North pit, NE corner	Fine gravel, moderately sorted	Much shale littering the pit area. Must be from Des Moines lobe till that has been removed by gravel operation.
23966	Des Moines	Stagnation moraine	Ice-contact	Coarse gravel, poorly sorted; overlying yellow-tan clay loam diamicton overlying medium gravel to fine sand with some interbedded silt, well sorted. Lithologies include: limestone, Pierre Shale, granite, gneiss, gabbro, basalt.	East central pit, west face	Medium to fine gravel, moderately sorted	
23967	Wadena	Stagnation moraine	Ice-contact	Interbedded medium gravel to fine sand, moderately poorly sorted to well sorted. Collapsed bedding. Lithologies include: limestone, granite, basalt, schist, rhyolite, gneiss, slate.	North pit, SE face	Heavy-mineral-concentrate sample provided by gravel pit operator	
23968	Wadena	Stagnation moraine	Ice-contact	Yellow-tan clay loam till containing Pierre shale, 0.5 meters thick; overlying medium to fine gravel, moderately well sorted. Lithologies include: limestone, basalt, slate, gabbro, granite,	NE face, 1.75 meters below top	Medium to fine gravel, well sorted, massive	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				gneiss, schist, porphyritic rhyolite.			
23969	Unknown	Unknown	Outwash	Yellow-tan clay loam diamicton, 0.8 meters thick, overlying interbedded fine sand to clayey silt; fine "salt and pepper" sand, well sorted; and medium to fine "salt and pepper" gravel, moderately sorted. Lithologies include: gneiss, granite, gabbro, limestone, slate, basalt, Pierre Shale.	NW pit, NE side, lower part of east face	Medium to fine "salt and pepper" gravel, moderately sorted	Possibly a pre-glacial alluvium
23970	Wadena	Stagnation moraine	Ice-contact	Interbedded pebbly sand, well sorted, massive; and fine gravel, well sorted. Lithologies include: granite, limestone, greenstone, gneiss, slate, rare Pierre Shale.	East end of pit, north face	Pebbly sand	
23971	N/A	Active stream	Alluvium	Site approximately 100 yards south of bridge in bed of Hay Creek. Active stream river gravels. Drill core information indicates creek crosses zoned pegmatites.	Downstream side of an exposed boulder in middle of Hay Creek. Sample collected from approximately the top 4 inches of stream sediments.	River gravels	
23972	Superior	Outwash plain	Outwash	12 to 24 inches of loess overlying interbedded sandy pebble gravel and pebbly sand, ranging from moderately to very poorly sorted. Better sorted units cross-bedded.	Southeastern portion of pit approximately 15 feet below disturbed land surface	Very-fine to fine pebbly sand, ranging from medium to very coarse, moderately to well sorted,	

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				Pebble lithologies: basalt, felsite, red sandstone, granite, gneiss, graywacke and limestone.		cross-bedded	
23973	Superior	Stagnation moraine	Ice-contact	Interbedded pebbly sand and sandy, cobbly pebble-gravel, coarser beds are more poorly sorted and massive while finer units are stratified and cross-bedded. Pebble and cobble lithologies: Paleozoic carbonate (locally derived?), basalt, red sandstone, felsite, gabbro, granite, gneiss, graywacke.	Western part of pit, approximately 20 to 25 feet below land surface	Very fine to medium pebbly sand, very-fine to very-coarse, moderately to poorly sorted, well stratified	
23974	Superior	Outwash fan	Ice-contact	Interbedded sandy pebble gravel; sandy, cobbly pebble gravel; pebbly sand; and sand; ranging from well to very-poorly sorted. Finer units stratified and cross-bedded, coarser units massive. Pebble and cobble lithologies: granite, gneiss, basalt, felsite, graywacke, red sandstone, greenstone.	NW part of pit approximately 35 to 40 feet below original land surface	Very-fine to fine pebbly sand, fine to very coarse, moderately to poorly sorted	
23975	Superior	Stagnation moraine	Ice-contact	Interbedded sand, pebbly sand, sandy pebble gravel. Pebble lithologies: basalt, red sandstone, graywacke, granite, gneiss, felsite.	Approximately 10 to 15 feet below original land surface	Very-fine to medium pebbly sand, fine to very coarse, coarse skewed poorly to very poorly sorted, crudely stratified	
24110	Superior	Kame	Ice-contact	Interbedded poorly to well sorted gravel, sand, silt, clay and	3 meters above pit floor, 12 meters	Sand and gravel, moderately to poorly	Replicate sample of 23906

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Table 5. Geologic descriptions of the gravel pit sampling sites and the sediments sampled ...continued

MDNR Sample Number	Glacial Lobe	Landform	Sediment Type	Gravel Pit Site Description	Sample Location	Sample Description	Remarks
				reddish to yellow diamicton. Collapsed bedding. Abundant Superior lobe litholgies present.	below surface	sorted, stratified, with interbedded diamicton (avoided in sampling)	
24111	Superior	Stagnation moraine	Ice-contact	5 meter high exposure of interbedded sand, gravel, silt, clay and red, sandy diamicton ranging from well sorted clay, silt and sand to very poorly sorted sandy, cobble- and boulder-gravel. Collapsed bedding.	SE pit, south face	Very well sorted medium sand with fine gravel layers	Replicate sample of 23908
24112	Superior	Esker	Ice-contact	SW face, 4 meters high. Poorly sorted sandy gravel, stratified and fine to medium gravel, cross-bedded. Granophyre, felsite and agate present.	SW face, approximately 3.5 meters below surface	Fine to medium gravel	Replicate sample of 23911
24113	Superior	Outwash plain	Outwash	3 meter high exposure. Brown, sandy diamicton, 0 to 0.3 meters thick, overlying fine to medium gravel, poorly sorted, stratified. Felsite, basalt, granite, some red sandstone and granophyre.	West face, near surface	Fine pebbly gravel	Replicate sample of 23924
24114	Rainy	Outwash plain	Outwash	Yellow-brown, sandy diamicton, 0.5 to 1.5 feet thick overlying stratified sand and gravel, ranging from medium sand, well sorted, to coarse gravel moderately sorted. Lithologies include: basalt, gabbro, granite, gneiss, felsite.	South end of pit, east face	Medium sand, well sorted and fine gravel, moderately well sorted	Replicate sample of 23927

Table 6. Volume and weight measurements of the various sample fractions for the test and pilot study samples

MDNR Sample Number	Bulk Sample Volume liters	Minus-10-mesh Weight grams x 10^3	Minus-20-mesh Volume liters	Minus-20-mesh Weight grams x 10^3	C-1 Weight grams	C-2 Weight grams	C-3 Weight grams	HMC In Bulk Sample %-weight
20431		9.1			126.7	316.9	1.86	
22631		9.8			31.6	95.8	3.94	
22632		8.9			15.8	50	0.55	
22633		6.2			10.6	34.5	0.74	
22634		9.8			21.4	68.8	2	
22635		7.9			71.4	142.2	1.34	
22636		7.6			29.2	53.8	3	
22637		7.9			8.5	46.8	0.9	
23901	6.5		5	9.8	16.1	64.2	1.47	0.7
23902	7.5		5	9	31.3	113.3	0.77	1.0
23903	8		4.3	7.5	15	54.1	1.04	0.5
23904	8		3	5.9	76.1	160.4	1.88	1.6
23905	7.5		4.5	8.3	29.5	98.5	0.72	0.9
23906	8		3	5.3	23	80.6	0.76	0.7
23907	6.5		4.8	7.8	19.6	53.9	0.37	0.6
23908	7		4.8	8	100.9	263.1	1.98	2.8
23909	8.5		4	5.7	15.1	49	0.28	0.4
23910	30		2	2.9	27.7	56.7	0.16	0.1
23911	10.5		2.5	4.4	45.1	106.8	0.33	0.8
23912	6.3		4	7.4	41.6	118.8	1.21	1.3
23913	9		4	6.8	15.7	50.7	1.07	0.4
23914	11		3	5.2	40.3	103.6	0.24	0.7
23915	9		4	7.6	40.7	111	0.43	0.9
23916	11		4	6.1	122.7	189.8	0.84	1.5
23917	10		4	6.5	84.1	199.2	0.3	1.5
23918	10		3.8	6.9	115.8	179.2	0.13	1.6
23919	8		4	7.1	36.7	141.1	0.98	1.2
23920	9		4	7.3	20	54.7	0.41	0.4
23921	12		4	7.3	72.4	168.3	0.85	1.1
23922	11		3.5	6	133.1	324.8	0.31	2.2

Note: Bulk sample volume = approximate volume of bulk sand/gravel seived to yield 6-7 liters of minus-10-mesh sand. Heavy-mineral-concentrates (HMC) were prepared from the minus-10-mesh fraction for the test study samples and from the minus-20-mesh fraction for the pilot study samples. C-1, C-2 and C-3 weights have been calculated to total weight before fire assay sample split. To determine %-weight of HMC in bulk sample, bulk sample weight was calculated from bulk sample volume using 1.9 g/cc as average specific gravity of sand/gravel.

Table 6. Volume and weight measurements of the various sample fractions for the test and pilot study samples ...continued

MDNR Sample Number	Bulk Sample Volume liters	Minus-10-mesh Weight grams x 10^3	Minus-20-mesh Volume liters	Minus-20-mesh Weight grams x 10^3	C-1 Weight grams	C-2 Weight grams	C-3 Weight grams	HMC In Bulk Sample %-weight
23923	8		5	9.1	148.1	299.3	0.14	3.0
23924	8		4.5	7.3	153.1	282.9	0.43	2.9
23925	8		3.5	6.3	103.3	221.8	0.54	2.2
23926	8.3		3.5	6	80.7	165.1	0.43	1.5
23927	7.5		4.8	7.5	158.9	299.7	1.4	3.3
23928	15		4.5	7.9	18.4	95.3	1.45	0.4
23929	11		3.8	6.1	24.3	102.1	0.97	0.6
23930			3.5	5.7	3.6	37.5	0.75	
23931	9		2.8	4.6	6.6	39.7	0.6	0.3
23932	11.5		2.8	4.3	7.5	45	0.68	0.2
23933	8.5		3	5.2	5.9	25.1	0.79	0.2
23934	6.5		5	8.9	458.4	639	7.68	9.2
23935	8		4	7.2	1.3	10.7	0.61	0.1
23936	7.5		4.3	7.4	13	47	0.82	0.4
23937	11		2.8	4.4	16.5	40.9	0.44	0.3
23938	7.5		4.3	7.1	10	35.3	1.3	0.3
23939	8.5		4	7.2	13.7	46.6	0.46	0.4
23940	8.5		4	6.6	11.4	38.8	0.29	0.3
23941	11		2	3	6.5	24.5	0.73	0.2
23942			3	5.5	9.2	19.7	0.43	
23943	25		2.3	3.9	39.6	85.3	0.37	0.3
23944	20.5		3	5.2	19.4	64.7	0.39	0.2
23945	10		3.8	6.3	27.8	79.1	0.38	0.6
23946	11		4	6.5	16.3	65.6	0.73	0.4
23947	13		3.5	6	21.2	71.7	0.57	0.4
23948	7.5		4.3	7.4	9.5	43.3	0.25	0.4
23949	15		3.5	5.7	8.7	23.5	0.59	0.1
23950	11		2.8	4.6	28.4	71.8	0.37	0.5
23951	15		3	5.4	32.1	78.1	0.73	0.4
23952	11		3	6	45.3	114.4	0.92	0.8

Note: Bulk sample volume = approximate volume of bulk sand/gravel seived to yield 6-7 liters of minus-10-mesh sand. Heavy-mineral-concentrates (HMC) were prepared from the minus-10-mesh fraction for the test study samples and from the minus-20-mesh fraction for the pilot study samples. C-1, C-2 and C-3 weights have been calculated to total weight before fire assay sample split. To determine %-weight of HMC in bulk sample, bulk sample weight was calculated from bulk sample volume using 1.9 g/cc as average specific gravity of sand/gravel.

Table 6. Volume and weight measurements of the various sample fractions for the test and pilot study samples ...continued

MDNR Sample Number	Bulk Sample Volume liters	Minus-10-mesh Weight grams x 10^3	Minus-20-mesh Volume liters	Minus-20-mesh Weight grams x 10^3	C-1 Weight grams	C-2 Weight grams	C-3 Weight grams	HMC In Bulk Sample %-weight
23953	11		5	9.4	33.1	153	4.12	0.9
23954	17.5		2	3.2	9	36.5	0.19	0.1
23955	14		4	7	7.6	31.7	0.57	0.1
23956	9		4	6.5	4.4	19.1	0.52	0.1
23957	10		3	5.4	3.8	24.4	0.56	0.2
23958	12		2	3.9	4.2	19.4	0.19	0.1
23959			4	7	4.1	20.1	0.33	
23960	10.5		3.8	6.5	46.9	69.8	1.79	0.6
23961	9.8		3	5.3	10.8	42.5	1.46	0.3
23962	9		6	10.5	18.2	78.2	1.6	0.6
23963	11		3.5	6.2	7.2	31	1.81	0.2
23964	16		3.3	5.6	23.2	58.6	0.62	0.3
23965			4	7.1	13.7	42.6	1.04	
23966	11		3.3	5.6	6.5	38.2	0.94	0.2
23967					6.1	114.3	17.98	
23968	13		1.8	2.7	5.7	28.2	0.15	0.1
23969	13.5		4.3	7.4	13.2	65	12.21	0.3
23970	7		5	9	13.4	46.2	1.63	0.5
23971	14		4.8	8.3	16.4	75.5	1.54	0.3
23972	11		4.3	7.6	14.9	35.4	0.29	0.2
23973	9		5.5	10.7	26.7	88.8	0.93	0.7
23974	8.5		4.8	8.2	19	60.7	0.38	0.5
23975	17		2.5	4.6	18.9	48.5	0.69	0.2
24110	8		3.8	6.4	34.2	99.8	0.77	0.9
24111	7		4	7.8	70.1	208.9	1.75	2.2
24112	10		3	4.5	33.3	73.8	0.2	0.6
24113	8		4	6.3	149.7	306.8	0.29	3.0
24114	9		4.5	7.6	144	348.4	1.55	2.9

Note: Bulk sample volume = approximate volume of bulk sand/gravel seived to yield 6-7 liters of minus-10-mesh sand. Heavy-mineral-concentrates (HMC) were prepared from the minus-10-mesh fraction for the test study samples and from the minus-20-mesh fraction for the pilot study samples. C-1, C-2 and C-3 weights have been calculated to total weight before fire assay sample split. To determine %-weight of HMC in bulk sample, bulk sample weight was calculated from bulk sample volume using 1.9 g/cc as average specific gravity of sand/gravel.

Table 7. Gold and platinum group element data for the heavy-mineral-concentrate samples as determined by fire assay

MDNR Sample Number	Au ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb
20431	1L	20N	200N	1L	10N	10N	100N
22631	10	20N	200N	1L	10N	10N	100N
22632	1L	20N	200N	1L	10N	10N	100N
22633	100	20N	200N	1L	10N	10N	100N
22634	2	20N	200N	1L	10N	10N	100N
22635	300	20N	200N	1L	10N	10N	100N
22636	50	20N	200N	1N	10N	10N	100N
22637	300	20N	200N	1N	10N	10N	100N
23901	7L	0.5L	2L	1.8	2.6	0.5L	0.6L
23902	7L	0.5L	2L	2.6	2.3	0.5L	0.6L
23903	7L	0.6	2L	1.5	2	0.5L	1
23904	7L	0.5L	2L	2.2	2.4	0.5L	0.6L
23905	7L	0.5L	2L	2.4	3	0.5L	0.6L
23906	7L	0.5L	2L	2.6	2.5	0.5L	0.6L
23907	7L	0.5L	2L	3.5	3.6	0.5L	0.6L
23908	7L	0.5L	2L	2.2	4.1	0.5L	0.6L
23909	7L	0.5L	2L	2.8	2	0.5L	0.6L
23910	10	0.5L	2L	4.2	3.8	0.5L	0.6L
23911	7L	0.5L	2L	3.4	3.4	0.5L	0.6L
23912	7L	0.5L	2L	1.8	2.3	0.5L	0.6L
23913	24	0.5L	2L	3	3.8	0.5L	0.6
23914	7L	0.5L	2L	3.3	3.4	0.5L	0.7
23915	7L	0.5L	2L	5.3	5.3	0.5L	0.6L
23916	730	0.5L	2L	4.4	5.1	0.5L	0.6
23917	10L	0.7L	3L	4	3.6	0.7L	0.8L
23918	7L	0.5L	2L	5	4.9	0.5L	0.8
23919	7L	0.5L	2L	3	3.3	0.5L	0.6L
23920	7L	0.5L	2L	2.6	3	0.5L	0.6L
23921	7L	0.5L	2L	4.9	4.8	0.5L	0.6
23922	10L	0.7L	3L	3.4	2.6	0.7L	0.8L

Note: Test study samples 20431 and 22631-22637 were analyzed using a lead-oxide flux; all other samples were analyzed using a nickel-sulfide flux; N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown.

Table 7. Gold and platinum group element data for the heavy-mineral-concentrate samples as determined by fire assay ...continued

MDNR Sample Number	Au ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb
23923	26	0.5L	2L	3.7	2.8	0.5L	0.6L
23924	7L	0.5L	2L	2.8	3.9	0.5L	0.6L
23925	7L	0.5L	2L	2.3	1.8	0.5L	0.6L
23926	7L	0.5L	2L	2.6	5	0.5L	0.6L
23927	7L	0.5L	2L	1.7	1.6	0.5L	0.6L
23928	7L	0.5L	2L	2	2.6	0.5L	0.6L
23929	7L	0.5L	2L	2.2	2	0.5L	0.6L
23930	44	0.5L	2L	1.7	2.1	0.5L	0.6L
23931	7L	0.5L	2L	2	2.4	0.5L	0.6L
23932	4700	0.5L	2L	1.4	1.4	0.5L	0.6L
23933	9.9	0.5L	2L	2	2.7	0.5L	0.6L
23934	7L	0.5L	2L	2.8	2	0.5L	0.6L
23935	10000	1L	5L	2	2	1L	1L
23936	34	0.5L	2L	1.3	2.2	0.5L	0.6L
23937	7L	0.5L	2L	1.8	1.9	0.5L	0.6L
23938	7L	0.5L	2L	1.9	2.4	0.5L	0.8
23939	7L	0.5L	2L	1.6	2.2	0.5L	0.6L
23940	7L	0.5L	2L	1.5	2.5	0.5L	0.6L
23941	7L	0.5L	2L	2.6	4.5	0.5L	0.6L
23942	7L	0.5L	2L	2.6	2.7	0.5L	0.6L
23943	7L	0.5L	2L	2.9	2.5	0.5L	0.6L
23944	7L	0.5L	2L	2.6	2.2	0.5L	0.6L
23945	7L	0.5L	2L	2.6	2.9	0.5L	0.6L
23946	7L	0.5L	2L	2.4	2.2	0.5L	0.6L
23947	7L	0.5L	2L	2.1	3	0.5L	0.6L
23948	7L	0.5L	2L	2	2.3	0.5L	0.6L
23949	960	0.5L	2L	1.7	2	0.5L	0.6L
23950	7L	0.5L	2L	2.4	2.9	0.5L	0.7
23951	7L	0.5L	2L	2.5	2.7	0.5L	0.6L
23952	10L	0.6L	3L	2.2	2.8	0.6L	0.7L

Note: Test study samples 20431 and 22631-22637 were analyzed using a lead-oxide flux; all other samples were analyzed using a nickel-sulfide flux; N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown.

Table 7. Gold and platinum group element data for the heavy-mineral-concentrate samples as determined by fire assay ...continued

MDNR Sample Number	Au ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb
23953	530	0.5L	2L	2.6	1.4	0.5L	0.6L
23954	7L	0.5L	2L	1.1	2	0.5L	0.6L
23955	7L	0.5L	2L	0.8	1.5	0.5L	0.6L
23956	8L	0.5L	2L	1.1	1.7	0.5L	0.6L
23957	7L	0.5L	2L	0.8	1.6	0.5L	0.6L
23958	8L	0.5L	2L	8	1.3	0.5L	0.6L
23959	8L	0.5L	2L	1.4	1.6	0.5L	0.6L
23960	1700	0.5L	2L	0.6	1.3	0.5L	0.6L
23961	7L	0.5L	2L	1.5	1.8	0.5L	0.6L
23962	7L	0.5L	2L	1	1.6	0.5L	0.6L
23963	780	0.5L	2L	1	1.9	0.5L	0.6L
23964	7L	0.5L	2L	1.7	2.1	0.5	0.6L
23965	7L	0.5L	2	0.8	1.6	0.5L	0.6L
23966	7L	0.5L	2L	1	1.6	0.5L	0.6L
23967*	13000	0.5L	2L	280	15	0.5L	0.6
23968	7L	0.5L	2L	1.6	2	0.5L	0.6L
23969*	11	0.5L	2L	1.4	1.8	0.5L	0.6L
23970	7L	0.5L	2L	0.8	1.2	0.5L	0.6L
23971*	1000	0.5L	2L	0.9	1.6	0.5L	0.6L
23972	7L	0.5L	2L	2.5	2.1	0.5L	0.6L
23973	7L	0.5L	2L	3.4	2.8	0.5L	0.7
23974	7L	0.5L	2L	4.2	2.7	0.5L	0.6L
23975	7L	0.5L	2L	3	3.2	0.5L	0.6L
24110	7L	0.5L	2L	2.6	2.6	0.5L	0.6L
24111	7L	0.5L	2	2.1	3.2	0.5	0.9
24112	7L	0.5L	2L	3.1	4.4	0.5L	0.6L
24113	10L	0.7L	3L	2.8	3.2	0.7L	0.7L
24114	7L	0.5L	2L	1.9	1.7	0.5L	0.6L

Note: Test study samples 20431 and 22631-22637 were analyzed using a lead-oxide flux; all other samples were analyzed using a nickel-sulfide flux;
N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown.
* 23967 = concentrate sample; 23969 = pre-glacial alluvium sample; 23971 = active stream sediment sample

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	Ti %	Ag ppm	B ppm	Ba ppm	Be ppm	Co ppm	Cr ppm	Cu ppm	Ga ppm
20431	0.7	20	10	0.5N	2	1N	20N	50L	2N	200	300	50	10N
22631	2	20	2	0.5N	2G	1	50	70	2N	70	500	50	10N
22632	2	20	3	0.5N	2G	1N	50	100	2N	100	500	70	10N
22633	3	20	3	0.5N	2G	1N	30	200	2N	100	300	150	10L
22634	2	20	5	0.5N	2G	1N	50	200	2N	100	300	50	10L
22635	2	20	5	0.5N	2	1N	20	100	2N	100	300	50	10
22636	2	15	5	0.5N	2	1N	100	100	2L	50	500	20	10
22637	2	20	3	0.5L	2	1N	100	150	2L	70	500	50	10
23901	2	20	5	0.5L	2G	1N	70	300	2N	100	500	70	20
23902	2	10	5	0.5L	2G	1N	50	200	2L	70	500	50	10
23903	5	20	5	0.5L	2	1N	70	300	2N	100	700	20	30
23904	2	10	5	0.5N	2	1N	50	150	2N	100	300	70	10
23905	3	10	5	0.5L	2G	1N	50	200	2N	70	300	50	10L
23906	5	15	5	0.5L	2G	1N	70	200	2N	100	300	50	10
23907	2	20	5	0.5L	2G	1N	50	150	2N	100	500	50	10
23908	2	10	7	0.5L	2	1N	50	100	2N	70	300	50	10
23909	2	20	5	0.5L	2	1N	70	200	2N	50	500	50	20
23910	3	20	7	0.5L	2	1N	30	200	2N	100	300	70	20
23911	5	10	7	0.5L	2G	1N	20	150	2N	100	500	50	5
23912	2	15	5	0.5L	2	1N	30	100	2N	70	500	50	10
23913	5	20	5	0.5N	2G	1N	100	200	2N	100	300	20	15
23914	2	20	7	0.5L	2	1N	20	150	2N	70	300	50	15
23915	2	10	7	0.5L	2G	1N	50	150	2N	100	300	70	10
23916	3	10	7	0.5L	2G	1N	30	100	2N	100	300	70	10
23917	2	10	7	0.5L	2	1N	30	100	2N	100	300	70	10L
23918	5	10	7	0.5L	2	1N	20L	100	2N	70	500	100	15
23919	2	10	5	0.5L	2	1N	50	200	2N	100	500	70	10L
23920	1.5	10	5	0.5L	2G	1N	50	150	2N	100	500	50	10L

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zr ppm
20431	100L	3000	10N	50N	500	20N	30	20N	200N	200N	200	20N	100
22631	300	7000	10N	50	70	30	50	20N	500	200N	200	200	200
22632	150	5000	10N	50L	100	20	50	20N	300	200N	300	100	150
22633	100	5000	10N	50L	100	20	50	20N	300	200N	300	70	200
22634	100	5000	10N	50L	100	20L	50	20N	200	200N	200	70	200
22635	100N	3000	10N	50L	150	30	50	20N	200L	200N	200	50	200
22636	500	5000	10N	50	100	30	50	20N	300	200N	200	150	300
22637	200	7000	10N	50	100	30	50	20N	500	200N	200	100	200
23901	150	10000	10L	50L	150	50	20	20N	200	200N	200	50	100
23902	150	7000	10L	50L	150	50	20	20N	200	200N	200	70	150
23903	100	7000	10N	50L	100	20	20	20N	300	200N	200	100	150
23904	150	5000	10N	50	100	30	20	20N	200L	200N	200	70	150
23905	150	5000	10N	50L	150	20	20	20N	200	200N	200	70	150
23906	100N	5000	10N	50L	100	20N	50	20N	200	200N	200	50	200
23907	100L	5000	10N	50L	100	20L	20	20N	200N	200N	200	70	200
23908	100L	5000	10N	50L	100	20	30	20N	200L	200N	200	50	150
23909	100L	5000	10N	50L	100	20	20	20N	200	200N	200	100	200
23910	100L	5000	10N	50L	150	20	15	20N	200	200N	200	100	200
23911	100N	3000	10N	50L	200	20N	50	20N	200	200N	200	70	150
23912	100N	5000	10N	50	100	20L	20	20N	200	200N	200	30	150
23913	100L	3000	10N	50L	150	20	20	20N	200N	200N	200	100	150
23914	100N	5000	10N	50L	150	20	15	20N	200L	200N	200	50	200
23915	100N	5000	10N	50L	150	20L	30	20N	200N	200N	200	50	150
23916	100N	3000	10N	50L	100	20L	30	20N	200N	200N	200	50	150
23917	100N	5000	10N	50L	150	20N	30	20N	200N	200N	200	50	200
23918	100N	5000	10N	50L	100	20L	30	20N	200N	200N	200	50	200
23919	100L	5000	10N	50	150	20	30	20N	200N	200N	200	50	200
23920	100L	3000	10N	50	100	20	30	20N	200N	200N	200	70	150

Note: The following elements were not detected at the lower determination limit shown: P (0.5 %), As (500 ppm), Au (20 ppm), Bi (20 ppm), Cd (50 ppm), Ge (20 ppm), Sb (200 ppm), W (50 ppm), Zn (500 ppm), Pd (5 ppm), and Pt (20 ppm).

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	Ti %	Ag ppm	B ppm	Ba ppm	Be ppm	Co ppm	Cr ppm	Cu ppm	Ga ppm
23921	2	10	5	0.5L	2	1N	30	150	2N	100	300	70	10L
23922	3	10	7	0.5L	2	1N	20L	100	2N	70	300	70	10
23923	2	10	7	0.5L	2	1N	20	100	2N	100	200	70	10
23924	3	10	10	0.5L	2	1N	50	150	2N	100	300	70	10
23925	2	15	7	0.5L	2	1N	20	100	2N	70	200	30	10
23926	2	15	7	0.5	2	1N	20	150	2N	100	500	50	10
23927	2	10	10	0.5L	2	1N	20	70	2N	100	200	30	10
23928	3	10	5	0.5	1.5	1N	30	100	2L	50	500	30	20
23929	10	10	7	0.5	2	1N	50	200	2N	70	500	50	15
23930	2	10	5	0.5	1	1	50	200	2L	100	200	100	15
23931	10	20	7	0.5	1.5	1N	20	200	2L	100	500	20	30
23932	3	20	5	0.5L	1.5	1N	70	200	2	50	500	50	50
23933	2	20	5	0.5L	2	1N	100	200	2L	70	300	50	15
23934	0.5	20	1.5	0.5N	2G	1N	30	70	2N	50	500	50	10
23935	2	15	5	0.5	2	1N	70	150	2N	50	500	20	10
23936	5	30	5	0.5L	2G	1N	100	200	2N	100	500	20	10
23937	2	20	5	0.5	2G	1N	50	200	2N	70	300	50	15
23938	2	20	5	0.5L	2G	1N	50	200	2L	70	300	50	15
23939	2	10	5	0.5L	2G	1N	70	200	2N	100	500	70	15
23940	5	20	5	0.5L	2	1N	50	150	2N	70	500	20	10
23941	7	20	5	0.5L	2	1N	30	200	2N	100	500	30	15
23942	2	20	5	0.5L	2	1N	50	100	2N	70	500	20	10L
23943	2	10	5	0.5L	2G	1N	50	150	2N	70	300	70	15
23944	2	20	5	0.5L	2	1N	50	100	2N	50	300	30	10
23945	2	15	5	0.5L	2	1N	50	150	2N	70	500	70	10
23946	2	15	5	0.5L	2	1N	50	150	2N	70	300	50	10
23947	5	20	5	0.5L	2G	1N	70	200	2N	100	500	70	30
23948	2	20	5	0.5L	2	1N	70	200	2N	70	500	50	20

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zr ppm
23921	100N	5000	10N	50	100	20L	50	20N	200N	200N	200	50	150
23922	100N	5000	10N	50N	150	20N	30	20N	200N	200N	200	50	150
23923	100N	5000	10N	50L	150	20N	30	20N	200N	200N	200	50	150
23924	100N	5000	10N	50	150	20L	30	20N	200N	200N	200	70	150
23925	100N	3000	10N	50L	150	20N	30	20N	200L	200N	200	50	100
23926	100N	5000	10N	50L	200	20N	30	20N	300	200N	200	30	100
23927	100N	5000	10N	50L	200	20N	20	20N	200	200N	200	50	100
23928	100L	5000	10N	50N	100	20	30	20N	500	200N	200	70	100
23929	100	5000	10N	50	150	20	30	20N	300	200N	200	70	150
23930	100	5000	10N	50N	150	50	20	20N	500	200N	200	50	100
23931	200	7000	10N	50L	150	20	20	20N	500	200N	150	100	150
23932	200	7000	10N	50L	100	50	20	20N	300	200N	200	100	200
23933	100L	7000	10N	50L	100	30	20	20N	300	200N	200	100	150
23934	200	5000	10N	50	50	50	20	20N	200N	200N	300	100	150
23935	150	5000	10N	50L	100	20	30	20N	300	200N	200	100	150
23936	100	5000	10N	50L	100	20	30	20N	200	200N	200	100	100
23937	150	5000	10N	50L	100	20	20	20N	200	200N	200	100	150
23938	100	7000	10N	50L	150	20	15	20N	200	200N	200	100	150
23939	150	5000	10N	50	100	30	20	20N	300	200N	200	70	200
23940	100	5000	10N	50	100	20L	20	20N	200L	200N	200	70	100
23941	100N	5000	10N	50L	100	20L	20	20N	200	200N	200	100	100
23942	100	5000	10N	50	100	20L	30	20N	200	200N	200	70	100
23943	100	7000	10N	50L	100	20L	20	20N	200L	200N	200	100	150
23944	100	7000	10N	50L	100	20	30	20N	200L	200N	200	100	100
23945	100	5000	10N	50L	100	20L	30	20N	200	200N	200	50	100
23946	100L	5000	10N	50	100	20L	30	20N	200	200N	200	50	150
23947	100L	7000	10N	50	100	20	30	20N	200	200N	200	100	150
23948	150	5000	10N	50	150	20L	20	20N	200	200N	200	100	150

Note: The following elements were not detected at the lower determination limit shown: P (0.5 %), As (500 ppm), Au (20 ppm), Bi (20 ppm), Cd (50 ppm), Ge (20 ppm), Sb (200 ppm), W (50 ppm), Zn (500 ppm), Pd (5 ppm), and Pt (20 ppm).

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	Ti %	Ag ppm	B ppm	Ba ppm	Be ppm	Co ppm	Cr ppm	Cu ppm	Ga ppm
23949	2	20	5	0.5L	2G	1N	50	200	2N	100	500	70	10
23950	3	20	5	0.5L	2	1N	20	200	2L	70	300	50	20
23951	2	10	5	0.5L	2	1N	50	200	2N	70	300	50	10
23952	3	10	5	0.5L	2	1N	70	150	2N	100	500	70	10
23953	2	15	3	0.5L	2	1N	100	150	2L	50	500	50	20
23954	2	20	5	0.5L	2	1N	70	150	2N	70	500	20	10
23955	2	30	5	0.5L	2G	1N	150	300	2N	100	500	50	15
23956	3	20	7	0.5	2	1N	150	300	2L	50	500	50	15
23957	5	20	7	0.5L	2	1N	100	300	2N	70	500	50	30
23958	7	20	7	0.5	2	1N	50	200	2N	100	500	15	30
23959	5	20	5	0.5	2	1N	70	200	2L	70	500	30	20
23960	2	20	5	0.5L	2G	1N	70	150	2N	50	700	20	15
23961	2	20	5	0.5L	2G	1N	100	200	2N	70	500	50	15
23962	2	20	5	0.5L	2	1N	200	150	2N	100	500	50	20
23963	2	15	5	0.5L	2	1N	100	200	2N	70	500	70	15
23964	2	20	5	0.5L	2G	1N	50	150	2N	70	500	50	10L
23965	2	10	5	0.5L	2G	1N	50	200	2N	70	700	30	20
23966	2	20	5	0.5L	2	1N	100	200	2N	50	500	30	20
23967*	0.1L	30	0.5	0.5N	2G	1N	20L	70	2N	50	2000	20	10L
23968	5	20	5	0.5	2	1N	50	500	2L	70	500	70	50
23969*	5	20	5	0.5L	2	1N	100	500	2N	70	500	50	20
23970	5	20	5	0.5L	2	1N	100	300	2N	70	700	50	20
23971*	2	20	5	0.5L	2G	1N	100	200	2N	50	700	50	15
23972	5	20	5	0.5L	2G	1N	50	300	2N	100	500	20	20
23973	2	20	5	0.5L	2G	1N	70	100	2N	70	500	50	10L
23974	2	15	7	0.5L	2G	1N	50	200	2N	100	300	50	10
23975	5	20	7	0.5L	2G	1N	30	200	2N	100	500	20	10
24110	2	20	7	0.5L	2	1N	50	200	2N	50	300	70	20

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown
* 23967 = concentrate sample; 23969 = pre-glacial alluvium sample; 23971 = active stream sediment sample

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zr ppm
23949	150	5000	10N	50L	100	20L	20	20N	200	200N	200	100	70
23950	100L	5000	10N	50L	150	20	20	20N	200	200N	200	100	200
23951	100	5000	10N	50L	100	30	20	20N	200	200N	200	100	150
23952	100	5000	10N	50	100	20	30	20N	200	200N	200	70	150
23953	200	5000	10N	50	70	30	30	20N	300	200N	200	100	300
23954	150	5000	10N	50L	100	50	50	20N	200	200N	200	100	100
23955	200	7000	10N	50L	100	50	15	20N	200	200N	200	100	100
23956	200	7000	10N	50L	100	30	15	20N	300	200N	200	70	200
23957	200	7000	10N	50L	100	20	15	20N	300	200N	200	150	200
23958	200	5000	10N	50	100	30	20	20N	500	200N	200	100	150
23959	150	5000	10N	50L	100	20	20	20N	500	200N	200	100	150
23960	300	7000	10N	50	100	50	20	20L	200	200L	200	150	150
23961	100	5000	10N	50	100	20	10	20N	200	200N	200	70	150
23962	150	5000	10N	50	100	50	30	20N	200	200N	200	100	150
23963	200	5000	10N	50L	100	50	30	20N	300	200N	200	100	100
23964	100	5000	10N	50	100	20N	30	20N	200	200N	200	100	150
23965	200	7000	10N	50	100	50	30	20N	500	200N	200	100	200
23966	200	7000	10N	50L	100	30	20	20N	500	200N	200	100	150
23967*	1000	5000	10N	50L	20	70	20	20N	200N	200	200	200	1000
23968	200	7000	10	50L	100	50	20	20N	200	200N	200	100	100
23969*	100	7000	10	50L	100	20L	20	20N	300	200N	200	100	100
23970	200	7000	10N	50	100	20	30	20N	500	200N	200	100	100
23971*	200	7000	10N	50	100	50	15	20N	200	200N	200	100	100
23972	200	7000	10N	50L	100	30	20	20N	200	200N	200	100	100
23973	100L	5000	10N	50L	100	20	20	20N	200L	200N	200	50	200
23974	100	5000	10N	50L	150	20L	50	20N	200L	200N	200	70	200
23975	100L	5000	10N	50L	100	20L	30	20N	200	200N	200	100	150
24110	100N	5000	10N	50L	100	20L	20	20N	200L	200N	200	50	150

Note: The following elements were not detected at the lower determination limit shown: P (0.5 %), As (500 ppm), Au (20 ppm), Bi (20 ppm), Cd (50 ppm), Ge (20 ppm), Sb (200 ppm), W (50 ppm), Zn (500 ppm), Pd (5 ppm), and Pt (20 ppm).

* 23967 = concentrate sample; 23969 = pre-glacial alluvium sample; 23971 = active stream sediment sample

Table 8. Analytical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	Ti %	Ag ppm	B ppm	Ba ppm	Be ppm	Co ppm	Cr ppm	Cu ppm	Ga ppm
24111	1.5	20	5	0.5L	2	1N	70	100	2N	70	300	50	10
24112	3	15	7	0.5L	2	1N	20	150	2N	50	300	50	20
24113	2	15	5	0.5L	2	1N	20	100	2N	70	200	50	10
24114	2	20	7	0.5L	2	1N	20	100	2N	70	200	30	10

MDNR Sample Number	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zr ppm
24111	100	5000	10N	50	100	20	20	20N	200L	200N	200	100	200
24112	100	5000	10N	50L	150	30	20	20N	200L	200N	200	50	200
24113	100N	3000	10N	50L	100	20N	20	20N	200N	200N	200	50	150
24114	100N	5000	10N	50L	200	20N	20	20N	200	200N	200	50	100

Note: The following elements were not detected at the lower determination limit shown: P (0.5 %), As (500 ppm), Au (20 ppm), Bi (20 ppm), Cd (50 ppm), Ge (20 ppm), Sb (200 ppm), W (50 ppm), Zn (500 ppm), Pd (5 ppm), and Pt (20 ppm).

N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Au ppm	B ppm	Ba ppm	Be ppm	Bi ppm
20431	10	1.5	2	0.5L	2	2G	1	500N	20N	50	70	2N	20N
22631	5	1	0.2	0.5N	5	2G	1N	500N	20N	50	100	2L	20L
22632	5	1	0.5	0.5L	5	2G	1	500N	20N	100	150	10	20N
22633	10	1.5	1	0.5L	7	2G	1N	500N	20N	100	200	2N	20N
22634	7	2	2	0.5L	2	2G	1N	500N	20N	200	200	2N	20N
22635	10	1	2	0.5L	7	2G	2	500N	20N	200	700	2N	50
22636	10	0.5	0.5	0.5N	5	2G	1N	500N	20N	150	700	2L	20N
22637	10	0.5	0.2	0.5N	7	2G	1N	500N	20N	150	500	20	20N
23901	20	0.5	0.3	0.5L	10	2G	1N	500N	20N	100	300	2N	20N
23902	20	0.5	0.2	0.5N	10	2G	1N	500N	20N	100	200	2N	20N
23903	20	0.5	0.5	0.5L	10	2G	1N	500N	20N	100	500	100	20N
23904	20	0.2	0.5	0.5L	20	2G	1N	500N	20N	100	700	2N	20N
23905	30	0.7	1.5	0.5L	15	2G	1N	500N	20N	200	700	2	20N
23906	10	0.5	0.5	0.5L	10	2G	1N	500N	20N	100	1000	2N	20N
23907	30	0.7	1.5	0.5L	15	2G	1N	500N	20N	500	300	2N	20N
23908	20	0.2	0.5	0.5L	20	2G	1N	500N	20N	100	200	2L	20N
23909	30	0.5	1.5	0.5	20	2G	1N	500N	20N	100	300	3	20N
23910	30	1	1	0.5L	10	2G	1N	500N	20N	50	150	2N	20N
23911	30	0.7	2	0.5	20	2G	1N	500N	20N	300	500	2N	20N
23912	30	0.3	1	0.5L	20	2G	1N	500N	20N	100	200	2N	20N
23913	20	0.5	1	0.5L	10	2G	1N	500N	20N	100	200	2N	20N
23914	20	1	1	0.5L	10	2G	1N	500N	20N	70	500	2N	20N
23915	50	0.7	2	0.5L	20	2G	1N	500N	20N	200	500	2N	20N
23916	30	0.3	1	0.5L	20	2G	7	500N	20N	100	200	2L	20N
23917	20	0.3	1	0.5L	20	2G	1N	500N	20N	100	100	2N	20N
23918	20	0.5	3	0.5L	20	2G	1N	500N	20N	100	200	2N	20N
23919	30	0.5	2	0.5N	20	2G	1N	500N	20N	300	500	2L	20N
23920	20	0.5	1.5	0.5N	15	2G	1N	500N	20N	500	300	2N	20N

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Co ppm	Cr ppm	Cu ppm	Ga ppm	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sb ppm	Sc ppm	Sn ppm
20431	30	200	15	20	200	700	10N	50	100	50	200N	20	20
22631	20N	150	20	10L	500	500	10N	50L	10N	70	200N	50	20
22632	20N	200	5000	20	300	500	10N	50	50	500	200N	20	50
22633	30	200	50	20	200	700	10N	50	30	100	200N	20	150
22634	20	200	20	30	200	700	10N	50L	50	200	200N	50	100
22635	20L	150	70	20	500	500	10N	50	20	50000	500	30	100
22636	20N	200	10L	10L	500	500	10N	50L	10N	100	200N	70	50
22637	20N	150	10	20	200	300	10N	50L	10N	700	200N	50	50
23901	20N	200	10N	10	300	500	10N	50L	10N	30	200N	20	20L
23902	20N	200	10L	10	300	200	10N	50L	10	50	200N	50	300
23903	20N	200	10L	20	200	300	10N	50L	10N	70	200N	30	200
23904	20N	200	10L	10	300	700	10N	50L	10N	70	200N	30	150
23905	20N	200	10	20	500	1000	10N	50	10N	70	200N	50	30
23906	20L	200	20	20	300	500	10N	50L	10N	100	200N	30	100
23907	20N	200	10	15	500	1000	10N	50L	10N	70	200N	70	150
23908	20N	200	100	10	300	1000	10N	50L	10N	70	200N	20	300
23909	20N	200	10	30	500	1000	10N	50	10N	70	200N	50	20
23910	20N	150	15	20	300	300	10N	50L	30	100	200N	20	20L
23911	20N	200	10	30	500	1000	10N	50	10N	300	200N	30	30
23912	20N	200	10L	15	300	500	10N	50L	10N	70	200N	20	100
23913	20N	200	300	15	300	700	10N	50L	10N	300	200N	20	200
23914	20L	300	10	20	300	500	10N	50L	30	50	200N	20	20L
23915	20N	200	10	20	500	700	10N	50L	10L	70	200N	50	100
23916	20N	200	20	10	300	500	10N	50L	10N	50	200N	20	50
23917	20N	200	10	20	500	500	10N	50N	10N	70	200N	15	20L
23918	20N	200	200	30	300	300	10N	50L	10N	300	200N	20	20
23919	20N	200	10L	15	500	1000	10N	50	10N	70	200N	50	100
23920	20N	200	10L	10	500	1000	10N	50L	10N	70	200N	50	70

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Sr ppm	Th ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
20431	500	200N	150	50N	150	500N	2000G
22631	500	200N	200	50N	300	500N	2000G
22632	700	200N	150	50N	200	5000	2000G
22633	700	200N	150	50N	200	500N	2000G
22634	700	200N	150	50N	200	500N	2000G
22635	700	200N	150	50N	300	500N	2000G
22636	500	200N	150	50N	300	500N	2000G
22637	500	200N	150	50N	300	500N	2000G
23901	500	200N	100	50N	300	500N	2000G
23902	1000	200N	100	50N	200	500N	2000G
23903	700	200N	100	50N	300	500N	2000G
23904	500	200N	150	50N	500	500N	2000G
23905	500	200N	150	50N	300	500N	2000G
23906	1000	200N	150	50N	500	500N	2000G
23907	500	200N	100	50N	300	500N	2000G
23908	500	200N	100	50N	500	500N	2000G
23909	500	200N	100	50N	200	500N	2000G
23910	700	200N	100	50N	500	500N	2000G
23911	500	200N	150	50N	300	500N	2000G
23912	700	200N	100	50N	500	500N	2000G
23913	700	200N	100	50N	500	500	2000G
23914	700	200N	100	50N	500	500N	2000G
23915	500	200N	100	50N	500	500N	2000G
23916	500	200N	100	50N	500	500N	2000G
23917	500	200N	100	50N	300	500N	2000G
23918	500	200N	100	50N	500	500N	2000G
23919	500	200N	150	50N	500	500N	2000G
23920	500	200N	150	50N	300	500N	2000G

Note: The following elements were not detected at the lower determination limit shown: Cd (50 ppm), Ge (20 ppm), Pd (5 ppm), and Pt (20 ppm).
N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Au ppm	B ppm	Ba ppm	Be ppm	Bi ppm
23921	20	0.2	1	0.5N	20	2G	1N	500N	20N	200	200	2N	20N
23922	50	0.3	0.5	0.5	20	2G	1N	500N	20N	50	150	2N	20N
23923	20	0.5	0.5	0.5L	20	2G	1N	500N	20N	50	150	2N	20N
23924	30	0.3	0.7	0.5L	20	2G	1N	500N	20N	150	200	2N	20N
23925	30	0.2	0.7	0.5L	20	2G	1N	500N	20N	30	150	2N	20N
23926	30	0.2	0.3	0.5L	15	2G	1N	500N	20N	50	200	2N	20N
23927	20	0.2	0.2	0.5L	20	2G	1N	500N	20N	50	150	2N	20N
23928	50	0.5	0.7	0.5	20	2G	1N	500N	20N	50	300	2N	20N
23929	20	0.5	0.5	0.5	10	2G	1N	500N	20N	30	200	2N	20N
23930	20	0.7	0.5	0.5	7	2G	1L	500N	20N	30	300	2L	20N
23931	20	0.7	0.7	0.5L	10	2G	1N	500N	20N	50	1500	5	20N
23932	30	0.5	0.5	0.5L	20	2G	1N	500N	20N	20	200	2N	20N
23933	15	0.5	0.7	0.5	5	2G	1N	500N	20N	50	300	2N	20N
23934	20	0.2	0.2	0.5N	10	2G	1N	500N	20N	50	150	2N	20N
23935	20	0.7	0.5	0.5L	7	2G	5	500N	150	70	200	2N	20N
23936	50	0.5	0.5	0.5L	20	2G	1N	500N	20N	200	300	2N	20N
23937	20	0.5	0.3	0.5L	15	2G	1N	500N	20N	50	100	2N	20L
23938	20	0.5	0.5	0.5L	7	2G	1N	500N	100	100	150	2N	100
23939	30	0.7	0.7	0.5L	20	2G	1N	500N	20N	200	200	2L	20N
23940	20	0.5	0.3	0.5L	15	2G	1N	500N	20N	70	500	2N	20N
23941	20	1	2	0.5	3	2G	1N	500N	300	100	500	2N	20N
23942	20	1.5	2	0.5L	3	2G	1N	500N	20N	300	1000	2N	20N
23943	15	0.5	0.5	0.5N	15	2G	1N	500N	20L	50	700	2N	20N
23944	30	0.5	0.5	0.5L	10	2G	1N	500N	20N	100	200	2L	20N
23945	10	0.5	0.5	0.5L	10	2G	1N	500N	20N	100	200	2N	20N
23946	30	0.5	1.5	0.5L	20	2G	1N	500N	20N	200	500	2N	20N
23947	20	0.5	0.3	0.5L	7	2G	1N	500N	20N	100	300	2N	20N
23948	20	0.7	1	0.5L	20	2G	1N	500N	20N	300	300	2N	20N

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Co ppm	Cr ppm	Cu ppm	Ga ppm	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sb ppm	Sc ppm	Sn ppm
23921	20N	150	10	15	300	300	10N	50L	10N	70	200N	20	200
23922	20N	150	10	30	500	500	10N	50N	10N	5000	200N	10	150
23923	20N	150	10	15	300	300	10N	50L	10N	70	200N	20	150
23924	20N	200	15	15	500	500	10N	50L	10N	70	200N	20	100
23925	20N	200	10L	15	500	500	10N	50L	10N	70	200N	10	100
23926	20N	150	10L	20	300	300	10N	50L	10N	200	200N	10	20
23927	20N	200	10	20	500	500	10N	50L	10N	100	200N	10	20
23928	20N	200	10	20	700	500	10N	50L	10N	100	200N	50	30
23929	20N	150	10	20	300	300	10L	50	10N	70	200N	20	20
23930	30	200	10	30	200	500	10N	50	10L	100	200N	20	20
23931	20L	200	15	20	300	500	10L	50	10N	70	200N	15	20
23932	20N	200	10L	20	700	500	10N	50L	10N	70	200N	15	20L
23933	20N	200	10	20	200	700	10N	50	10N	50	200N	20	20
23934	20N	300	10N	20	300	300	10N	50N	10N	100	200N	50	150
23935	20N	200	10L	20	200	500	10N	50	10N	2000	200	20	20
23936	20N	300	10L	20	500	700	10N	50L	10N	100	200N	100	50
23937	20N	200	10	20	200	500	10N	50L	10N	70	200N	20	20
23938	20N	150	10L	15	200	500	10N	50	10N	50	200N	20	20L
23939	20N	300	10L	50	500	700	10N	50	10N	100	200N	50	1000
23940	20N	200	10L	20	200	500	10N	50L	10N	70	200N	20	150
23941	20	300	20	30	200	1500	10N	50	50	100	200N	20	20
23942	20	300	20	15	300	1000	10N	50L	70	70	200N	20	20L
23943	20N	200	10	15	300	300	10N	50L	10N	700	200N	20	50
23944	20N	200	10	20	300	300	10N	50L	10N	150	200N	30	70
23945	20N	200	10	20	500	300	10N	50L	10N	500	200N	50	100
23946	20N	200	10	20	500	1000	10N	50	10L	70	200N	50	200
23947	20N	200	10	20	300	300	10N	50L	10N	70	200N	30	300
23948	20N	300	10	30	500	1000	10N	50	10N	70	200N	50	50

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Sr ppm	Th ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
23921	500	200N	100	50N	500	500N	2000G
23922	300	200N	100	50N	500	500N	2000G
23923	200	200N	100	50N	500	500N	2000G
23924	200	200N	100	50N	500	500N	2000G
23925	300	200N	100	50N	500	500N	2000G
23926	300	200N	150	50N	300	500N	2000G
23927	200	200N	150	50N	500	500N	2000G
23928	2000	200N	150	50N	500	500N	2000G
23929	1000	200N	100	50	200	500N	2000G
23930	700	200N	100	50N	150	500N	2000G
23931	500	200N	100	50N	200	500N	2000G
23932	3000	200N	100	50N	200	500N	2000G
23933	500	200N	100	50N	200	500N	2000G
23934	200	200N	100	50N	500	500N	2000G
23935	500	200N	100	50N	200	500N	2000G
23936	500	200N	150	50N	500	500N	2000G
23937	700	200N	100	50N	200	500N	2000G
23938	700	200N	100	50N	200	500N	2000G
23939	500	200N	100	50N	200	500N	2000G
23940	700	200N	100	50N	300	500N	2000G
23941	500	200N	100	50N	150	500N	2000G
23942	700	200L	100	50N	150	500N	2000G
23943	700	200N	100	50N	200	500N	2000G
23944	700	200N	100	50N	300	500N	2000G
23945	1000	200N	100	50N	300	500N	2000G
23946	500	200N	150	50N	300	500N	2000G
23947	1000	200N	100	50N	500	500N	2000G
23948	500	200N	100	50L	300	500N	2000G

Note: The following elements were not detected at the lower determination limit shown: Cd (50 ppm), Ge (20 ppm), Pd (5 ppm), and Pt (20 ppm).
N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Au ppm	B ppm	Ba ppm	Be ppm	Bi ppm
23949	20	0.7	0.7	0.5L	10	2G	1N	500N	100	100	150	2N	20N
23950	20	0.7	0.7	0.5L	10	2G	1N	500N	20L	70	500	2L	20N
23951	20	0.5	0.5	0.5L	10	2G	1N	500N	20N	50	700	2N	20N
23952	30	0.2	1.5	0.5	15	2G	1N	500N	20N	100	200	2N	20N
23953	30	0.2	0.5	0.5N	20	2G	1N	500N	20N	100	200	2	20N
23954	20	0.5	0.5	0.5L	10	2G	1N	500N	20N	70	300	5	20N
23955	30	0.5	0.7	0.5L	20	2G	1N	500N	20N	150	300	2	20N
23956	50	0.7	1.5	0.5L	20	2G	1N	500N	20N	150	300	2N	20N
23957	30	0.5	0.7	0.5L	20	2G	1N	500N	20N	50	200	2N	20N
23958	20	0.5	0.5	0.5L	15	2G	1N	500N	20N	30	100	2N	20N
23959	15	0.3	1	0.5N	10	2G	1N	500N	20N	30	200	2N	20N
23960	30	0.5	2	0.5N	15	2G	1N	500N	20N	100	1000	2	20N
23961	20	0.5	1	0.5L	10	2G	1N	500N	20N	100	500	2N	20N
23962	20	0.5	0.5	0.5N	10	2G	1N	500N	20N	150	200	3	20N
23963	30	0.5	1	0.5L	15	2G	1N	500N	20N	100	500	2N	20N
23964	50	0.5	1	0.5L	15	2G	1N	500N	20N	200	300	2N	20N
23965	20	0.2	0.3	0.5N	15	2G	1N	500N	20N	70	3000	2N	20N
23966	30	0.5	1	0.5L	20	2G	1N	500N	20N	200	1000	2	20N
23967*	0.5	0.1	0.05L	0.5N	1	2	20	500N	1000G	20	300	2N	20N
23968	20	0.5	0.5	0.5L	10	2G	1N	500N	20N	20	500	2N	20N
23969*	2	30	0.5	0.5N	1	1	1N	500	20N	20L	10000G	2N	20N
23970	20	0.5	0.5	0.5L	10	2G	1N	500N	20N	70	500	2N	20N
23971*	20	10	0.5	0.5N	5	2G	1N	500N	20N	50	500	2L	20N
23972	20	0.5	0.5	0.5L	10	2G	1N	500N	150	100	500	7	20N
23973	20	0.5	0.5	0.5N	10	2G	1N	500N	20N	100	150	2L	20N
23974	20	0.7	1.5	0.5L	10	2G	1N	500N	20N	150	300	2N	20N
23975	20	0.7	1	0.5L	7	2G	1N	500N	20N	50	500	2L	20N
24110	15	0.5	0.7	0.5L	10	2G	1N	500N	20N	100	500	2L	100

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown
* 23967 = concentrate sample; 23969 = pre-glacial alluvium sample; 23971 = active stream sediment sample

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Co ppm	Cr ppm	Cu ppm	Ga ppm	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sb ppm	Sc ppm	Sn ppm
23949	20N	200	10	15	300	500	10N	50L	10N	20	200N	20	20L
23950	20N	200	10	30	200	300	10N	50L	20	1500	200N	20	20
23951	20N	150	10	20	300	200	10N	50	10N	5000	200L	20	20
23952	20N	200	10L	50	200	500	10N	50	10N	70	200N	10	30
23953	20N	300	10L	15	200	300	10N	50L	10N	70	200N	50	100
23954	20N	200	10	15	200	500	10N	50L	10N	70	200N	20	20
23955	20N	300	10L	20	500	700	10N	50	10N	70	200N	70	300
23956	20N	200	10	30	500	700	10N	50L	10N	70	200N	50	20
23957	20N	300	10	20	500	700	10N	50L	10N	70	200N	50	20
23958	20N	200	10L	10	200	1000	10N	50L	10N	100	200N	20	20
23959	20N	100	10L	10	150	300	10N	50	10N	70	200N	15	20L
23960	20N	200	10L	20	500	700	15	50	10N	150	200N	50	1000
23961	20N	200	10L	10	200	700	10N	50	10N	70	200N	50	30
23962	20N	200	10L	20	300	500	10N	50L	10N	100	200N	50	70
23963	20N	500	10L	20	200	700	10	50L	10N	100	200N	30	20
23964	20N	300	10L	20	500	700	10N	50L	10N	150	200N	50	50
23965	20N	200	10N	10	200	500	10N	50L	10N	50	200N	30	300
23966	20	300	30	30	500	1000	10N	50L	10N	200	200N	70	30
23967*	20N	100	10L	10L	2000	100	10N	50N	10L	100	200N	20	500
23968	20N	200	10L	15	200	500	10	50	10N	50	200N	20	20L
23969*	50	20N	100	10N	150	500	15	50N	100	100	200N	10L	20N
23970	20N	150	10L	10	300	500	10N	50	10N	150	200N	30	20
23971*	20	150	30	10L	200	500	10N	50L	50	100	200N	30	30
23972	20N	200	10L	20	200	500	10N	50L	10N	50	200N	30	20
23973	20N	200	10	10	500	300	10N	50	10N	50	200N	30	50
23974	20N	200	15	10L	300	500	10N	50	10N	50	200N	20	50
23975	20N	150	10	15	300	500	10N	50	10N	50	200N	20	20
24110	20L	200	10L	20	500	500	10N	50L	10N	70	200N	20	100

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N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown
* 23967 = concentrate sample; 23969 = pre-glacial alluvium sample; 23971 = active stream sediment sample

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Sr ppm	Th ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
23949	700	200N	100	50N	200	500N	2000G
23950	700	200N	150	50N	200	500N	2000G
23951	1000	200N	100	50N	300	500N	2000G
23952	200	200N	100	50N	300	500N	2000G
23953	200	200N	150	50N	300	500N	2000G
23954	700	200N	100	50N	200	500N	2000G
23955	500	200N	100	50N	300	500N	2000G
23956	500	200N	100	50N	200	500N	2000G
23957	500	200N	100	50N	200	500N	2000G
23958	500	200N	100	50N	300	500N	2000G
23959	200N	200N	100	50N	150	500N	2000G
23960	500	200N	100	100	300	500N	2000G
23961	500	200N	150	50L	200	500N	2000G
23962	700	200N	150	50N	500	500N	2000G
23963	700	200N	150	50N	300	500N	2000G
23964	500	200N	100	50N	300	500N	2000G
23965	500	200N	100	50N	200	500N	2000G
23966	500	200N	150	50N	300	500N	2000G
23967*	200N	200N	100	50N	700	500N	2000G
23968	500	200N	100	50N	200	500N	2000G
23969*	500	200N	50	50N	100	500	2000G
23970	500	200N	100	50N	200	500N	2000G
23971*	500	200N	100	50N	200	500N	2000G
23972	700	200N	100	50N	200	500N	2000G
23973	500	200N	100	50N	500	500N	2000G
23974	700	200N	100	50N	200	500N	2000G
23975	700	200N	100	50N	200	500N	2000G
24110	1000	200N	100	50N	300	500N	2000G

Note: The following elements were not detected at the lower determination limit shown: Cd (50 ppm), Ge (20 ppm), Pd (5 ppm), and Pt (20 ppm).
N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown
* 23967 = concentrate sample; 23969 = pre-glacial alluvium sample; 23971 = active stream sediment sample

Table 9. Analytical data for the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by semiquantitative emission spectroscopy ...continued

MDNR Sample Number	Ca %	Fe %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Au ppm	B ppm	Ba ppm	Be ppm	Bi ppm
24111	30	0.2	0.5	0.5L	20	2G	1N	500N	20N	200	150	2L	20N
24112	20	0.5	0.7	0.5L	10	2G	1N	500N	20N	100	200	2L	20N
24113	30	0.2	1	0.5L	20	2G	1N	500N	20N	70	100	2L	20N
24114	50	0.3	0.3	0.5L	20	2G	1N	500N	20N	50	100	2N	20N

MDNR Sample Number	Co ppm	Cr ppm	Cu ppm	Ga ppm	La ppm	Mn ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Sb ppm	Sc ppm	Sn ppm
24111	20N	200	10L	10	300	500	10N	50L	10N	70	200N	20	70
24112	20N	200	10	50	500	300	10N	50L	10N	50	200N	20	200
24113	20N	200	10L	20	300	500	10N	50L	10N	50	200N	15	30
24114	20N	200	10	20	300	500	10N	50	10N	70	200N	15	20

MDNR Sample Number	Sr ppm	Th ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
24111	200	200N	150	50N	300	500N	2000G
24112	1000	200N	100	50N	500	500N	2000G
24113	200	200N	100	50N	500	500N	2000G
24114	300	200N	150	50N	300	500N	2000G

Note: The following elements were not detected at the lower determination limit shown: Cd (50 ppm), Ge (20 ppm), Pd (5 ppm), and Pt (20 ppm).
N = element was not detected at the lower determination limit shown; L = element observed, but was below the lower determination limit shown;
G = element observed, but was above the upper determination limit shown

Table 10. Cyanide-soluble gold recovery data for three pilot study archive samples as determined by cyanide leach assay

MDNR Sample Number	Minus-20-Mesh Sample Weight grams	Preg-rob Test	Gold Recovery in Leach ounces/short ton	Gold Recovery in Tailings ounces/short ton
23932	1861	Negative	<0.002	<0.002
23935	1824	Negative	<0.002	<0.002
23960	1695	Negative	<0.002	<0.002

Table 11. Visual description of the ore-related, rock-forming, and accessory minerals observed in the nonmagnetic (C-3) fraction of the heavy-mineral-concentrate samples

Ore-related Minerals

Arsenopyrite, FeAsS - Grayish-black, granular, and intimately associated with pyrite

Barite, $BaSO_4$ - Occurs as single euhedral crystals or as broken cleavage fragments, mostly white, some showing multiple growth lines; edges of some crystals show jagged dissolution features

Cassiterite, SnO_2 - Occurs as pale yellow to brownish-black irregular grains with adamantine to greasy luster

Chalcopyrite, $CuFeS_2$ - Occurs as oxidized fine granular material in pyrite; appears to be locally derived

Gold, Au - Occurs as flattened grains or scales with rounded to ragged edges; usual color is yellow, but some scales show a brownish to orange-red tarnish; the largest gold grain observed was less than 0.5 mm

Marcasite, FeS_2 - Occurs as stalactite masses and in concentric structures with pyrite in sample number 23969

Powellite, $CaMO_4$ - Physical properties of powellite are similar to scheelite, but the fluorescent color under short-wave ultraviolet light is a brilliant lemon-yellow inclining to yellowish-white with increasing substitution of tungsten for molybdenum; often associated with scheelite

Pyrite, FeS_2 - Occurs as isolated cubes, tarnished reddish-brown; in sample number 23969, the pyrite appears as stalactite-like pseudomorphs after organic material

Scheelite, $CaWO_4$ - Equigranular grains with few euhedral faces; inclines to an adamantine luster and white to yellowish-white color; best identified under short-wave ultraviolet light where the fluorescent color is a vivid blue-white; often associated with gold

Rock-forming and Accessory Minerals

Andalusite, Al_2SiO_5 - Usually prismatic to nearly square in form; from flesh-red to pale violet, many showing dark inclusions

Apatite, $Ca_5(F,Cl,OH)(PO_4)_3$ - Well-rounded frosted grains to clear hexagonal prisms; color from sky-blue to white

Corundum, Al_2O_3 - Rough angular pieces; typically dark smoky blue to pale blue color, some showing dark inclusions

Kyanite, Al_2SiO_5 - Bladed cleavages of clear to white color, rarely blue; with numerous internal cleavage planes developed normal to the broad cleavage plane of the pinacoid

Manganoan diopside, $(Ca,Mn)(Mg,Fe,Mn)[Si_2O_6]$ - Translucent colorless to white rounded grains; most distinguishable by its greenish-white to greenish-yellow fluorescence

Rutile, TiO_2 - Well rounded grains to prismatic crystals, sometimes striated; from black to ruby red to orange-yellow

Sillimanite, Al_2SiO_5 - Usually occurs in white compact fibrous aggregates in rounded pebbles

Sphene, $CaTiSiO_5$ - Sharp-edged tabular crystals to blocky grains, translucent to opaque; from brown to pale yellow, commonly color-zoned with paler material surrounding darker interior

Spinel, $MgAl_2O_4$ - Occurs in colorless to pale blue octahedrons

Tourmaline, $Na(Fe^{+2},Mg)_3Al_6(BO_3)_3(Si_6O_{18})(OH)_4$ - Well-worn translucent to opaque black to brownish-grey frosted grains; occasionally as euhedral short prismatic hexagonal crystals

Zircon, $ZrSiO_4$ - Short prismatic euhedral crystals, of square cross-section, usually transparent, from clear to pale pink; or well-rounded frosted grains, translucent, from pale pink to deep reddish-violet; some grains show radiation damage - they are opaque and range from gray to blackish-brown

Rock-forming silicate minerals - Rounded to blocky grains which are a mixture of quartz, feldspar, amphibole, and chlorite

Phosphatic shell fragments - Occur in shades of brown to blackish-brown, translucent to opaque, adamantine to resinous luster; presumedly represent remnants of fossils

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques

	Ore-Related Minerals								
MDNR Sample Number	Gold Grains	Scheelite Grains	Powellite Grains	Arsenopyrite %	Barite %	Cassiterite %	Chalcopyrite %	Marcasite %	Pyrite %
20431									
22631									<1
22632									
22633									<1
22634									<1
22635		1							
22636		2							
22637	1	1							
23901	1								
23902		2							
23903		3							<1
23904		6							
23905									
23906		1							<1
23907					<1				
23908		4							
23909									
23910									<1
23911		2			<1				
23912		1							
23913									
23914		3							<1
23915		1							
23916	2								
23917									
23918		3							<1
23919		1			<1				
23920		1							
23921		4							<1
23922			1						

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Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

Gross Percentages of Rock-Forming and Accessory Minerals

MDNR Sample Number	Andalusite %	Apatite %	Corundum %	Kyanite %	Manganoan diopside %	Rutile %	Sillimanite %	Sphene %	Spinel %	Tourmaline %	Zircon %	Rock Forming Silicate Minerals	Phosphatic Shell Fragments
20431		15				25		35			20	P	
22631		30		<1		20		15			30	P	
22632		20		10		25		25			15	P	
22633		25		2		25		25			20	P	
22634	<1	15		<1		30		30			25	P	
22635		30				20		20			20	P	
22636		25		10		10		10			35	P	
22637		30		10		15		15			25	P	
23901	<1	30		5		5	5	20		5	30		P
23902	30	30		2		2		2		2	30		
23903	30	30		2		2		2		2	30		
23904	5	50		5		5		10		5	20		
23905	2	30		2		2	2	30			30		P
23906	2	30		2	<1	2	2	30			30		
23907	2	40		2	<1	2	2	20		2	30		
23908	4	50		4		4	4	10		4	20		
23909	10	30		6		6	6	20	<1		20		P
23910	4	30		4		4	4	30		4	20		
23911	3	30		3		3		30			30		
23912	4	50		4		4	4	10		4	20		
23913	<1	30		7		7	7	10		<1	30		
23914	15	30		5		5	5	10			30		
23915	2	40		2	<1	2	2	20			30		
23916	30	30		5		5	5	5		<1	20		
23917	40	30				2	2	2		2	20		
23918	30	30		2		2	2	2		<1	30		
23919	2	30		2	<1	2	2	30			30		
23920	2	40		2		2	2	20			30		
23921	2	50		2		2	2	10			30		
23922	50	10		2		2	20	5		<1	10		

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Note: In the last two data columns P = present

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

MDNR Sample Number	Contaminants: Aluminum Particles	Brass Particles	Copper Particles	Lead Particles	Remarks
20431					
22631					
22632		1			Contamination possibly from brass shell casing
22633					
22634					
22635			1	10	Contamination from leadshot
22636					
22637					
23901	5				Probably contains andalusite
23902					
23903					
23904					Probably contains andalusite
23905					
23906					Probably contains manganoan diopside (fluoresce pale blue-white)
23907					Probably contains manganoan diopside (fluoresce pale blue-white)
23908					
23909					Confirmed clear spinel which occurs as colorless, octahedral crystals
23910					
23911					
23912					
23913					Probably contains andalusite and tourmaline
23914					
23915					Manganoan diopside confirmed
23916					Probably contains tourmaline
23917					
23918		12			Probably contains tourmaline
23919					Probably contains manganoan diopside
23920					
23921					
23922				3	Probably contains tourmaline

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

MDNR Sample Number	Gold Grains	Scheelite Grains	Powellite Grains	Arsenopyrite %	Barite %	Cassiterite %	Chalcopyrite %	Marcasite %	Pyrite %
	Ore-Related Minerals								
23923		3							
23924		1							
23925		1							
23926		3							
23927		3							
23928		6							
23929		3							<1
23930									
23931		1							
23932									
23933									<1
23934		2							
23935									
23936		1							
23937									
23938	2	1							
23939						<1			
23940									
23941	1								
23942									
23943		6							
23944									
23945									
23946		6							
23947									
23948					<1				
23949	1	1							
23950	1		2						
23951		2							<1
23952		5							

...continued next page...

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

	Gross Percentages of Rock-Forming and Accessory Minerals												
MDNR Sample Number	Andalusite %	Apatite %	Corundum %	Kyanite %	Manganoan diopside %	Rutile %	Sillimanite %	Sphene %	Spinel %	Tourmaline %	Zircon %	Rock Forming Silicate Minerals	Phosphatic Shell Fragments
23923	30	30		5		5	5	5			20		
23924	30	10		3		3	3	30		<1	20		
23925	30	20		5		10	5	30					
23926	10	3		3		3	30	40			10		
23927	30	20	3	3		3		30			10		
23928	2	40		2	<1	2	2	20			30		
23929	5	30		5		5	5	30			20		
23930	5	30		5		5	5	15			30	P	
23931	5	30		5		5	5	15			30		
23932		30		5		5	5	15			30		
23933	30	30		2		2	2	2		<1	30		
23934	10	30		3		3	3	20		<1	30		
23935		30		5		5	5	15			30		
23936	<1	40		3	<1	3	3	20			30		
23937		30		5		5	5	15			30		
23938		30		5		5	5	15			30		
23939		40		3		3	3	20			30		
23940		30		5		5	5	15		<1	30		P
23941	20	40		1		1	1	15		<1	20		
23942	10	40		1		1	1	15		<1	30		
23943	10	40		3		3	3	10			30	P	
23944	2	50	2	2		2	2	10			30		
23945	10	30		3		3	3	30			20		
23946	2	50		2		2		20			20	P	P
23947	30	30		3		3		3			30		
23948	2	40		2		2	2	20			30		P
23949		30		5		5	5	15		<1	30		
23950	2	30		2		10	2	10			40	P	
23951	10	30		2		2	2	30			20		P
23952	15	30	<1	5		5	5	10			30		

...continued next page...

Note: In the last two data columns P = present

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

MDNR Sample Number	Contaminants Aluminum Particles	Brass Particles	Copper Particles	Lead Particles	Remarks
23923					
23924					Probably contains tourmaline
23925					
23926					
23927					Corundum confirmed
23928					Manganoan diopside confirmed
23929					
23930					Red and black schist fragments
23931	3				
23932					
23933					Probably contains tourmaline
23934					Tourmaline confirmed
23935					
23936					Probably contains andalusite; manganoan diopside confirmed
23937					
23938					
23939					Cassiterite confirmed
23940					Probably contains tourmaline
23941	5				Probably contains tourmaline
23942					Probably contains tourmaline
23943				3	
23944	3			2	Corundum confirmed
23945				2	
23946					
23947					
23948					
23949	3				Probably contains tourmaline
23950				2	
23951		3		2	
23952					Corundum confirmed

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

MDNR Sample Number	Ore-Related Minerals								
	Gold Grains	Scheelite Grains	Powellite Grains	Arsenopyrite %	Barite %	Cassiterite %	Chalcopyrite %	Marcasite %	Pyrite %
23953		3							
23954									<1
23955		4							
23956		1							
23957									<1
23958									
23959									
23960	3	9	1			<1			
23961		1							
23962		2							<1
23963		2							<1
23964		1							
23965					<1				
23966									
23967	+20	+20							<1
23968									
23969		+6		<1	<1		<1	<1	80
23970									
23971									30
23972	1	1							
23973		1							
23974		2							
23975									
24110		2							
24111		3							
24112									<1
24113									
24114		3							

...continued next page...

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

MDNR Sample Number	Andalusite %	Apatite %	Corundum %	Kyanite %	Manganoan diopside %	Rutile %	Sillimanite %	Sphene %	Spinel %	Tourmaline %	Zircon %	Rock Forming Silicate Minerals	Phosphatic Shell Fragments
	Gross Percentages of Rock-Forming and Accessory Minerals												
23953	15	30		3		3	3	15			30		
23954		50		2		2	2	10			30	P	P
23955	2	40		2		2	2	20			30		
23956	2	30		2	<1	2	2	30			30		P
23957	2	30		2		2	2	30			30		P
23958	30	30		2		2	2	2			30		
23959	3	30		3		15	3	15			30		P
23960	10	30		3		3	3	20			20		P
23961	30	30		3		3	3	3			30		
23962	30	30		3			3	3			30		
23963		40		3		10	3	10			30	P	P
23964	2	40		2		2	2	20			30		
23965	20	50		3		3	3				20		P
23966	2	40		2		2	2	20			30		P
23967	<1	20		<1		<1					80		
23968	2	30		2		15	2	15			30		P
23969	2	2		2		2					2		
23970	3	30		3		15	3	15			30		
23971		30	2	2		2	2	10	<1		20		P
23972	3	30		3		15	3	15			30		P
23973	20	30		3		3	3	10			30		
23974	20	30		3		3	3	10			30		P
23975		30		5		10	5	20			30		P
24110	3	30		3		10	3	20			30		P
24111	10	30		5		10	5	10			30		
24112	2	30		2		2	2	30			30		
24113	10	30		5		10	5	10			30		
24114	10	30		5		10	5	10			30		

...continued next page...

Note: In the last two data columns P = present

Table 12. Mineralogical data for the non-magnetic (C-3) fraction of the heavy-mineral-concentrate samples as determined by binocular microscopy and x-ray diffraction techniques ...continued

MDNR Sample Number	Contaminants: Aluminum Particles	Brass Particles	Copper Particles	Lead Particles	Remarks
23953					
23954	4				
23955					
23956					Manganoan diopside confirmed
23957					
23958					
23959					
23960					Cassiterite confirmed
23961					
23962					
23963					
23964					
23965					
23966					
23967					Heavy-mineral-concentrate sample provided by gravel pit operator; visually, the grain morphology of this sample does not look like normal glaciofluvial samples; very fine rounded grains, dozens of gold grains
23968	4				
23969					Possibly a pre-glacial alluvium sample; visually, the grain morphology of this sample does not look like normal glaciofluvial samples; grain morphology of pyrite appears as stalactite-like pseudomorphs after organic material; chalcopyrite confirmed
23970					
23971					Active stream-sediment sample; corundum confirmed; clear spinel octahedral crystals confirmed
23972					
23973					
23974					
23975	3				
24110					
24111					
24112					
24113					
24114					

Table 13. Quantitative mineralogical data for the paramagnetic (C-2) fraction of the heavy-mineral-concentrate test study samples as determined by point count analysis

MDNR Sample Number	Hornblende %	Olivine %	Epidote %	Pyroxene %	Garnet %	Opaques %	Iron Formation %	Rock Fragments %	Feldspar %	Sphene %	Biotite %	Staurolite %	Actinolite %	Tourmaline %	Quartz %
20431	2.24	61.79	7.11	2.64	0.2	20.73			3.66	0.41					1.22
22631		5.42	14.63	5.96	20.33	31.17	4.3	4.06							
22632	7.21	5.53	3.13	14.18	7.21	17.55	24.04	19.47				0.72	0.96		
22633	13.67	3.75	5.9	17.96	8.58	17.16	12.06	19.57			0.27	0.8	0.54		
22634	12.44	10.14	5.76	15.21	5.3	17.05	14.75	18.43			0.46		0.23	0.23	
22635	11.57	14.94	8.43	16.87	2.17	30.12	1.93	13.25	0.48				0.24		
22636	29.64	0.45	16.29	4.3	24.89	13.12	2.26	8.37		0.68					
22637	25.91	3.63	21.31	2.42	14.53	14.04	4.6	13.32		0.24					

Table 14. Mineralogical remarks and chemical composition of various apatite grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis

MDNR Sample Number	Heavy-Mineral Concentrate Fraction	Mineral	Grain Size in Micrometers	Remarks	Weight % of Elements F	F=O	Cl	Cl=O	Weight % of Oxides BaO	CaO	FeO	MgO	MnO	P_2O_5	SrO	Total Wt. %
20431	C-3	Apatite			5.73	2.41	0.02	0.00	0.01	54.90	0.00	0.01	0.05	41.70	0.01	100.0
20431	C-3	Apatite			5.43	2.29	0.39	0.09	0.02	54.03	0.38	0.10	0.95	41.04	0.05	100.0
20431	C-3	Apatite					1.30			51.84				41.23		94.37
20431	C-3	Apatite			3.73	1.57	1.78	0.40	0.00	54.59	0.23	0.07	0.05	41.47	0.06	100.0
20431	C-3	Apatite			5.32	2.24	0.02	0.00	0.00	55.05	0.03	0.00	0.00	41.81	0.02	100.0
22631	C-3	Apatite			4.38	1.84	0.01	0.00	0.00	55.22	0.02	0.00	0.00	41.94	0.27	100.0
22631	C-3	Apatite			5.09	2.14	0.11	0.02	0.00	55.03	0.01	0.02	0.10	41.80	0.00	100.0
22631	C-3	Apatite			5.04	2.12	0.01	0.00	0.04	55.07	0.04	0.02	0.05	41.83	0.03	100.0
22631	C-3	Apatite			3.71	1.56	0.03	0.01	0.01	55.50	0.04	0.00	0.05	42.16	0.08	100.0
22632	C-3	Apatite			4.50	1.89	0.80	0.18	0.00	54.86	0.18	0.04	0.03	41.67	0.00	100.0
22632	C-3	Apatite			5.52	2.33	0.10	0.02	0.01	54.79	0.23	0.02	0.06	41.62	0.00	100.0
22632	C-3	Apatite			5.37	2.26	0.00	0.00	0.00	55.01	0.01	0.00	0.01	41.79	0.07	100.0
22632	C-3	Apatite			4.93	2.08	0.22	0.05	0.00	55.04	0.03	0.00	0.04	41.81	0.05	100.0
22633	C-3	Apatite			4.40	1.85	0.14	0.03	0.00	54.99	0.23	0.11	0.06	41.77	0.19	100.0
22633	C-3	Apatite			6.08	2.56	0.00	0.00	0.05	54.57	0.02	0.00	0.05	41.45	0.34	100.0
22633	C-3	Apatite			4.77	2.00	0.01	0.00	0.00	54.97	0.00	0.00	0.00	41.75	0.51	100.0
22633	C-3	Apatite			5.80	2.44	0.42	0.10	0.00	54.40	0.31	0.23	0.36	41.32	0.00	100.0
22634	C-3	Apatite			4.84	2.04	0.02	0.00	0.04	55.16	0.04	0.01	0.05	41.89	0.00	100.0
22634	C-3	Apatite			4.17	1.76	0.02	0.00	0.00	55.27	0.04	0.01	0.00	41.98	0.28	100.0
22634	C-3	Apatite			3.67	1.54	0.03	0.01	0.00	55.51	0.03	0.01	0.07	42.16	0.08	100.0
22634	C-3	Apatite			3.68	1.55	0.15	0.03	0.01	55.49	0.06	0.02	0.04	42.14	0.00	100.0
22635	C-3	Apatite			4.80	2.02	0.01	0.00	0.00	54.68	0.00	0.00	0.02	41.53	0.99	100.0
22635	C-3	Apatite			4.65	1.96	0.00	0.00	0.00	55.24	0.01	0.00	0.00	41.96	0.11	100.0
22635	C-3	Apatite			3.17	1.33	0.15	0.04	0.00	55.62	0.03	0.00	0.07	42.25	0.07	100.0
22635	C-3	Apatite			3.55	1.49	1.15	0.26	0.00	54.98	0.20	0.01	0.06	41.76	0.06	100.0
22636	C-2	Apatite		Inclusion in monazite						53.34				41.17		94.51
22636	C-2	Apatite	10x10	Inclusion in fibrous rare earth element-carbonate?						54.66				41.70		96.36
22636	C-3	Apatite			5.69	2.39	0.02	0.01	0.03	54.81	0.07	0.02	0.14	41.63	0.00	100.0
22636	C-3	Apatite			4.17	1.75	0.01	0.00	0.00	55.41	0.03	0.01	0.05	42.09	0.00	100.0
22636	C-3	Apatite			5.99	2.52	0.22	0.05	0.00	54.72	0.03	0.00	0.05	41.56	0.00	100.0
22636	C-3	Apatite			5.38	2.63	0.01	0.00	0.00	55.00	0.00	0.00	0.07	41.78	0.03	100.0
22637	C-3	Apatite			5.96	2.51	0.02	0.00	0.03	55.57	0.00	0.00	0.03	41.45	0.47	100.0
22637	C-3	Apatite			5.37	2.26	0.06	0.01	0.00	55.12	0.00	0.01	0.04	41.78	0.00	100.0
22637	C-3	Apatite			5.22	2.20	0.07	0.02	0.01	55.00	0.08	0.01	0.06	41.77	0.00	100.0
22637	C-3	Apatite			5.64	2.37	0.19	0.04	0.01	54.83	0.03	0.00	0.05	41.64	0.03	100.0

Table 15. Mineralogical remarks and chemical composition of various monazite grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis

MDNR Sample Number	Heavy-Mineral-Concentrate Fraction	Mineral	Remarks
20431a	C-3	Monazite	
20431b	C-3	Monazite	A yttrium-rich variety of monazite
20431c	C-3	Monazite	
20431d	C-3	Monazite	
22631a	C-1	Monazite	Inclusion in magnetite
22631b	C-1	Monazite	Inclusion in magnetite
22631c	C-2	Monazite	
22631d	C-2	Monazite	
22631e	C-2	Monazite	Inclusion in ilmenite
22631f	C-2	Monazite	
22631g	C-3	Monazite	
22631h	C-3	Monazite	
22632a	C-1	Monazite	In contact with titanium magnetite
22632b	C-2	Monazite	
22632c	C-2	Monazite	
22632d	C-3	Monazite	
22633a	C-3	Monazite	
22634a	C-1	Monazite	Inclusion in magnetite
22634b	C-2	Monazite	
22634c	C-2	Monazite	Inclusion in hematite?
22634d	C-2	Monazite	Inclusion in hematite (?), Ce-rich variety
22634e	C-3	Monazite	
22634f	C-3	Monazite	
22635a	C-3	Monazite	
22636a	C-1	Monazite	
22636b	C-2	Monazite	
22636c	C-2	Monazite	Point 2 of 3 on 100x50 micrometer grain
22636d	C-2	Monazite	
22636e	C-2	Monazite	
22636f	C-2	Monazite	

...continued next page...

Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 15. Mineralogical remarks and chemical composition of various monazite grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Grain Size micrometers	Weight % of Oxides As_2O_3	BiO_2	CaO	CeO_2	FeO	Gd_2O_3	Ho_2O_3	La_2O_3	Nd_2O_3	P_2O_5	PbO	PrO_2	SiO_2	Sm_2O_3	SO_3	SrO	ThO_2	UO_2	Y_2O_3	Total Wt. %
20431a				0.83	29.00			1.04	13.79	9.47	27.51	0.72	2.89	1.25	1.05			9.88			97.4
20431b				1.31	27.77				14.88	8.90	28.46	0.91	2.36		0.77			7.38	1.05	2.39	96.2
20431c				0.21	32.56				8.54	15.24	28.49	0.44	4.48		1.13			0.24			91.3
20431d				1.16	29.70				15.39	11.26	29.39	1.31	4.24		0.71			5.60			98.8
22631a	6x3			.56	28.65				12.72	9.95	26.08	2.26	3.53	2.38				12.19			98.37
22631b	13x8			1.17	33.54				17.99	9.28	28.47	.49	4.00	1.52				5.41			101.9
22631c	12x13			1.68	27.70				14.75	9.62	29.74	0.84	2.58					5.67	2.60		95.19
22631d	100x40			1.36	29.61				15.89	10.01	29.52	0.96	2.93					6.61			96.93
22631e	12x13			0.54	25.55	1.58	2.17		11.49	14.63	30.17	0.72	2.82		2.27			2.60			94.60
22631f	150x50			0.68	29.46				15.27	10.16	27.45	1.49	4.37	1.58				10.01			100.5
22631g				0.63	31.81				16.97	9.74	28.28	1.16	3.85	0.78				6.26			99.5
22631h				1.36	26.36				15.67	6.73	27.49	1.61	1.31	1.40	1.08			12.11			95.1
22632a	15x25			.93	32.83				15.77	11.16	28.28		3.53	.55		1.96		1.41			96.45
22632b	100x150			1.23	29.25				14.73	9.03	30.43	1.22	3.49					6.95			96.37
22632c	60x40			0.72	25.90		1.77		12.73	14.37	30.27		3.91		2.24			3.49			95.43
22632d			0.66	1.35	29.67				13.79	10.81	29.68	1.23	2.81		1.52			7.48			99.0
22633a				1.06	29.55		1.01		15.73	10.56	29.49	0.70	2.91		1.51			4.82			97.4
22634a	7x5			1.49	27.38				14.72	8.18	28.31	1.77	3.06	.63				10.76			96.33
22634b	100x60			0.70	30.78	0.23			15.79	9.63	27.76	0.88	2.21	0.78				4.91			93.71
22634c	35x20	1.86		0.23	26.47	2.11	1.36		10.06	17.83	29.16		3.83	0.54	3.68			0.36			97.55
22634d	12x15			1.08	64.36						24.89										90.34
22634e				0.52	31.46				17.82	9.84	28.86	1.24	2.89	0.96	1.13			4.86			99.6
22634f				1.39	28.60				13.75	11.45	30.88	1.05	3.60		1.10			5.64			97.4
22635a				0.90	29.34				17.80	11.97	29.77		3.44		1.47			1.31			96.0
22636a	35x100			.81	30.31				17.29	8.65	27.33	1.11	2.61	1.27				10.24			99.66
22636b	100x50			1.34	23.99				12.54	8.16	24.55	2.50	3.00	2.39				15.36			93.87
22636c	100x50			1.33	29.04				15.97	8.37	28.24	1.51	2.21	0.36				8.87			95.95
22636d	30x40			0.84	29.79		1.96		12.65	12.98	30.50	0.71	3.88		1.66			3.65			98.66
22636e	6x5			0.27	31.09	2.02	1.42		13.28	12.44	30.24		2.47					0.39			93.86
22636f	150x70			1.27	28.21				14.79	10.15	29.79	0.53	2.79					5.61			93.57

Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 15. Mineralogical remarks and chemical composition of various monazite grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Heavy-Mineral-Concentrate Fraction	Mineral	Remarks
22636g	C-2	Monazite	Point 1 of 3 on 45x80 micrometer grain
22636h	C-2	Monazite	Point 2 of 3 on 45x80 micrometer grain
22636i	C-2	Monazite	
22636j	C-2	Monazite	With two inclusions, thorianite and apatite
22636k	C-3	Monazite	
22637a	C-2	Monazite	Core; same grain in all 5 analyses of 22637a-e
22637b	C-2	Monazite	Zone 1; same grain in all 5 analyses of 22637a-e
22637c	C-2	Monazite	Zone 2, Th-rich; same grain in all 5 analyses of 22637a-e
22637d	C-2	Monazite	Rim 1; same grain,in all 5 analyses of 22637a-e
22637e	C-2	Monazite	Rim 2; same grain in all 5 analyses of 22637a-e
22637f	C-2	Monazite	Inclusion in magnetite (?); high Fe, which is probably at least partly derived from surroundings
22637g	C-2	Monazite	Inclusion in silicate
22637h	C-2	Monazite	Zoned monazite, Th-rich, same grain as 22637i
22637i	C-2	Monazite	Zoned monazite, Th-rich, same grain as 22637h
22637j	C-3	Monazite	Nd-rich monazite occurring as a 20x20 micrometer inclusion in rutile
22637k	C-3	Monazite	Nd-rich monazite occurring as a 20x20 micrometer inclusion in rutile
22637l	C-3	Monazite	Inclusion in apatite; Th-rich; high silica could indicate a mixture of monazite and thorite

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 15. Mineralogical remarks and chemical composition of various monazite grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Grain Size micrometers	Weight % of Oxides																			
		As_2O_3	BiO_2	CaO	CeO_2	FeO	Gd_2O_3	Ho_2O_3	La_2O_3	Nd_2O_3	P_2O_5	PbO	PrO_2	SiO_2	Sm_2O_3	SO_3	SrO	ThO_2	UO_2	Y_2O_3	Total Wt. %
22636g	45x80			1.29	26.10				13.86	8.37	27.36	1.27	2.26	1.09				10.57		2.57	94.77
22636h	45x80			0.65	22.22		1.65		8.76	11.34	23.70	2.31	3.83	3.26	1.56			19.25		2.33	100.8
22636i	6x3			1.20	28.86				17.23	7.70	27.73		3.47	0.43			1.82	7.99			96.45
22636j	70x70			0.67	31.76				16.45	10.19	29.45		3.27	0.53	1.04			4.15			97.54
22636k			0.55	0.89	31.56				15.48	10.96	28.83	1.27	3.48					6.91			100.0
22637a				0.41	28.67				15.90	9.17	27.19	1.08	1.96	1.16				6.76		1.43	93.77
22637b				0.40	29.20				15.35	10.32	27.91	1.09	3.26	1.11				6.70		2.14	97.53
22637c				0.61	27.74				14.57	9.92	25.35	2.22	4.33	2.50				13.87			101.1
22637d				0.29	31.59				15.24	10.26	27.84	1.06	3.97	0.83	1.40			5.50		1.77	99.80
22637e				1.10	31.94				17.70	9.78	29.05	0.95	3.67					1.64			95.86
22637f	15x5			0.85	27.37	8.20	1.48		9.57	16.76	27.77	0.80	4.74		3.06			0.67			101.3
22637g	30x15				21.93				7.78	13.67	24.51	1.95	2.25	2.52	1.78			11.92		3.19	91.54
22637h				0.84	24.47				11.65	8.56	22.40	2.78	2.69	3.63				18.99			96.05
22637i				1.83	26.33				12.82	9.68	28.50	1.61	3.64					10.17		1.95	96.57
22637j	20x20				16.81		3.44	0.75		33.15	34.35		4.56		6.94						100.0
22637k	20x20				16.44		2.91			31.53	30.43		5.63		6.91			0.28			100.0
22637l	8			4.93		1.64			1.53		10.53	2.65		8.31				66.81	3.60		100.0

Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis

MDNR Sample Number	Heavy-Mineral-Concentrate Fraction	Mineral	Remarks
20431a	C-1	Baddeleyite	Inclusion in Ti-magnetite
20431b	C-1	Baddeleyite	Inclusion in Ti-magnetite
20431c	C-1	Baddeleyite	
20431d	C-1	Baddeleyite	Inclusion in ilmenite
20431e	C-1	Baddeleyite	Inclusion in ilmenite
20431f	C-1	Baddeleyite	Inclusion in ilmenite
20431g	C-3	Baddeleyite	Very pure, 100.05 weight percent ZrO_2
20431h	C-3	Baddeleyite	Apatite, 10x10 micrometer, occurs as an inclusion in this baddeleyite grain
20431i	C-3	Baddeleyite/thorianite	A solid solution or mixture between baddeleyite and thorianite
20431j	C-3	Thorite	This grain contains also some 'lighter phase'
20431k	C-3	Microlite?	A tantalum-bearing mineral; this mineral is probably microlite, a member of the pyrochlore group
20431l	C-3	Galena	
22631a	C-1	Unknown	Inclusion in magnetite; all elements analyzed
22632a	C-2	Baddeleyite	Inclusion in ilmenite
22632b	C-2	Baddeleyite	Inclusion in ilmenite
22632c	C-2	Native silver	Si and Fe from surrounding matrix?; all elements analyzed
22633a	C-1	Thorite ?	Inclusion in magnetite
22633b	C-1	Baddeleyite	In the core of the magnetite
22633c	C-1	Zircon	In the rim of the magnetite
22633d	C-1	Baddeleyite	Inclusion in ilmenite
22633e	C-1	Baddeleyite	Inclusion in ilmenite
22633f	C-1	Baddeleyite	Inclusion in ilmenite
22633g	C-3	Tin-lead-copper alloy?	
22633h	C-3	Thorite	
22634a	C-2	Baddeleyite	Inclusion in ilmenite
22635a	C-1	Baddeleyite	Inclusion in feldspar (?), which is an inclusion in Ti-magnetite
22635b	C-1	Baddeleyite	Inclusion in ilmenite
22635c	C-1	Baddeleyite	Inclusion in ilmenite
22635d	C-1	Baddeleyite	Inclusion in silicate
22635e	C-1	Baddeleyite	Inclusion in ilmenite

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Grain Size in Micrometers	Weight % of Elements									
		Ag	Bi	Cu	Fe	Pb	Pt	S	Si	Sn	W
20431a	60x15										
20431b	50x50										
20431c	35x22										
20431d	30x5										
20431e	60x3										
20431f	5x25										
20431g	600x650										
20431h	70x65										
20431i											
20431j	1100x800										
20431k											
20431l						90.68		12.37			
22631a	5x6					.80	55.36				40.47
22632a	25x7										
22632b	20x5										
22632c		92.63			2.23				0.58		
22633a	4x2										
22633b	10x6										
22633c	15x15										
22633d	25x6										
22633e	10x18										
22633f	9x7										
22633g				1.77		8.95				88.70	
22633h											
22634a	75x5										
22635a	25x8										
22635b	25x8										
22635c	15x10										
22635d	16x8										
22635e	5x12										

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Weight % of Oxides																	
	Al_2O_3	BaO	CaO	CeO_2	CuO	Dy_2O_3	Er_2O_3	FeO	Gd_2O_3	HfO_2	La_2O_3	MnO	Nb_2O_5	Nd_2O_3	P_2O_5	PbO	PrO_2	SeO_2	SiO_2
20431a										1.15									
20431b										.49									
20431c										1.46									
20431d																			
20431e																			
20431f																			
20431g																			
20431h																			
20431i																3.87			0.77
20431j	0.93		0.84	2.40				2.48						2.13	1.68	1.63			17.23
20431k			13.17					0.45				1.60	3.24						
20431l																			
22631a																			
22632a																			
22632b																			
22632c																			
22633a			2.83	.80				4.27						1.51	3.89	2.02			14.00
22633b																			
22633c										.83									31.29
22633d																			
22633e																			
22633f																			
22633g																			
22633h			2.89	1.25				1.84							7.25	1.84			10.12
22634a																			
22635a										1.68									
22635b										.67									
22635c										1.36									
22635d										1.43									
22635e										1.09									

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Weight % of Oxides...continued										Total Wt. %
	SO_3	SrO	Ta_2O_5	ThO_2	TiO_2	UO_2	V_2O_5	Y_2O_3	Yb_2O_3	ZnO	ZrO_2	
20431a											105.2	106.4
20431b											104.9	105.4
20431c											104.1	105.5
20431d											96.16	96.16
20431e											91.07	91.07
20431f											102.4	102.4
20431g											100.0	100.0
20431h					0.53						99.18	99.7
20431i		1.02		37.82		9.97					42.90	96.4
20431j	1.03			65.25								95.6
20431k			77.92		0.44							96.8
20431l												103.0
22631a												96.64
22632a											100.0	100.0
22632b											98.67	98.67
22632c												95.45
22633a				60.52				5.56				95.44
22633b											96.19	96.19
22633c											67.74	99.87
22633d											98.97	98.97
22633e											100.5	100.5
22633f											93.52	93.52
22633g												99.4
22633h				53.23		6.55					4.26	89.2
22634a											99.17	99.17
22635a											100.5	102.2
22635b											100.8	101.5
22635c											101.7	103.1
22635d											101.8	103.2
22635e											101.0	102.1

Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Heavy-Mineral-Concentrate Fraction	Mineral	Remarks
22636a	C-1	Unknown	Inclusion in chalcopyrite
22636b	C-2	Zircon	Point 3 of 3 on 100x50 micrometer grain
22636c	C-2	REE-carbonate(?)	Fibrous rare earth element-carbonate(?); low 69.7 wt. % total could suggest CO3 ion instead of oxygen
22636d	C-2	Unknown	Point 3 of 3 on 45x80 micrometer grain; this could be a mixture between zircon and something else
22636e	C-2	Unknown	Very small grain; this could be a composite grain of vanadinite and something else
22636f	C-2	Galena	Inclusion in monazite; all elements analyzed
22636g	C-2	Pyrite	FeS2 inclusion in the monazite with Pbs; all elements analyzed
22636h	C-2	Unknown	
22636i	C-2	Thorianite	Inclusion in monazite
22636j	C-2	Xenotime	
22636k	C-3	Barite	
22636l	C-3	Uraninite	
22637a	C-1	Unknown	In magnetite, most probably Pb-Fe-oxide; extra Fe in the analysis from surrounding magnetite
22637b	C-1	Unknown	In magnetite, most probably Pb-Fe-oxide; extra Fe in the analysis from surrounding magnetite
22637c	C-1	Unknown	In magnetite, most probably Pb-Fe-oxide; extra Fe in the analysis from surrounding magnetite
22637d	C-1	Unknown	
22637e	C-1	Unknown	Inclusion in magnetite
22637f	C-1	Baddeleyite	In contact with magnetite
22637g	C-2	Zircon	Inclusion in silicate

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Grain Size in Micrometers	Weight % of Elements									
		Ag	Bi	Cu	Fe	Pb	Pt	S	Si	Sn	W
22636a	1.5x2		84.58	7.08	8.06			3.03			
22636b	100x50										
22636c	200x60										
22636d	45x80										
22636e	2x2										
22636f	1x1					86.91		13.06			
22636g	7x6				46.01			51.77			
22636h											
22636i											
22636j	30x15										
22636k											
22636l											
22637a	10x15										
22637b	7x6										
22637c	2x5										
22637d	6x6										
22637e	7x5										
22637f	30x20										
22637g	7x6										

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Weight % of Oxides																		
	Al_2O_3	BaO	CaO	CeO_2	CuO	Dy_2O_3	Er_2O_3	FeO	Gd_2O_3	HfO_2	La_2O_3	MnO	Nb_2O_5	Nd_2O_3	P_2O_5	PbO	PrO_2	SeO_2	SiO_2
22636a																			
22636b																			30.40
22636c			3.93	29.95				2.52			20.92			7.31			3.04		0.86
22636d	2.49		1.28	1.37				38.47						0.72	1.99	0.52			14.59
22636e					1.62			3.28								55.46			
22636f																			
22636g																			
22636h	20.17		12.31	9.34				12.21			5.07			2.00				2.71	32.96
22636i																10.87			
22636j						4.16	3.01		1.78						31.22				
22636k		63.20																	
22636l																27.14			
22637a								15.49								92.72			
22637b								12.74								96.13			
22637c								15.95								89.75			
22637d								24.31								76.11			
22637e								29.17								79.56			
22637f										1.26									
22637g								1.11											31.21

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Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

Table 16. Mineralogical remarks and chemical composition of miscellaneous mineral grains identified in the heavy-mineral-concentrate test study samples by electron microprobe analysis ...continued

MDNR Sample Number	Weight % of Oxides...continued										Total Wt. %
	SO_3	SrO	Ta_2O_5	ThO_2	TiO_2	UO_2	V_2O_5	Y_2O_3	Yb_2O_3	ZnO	ZrO_2	
22636a												102.7
22636b											65.39	95.80
22636c				1.14								69.70
22636d				1.85							18.26	81.58
22636e							20.25			16.04		96.68
22636f												99.98
22636g												97.79
22636h		1.59										98.39
22636i				84.18		9.22						104.2
22636j								61.97	2.71			104.8
22636k	34.87	0.85										98.9
22636l				7.59		59.08		3.47				97.3
22637a												108.2
22637b												108.8
22637c												105.7
22637d												100.4
22637e												108.7
22637f											103.6	104.9
22637g											65.95	98.27

Note: Within a sample, separate analyses are identified by a lower-case letter following the sample number.

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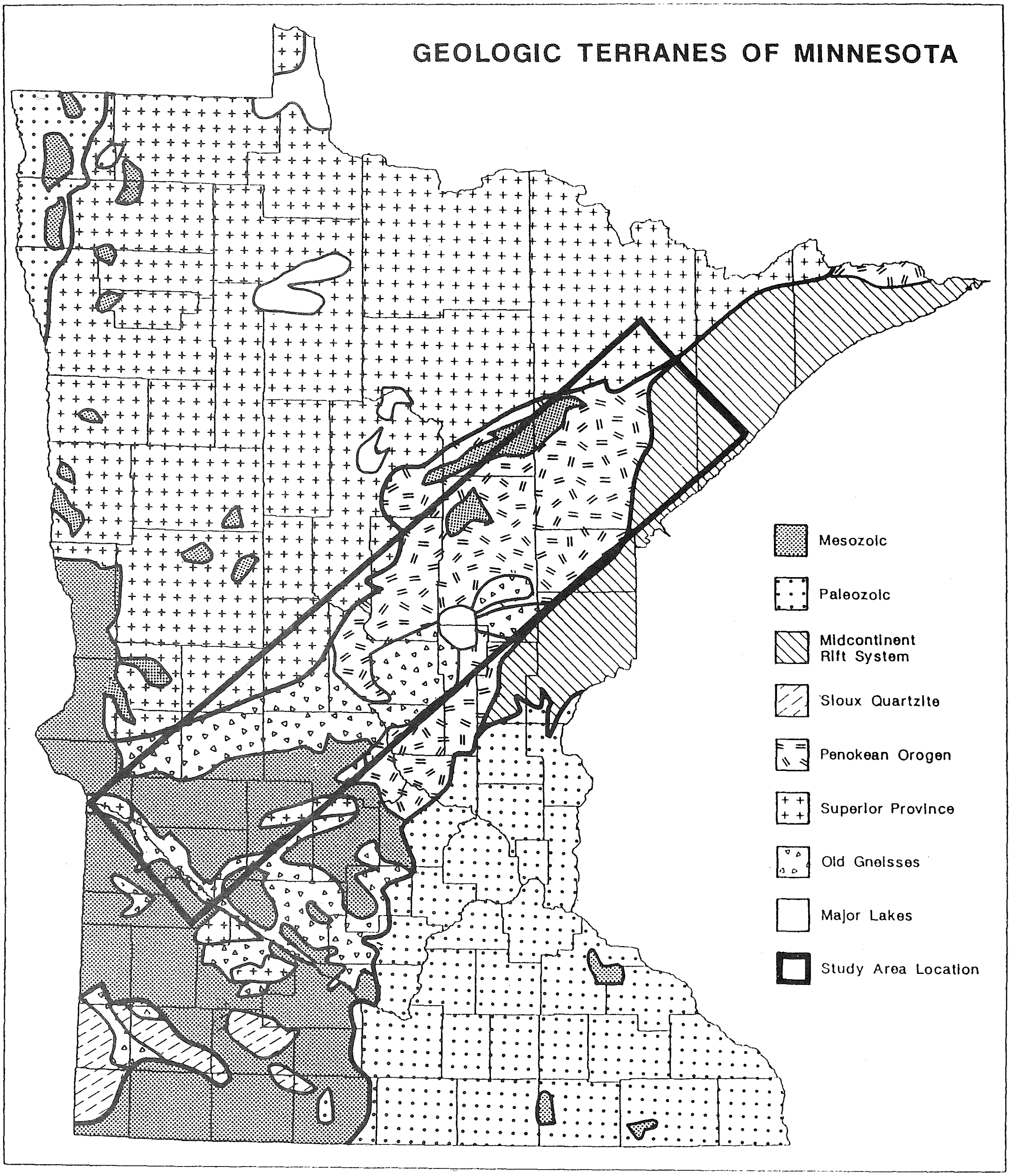


Source: The Geologic Map of the Lake Superior Region by G.B. Morey and others, 1982, (MGS Map S-13), which was encoded by the Minnesota Land Management Information Center (LMIC) using manual map transfer and grid overlay techniques. Modification of the original LMIC file has been made by the Minnesota Department of Natural Resources, Division of Minerals.

Appendix A. Generalized map of the geologic terranes of Minnesota

THE GEOLOGIC TERRANES OF MINNESOTA

MESOZOIC

A long period of weathering and erosion in Minnesota was interrupted by brief invasions of the sea with deposition of a few hundred feet of sediments, mostly silt and clay, first during the Jurassic in the far northeastern corner, then in the Cretaceous, spreading from the west over much of the State.

PALEOZOIC

During the Cambrian, Ordovician, and Devonian periods, southeastern and northwestern Minnesota subsided beneath the sea for long intervals of time. Fossiliferous marine sandstones, dolomitic limestones and shales up to 500 meters (1,640 feet) thick accumulated.

PRECAMBRIAN

There are five Precambrian terranes in Minnesota. From youngest to oldest these terranes are:

<u>Midcontinent Rift System</u> Formed about 1,100 million years ago. A major rift zone split the continent from Lake Superior down through eastern Minnesota and into southern Kansas. Basaltic magma welled up along the rift to form lava flows and intrusive bodies, including volcanic rocks, troctolitic gabbro and variants, anorthositic gabbro and variants, granitic differentiates, and basaltic dikes, sills and stocks. Clastic sediments were deposited in and near the rift zone as subsidence followed igneous activity. From central Minnesota south the rift zone is concealed beneath Paleozoic rocks.

<u>Sioux Quartzite</u> Deposited between 1,400 million and 1,700 million years ago. Quartzitic sedimentary rocks, derived from regions to the north, occupy a large, shallow basin extending from south-central Minnesota westward and southward into adjoining states.

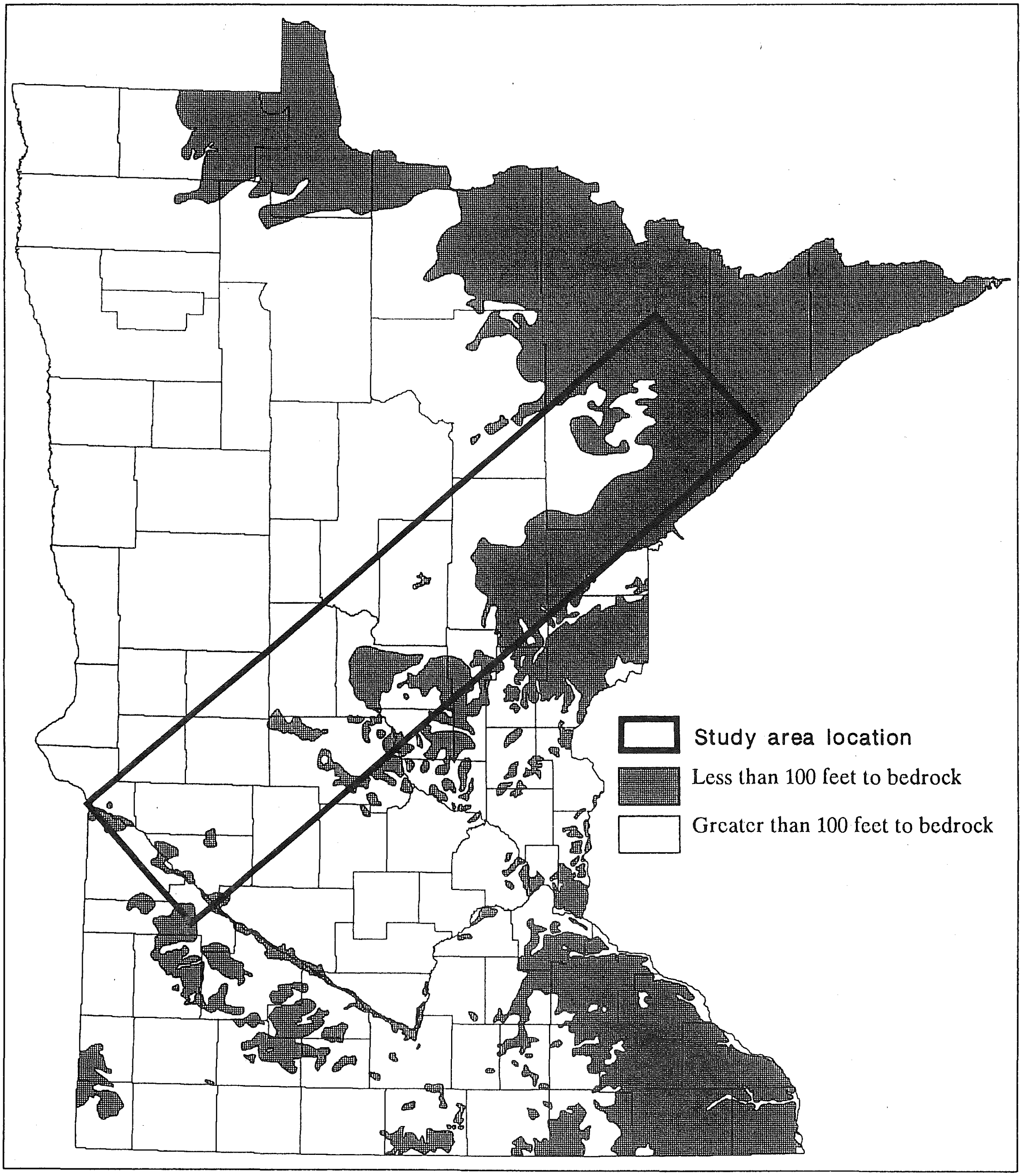
<u>Penokean Orogen</u> Deposited 1,800 million to 2,000 million years ago. Some volcanic rocks, abundant clastic rocks and rocks of chemical and biological origin accumulated in a subsiding basin that extended from east-central Minnesota north and east into Canada and upper Michigan. The resulting sedimentary rocks include quartzite, siltstone, iron-formation, and much graywacke and interbedded carbonaceous and pyritic black shale. About 1,700 million years ago the southeastern margin of the basin was folded and metamorphosed during an episode known as the Penokean Orogeny. About 1,100 million years ago, the basin was split by the Keweenawan rift. The iron-formation is the host rock of the Cuyuna, Mesabi and Gunflint Iron Ranges.

<u>Superior Province</u> Formed between 2,600 million and 2,700 million years ago. Within one relatively short period of intense geological activity in northern Minnesota and extending far into Canada, submarine and subaerial volcanic rocks and interbedded sedimentary rocks were deposited and then invaded by large intrusions of granitic rocks (Algoman granites) along northeast-trending belts. The resulting terrane of greenstone metavolcanics, metasediments, granitic rocks, and migmatites ends abruptly in central Minnesota at a line or narrow zone along which three earthquakes have occurred in historic time. Much older rocks occur south of this line. The Soudan Iron Formation and other banded iron-formations occur in this terrane in Minnesota.

<u>Old Gneisses</u> Formed 3,200 million to 3,800 million years ago and later igneous rocks formed about 2,600 million and 1,700 million years ago. Some of the oldest radiometric ages yet measured in terrestrial rocks come from strongly metamorphosed gneisses of unknown origin exposed in the Minnesota River Valley. These gneisses were invaded by "Algoman" granitic intrusions about 2,600 million years ago, and later, especially in east-central Minnesota, by "Penokean" granitic rocks about 1,700 million years ago.

Source: Summarized/modified from Matt Walton *in* Morey, 1976.

Appendix A: Generalized map of the geologic terranes of Minnesota ...continued



Source: Adapted from the Minnesota Land Management Information Center's MLMIS40 data base, filename DEPTHCRP.EPP. LMIC created this file by digitizing the state depth to bedrock map (Olson and Mossler, 1982), converting this file to ARC/INFO polygon coverage, then converting the ARC/INFO coverage to a 40-acre grid-cell EPPL7 file. The ARC/INFO coverages were modified by the Minnesota Pollution Control Agency to create closed polygon coverage where none existed on the original map.

Appendix B. Generalized depth to bedrock map of Minnesota

Appendix C. Underlying bedrock map unit symbols and depth to bedrock data derived from maps and well logs for the test and pilot study sample sites

MDNR Sample Number	Depth to Underlying Bedrock*	Bedrock Map Unit Symbol**
20431	<100	Yda
22631	200-300	Pvt
22632	200-300	Ams
22633	100-200	Pua
22634	100-200	Pua
22635	<100	Xg
22636	200-400	Agn
22637	200-400	Agr
23901	100-200	Psa
23902	100-200	Psa
23903	100-200	Pgvi
23904	200-300	Pgvi
23905	100-200	Pq
23906	<100	Pdv
23907	<100	Amc
23908	100-200	Piw
23909	<100	APh
23910	<100	Pvt
23911	<100	Pvt
23912	<100	Pvt
23913	<100	Pvt
23914	<100	Pvt
23915	<100	Xsg
23916	<100	Xsg
23917	<100	Xsg
23918	<100	Pvt
23919	<100	Pvt
23920	<100	Pps
23921	<100	Ydt
23922	<100	Ydt
23923	<100	Ynbn
23924	<100	Ydt
23925	<100	Ydt
23926	<100	Xsg
23927	<100	Ydt
23928	<100	Agr
23929	<100	Agr
23930	<100	Afv
23931	<100	Agr
23932	<100	Agr
23933	100-300	Amvs
23934	100-300	Amvs
23935	100-300	Amvs
23936	200-300	Pvt
23937	200-300	Pvt
23938	200-300	Pvt
23939	100-300	Pua

* Source of data is Olsen and Mossler, 1982; also well log data on 20431 and 22631-22637

** Source of data is Southwick and others, 1988, or Morey and others, 1982; see Appendix D for explanation of map unit symbols

Appendix C. Underlying bedrock map unit symbols and depth to bedrock data derived from maps and well logs for the test and pilot study sample sites ...continued

MDNR Sample Number	Depth to Underlying Bedrock*	Bedrock Map Unit Symbol**
23940	100-200	Pua
23941	<100	Pgvi
23942	<100	Plf
23943	<100	APh
23944	<100	APh
23945	<100	APh
23946	<100	APh
23947	100-200	Pvdg
23948	<100	Psa
23949	<100	Pvdg
23950	<100	APh
23951	100-200	Plf
23952	100-200	Plf
23953	100-200	Plf
23954	<100	Plf
23955	100-200	At
23956	200-300	Pua
23957	200-300	Pua
23958	300-400	Amvs
23959	200-300	Agn
23960	200-400	K
23961	100-200	K
23962	100-200	K
23963	<100	APgn
23964	<100	Plf
23965	300-400	APgn
23966	300-400	Agr
23967	200-300	K
23968	100-200	Agn
23969	<100	Agr
23970	200-300	K
23971	<100	Plf
23972	<100	O
23973	<100	O
23974	100-200	C
23975	100-200	C
24110	<100	Pdv
24111	100-200	Piw
24112	<100	Pvt
24113	<100	Ydt
24114	<100	Ydt

* Source of data is Olsen and Mossler, 1982; also well log data on 20431 and 22631-22637

** Source of data is Southwick and others, 1988, or Morey and others, 1982; see Appendix D for explanation of map unit symbols

Appendix D. Explanation of bedrock map unit symbols as shown in Appendix C

Bedrock Map Unit Symbol	Bedrock Age	Bedrock Terrane	Bedrock Map Unit Description	Source of Data
Afv	Archean	Superior Province	Metamorphosed felsic volcanic rocks - includes pyroclastic rocks, hypabyssal intrusions, and rare flows.	Morey and others, 1982, 1:1,000,000
Agn	Archean	Old Gneisses	Migmatitic gneiss, amphibolite, and granite - may include younger rocks in poorly exposed areas of central Minnesota.	Morey and others, 1982, 1:1,000,000
Agr	Archean	Superior Province	Granitoid rocks - includes Saganaga, Lac La Croix, and Giants Range Granites of northern Minnesota and the Odessa, Sacred Heart, and Fort Ridgely Granites of southwestern Minnesota.	Morey and others, 1982, 1:1,000,000
Amc	Middle to Late Archean	Old Gneisses	McGrath Gneiss - pinkish-gray, medium- to coarse-grained gneiss of granitic composition. Generally biotite-bearing and locally biotite-rich; contains zones of abundant microcline augen and layers of inclusions of biotite schist.	Southwick and others, 1988, 1:250,000
Ams	Late Archean	Superior Province	Metamorphosed Sedimentary Rocks, Undivided - gray, brown-weathering, medium-grained, biotite-bearing schists derived chiefly from interbedded graywacke and pelite.	Southwick and others, 1988, 1:250,000
Amvs	Late Archean	Superior Province	Metamorphosed Volcanic and Sedimentary Rocks, Undivided - includes pillowed greenstone, intermediate to felsic tuffaceous rocks, and associated volcaniclastic and epiclastic sedimentary rocks. Metamorphosed under greenschist-facies conditions.	Southwick and others, 1988, 1:250,000

Appendix D. Explanation of bedrock map unit symbols as shown in Appendix C ...continued

Bedrock Map Unit Symbol	Bedrock Age	Bedrock Terrane	Bedrock Map Unit Description	Source of Data
APgn	Archean to Early Proterozoic	Penokean Orogen	Gneissic Rocks, Undivided - predominantly gneiss of quartzofeldspathic composition, including granitic to tonalitic varieties; lithology and age are poorly known in the map area.	Southwick and others, 1988, 1:250,000
APh	Archean to Early Proterozoic	Penokean Orogen	Hillman Migmatite - light- to dark-gray, medium- to coarse-grained, foliated biotite-garnet-cordierite schist, hornblende schist, and biotite-feldspar-quartz granofels migmatized by tonalitic neosome.	Southwick and others, 1988, 1:250,000
At	Late Archean	Superior Province	Tonalite - light-gray to medium-gray, medium-grained, biotite-hornblende tonalite and leucotonalite. Moderately to strongly foliated; locally altered extensively to epidote, chlorite, albite, sericite.	Southwick and others, 1988, 1:250,000
C	Cambrian	Paleozoic	Cambrian rocks, undivided - dominantly quartzose and glauconitic sandstone and siltstone with lesser amounts of carbonates.	Morey and others, 1982, 1:1,000,000
K	Cretaceous	Mesozoic	Cretaceous rocks, undivided - includes dark-colored marine shale overlying white to brown sandstone and variegated shale of terrestrial origin.	Morey and others, 1982, 1:1,000,000
O	Ordovician	Paleozoic	Ordovician rocks, undivided - dominantly carbonate rocks with lesser amounts of quartzose sandstone, siltstone, and shale.	Morey and others, 1982, 1:1,000,000

Bedrock Map Unit Symbol	Bedrock Age	Bedrock Terrane	Bedrock Map Unit Description	Source of Data
Pdv	Early Proterozoic	Penokean Orogen	Mille Lacs Group, Unnamed metadiabase and metabasalt - similar to and probably cogenetic with hypabyssal rocks in units Pvdg, Pgvi, and Pbs; forms lenticular bodies, interpreted to be chiefly sills, within and between those units and within the Dam Lake quartzite.	Southwick and others, 1988, 1:250,000
Pgvi	Early Proterozoic	Penokean Orogen	Mille Lacs Group, Unnamed unit of metasedimentary and metavolcanic rocks - unit consists dominantly of graphitic schist and slate, mafic to intermediate flows and volcaniclastic rocks, and lean iron-formation. Rocks are generally metamorphosed under greenschist-facies conditions.	Southwick and others, 1988, 1:250,000
Piw	Early Proterozoic	Penokean Orogen	Granite - light-gray to light pinkish-gray, medium-grained, equigranular to porphyritic biotite granite.	Southwick and others, 1988, 1:250,000
Plf	Early Proterozoic	Penokean Orogen	Mille Lacs Group, Little Falls Formation - light-gray to dark-gray, quartz-rich slate, argillite, and schist. Metamorphic grade increases from NW to SE; coarse-grained, megacrystic garnet-staurolite schist is widespread in southern half of outcrop/subcrop belt.	Southwick and others, 1988, 1:250,000
Pps	Early Proterozoic	Penokean Orogen	Mille Lacs Group, Unnamed pelitic schist - quartz-mica schist, locally containing garnet, staurolite, and aluminosilicate minerals. Poorly constrained as to detailed lithology and areal extent in western part of inferred subcrop.	Southwick and others, 1988, 1:250,000

Appendix D. Explanation of bedrock map unit symbols as shown in Appendix C ...continued

Bedrock Map Unit Symbol	Bedrock Age	Bedrock Terrane	Bedrock Map Unit Description	Source of Data
Pq	Early Proterozoic	Penokean Orogen	Mille Lacs Group, Dam Lake quartzite (informal usage) - gray to light-gray, massive to thick-bedded quartzite.	Southwick and others, 1988, 1:250,000
Psa	Early Proterozoic	Penokean Orogen	Unnamed Metasedimentary Rocks - inferred from geophysical data and meager drilling control to consist mainly of slate, argillite, and metasiltstone.	Southwick and others, 1988, 1:250,000
Pua	Early Proterozoic	Penokean Orogen	Animikie Group, Unnamed argillaceous rocks of the Long Prairie basin - medium- to dark-gray, rhythmically interbedded argillite, siltstone, and graywacke in central and western parts of basin; coarse-grained, massive-bedded graywacke and polymictic paraconglomerate occur locally along eastern basin margin. Deformation and metamorphic recrystallization (under greenschist-facies conditions) increase from NW to SE.	Southwick and others, 1988, 1:250,000
Pvdg	Early Proterozoic	Penokean Orogen	Mille Lacs Group, Unnamed unit of metabasalt and metadiabase - fine- to medium-grained metabasalt (metamorphosed to greenschist- and lower amphibolite-facies assemblages) and equigranular to ophitic metadiabase. Diabase locally dominant, presumably as subvolcanic sills and thick flows. Interbedded pelitic schist is locally abundant.	Southwick and others, 1988, 1:250,000

Appendix D. Explanation of bedrock map unit symbols as shown in Appendix C ...continued

Bedrock Map Unit Symbol	Bedrock Age	Bedrock Terrane	Bedrock Map Unit Description	Source of Data
Pvt	Early Proterozoic	Penokean Orogen	Animikie Group, Virginia and Thomson Formations - medium- to dark-gray, rhythmically interbedded argillite, argillaceous siltstone, and feldspathic to lithic graywacke; graywacke beds are thicker, coarser, and more abundant in the southeastern part of the map area than elsewhere. Metamorphic grade ranges from sub-greenschist facies near the Mesabi range to mid-greenschist facies in the most strongly deformed rocks in eastern Carlton County.	Southwick and others, 1988, 1:250,000
Xg	Lower Proterozoic	Penokean Orogen	Granitoid rocks - includes Stearns Granitic Complex of central Minnesota.	Morey and others, 1982, 1:1,000,000
Xsg	Lower Proterozoic	Penokean Orogen	Slate, metagraywacke, and associated metavolcanic rocks - includes Viriginia, Thomson, and Rabbit Lake Formations of the Animikie Group, and associated unnamed iron-formations.	Morey and others, 1982, 1:1,000,000
Yda	Middle Proterozoic	Midcontinent Rift System	Anorthositic, gabbroic, and peridotitic rocks of Duluth and Beaver Bay Complexes.	Morey and others, 1982, 1:1,000,000
Ydt	Middle Proterozoic	Midcontinent Rift System	Troctolitic and gabbroic rocks of Duluth and Beaver Bay Complexes.	Morey and others, 1982, 1:1,000,000
Ynbn	Middle Proterozoic	Midcontinent Rift System	North Shore Volcanic Group - basalt and related rocks having normal magnetization.	Morey and others, 1982, 1:1,000,000

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