EXPLORATION DRILL HOLE LITHOLOGY, GEOLOGIC UNIT, COPPER-NICKEL ASSAY, AND LOCATION DATABASE FOR THE KEWEENAWAN DULUTH COMPLEX, NORTHEASTERN MINNESOTA

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SUMMARY

This report and database compiles virtually all publically available drill hole location data, lithological logging data, copper-nickel assay data, and rock quality data for about 2,145 exploration drill holes in and near the Keweenawan Duluth Complex in northeastern Minnesota. This database covers about 1,779,600 feet of drilling over about 70,000 lithological, and about 70,000 separate assay intervals. All of this drilling is in St. Louis, Lake, and Cook counties.

The digital data are presented in an industry standard (Gemcom for Windows) exploration and mine modeling software format, as well as spreadsheet and comma-delimited files for use in other programs. This format can be adapted for use in a GIS program such as ArcView.

The purpose of this report is to make these data available to mineral exploration companies in a format almost immediately usable by them.

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CD-ROM WITH DATABASE, PDF FILE OF THIS REPORT AND ALL DATA FILES ARE IN BACK POCKET

INTRODUCTION AND BACKGROUND

INTRODUCTION

This report centers on a digital compilation of all drill core logging done in the Duluth Complex (Complex) by the Natural Resources Research Institute of the University of Minnesota Duluth (NRRI), as well as company logging for drill holes that NRRI geologists have not logged (about 2,145 drill holes total). Drill holes not logged include many drill holes with no core available. For drill holes with no core and/or sparse documentation, we included what we do know as a place keeping record within the database. This lithologic data is presented with publically available location, copper-nickel-sulfur assay, and downhole survey data for these drill holes in a comprehensive industry standard database format (Gemcom for Windows database and as separate Microsoft Excel and comma-delimited files for each database table; see CD-ROM in back pocket and detailed descriptions in Appendices 1 though 6). The total drill hole count varies depending on how one treats wedges and "placeholder data" inserted for drill holes with little documentation.

This database and report assumes familiarity with Duluth Complex geology and geography on the part of the user. The data was entered as we would enter it for our own use in Excel, Gemcom, or other geologic modeling programs.

This report can be considered to be a continuation of a portion of Minnesota Geological Survey (MGS) Report of Investigations 58, "Geology and Mineral Potential of the Duluth Complex and Associated Rocks" (Miller et al., 2002), which includes a GIS-based compilation geologic map of the Duluth Complex. That map is available as a separate publication (MGS Miscellaneous Map 119, Miller et al., 2001). Much of that mapping is based on the same data as listed in this database. Report of Investigations 58 (RI-58) with its associated GIS database is available from the Minnesota Geological Survey on-line at http://www.geo.umn.edu/mgs/.

PURPOSE

Introduction

The purpose of this project was the digital compilation of drill hole-based lithological data for the Duluth Complex. The original intent was to only record drill holes that NRRI had logged. The project was expanded to include all available Duluth Complex drilling records and Beaver Bay Complex drill holes (about 2,145 drill holes). It became apparent early on in the process that the final product would be much more useful if these data were tied to existing available location and assay data. The majority of time on this project was spent on the lithology and location data, with the only time spent on the assays being the reformatting of previous work.

The intention of this database is to give easy access to Duluth Complex drill hole-derived lithological data, as well as a basic set of copper-nickel-sulfur assay data, for regional exploration purposes. For the most part this drilling is localized in a series of moderate-sized to world class- size copper-nickel (plus PGE) deposits and smaller massive-oxide deposits (deposit is used in this report with no economic connotation). While some of the larger deposits are currently under lease (Dunka Road/NorthMet, Babbitt/MinnAMAX/Mesaba, Birch Lake, Maturi Road, Spruce Road, and South Filson Creek), no major publically reported new work has been done to move these projects from exploration to development. These data reflect that much ground is available for exploration and development.

Assumptions and Goals

The final purpose is then to compile a database that:

1) can be used in mine modeling or GIS software with little or no modification;

2) can be used in spreadsheet format for certain analyses;

3) can be expanded or filled in with more refined (or new) information with ease, and without having to modify any other original data in the package;

4) makes these data easily available to as many interested parties as possible;

5) ties all of the NRRI work together in a way that work on the Complex can go forward without ever recreating this dataset;

6) keeps the interpretive (lithological and map unit) data separate from the assay and location data;

7) assumes the user has the skill to break out whatever subsets of data they need;

8) accounts for the entire length of the drill hole, i.e., there are generally no breaks in the data format, though there may be breaks in the data itself (unsampled or undescribed intervals are all listed as such);

9) reasonably cross-references with the data in Miller et al. (2002);

10) contains at least a minimal record for every known drill hole in the Complex. Note that there may be some drill holes omitted from this dataset if the drilling was done prior to the Minnesota Department of Natural Resources (MDNR) data submission requirements, and thus, have no public record whatsoever. We think that this is only a marginal possibility. There are also about 500 Minnesota Department of Transportation geotechnical drill holes located in St. Louis, Lake, and Cook counties. These are rotary and/or core drill holes with sample or records stored at the MDNR in Hibbing. Some of these geotechnical drill holes may penetrate the Duluth Complex, North Shore Volcanic Group, or Beaver Bay Complex. We have not assessed any data about these geotechnical drill holes and no further reference is made to them in this report or dataset. The user should see the MDNR drill core library index for more information;

11) assumes a familiarity of the user with the geology of the Duluth Complex (and associated units), the terminology of rock types and map (cross-section) units, and general geography of the drilling data. In such a large dataset there are a large number of drill core intervals that don't neatly fit the classification schemes of the majority, as there are always exceptions to the rule. The user needs to be able to recognize these exceptions in filtering and manipulating the data. This database and report is not the venue to describe the geology of these units in depth nor solve the many geologic problems yet to be addressed in the Complex. See the short listing of available reports on the Complex in the User Assumptions section below.

The familiarity issue matters because the dataset will allow the user to find such things, as for instance, all drill holes that intersect the Giants Range batholith rocks or massive-oxide intervals in the Complex. Overall however, these are very small percentages of the total drilling intercept, and the data as formatted here will not be much use in examining these smaller percentage units, because the more subtle differences in these unique units are not covered in this dataset. Once again, the user needs to use their familiarity to go to the original logs and probably to the core itself to answer specific questions.

At the same time, the availability of these data will trivialize the effort needed to answer certain questions, such as: what percentage of the drill core has been sampled for copper-nickel analysis, the percentage of norite within four hundred feet of the basal contact, the locations of the highest copper-nickel values in the Duluth Complex, and numerous other questions.

DISCLAIMERS AND DATA ISSUES

USER ASSUMPTIONS

There are some critically important overriding assumptions that must be recognized in using this data:

1) The user must have familiarity with Duluth Complex geology and geography, and is assumed to have read or have access to:

Minnesota Geological Survey Report of Investigations 58 (RI-58) by Miller, Severson, Hauck, Green, Chandler, Peterson, and Wahl, 2002, for the most recent overview of the geology and mineral potential of the Duluth Complex (Miller et al., 2002). The database in this report could be integrated into the GIS database included in the MGS report, and much of the intrusion description referenced here also comes from that report. This is the most current published document available for the entire Duluth Complex and Beaver Bay Complex and contains extensive references for Keweenawan and Midcontinent Rift geology;

Mark Severson's 1995 report on the South Complex area, from the Mesabi Range to Duluth (Severson, 1995). The drilling area descriptions for the western edge of the Complex in this report were derived from that document;

Reports on the general igneous stratigraphy of the Partridge River intrusion by Severson and Hauck (1990, 1997);

Babbitt (MinnAMAX or Mesaba) area reports by Severson et al. (1994, 1996); Severson and Barnes (1991); Patelke (1994), which includes assay data and an inventory of drill hole specific data for Babbitt and Serpentine deposits; geologic maps by Severson and Miller (1999), and Miller, Severson, and Foose (2002). Some of these reports have extensive cross-sections included, and all contain geologic descriptions;

Steve Geerts' reports and thesis on the Dunka Road (NorthMet) deposit (Geerts, Barnes, and Hauck, 1990; Geerts, 1991, 1994). These reports include numerous cross-sections and are the best publicly available work on the Dunka Road (NorthMet) deposit;

Severson's South Kawishiwi intrusion report (1994), especially for the cross-sections;

The Zanko, Severson, and Ripley (Zanko et al., 1994), report on the Serpentine deposit, for cross-sections and relations of the Grano Fault to mineralization;

Dean Peterson's "Project 317" done for the MDNR in 1997, maps much of the copper-nickel assay chemistry across the Complex, and his recent reports for the NRRI refine these concepts and data presentation (Peterson, 1997, 2002);

Morton and Hauck (1987) summary report on PGEs in the Complex;

Severson and Hauck (in prep., 2003) review of PGE mineralization in the Complex, with some newer assays;

Hauck, et al. (In prep.) For petrography of the Birch Lake deposit;

and, Hauck et al. (1997), a Geological Society of America review paper with extensive references.

There are a great number of other reports and papers on the Duluth Complex. Steve Hauck of the NRRI has developed a searchable, keyworded, bibliography of Midcontinent Rift geology. This bibliography is constantly being updated, and Mr. Hauck's contact information is in Appendix 8;

2) The digital data are not substitutes for the original logs, nor should they substitute for future logging. We did not throw out the original logs and would use them first ourselves in re-examining an area;

3) The NRRI lithologic drill logs used here to develop the database are somewhat narrative, intended mostly to assist us in the drawing of cross-sections at scales from one inch equals two hundred feet to one inch equals fifty feet. The coding here (described later in the database format section and Appendix 3) is at best less informative than the complete logs as they were written and generally represents the consolidated information one would see on cross-section. In other words, the data in the digital files are an interpretation of an interpretation;

4) These data were formatted on the premise that the users would be very familiar with either a drill hole-based modeling and database program, i.e., Gemcom, MedSystem, DataMine; or in the case of using these data in spreadsheet format, Microsoft Excel filters and subtotal tools;

5) There is a large amount of data here, but it would be incorrect to assume that these data represent the overall geology, lithology, or assay geochemistry of the entire Duluth Complex. At best, these data should be used as representing the geology in and near the deposits and exploration areas as listed. The majority of the Complex has not been mapped in detail nor drilled, and most of the drilling is in areas of visible copper-nickel or massive-oxide mineralization;

6) Lastly, as discussed in Miller et al. (2002), the MGS and USGS sponsored the collection and compilation of statewide aeromagnetic data in the 1980s (Chandler, 2001). These data have since become an integral part of any regional geologic work on the Complex. The digital data (and paper maps for some areas) are available from the MGS. The MDNR Lands and Mineral Division has reformatted the aeromagnetic data for GIS use. Those doing exploration studies in northeastern Minnesota should seek out and use these data. Contact information for both agencies is in Appendix 8.

Metadata

There is limited formal metadata in this report or in the database. The reporting does not try to document every data source because virtually every record listed in these data files is in the paper files at the NRRI or the MDNR. The lithology and map unit data are generally from our own logging and the compilation of cross-sections, mostly published. Nearly everything else comes from copies of original company logs, assay sheets, driller reports, composite sheets, short memos, and reports, etc. We have used our best geologic judgment when faced with conflicting information in the paper files. Probably much less than 1% of the information herein is not on file at NRRI or MDNR. Currently, the work involved in documenting and inventorying all items in the NRRI and MDNR paper files isn't justified in terms of improving the final database product or of our understanding of the Duluth Complex.

A second reason to limit the included metadata is that some of the data in this project is pieced together from earlier digital compilations (notably the assays and parts of the header file data). It must be assumed that the original work was conscientious. Also, much of the data used here results from applying some judgement (learned from familiarity with the paper copies of the data) in deciding which part of conflicting or multiple data to use for a particular interval or drill hole.

Should a situation arise (as it has in the past) where better documentation of the data source is required, the staff geologists at the NRRI and MDNR are more than willing to help with detailing documentation for specific areas of the Complex. Contact information for these individuals and organizations is listed in Appendix 8.

Company Logging

Where we utilized company logging information, we tried to minimize our interpretation of their rock naming conventions to those that were clear, usually based on our knowledge from surrounding drill holes or familiarity with the company scheme. Rock units (geologic cross-section or map units as opposed to rock type) from company logs have seldom been used. We either fit units to our naming scheme where very obvious or classed these units as "mixed", as with "MXDC" for undivided Duluth Complex, "MXPRI" for undivided Partridge River intrusion, "MXSKI" for undivided South Kawishiwi intrusion, etc. This approach is legitimate, as much of the current subdivision of igneous rock units in the drilled areas of the Duluth Complex has been defined over the past fifteen years by NRRI geologists or from MGS mapping projects.

Absent Data

The data entry and data reconciliation for this project took over 2,000 hours. Therefore, time constraints mean that much of the drill hole interval-related data that could be in these data files is not. These data could be added later by an interested user. These data are mostly items that would require other sets of intervals, in that they overlap the rock type, unit, and assay data intervals listed here. These absent interval data include such items as: alteration, i.e., saussurization, uralitization, serpentinization, chloritization; chlorine drops (what type and any record of what mineral they are growing on); grain size (except for pegmatitic); mineralogy (no mineral percentages are directly recorded here); magnetism (either relative or measured with a susceptibility meter); sulfide mineral percentage estimate; sulfide mineralogy type (though this can be roughly estimated from the Cu:S ratio); sulfide occurrence (generally disseminated unless noted as massive or semi-massive, but with a wide range of variation); split core versus whole core remaining (which would allow for a further check for missing assay records); and structural features such as: contact relationships, joint orientations, and notation of the often ubiquitous serpentine and uralite veining.

However, the lithological intervals, location, survey, and assay data assembled in this database should need no other major work at the deposit scale. Future attention can be given to adding the components listed above, should science or economics indicate that digitizing that data will improve our knowledge of the Duluth Complex or assist in the development of a mineral deposit.

In the future, it would be very useful to compile the available land and minerals ownership information into this database, especially the ownership and leasing history. The history would be useful in that there may have been work completed on some of these properties that is not publically available. For instance, there is very little compiled geophysical information for the Duluth Complex in the public domain relative to the amount of work that has probably been done over time. Land owners may have records for geophysics, drilling, or sampling that the original exploration companies did not submit to the public record.

FUNDING

This project was funded under the PUTF (Permanent University Trust Fund) program of the University of Minnesota. This research money is generated from mining revenues and is granted in keeping with the NRRI mission of encouraging economic development in northeastern Minnesota, in this case by providing a dataset useful for regional mineral exploration by private companies.

ACKNOWLEDGMENTS

There is virtually nothing original in this work. This project would not have been possible (nor necessary) without the large amounts of Duluth Complex drill core logging work done since 1988 by Mark Severson, Steve Hauck, Steve Monson-Geerts, Larry Zanko, and the lesser amounts of logging done by James Strommer, Mary Jo Kuhns, John Heine, Jim Miller, Steve Hovis, and Richard Patelke. Also, much of the logging and assay information for drill holes without existing drill core was taken from company files (mostly supplied by INCO) and originally organized and/or digitized by Dean Peterson for MDNR “Project 317" (Peterson, 1997). Many other geologists in the region have worked on these drill holes for other agencies or companies, and their work is not quoted here, but has been a valuable contribution to the model upon which the NRRI logging is based. The main repository of these other records is the drill core library at the Minnesota Department of Natural Resources-Lands and Minerals Division, Hibbing, Minnesota.

The assay work presented here has been reformatted, but was actually collected and digitized sporadically over the last fifteen years for various reports, with much coming from Geerts (1991), Patelke (1994), and Zanko et al. (1994). Peterson (1997) included all of the above data and filled in most of the remainder of the South Complex area assay data and South Kawishiwi intrusion assay data. This report adds in some minor scattered data, clarifies the unsampled intervals, and removes the duplicates and overlapping intervals from previous work. Mark Severson is owed thanks for assembling the reference files of paper copies for virtually all of the assays, which are on file at the NRRI.

Mark Severson, recently with Jim Miller, has done the majority of the detailed surface mapping that ties the drill holes along the basal contact at the western and northern margins of the Complex together in a coherent geological framework. Much of Seversons work builds on work done by Bill Bonnichsen (1971) for the Minnesota Geological Survey.

The Minnesota Department of Natural Resources must be thanked for having the presence of mind and securing the resources to retain much of this core and the associated records. They have also allowed easy access to core and working space for the NRRI geologists. Specifically the NRRI staff would like to thank: Al Dzuck for his years of friendly service in the core buildings; as well as Rick Ruhanen, Barry Frey, Dave Dahl, Marty Vadis, Daryl (Ricco) Riihiluoma, Mike Ellet, Doug Rosnau, Tom Anderson, Mike Lubotina, Jim Sellner, Matt Oberhelman, Al Klaysmat, and the late Henk Dahlberg.

NRRI also needs to thank all individuals and companies who have helped out over the years: John McGoran, Don Gentry, Leah Mach, and Chris Matson of Fleck Resources (now PolyMet Mining); Jeff Clark, Al Samis, Terry Hodson, and Jerry Zeig of Cominco (now Teck Cominco); Ernest Lehmann, Leon Gladden, William Rowell, John Beck, and Ted Dematties of Lehmann Exploration Management and its various joint venture partners; William Ulland of American Shield Company; R.C. Bell and Andy Bite of INCO; Doug Hunter of Wallbridge Mining; Harrison Mattson of Arimetco International; Dennis Hendricks and the late Cedric Iverson of United States Steel Corp.; Dave Meineke of Meriden Engineering; Dan England and Richard Buchheit of Eveleth Fee Office; Rhude and Fryberger; Pete Pastika, Jay Mackie, and Doug Halvorson of North Shore Mining; Stuart Behling of the United States Forest Service; and the geologists of the Minnesota Geological Survey.

The many other companies who left the Duluth Complex exploration scene before NRRI was involved in this work, but whose data we are now using, with much thanks, include: AMAX, Bear Creek, Cleveland Cliffs, Duval, Exxon, Hanna Mining, Kennecott, W.S. Moore, New Jersey Zinc, NICOR, Nerco, Newmont, Phelps Dodge, Resource Exploration, and others.

The author also extends many thanks to: Mark Severson, Dean Peterson, Larry Zanko, Steve Hauck, and Steve Monson-Geerts of the NRRI for the huge amount of uncompensated time they have put into disscussions about how to make this a usable product.

The author of this report is solely responsible for all errors in fact or in judgement during the transcription of the lithological logs and other data to the digital format. Future use of this database will show some errors and misinterpretations. Please inform NRRI staff when these errors are found. As always, the mistakes are easiest to find by using the product.

RECOMMENDATIONS

This report draws no conclusions. However, it is important to realize that this is not all of the available data about these drill holes. Future work should include:

1) entering all data to a common format as the data are developed, not later;

2) an assessment of the written logs to see if there is enough alteration data recorded to justify the effort in transcribing the data to digital format;

3) logging (and re-logging) of the drill holes NRRI has not logged yet, which would fill in much of the missing data;

4) reformatting the data as given here to function in ArcView, which would allow a better tie-in with the surface mapping data;

5) entering all available whole rock and trace element data into this database;

6) re-inventorying and checking the paper files at MDNR and NRRI to make both sets are complete, and to consolidate all data about each hole at both locations;

7) inventory and record the available thin section and polished section data, which can easily be tied into this database by footage;

8) recheck all the assay data from the original sheets, and document these checks;

9) digitize the property ownership;

10) digitize all the geophysical work that has been done on the Complex to a common format.

11) recognizing that in all modern geologic work the expectation is that the data will eventually be placed into a Geographic Information System and that this needs to be accounted for in planning and executing projects.

DATA FORMATS, DATA TABLE LISTING, AND SHORT EXPLANATIONS

INTRODUCTION

This section contains short tables that are summary listings of all the data file formats used in either the Gemcom relational database (GCDBDC.MDB) or the Microsoft Excel spreadsheet and comma-delimited files (*.XLS and *.CSV) that form the core of this report. The same data, though not necessarily in the same column order within each of the tables, is in all files or tables with the same name.

The user should open these data files for a quick examination before reading these explanations.

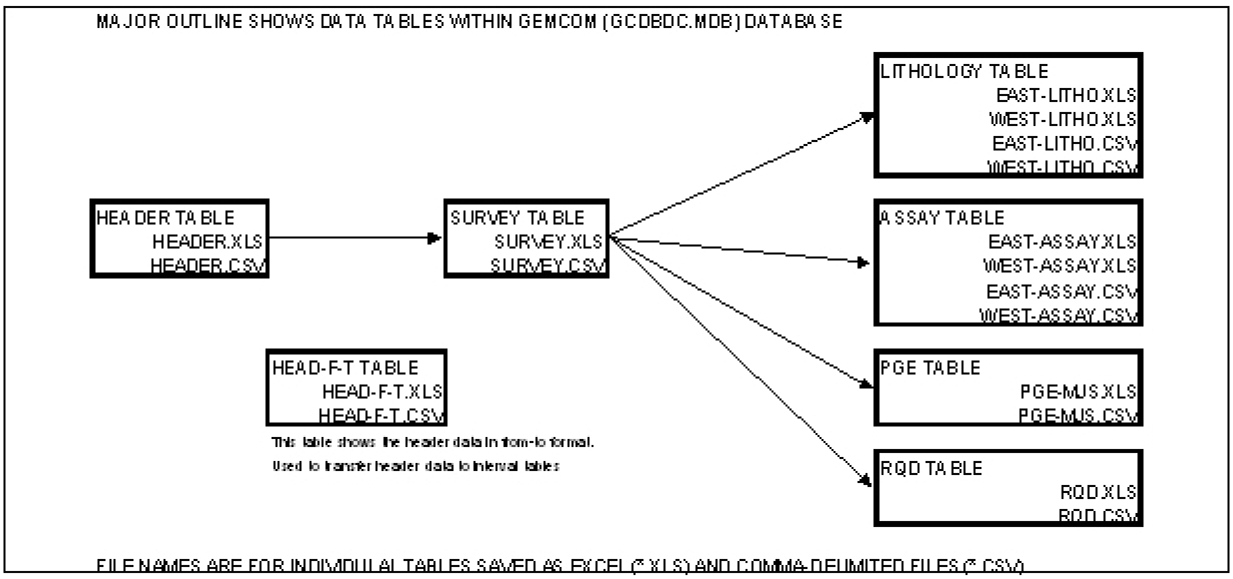

Figure 1. Schematic of data layout and table relationships in Gemcom database.

Data Layout

Figure 1 is a schematic outline of the Gemcom database and its included tables. The HEADER table contains a single record for each drill hole, with fields covering data about the drill hole in its entirety, such as location, depth, County, USGS quadrangle map, logging geologist, etc. The other tables generally contain multiple records for each drill hole. The SURVEY table contains the down hole survey data for each hole in “interval” or “from-to” format. Holes with no down hole surveys are treated as a single interval and are given their collar orientation for their entire length. The LITHOLOGY, ASSAY, PGE, and RQD tables are “interval” or “from-to” tables for their respective data types. The Gemcom program (and other mine modeling and exploration programs) uses the collar location data in the header file and the down hole survey data from the survey file to locate these down hole intervals in three-dimensional space for display or analysis.

The database table HEAD-F-T is the HEADER table converted to a “from-to” format to facilitate transferring data from the HEADER to the SURVEY, LITHOLOGY, ASSAY, PGE, and RQD tables in Gemcom. In this file, every drill hole is treated as a single interval, where "from" equals "0" (zero) and the total depth is given as the "to" value for the entire drill hole as a single interval.

Note that the Gemcom data are in a Microsoft Access (*.MDB) database format, as this is the main core of Gemcom. However, Gemcom does not publish table relationships for their product; therefore, relationships would have to be defined to use this database file in Microsoft Access as a stand-alone application.

Gemcom also includes "special value" columns in its database that are hidden from the user in Gemcom, but are visible in Microsoft Access. The "special value" columns control which data is included in compositing and other functions, as well as how data is displayed in Gemcom, i.e., how the "NS" used for "not sampled" is seen on the screen. The "special value" columns have been removed from the Excel spreadsheet and comma-delimited files.

Note that GEMCOM only allows 10 characters in a column name, and that convention has been adhered to in this listing. Other applications may allow longer names.

Data File Sizing, Splitting, and Naming

Each Gemcom table is included as a separate Excel spreadsheet (*.XLS) and comma-delimited (*.CSV) file. Column headings were left in the Excel (*.XLS and *.CSV) files. Depending on their final use, they may need to be removed. Because Excel has a line limit of about 64,000 lines, and there are more than 64,000 entries for each of lithology and assays, the LITHOLOGY and ASSAY tables have been broken into a west and an east file for the *.XLS and *.CSV formats. The header file contains a reference to this under the heading "XLSFILE".

The west and east file distinction was based on the listed intrusion for the drill hole. This division is shown below in Table 1. The record of this east-west division is carried in all data files, even though only the ASSAY and LITHOLOGY files are actually split.

Table 1. Listing of deposit areas showing to which, east or west, assay and lithology file the drill holes were assigned. This convention is recorded in all data files on a drill hole by drill hole basis, even though other data files were not split.

West Lithology and Assay Files	East Lithology and Assay Files
Boulder Lake intrusion (BLI)	Bald Eagle intrusion (BEI)
Duluth Complex Felsic Undivided	Brule Lake intrusion
Diabase Undivided	Cloquet Lake Layered Series of Beaver Bay Complex (CLLS of BBC)
Duluth Layered Series (DLS), Layered Series at Duluth of Miller et al., 2002	Houghtaling Creek Troctolite of Beaver Bay Complex (HCT of BBC)
Duluth Complex Anorthositic Undivided	Logan Sill
Partridge River intrusion (PRI)	North Shore Volcanic Group (NSVG)

Table 1 (continued)	
Virginia Formation at Margin of Partridge River intrusion (VF at margin)	Osier Lake
Virginia Formation-Biwabik Iron Formation (VF-BIF)	Poplar Lake intrusion
Western Margin intrusion (WMI)	South Kawishiwi intrusion (SKI)
	Tuscarora intrusion
	Unknown and Unnamed
	Virginia Formation-Biwabik Iron Formation (VF-BIF) at Serpentine

Drill Hole Numbering

There have been changes in drill hole numbering to ease computer sorting:

1) For series of drill holes such as at Babbitt/Serpentine (B1- series holes) or Water Hen (SL-series holes) where there are more than nine drill hole numbers assigned, leading zeros have been added to the numeric portion of the drill hole number. For instance, drill hole B1-1 is now B1-001, B1-32 is now B1-032, and SL-1 is now SL-01. This notation will conflict with the MDNR drill core library index, the numbers on core boxes at MDNR and at other locations, and previous NRRI work as well as parts of Miller et al. (2002), but this change seemed the best way to deal with this large number of drill holes. This renumbering has not caused any duplication of drill hole numbers;

2) All drill hole numbers given here are in upper case. Some holes, such as the "Du" series (by Duval) have always been labeled with upper and lower case. The mixed case can cause difficulties in some sorting operations;

3) All of the holes drilled by MDNR have had "-MDNR" added as a suffix because two of them had ambiguous names that conflicted with other drill holes.

Data Comments

There are no commas in the data. All characters are upper case. Only the "from", "to", "interval length", other footage or length columns, and assay value columns are intended as numeric data. In Microsoft Excel it can be a problem to keep numbers intended as text to remain in text format when copied or moved from column to column or transferred from one file to another or one program to another. The best solution may be to use the comma-delimited (*.CSV) files and import the data to ones own formatting needs.

Drill Hole Coordinate and Location Comments

The Gemcom database system allows only one location coordinate for each drill hole. The Minnesota State Plane North NAD27 (North American Datum 1927) coordinate system, in feet, was used for location points in Gemcom. The NAD83 (North American Datum 1983) Minnesota State Plane

North coordinate, in feet, is also given. The UTM Zone 15 coordinate, in meters, is included in NAD27 and NAD83 format. The choice to use the 1927 coordinate system in feet as the basic unit of measure was driven by:

1) downhole units are in feet;

2) not all USGS maps are updated to the 1983 datum. The use of NAD27 in feet may make cross-referencing easier;

3) GIS systems and computer programs such as “Corpscon for Windows” allow conversion to the users preferred coordinate systems whereas Gemcom is not very flexible in this regard.

Drill hole locations are as good as they can be, but probably vary in their accuracy. The Babbitt/Serpentine, Dunka Road (NorthMet), some of Maturi, some of Spruce Road, and South Filson Creek area drill hole locations are based on recent (last ten-fifteen years) conventional and GPS surveying of some or all of the collars and a recalculation of grid locations of unsurveyed holes from those surveyed locations. Most of the INCO drill hole locations came straight from data supplied by them to Dean Peterson and/or Mark Severson. In most other areas, locations are based on plotting the company grid to a 1:24,000 USGS topographic map, plotting the drill holes based on grid coordinates given on original logs (i.e., 3422N, 1286E) or scaled off of the available maps, and then determining the UTM coordinate. For different deposits this has been done manually, in AutoCAD, or in ArcView.

Note that the digital data on CD-ROM includes an ArcView shapefile containing drill hole locations and other data where there is only one record per drill hole. The shapefile is based on the HEADER table and file. The shapefile uses NAD83 UTM as its location coordinate and can supercede or supplement the file supplied with Miller et al. (2002) as a way to quickly bring some updated information into that ArcView project.

DATA TABLES-SHORT DESCRIPTIONS

Common Elements in All Data Tables

Short descriptions of the individual data table contents (for Tables 3 through 8 and associated text) for the database are given in Table 2. Appendices 1 through 6 provide the same information in an expanded form that details most of the discussion items related to each table or record type, such as data source and quality, intrusion and deposit descriptions, or rock naming conventions.

With the exception of the header table, all tables are in “from-to” interval format with minimum common elements for each interval as follows:

Table 2. General format of common fields in interval data tables.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length in feet along core
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)
XLSFILE: Whether lithology or assay data is in east or west Excel and comma-delimited files, given for each data type, regardless of whether or not the data files were split

Desurveying

All of the down hole interval tables include "desurveyed" data for the individual intervals. This is a Gemcom generated value where Gemcom calculates the true geographic location (NAD27) of each data point (in this case the "from" and "to" points in the interval tables) relative to sea level. This calculation is based on the collar location data in the header table and any downhole survey data in the database. Drill holes with no down hole survey data available have been given the collar orientation (dip and azimuth) for their entire length in the survey interval table and therefore also in this calculation.

Column Order in Data Tables

Note that the column order may not be the same in all similar tables, nor be in the order given in these descriptions. Also note that when the GCDBDC.MDB file is loaded as a blank project into Gemcom, the column display order will be sorted alphabetically, left to right.

HEADER Table-Short Description

This table contains the drill hole location information, length, dip angle, azimuth, deposit name, and other information that can be applied to the drill hole in its entirety.

The HEADER data are repeated in the HEAD-F-T table, which, with the addition of a "from" column (always 0 ft.), and using the total drill hole depth as a "to" value, in interval format, allows all of the HEADER data to be applied to the intervals in other data tables through the cross-table transfer feature in Gemcom.

Table 3. Format of Header Table-see Appendix 1 for expanded explanation.

DDH: drill hole number
EASTSP27: easting NAD27 state plane feet
NORTHSP27: northing NAD27 state plane feet
COLLAR-EL: collar elevation in feet above sea level
TOTALDEPTH: total depth in feet
DIP: collar dip, measured from horizontal, 0˚ = horizontal, -90˚ = vertical
AZIMUTH: collar azimuth relative to true north
EASTSP83: easting NAD83 state plane feet
NORTHSP83: northing NAD83 state plane feet
EASTUTM27 easting NAD27 UTM meters
NORTHUTM27: northing NAD27 UTM meters
EASTUTM83 easting NAD83 UTM meters
NORTHUTM83: northing NAD83 UTM meters
COL-EL-MET: collar elevation in meters above sea level
TOTDEPMETR: total depth in meters
DEPOSIT: deposit area
INTRUSION: which intrusion drill hole is located in
QUAD: USGS 7.5 minute quadrangle
TOWNSHIP: Public Land Survey Township
RANGE: Public Land Survey Range
SECTION: Public Land Survey Section
FORTY: partial list of forty acre subdivision
COUNTY: St. Louis, Lake, or Cook County
GEOLOGIST: geologist responsible for the logging or company that supplied data
DATE-DRILL: Date drilling finished
GRIDEAST: Grid east on original company grid
GRIDNORTH: Grid north on original company grid
GRIDCOMP: Company responsible for original grid
OVBTHICK: overburden thickness
FWDEPTH: depth to footwall (i.e., basal contact)
LESSEE: best available information for which company drilled this hole
VERT-ANG: vertical or angled at collar
INITIAL?: initial hole or wedge
SUR-UNDG: hole drilled from surface or underground drift
NRRI-XSECT: NRRI cross-section which shows this drill hole

Table 3 (continued)
COMP-XSECT: Company cross-section on which this drill hole should plot-listed only for Dunka Road (NorthMet) and Babbitt/Serpentine (Mesaba). These cross-sections are not necessarily available.
BEST-REF: best first reference for report about area containing drill hole, not intended to be a definitive listing
HEAD-COMM: Comments related to data in the header file for this drill hole
SURV-COMM: Comments related to data in the survey file for this drill hole
LITH-COMM: Comments related to data in the lithology file for this drill hole
ASSAY-COMM: Comments related to data in the assay file for this drill hole
SOURCEFILE: NRRI record keeping entry
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 line limit of Microsoft Excel, this shows which file set this drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV. This data is carried in all interval tables, even though not all files are split.

HEAD-F-T Interval Table For Header Data-Short Description

This table repeats the information found in the HEADER table, but in a "from-to" interval format where the entire drill hole is treated as a single interval ("from" equals "0 " (zero) and "to" equals total depth in feet). In Gemcom this table is useful for cross-table transfer of data from one set of intervals to another. This table is needed because Gemcom does not allow transfer from the HEADER table to interval data tables. One would use this to, for instance, translate information from the header file (for instance logging year, quadrangle map, or intrusion) to the individual intervals in the ASSAY or LITHOLOGY interval tables. Remember that for angled holes, the locations in this file refer to collar location, not downhole locations.

No format description is given here or in the expanded table format descriptions provided in the appendices as the format and data contained in the HEAD-F-T table is the same as for the main HEADER table.

SURVEY Table-Interval Table-Short Description

This table lists the downhole survey data available for each drill hole. In this database we have included the extensive downhole dip and azimuth surveying at Babbitt / Serpentine in "from-to" format. The majority of the holes at other areas do not have downhole azimuth testing, and may have used a simple acid test for dip measurement. In the latter case, we make assumptions about the compass direction the hole deviated towards. The assumption is that all holes turned northwest (into the basal contact). Usually this will be grid north for an individual deposit area. This is generally how companies have plotted these drill holes, though this is an item that must be reviewed when using these data for site specific rather than regional work.

The survey data are used in modeling programs to establish the three-dimensional location of the other data for analysis and display. This format accounts for the entire drill hole length, i.e., all intervals, measured or not, are listed in the file. The sum of the intervals equals the length of the drill hole.

Those drill holes with no downhole work done (or recorded here) are assigned the collar dip and azimuth for the length of the drill hole. Some modeling programs will require that the survey data be in this separate file, even if there is no change in the data downhole.

Dip is given as a negative value for holes from the surface. Note that some underground drill holes in the Local Boy portion of the Babbitt deposit and a few holes in the drift at Maturi were drilled upwards from the drifts and therefore have a positive dip.

Table 4. Format of Survey Table-see Appendix 2 for expanded explanation.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length in feet
DIP: Dip of interval, -90˚ equals straight down
AZIMUTH: azimuth of interval clockwise from true north, for vertical holes azimuth equals 0˚
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel. This entry shows which file set the drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV for lithology and assays . The survey data is all in one table or file, i.e., it is not split.

LITHO Interval Table-Short Description

This table contains the lithological data for each hole in "from-to" interval format. This table covers the NRRI logging, filled in on a hole by hole basis with company data for holes either unavailable for logging or not logged by NRRI. This format accounts for the entire drill hole length, i.e., all intervals, logged or not, are listed in the file. The sum of the intervals equals the length of the drill hole. See Appendix 3 for complete explanation.

Table 5. Format of Lithology Data Table-see Appendix 3 for expanded explanation.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length in feet along the drill hole
ROCKTYPE: logged rocktype by abbreviation
EXP-RTYPE: logged rocktype-full expanded name
CON-RTYPE: example of consolidation of rocktype names–reduces the number of rocktype names
UNIT: cross-section (map) unit
NRRI–XSECT: NRRI cross-section showing this drill hole, as in header file
COMP-XSECT: company cross-section this hole would be on, listed only for Babbitt and Dunka Road
FW-MARKER: marks interval as overburden, Complex, or footwall
FW-FROM: interval "from" measuring upward or downward from drill hole footwall penetration point, in feet
FW-TO: interval "to" measuring upward or downward from drill hole footwall penetration point, in feet
GEOLOGIST: geologist responsible for logging, as in header file
DEPOSIT: which deposit, as in header file
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel. This column shows which table or file set this drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV files.

ASSAY Interval Table-Short Description

Essentially, all of the original assay work in the Duluth Complex is on copper-nickel sulfides. In a few cases, the emphasis was on massive-oxides in the Oxide-bearing Ultramafic Intrusions (OUIs at Longear, Longnose, Section 17, Section 22, etc.). Those oxides and related elements are not included here. Also, United States Steel almost always assayed for iron, which is included here for the Dunka Road (NorthMet) area, and INCO and others often assayed for cobalt, which is not included here due to data entry time constraints. Not all companies assayed all intervals for sulfur.

These are generally the assays done at the time of original drilling and sampling, and usually represent the greatest number of samples done for a particular drill hole. The format here covers the entire hole from collar to total depth, with a "NS" marker for intervals not sampled in the original work. Not all elements were equally sampled for each interval or equally by each company. This format accounts for the entire drill hole length, i.e., all intervals, sampled or not, are listed in the file. The sum of the interval lengths equals the length of the drill hole.

Numerous duplicates and overlapping intervals (about 1,500 total) were removed from the previous compilations used to develop this data file. This subtraction is done by Gemcom when loading the data. The duplicates were, therefore, not retained in a separate file.

Table 6. Format of Assay Data Table-see Appendix 4 for expanded explanation.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length in feet along the drill hole
COPPER: copper in percent
NICKEL: nickel in percent
SULFUR: sulfur in percent
CU+NI: copper plus nickel in percent
CU/NI: copper/nickel ratio
CU/S: copper/sulfur ratio
DEPOSIT: which deposit, from header file
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)
XLSFILE: the lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel. This format this shows which file set this drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV files.

RQD Interval Table-Short Description

This is the Rock Quality Designation (RQD) data calculated by AMAX for the Babbitt and Serpentine deposits. There is no publicly available data on these rock properties for any other exploration area in the Duluth Complex. It is unknown, but doubtful, if this work has been done elsewhere. Contact NRRI or the MDNR for information from the AMAX files about the calculation of the AMAX RQD numbers.

This format accounts for the entire drill hole length, i.e., all intervals, sampled or not, are listed in the file. The sum of the intervals equals the length of the drill hole.

Table 7. Format of RQD Data Table-see Appendix 5 for expanded explanation.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length along core in feet
RQD: RQD value as calculated by AMAX. Higher number equals more natural fractures for indicated interval
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)

PGE-ETC Interval Table-Short Description

In general, except for in the Birch Lake area, all publically available PGE and precious metal assaying done in the Duluth Complex was done after the original Cu-Ni sampling. Sometimes this sampling was on the original pulps, sometimes on composite pulps, and sometimes on fresh core. Morton and Hauck (1987) summarized the publically available assaying up to that point in time and added some new analyses. The data in this database table are taken from Severson and Hauck (in prep., 2003) and represents all publically available data. It is important to stress that there may be other proprietary data for Dunka Road/NorthMet (PolyMet), Babbitt/Serpentine (Teck Cominco), Birch Lake (Lehmann), and Maturi (Wallbridge and INCO) areas, as well as other locations.

Besides PGE data, this table includes some major, minor, and trace element analysis data. Reference should be made to Severson and Hauck (in prep., 2003) for information on the quality and source of individual samples. The final data tables in Severson and Hauck (in prep., 2003) will be far more complete and record more elements. The data here are a sub-set of the data in their report.

The format here does <u>not</u> account for the entire length of the drill hole, only including intervals that were sampled. About 1,000 duplicate and overlapping intervals have been removed from this dataset during the loading process. There is no record here of which intervals are duplicated or were overlapping. The dataset in Severson and Hauck (in prep., 2003) is far more complete.

Table 8. Format of PGE-ETC Data Table-see Appendix 6 for expanded explanation.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INT-AS-TXT: "from-to" for interval as single text entry
LENGTH: length along core of sample interval
INTRUSION: which intrusion drill hole is in
UNIT: rock unit, from Severson and Hauck (in prep., 2003)
ROCKTYPE: rock type, from Severson and Hauck (in prep., 2003)
DEPOSIT: deposit drill hole is in
AU-PPB: gold in parts per billion-as recorded in original data
PT-PPB: platinum in parts per billion-as recorded in original data
PD-PPB: palladium in parts per billion-as recorded in original data
CU-PPM: copper in parts per million-as recorded in original data
NI-PPM: nickel in parts per million-as recorded in original data
S%: sulfur in percent-as recorded in original data
CO-PPM: cobalt in parts per million-as recorded in original data
ZN-PPM: zinc in parts per million-as recorded in original data

Table 8 (continued)
AG-PPM: silver in parts per million-as recorded in original data
AU-PPM: gold in parts per million-as recorded in original data
AS-PPM: arsenic in parts per million-as recorded in original data
CR-PPM: chromium in parts per million metal-as recorded in original data
TIO2%: titanium as percent oxide as reported in original data
TI%: titanium as percent, metal as reported in original data
MGO%: magnesium as percent oxide as reported in original data
MG%: magnesium percent metal as reported in original data
CR2O3%: chromium as percent metal as reported in original data
CL-PPM: chlorine in parts per million-as recorded in original data
MO-PPM: molybdenum in parts per million-as recorded in original data
V-PPM: vanadium in parts per million-as recorded in original data
CU/PD: copper:palladium ratio
CU%: copper percent, calculated from ppm data
NI%: nickel percent, calculated from ppm data
REFERENCE: data source, see Severson and Hauck (in prep., 2003) for details on sample selection
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel. This column shows which file set this drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV files. This file is not split.

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APPENDICES 1 THROUGH 8 INTRODUCTION

APPENDICES 1 THROUGH 8 INTRODUCTION

INTRODUCTION

There are eight written appendices. Most of these (1 through 6) address the contents of the data files forming the core of this report. One (Appendix 7) addresses some generalities about the relation between the various drill hole numbering schemes, grid names, and deposit areas; and one (Appendix 8) is a listing of potentially useful contacts related to exploration and mining in Minnesota.

FILE NAMES AND CONTENTS

Refer to Figure 1 for the schematic database layout. The CD-ROM enclosed with this report contains the following files (XLS are Microsoft Excel files, CSV are comma-delimited files):

NRRI-DIGITAL-LOGS.PDF: Adobe “portable document format” version of this report.

GCDBDC.MDB: Master database in Microsoft Access format, intended for use in Gemcom for Windows. Not specifically described in an appendix, see Appendices 1 through 6 and descriptions for individual tables within this database.

HEADER.XLS & HEADER.CSV: Header data (one record per hole, data such as: location, year, orientation, etc.). See Appendix 1 for explanation.

MDDHHEAD.SHP, MDDHHEAD.DBF, MDDHHEAD.SBN, MDDHHEAD.SBX, MDDHHEAD.SHX: Header table, with NAD83 UTM drill hole location in meters as the location coordinate (as opposed to the 1927 state plane feet coordinate used in this report), intended for use in ArcView. This could be used to supercede or supplement the drill hole location file supplied with the ArcView data in Minnesota Geological Survey Report of Investigations 58, “Geology and Mineral Potential of the Duluth Complex and related Rocks of Northeastern Minnesota”, (Miller et al., 2002). The drill hole locations vary somewhat from those in RI-58, and this file contains more data than the drill hole location file in RI-58. There is some unique data in the file supplied with RI-58 not in this file, and some data in this file not in that supplied with RI-58. See Appendix 1 for the column explanations.

DEPOSITS.SHP, DEPOSITS.DBF, DEPOSITS.SHX: An ArcView polygon dataset showing the deposit areas of the Duluth Complex. Created by drawing closed lines around most groups of drill holes named in this report. Not intended to be a detailed map of deposit geometry, but useful for posting deposit data labels to maps. In NAD83 UTM datum, which is contrary to the bulk of the data in this report, which uses 1927 state plane feet for the location coordinate.

HEAD-F-T.XLS & HEAD-F-T.CSV: Header data (one record per hole, data such as: location, year, orientation, etc.) in “from-to” format. See Appendix 1.

SURVEY.XLS & SURVEY.CSV: Downhole survey data for each drill hole. See Appendix 2 for explanation.

EAST-LITHO.XLS & EAST-LITHO.CSV: Downhole lithology data for (approximately) the east half of the Duluth Complex. See Appendix 3 for explanation.

WEST-LITHO.XLS & WEST-LITHO.CSV: Downhole lithology data for (approximately) the west half of the Duluth Complex. See Appendix 3 for explanation.

EAST-ASSAY.XLS & EAST-ASSAY.CSV: Downhole Cu-Ni-S assay data for (approximately) the east half of the Duluth Complex. See Appendix 4 for explanation.

WEST-ASSAY.XLS & WEST-ASSAY.CSV: Downhole Cu-Ni-S assay data for (approximately) the west half of the Duluth Complex. See Appendix 4 for explanation.

RQD.XLS & RQD.CSV: "Rock Quality Designator" data for Babbitt and Serpentine deposits. See Appendix 5 for explanation.

PGE-MJS.XLS & PGE-MJS.CSV: PGE data taken from Severson and Hauck (in prep., 2003). See Appendix 6 and their paper.

DATA ENTRY AND RECONCILIATION DETAILS

All original data entry and calculation (interval lengths, ratios) for this project was done in Microsoft Excel. Some data were reformatted from older Lotus 123 (*.WK1) and Quattro Pro (*.WB1) files. The Excel files were then saved in *.CSV format and loaded to the GCDBDC.MDB file using Gemcom for Windows (version 4.02). This was the oldest version of Gemcom available to us. It was used on the assumption that the older the data file format the more programs that would be able to read it. Gemcoms' excellent error checking and validity checking routines were used, corrections were made over various iterations of reloading data to fix items such as making sure that the length for a particular hole was the same in all files referencing that hole, or that there were no overlapping or missing intervals. Once finally corrected and rectified, each data table was exported to Microsoft Excel format out of the database, using Microsoft Access. The error checked tables were then reformatted in Excel to the comma delimited (*.CSV) files. These comma delimited files were then loaded to a blank project in Gemcom to create the "clean" and final copy of the database referenced here. Consequently, these files should be carrying no coding from earlier iterations of calculation or any other specific program formatting.

In the following appendices, column headings in the specific data files are given as "HEADING:", i.e., all caps, followed by a colon.

APPENDIX 1

HEADER TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE (GCDBDC.MDB) AND SPREADSHEET FILES (HEADER.XLS, HEADER.CSV)

APPENDIX 1: HEADER TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE AND SPREADSHEET FILES

HEADER TABLE INTRODUCTION

Following is the expanded description of the HEADER file contents for the database. The column order in this description is not the same as that in the database table or spreadsheet files. Columns have been grouped by data type. In particular, note that the DEPOSIT: and INTRUSION: listings have been moved to the end of this appendix because of the length of those two discussions.

DRILL HOLE NUMBERING

DDH: drill hole number: The drill hole number used here is the original company number with few exceptions. All characters are now in upper case letters. See Appendix 7 for some unreferenced generalities about drill hole numbering versus deposit area or grid name.

There have been a few small changes here in drill hole numbering to ease computer sorting:

1) For series of drill holes such as at Babbitt/Serpentine (B1- series holes) or Water Hen (SL- series holes) where there are more than nine drill hole numbers assigned, leading zeros have been added to the numeric portion of the name. For instance B1-1 is now B1-001, B1-32 is now B1-032, and SL-1 is now SL-01. This re-numbering will conflict with the MDNR drill core library index, the numbers on core boxes at MDNR and at other locations, and previous NRRI work as well as parts of Miller et al. (2002). This minor change in numbering seemed the best way to deal with the large number of drill holes, and this renumbering has not caused any duplication of drill hole numbers;

2) All drill hole numbers given here are in upper case. Some holes, such as the "Du" series (by Duval) have always been labeled with upper and lower case. This case difference can cause difficulties in some computer sorting operations and is avoided in this dataset;

3) The holes drilled by MDNR have had "-MDNR" added as a suffix because two of them had ambiguous names that could conflict with other drill holes.

Some drill holes in the Complex have more than one number in the paper records. Notably some of the first eleven "NM" series (Newmont) drill holes in the Dunka Pit area have been re-labeled as "E" series drill holes. The GF series drill holes (sometimes labeled as ON series drill holes in paper files) in the Gunflint area were re-entered (and re-numbered) by second or third companies after their initial drilling. Some USS Corp. drill holes that penetrate both the Duluth Complex and the Biwabik Iron Formation have a hole number for each of those portions. Sometimes these multiple numbers are clear in the paper records, sometimes they are not, and are discovered by accident when trying to reconcile data discrepancies. These alternate numbers (where known) are shown in parentheses.

Also, note that many of these drill hole numbers may be repeated in other geologic terranes of Minnesota, and when requesting information, it is best to also know the coordinate or public land survey location point for any particular drill hole.

DRILL HOLE LOCATION BY X, Y, AND Z COORDINATES

EASTSP27: easting NAD27 state plane feet
NORTHSP27: northing NAD27 state plane feet
Drill hole easting and northing in NAD27, Minnesota State plane north feet

EASTSP83: easting NAD83 state plane feet
NORTHSP83: northing NAD83 state plane feet
Drill hole easting and northing in NAD83, Minnesota State plane north feet

EASTUTM27: easting NAD27 UTM meters
NORTHUTM27: northing NAD27 UTM meters
Drill hole easting and northing in NAD27, UTM zone 15

EASTUTM83: easting NAD83 UTM meters
NORTHUTM83: northing NAD83 UTM meters
Drill hole easting and northing in NAD83, UTM zone 15

Drill hole locations are fairly reliable, and the locations are internally consistent to one another. However, as with many items, it is recommended that one understand how various drill hole locations were derived before starting detailed work in an area. Collar locations were derived from: recalculation of surveyed grid and drill hole data for Babbitt and Serpentine; some recent (since ~1990) survey and recalculation of the grid work by NRRI for Dunka Road, South Filson Creek, Maturi, and Spruce Road; for other areas, by plotting the company grids and/or drill hole locations on 1:24,000 (or better) maps and scaling the state plane or UTM coordinate from that map.

All conversions between coordinate systems were done by the "Corpscon for Windows" program available from the United States Army Corps of Engineers.

Locations used in this database should supercede those in Miller et al. (2002), as the ability to check drill hole location in cross-section has lead to some corrections. Drill hole geology generally fits the expected location of the collar and basal contact where examined in cross-section, indicating no readily recognizable gross errors in drill hole location.

Locations for Birch Lake holes drilled after 1995 and the drill holes by PolyMet at Dunka Road (NorthMet) were estimated from the abandonment reports turned in to the Minnesota Department of Health.

The choice to use state plane feet in NAD27 was driven by three items:

> 1) there are still many USGS maps in circulation without any UTM grid, and much of the original work was done prior to NAD83;
>
> 2) virtually every reference to measurement in the original data is in feet;
>
> 3) Gemcom does not allow different coordinate systems for the vertical (downhole) measurements and the horizontal measurements.

The UTM location data and the few downhole measurements given in meters are to allow a quick insertion of some of these data into a GIS system, e.g., ArcView. The header file is included as an ArcView "shapefile" in NAD83 on the CD-ROM. However, to fully use this dataset in a metric system of measure will require reformatting of every data table.

We chose to not include the exact source for each data point both in this report and in the database. From information at NRRI or MDNR one could recreate these locations to demonstrate their accuracy if need be. Please contact NRRI or MDNR for any location data point that needs further documentation.

The level of accuracy/precision shown for the hole locations, to the second decimal point, is not realistic, but is retained so that locations won't "creep" one unit or less if rounded and then reprocessed or converted again between coordinate systems. The spreadsheet and comma-delimited files have had their precision cut to one or two decimal points for all footage measurements, however, Gemcom (and sometimes Excel) has a tendency to show up to ten or twelve numbers to the right of the decimal point that round to the correct value, but do not represent the values as entered or calculated.

COLLAR-EL: collar elevation in feet above sea level
COL-EL-MET: collar elevation in meters above sea level

Collar elevations were derived from the same process as described above for the drill hole locations. Many drill holes had very reliable elevations in the original data. Elevations on 1:24,000 maps were estimated for the locations where no elevation was given in the original data. Most of the USGS base maps used are 10 foot contour interval. As with the location data, the collar elevations have been checked in cross-section and appear reasonable.

The metric collar elevation was derived by dividing the footage by 3.2808 to arrive at meters.

DRILL HOLE DEPTH

TOTALDEPTH: total depth in feet
TOTDEPMETR: total depth in meters

Total depth is length from collar along the drill hole to the toe of the hole. Total depth numbers were taken from the original company data wherever possible. Discrepancies between the company data and what was recorded in the logging were resolved on a case by case basis depending on available data. The comment column in the database reflects that some drill holes (such as at Mile Post 7 and others) had no depth recorded, in those cases we used a placeholder value, such as 100 feet, which may be much more than the true length. These placeholder values are needed in Gemcom (and probably other software) because a drill hole cannot have a length of "0". Generally this will not be a data quality issue because these are drill holes with little or no documentation otherwise.

The metric total depth value was derived by dividing the footage by 3.2808 to arrive at meters.

Gemcom refers to total depth as "length".

For drill holes from the underground work at Babbitt and Maturi, total depth is length from the collar to the end of hole. For wedge holes, total length equals depth from surface along the drill hole, not from the wedge point. Note that the wedge holes at Birch Lake were treated differently than other wedged holes. See discussion about this in the survey data table explanation.

For some holes, such as the RMC series holes drilled by Reserve Mining Company and a few USS holes at Dunka Road (NorthMet) the total depth (and the listed geology) stops just into the Biwabik Iron Formation. At the Babbitt (Mesaba) Deposit, Reserve Mining drilled through the Duluth Complex to reach the iron-formation below, and Bear Creek Mining assayed the Duluth Complex portion of the drill hole. The data for the rest of the drill hole (the iron-formation portion) was not available to NRRI. At Dunka Road (NorthMet) the iron-formation core from drilling below the Duluth Complex was passed on to the Minntac mine, often with a different drill hole number, such as USS drill hole 25403, which is also recorded as 26089. Two different data sources give this hole as being in slightly different locations, but with all downhole data being the same. This is an excellent example of why we feel these data should not be used without some familiarity with the Duluth Complex and the exploration history of the region.

DRILL HOLE ORIENTATION

DIP: collar dip, measured from horizontal, 0˚ = horizontal, -90˚ = vertical
AZIMUTH: collar azimuth clockwise relative to true north

Dip and azimuth values in the header file refer only to the recorded collar orientations. There may or may not be further downhole measurements (see survey table). Collar dip data was taken from original logs. Dip is recorded as a negative value from the horizontal.

Azimuth data was taken from the original logs or original grid maps, if available. Azimuth is recorded as clockwise from true north. As with many other parts of the data in this database, we have used these azimuth values for various projects over the years and find these to be reasonable numbers. However, it is not always completely clear on logs whether or not the northing refers to true north or grid north. In the larger datasets, it seems there are always a few drill holes with some notational uncertainty in this regard. We used our judgement on a case by case basis.

VERT-ANG: vertical or angled at collar

Was this hole drilled vertical or at an angle? If the collar angle was anything but -90˚, it is listed in this column as an angled hole.

INITIAL?: initial hole or wedge

Was this hole drilled as an original hole, or as a wedge off of the original? Wedge holes have their own geometry issues in various drill hole plotting programs, and not all wedges in this database were treated in exactly the same way.

For wedged drill holes at Babbitt and Serpentine, the portion in the database above the wedge is the same location data as for the original drill hole. The lithology and assays for this upper portion are listed as not logged or not sampled for the wedge hole.

Other wedged holes, such as Birch Lake, where the true geometry has not been released to public domain, do not follow this convention. There the wedges are given as a separate hole with a location for each successive wedge one meter east and one meter north of the original hole or previous wedge. The main effect of this adjustment is to make sure the holes plot in cross-section or plan view. At Birch Lake there may be many wedges off of each drill hole.

SUR-UNDG: drilled from surface or underground drift?

Was this hole drilled from the surface or from underground? At Babbitt about 220 holes and at Maturi about 13 holes were drilled from drifts in the deposits. This column is to allow one to separate these, as they may represent different sampling populations than the other drilling, primarily due to their close proximity to one another.

DRILL HOLE LOCATION BY PUBLIC LAND SURVEY (PLS), COUNTY, AND QUAD

COUNTY:

All drilling in this report is in St. Louis, Lake, or Cook Counties in northeastern Minnesota.

QUAD:

This is the USGS 7.5 minute topographic quadrangle map where the drill collar plots. Data taken from NRRI files, MGS files, and inspection of drill hole locations using the GIS database included in Miller et al. (2002).

TOWNSHIP: Public Land Survey Township
RANGE: Public Land Survey Range
SECTION: Public Land Survey Section
FORTY: partial list of forty acre subdivision

The public land survey location data were taken from the original logs, NRRI plots of drill hole locations, and inspection of drill hole locations using the GIS database included in Miller et al. (2002). Because land and mineral ownership issues can be complex, and because ground surveys may give different results than paper plots of drill hole locations, these should be used only as a guide. Property specific assumptions about land and mineral rights should not be based solely on this PLS data.

There are three drill holes that fall in PLS Range East, in eastern Cook County, all others fall in Range West. All Township values are North. The forty acre subdivision given here are those readily available during data compilation. We did not estimate any new forty acre subdivision locations.

GEOLOGIST(S), CROSS-SECTIONS, GRIDS, and DATE

GEOLOGIST:

This column lists the geologist responsible for the log used here. There are other (company and other geologist) logs for almost all drill holes that NRRI has logged. For drill holes we have not logged, we used any available company logging.

MJS: Mark J. Severson of NRRI, all deposits

MJS-FW: Mark J. Severson logged footwall portion of hole, rest of data for drill hole assembled from surrounding holes and original company logging. Severson did <u>all</u> of the footwall logging or re-logging at Babbitt, Serpentine, Dunka Road, and Dunka Pit, even where not specifically noted as such

SAH: Steven A. Hauck of NRRI, mostly Babbitt, but some work on all deposits

LMZ: Lawrence M. Zanko of NRRI, Babbitt and Birch Lake and Serpentine deposits

SDG: Steven D. Monson-Geerts of NRRI, Dunka Road deposit only

RLP: Richard L. Patelke of NRRI, Babbitt and Dunka Road deposits

JJH: John J. Heine of NRRI, Babbitt only

STROMMER: James Strommer of NRRI, Water Hen only

KUHNS: Mary Jo Kuhns of NRRI, South Filson Creek only

JSO: John S. Owens of Hanna Mining Company

SJM: Sarah Jane Mills

INCO (with modifiers): Data supplied by INCO, usually digital

Lehmann Abandonment Report: Drill hole abandonment reports turned in to Minnesota Department of Health

PolyMet Abandonment Report: Drill hole abandonment reports turned in to Minnesota Department of Health

LTV Data: Data from LTV Steel Mining Company (now Cliffs-Erie Mining Company LLC) collected by Dean Peterson and Mark Severson. Originally digitized by Dean Peterson.

NL: Not logged

NL Rotary: Not logged because only chips are available

Venzke: Edward Venzke thesis (in prep.)

Placeholder data: “Made up” values to keep spot open in database for this drill hole

The Minnesota Geological Survey, Newmont, Exxon, Bear Creek, AMAX, Humble, USBM, MDNR, New Jersey Zinc, Lehmann Exploration Management, Wallbridge Mining, USS, and Reserve Mining Company all contributed logs to the drill data files at NRRI and MDNR that are referenced here.

NRRI-SECT:

This is the NRRI cross-section that the geologic unit data for this drill hole was taken from. Multiple sections were used for some holes, and in some cases drill holes off of section were estimated from surrounding sections.

COMP-SECT:

This is the company cross-section for this drill hole based on company grid coordinates. This was calculated only for Dunka Road (NorthMet) and Babbitt (Mesaba) where NRRI has done cross-sections through the entire deposit and allows us to make comparisons between our sections and the company data. We have never found geologic sections for these deposits, though grade sections do exist. This comment is not intended to imply that these company geologic sections are available for inspection at any archive we know of.

GRIDEAST:

This is the grid easting reported by the company. This is a case where we entered what data we already had, but did not search the archives for more information.

GRIDNORTH:

This is the grid northing reported by the company. This is a case where we entered what data we already had, but did not search the archives for more information.

GRIDCOMP:

This is the grid designation or name assigned by the company. This is a case where we entered what data we already had, but did not search the archives for more information.

DATE:

Date drilled, taken from the data file for the GIS database in Miller et al. (2002).

OVERBURDEN THICKNESS AND FOOTWALL DEPTH

OVBTHICK:

Overburden thickness (depth to ledge) is taken directly from the lithology files used in this report. We have assumed that if there is no core at the top of the hole that interval must have been overburden, and if there is rock, it is in place. This could be wrong for two reasons:

1) the drillers may have passed thru weathered ledge before beginning coring, as we saw evidence for in the 1995-1996 Arimetco test Pit at hole B1-411 in the Babbitt deposit (Patelke, unpublished observation); and at areas such as Water Hen, where deep saprolite was encountered over an OUI. Saprolitic intervals may have been drilled in some holes and not clearly recorded. (Deep saprolites are generally not reported in this region, due to removal by glaciation);

2) at the 2001 Cominco test pit at hole B1-321 in the Babbitt deposit there were very large boulders in the drift, in some cases boulders similar to the ledge bedrock may have been cored as being in place (Severson, unpublished observation).

This depth to ledge value is along the drill hole, and is <u>not</u> corrected for angled drill holes.

FWDEPTH: depth to footwall

This is the distance along the core to the footwall contact (basal contact). This is usually the intercept point for the Virginia Formation (VF), the Biwabik Iron Formation (BIF), or the Giants Range batholith (GRB). There may be Keweenawan intrusive rocks below this point. The definition of this intercept point has usually been placed in a location that makes best sense in cross-sectional view where ambiguities arise, such as at the western end of the Babbitt deposit or in the Wetlegs area where there is "overhanging" Virginia Formation.

Some holes, those entirely in the Virginia Formation or Biwabik Iron Formation, will show footwall at the ledge. These are non-Duluth Complex holes included for stratigraphic control.

METADATA AND RECORD KEEPING ENTRIES

LESSEE:

This information is from the logs and our general knowledge. Interconnected joint ventures between mining companies are the rule, not the exception, and these data reflects our best judgement as to what company was responsible for drilling this hole. This has not been completely checked with all available data and should be used only as a guide. No research into the true responsibility for drilling is implied here.

BEST-REF:

Best first reference for report about area containing drill hole

Miller et al. (2002) and the references within are by far the best references on the Duluth Complex as a whole. The references here are those related most to these deposit areas. This is not intended to be a complete list.

HEAD-COMM:

Comments about this hole related to the header file data, if any

SURV-COMM:

Comments about this hole related to survey data, if any

LITH-COMM:

Comments about this hole related to the lithology data, if any

ASSAY-COMM:

Comments about this hole related to the assay data, if any

SOURCEFILE:

Record keeping for data entry at NRRI

XLSFILE:

Are these data in the EAST-LITH.XLS, EAST-CUNI.XLS, WEST-LITH.XLS, or WEST-CUNI.XLS files (and their *.CSV comma-delimited equivalents)? The lithology and copper-nickel assay files are too long for MS Excel. They were split into the above named east and west files. The west and east distinction was based on listed intrusion for the drill hole. This division is shown on Table 9 below. These data are carried in all data files, even though only the ASSAY and LITHO files are split.

Table 9. Repeat listing of deposit areas showing to which (east or west) assay and lithology file drill holes were assigned. This convention is recorded in all files on a drill hole by drill hole basis, even though other data files were not split. Intrusion names in parentheses are those used in database, otherwise full name was used.

West Lithology and Assay Files	**East Lithology and Assay Files**
Boulder Lake intrusion (BLI)	Bald Eagle intrusion (BEI)
Duluth Complex Felsic Undivided	Brule Lake intrusion
Diabase Undivided	Crocodile Lake intrusion
Duluth Layered Series (DLS) Layered Series at Duluth of Miller at al., 2002	Cloquet Lake Layered Series of Beaver Bay Complex (CLLS of BBC)
Duluth Complex Anorthositic Undivided	Greenwood Lake intrusion (GLI)
Partridge River intrusion (PRI)	Houghtaling Creek Troctolite of Beaver Bay Complex (HCT of BBC)
Virginia Formation at Margin of Partridge River intrusion (VF at margin)	Logan Sill
Virginia Formation-Biwabik Iron Formation (VF-BIF)	North Shore Volcanic Group (NSVG)
Western Margin intrusion (WMI)	Osier Lake intrusion
	Poplar Lake intrusion
	South Kawishiwi intrusion (SKI)
	Sonju Lake intrusion (SLI)
	Tuscarora intrusion
	Unknown or Unnamed
	Virginia Formation-Biwabik Iron Formation (VF-BIF) at Serpentine

INTRUSION AND DEPOSITS REVIEWS

Introduction to Intrusions and Deposits

INTRUSION DEFINITION:

This database reports drill holes in fifteen named intrusions of the Duluth Complex and associated rocks, and some areas without formal or informal intrusion names (see Figure 2 for generalized Duluth Complex map). The named intrusions at the edge of the Complex proper are, starting in Duluth and following the basal contact around the Complex counterclockwise: Duluth Layered Series (DLS), Boulder Lake intrusion (BLI), Western Margin intrusion (WMI), Partridge River intrusion (PRI), South Kawishiwi intrusion (SKI), and the Bald Eagle intrusion (BEI). Intrusions in the interior of the Complex include: Duluth Complex Anorthositic Undivided, the Greenwood Lake intrusion (GLI), Osier Lake intrusion, Diabase Undivided, and Duluth Complex Felsic Undivided.

In the Finland-Silver Bay area, this drilling also includes some rocks of the Beaver Bay Complex (BBC): the Cloquet Lake layered series (CLLS) and the Sonju Lake intrusion (SLI). Associated with the BBC for purposes of this database are rocks of the North Shore Volcanic Group (NSVG, see Miller et al., 2002, for description).

In the Gunflint area, the intrusions are now classed as separate intrusions from the Duluth Complex (Miller et al., 2002): the Poplar Lake intrusion (PLI, formerly known as "Nathans Layered Series"), Crocodile Lake intrusion (CLI), Brule Lake intrusion, Tuscarora intrusion, and the Logan Sills, which are early Keweenawan sills intruding the Rove Formation and Gunflint Iron Formation (GIF; Figure 2 and parts of the text, as well as many of the files at NRRI, group all of these holes as being in the "Gunflint Corridor").

Detailed descriptions of these intrusions are far beyond the scope of this paper. The current best reference is Miller et al. (2002) and the references within.

DEPOSIT DEFINITION:

A "deposit" for the purpose of this study is geologically distinct, by: grade, rock type, predominant map unit, or intrusion; and is defined by a cluster of drill holes generally drilled for a common purpose (i.e., to test a geophysical feature or translate geology downward from outcrop) or done as a single project. There is no economic judgement or connotation intended by the use of the terms deposit, project, prospect, or ore.

The intrusions and deposits within them described here are arranged starting from southwest, near Duluth (see Figure 2), along the basal contact of the Duluth Complex north to the Mesabi Iron Range, then following the basal contact as it turns northeast near Wyman Creek. Drilling does not extend northeast past the Spruce Road area because of restrictions associated with the Boundary Waters Canoe Area Wilderness (BWCAW). Drill holes or

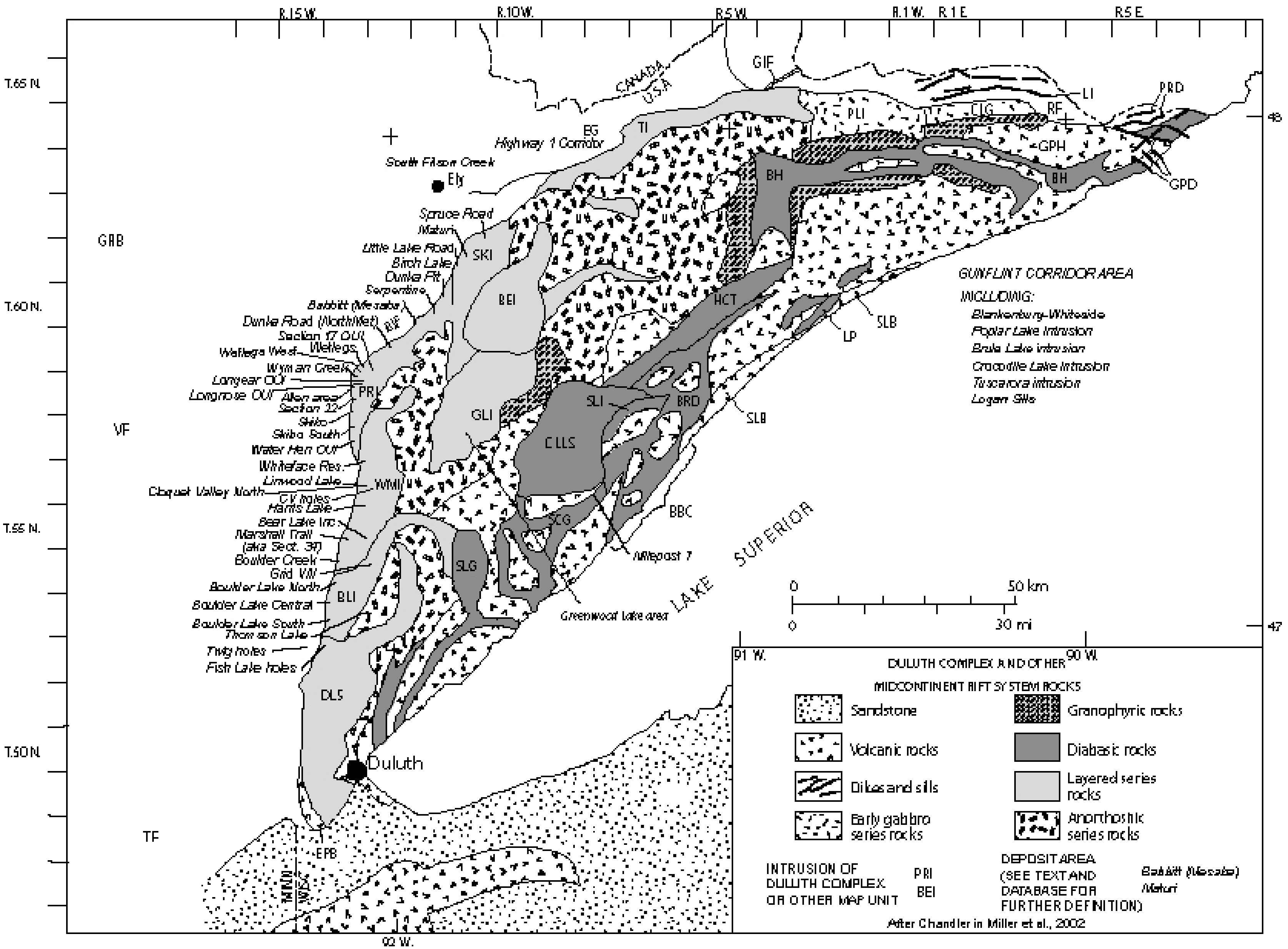

Figure 2. Generalized map of Duluth Complex, complete caption on next page.

Figure 2. Generalized map of Duluth Complex showing intrusion names and deposit areas as named in this report. Taken after Chandler (Figure 3.1) in Miller et al. (2002). Intrusion and/or formation abbreviations are as shown in following list. Those units listed as not mentioned in report have no recorded exploration drilling. Most deposit areas mentioned in text are shown on map in italics.

BBC-Beaver Bay Complex
BEI-Bald Eagle intrusion
BIF-Biwabik Iron Formation (Paleoproterozoic)
BH-Brule Lake and Hovland gabbros (Brule Lake intrusion)
BLI-Boulder Lake intrusion
BRD-Beaver River diabase (not mentioned in this report)
CLG-Crocodile Lake gabbro
CLLS-Cloquet Lake layered series of BBC
DLS-Layered Series at Duluth
EG-Ely Greenstone (Archean) (not mentioned in this report)
EPB-Ely's Peak Basalts (not mentioned in this report)
GIF-Gunflint Iron Formation (Paleoproterozoic)
GLI-Greenwood Lake intrusion
GPD-Grand Portage dikes (not mentioned in this report)
GPH-Grand Portage basalts and Hovland lavas (not mentioned in this report)
GRB-Giants Range batholith (Archean)
HCT-Houghtaling Creek troctolite (not mentioned in this report)
LI-Logan intrusions
LP-Leveaux porphyry (not mentioned in this report)
PLI-Poplar Lake intrusion
PRD-Pigeon River diabase (not mentioned in this report)
PRI-Partridge River intrusion
RF-Rove Formation (Paleoproterozoic)
SCG-Silver Creek gabbro (not mentioned in this report)
SKI-South Kawishiwi intrusion
SLB-Schroeder-Lutsen basalts (not mentioned in this report)
SLG-Sawmill Lake gabbro (not mentioned in this report)
SLI-Sonju Lake intrusion
TF-Thomson Formation (Paleoproterozoic)
TI-Tuscarora intrusion
VF-Virginia Formation (Paleoproterozoic)
VGC-Vermilion Granitic Complex (Archean)
WMI-Western Margin intrusion

deposit areas that are not classified into the named intrusions and those drilled some distance away from the basal contact are listed last.

DULUTH LAYERED SERIES (DLS)

The Duluth Layered Series (DLS; Layered Series at Duluth of Miller et al., 2002) includes all exposures of the Complex in the Duluth area and continuing to the area north of Duluth near Island Lake. This area also includes extensive outcrop of North Shore Volcanic Group (NSVG) volcanic and sedimentary rock, as well as diabase sills and dikes. Footwall rocks to the Complex in this area are either localized patches of NSVG basalts or the Thomson Formation (Paleoproterozoic metasedimentary rocks considered equivalent to the Virginia Formation).

There is minimal recovered drilling in this area, represented by a few core holes drilled by MDNR, scattered geotechnical drilling (not reported here), and data from water well drilling. There is extensive outcrop control in this area. The DLS is described in detail in Miller et al. (2002).

Duluth, Fish Lake, and Twig Holes

The seven holes in the Duluth Layered Series includes the two "Fish Lake holes", drilled on Island Lake by the MDNR (data summarized in MDNR Report 251, Dahlberg, et al., 1987; Severson, 1995; and Sassani, 1992), two holes in the Twig area drilled by MDNR, two water wells in Duluth, and a hole drilled jointly by Minnesota Power & Light and the MDNR.

No extensive publically available exploration work has been done on this intrusion, but Millers outcrop traverse geochemical sampling has shown horizons prospective for PGE mineralization (Miller et al., 2002).

BOULDER LAKE INTRUSION (BLI)

The Boulder Lake intrusion extends from the Island Lake-Boulder Lake area north of Duluth to a point about sixteen miles north-northeast, and then hooks east and back south to a point about fifteen ground miles from Island Lake. Five drilling areas are outlined in this intrusion. They are: Boulder Lake South (Grid V), Boulder Lake Central (Grids VI and VII), Boulder Lake North (Grid IV), and Grid VIII. These are all grids defined by Phelps Dodge Corporation. The short area descriptions below are summarized from Severson (1995), which has more complete description and cross-sections for these localities.

Boulder Lake South (Grid V)

Three core holes were drilled by the Phelps Dodge Corporation in what they referred to as Grid V. These holes intersect an OUI that intrudes both troctolitic-gabbroic rocks and an inclusion of basalt. This grid is located on land between Island Lake and Boulder Lake.

Boulder Lake Central (Grids VI and VII)

Near the southwestern portion of the Boulder Lake Reservoir, Phelps Dodge Corp. drilled 10 core holes in what they referred to as Grids VI and VII. Within Boulder Lake Central there are no recognized correlative igneous units. Rather, each hole intersects a completely different package of rocks that bear no similarities to nearby drill hole rock types. Footwall rocks are intersected in the bottom of only one drill hole (VII-7).

Several thin OUI intervals are present in two drill holes in the Boulder Lake Central area and may represent apophyses off of a much larger body.

Boulder Lake North (Grid IV)

A total of 12 core holes are available in the Boulder Lake North area, referred to as the Grid IV area by Phelps Dodge Corporation (1970 - 9 holes) and by ASARCO (1968 - 3 holes). No footwall rocks are encountered in any of the drill holes at Boulder Lake North. This grid is located on the shore of the northernmost part of Boulder Lake.

Late pods and lenses of OUI are present in 7 of the 12 holes at Boulder Lake North. The OUIs vary from single thick intervals (or thick pods) to abundant thin intervals.

Grid VIII

Two holes were drilled by Phelps Dodge Corporation on their Grid VIII. These holes intersect moderately magnetic, oxide-bearing troctolitic and gabbroic rocks that correspond to a north-northeast-trending aeromagnetic high. This grid is located about one-half mile east of County Highway 4, three miles north of the intersection of County Highway 4 and Three Lakes Road.

WESTERN MARGIN INTRUSION (WMI)

The Western Margin intrusion (WMI) extends from about four miles north of Boulder Lake for thirty miles north-south and extends about six miles eastward from the basal contact. It includes eight exploration areas: Boulder Creek (Grid I), Marshall Trail (also known as Section 34 by USS), Harris Lake, Cloquet Valley (CV holes), Cloquet Valley North, Otto Lake, Linwood Lake, and Whiteface Reservoir.

As with the previous two intrusions, the WMI is described in Miller et al. (2002), and there is detailed geologic description and cross-sections of the drilling areas in Severson (1995). These descriptions are generalized from Severson.

Boulder Creek (Grid I)

In 1969, Phelps Dodge Corporation drilled 12 core holes in an area they referred to as Grid I. Units intersected in these holes consist of heterogeneous troctolitic rocks, troctolitic to gabbroic rocks with a well developed plagioclase lamination, and a disjointed, stratabound OUI. No footwall rocks are present in these holes. The linear distribution of the OUI at Boulder Creek may be related to an inferred north-trending fault zone. The Boulder Creek grid is near the southern tip of the WMI about two miles west of County Highway 4.

Marshall Trail (A.K.A. Section 34)

U. S. Steel Corporation (USS) drilled six core holes into a magnetic high in the Section 34 area. Three of the holes intersect an Oxide-bearing Ultramafic Intrusion (OUI) that is present throughout the entire length of the holes. The remaining three holes intersect numerous apophyses of OUI that alternate with anorthositic host rocks. This area is along St. Louis County Highway 4, just south of the "Kelsey Brimson Road", where the Marshall Trail intersects St. Louis County Highway 4.

Harris Lake Drill Holes

U. S. Steel Corporation leased state lands in the vicinity of Harris Lake (about 8 miles southwest from Fairbanks) on the basis of a coincident magnetic high and strong airborne electromagnetic (EM) anomaly. After conducting geophysical surveys in the area, they drilled three vertical holes in 1967-68. Because the holes intersected mainly serpentinized ultramafic rocks with no visible sulfide mineralization, USS dropped the state leases. Shortly after this period, Phelps Dodge Corp. leased the same lands and subsequently drilled two inclined holes into the same magnetic-EM conductor in 1971. These holes are located approximately 2.5 miles east of the basal contact subcrop. No footwall rocks are present in the holes.

CV Holes

The two "CV" drill holes (Cloquet Valley?) were drilled by Exxon in 1974. CV-1 is about four and a half miles south-southeast of Whiteface Reservoir, and CV-2 is about three miles southeast from the reservoir.

Cloquet Valley North

A single drill hole at Cloquet Valley North was drilled by W.S. Moore two miles east of Linwood Lake and about one-half mile west of County Highway 4.

Linwood Lake Drilling

This area is along the east shore area of Linwood Lake, west of the "Camp 26 Truck Road". Four core holes are available for the Linwood Lake area and include: 26012 -drilled by U. S. Steel Corporation; CL-1 - drilled by W.S. Moore Co.; SL-1A-MDNR and SL-1B-MDNR - both drilled by the MDNR. All of the holes are collared in rocks of the Duluth Complex. Several outcrops of the Virginia Formation are also present in the Linwood Lake area. These outcrops show a progressive increase in the amount of deformation and metamorphism towards the basal contact of the Complex. Both drill hole and outcrop data suggest that the basal contact of the Complex in the area is near vertical at the surface. This condition is indicated by:

> 1) bedding planes in the Virginia Formation that become progressively steeper and more north-trending closer to the contact; and,
>
> 2) drill hole SL-1B-MDNR, located approximately 700 feet eastward from the contact, does not intersect the Virginia Formation at a total drilled depth of 1,008 feet.

Unfortunately, there are no correlative stratigraphic units in the Linwood Lake area based on the information from these four holes. Several thin OUI horizons, varying from 1 to 4 feet thick with 15%-30% oxides, are present in portions of 26012 and CL-1. Drill hole SL-1B-MDNR intersects numerous sedimentary hornfels inclusions and noritic rocks at many intervals - it is presumed to be very close to a steeply dipping basal contact. Sl-1A-MDNR was drilled a few feet from SL-1B-MDNR and abandoned at about 190 feet.

Nearby outcrops of the Virginia Formation are characterized by interbedded argillite and graywacke (Bouma B and/or D with minor C). The rock types are very similar to the rocks intersected in drill holes to the immediate north in the Whiteface Reservoir area. What makes these outcrops unique is that they record a progressive increase in the amount of deformation, metamorphism, and partial melting toward the contact with the Complex.

Outcrops in the northern part of the area consist of gently southward dipping sediments that show a gradual increase in the amount of dip toward the contact. Outcrops farthest away from the contact display normal dips of 5°-10° to the south; whereas, outcrops that are closest to the contact show an increase in dip to about 40°-50° (locally 60°-75°) to the east beneath the Complex. Also at this locale, the sedimentary rocks contain thin wisps of leucocratic partial melts that parallel the bedding plane trend.

Outcrops in the southern part of the area exhibit north-trending bedding-planes that are highly deformed and recrystallized adjacent to the Complex. Consistent dips of 80°-90° toward the east are present within the deformed rock. Rock types can be divided into two categories - the DISRUPTED unit and the RXTAL unit of the

Virginia Formation. Both of these footwall units have been noted elsewhere (and are described later in this report) along the margin of the Duluth Complex, e.g. at the Babbitt (Mesaba), Dunka Road (NorthMet), and Water Hen deposits.

Whiteface Reservoir

This area is near the intersection of the "Camp 26 Truck Road" and St. Louis County Highway 16, north-northeast of the Linwood Lake exploration area. Four core holes were drilled into rocks of the Duluth Complex in the Whiteface Reservoir area by United States Steel Corporation (USS). An additional two holes were drilled into geophysical conductors within the Virginia Formation to the west of the Complex by AMAX (drill hole BC-80-1) and by W.S. Moore Co. (drill hole CL-3). The drilling was not detailed enough to provide any information on the attitude of the basal contact in the Whiteface Reservoir area.

Otto Lake

One hole was drilled at Otto Lake by Lehmann Exploration Management in 1983. This is a short (209 feet) hole and has not been logged by NRRI. The targeting reason for this hole is unknown. Otto Lake is located about 4 miles south-southeast of Fairbanks, about 3-4 miles northeast of the Harris Lake exploration area.

DULUTH COMPLEX ANORTHOSITIC SERIES (AS)

The Anorthositic Series drill holes are within large (and not necessarily contiguous) areas of undivided anorthositic rocks (see Miller et al., 2002) not necessarily related to one another. This group includes drill holes in the area of the Bear Lake inclusion, the single drill hole at Thomsom Lake (Grid X), plus holes in the area of the Brimson quadrangle further to the east, and the Mt. Weber quadrangle to the north of Two Harbors.

Bear Lake Inclusion Drill holes

Numerous outcrops are present to the west of Bear Lake in the southeastern corner of T.55N., R.13W. This area is about eight ground miles due east of the Section 34 (Marshall Tail) area drilled by USS. This area is associated with a 2,500 gamma aeromagnetic anomaly that was drilled by the MDNR in 1984 (drill hole BL-1-MDNR, Sellner et al., 1985, east side of Cloquet River, near campground). At least two major rock types are present that include an inclusion of magnetic basalt that overlies and is in sharp contact with a package of oxide-bearing gabbroic rocks. Outcrop data suggest that both the inclusion and the gabbroic rocks dip about 10°-20° toward the southeast. Drill hole BL-1-MDNR gives a minimum thickness for the inclusion of 563 feet (the hole was collared and terminated in magnetic basalt).

Even though the basaltic rocks lack obvious volcanic features, the unit is believed to be an inclusion of magnetic basalt derived from the Keweenawan hanging-wall material. Sharp contacts, of 15° to the east, with the underlying gabbroic rocks are observed in two close-spaced outcrop areas. Similar material, also referred to as magnetic basalt, is present elsewhere in the Duluth Complex: 1) within portions of the Colvin Creek Body described by Patelke (1996); 2) associated with an anorthositic inclusion within the Highway One Corridor of the South Kawishiwi intrusion (where it is referred to as the "INCL" unit, Severson, 1994); and 3) in a drill hole (IS-1-MDNR; Sellner et al., 1985) near Isabella, Minnesota (J. Miller, pers. comm., to M. Severson, 1994).

One hole was drilled in this area by Franconia Minerals in 2002 (FCV-02-1). Only the location and length data are known for this hole from abandonment reports. No core has been submitted to the MDNR. The hole <u>appears</u> to test the west margin of the inclusion.

Thomson Lake (Grid X)

One hole was drilled by Phelps Dodge Corporation in an area they termed Grid X. The hole (X-1) was drilled to test a sinuous, north-trending magnetic anomaly. Rocks encountered in the hole consist of troctolitic rocks with a thick dunite layer. No footwall rock types are present in the inclined (-45°) 613 foot deep hole. This hole was skeletonized with little sample remaining. Severson (1995) placed this exploration area in the Boulder Lake intrusion.

PARTRIDGE RIVER INTRUSION (PRI)

Moving northward from the Western Margin intrusion (WMI) we pass into the Partridge River intrusion (PRI). The Partridge River intrusion is arguably the most studied portion of the Duluth Complex, at least in drill core (~1,000 drill holes). It is host to the Babbitt Deposit (formerly known as MinnAMAX and now under development by Teck Cominco as the Mesaba deposit), the Dunka Road deposit (now called NorthMet by PolyMet Mining), plus smaller projects at the Allen area, Wetlegs, and Wyman Creek areas. Lesser prospects are found at Skibo Road and Skibo South. Besides the above copper-nickel projects, there are ilmenite-rich “Oxide Ultramafic Intrusions” (OUIs) with possible economic potential at Longear, Longnose, Section 17, Section 22, Skibo, and Water Hen.

The database subdivides a few of these into smaller sets of holes, generally based on how NRRI has grouped them on maps or for our own internal studies. These include “Babbitt Underground” for the drilling at the Local Boy massive sulfide deposit, “Longear/Longnose” for a hole between the two, “Skibo Road” for a single hole, “Wetlegs West” for about six holes, “Wetlegs-Siphon” fault area for one hole, and there is some question for holes near Wyman Creek as to whether they should be included as part of the Wyman Creek deposit.

Also, because the Babbitt B-1 (Bear Creek) grid crosses from the Partridge River intrusion into the South Kawishiwi intrusion, covering the Babbitt and Serpentine deposits, we split the areas associated with that grid into five areas: "Babbitt" (holes in the Partridge River intrusion portion of the main Babbitt deposit); "Babbitt Underground" for the Local Boy area (on the B-1 grid, but with 5 digit numbers); "Babbitt Valley" for drill holes on the B-1 grid, collared in the South Kawishiwi intrusion and located in the area between the main Babbitt deposit and the Peter Mitchell taconite pit of NorthShore Mining Company; "Babbitt/Serpentine" for widely spaced drill holes on the eastern third of the B-1 grid, collared in the South Kawishiwi intrusion, but not clearly a part of either the Babbitt or Serpentine deposits; and lastly the "Serpentine" deposit proper. There are a few drill holes drilled by companies other than Bear Creek or AMAX listed as being within the Babbitt deposit.

Rocks of the PRI consist of varied troctolitic and gabbroic rock types that have been subdivided into eight igneous stratigraphic units, plus some cross-cutting OUIs and other units. These igneous rocks overlie Virginia Formation, and where the Virginia Formation was removed during intrusion and assimilation, the Biwabik Iron Formation. Nowhere in the PRI is the footwall (basal) contact with Archean granitic rocks, as it is to the northeast in the South Kawishiwi intrusion. The PRI units have been described in detail by Severson and Hauck (1990), and there is further description and references in Miller et al. (2002).

Water Hen

Since the late 1950s, 37 holes have been put down into the Water Hen deposit by various companies. Water Hen is east of St. Louis County Highway 130, two miles north of St. Louis County Highway 16 and about eight miles due south from Hoyt Lakes. Most of these drill holes intersect an OUI body within troctolitic rocks, and only four holes intersect the footwall Virginia Formation contact. This drilling mainly targeted the oxide mineral potential of the deposit. While Water Hen is in the PRI, it exhibits little of the "stratigraphy" typical of the majority of the PRI. The troctolitic host rocks may be correlative with Unit 5 of the PRI (Severson, 1995).

The Water Hen area has been studied extensively, including work by: Mainwaring (1975), Mainwaring and Naldrett (1977), Dahlberg et al., (1987), and Strommer et al. (1990). See Severson (1995) for detailed discussion and references for the Water Hen area.

Skibo-South (Grid II)

A total of seven drill holes are present in the Skibo-South area, or the Grid II area, as referred to by the Phelps Dodge Corporation. One hole is collared in the Virginia Formation (II-2), one hole intersects a thick OUI body (SR-1), and the remaining five holes intersect weakly-mineralized troctolitic rocks. The nature of the basal contact of the Complex at Skibo-South is unknown as only one hole encountered footwall rocks (Severson, 1995). This area is about six miles south-southeast from Hoyt Lakes.

Skibo

Twenty holes were drilled into an OUI body in the Skibo area, about four miles south-southeast from Hoyt Lakes. INCO drilled 18 of the holes during 1956-57 and 1969; none of the core for these holes remains for examination. Drill hole DDH-3 was drilled by an unknown company (INCO?) and only skeletonized core remains for this hole (core stored at the MDNR). United States Steel Corporation drilled hole 27016 in 1982. This single USS hole represents the only complete core available for the Skibo area (Severson, 1995).

Section 22

Core from six holes is available for the Section 22 area. This area is about three miles southeast from Hoyt Lakes. One hole is collared in the Virginia Formation, and the remaining holes are collared in the Duluth Complex; presumably in Unit 1 of the PRI. Three of these holes also intersect OUI rocks that are present over both thick and thin intervals. Drill hole data suggest that the basal contact is not as steep as at the Allen area to the north (Severson, 1995).

Allen Exploration Area

The Allen area is located immediately south of the Wyman Creek deposit, and due east of Hoyt Lakes. This area was drilled by Bear Creek Mining Company (1958-1960) and Exxon Minerals Company (1976-1979). The holes encounter troctolitic rocks that are roughly correlative with units of the Partridge River Troctolite Zone (PRTZ in MGS RI-58 and Map 119, Miller et al., 2001, 2002) that are present to the north in the Wyman Creek deposit. Many of the PRI marker beds that are clearly present at Wyman Creek begin to "lose their identity" to the south toward the Allen area, and correlation of units becomes progressively more difficult in a southerly direction. The mapped contact of the Complex with the Virginia Formation in the Allen area is based on the distribution of rock types intersected in the collars of drill holes (Severson, 1995).

It is important to note that the Wyman Creek/Allen area marks a dramatic change in the trend of the western contact of the Complex. In this area, the contact exhibits a rapid change from a northeasterly trend at Wyman Creek to a nearly north-south trend in the Allen area. Drill hole data at this inflection point indicate that the attitude of the basal contact beneath the Complex steepens from a 15°-25° dip (to the southeast) at Wyman Creek, to 60° or more (to the east) in the Allen area (Severson, 1988). Because the configuration of the basal contact is almost cliff-like in the Allen area, the entire section of troctolitic rocks intersected in drill holes is in close contact with footwall rocks and is probably contaminated via assimilation of the country rocks.

Thus, correlation of igneous units is hampered by a thick package of contaminated and heterogeneous rocks in close contact with the footwall (Severson, 1995).

Wyman Creek

The Wyman Creek area includes about 35 drill holes, most by U.S. Steel, with a few each by Bear Creek and Exxon. Most of these drill holes penetrate Virginia Formation footwall, with a few being collared in the Virginia Formation.

Note that in addition to the drill holes in this database, NRRI holds some drill core from the former LTV Steel Mining Company mine, about one to one and a half miles north of the Wyman Creek area. This core is from the upper parts of iron-ore mining development drill holes, and penetrates the base of the Virginia Formation into the upper marble unit of the iron-formation (the A submember). This core represents some of the better preserved Virginia Formation core available (it is usually disposed of by the iron mines) and is relatively unmetamorphosed argillite, and carbonaceous argillite, with thin limestone / chert units. Sulfide content is up to 5% of the rock in the carbonaceous argillite, generally nearer the base, and is marcasite dominated. These rocks may be the unmetamorphosed equivalent of the "bedded pyrrhotite unit" commonly seen where the Virginia Formation is metamorphosed by the Partridge River intrusion.

The data that NRRI has for this core, along with LTV drill logs for some drill holes, is on file at NRRI and is available for use. It was not put into this database due to time constraints for correcting locations and other data.

Wetlegs and Wetlegs West

The data for Wetlegs and Wetlegs West includes forty eight drill holes, sixteen by INCO (with no core remaining), eighteen by Bear Creek, and twelve by Exxon. The rocks of the Complex intersected in holes at Wetlegs consist of the Partridge River Troctolite Series (PRTS-Severson and Hauck, 1990), or, as it has been more recently called, the Partridge River Troctolite Zone (PRTZ; Miller et al., 2002).

Section 17 OUI

This is one of three OUIs (Oxide Ultramafic Intrusions) lying along a trend in the PRI. It is located due east of the Wetlegs area. There is one INCO hole and six USS drill holes in this area. All but one are angled holes, none penetrate footwall, and the bulk of the footage is in OUI rocks.

Longear OUI

This OUI is located directly south of the Wetlegs area, and three holes were drilled by American Shield in the 1970s and 1980s to evaluate the potential for massive oxides, particularly as an ilmenite feedstock for synthetic rutile processes.

Longnose OUI

This is an OUI located a few miles south and west of the OUI at Longear, besides drilling here by American Shield in joint venture with NICOR, bulk samples have been taken from this body with the aim of metallurgical testing for suitability as an ilmenite feedstock for synthetic rutile production. Some of this massive oxide material is stockpiled at the Coleraine Minerals Research Laboratory of the NRRI.

Dunka Road (NorthMet)

Dunka Road (NorthMet) is a United States Steel (USS) property drilled out in the 1960s and early 1970s (114 drill holes, plus a few by other companies). Currently (2003), it is under lease by USS to PolyMet Mining of Vancouver, British Columbia. PolyMet's precursor company, Fleck Resources, resampled virtually all of the pulps from the original sampling. They re-ran copper, nickel, and sulfur, as well as a suite of PGEs. PolyMet has also drilled another ninety holes in the deposit, some reverse circulation and some diamond core. The material from this drilling formed a bulk sample for metallurgical testing as well as providing confirmation of the historical drilling by USS.

PolyMet's published plan is to mine the deposit as a copper-nickel deposit with credits from PGEs, gold, cobalt, and other metals. Processing will be by a proprietary hydometallurgical method known as PlatSol.

Geerts et al., 1990, Geerts, 1991, and 1994, completed the most recent and comprehensive public studies on the deposit. The location, depth, and geology for the USS drilling at Dunka Road in this database come from Geerts. Three confidential reports by the NRRI have been done recently, but no information from them is included in this dataset.

PolyMet has released no detailed data on their drilling. The location and downhole data in the database for the PolyMet drill holes comes from abandonment reports turned in to the Minnesota Department of Health. Older press releases by the company have some assay composite values.

Babbitt (MinnAMAX or Mesaba)

Like the Dunka Road project, the Babbitt deposit has a long history of interest. Ownership is a mix of state lands and lands controlled by the Longyear Mesaba Trust. The Babbitt deposit is located between the Dunka Road and the Peter Mitchell Mine of NorthShore Mining, east of the Dunka Road (NorthMet) deposit and about eight miles due south from the town of Babbitt.

Bear Creek was responsible for about 208 surface drill holes at Babbitt. AMAX drilled about 224 surface holes, sunk a 1,700 foot deep shaft, and drilled 230 holes from underground drifts (3,800 feet of drift) at the Local Boy massive sulfide. This total includes thirty surface holes at Serpentine in the South Kawishiwi intrusion and twelve holes between Babbitt and Serpentine proper on the same grid. The database shows 473 surface drill holes in the Babbitt/Serpentine area, some are wedges on the original drilling, some are iron-formation drill holes from Reserve Mining (NorthShore Mining) included here for stratigraphic control, and some were drilled by companies other than Bear Creek or AMAX.

None of the lithological data for the underground drill holes at Babbitt (the Local Boy drilling) has been included in this database. The logging has been done for virtually all holes, but the final report is not published (Severson and Zanko, in prep.). The data are publically available, but are not yet digital. The original assays for the underground work are included here in digital format. NRRI and MDNR files also have about 500 records for rib sampling in the drifts. These rib sample data are digital in Patelke (1994).

Currently (2003), the Babbitt (now Mesaba) deposit is undergoing pre-feasibility study by Teck Cominco as a potential copper-nickel mine, with credits for PGEs, gold, cobalt, and other metals deferred to the future when processing technology catches up with mineralogy. This deposit (and probably all Partridge River copper-nickel deposits) has a difficult mineralogy where much of the copper metal is in cubanite, a copper-iron sulfide similar to chalcopyrite, but with only about 25% copper instead of the 35% copper of chalcopyrite. The sulfide concentrate may not be amenable to pyrometalurgical smelting, especially in regards to recovery of any nickel metal.

Besides Miller et al. (2002), the most recent public works on the Babbitt deposit are the three reports completed by the NRRI in the mid-1990s for Arimetco International during their evaluation of the deposit. Arimetco never completed their evaluation and went bankrupt in 1999. These reports include: Part “A” (Patelke, 1994) a digital compilation of assay data, drill hole location data, and drill hole location map. Also included is an index of other work conducted on these drill holes, such as theses, polished section inventory for NRRI, metadata, if whole rock geochemistry samples have been taken, etc. Part “B” of these reports (Severson et al., 1994) covers the geology of the deposit in plan view with five plates detailing various geologic horizons. Part “C” of this series (Severson et al., 1996) includes more plan view maps, and twenty five detailed cross-sections at one inch equals two hundred feet. Part “D”, as yet unpublished (Severson and Zanko, in prep), details the geology of the Local Boy massive sulfide with numerous cross-sections at one inch equals fifty feet (see comment above about this geology data being absent from the database). Hauck and Severson (2000) published the precious metals data for the Local Boy area collected for Arimetco in the mid 1990s.

VIRGINIA FORMATION DRILL HOLES

The database contains a number of scattered drill holes that do not penetrate the Duluth Complex. They collar in and pass through either Virginia Formation (VF) and/or the Biwabik Iron Formation (BIF). They are included here for two purposes. First, the Virginia Formation drill holes along the western margin of the Complex, referenced in Severson's South Complex report (Severson, 1995) help define the limits of the Complex, as well as demonstrating that bedding angles in the Virginia are steepening to the south. Future work in this area may better define the nature of the basal contact of the Complex through this area. These drill holes will be useful in that study. These drill holes are shown on cross-section in the Severson (1995) report. Secondly, the Virginia Formation and Biwabik Iron Formation drill holes along the northwest margin of the Complex, from Wyman Creek to the Dunka Pit deposit, help to define the location of the basal contact and its geometry in that area.

Also see the reference to the LTV Virginia Formation and iron-formation drill holes in the Wyman Creek area description.

SOUTH KAWISHIWI INTRUSION (SKI)

Northeast of the Partridge River intrusion is the South Kawishiwi intrusion (SKI). This intrusion extends along the basal contact from the Serpentine deposit and Dunka Pit iron mine area, of LTV Steel Mining Company, and east just into the Boundary Waters Canoe Area Wilderness (BWCAW) south of the Kawishiwi River, east of Minnesota Highway 1.

The South Kawishiwi is heavily drilled, with almost 800 drill holes and wedges, but unfortunately much of this core is gone or unavailable. About 290 INCO drill holes and about 165 LTV Steel Mining Company (Erie Mining at the time of drilling) drill holes have no core remaining, and about 70 drill holes and wedges are part of the ongoing Birch Lake exploration program and are not available to the public. Many of the other drill cores are lost or incomplete.

Work in the South Kawishiwi intrusion is made more complicated by a more complex geology than that of the Partridge River intrusion. At Babbitt and Dunka Road, as well as throughout most of the Partridge River intrusion, the tabular stratigraphic format of wide, but thin, major (map or cross-section) units works well in describing the igneous stratigraphy. This is especially true in the footwall area. In general, units in the Partridge River intrusion do not seem to repeat. However, in the South Kawishiwi intrusion the drill hole data must be put on cross-section and examined in context to fully make sense, as there are discontinuous horizons, many isolated textural and mineralogical changes, vertical repetition of many units, more inclusions of uncertain origin, more interfingering of rock types and map units, and less of an overriding and relatively clear igneous stratigraphy. The South Kawishiwi is made up of many sub-intrusions or sub-pulses, as is the PRI, but the localized nature of the drilling, combined with the absence of most of the core makes understanding the intrusion in the neat terms of the PRI problematic.

Serpentine

The Serpentine area is classed as both part of the Babbitt deposit and as a separate deposit. The drill hole numbering at Serpentine is continuous and intermixed with Babbitt, as both were drilled by Bear Creek/AMAX on the same grid, at the same time.

The Serpentine drilling was done to target a magnetic high or electromagnetic conductor associated with a massive sulfide at the basal contact. This massive sulfide is mostly pyrrhotite. Overall, the Serpentine deposit has average copper-nickel values slightly lower than the Babbitt deposit (Zanko et al., 1994). The massive sulfide of the Serpentine deposit (or very similar material) crops out at the south margin of the Peter Mitchell taconite mine of Cliffs NorthShore Mining.

Zanko et al. (1994) and Severson (1994) describe this area in the most detail, with Miller et al. (2002) providing the most recent background information on the South Kawishiwi intrusion.

Dunka Pit

Drilling at Dunka Pit iron mine includes drilling by Erie Mining Company (LTV Steel Mining Company) for taconite of the Biwabik Iron Formation beneath the Duluth Complex, and drilling by Newmont, Bear Creek, Duval, and Exxon for definition of the copper-nickel material above the iron-formation.

Much of the LTV core is lost, and the best records were notebooks of drill data kept at LTV, which is now closed. Presumably Cleveland Cliffs Incorporated kept these data after their 2002 purchase of LTV Steel Mining Company after the LTV bankruptcy.

A large amount of sulfide-bearing Duluth Complex material was moved to mine the iron ore at the Dunka Pit. This material is stockpiled on the south side of the Dunka Pit iron mine area.

Birch Lake

Birch Lake is an ongoing exploration and development project managed by Lehmann Exploration Management for the Beaver Bay Joint Venture. The primary target here is a deep zone or zones of higher grade platinum group minerals with associated copper-nickel-cobalt values.

As an ongoing project, much of the data developed since 1995 for Birch Lake is held confidential by the company. For this database, we used data from drill hole abandonment reports for the holes drilled since 1995. For the most part, the Birch Lake data is primarily included as "placeholder" data to remind geologists that work is ongoing there, and once project development is further along, more data may be forthcoming from the company.

Drilling on this property includes seven holes by Duval (with core available) and seventy-three holes and wedges by Lehmann Exploration Management.

The Birch Lake area straddles the county line between St. Louis and Lake counties. It is located on the southern shore of Birch Lake in the Bob Bay area, two or three miles east of the Dunka Pit iron mine and exploration area.

See the survey table discussion section for comments about the treatment of the many wedge holes at Birch Lake with no publically available orientation data.

Little Lake Road (Birch Lake North)

The Little Lake Road area (Birch Lake North by Peterson, 2001) could also be classed as a part of the Birch Lake area. The area parallels the north side of Birch Lake, west of Minnesota State Highway 1. The drilling here (fifteen holes) is older work by INCO and Bear Creek, with two holes in 1990 by Lehmann. Peterson et al. (2001 and in prep.) have collected some surface samples and refined the geologic map for the area, which is a small area of Duluth Complex at the corner of a USGS quadrangle sheet covering mostly Archean granitic rocks.

Maturi

Maturi (also historically listed as Maturi Road) lies on the south side of Birch Lake and the Kawishiwi River, west of Minnesota Highway 1, and is a deep mineralized zone below an extensive thickness of homogenous troctolitic rocks. Virtually all previous work in this area was by INCO (43 holes), who still control the federal leases. There are a few Hanna Mining and Duval drill holes (10 holes), and Wallbridge Mining put down one hole in 2000 to twin an INCO hole.

The geology of this area is covered in Severson (1994) and Miller et al. (2002). Peterson (2002) has done some re-definition of ore zones based on mineralization styles related to the above mentioned homogenous troctolitic rocks.

The database includes "Maturi Underground" for twelve holes INCO drilled from a drift, and a single hole for "Maturi Extension" to the south. We did not completely succeed in reconciling the number of underground drill holes for which we have records with the available drift map. MDNR or INCO may have better maps.

South Filson Creek

South Filson Creek area is a mineralized zone relatively high up in the Complex. There is no evident relation to the footwall rocks, which is not the case for most Duluth Complex sulfide deposits. The deposit is located south of the Spruce Road deposit on Forest Road 181 (Spruce Road), east of Minnesota State Highway 1. This is a property originally drilled by Hanna in the 1960s with one drill hole by Duval (about 28 drill holes total). An NRRI report was done on this area in 1990 (Kuhns et al.). This report was done before any South Kawishiwi intrusion igneous stratigraphy had been outlined, so no unit definitions were given. Most likely all of the South Filson Creek deposit is in the "AT&T" unit of the SKI (Severson, pers. comm., 2003).

The 1990 NRRI report indicted some PGE potential. The deposit is currently under lease to Encampment Resources of Jelm, Wyoming. William Cronk at the University of Minnesota Duluth (UMD) began a masters thesis on this area in the early 1990s. It was not finished, but some of his work may be on file at UMD.

Spruce Road

Spruce Road (also east of Highway 1 along the south side of the Kawishiwi River) is another large INCO project. Along with Maturi, it was one of the two they intended to develop in the 1970s.

There are over 200 drill holes in the Spruce Road area, but almost no core available. Most of this drilling was by INCO with a few drill holes by Bear Creek and the United States Bureau of Mines (USBM). The three USBM holes are among the first copper-nickel exploration holes drilled into the Complex in 1953.

The database groups these holes into Spruce Road, Spruce Road East, Spruce Road West, and Spruce Road Southwest. These area names have no meaning outside of how NRRI has classed these drill holes at various times for various projects.

Highway 1 Corridor

The Highway 1 Corridor is a Severson (1994) term for a group of deep holes along Highway 1 to the south of the South Kawishiwi River. These are the deepest holes in the Complex. The seven holes average about 4,300 feet in depth, with the deepest being 5,225 feet deep. This is a mix of drilling by Newmont and Duval. The holes intersect a thick package of anorthositic rocks, presumably a large raft of earlier Anorthositic Series, that overlies a thin zone of SKI copper-nickel mineralization near the basal contact. Peterson (2002) refers to part of this area as the "Maturi Extension", and the raft as a large anorthositic "pillar".

BALD EAGLE INTRUSION

There are about ten drill holes scattered throughout the Bald Eagle intrusion (BEI). The exploration areas in the Bald Eagle intrusion include Slate Lake East, Tomahawk Trail, and Fools Lake. These are not well defined prospective areas, but simply names taken from drilling areas. The BEI is located to the south and east of the South Kawishiwi intrusion, and to the north of the Greenwood Lake intrusion. Note that drill hole NE-2-MDNR may collar in the Greenwood Lake intrusion or a raft of Greenwood Lake intrusion rock in the Bald Eagle intrusion. See Miller et al. (2002) for more description and references.

MISCELLANEOUS INTRUSIONS–GUNFLINT CORRIDOR

The Gunflint Corridor drilling penetrates the Poplar Lake intrusion (PLI), Tuscarora intrusion, Brule Lake intrusion, Crocodile Lake intrusion (CLI), and the Logan Sills. This area lies along the Gunflint Trail, Cook County Highway 12, which connects Grand Marais to Saganaga Lake on the Minnesota-Ontario border. This is not a single group of drill holes, but many holes over a fairly wide area. All drill holes in Cook County are broadly defined as being in this group. Part of the reason for defining this as the Gunflint Corridor is the difficulty in access from the west. These areas are best accessed from the east along the Gunflint Trail.

The information given in the database for the Gunflint Corridor drill holes is based on historic logs, and the "quick scan" logging of drill holes by Severson in preparing data for the Duluth Complex mapping project (Miller et al., 2002). Because fully describing these holes would require further logging and probably an attempt at a definition of an igneous stratigraphy for this relatively unstudied area, these descriptions are much abridged and abbreviated. The main purpose of the data given here is to define general rock types to align with any assays we find for these drill holes in the future and to show that some Duluth Complex (or other Keweenawan intrusive) rock has been drilled in this area. As with all of the deposit areas, interested parties should consult the records held at the NRRI and the MDNR prior to doing any projects in the area.

The drill hole locations for the Gunflint Corridor holes have been problematic. The drill hole locations here are roughly those in Miller et al. (2002), and represent what we think are valid locations, but much of the written and unwritten record of work in this area has been lost over the last few years as older geologists have retired or moved on to other projects outside of Minnesota. Most of this company work was done before the current MDNR requirements for exploration data submission were in place. There is a possibility that there is much more iron-formation or massive-oxide (ilmenite) related exploration data for this area, but it has not been found.

MISCELLANEOUS INTRUSION–INTERIOR DULUTH COMPLEX

Greenwood Lake Intrusion (GLI)

This Duluth Complex drilling was done by the Minnesota Geological Survey to define geology in an area of very poor exposure. These drill holes are "touchdown holes" where the core drilling generally only penetrates about 10 feet of the ledge.

These holes were drilled along the LTV railroad grade to the west of Lake County Highway 2, north of Two Harbors.

The data source for these holes is Miller (in prep.), where there is a more complete description and some whole rock analyses.

Osier Lake Intrusion

The Osier Lake intrusion (defined by magnetic signature) has two drill holes, one by the MDNR (NR-1-MDNR), and one by the MGS (CDC-14B). Miller et al. (2002), suggests that this may a feeder zone for a now eroded intrusion that was higher up in the Complex. The area is near Isabella in central Lake County.

BEAVER BAY COMPLEX AND NORTH SHORE VOLCANIC GROUP

Milepost 7

The Milepost 7 drill holes, at the NorthShore Mining (Reserve Mining Company) tailings basin near Silver Bay, were located by Miller et al. (2002) for the 2002 Duluth Complex compilation project. A comprehensive listing of the total depths for these ninety five drill holes, as well as any detailed logging, are not available. <u>The drill holes were given an artificial and arbitrary depth to ledge of 50 ft. and a total depth of 100 ft</u>. The collar elevation was arbitrarily set to 1,200 feet above sea level. These drill holes are listed here to maintain consistency with the data in Miller et al. (2002). There is <u>probably</u> not any core available for these drill holes, and the area (private property) is now under tailings from the iron ore concentrating plant at Silver Bay.

Dr. John C. Green of the University of Minnesota Duluth produced a report for the Minnesota Geological Survey in 1982 titled: "Geology of the Milepost 7 Area, Lake County, Minnesota." This report, and the modifications made to the regional geology in Miller et al. (2002) would give the best picture of the geology of that area. NRRI has draft copies of some of Green's cross-sections used in his report, but they do not appear to be a complete set. The drill holes pass through glacial till and lake clays, and penetrate units of the North Shore Volcanic Group (NSVG) and undivided hypabyssal rocks of the Beaver Bay Complex (BBC). Some whole rock assays are reported in Green (1982), but no metals assays are known to exist.

Green's report references at least five reports written on drilling in the area during the preparation of the Environmental Impact Statement (EIS) for the Reserve Mining tailings pond project. These reports are by Klohn Leonoff Consultants (now Klohn Crippen?). Further information on this drilling could possibly be obtained from Cliffs NorthShore Mining of Silver Bay (successor company to Reserve Mining), the Minnesota Pollution Control Agency (if such EIS background records are kept), or Klohn Crippen, if they still have these data, and are allowed to release it.

Sonju Lake Intrusion (SLI)

The Sonju Lake intrusion of the Beaver Bay Complex (in the Finland area) has been drilled by the MGS (two holes) for scientific purposes (to discriminate a potential PGE-bearing horizon related to closed magma chamber crystallization processes) and by Lehmann Exploration (six holes) to further test this theory. The MDNR also drilled one hole in this area. The PGE-enriched horizon is found in drilling where predicted by outcrop mineral chemistry. The drilling and assay data are not sufficient to define a specific deposit area yet.

Miller (1999) discusses the logic of this exploration approach. Currently (2003), Greg Joslin of the University of Minnesota Duluth Geology Department is working on a masters thesis on these drill holes.

Cloquet Lake Layered Series (CLLS)

The Cloquet Lake layered series (CLLS) of the Beaver Bay Complex covers an area about 15 miles north-south and 10 miles east-west with Lake County Highway 2 on its west, Lake County Highway 15 (Forest Highway 11) cutting across the middle third, and Lake County Highway 4/Minnesota Highway 1 on the east. Outcrop is poor, and the intrusion is mainly defined by a pronounced circular aeromagnetic signature (Miller et al., 2002). Drilling here includes ten MGS "touchdown holes" (Meints et al., 1993), three holes with no record (related to the Milepost 7 drilling), and four holes by Lehmann Exploration Management in the 1980s.

APPENDIX 2

SURVEY TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE (GCDBDC.MDB) AND SPREADSHEET FILES (SURVEY.XLS, SURVEY.CSV)

APPENDIX 2: SURVEY TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE AND SPREADSHEET FILES

SURVEY TABLE INTRODUCTION

This table lists the downhole survey data available for each drill hole. In this database we have included the extensive downhole dip and azimuth surveying at Babbitt / Serpentine in "from-to" interval format. The majority of the other holes do not have downhole azimuth testing, and use simpler acid tests. In these cases, we need to make assumptions about which compass direction the hole deviated towards to use this data. We assume that all holes turned northwest (into the basal contact). This assumption is in line with those made by most of the exploration companies.

The Babbitt / Serpentine data was taken from Patelke (1994), most of the other drill holes with acid tests were taken and reformatted (recalculated from "mid-point" of interval to "from-to" for interval) from Peterson (1997). Those drill holes with no downhole work done (or recorded here) are given the collar dip and azimuth for the length of the drill hole. Some modeling programs will require that the survey data be in this separate file, even if there is no change in the data downhole.

Dip is given as a negative value for holes from the surface. Note that some drill holes in the Local Boy (underground) portion of the Babbitt deposit and a few holes at Maturi underground were drilled upwards from the drifts, and therefore have a positive dip.

SURVEY DATA

The format for the survey table is:

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length along core in feet
DIP: Dip of survey interval, -90˚ equals straight down
AZIMUTH: azimuth of survey interval clockwise from true north, for vertical holes the azimuth equals 0˚
SURV-TYPE: Type of survey, see Patelke (1994) for further description of the Babbitt and Serpentine surveys. In other cases this is a rough estimate of type of survey based on easily available data.
DSURVFROM[X]: desurveyed easting-interval "from" easting in NAD27 state plane feet
DSURVFROM[Y]: desurveyed northing-interval "from" northing in NAD27 state plane feet
DSURVFROM[Z]: desurveyed elevation-interval "from" elevation in feet above sea level
DSURVTO[X]: desurveyed easting-interval "to" easting in NAD27 state plane feet
DSURVTO[Y]: desurveyed northing-interval "to" northing in NAD27 state plane feet
DSURVTO[Z]: desurveyed elevation-interval "to" elevation in feet above sea level
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel. This shows which file set this drill hole is in, either "EAST" or

“WEST”, *.XLS and *.CSV. This designation is carried for each data type, even though only the lithology and assay files were split.

This format accounts for the entire drill hole length, i.e., all intervals, measured or not, are listed in the file. The sum of the intervals equals the length of the drill hole.

APPENDIX 3

LITHO (LITHOLOGY) TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE (GCDBDC.MDB) AND SPREADSHEET FILES (EAST-LITH.XLS, WEST-LITH.XLS, EAST-LITH.CSV, AND WEST-LITH.CSV)

APPENDIX 3: LITHOLOGY TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE AND SPREADSHEET FILES

LITHO TABLE INTRODUCTION

This is the lithological data for each hole in "from-to" interval format. This information covers the NRRI logging, filled in on a hole by hole basis with company data for holes either unavailable or not yet logged by NRRI.

LITHO (LITHOLOGY)

The format is:

- DDH: drill hole number
- FROM: start of interval relative to collar in feet
- TO: end of interval relative to collar in feet
- INTERVAL: interval length in feet measured along core
- ROCKTYPE: logged rocktype by abbreviation
- EXP-RTYPE: logged rocktype-full name
- CON-RTYPE: example of consolidation of rocktype
- UNIT: cross-section (map) unit
- NRRI–XSECT: NRRI cross-section showing this drill hole
- COMP-XSECT: which original company cross-section this hole would be on, done only for Babbitt and Dunka Road
- FW-MARKER: marks interval as overburden, Complex, or footwall
- FW-FROM: interval "from" going up from drill hole from footwall penetration point, in feet
- FW-TO: interval "to" going up from drill hole from footwall penetration point, in feet
- GEOLOGIST: geologist responsible for logging, as in header file
- DEPOSIT: which deposit, as in header file
- DSURVFROM[X]: desurveyed easting-interval "from" easting in NAD27 state plane feet
- DSURVFROM[Y]: desurveyed northing-interval "from" northing in NAD27 state plane feet
- DSURVFROM[Z]: desurveyed elevation-interval "from" elevation in feet above sea level
- DSURVTO[X]: desurveyed easting-interval "to" easting in NAD27 state plane feet
- DSURVTO[Y]: desurveyed northing-interval "to" northing in NAD27 state plane feet
- DSURVTO[Z]: desurveyed elevation-interval "to" elevation in feet above sea level
- XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel. This shows which file set this drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV. This designation is carried for each data type, even though only the lithology and assay files were split.

This format accounts for the entire drill hole length, i.e., all intervals, logged or not, are listed in the file. The sum of the intervals equals the length of the drill hole.

Explanation:

The entries in this table not self-evident after inspection of the other table descriptions are the following: ROCKTYPE:, EXP-RTYPE:, CON-RTYPE:, UNIT:, FW-MARKER:, FW-FROM:, and FW-TO:. The expanded descriptions are below, first the four lithology related intervals (ROCKTYPE:, EXP-RTYPE:, CON-RTYPE:, and UNIT:), followed by the footwall marker and distance discussion (FW-MARKER:, FW-FROM:, and FW-TO:).

ROCKTYPE-LOGGED ROCKTYPE BY ABBREVIATION CODE

The rock naming and unit designation conventions are where a familiarity with the previous work on the Complex becomes most important. Miller et al. (2002), the references therein, and NRRI reports listed in the introduction are the best possible explanations of this terminology. The rock type explanations here are very cursory at best. Mark Severson assisted in the outline of rock types and units described here.

The lithology coding for rocktype and unit in these data files is not perfect. Time did not permit the entering of every detail recorded in the logging. Because the purpose here is to make these data available for deposit-wide or regional evaluation, we wanted to make comparisons of rocktype versus assay value a relatively simple process, as well as using our "map unit" (or "cross-section unit") as a way of grouping the rocktype intervals together into presumably related packages. We wanted these rocktype names to be meaningful when viewing computer generated cross-sections at a reasonable scale on screen, in programs such as Gemcom, MedSystem, DataMine, etc. There is an overriding assumption here that these data will be used by someone familiar with one of these or similar programs, and/or be well versed in sorting and the use of filters in Excel or other spreadsheets. The concept followed in rock naming was to simplify, on the assumption that too many modifiers of rock names would make meaningful sorting or display all but impossible.

In the NRRI logging, we have generally used a modification of the Phinney (1972) system (Fig. 3). Names for mafic rocks are based on the visually estimated modal percentages of plagioclase, olivine, and augite. We have also added some definitions to our rock naming convention to accommodate the needs of logging. These are not necessarily the naming conventions we would use for detailed petrological study or more formal publication. Below is some explanation of these logging codes. For a rigorous discussion on how Duluth Complex rock types and units should be formally named see Miller et al. (2002).

The database is predicated on the user using the rocktype designation and cross-section unit designation in tandem to filter data. In other words, it is possible to sort data by rocktype, by unit, or by both.

The rocktype name (and modifier) is based on the shortest possible name that describes that interval. Rather than redescribing every possible rock name code in the database, we have added a column in the lithology table with the rock code expanded to its full name.

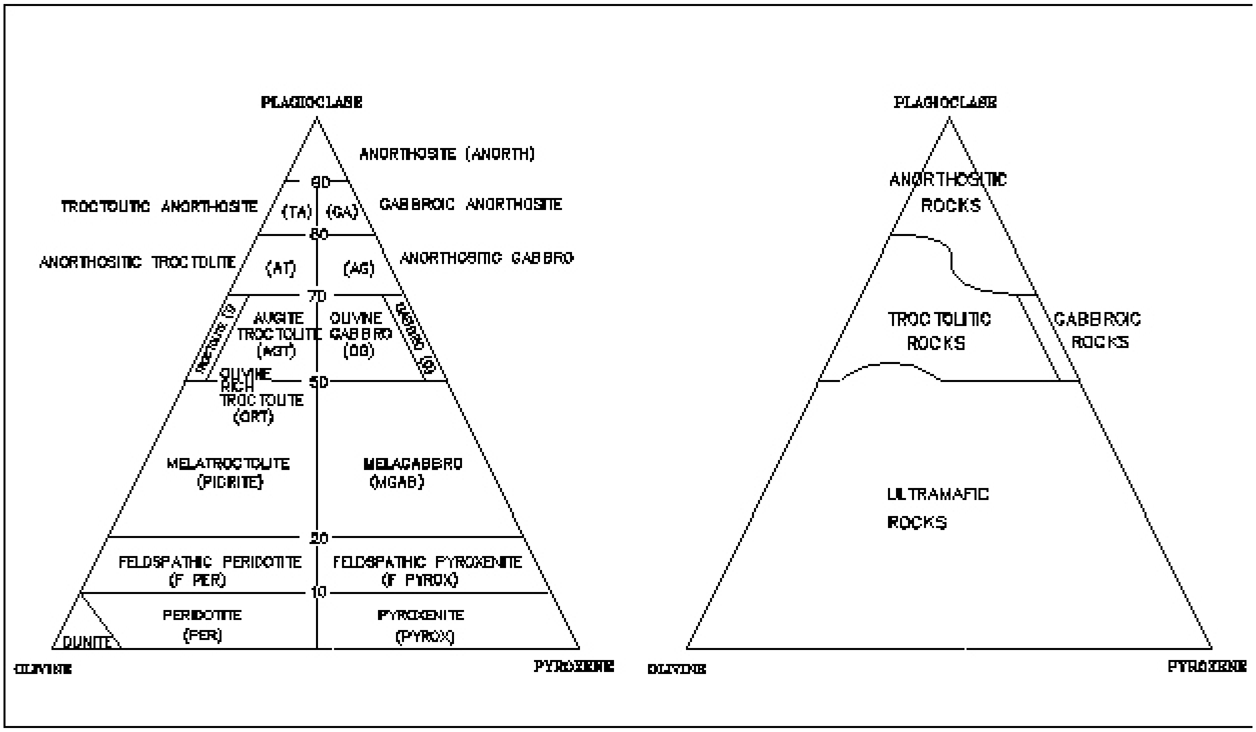

Figure 3. Modified Phinney (1972) diagram for rock unit classification on left side. Right side shows how units were consolidated in the database as an example of simplifying the data.

In the data file we present the rock types for the interval as we recorded them, as well as an example version of how these rock types can be condensed down to a manageable number (somewhat less than 2,000). We also placed rocktype names and modifiers in an order with the name first, followed by the modifier. A white granophyre vein is listed as "vein granophyre white", a massive oxide interval is listed as "oxide massive", and a heterogeneous augite troctolite is listed as "AGT HET", which expands to "heterogeneous augite troctolite". Hopefully, this will lead to easier sorting for users.

Hyphenated rock names for intervals, such as "AGT-T" (augite troctolite-troctolite) or "MT-ORT" (melatroctolite-olivine rich troctolite) can be read as either "and" or "to" because the judgement used here was to make each lithologic interval homogenous, i.e., what would the mineralogy or chemistry of the interval show if tested as a single sample. The lithology intervals for logged drill holes average about fifteen feet. Therefore, each one represents a tiny part of the total.

For each interval we recorded the rocktype as given on the log. Here are two examples of how this looks:

1) The data file will show an interval, for example, as "AGT" (augite troctolite), "OG" (olivine gabbro), "H CORD" (cordieritic hornfels), or "VF MASSIVE" (massive Virginia Formation). These single rocktype intervals are fairly straightforward. Considering that the Phinney (1972) diagram shows 17 individual rock types, and considering a variety of hanging wall and footwall rocks, plus

combinations of rock types, one might guess there would be between 50 and 100 rock types in the data file. In reality, there are over 2,000 different abbreviations recorded after much simplifying.

A problem in this simplifying of rock type is that a hyphenated interval recorded as "AGT-OG" (augite troctolite-olivine gabbro) carries no record of whether this means:

a) augite troctolite and olivine gabbro in equal amounts;

b) augite troctolite with lesser olivine gabbro, a gradation from one part of the interval to another;

c) a mineralogy that falls between augite troctolite and olivine gabbro on the Phinney diagram, let alone how these rock types (and their textures) are mixed or intermingled over this interval.

2) Another example is the "AT-T" (anorthositic troctolite-troctolite) . This could be:

a) a mineralogical range of AT to T (anorthositic troctolite to troctolite);

b) mixed thin intervals of AT and T (anorthositic troctolite and troctolite);

c) AT grading to T (anorthositic troctolite grading to troctolite).

Various geologists have used various schemes, with logging done for different purposes. This situation makes trying to offer more definitive definition of a term such as AT-T difficult. There are at least five references for AT-T in our logging, these are: (AT)T, AT-T, AT/T, AT & T, and AT-(T). This coding is simpler to understand on the logs themselves, where they can be read in complete context.

For intervals that span across entire fields (i.e., skip fields) on the modified Phinney triangular diagram, such as "AT-MT" (anorthositic troctolite-melatroctolite) the usual case is that both distinct rock types were present in the interval.

For intervals recorded with more than two very distinct rocktypes, we usually tried to consolidate this to two names. Also, in some cases we used "W/" such as "NOR W/H" for norite with sedimentary hornfels or "NOR W/H BASALT" for norite with basalt inclusion(s).

In sum, the view taken here is this: in the Duluth Complex (especially in the area where the majority of the drilling is recorded) the rocks are heterogeneous cumulate rocks as a rule. The logged lithological intervals in the database average about 15 feet. Any individual interval represents a very tiny increment of the total drilling. It would be best to read the interval descriptions in the data file as representing a data point on the Phinney diagram, which is essentially what their chemical or mineralogical analysis would show. For more detailed studies, either don't use the mixed rock types, or refer back to the original logs and re-code the lithology to meet your needs. In other words, we intend this data to be used *en* *masse* where a large number of intervals ought to average out to a limited number of simple names.

Modifiers

We have tried to limit the number of modifiers to these rock names. The main ones are:

a) "HET" for heterogenous, where there are rapid and inconsistent changes in modal percentage and/or grain size over very short distances. It is common to see packages of rock where no one description fits at any given point in an interval, even over very short intervals;

b) "HOMO" for homogenous, where the rocks are marked by very consistent modal percentages and/or grain size;

c) "PEG" is used both as a modifier and a rocktype, meaning very coarse-grained. Generally, but not always, it is assumed to be an irregular, patchy phenomenon, and it is usually gabbroic;

d) "MOTT" for mottled, which is a characteristic mottling caused by poikiolitic olivine, especially in Unit 3 of the Partridge River intrusion (Unit III of Severson and Hauck, 1990), but present elsewhere.

Some less used, but present, modifiers include: graphite or graphitic for graphite-bearing intervals, ural (uralitized, i.e., pyroxene replaced by amphibole), serp (the olivine is serpentinized), and fluxion for plagioclase lamination.

Rock Names Not Covered By The Modified Phinney Diagram

Massive Sulfide (MS): where the logging geologist described an interval as massive sulfide (greater than 75% sulfide) we noted it as such. MS PO means massive sulfide pyrrhotite, MS CP means massive sulfide chalcopyrite and/or cubanite.

Semi-Massive Sulfide (SMS): where the logging geologist described an interval as semi-massive sulfide (50-75% sulfide) we noted it as such. SMS PO means semi-massive sulfide pyrrhotite. SMS CP means semi-massive sulfide chalcopyrite and/or cubanite.

Granophyre: refers to cross-cutting veins of felsic rock. These rocks are volumetrically unimportant. These veins are common and while they are most common in areas around fault systems, their presence alone has not proved to be diagnostic of proximity to a structure. Contacts are usually sharp. There are also ubiquitous saussurite patches that superficially appear to be granitic veins, generally these have gradational contacts with the surrounding rocks and contain some relict plagioclase.

Large amounts of ubiquitous patchy granophyre and felsic material generated by partial melting and seen in the footwall Virginia Formation are minimally recorded here. Almost any of the "recrystallized" (RXTAL) or "disrupted" (DISRUPT) Virginia Formation intervals will contain some evidence of partial melting.

The veining in the SKI may consist of the "usual" Duluth Complex granophyric veining, as well as a large amount of "backveining" nearer the base of the intrusion. This "backveining" is remelted Giants Range granite and has not been clearly discriminated in this database from the Complex differentiates. This is mostly due to lack of available core. Much of the geology notation for the SKI came directly from INCO logging and we have no way to correlate much of their detailed work with our own.

Faults: We have included "fault", "breccia", and "fault/breccia" as a rock type in this database where the logging geologist clearly felt an interval was a fault. This notation does not include strongly serpentinized zones (generally not noted in this database) nor zones intruded by granophyric rocks, and therefore represents a minimum starting point for correlating fault geometry from drill hole to drill hole.

For a number of reasons, faulting is problematic in these deposits:

a) the majority of drill holes are vertical and therefore might miss the expected half-graben normal faults;

b) the rocks can be non-descript over very long intervals;

c) large scale marker units (like Unit 3 in the PRI) are rare;

d) if there is offset it may be accommodated in the serpentinized ultramafic zones, but there is not good enough control on the continuity of specific ultramafic horizon to always use them as markers;

e) this lack of specific markers and the generally wide drill hole spacing helps prevent developing these correlations;

f) cross-sections drawn with and without faults can both work and be consistent with the dips seen in bedding of the iron-formation;

g) the lack of surface exposure means that there are few faults mapped at the surface that can be checked against drill data;

h) and the geophysical response of any of these faults is not distinct enough to use for mapping at less than 1:24,000 scale (J. Miller, pers. comm. 2003).

The RQD data for Babbitt, which might be expected to define some more broken up zones of rock, generally shows no <u>quickly evident</u> pattern to the 3-D geometry of more fractured rock. These data may be worthy of some detailed evaluation in this regard.

Massive Oxide: is listed as "oxide massive". This is usually ilmenite greater than magnetite. No other oxides are generally noted in the logs. Note that other oxides have been seen in thin and polished section, i.e., chromium magnetite, chromium titanomagnetite, chromite, hercynite, pleonaste, and others.

Semi Massive Oxide: listed as "oxide semi-massive".

Norite (and noritic rocks and orthopyroxenites): Noritic rocks with plagioclase-orthopyroxene +/- augite +/- olivine rocks are very common in the Duluth Complex, especially in areas where there has been digestion of disaggregated footwall rocks. These norites are probably not of a strictly igneous origin as seen in other layered intrusions, but rather are related to magmatic contamination through assimilation of pre-existing footwall rocks.

OUI (Oxide-bearing Ultramafic Intrusion): OUI is a class of cross-cutting oxide-bearing ultramafic rocks. OUI is used here as both a rocktype for the apparently discontinuous, but distinct, intervals of these rocktypes seen throughout the Duluth Complex; and as a unit name for large OUI bodies such as at Water Hen, Section 17, Section 22, Section 34, Longnose, Longear, and smaller bodies along the southern margin of the Babbitt Deposit.

Hornfels (H): is meant to encompass all inclusions that are not intrusive rock. These generally break down into four classes: Biwabik Iron Formation (H BIF), metamorphosed subunits of the Virginia Formation (H CORD, H DISRUPT, H RXTAL, etc.), hanging wall basaltic rocks (H BASALT, and some "CC" for Colvin Creek-type magnetic basalt inclusions), and some inclusions of Archean granitic and mafic rocks.

Scattered throughout the Duluth Complex are cognate inclusions of intrusive rock, for instance, anorthosite inclusions in troctolitic intervals. These have not been noted as inclusions in this database.

Where footwall rocks are detached from the footwall (inclusions moved into the Complex by dilation or floating), these rock names are preceded with an "H" for hornfels, such as "H CS" for hornfelsed calc-silicate or "H CORD" for cordieritic hornfels. Where these footwall rocks are thought to be in place, they are preceded with the map unit designator, such as "VF CORD" for cordieritic Virginia Formation, or "VF CS" for a calc-silicate horizon in the Virginia Formation. Therefore, a hornfelsed cordieritic Virginia Formation inclusion in Unit 1 of the Partridge River intrusion would be read as: "H CORD" in Unit 1; a Biwabik Iron Formation inclusion would be shown as "H BIF"; and basalt inclusions as "H BASALT".

Footwall Cordieritic Metasediments: (VF CORD in place or H CORD when they are present as inclusions). Directly beneath the basal contact of the PRI, metasediments of the Virginia Formation are generally cordierite-rich and display a bluish-gray color in drill core. Original bedding planes are preserved in some instances, but for the most part, the bedding planes have been obliterated by contact metamorphism.

Disrupted Unit (VF DISRUPT in place or H DISRUPT when present as inclusion) - well-bedded argillites of the Virginia Formation are commonly transformed into a highly deformed rock, or a metatexite (Sawyer, 1999), in close proximity to the Duluth Complex. Textures that characterize this rock are bedding planes that are extremely chaotic and random in orientation due to pervasive micro-folding, micro-faulting, and micro-brecciation. Superimposed on this chaotic pattern are abundant partial melt zones that are also chaotic and micro-folded. The overall texture of the DISRUPT unit appears to be a result of a combination of partial melting (in response to emplacement of the Duluth Complex) and intense pervasive structural deformation (also related to emplacement of the Complex).

Recrystallized Unit (VF RXTAL in place or H RXTAL when present as inclusion) - the RXTAL Unit is a higher-grade metamorphic equivalent of the DISRUPT Unit. However, in the RXTAL's case, the rock was heated enough to generate 20%-30% pervasive partial melts that enabled the rock to literally flow (pers. com. to Severson, Ed Sawyer, 1998) in response to stresses applied during emplacement of the Duluth Complex. All bedding planes are completely obliterated in the RXTAL Unit, and what remains is a recrystallized rock that contains medium-grained biotite flakes that are arranged in a decussate manner. Floating within this recrystallized matrix are blocks/boudins of more structurally competent siltstone and calc-silicate (originally limey layers).

Graphitic Argillite (usually VF GRAPHITIC in place or H GRAPHITIC when present as inclusion) - hornfelsed carbonaceous argillite is preserved as graphitic argillite in close proximity to the Duluth Complex. This rock commonly contains up to 5% disseminated pyrrhotite. <u>Whenever the pyrrhotite is concentrated in laminae (generally < 2mm thick), the rock is referred to as the Bedded Pyrrhotite Unit (BDD PO Unit).</u>

Bedded (VF BDD in place or H BDD when present as inclusion) generally non-descript, but bedded Virginia Formation or hornfels inclusions.

Virginia Formation undivided - (VF in place or H when present as inclusion) - generally non-descript, but without bedding noted on log, Virginia Formation or hornfels inclusions.

MG and V SILL (Virginia Sill) -The bottom-most, but discontinuous, portion of the Virginia Formation is referred to as the Massive Gray Unit (MG Unit). Originally, this unit was thought to represent massive-bedded graywackes of the Virginia

Formation; however, work at the Babbitt (Mesaba) Cu-Ni deposit (Severson, 1991; Severson et al., 1996; Hauck et al., 1997; Park et al., 1999) indicated that the MG Unit is a fine-grained equivalent (chilled?) of a sill with high Cr contents (>800 ppm). In some cases, the center of this Cr-rich Sill (Hauck et al., 1997) is easily recognized due to a coarse to medium-grained texture with olivine and/or hornblende (the coarser portion is listed here as V SILL for Virginia Sill). However, in most cases the presence of the sill is indicated by much finer-grained material, referred to as the MG Unit, which is extremely difficult to tell apart from the hornfelsed Virginia Formation. The age of the Cr-rich Sill/MG Unit is inferred to be early Keweenawan, but a much older age (1.8 Ga?) is also possible. The intrusion of this sill may be responsible for some metamorphism in the Virginia Formation, thus forming a thin "armored or refractory" horizon of previously metamorphosed rock that resisted assimilation during the intrusion of the Duluth Complex.

Biwabik Iron Formation - Beneath the Virginia Formation and the MG Unit is the Paleoproterozoic (1.8 Ga) Biwabik Iron Formation (BIF). The BIF is about 400 feet thick and has been subdivided into 22 submembers (A through V) by Gundersen and Schwartz (1962). The upper-most four submembers of the BIF are easily recognized and noted in the NRRI logging as follows:

> Submember A - well-bedded white chert and marble; chert and marble are present in varying proportions.
>
> The BIF Sill unit in the BIF generally occurs at this level.
>
> Submember B - irregularly-bedded white chert and diopside with local thin marble interbeds, generally non-magnetic.
>
> Submember C - magnetic, thin-bedded, slaty iron-formation with chert, magnetite, fayalite, and ferrohypersthene.
>
> There also Logan-type(?) sills in the C submember. See Miller et al. (2002).
>
> Submember D - magnetic, thin-bedded to wavy-bedded, cherty iron-formation.

When reviewing the NRRI cross-sections against the rock naming given by INCO, it seems that much of what they described in their logging as hornfels or metasediment is probably inclusions of iron-formation. Where Severson has interpreted INCO logs in relation to surrounding holes logged by NRRI, we see the U3 unit often overlapping with INCO's "hornfels" units. <u>See the Maturi Stratigraphic Line in Severson (1994) for examples.</u>

Also note that much of the unit definition of the sills below the Complex is based on post-logging interpretation during cross-section development. Any study of these sills needs to look beyond the limited data included here. The data here locate the sills, but as with many other items, the sills should be a study in themselves.

Mixed Duluth Complex (MX*)** - For drill holes either not logged by NRRI or with no clear (and reliable) company records, we have used the rock type "MXDC" for "mixed Duluth Complex", usually as MXPRI for Mixed Partridge River intrusion, MXSKI for mixed South Kawishiwi intrusion, MXBLI for mixed Boulder Lake intrusion, etc. We used this for <u>both</u> rock names and unit types.

In many cases the rocktype MX*** will be shown as being within an assigned cross-section unit. This unit definition is usually derived from surrounding drill holes.

Logging Differences

The question may arise that because of differences in logging by individual geologists over time, and the many geologists who have contributed to this work: are these different drill logs the same population? Yes, while definitions may vary between NRRI geologists, the dataset is as internally consistent as could be expected for work done over fifteen years.

Our comparisons of logs done by different NRRI geologists on the same holes, which include both scattered holes and 15,000 ft. to 30,000 ft. re-logging programs by different geologists at Dunka Road (NorthMet) and Babbitt (Mesaba) show a fair level of consistency. Rock names may be shifted by one classification on the Phinney (1972) chart (see Figure 3), but there is little wholesale disagreement between the NRRI geologists on rock naming.

We do observe that in the past many company geologists have probably overused the term "gabbro" in the Complex in their logging. These are rocks that the NRRI (and probably MDNR and MGS) geologists would have called troctolite, augite troctolite, olivine gabbro, gabbro, anorthositic troctolite, anorthositic gabbro, and olivine-rich troctolite. This naming is not due to ignorance on their part, but that their concern was with mineralization, and they often labeled all intrusive rock (particularly non-mineralized intervals) that was not clearly anorthositic nor ultramafic as "gabbro". It is quite possible that in terms of studying the mineralized rocks (and the distribution of mineralization) this level of lithological definition may be all that is needed.

EXP-RTYPE-logged rocktype-full name

This is simply the rock naming described above expanded to its full name, with some change in modifier order. Inspection of this field in the database should be self-explanatory.

CON-RTYPE-EXAMPLE OF CONSOLIDATION OF ROCKTYPE

This column is <u>an example</u> of how one can consolidate the rocktypes to a smaller dataset, in this case for example, mostly by merging adjoining fields on the Phinney diagram and removing the specific unit for rocks of the Virginia Formation and Biwabik Iron Formation. Inspection of the database will make it clear which rocktypes have been reduced to which name in this list. See Figure 3 for examples of how this naming scheme correlates with the original Phinney (1972) plot.

The Duluth Complex rocktypes have been reduced to:

Anorthositic
Troctolitic
Gabbroic
Noritic
Ultramafics
OUI
Vein
Fault/Breccia
Massive Graphite
Massive Chlorite
Massive Serpentine
Massive Oxide
Massive Sulfide
Hybrid
Pegs-Misc

The other (non-Duluth Complex) rocktypes are reduced to:

OVB
Dike
Sill
Basaltic Hornfels
Sedimentary Hornfels
Virginia Formation
Biwabik Iron Formation
Archean
Other (all other intervals)

UNIT-CROSS-SECTION (MAP) UNIT

This is the cross-section unit taken from the NRRI logging. For the most part the logging done by NRRI has been plotted on cross-sections and correlated with the geology in nearby drill holes. The unit data presented here is from those cross-sections or notations on the logs. Where the hole was not plotted on a cross-section, we either filled in the unit data from surrounding holes in areas where we have some confidence in the continuity of the geology, or used the MX*** notation to discriminate the unit as a part of a larger intrusion. This MX*** naming convention is very prevalent in the South Kawishiwi intrusion (MXSKI) where we have little confidence in the continuity of geologic description in areas where there is logging data for rocktype (mostly from INCO), but no core available to log.

The rock types and map units are presented as is if they were read off a moderately detailed cross-section, on the order of one inch equals fifty feet to one inch equals two hundred feet. This scale implies that to make the best sense of these data one should refer to the cross-sections from various reports that are listed for each hole, or look at nearby sections when a drill hole is not on a published cross-section.

The level of confidence in this unit assignment is directly related to the density of drilling in a particular area, and the amount of study we have made of that area. At Babbitt (Mesaba), Dunka Road (NorthMet), and the other Partridge River intrusion deposits, the igneous stratigraphy is fairly well-defined, and we are confident about the map units. In the South Complex area (between Duluth and Wyman Creek) the drilling density is less, and the confidence level is less. In the South Complex area, we generally find clusters of drill holes defining a local stratigraphy within an overlying (and not necessarily clear) framework.

In the South Kawishiwi intrusion (Serpentine, Dunka Pit, Birch Lake, Maturi, Spruce Road, South Filson Creek, and the Highway One Corridor) we again find clusters of drill holes each defining a local stratigraphy mixed within an overlying continuity from one deposit to the next, but not necessarily carrying across the entire intrusion.

The NRRI geologists recognize that the igneous stratigraphy is both "imposed" and natural, and is subject to changing interpretations. This report is not the venue to reconcile all possible solutions for the "stratigraphy" within these areas.

The only unit designations unique to this database, i.e., not found on published cross-sections, are some subdivisions of Unit 1 of the Partridge River intrusion. These are based only on the examination of the logs, and have not been field checked in any sense. These include: 1S1 ("Sub 1"), and 1NZ ("norite zone") which is the basal portion of Unit 1 that shows possible strong contamination from the underlying footwall rocks, i.e., norite, olivine gabbro, and/or a high percentage of hornfels inclusions. 1NZ is used at Dunka Road, and 1S1 is used at Babbitt and in the rest of the PRI drill holes. This zone does not extend upwards to the uppermost hornfels occurrence, but is limited to a continuous zone or rind of contaminated rocks of varying thickness adjacent to the basal contact. The 1S1 or 1NZ subdivision is not found in every drill hole. The other new subdivisions interpreted from the logs are 1UM1 and 1UM2, quasi-continuous(?) zones containing ultramafic horizons in Unit 1 at Babbitt. These ultramafic zones have not been field checked, but may correlate with ultramafic zones in Unit 1 mapped by Geerts (1991, 1994) at Dunka Road (NorthMet).

Footwall rocks units:

The various footwall rocks to the Complex include Virginia Formation (VF) deep water sedimentary rocks, Biwabik Iron Formation (BIF) banded iron-formation, Pokegama Quartzite (PQ) near shore sandstones, and the Giants Range batholith Archean rocks (GRB) which are mostly diorite/monzodiorite, quartz monzonite, and which often have inclusions of schistose rocks and Knife Lake Group metasedimentary rocks. There are some Keweenawan basalts that are (or appear to be) in contact with Virginia Formation or near to cordieritic metasedimentary rocks. Regionally, the Keweenawan basalts are hanging wall to the Duluth Complex, but locally they can also be classed as footwall units.

Hanging wall rocks:

These are Keweenawan basalts. Except for the basalts on top of anorthositic rocks seen in drill holes of the Highway One Corridor, these are mostly blocks detached from the roof, i.e., nowhere else besides Highway One is the roof of the intrusion seen intact in drill hole. These contact metamorphosed basalts include two broad classes of rock:

1) magnetic basalts with the assemblage plagioclase-augite-magnetite-ilmenite, generally with a gabbroic to gabbroic anorthosite mineralogy (Colvin Creek type rocks; Patelke, 1996);

2) non-magnetic basalts with the assemblage plagioclase-orthopyroxene with only minor oxides, generally a noritic mineralogy (Moose Mountain hornfels, Severson and Hauck, 1990). Both types may contain some olivine. (Patelke, 1996).

These rocks are usually classed as either H BASALT, or in the special case of inclusions of strongly magnetic, augite-bearing, metavolcanics similar to the Colvin Creek Body (Patelke, 1996) classed as "CC".

The Virginia Formation, the Biwabik Iron Formation, and the Giants Range batholith descriptions in these data files are somewhat generalized. The footages given are as shown on the logs, but much of the comment about bedding, foliation, partial melt horizons, mineralogy, etc. has been lost in the simplifying. Some sill horizons may also be absent from these data files. These units under the Complex are a study in themselves, and have usually been secondary to our purposes when logging these drill holes.

DISTANCE TO FOOTWALL MEASUREMENTS

FW-MARKER: marks interval as overburden, Complex, or footwall
FW-FROM: lithology interval "from" going up drill hole from footwall penetration point, in feet
FW-TO: lithology interval "to" going up drill hole from footwall penetration point, in feet

"From" and "to" relative to footwall, are the interval "from" and "to" distances upward (positive values) and downward (negative values) from the footwall intercept for drill holes that actually intercepted the basal contact (also estimated in a few rare cases), whether into Virginia Formation, Biwabik Iron Formation, or Giants Range batholith granitic rocks; these columns record the interval distance above (positive values) or below (negative values) from the contact. Using cross-table transfer in Gemcom one could then assign distance along the hole to the assays or other data for analysis, i.e., average distance for massive oxide horizons from basal contact, or build composite tables relative to footwall intercept point.

APPENDIX 4

ASSAY (COPPER-NICKEL ASSAYS) TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE (GCDBDC.MDB) AND SPREADSHEET FILES (EAST-CUNI.XLS, WEST-CUNI.XLS, EAST-CUNI.CSV, AND WEST-CUNI.CSV)

APPENDIX 4: ASSAY TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE AND SPREADSHEET FILES

ASSAYS INTRODUCTION

Essentially, all of the original assay work in the Duluth Complex is on copper-nickel sulfides. In a few cases, the emphasis was on massive oxides in the Oxide-bearing Ultramafic Intrusions (Longear, Longnose, etc.) and the assays for those oxides and other elements are not included here. Also, United States Steel almost always assayed for iron (also not included here except for Dunka Road), and INCO and others often assayed for cobalt (not included here). Not all companies assayed for sulfur.

The values listed in these tables and spreadsheets are generally the assays done at the time of original drilling and sampling, and usually represent the greatest number of samples done for a particular drill hole. The format here covers the entire hole top to bottom, with a "NS" marker for intervals not sampled in the original work. Not all elements were equally sampled for each interval or equally by each company.

While this data file contains a huge majority of the copper-nickel-sulfur assays available for the Duluth Complex, it does not contain every known assay. This table was mostly compiled from pre-existing digital data (Geerts et al., 1990; Patelke 1994; Zanko et al., 1994; and Peterson 1997) with minimal new data entry. Drill hole lengths were checked and the intervals that were not sampled were inserted into the data file with a "NS" value. All overlapping and duplicate assays were removed. Some of the duplicate data is in archive at NRRI in files not included in this report. The data as reported here are sufficient for regional work, but should absolutely be revisited for property specific projects.

COPPER-NICKEL ASSAY DATA

The format is:

- DDH: drill hole number
- FROM: start of interval relative to collar in feet
- TO: end of interval relative to collar in feet
- INTERVAL: interval length in feet along the core
- COPPER: copper in percent
- NICKEL: nickel in percent
- SULFUR: sulfur in percent
- CU+NI: copper plus nickel in percent
- CU/NI: copper/nickel ratio
- CU/S: copper/sulfur ratio
- DEPOSIT: which deposit
- DSURVFROM[X]: desurveyed easting-interval "from" easting in NAD27 state plane feet
- DSURVFROM[Y]: desurveyed northing-interval "from" northing in NAD27 state plane feet
- DSURVFROM[Z]: desurveyed elevation-interval "from" elevation in feet above sea level

DSURVTO[X]: desurveyed easting-interval “to” easting in NAD27 state plane feet
DSURVTO[Y]: desurveyed northing-interval “to” northing in NAD27 state plane feet
DSURVTO[Z]: desurveyed elevation-interval “to” elevation in feet above sea level
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 record limit of Microsoft Excel, this shows which file set this drill hole is in, either “EAST” or “WEST”, *.XLS and *.CSV. This designation is carried for each data type, even though only the lithology and assay files were split.
DATASOURCE: These data were mostly taken and reformatted from Geerts et al. (1990), Patelke (1994), and Peterson (1997). Minimal data were entered to fill in this table. The reformatting involved checking all drill hole lengths to match the total depth recorded in the header file, and intervals with no samples were filled in with “NS”. Duplicate samples and overlapping samples (usually from different sources) were removed and mostly set aside in digital format. There are about 1,500 such intervals from a variety of sources. Previous data entry work was not checked for completeness nor correctness. Peterson’s (1997) data as received were formatted to the third decimal place; the other data were not. All values were reset to two decimal places. The data Peterson used for the INCO drill holes mostly came directly from INCO. NRRI (and MDNR) have the paper data for this assay work on file.

Because the overall purpose of this project was to digitize the lithological logging, not the assay work, these data represents a minimum of the assay data available. However, it is believed that this constitutes the great majority of the available assay data. As with many other items, contact the NRRI geologists if getting every last assay record for an area becomes critical.

This format accounts for the entire drill hole length, i.e., all intervals, sampled or not, are listed in the file. The sum of the intervals equals the length of the drill hole.

APPENDIX 5

RQD (ROCK QUALITY DESIGNATOR) TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE (GCDBDC.MDB) AND SPREADSHEET FILES (RQD.XLS AND RQD.CSV)

APPENDIX 5: RQD TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE AND SPREADSHEET FILES

RQD INTRODUCTION

This is the RQD (Rock Quality Designation) data calculated by AMAX for the Babbitt and Serpentine deposits. There are no known public data on these rock properties available for any other exploration areas in the Duluth Complex. It is unknown if this work has been done elsewhere.

The calculation of RQD values for the Babbitt and Serpentine deposits is explained in an AMAX inter-office memo dated February 4th, 1976, on file at NRRI and MDNR. In short, RQD is a recovery percentage and rock strength value calculated from length and number of core pieces, number of natural fractures, and amount of core actually recovered over the measured interval (Patelke, 1994).

Contact NRRI or the MDNR for information about the AMAX memo detailing the calculation of the RQD values.

The format is:

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INTERVAL: interval length along core, in feet
RQD: RQD value as calculated by AMAX. Higher number equals more natural fractures.
DSURVFROM[X]: desurveyed easting-interval “from” easting in NAD27 state plane feet
DSURVFROM[Y]: desurveyed northing-interval “from” northing in NAD27 state plane feet
DSURVFROM[Z]: desurveyed elevation-interval “from” elevation in feet above sea level
DSURVTO[X]: desurveyed easting-interval “to” easting in NAD27 state plane feet
DSURVTO[Y]: desurveyed northing-interval “to” northing in NAD27 state plane feet
DSURVTO[Z]: desurveyed elevation-interval “to” elevation in feet above sea level

APPENDIX 6

PGE, WHOLE ROCK, AND TRACE ELEMENT DATA FOR DULUTH COMPLEX DRILL CORE SAMPLES (TAKEN FROM SEVERSON AND HAUCK, 2003) TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE (GCDBDC.MDB) AND SPREADSHEET FILES (PGE-ETC.XLS AND PGE-ETC.CSV)

APPENDIX 6: PGE, WHOLE ROCK, AND TRACE ELEMENT DATA FOR DULUTH COMPLEX DRILL CORE SAMPLES (TAKEN FROM SEVERSON AND HAUCK, 2003) TABLE FORMAT AND EXPANDED DESCRIPTION FOR GEMCOM DATABASE AND SPREADSHEET FILES

PGE DATA INTRODUCTION

These data are taken from the Severson and Hauck (2003) report and compilation of PGE and other data for the Duluth Complex. This text is a repeat of the text from the earlier section in this report.

Assays PGE and Others Table-Short description

In general, except for in the Birch Lake area, all publically available PGE and precious metal assaying done in the Duluth Complex was done after the original Cu-Ni sampling. Sometimes this was on the same pulps, sometimes on composites, and sometimes on fresh core. Morton and Hauck (1987) summarized the assaying up to that point in time and added some new analyses. The data in this table is taken from Severson and Hauck (2003) and represents all publically available data on file at MDNR and NRRI. It is important to stress that there may be other proprietary data for Dunka Road/NorthMet (PolyMet), Babbitt/Serpentine (Teck Cominco), Birch Lake (Lehmann), and Maturi (Wallbridge and INCO) areas, as well as other locations.

Besides PGE data, this table includes some major, minor, and trace element analytical data. Reference should be made to Severson and Hauck (2003) for information on the quality and source of individual samples.

The format here does <u>not</u> account for the entire length of the drill hole, only including intervals that were sampled. About 1,000 duplicate and overlapping intervals have been removed from this dataset. The dataset in Severson and Hauck (2003) is far more complete.

DDH: drill hole number
FROM: start of interval relative to collar in feet
TO: end of interval relative to collar in feet
INT-AS-TXT: "from-to" for interval as single text entry
LENGTH: length along core of sample interval
INTRUSION: which intrusion drill hole is in
UNIT: rock unit, from Severson and Hauck (2003)
ROCKTYPE: rock type, from Severson and Hauck (2003)
DEPOSIT: deposit drill hole is in
AU-PPB: gold in parts per billion-as recorded in original data
PT-PPB: platinum in parts per billion-as recorded in original data
PD-PPB: palladium in parts per billion-as recorded in original data
CU-PPM: copper in parts per million-as recorded in original data
NI-PPM: nickel in parts per million-as recorded in original data
S%: sulfur in percent-as recorded in original data
CO-PPM: cobalt in parts per million-as recorded in original data
ZN-PPM: zinc in parts per million-as recorded in original data

AG-PPM: silver in parts per million-as recorded in original data
AU-PPM: gold in parts per million-as recorded in original data
AS-PPM: arsenic in parts per million-as recorded in original data
CR-PPM: chromium in parts per million metal-as recorded in original data
TIO2%: titanium as percent oxide as reported in original data
TI%: titanium as percent, metal as reported in original data
MGO%: magnesium as percent oxide as reported in original data
MG%: magnesium percent metal as reported in original data
CR2O3%: chromium as percent metal as reported in original data
CL-PPM: chlorine in parts per million-as recorded in original data
MO-PPM: molybdenum in parts per million-as recorded in original data
V-PPM: vanadium in parts per million-as recorded in original data
CU/PD: copper:palladium ratio
CU%: copper percent, calculated from ppm data
NI%: nickel percent, calculated from ppm data
REFERENCE: data source, see Severson (in prep) for details on sample selection
DSURVFROM[X]: desurveyed easting (interval "from" easting in NAD27 state plane feet)
DSURVFROM[Y]: desurveyed northing (interval "from" northing in NAD27 state plane feet)
DSURVFROM[Z]: desurveyed elevation (interval "from" elevation in feet above sea level)
DSURVTO[X]: desurveyed easting (interval "to" easting in NAD27 state plane feet)
DSURVTO[Y]: desurveyed northing (interval "to" northing in NAD27 state plane feet)
DSURVTO[Z]: desurveyed elevation (interval "to" elevation in feet above sea level)
XLSFILE: The lithology and assay tables needed to be split to stay within the 64,000 limit of Microsoft Excel, this shows which file set this drill hole is in, either "EAST" or "WEST", *.XLS and *.CSV files. This file is not split.

APPENDIX 7

DULUTH COMPLEX DRILL HOLE NUMBERING GENERALITIES

APPENDIX 7: DULUTH COMPLEX DRILL HOLE NUMBERING GENERALITIES

INTRODUCTION

Of the approximately 2,145 drill holes in this database (the number varies depending on how one treats drifts, wedges, and other "odd" holes):

1,014 are in the Partridge River intrusion.

780 are in the South Kawishiwi intrusion.

71 are along the west edge of the Complex from Duluth to the Iron Range.

27 are in the Greenwood Lake intrusion and are mostly "touchdown" holes.

About 95 holes associated with the NorthShore Mining tailings basin are in the NSVG or BBC and have no reliable logging records.

About 65 are in the various intrusions along the Gunflint Corridor.

The other 200 or so drill holes are scattered through the Central Duluth Complex, or are in Anorthositic Series rocks, the Bald Eagle intrusion, the Osier Lake intrusion, felsic rocks, diabase, Virginia Formation, or are unclassified. Over 90% of the "legitimate" exploration drilling (logged core holes with some metals assaying) is within two and one-half ground miles (4 km.) of the basal contact of the Duluth Complex. Grid spacing in the deposit areas is generally wide (>800 ft.) with large sparsely drilled (unexplored) areas available between deposit areas and in the interior of the Complex.

Drill Hole Numbering

This listing gives the generalized assignment of drill hole numbering by companies and agencies that have done drilling in the Duluth Complex. This listing is not complete. There are numerous other small groups of drill holes, but these are the main groups. Note that there is no hole numbering duplication in the Duluth Complex, but that some of these numbers may be duplicated elsewhere in Minnesota. See the database itself for better definition of these localities. We include our guess on what the acronyms represent for a few areas.

1) Holes and grids designated with a Roman Numeral are usually Phelps Dodge drill holes in the South Complex (Iron Range to Duluth) area. There are a number of these grids. Many of these have also been given area names in various NRRI reports. These are generally in the Boulder Lake intrusion (BLI), Western Margin intrusion (WMI), and Partridge River intrusion (PRI).

Grid I is also labeled as Boulder Creek in the WMI.
Grid II is also labeled as Skibo South in the PRI.
Grid IV is also labeled as Boulder Lake North in the BLI.
Grid V is also labeled as Boulder Lake South in the BLI.
Grids VI and VII are also labeled as Boulder Lake Central in the BLI.
Grid VIII in the BLI has not been renamed.
Grid X in the Duluth Complex Anorthositic Series is also labeled as Thomson Lake.

2) CV (Cloquet Valley?) drill holes are in the South Complex (Iron Range to Duluth) area in the WMI.

3) LE series are at Longear in the PRI.

4) LN series are at Longnose in the PRI.

5) SL (St. Louis?) series and CN (Copper-Nickel? or Cloquet North?) series holes are at the Water Hen area in the Partridge River intrusion (PRI).

6) A series (A-3, A-4) are Allen grid(s) drill holes drilled by Bear Creek in the PRI.

7) W series holes are at Wetlegs and Wyman Creek holes by Exxon in the PRI

8) 26000 series holes are, in the majority, USS holes at Dunka Road, but include drill holes in the South Complex (Iron Range to Duluth) area. Mostly in the PRI.

9) 99-XXX and 00-XXX followed by a B or C are PolyMet holes at Dunka Road (NorthMet) in the PRI.

10) 10000 to 10219 series are drill holes underground at the Local Boy part of the Babbitt Deposit.

11) B1- series holes are mostly Babbitt and Serpentine by Bear Creek and AMAX, in the PRI and the western edge of the South Kawishiwi intrusion (SKI).

12) B2- series are Dunka Pit holes by Bear Creek in the SKI.

13) BL and C series are Birch Lake hole in the SKI (except for BL-1-MDNR near Bear Lake).

14) E (also NM) series holes are Erie mining holes at Dunka Pit, renumbered by USBM, in the SKI.

15) DU are Duval holes, mostly in the Dunka Pit and Birch Lake area of the SKI.

16) 8000 series are mostly Erie Mining (LTV) drilling at Dunka Pit in the SKI.

17) NM series holes 1 through 6 are Newmont holes, mostly in the Highway 1 Corridor in the SKI.

18) NM series holes 12 through 63 are Newmont holes at Dunka Pit in the SKI.

19) 11500 series are INCO drill holes, mostly in the South Kawishiwi intrusion (Maturi and Spruce Road) with a few in the Partridge River intrusion.

20) 13600 series are INCO holes mostly in the Partridge River intrusion with a few in the South Kawishiwi intrusion.

21) 32700 series are INCO drill holes in the South Kawishiwi intrusion (Maturi and Spruce Road).

22) 34800 are INCO holes, mostly at Spruce Road in the SKI.

23) AD (AD = Adams?, land originally owned or controlled by Robert Adams) series are Bear Creek holes just west of Spruce Road in the SKI.

24) 40900 series are INCO drill holes mostly at Spruce Road, but also scattered throughout the South Kawishiwi intrusion and the Partridge River intrusion.

25) KA- and KAF are Bear Creek holes at Little Lake Road (KA=Kangas Bay Quad?) in the SKI.

26) K series are mostly South Filson Creek drilling by Hanna Mining. Those not at South Filson Creek are all in the South Kawishiwi intrusion.

27) CDC drill holes are MGS drill holes in the Central Duluth Complex.

28) GLI drill holes are MGS holes in the Greenwood Lake Intrusion.

29) SL0- and SNA series are holes in the Sonju Lake area.

30) STP series are holes north of the NorthShore Mining tailings basin in the Cloquet Lake layered series.

31) 1000 series are drill holes at the Reserve Mining Company (NorthShore Mining) tailings basin north of Silver Bay, in the NSVG and BBC.

32) BW series drill holes are the “Blankenberg-Whiteside” holes in the Gunflint Corridor.

33) G and GF series holes are in the Gunflint Corridor.

34) LI and LL (Long Lake?) are holes in the Gunflint Corridor.

35) ON (Oglebay Norton) are holes in the Gunflint Corridor.

APPENDIX 8

USEFUL CONTACT INFORMATION FOR DULUTH COMPLEX MINING AND EXPLORATION ISSUES

APPENDIX 8: USEFUL CONTACT INFORMATION FOR DULUTH COMPLEX MINING AND EXPLORATION ISSUES

CONTACTS

For general data issues, and geologic questions:

At NRRI:

Steve Hauck, Mark Severson, Larry Zanko, Richard Patelke, and Dean Peterson at:

Natural Resources Research Institute
University of Minnesota Duluth
5013 Miller Trunk Highway
Duluth MN 55811-1442
218-720-4294

At MDNR:

Marty Vadis, Dave Dahl, Rick Ruhananen, Al Dzuck at:

Minnesota Department of Natural Resources
Lands and Mineral Division
1525 Third Ave. East
Hibbing MN 55746-1461
218-262-6767

For initial mineral leasing information questions:

State lands:

Kathy Lewis
Minnesota Department of Natural Resources
Lands and Mineral Division
500 Lafayette Road
St. Paul MN 55155
651-296-4807

For Federal lands:

Stu Behling-Geologist (ex-Bear Creek geologist)
United States Forest Service
Commonwealth Avenue
Duluth MN 55808
218-626-4300

For general tax questions related to Minnesota mining:

Tom Schmucker
Minnesota Department of Revenue
Eveleth MN 55734
218-744-7420

For information about economic development issues in northern Minnesota:

Brian Hiti
Iron Range Resources and Rehabilitation Agency
PO Box 441
1006 Highway 53 South
Eveleth MN 55734-0441
218-744-7400

John Chell-Director
Arrowhead Regional Development Commission
221 West First Street
Duluth MN 55802
218-722-5545

For regional geology:

Dr. James D. Miller Jr.
Minnesota Geological Survey
c/o Natural Resources Research Institute
5013 Miller Trunk Highway
Duluth MN 55802
218-720-4294

and:

Minnesota Geological Survey
2642 University Avenue
St. Paul MN
651-627-4780

Trade groups related to exploration and mining in Minnesota:

Minnesota Exploration Association (MExA)
Suite 622, Plymouth Building
12 South 6th Street
Minneapolis MN 55402-1506
612-338-5584

Frank Ongaro
Iron Mining Association of Minnesota
505 Lonsdale Building
302 West Superior Street
Duluth MN 55802
218-722-7724

For exploration and mining permitting and environmental review information:

Ann Foss
Minnesota Pollution Control Agency (MPCA)
520 Lafayette Road
St. Paul MN 55155-4194
651-296-7512

Rebecca Wooden
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul MN 55155

Drilling regulation

Also note that Minnesota Department of Health governs drilling operations on areas outside of permitted mine properties (test pits are governed by MDNR and MPCA if large enough):

Minnesota Department of Health
Well Management Unit
P.O. Box 64975
St. Paul MN 55164-0975
1-651-215-0812