



**GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6650**

**3D Drill Hole and Geologic Map Database of the Flin Flon Mining
District, Manitoba and Saskatchewan**

E. Schetselaar, M. Currie, S. Pehrsson, C. Devine and J. Mwenifumbo

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INTRODUCTION

A central objective of the Geological Survey of Canada third Targeted Geoscience Initiative Program (TGI3) was to update the geoscience knowledge base in VMS mining districts across Canada. Towards this objective a 3D modelling initiative was undertaken to enhance insight into the subsurface geology of the Flin Flon-Callinan-777 VMS ore system hosted in the Paleoproterozoic Flin Flon Belt of Central Manitoba and Saskatchewan. This Open File CD-ROM publication presents relational and spatial databases populated with drill hole and geologic map data that were used to constrain the 3D geologic model of the Flin Flon exploration camp. The file contents of this CD-ROM publication are listed in Appendix 1.

The relational database (MS Access® format) archives 2769 surface and subsurface drill holes compiled from exploration drilling programs conducted from 1916 to recent by HudBay Minerals Inc. and previous operational firms exploring the Flin Flon-777-Callinan VMS ore system. It contains geological, geochemical and geophysical drill log data organized in eight thematic tables that are relationally linked to tables containing deviation log surveys and drill collar locations georeferenced in mine and UTM NAD83 coordinates. The MS Access® database also contains structural field and surface whole-rock geochemistry data acquired from the archives of legacy mapping projects and the recent TGI3 Flin Flon 1: 10000 scale geological mapping projects (Simard et al., 2010 and references therein).

The spatial database (ESRI® geodatabase format) provides a comprehensive 3D geoscience GIS dataset of the Flin Flon exploration camp. It allows users to jointly visualize and analyze the drill hole data with geological and topographic map data in 2D ArcGIS® and 3D ArcScene® GIS environments. The 2D digital map data in the geodatabase were compiled from the digital archives of the TGI3 Flin Flon 1: 10 000 scale geological mapping project (Simard et al., 2010). The geodatabase contains, in addition to the drill hole and digital map data, the 3D-modelled lithostratigraphic and fault surfaces found in the affiliated Open File Publication OF6313: “The 3D Flin Flon Knowledge Cube”. OF6313 presents a 3D interactive geologic model of the exploration camp and a report that describes the geologic background, the employed 3D modelling methodology and a synthesis of the 3D modelling results (Schetselaar et al. 2010). These 3D model elements are also provided in Autocad® dxf format to facilitate import/export to various 3D modelling and 3D GIS software packages. The databases presented in this Open File report provide a multi-thematic and reconciled surface and subsurface geoscience dataset to support future mapping, exploration and 3D modelling initiatives in the Flin Flon mining district. They can also be used for testing 3D geologic modelling methods applicable to mineral exploration and hard-rock settings in general.

GEOMETRIC CORRECTION OF DRILL COLLARS

The databases presented in this Open File Report are georeferenced to UTM, Zone 14N, North American Datum (NAD83) coordinates. The drill hole collar locations, originally registered in mine coordinates, were converted to UTM coordinates by estimating the geometric transformation between the two coordinate systems at eight drill hole collar locations using differential GPS equipment. 2D GPS surveys of two collars (FFM008 and FFS044) were added at a later stage to improve the spatial distribution in the east and south portions of the surveyed area (Fig. 1). Table 1 lists the mine and UTM coordinates of the ten GCP's and the residuals of the estimated transformation. The planimetric (xy) and depth (z) root mean square errors of the 3D transformation are 0.92 and 1.79 m (1 σ) respectively. It should be noted that these error estimates refer to the collar locations and not to the accuracy of the drill hole logs themselves, which are also cumulatively dependent on errors in deviation log readings down the drill hole. Although the combined collar position and deviation log error has not been estimated, the discrepancies between mine-surveyed ore shell models and ore intersections in the deepest drill holes provided a rough maximum error estimate of 40 m. The conversions from mine coordinates (Callinan grid) to UTM NAD83 coordinates and vice versa are defined by the following transformations:

$$\begin{aligned} X_{\text{NAD83UTMZ14N}} &= X_{\text{mine}} + 0.042 Y_{\text{mine}} + 265195.38 \\ Y_{\text{NAD83UTMZ14N}} &= -0.042 X_{\text{mine}} + 0.999 Y_{\text{mine}} + 6094279.10 \\ Z_{\text{NAD83}} &= Z_{\text{mine}} - 2216.134 \\ \\ X_{\text{mine}} &= 0.998143 \text{ UTMX} - 0.041706 \text{ UTM Y} - 10524.882 \\ Y_{\text{mine}} &= 0.041782 \text{ UTMX} + 0.9991494 \text{ UTM Y} - 6100168.6008 \\ Z_{\text{mine}} &= Z_{\text{NAD83}} + 2216.134 \end{aligned}$$

DRILL LOG DATABASE NORMALIZATION

The drill hole lithology logs were originally coded by HudBay Minerals Inc. with a single descriptive field 'rock type' and a sequence of abbreviated characters describing lithostratigraphy, lithology, disposition, alteration, ore texture and deformation. These six themes were parsed out by defining Structured Query Language (SQL) queries against the table holding the drill log codes, and tables that cross-reference these codes with classifications defined for each of the themes (Fig. 2). The classification tables were hierarchically structured, which in combination with the parsed out drill log information, facilitated the reclassification and visualization of the six drill log themes at multiple levels of generalization. The database normalization was essential to support hole-to-hole correlation of lithostratigraphic markers underpinning the 3D geological model of the Flin Flon exploration camp (Schetselaar et al. 2010).

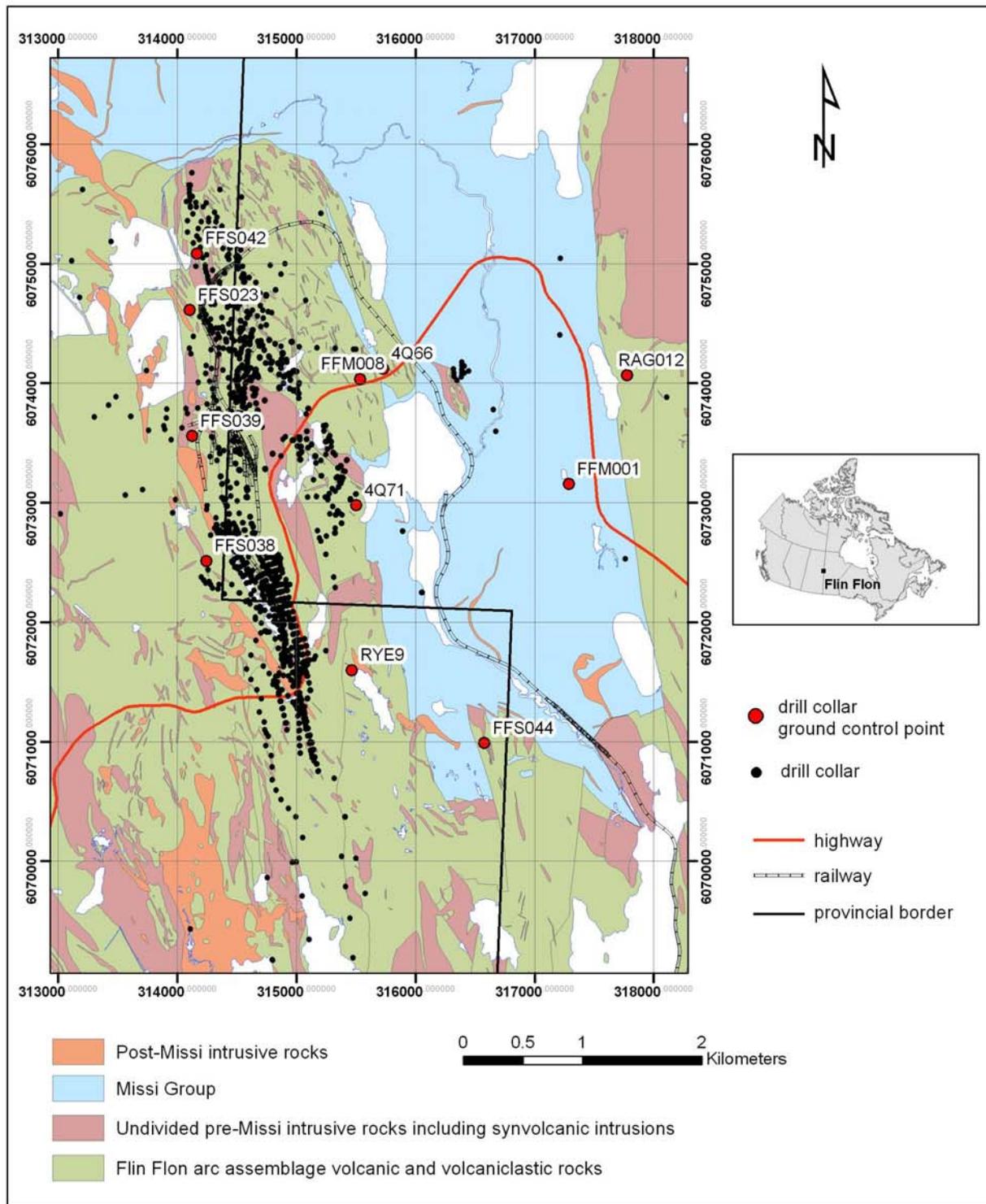


Figure 1. Map of the Flin Flon mining district showing drill hole collar locations (black dots) and drill hole collars used as ground control points (red circles). Generalized geology (after Simard et al. 2010) is shown in the background.

GCP	CollarID	X _{mine}	Y _{mine}	Z _{mine}	X _{utmNAD83}	Y _{utmNAD83}	Z _{NAD83}	dX	dY	dZ
1	FFS042	49687.00	-17125.00	-	314163.39	6075085.92	325.43	-0.57	-1.33	-
2	FFS023	49647.35	-17598.06	-	314102.89	6074613.07	329.60	0.45	0.58	-
3	FFS039	49711.66	-18650.57	2547.71	314123.64	6073558.64	330.93	0.07	0.74	0.64
4	FFS038	49871.32	-19690.97	2525.42	314240.65	6072512.95	308.58	-0.67	0.25	0.57
5	4Q71	51116.15	-19168.54	2525.00	315502.27	6072978.75	330.42	4.31	4.56	2.62
6	FFM001	52884.70	-18919.30	2532.93	317286.67	6073157.47	310.46	-0.78	0.68	2.87
7	RYE09	51104.80	-20538.57	2545.00	315464.82	6071598.90	346.71	-27.21	14.77	19.12
8	4Q66	51292.23	-18021.67	2532.93	315728.96	6074122.10	315.21	1.80	-0.42	-0.31
9	FFM008	51100.885	-18115.944	-	315534.390	6074035.600	-	1.06	-0.13	-
10	FFS044	52269.000	-21117.000	-	316578.000	6070989.000	-	0.44	-0.79	-

RMSE_{XY} = 0.92 m, RMSE_Z = 1.79 m; average mine datum (Z_{mine} - Z_{NAD83}) = 2216.134 m

Table 1. Ground control points (GCP's) used to compute the geometric transformation between the mine and NAD83, Zone 14 UTM coordinates of ten drill hole collar locations surveyed with differential GPS; dX, dY and dZ are residuals, RMSE_{XY} is the planimetric root mean square error and RMSE_Z is the elevation root mean square error for the least squares estimation of the linear geometric transformation. GCP's (4Q71) and GCP 7 (RYE09) (gray font) were excluded from the least squares estimation due to their anomalously high residuals.

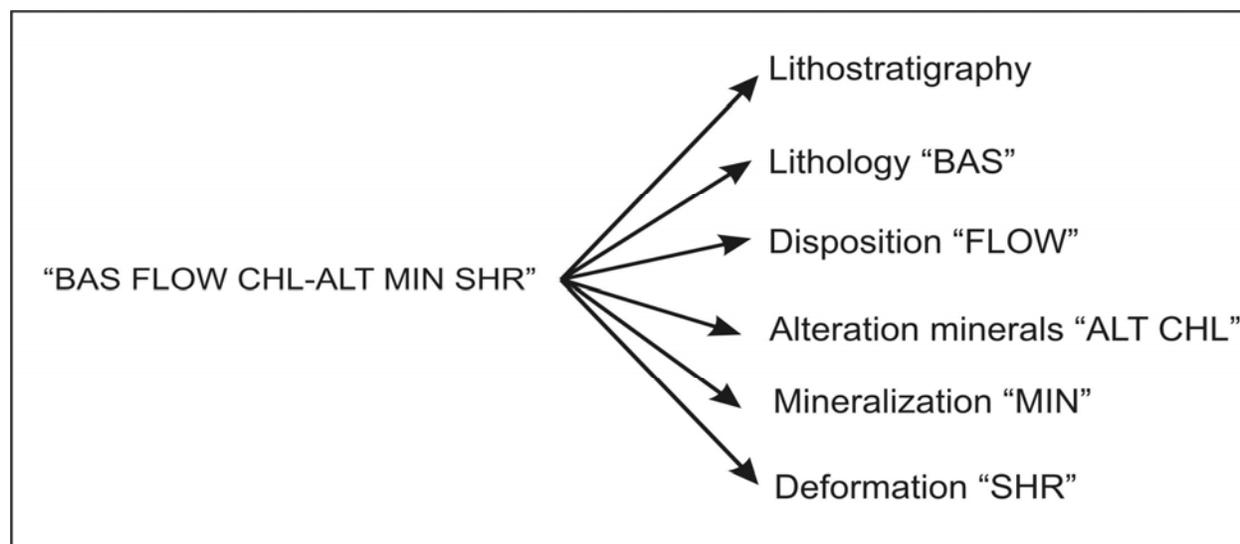


Figure 2. Attribute themes (right) parsed out from industry drill log coding (left) for normalizing the drill hole database.

MS ACCESS DATABASE DESCRIPTION

The MS Access® database 'FlinFlon3DGeoscienceDatabase.mdb' consists of eighteen tables including six drill log tables (Fig.3), describing: (1) lithostratigraphy-lithology-disposition, 'LithostratigraphicLog' (2) fault rock drill intervals, 'FaultrockLog' (3) presence/absence of hydrothermal alteration and associated mineral species, 'AlterationLog' (4) sulphide ore texture, 'OreTextureLog' (5) geophysical well log data 'GeophysicalLog' and (6) whole-rock geochemical analyses 'GeochemicalLog'.

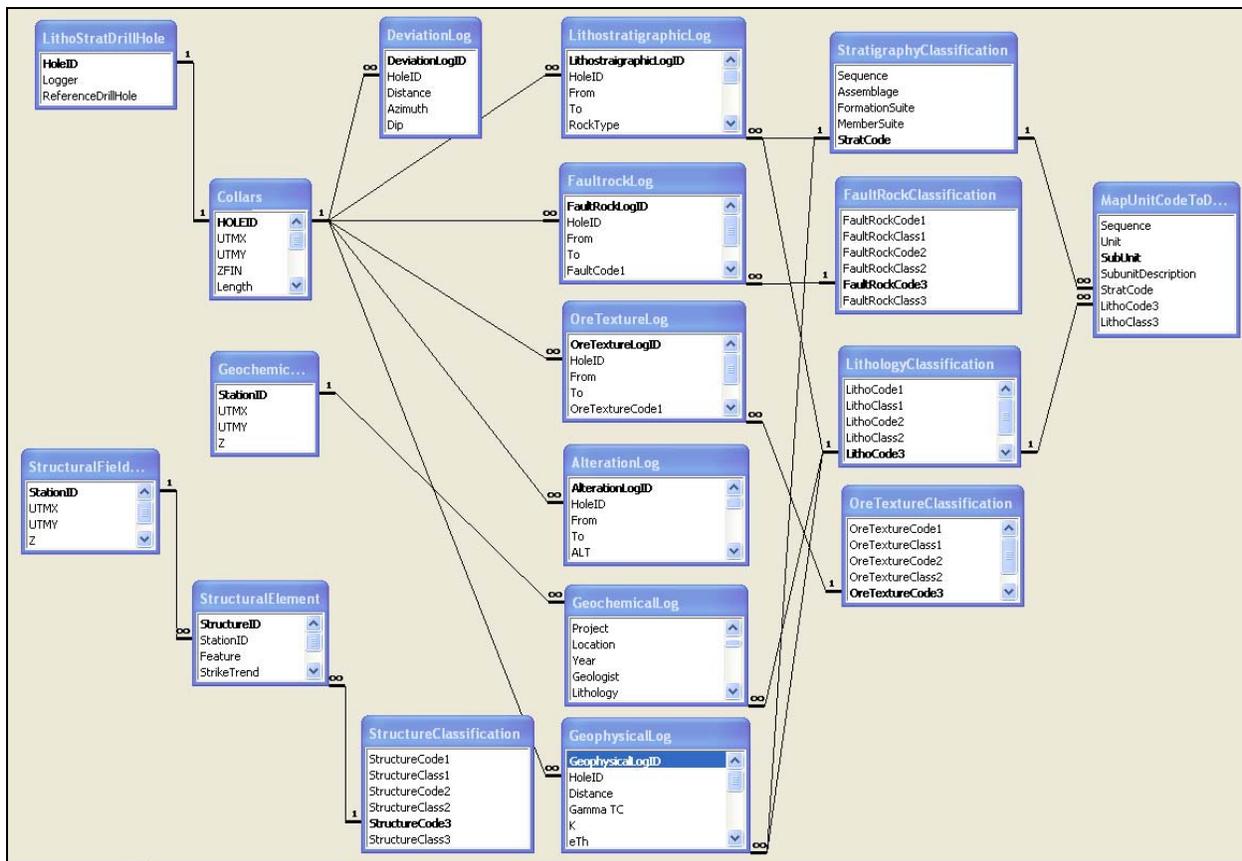


Figure 3. Database structure of the MS Access® relational database containing drill hole, surface whole rock geochemistry and structural data of the Flin Flon mining district.

The database also contains, in addition to the drill log thematic tables, the field locations, compass measurements and classification of structural elements (stored in the ‘StructuralFieldStation’, ‘StructuralElement’ and ‘StructuralClassification’ tables respectively) that were acquired during TGI3 and previous geological mapping projects (Simard et al. 2010).

The structure of the relational database is illustrated in Figure 3. The records in the six thematic drill log tables are linked on their drill hole identifier ‘HoleID’ to the ‘Collar’ table and to the ‘DeviationLog’ table in many-to-one relationships. The descriptive drill log data, including lithology, lithostratigraphy, sulphide ore texture and fault rock descriptions are linked to hierarchical classification lookup tables to facilitate user-defined generalization/specialization in querying the various drill log themes. The ‘LithologyClassification’ table is also relationally linked to the ‘GeochemicalLog’, ‘GeophysicalLog’ and ‘UnitToLithocode’ tables. The first two tables link geochemical analyses and well log geophysical data to lithology descriptions of corresponding drill intervals whereas the second table links drill core lithology descriptions to the legend of the TGI3 geological map.

The table ‘StratLoggers’ contains the drill hole ID’s and the geologists that were involved in assigning lithostratigraphic units to selected drill hole intervals in the ‘LithostratigraphicLog’ table. This subset of lithostratigraphic reference drill hole intervals was the principal data source for constraining the modelled

lithostratigraphic surfaces of the 3D Flin Flon Knowledge Cube Open File Report 6313 (Schetselaar et al. 2010). The structural map data are stored in three tables that contain the location, type-orientation and classification of field-collected structural elements. These planar and linear structural elements were collected during the TGI3 and previous geological mapping projects conducted in the Flin Flon mining district (Simard et al., 2010 and references therein).

The geochemical drill log data ‘GeochemicalLog’ table integrates geochemical analyses of major oxides and trace elements from rock samples acquired in outcrops and drill core by HudBay Minerals Inc., provincial geological survey, and GSC geologists. The drill hole geochemical data is, in addition to being georeferenced to their corresponding drill hole collar and deviation log surveys, georeferenced to 3D UTM xyz coordinates in the ‘GeochemicalSampleLocation’ table to facilitate integrated visualization and analysis of the surface and subsurface geochemical data in a single 3D point data set. The ‘GeophysicalLog’ table contains physical property measurements for nine drill holes, including gamma-ray spectrometry (total count, K, eTh and eU), magnetic susceptibility, density and seismic (P velocity) acquired by the GSC (Mwenifumbo *in prep.*) and DGI Geoscience Inc. The table also contains the encoding to link the geophysical signatures of drill hole intervals to their corresponding lithostratigraphic and lithologic descriptions. For more details on the relational MS Access® database, including descriptions of all the database tables and fields, the reader is referred to Appendix 2.

3D ESRI GEODATABASE

The geodatabase ‘3DFlinFlonGeoscienceGeodatabase.gdb’ was compiled for the integrated visualization and analysis of drill hole data, geological map data and 3-D modelled lithostratigraphic and structural surfaces in the ESRI® ArcScene® (3D) or ArcMap® (2D) GIS applications. Figure 4 shows the contents and structure of the geodatabase. For a detailed description of the geodatabase feature classes and attribute fields the reader is referred to Appendix 3. The drill hole data were compiled from the collar, deviation log and thematic tables of the MS Access® database. They were stored in the ‘DrillHoleData’ spatial feature set using an in-house developed drill hole geodatabase import tool. This spatial feature set consists of three 3D feature classes (Fig. 4): (1) the 3D point feature class ‘DrillCollars’ containing the xyz coordinates and attributes of the drill collar locations, (2) the 3D polyline feature class ‘DrillPaths’ representing the geometry of the drill holes uniquely identified by their ‘HoleID’ and (3) the 3D polyline feature class ‘DrillLogs’ containing ‘From’– ‘To’ drill intervals linked to all the descriptive geological attributes at multiple levels of classification. This allows users to display the drill hole thematic information at different levels of generalization.

The geological map data, stored in the ‘GeologicMapElementsTGI3’ spatial feature set (Fig. 4) were derived from the GIS digital archives of the TGI3 Flin Flon geological map publication (Simard et al. 2010) and comprise geological map units, faults, structural field stations, the outlines of outcrops and a hydrography mask. The geological map units were linked to lithostratigraphic classes on three hierarchical classification levels,

including setting, formations/intrusive suits and members. The TGI3 geological map units are also attributed on their legend description to corresponding drill log lithology classes. Although these attributes only facilitate a generalized recoding of geological map units into drill log lithology classes, they allow users to jointly render the geological map polygons and drill log intervals using a single lithologic classification system. The ESRI® geodatabase contains, in addition to the drill hole and geologic map spatial feature sets, the fourteen lithostratigraphic and seventeen fault triangulated surfaces from the Flin Flon 3D Knowledge Cube publication (Schetselaar et al. 2010). These 3D-modelled surfaces were imported from gOcad® and stored in the spatial feature set ‘GeologicModel3Delements’. Topographic map elements including roads, railways, hydrography and the provincial border are stored in the spatial feature set ‘TopographicMapelements’ (Fig. 4).

LIMITATIONS OF THE DATABASES

The drill hole data were compiled from a variety of sources some of which date back to the early 1900’s when exploration at Flin Flon commenced. This compilation involved reconciling industry coding (‘GEMSCODE’) and lithologic descriptions of a large number of geologists that logged drill core in the Flin Flon exploration camp. Although the majority of drill log descriptions were checked against their ‘GEMSCODE’ via SQL queries and a substantial percentage (approximately 15 %) were checked against the original drill log reports, it was not possible to validate all 54235 lithologic log descriptions in this manner. Therefore it is possible that data transcription errors, inconsistencies in rock classification and coding errors were propagated in the compilation process. Data transcription errors also occasionally caused offsets of one to two consecutive records in registering geochemical sample locations (‘DISTANCE’) to the drill hole paths. The geological map unit layer ‘TGI3GeologicMapUnit’ feature class in the geodatabase was attributed with drill log lithology classes to facilitate integrated 3D visualization of the drill log and geological map data. This reconciliation was based on the legend description of the TGI3 geological map units (Simard et al. 2010). For geological map units composed of multiple rock types, the predominant lithology in the unit description was used as a compromise. As a result, a reclassification of the TGI3 geological map layer with attributes at the most detailed level of the drill log lithology classification (LithoClass3) will provide a generalized and oversimplified rendition of lithologic composition for these map units.

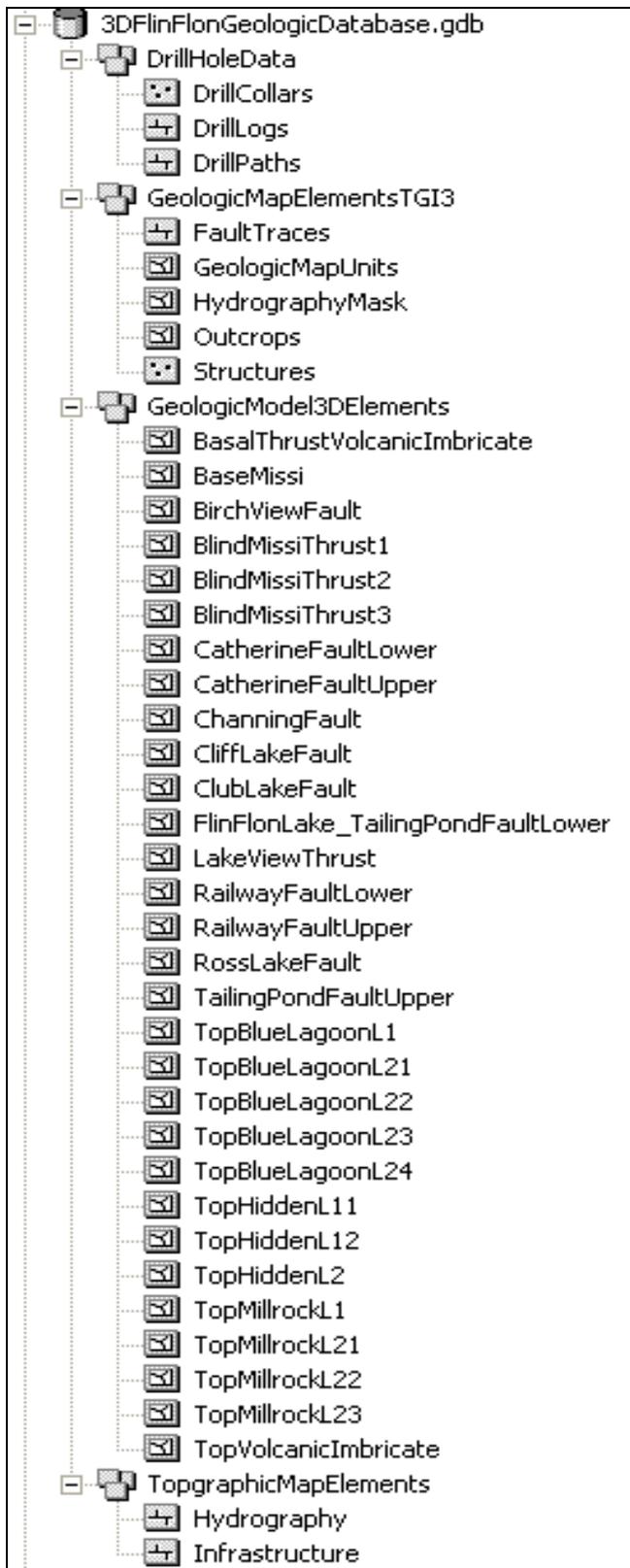


Figure 4. Spatial feature sets and feature classes of the 3D ESRI® geodatabase of the Flin Flon exploration camp containing geologic, topographic map and drill hole data, as well as 3D model elements.

ACKNOWLEDGEMENTS

HudBay Minerals Inc. is thanked for making the drill hole data available for the 3D database compilation presented in this open file report. Renée-Luce Simard from Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey is thanked for providing the digital geological map data from the GIS data archives of the TGI3 Flin Flon geological mapping project. We also wish to thank Paulo Strapazon of HudBay Minerals Inc. for the differential GPS survey of drill hole collars in the Flin Flon exploration camp, which made it possible to accurately compute the geometric transformations between the Callinan mine coordinates and UTM coordinates.

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- Mwenifumbo, C.J. (in prep.) Borehole Geophysical Logging in the Flin Flon Mining Camp.
- Schetselaar, E., Pehrsson, S., Devine, C., Currie, M., White, D. and Malinowski, M., 2010. The Flin Flon 3D Knowledge Cube, Geological Survey of Canada, Open File 6313, 36 p.
- Simard, R-L., MacLachlan, K., Gibson, H.L., DeWolfe, Y.M., Devine, C., Kremer, P.D., Lafrance, B., Ames, D.E., Syme, E.C., Bailes, A.H., Bailey, K., Price, D., Pehrsson, S., Cole, E., Lewis, D. and Galley, A.G. 2010. Geology of the Flin Flon area, Manitoba and Saskatchewan (part of NTS 63K12, 13); Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Geoscientific Map MAP2010-1 and Saskatchewan Ministry of Energy and Resources, Geoscience Map 2010-2, 1 colour map, scale 1:10000.

Appendix 1: CD-ROM Table of Contents

- **MS Access® relational database: ‘FlinFlon3DGeoscienceDatabase.mdb’**
- **ESRI® 3D file geodatabase: ‘FlinFlon3DGeoscienceGeodatabase.gdb’**
- **Folder with .dxf files of 3D-modelled elements: ‘DXF3DModelElements’**
- **Open File 6650 Report in Acrobat® format: ‘OF6650.pdf’**
- **‘readme.rtf’**
- **‘licence_e.rtf’**

Appendix 2: Description MS Access® database ‘FlinFlon3DGeoscienceDatabase.mdb’

Collar

This table contains 3D location information for each drill hole in UTM and mine coordinates.

HOLEID - Unique ID assigned to each drill hole (primary key)

UTMX - UTM, Zone 14, NAD83 (easting) x coordinate of the drill collar/start location

UTMY – UTM, Zone 14, NAD83 (northing) y coordinate of the drill collar/start location

ZFIN - Z elevation coordinate computed from GPS survey and mine-surveyed Z coordinate

Length – Length of the drill hole in meters

Surface – Binary field to distinguish drill holes collared from the earth surface or subsurface drill holes; 0 = subsurface drill hole, 1 = surface drill hole

Strat - Binary field to encode drill holes that are lithostratigraphic reference holes; 0 = no lithostratigraphic reference drill hole, 1 = lithostratigraphic reference drill hole

Grid – Specification of mine grid in which the drill hole was originally georeferenced (all mine coordinates of the drill holes in the database were transformed to the Callinan metric grid).

X_MINE – X mine coordinate in meters (Callinan metric grid)

Y_MINE – Y mine coordinate in meters (Callinan metric grid)

Z_MINE – Z mine coordinate in meters (Callinan metric grid)

Surveyed – Binary field to indicate if the collar of a surface drill hole has been surveyed by GPS; 0 = no GPS survey 1 = differential GPS-surveyed drill hole, 2 = handheld GPS-surveyed drill hole

Deviation log

This table contains the deviation log survey of each drill hole.

DevlogID – Unique identifier for each deviation log record (primary key)

HoleID - Unique ID assigned to each drill hole (foreign key to Collar table)

Distance – Logged distance along the drill hole in meters

Azimuth – Logged azimuth angle (in degrees) of the drilling direction with respect to geographic north at each distance increment

Dip – Logged dip angle (in degrees) of the drilling direction with respect to the horizontal at each distance increment

LithoStratDrillHole

This table lists the drill holes that were subject to lithostratigraphic classification and the geologists involved in stratigraphic logging.

HoleID - Unique ID assigned to each drill hole with a lithostratigraphic log (primary key)

Geologist – Reference to geologist that applied lithostratigraphic classification to the logged intervals of the drill hole

ReferenceDrillHole - Binary field that indicates if a drill hole with lithostratigraphic classification has been used for 3D geologic modelling of the Flin Flon exploration camp; Y = used, N = not used

LithostratigraphicLog

This table contains the lithologic and lithostratigraphic codes and associated descriptions of logged drill hole intervals. The most detailed level of the lithology and lithostratigraphy codes are linked to the LithologyClassification and StratigraphyClassification tables, respectively.

LithoStratLogID – Numeric ID (Autonumber) to uniquely identify each lithostratigraphic log record (primary key)

HoleID – Unique ID assigned to each drill hole with a lithostratigraphic log (foreign key to Collar table)

From – Start of drill hole interval in meters

To – End of drill hole interval in meters

RockType – Rock type text description from industry drill log report

LithoCode1 – Abbreviated character string to encode lithology at the first (most general) level of lithology classification

LithoClass1 – Text description associated to LithoCode1 to describe lithology at the first (most general) level of lithology classification

LithoCode2 – Abbreviated character string to encode lithology at the second level of lithology classification

LithoClass2 – Text description associated to LithoCode2 to describe lithology at the second level of lithology classification

LithoCode3 – Abbreviated character string to encode lithology at the third level of lithology classification

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

Disposition – Interpreted disposition of lithologic drill hole interval (e.g. flow, intrusion, bed,)

StratInterpreted – Text string to describe the interpreted lithostratigraphic class assigned without physical inspection to a drill hole interval

StratLogged – Text string to describe the logged lithostratigraphic class assigned by physical inspection to a drill hole interval

StratRefDH – Text string to describe the logged lithostratigraphic class assigned to a drill hole interval by means of physical inspection used for 3D geologic modelling

LithologyClassification

This table contains a three-level hierarchical lithology classification tailored to the description of volcanic, intrusive and sedimentary rocks of the Flin Flon exploration camp.

LithoCode1 – Abbreviated character string to encode lithology at the first (most general) level of lithology classification

LithoClass1 – Text description associated to LithoCode1 to describe lithology at the first (most general) level of lithology classification

LithoCode2 – Abbreviated character string to encode lithology at the second level of lithology classification

LithoClass2 – Text description associated to LithoCode2 to describe lithology at the second level of lithology classification

LithoCode3 – Abbreviated character string to encode lithology at the third level of lithology classification

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

StratigraphicClassification

This table contains a four-level hierarchical tectonostratigraphic / lithostratigraphic classification with associated lithostratigraphic codes after the TGI3 1 : 10 000 scale cross-provincial border Flin Flon geological map (Simard et al., 2010).

Sequence – Number (ordered from young to old) indicating relative geochronologic order of lithostratigraphic class

Assemblage – Regional tectono-stratigraphic assemblage

Block – Block with semi-coherent to coherent internal lithostratigraphy bounded by regional faults across which lithostratigraphic correlation is difficult to impossible

FormationSuite – Lithostratigraphic formation (informal), Group or undivided unit or intrusive suite

MemberSuite – Lithostratigraphic member (informal), undivided unit or intrusive suite

StratCode – Lithostratigraphic abbreviated code of group, formation, member or intrusive rock for logging or drill hole import functions with string length limit

FaultRockLog

This table contains the descriptive code of faulted or sheared drill log intervals

FaultRockID– Numeric ID (Autonumber) to uniquely identify each faulted or sheared drill hole interval record (primary key)

HoleID – Unique ID assigned to each drill hole in which faulted or sheared drill hole interval were identified (foreign key to Collar table)

From – Start to drill hole interval in meters

To – End of drill hole interval in meters

FaultCode1 – Abbreviated character string to encode faulted or shear drill hole interval at the first (most general) level of fault rock classification

FaultCode2 – Abbreviated character string to encode faulted or shear drill hole interval at the second level of fault rock classification

FaultCode3 – Abbreviated character string to encode faulted or shear drill hole interval at the third (most detailed) level of fault rock classification

FaultRockClassification

This table contains a three-level hierarchical fault rock classification tailored to the ductile, brittle-ductile and brittle geologic structures that occur in the Flin Flon exploration camp

FaultCode1 – Abbreviated character string to encode faulted or shear drill hole interval at the first (most general) level of fault rock classification

FaultClass1 – Text description associated to FaultCode1 to describe faulted or sheared interval at the first (most general) level of fault rock classification

FaultCode2 – Abbreviated character string to encode faulted or shear drill hole interval at the second level of fault rock classification

FaultClass2 – Text description associated to FaultCode1 to describe faulted or sheared interval at the second level of fault rock classification

FaultCode3 – Abbreviated character string to encode faulted or shear drill hole interval at the third (most detailed) level of fault rock classification (primary key)

FaultClass3 – Text description associated to FaultCode3 to describe faulted or sheared interval at the third (most detailed) level of fault rock classification

AlterationLog

This table contains identified drill hole intervals with altered rocks and a specification of the presence (1) / absence (0) of alteration mineral species or silicification

AlterationID– Numeric ID (Autonumber) to uniquely identify each altered drill hole interval record (primary key)

HoleID – Unique ID assigned to each drill hole interval in which alteration was identified (foreign key to Collar table)

From – Start to drill hole interval in meters

To – End of drill hole interval in meters

ALT – Binary field indicating presence/absence of altered drill hole intervals; 0 = no alteration documented, 1 = alteration observed

CHL – Binary field indicating presence/absence of chlorite

EP – Binary field indicating presence/absence of epidote

CARB– Binary field indicating presence/absence of carbonate

SER – Binary field indicating presence/absence of sericite

BIO – Binary field indicating presence/absence of biotite

QTZ – Binary field indicating presence/absence of quartz

TALC – Binary field indicating presence/absence of talc

MAG – Binary field indicating presence/absence of magnetite

GRT – Binary field indicating presence/absence of garnet

AMPH – Binary field indicating presence/absence of amphibole

SILICIF – Binary field indicating presence/absence of silicification

SCHIST – Binary field indicating presence/absence of schist (chlorite or chlorite-talc or chlorite-biotite or chlorite-sericite schist)

OreTextureLog

This table contains sulphide mineralization and sulphide ore log intervals that intersect mineralized or VMS ore bodies.

OreTextureID – Numeric ID (Autonumber) to uniquely identify each altered drill hole interval record (primary key)

HoleID – Unique ID assigned to each mineralized or ore drill hole interval (foreign key to Collar table)

From – Start to drill hole interval in meters

To – End of drill hole interval in meters

OreTextureCode1 – Abbreviated character string to encode texture of sulphide ore drill hole interval at the first (most general) level of ore texture classification

OreTextureCode2 – Abbreviated character string to encode texture of sulphide ore drill hole interval at the second level of ore texture classification

OreTextureCode3 – Abbreviated character string to encode texture of sulphide ore drill hole interval at the third (most detailed) level of ore texture classification

OreTextureClassification

This table contains a three-level hierarchical textural classification of sulphide mineralization and sulphide ore of intervals that intersect mineralized or VMS ore bodies.

OreTextureCode1 – Abbreviated character string to encode texture of sulphide mineralized / ore drill hole interval at the first (most general) level of ore texture classification

OreTextureClass1 – Text description associated to OreTextureCode1 to describe texture of sulphide mineralized / ore drill hole interval at the first (most general) level of ore texture classification

OreTextureCode2 – Abbreviated character string to encode texture of sulphide mineralized / ore drill hole interval at the second level of ore texture classification

OreTextureClass2 – Text description associated to OreTextureCode2 to describe texture of sulphide mineralized / ore drill hole interval at the second level of ore texture classification

OreTextureCode3 – Abbreviated character string to encode texture of sulphide mineralized / ore drill hole interval at the third (most detailed) level of ore texture classification (primary key)

OreTextureClass3 – Text description associated to OreTextureCode1 to describe texture of sulphide mineralized / ore drill hole interval at the third (most detailed) level of ore texture classification

GeophysicalLog

This table contains logged geophysical properties of a selected set of drill holes

GeophysicalLogID – Numeric ID (Autonumber) to uniquely identify each geophysical log drill hole record (primary key)

HoleID – Unique ID assigned to each drill hole (foreign key to Collar table)

Distance – Logged distance along the drill path in meters

Gamma TC - Gamma spectrometry total count (in counts per second)

K – Potassium gamma-ray spectrometry channel (in %)

eTh – Equivalent Thorium gamma-ray spectrometry channel in ppm

eU – Equivalent Uranium gamma-ray spectrometry channel in ppm

MagSusc – Magnetic susceptibility in SI x 10⁻⁶

Density – Density in grams/cm³

PVelocity – P wave velocity in m/s

LithoCode3 – Abbreviated text string to encode lithology at the third (most detailed) level of lithology classification (foreign key to LithologyClassification table)

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

StratLogged – Text string to describe the logged lithostratigraphic class assigned by physical inspection to a drill hole interval (foreign key to StratigraphyClassification table)

GeochemicalLog

This table contains geochemical analyses of samples from outcrops and drill hole intervals

SampleID – Unique identifier for geochemical sample (primary key)

StationID – Field station location for outcrop sample (foreign key to GeochemicalSampleLocation table)

HoleID – Unique ID for drill hole of the drill core sample (foreign key to Collar table)

Distance – Logged distance along the drill path in meters

SampleType – Sample type: ‘Outcrop’, ‘Drill hole’

Duplicate – Numeric encoding for duplicate samples; 0 = no duplicate, 1 = duplicate

Project – Project for which the geochemical sample was collected

Location – Geographic description of sample location

Year – Year in which the sample was analyzed

Geologist – Geologist that collected the geochemical sample

Lithology – Lithologic description of the geochemical sample by geologist that collected the sample

LithoCode3 – Abbreviated text string to encode lithology at the third (most detailed) level of lithology classification (foreign key to LithologyClassification table)

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

StratInterp – Stratigraphic interpretation of the outcrop or drill core by geologist that collected the sample

Sourcefile – Reference to identifier of HudBay Minerals Inc. Spreadsheet file

Method – Laboratory method used to analyze the sample (ICP or XRF)

Lab – Laboratory that conducted the geochemical analyses

Batch – Identification for a group of outcrop or drill core samples that were analyzed together

Major oxides: SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, P₂O₅, MnO, Cr₂O₃, in weight %; negative numbers are analyses at detection limit for a particular method/batch

LOI – Loss on ignition in weight %

Ctot – Carbon in weight %

Stot – Sulphur in weight %

SUM – Summed weight % major oxides, LOI, Stot and Ctot fields

Elements Ba, Ni, Sc, Co, Cs, Ga, Hf, Nb, Rb, Sn, Sr, Ta, Th, U, V, W, Zr, Y, La, Ce, Pr, Nd, Sm, U, Gd, Tb, Dy, Ho, Er, Tm, Yn, Lu, Mo, Cu, Pb, Zn, Cr, As, Cd, Sb, Bi, Ag, Ti, Be, Li, Ge, In, Se, Ir, Au, Hg, Tl, F, I, Ni₂ in ppm; negative numbers are analyses at detection limit for a particular method/batch

GeochemicalSampleLocation

This table contains 3D location information for each geochemical sample in UTM coordinates

StationID – Unique identifier for location of geochemical sample (primary key)

UTMX - UTM, Zone 14, NAD83 (easting) x coordinate of the outcrop/drill hole sample location

UTMY – UTM, Zone 14, NAD83 (northing) y coordinate of the outcrop/drill hole sample location

Z - Elevation coordinate sampled from 1: 50 000 scale digital elevation model of the outcrop sample location or computed from Z-mine coordinate (Callinan grid) of the drill hole sample location

StructuralFieldStation

This table contains 3D location information for each field-collected structural element in UTM coordinates

StationID – Unique identifier for field station location of structural observation (primary key)

UTMX - UTM, Zone 14, NAD83 (easting) x coordinate of the field station location

UTMY – UTM, Zone 14, NAD83 (northing) y coordinate of the field station location

Z - Elevation coordinate sampled from 1: 50 000 scale digital elevation model of the field station location

Geologist – Geologist that acquired the structural observation and strike/dip measurements

StructuralElement

This table contains the strike/dip or trend/plunge for linear respectively planar structural elements

StructureID – Unique identifier for structural element

StationID – Unique identifier for field station location of structural observation (foreign key to StructuralFieldStation table)

Feature – Class or description of planar or linear structural element

StrikeTrend – Strike of planar structural element or trend of linear structural element

DipPlunge - Strike of planar structural element or trend of linear structural element

StrucCode3 – Abbreviated text string to encode the most detailed level of structural classification (foreign key to StructureClassification table)

StructureClassification

This table contains a three-level hierarchical classification of planar and linear geological structures.

StructureCode1 – Abbreviated character string to encode type of geological structure at the first (most general) level of classification; p = planar-, l = linear structure

StructureClass1 – Text description associated to StructureCode1 to describe geological structure at the first (most general) level of classification

StructureCode2 – Abbreviated character string to encode type of geological structure at the second level of classification

StructureClass2 – Text description associated to StructureCode1 to describe geological structure at the second level of classification first

StructureCode3 – Abbreviated character string to encode type of geological structure at the third (most detailed) level of classification

StructureClass3 – Text description associated to StructureCode3 to describe geological structure at the third (most detailed) level of classification (primary key)

MapUnitCodeToDrillLogCode

This table links the units and subunits of the TGI3 geological map and lithologic and stratigraphic codes of the lithostratigraphic and lithologic drill log classifications. The lithologic classes of the drill hole intervals were linked to the predominant rock type of TGI3 map units that contain multiple rock types.

Sequence - Number (ordered from young to old) indicating relative geochronologic order of lithostratigraphic class

Unit – Abbreviated character string to encode unit of TGI3 geological map

Subunit – Abbreviated character string to encode subunit of TGI3 geological map (primary key)

SubunitDescription – Legend description of subunit TGI3 geological map

StratCode - Abbreviated text string to encode lithostratigraphy at the fourth (most detailed) level of lithostratigraphy (foreign key to StratigraphyClassification table)

LithoCode3 – Abbreviated text string to encode lithology at the third (most detailed) level of lithology classification (foreign key to LithologyClassification table)

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

StratCode - Abbreviated text string to encode lithostratigraphy at the fourth (most detailed) level of lithostratigraphy (foreign key to StratigraphyClassification table)

Appendix 3: Description ESRI® geodatabase ‘FlinFlon3DGeoscienceGeodatabase.gdb’

Spatial feature sets

1. Drill hole data

Feature classes

DrillCollars

This feature class contains the collar position for each drill hole

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Point Z)

PointlocationID – Unique identifier for drill hole collar position (corresponds to HoleID in MS Access® database)

Length – Length of the drill hole in meters

DrillPaths

This feature class contains the 3D-modelled drill paths

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polyline ZM)

LineLocationID – Unique identifier for drill hole collar position (corresponds to HoleID in MS Access® database)

SHAPE_Length – Length of 3D polyline feature (ESRI® object)

DrillLogs

This feature class contains the descriptive log attributes of the FROM – TO intervals of the drill holes

OBJECTID – Unique identifier for spatial object (ESRI® object)

HoleID – Unique identifier for drill hole of the interval

From_ – Start to drill hole interval in meters

To – End of drill hole interval in meters

LithoCode1 – Abbreviated character string to encode lithology at the first (most general) level of lithology classification

LithoClass1 – Text description associated to LithoCode1 to describe lithology at the first (most general) level of lithology classification

LithoCode2 – Abbreviated character string to encode lithology at the second level of lithology classification

LithoClass2 – Text description associated to LithoCode2 to describe lithology at the second level of lithology classification

LithoCode3 – Abbreviated character string to encode lithology at the third level of lithology classification

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

Disposition – Interpreted disposition of lithologic drill hole interval (e.g. flow, intrusion, bed, ……)

StratRefDH – Text string to describe the logged lithostratigraphic class assigned to a drill hole interval by means of physical inspection used for 3D geologic modelling

StratLogged – Text string to describe the logged lithostratigraphic class assigned by physical inspection to a drill hole interval

Sequence – Number (ordered from young to old) indicating relative geochronologic order of lithostratigraphic class

Setting – Regional tectono-stratigraphic assemblage

FormationGroup – Lithostratigraphic formation (informal), Group or undivided unit or intrusive suite

MemberSuite – Lithostratigraphic member (informal), undivided unit or intrusive suite

FaultCode1 – Abbreviated character string to encode faulted or shear drill hole interval at the first (most general) level of fault rock classification

FaultClass1 – Text description associated to FaultCode1 to describe faulted or sheared interval at the first (most general) level of fault rock classification

FaultCode2 – Abbreviated character string to encode faulted or shear drill hole interval at the second level of fault rock classification

FaultClass2 – Text description associated to FaultCode1 to describe faulted or sheared interval at the second level of fault rock classification

FaultCode3 – Abbreviated character string to encode faulted or shear drill hole interval at the third (most detailed) level of fault rock classification

FaultClass3 – Text description associated to FaultCode3 to describe faulted or sheared interval at the third (most detailed) level of fault rock classification

OreTextureCode1 – Abbreviated character string to encode texture of sulphide mineralized / ore drill hole interval at the first (most general) level of ore texture classification

OreTextureClass1 – Text description associated to OreTextureCode1 to describe texture of sulphide mineralized / ore drill hole interval at the first (most general) level of ore texture classification

OreTextureCode2 – Abbreviated character string to encode texture of sulphide mineralized / ore drill hole interval at the second level of ore texture classification

OreTextureClass2 – Text description associated to OreTextureCode2 to describe texture of sulphide mineralized / ore drill hole interval at the second level of ore texture classification

OreTextureCode3 – Abbreviated character string to encode texture of sulphide mineralized / ore drill hole interval at the third (most detailed) level of ore texture classification (primary key)

OreTextureClass3 – Text description associated to OreTextureCode1 to describe texture of sulphide mineralized / ore drill hole interval at the third (most detailed) level of ore texture classification

ALT – Binary field indicating presence/absence of altered drill hole intervals; 0 = no alteration documented, 1 = alteration observed

CHL – Binary field indicating presence/absence of chlorite

EP – Binary field indicating presence/absence of epidote

CARB – Binary field indicating presence/absence of carbonate

SER – Binary field indicating presence/absence of sericite

BIO – Binary field indicating presence/absence of biotite

QTZ – Binary field indicating presence/absence of quartz

TALC – Binary field indicating presence/absence of talc

MAG – Binary field indicating presence/absence of magnetite

GRT – Binary field indicating presence/absence of garnet

AMPH – Binary field indicating presence/absence of amphibole

SILICIF – Binary field indicating presence/absence of silicification

Shape – Type of spatial object (Polyline ZM)

Shape Length – Length of 3D polyline feature (ESRI® object)

GeophysicalLog

This feature class contains logged geophysical property samples of nine drill holes

OBJECTID – Unique identifier for spatial object (ESRI® object)

HoleID – Unique ID assigned to each drill hole (foreign key to Collar table)

Distance – Logged distance along the drill path in meters

Gamma TC - Gamma spectrometry total count (in counts per second)

K – Potassium gamma-ray spectrometry channel (in %)

eTh – Equivalent Thorium gamma-ray spectrometry channel in ppm

eU – Equivalent Uranium gamma-ray spectrometry channel in ppm

MagSusc – Magnetic susceptibility in SI x 10⁻⁶

Density – Density in grams/cm³

PVelocity – P wave velocity in m/s

LithoCode3 – Abbreviated text string to encode lithology at the third (most detailed) level of lithology classification (foreign key to LithologyClassification table)

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

StratLogged – Text string to describe the logged lithostratigraphic class assigned by physical inspection to a drill hole interval (foreign key to StratigraphyClassification table)

Shape – Type of spatial object (Point ZM)

GeochemicalLog

This feature class contains geochemical analyses of samples from outcrops and drill holes

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Point Z)

UTMX - UTM, Zone 14, NAD83 (easting) x coordinate of the outcrop/drill hole sample location

UTMY – UTM, Zone 14, NAD83 (northing) y coordinate of the outcrop/drill hole sample location

Z - Elevation coordinate sampled from 1: 50 000 scale digital elevation model of the outcrop sample location or computed from Z-mine coordinate (Callinan grid) of the drill hole sample location

SampleID – Unique identifier for geochemical sample (primary key)

StationID – Field station location for outcrop sample (foreign key to GeochemicalSampleLocation table)

HoleID – Unique ID for drill hole of the drill core sample (foreign key to Collar table)

Distance – Logged distance along the drill path in meters

SampleType – Sample type: ‘Outcrop’, ‘Drill hole’

Duplicate – Numeric encoding for duplicate samples; 0 = no duplicate, 1 = duplicate

Project – Project for which the geochemical sample was collected

Location – Geographic description of sample location

Year – Year in which the sample was analyzed

Geologist - Geologist that collected the geochemical sample

Lithology – Lithologic description of the geochemical sample by geologist that collected the sample

LithoCode3 – Abbreviated text string to encode lithology at the third (most detailed) level of lithology classification (foreign key to LithologyClassification table)

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

StratInterp – Stratigraphic interpretation of the outcrop or drill core by geologist that collected the sample

Sourcefile – Reference to identifier of HudBay Minerals Inc. Spreadsheet file

Method – Laboratory method used to analyze the sample (ICP or XRF)

Lab – Laboratory that conducted the geochemical analyses

Batch – Identification for a group of outcrop or drill core samples that were analyzed together

Major oxides: SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, P₂O₅, MnO, Cr₂O₃, in weight %; negative numbers are analyses at detection limit for a particular method/batch

LOI – Loss on ignition in weight %

Ctot – Carbon in weight %

Stot – Sulphur in weight %

SUM – Summed weight % major oxides, LOI, Stot and Ctot fields

Elements Ba, Ni, Sc, Co, Cs, Ga, Hf, Nb, Rb, Sn, Sr, Ta, Th, U, V, W, Zr, Y, La, Ce, Pr, Nd, Sm, U, Gd, Tb, Dy, Ho, Er, Tm, Yn, Lu, Mo, Cu, Pb, Zn, Cr, As, Cd, Sb, Bi, Ag, Ti, Be, Li, Ge, In, Se, Ir, Au, Hg, Tl, F, I, Ni2 in ppm; negative numbers are analyses at detection limit for a particular method/batch

2. GeologicMapElements

Feature classes

FaultTraces

This feature class contained the mapped surface traces of faults and shear zones acquired via TGI3 geologic mapping

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polyline ZM)

Layer – Type of fault structure or shear zone including suffix for approximate and defined map traces

Shape_Length – Length of 2D polyline feature (ESRI® object)

HydrographyMask

This feature class contains hydrography polygons to mask inferred bedrock geology beneath lakes and rivers

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polygon)

Class – Polygon classification (water / land)

Shape_Length – Length of 2D polyline feature (ESRI® object)

Shape_Area – Area of 2D polygon feature (ESRI® object)

Outcrops

This feature class contains outcrop polygons obtained through interpretation of aerial photographs

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polygon)

Shape_Length – Length of 2D polyline feature (ESRI® object)

Shape_Area – Area of 2D polygon feature (ESRI® object)

TGI3GeologicMapUnit

This feature class contains the units of the TGI3 1:10 000 scale geology map (Simard et al. 2010)

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polygon)

Unit – Map unit code from TGI3 map legend

UnitDescription – Unit description from the TGI3 map legend

LithoCode1 – Abbreviated character string to encode lithology at the first (most general) level of lithology classification

LithoClass1 – Text description associated to LithoCode1 to describe lithology at the first (most general) level of lithology classification

LithoCode2 – Abbreviated character string to encode lithology at the second level of lithology classification

LithoClass2 – Text description associated to LithoCode2 to describe lithology at the second level of lithology classification

LithoCode3 – Abbreviated character string to encode lithology at the third level of lithology classification

LithoClass3 – Text description associated to LithoCode3 to describe lithology at the third level of lithology classification

LithoCode4 – Abbreviated text string to encode lithology at the fourth (most detailed) level of lithology classification (primary key)

LithoClass4 – Text description associated to LithoCode4 to describe lithology at the fourth (most detailed) level of lithology classification

StratCode – Lithostratigraphic abbreviated code of group, formation, member or intrusive rock for logging or drill hole import functions with string length limit

Setting – Regional tectono-stratigraphic assemblage

Block – Block with semi-coherent to coherent internal lithostratigraphy bounded by regional faults across which lithostratigraphic correlation is difficult to impossible

FormationGroup – Lithostratigraphic formation (informal), Group or undivided unit or intrusive suite

MemberSuite – Lithostratigraphic member (informal), undivided unit or intrusive suite

Sequence – Number (ordered from young to old) indicating relative geochronologic order of lithostratigraphic class

3. TopographicMapElements

Feature classes

Infrastructure

This feature class contains infrastructure elements of the topographic base map including roads, railways, trails, airstrip and the provincial border

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polyline)

Type – Type of infrastructure (road, railway, airstrip, border)

Shape_Length – Length of 2D polyline feature (ESRI® object)

Hydrography

This feature class contains the hydrographic elements of the topographic base

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polyline)

Type – Type of hydrographic feature

Shape_Length – Length of 2D polyline feature (ESRI® object)

4. **GeologicModel3DElements**

3D-modelled surfaces imported from Flin Flon 3D Knowledge Cube (Schetselaar et al. 2010).

Feature classes

All the listed feature classes have the following attribute fields:

OBJECTID – Unique identifier for spatial object (ESRI® object)

Shape – Type of spatial object (Polygon ZM)

Shape_Length – Perimeter 3D polygon feature (ESRI® object)

Shape_Area – Area 3D polygon feature (ESRI® object)

BasalThrustVolcanicImbricate

Thrust fault at base of the intra-Missi imbricate of Flin Flon arc assemblage volcanic rocks (D3)

BaseMissi

Unconformity- regolith-tectonic contact (D3) between Flin Flon arc assemblage and sedimentary rocks of the Missi Group

BirchViewfault

Birch View thrust fault (D4)

BlindMissiThrust1

Blind thrust within Missi structural basin (D4)

BlindMissiThrust2

Blind thrust within Missi structural basin (D4)

BlindMissiThrust3

Blind thrust within Missi structural basin (D4)

CatherineFaultLower

Lower Catherine fault (D4)

CatherineFaultUpper

Upper Catherine fault (D4)

ChanningFault

Channing fault (D7)

CliffLakeFault

Cliff Lake fault (D7)

ClubLakeFault

Club Lake fault (D4)

FlinFlonLake-TailingPondFaultLower

Flin Flon Lake and lower Tailing Pond faults (D3)

LakeViewThrust

Lake View thrust fault (D4)

RailwayFaultLower

Lower Railway fault (D4)

RailwayFaultUpper

Upper Railway fault (D4)

RossLakeFault

Ross Lake fault (D7)

TailingPondFaultUpper

Tailing Pond fault (D3)

TopBlueLagoonL1

Top Blue Lagoon member, lower stack (tectonic contact with Millrock member)

TopBlueLagoonL21

Top Blue Lagoon member imbricate upper stack

TopBlueLagoonL22

Top Blue Lagoon member imbricate upper stack

TopBlueLagoonL23

Top Blue Lagoon member imbricate upper stack

TopBlueLagoonL24

Top Blue Lagoon member imbricate upper stack

TopHiddenL1

Top Hidden formation imbricate in footwall of VMS horizon

TopHiddenL12

Top Hidden formation in footwall of VMS horizon

TopHiddenL2

Top Hidden formation (stratigraphic contact with Louis formation)

TopMillrockL1

Top Millrock member lower stack

TopMillrockL21

Top Millrock member upper stack (stratigraphic contact with Hidden formation)

TopMillrockL22

Top Millrock member imbricate upper stack (stratigraphic contact with Hidden formation)

TopMillrockL23

Top Millrock member upper stack

TopVolcanicImbricate

Top intra-Missi imbricate of Flin Flon arc assemblage volcanic rocks (stratigraphic contact with Missi Group)

-- END