Drillhole Database Compilation from Legacy Archives in Support of 3D Geological Modelling and Mineral Exploration in the Purcell Anticlinorium, British Columbia

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Abstract

This paper summarizes the compilation methodology used to build a 3D drillhole database of the Purcell Anticlinorium from archives of industry drilling programs from 1912 to recent. This drillhole database was used to extract key lithostratigraphic markers to support regional-scale 3D geological modelling of regional faults and key lithostratigraphic contacts, including the SEDEX-hosting Sullivan horizon. The drillhole database stores collar information and deviation log surveys systematically linked to thematic logs, encoding lithostratigraphy, lithology, alteration, mineralization, structure and facies of the Sullivan Sub-basin. The multi-thematic drillhole data can be visualized with geological map data in 3D and can be queried to support exploration planning and drill targeting projects in the region.

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Introduction

A central objective of the Geological Survey of Canada fourth Targeted Geoscience Initiative Program (TGI4) is to develop knowledge and techniques to enhance the effectiveness of deep mineral exploration. Towards this objective a regional-scale 3D modelling initiative was undertaken to enhance insight into the subsurface geology of the Purcell Anticlinorium (southeast British Columbia) to support exploration for SEDEX deposits. This paper presents the methodology that was used to compile a Microsoft-ACCESS© relational database populated with drillhole data acquired over several decades by industry exploring for SEDEX, carbonate-hosted Zn-Pb and gold deposits in this region. Because drillhole data provide important subsurface constraints for generating 3D geological models (e.g. XYZ-referenced subsurface markers of formation contacts, alteration zones, mineralization occurrences and structural controls) this is an essential resource that can support planning exploration projects and 3D modelling endeavours in the Purcell Anticlinorium. For detailed descriptions and discussions of Sullivan deposit geology, the Sullivan Sub-basin and regional geology, reference to the Geological Association of Canada publication on the geological environment of the Sullivan deposit (Lydon et al., 2000) is recommended.

Results/Data Analysis

The drillhole database of the Purcell Anticlinorium archives 726 drillholes from exploration drilling programs conducted from 1912 to recent by operational firms exploring the 150 MT Sullivan SEDEX deposit and surrounding area, its satellites and other base metal and gold deposits. It contains lithologic and lithostratigraphic drill log descriptive 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. Figure 1 shows the location of the drillholes against a backdrop of a generalized geological map of the Purcell Anticlinorium compiled from TGI3 digital geology archives (Brown and MacLeod, 2011a, b, c, d; Brown et al., 2011a, b, c, d, e, f; Glombick et al., 2011a, b). The MS Access© database also contains genetic lithofacies interpretations of the Sullivan horizon, assay data and structural observations, digitized mainly from legacy Cominco Ltd. archives. Many drillhole collar identifiers, their coordinates and metadata were obtained from a previous TGI3 publication of legacy drillhole archives (Joseph et al., 2011a). All the tables of the MS Access© database are also provided in .CSV ASCII format stored in a separate folder, for users who want to inspect the drillhole data in spreadsheet format and/or import the data into 2D/3D GIS software. The Collar table is also stored in MS Excel© format to retain hyperlinks to the mineral exploration assessment reports on the British Columbia government website.

3D visualization of the drillhole data is provided through the free downloadable Leapfrog© 3D viewer to accommodate users who do not have access to dedicated 3D GIS or modelling software packages. Regional 3D views of the database show annotated drillhole lithology, lithostratigraphy, alteration and mineralization themes together with a seamless 3D compilation of the TGI3

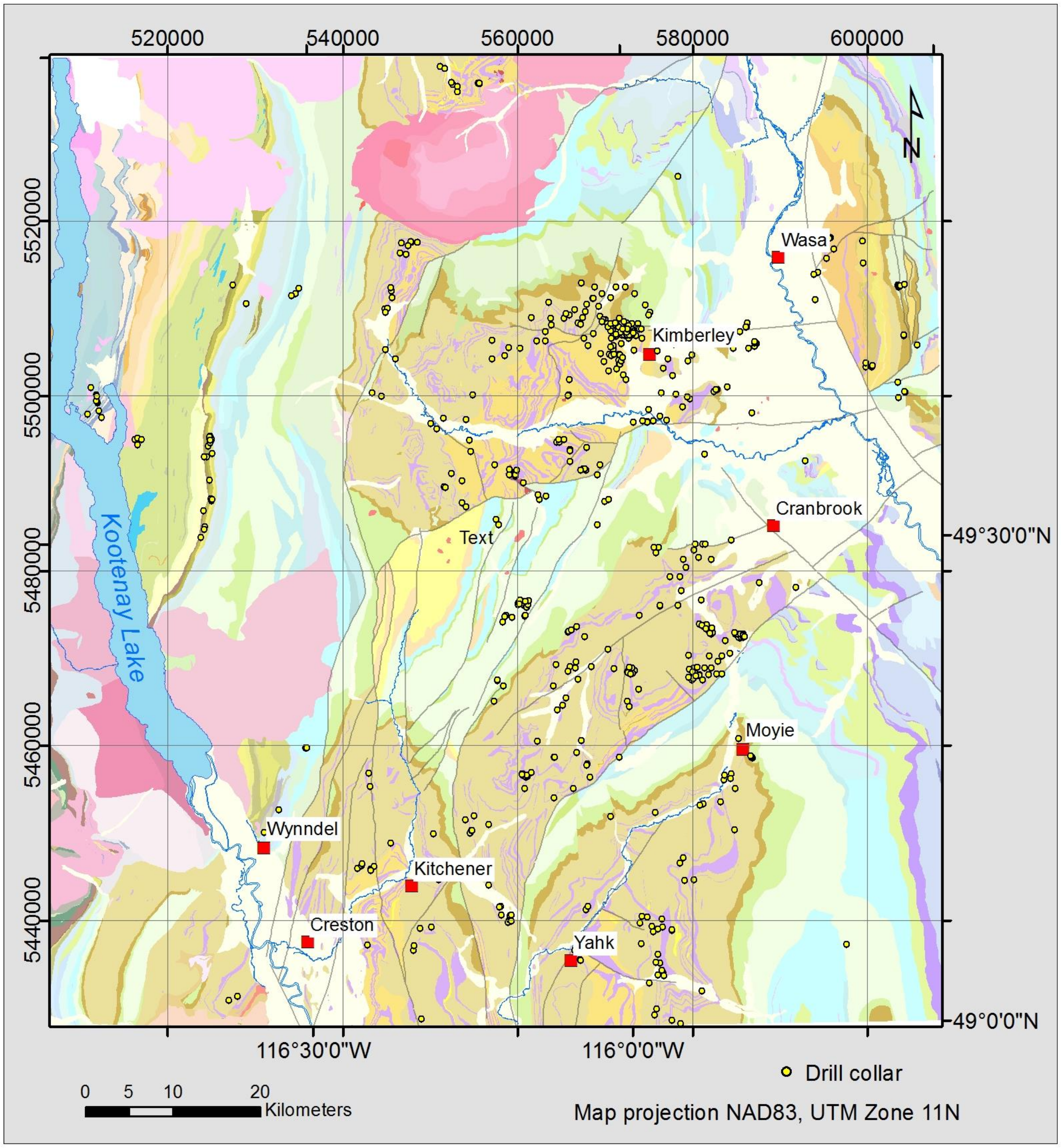

Figure 1. Map showing collar locations of drillholes contained in the drillhole database. Generalized geology (after Brown and MacLeod, 2011a, b, c, d; Brown et al., 2011a, b, c, d, e, f; Glombick et al., 2011a, b) is shown on the background.

geological map (Brown and MacLeod, 2011a, b, c, d; Brown et al., 2011a, b, c, d, e, f; Glombick et al., 2011a, b; Figure 2). A more detailed 3D view of the Sullivan Sub-basin is also provided that includes, in addition to the themes of the regional view, specific lithofacies drillhole intervals of the Sullivan horizon.

The drillhole database, 3D scenes and detailed descriptions of the tables and database fields can be downloaded from an accompanying Open File publication (Schetselaar et al., 2015).

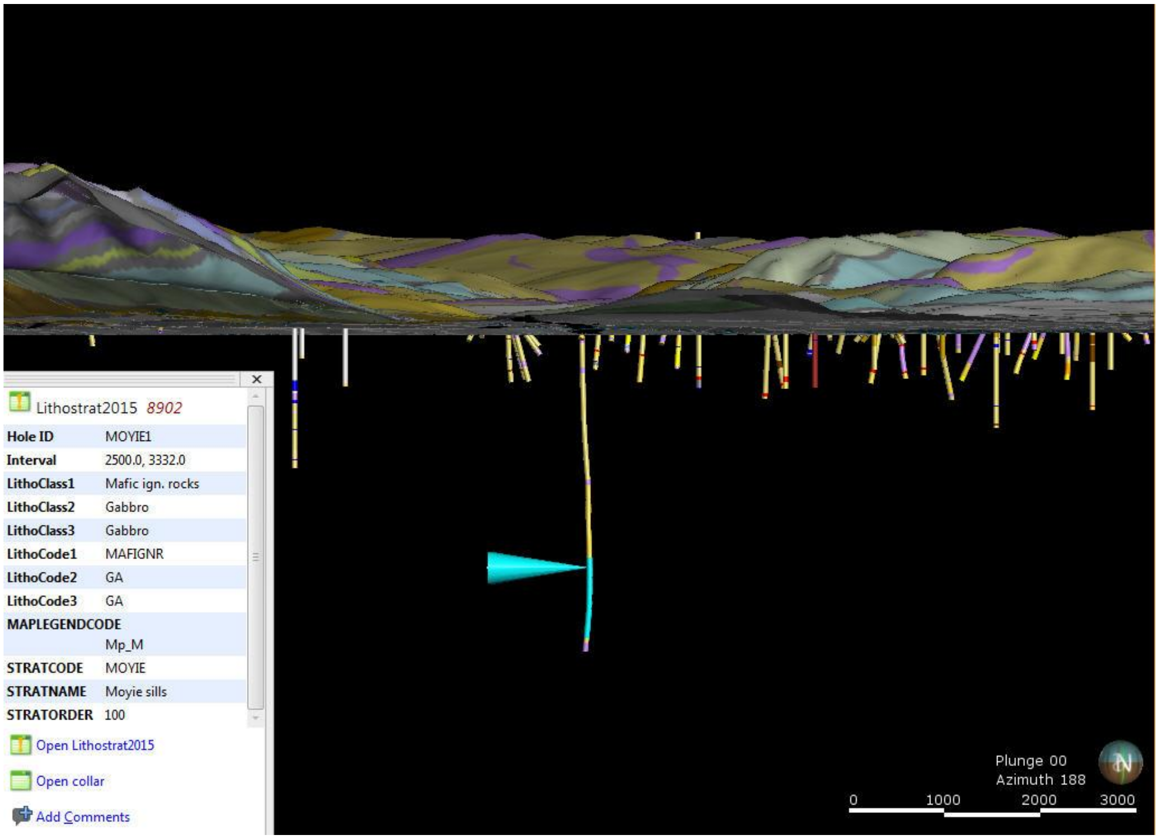

Figure 2. 3D image of the Purcell drillhole database showing example of interactive query of lithostratigraphic information of a FROM-TO interval.

Geometric Registration of Drillhole Collars

The drillhole database is georeferenced to UTM, Zone 11N, North American Datum (NAD83) coordinates. The drillhole collar locations, either precisely surveyed or originally registered on a variety of hard copy topographic maps and mine grids, were digitized in UTM coordinates using surveyor provided conversion factors or affine transformations that were estimated from control points digitized from these legacy map archives, including mine grids and topographic landmarks such as intersections and bends in rivers and roads. Some of the drillhole collar locations, however, were more recently surveyed using single handheld GPS units. As a result, the planimetric (xy) root mean square error of drill collar locations significantly varies, with an estimated range of 5 to 250 metres (1 sigma). It should be noted that these error estimates refer to the collar locations and not to the accuracy of the drillhole logs themselves, which are also cumulatively dependent on errors in deviation log readings down the drillhole. Many of the drillhole paths were surveyed using older instruments with relatively low standards in accuracy and precision as compared to modern deviation log surveys. Moreover a significant portion of the older drillholes do not have deviation log surveys and are therefore assumed to be straight line projections from the recorded collar orientation. Although the value of these particular holes for exploration planning on detailed map scales may be limited, they may still be useful at more regional map scales, considering that they provide the only available subsurface geologic data around their collar positions.

Drillhole Database Compilation

Drillhole descriptive attributes, including lithology, lithostratigraphy, structure, alteration and mineralization were obtained from approved mineral exploration assessment reports maintained by the B.C. government (British Columbia Ministry of Energy and Mines, undated) and unpublished industry reports (mainly from Cominco Ltd.). Where available hyperlinks to the B.C. Ministry of Energy and Mines ARIS (assessment report indexing system) are provided in the database ('Collar' table) so that the digitized information can be easily compared with the source archives maintained on the B.C. Ministry of Energy and Mines website. Records for drillholes that were deepened at a later stage were combined in a single 'HoleID' record in the 'Collar' table. For these drillholes the ARIS report code and associated hyperlink field refer to the latest drilling activity in the hole.

Six thematic tables, including lithology, lithostratigraphy, alteration, mineralization, structure and Sub-basin facies (described in more detail below) were compiled from legacy drill log descriptions (Figure 3). The drillhole lithology logs were originally coded by industry and consulting geologists using locally established lithological and lithostratigraphic terminology. The lithology table also contains a field 'StratCode' to encode the lithostratigraphic formations of the Purcell Supergroup and Mesoproterozoic and Mesozoic intrusive suites (Höy et al., 2000). The lithostratigraphic classification includes 'barcode' siltstone markers consisting of millimetric to centimetric alternating dark grey and light grey laminated siltstone within the turbiditic sequence of the Middle Aldridge Formation (Huebschman, 1973). These unique 'barcode' patterns that characterize basin-wide fine-grained sediments formed when they settle from suspension during time intervals between turbidite flows, facilitate lithostratigraphic correlation over distances up to 300 km (Chandler, 2000). The position along the drillhole and thickness of the laminated siltstone markers were recovered from drill core stored at the Vine property and from Cominco's legacy archives to facilitate 3D lithostratigraphic modelling.

Drillhole Database Structure

The MS Access© database 'PurcellDrillholeDatabase.mdb' consists of ten tables including five thematic drill log tables (Figure 4), describing: (1) lithology and lithostratigraphy (2) presence/absence of hydrothermal alteration and associated mineral species, (3) sulphide mineralization type (e.g.'massive', 'disseminated') occurrence (e.g. 'vein', 'bleb') and mineral species (4) structures with their core-angle to the drill path and (5) descriptions of sedimentary facies found in the Sub-basin that hosted the now mined-out 150 Mt Sullivan massive sulphide deposit. The database normalization into five themes was essential to support hole-to-hole correlation of lithostratigraphic markers over large distances

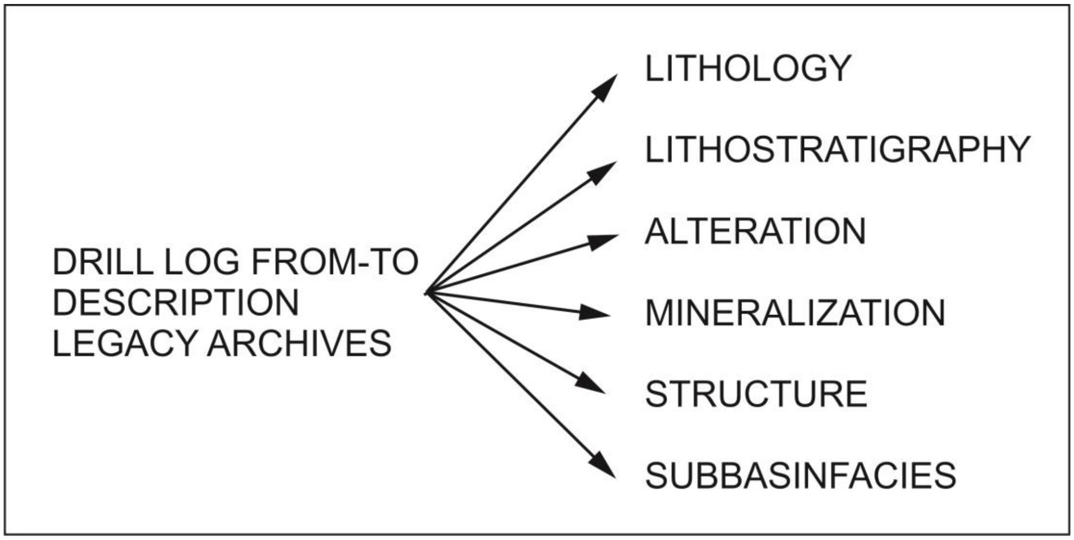

Figure 3. Attribute themes (right) parsed out from industry drill log archives (left) for normalizing the drillhole database into six themes. The lithology and lithostratigraphy themes were integrated in a single table because their 'FROM' – 'TO' descriptions refer to the same interval.

underpinning, in combination with mapped geological contacts, 3D regional-scale modelling of the contacts between the Mesoproterozoic formations of the Purcell Supergroup, including the Sullivan horizon.

As shown in Figure 4, the records in the five thematic drill log tables are linked by their drillhole identifier 'HoleID' to the 'Collar' table and to the 'DeviationLog' table in many-to-one relationships. The 'Litholog' and 'SubbasinFacies' tables are also linked to classification tables, which facilitate translating database fields with abbreviated codes to full text descriptions. The lithology classification table is hierarchically-structured, which permits recoding the most detailed drill log classification at multiple levels of generalization (Figure 5). The hierarchical structure is also used to encode mixtures of different lithofacies within a particular FROM-TO interval. The 'LithoCode2' field encodes either the dominant lithology or a mixture of lithology components when they are approximately equally abundant. The 'LithoCode3' field, regardless of the abundance of the components, always presents the abbreviation for the coarsest-grained lithology (if applicable) as the first character(s) of the code in cases where more than one lithology is present. So when the interval consists of more than one lithology, the 'Lithocode3' field encodes all the lithologies that occur in the interval, while 'Lithocode2' field encodes the most abundant. The Litholog table has in addition to this hierarchically-structured lithological information, a field that encodes the lithostratigraphy of the Mesoproterozoic formations of the Purcell Supergroup, including the names of the siltstone markers of the Middle Aldridge formation. Full descriptions of the database tables and the fields contained within them are provided in Schetselaar et al. (2015).

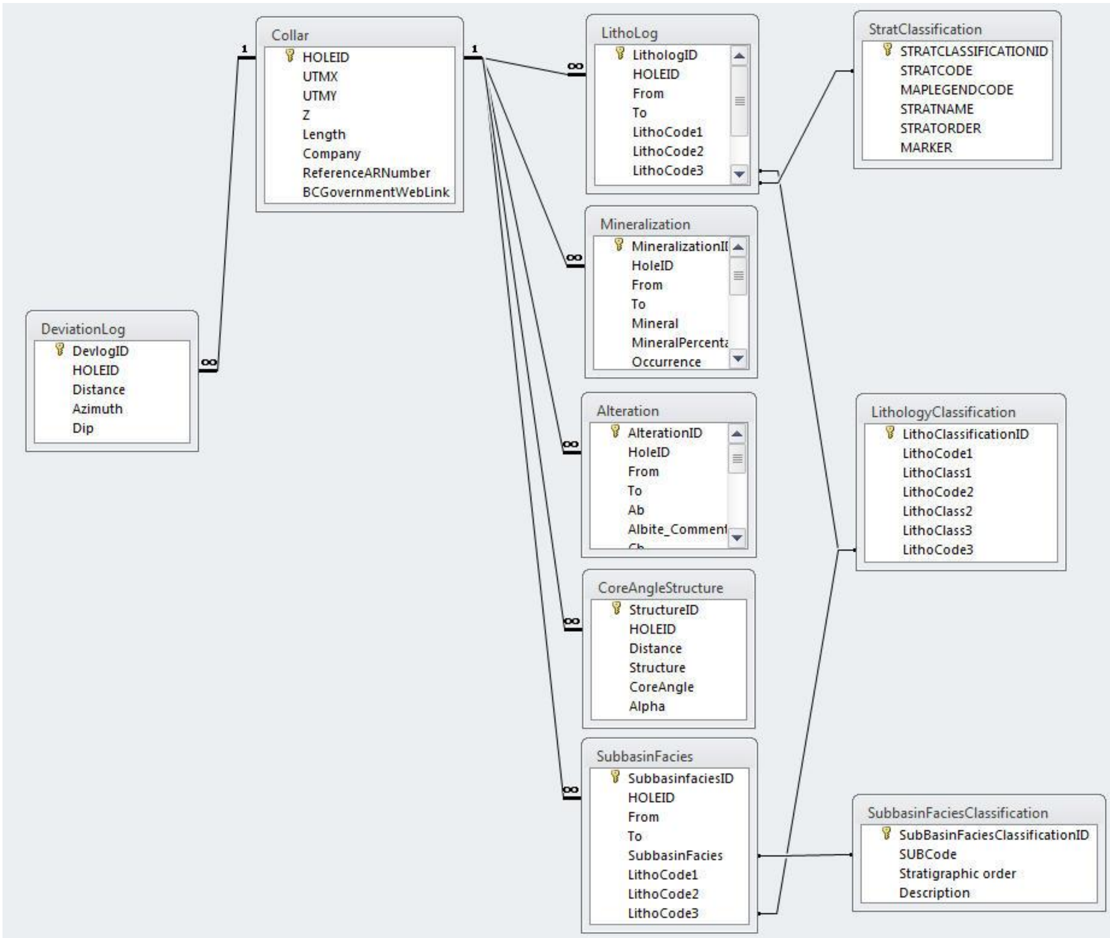

Figure 4. Database structure of the MS Access© relational drillhole database of the Purcell Anticlinorium.

Lithology encoding for single lithologies

LithoCode1: SEDCL = clastic (meta)sedimentary rocks
LithoCode2: W = wackestone
LithoCode3: Wl = laminated wackestone

Lithology encoding for mixed lithologies

LithoCode1: SEDCL = clastic (meta)sedimentary rocks
LithoCode2: W = wackestone
LithoCode3: QWl = laminated wackestone dominant / minor quartzite

LithoCode1: SEDCL = clastic (meta)sedimentary rocks
LithoCode2: Q = quartzite
LithoCode3: QWl = quartzite dominant / minor laminated wackestone

LithoCode1: SEDCL = clastic (meta)sedimentary rocks
LithoCode2: QW = quartzite and wackstone in approximately equal abundance
LithoCode3: QWl = quartzite / laminated wackestone

Figure 5. Examples of hierarchical lithology encoding of single and mixed FROM-TO intervals.

Discussion/Models

Limitations of the database

The drillhole data were compiled from a variety of sources some of which date back to the early 1900s. Starting in the 1960s exploration drilling became guided by structural and stratigraphic constraints in the search for SEDEX deposits. This compilation involved reconciling industry coding and lithological descriptions of a large number of geologists from a variety of exploration firms that logged drill core in the Purcell Anticlinorium. Although the drill log records were checked against their original interval descriptions in the legacy archives, it is possible that data transcription errors, inconsistencies in rock classification and coding errors were propagated. Inconsistencies in lithological and lithostratigraphic drill log coding may also be due to ambiguities in interpreting drill log interval descriptions, particularly for the most detailed interval descriptions that often contain lithofacies mixtures, such as alternating intervals of mudstone, siltstone, wacke and subwacke.

It should be noted that a significant proportion of the alteration and mineralization tables have overlapping FROM-TO intervals, as a result of parsing mineral species from text descriptions linked to different but overlapping intervals. Therefore it is recommended that separate queries be made for each mineral. Another significant limitation of this database is related to positioning of some of the drillhole collars that were carried out before the GPS era using topographic maps and/or air photographs. As a result, a few coordinates of, and shown drillhole collar locations may be tens to a maximum of a few hundreds of metres from their actual location.

Implications for Exploration

The relational database structure and standardized descriptive information of the drillhole data, including alteration and sulphide mineralization logs and a lithostratigraphic classification that matches the legend codes of the previously published TGI3 digital geologic map database (Brown and MacLeod, 2011a, b, c, d; Brown et al., 2011a, b, c, d, e, f; Glombick et al., 2011a, b) enables defining a wide range of spatial and attribute queries in support of exploration in the Purcell Anticlinorium with applicability to geological feasibility studies, mineral potential mapping, drill targeting and 3D modelling projects. This 3D database also provides the first comprehensive digital archive of the siltstone 'barcode' markers of the Middle Aldridge Formation that can be correlated over hundreds of kilometres and play an unique role in the subsurface prediction of favourable horizons hosting SEDEX mineralization, including the Sullivan horizon.

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