DIGITAL MAPPING TECHNIQUES 2019

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Geospatial Frame Data Model to Simplify Digital Geological Map Compilation and Integration

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BRITISH COLUMBIA | Ministry of Energy, Mines and Petroleum Resources

Abstract

Digital maps in the Earth sciences have long-used polygons to define bedrock units. However, polygons are prone to topological errors when used to compile, update, and integrate digital maps. These errors include gaps, overlaps, slivers, and discontinuities in the data that are hard to detect and fix. Using polygons also makes it time consuming to reconcile geometric differences at shared boundaries such as faults. To avoid these problems, we developed a geospatial frame data (GFD) model that dispenses with polygons at the map compilation and integration stages. Instead, the GFD model consists only of two data components: centroids describing geological units, and lines defining geological boundaries. Polygons representing geological units are not part of the GFD but are generated from GFD at the data production stage in the finished data products. Implementing the GFD model in a spatial database allows us to develop a fully automated data checkout process and anchoring mechanism to simplify data integration and eliminate boundary problems when maps are updated and merged. With only linework and point geometries, GFD also simplifies other processes without the risk of losing integrity or introducing topological errors. Furthermore, the bedrock polygons in finished geological maps are the result of spatial database 'views' or 'materialized views' of the GFD data. These 'views' and 'materialized views' can be used to customize a map by, for example, reducing coordinate precision, re-projecting the map coordinate system, simplifying lines, and generalizing bedrock units, without the need to change the source data. The GFD model and integration processes can be applied to any discipline that uses polygons and lines in digital mapping.

Introduction

The British Columbia Geological Survey (BCGS) commenced province-wide digital compilation of bedrock geology in the early 1990s as part of the mineral resource assessment project, and the digital geology data was released to the public in 2005.

The BC digital geology is considered as the authoritative data source, contains all details at scales from 1:50,000 to 1:250,000, and is seamless in digital coverage (no gaps, no overlaps, and map sheet boundaries resolved).

Since 2005, we had faced with the challenge of updating the BC digital geology by integrating new field mapping into our corporate database (Figure 1). Our goal is to compile and integrate bedrock geology of all scales and to encode the bedrock geology with consistent nomenclature and eventually compliant to the international geoscience standard (i.e., GeoSciML), to support computations: rendering geological maps for visualization, carrying out spatial and non-spatial queries, performing statistical analysis and modelling, producing custom maps (e.g., to generalize maps or with a specific theme), and enabling machine learning.

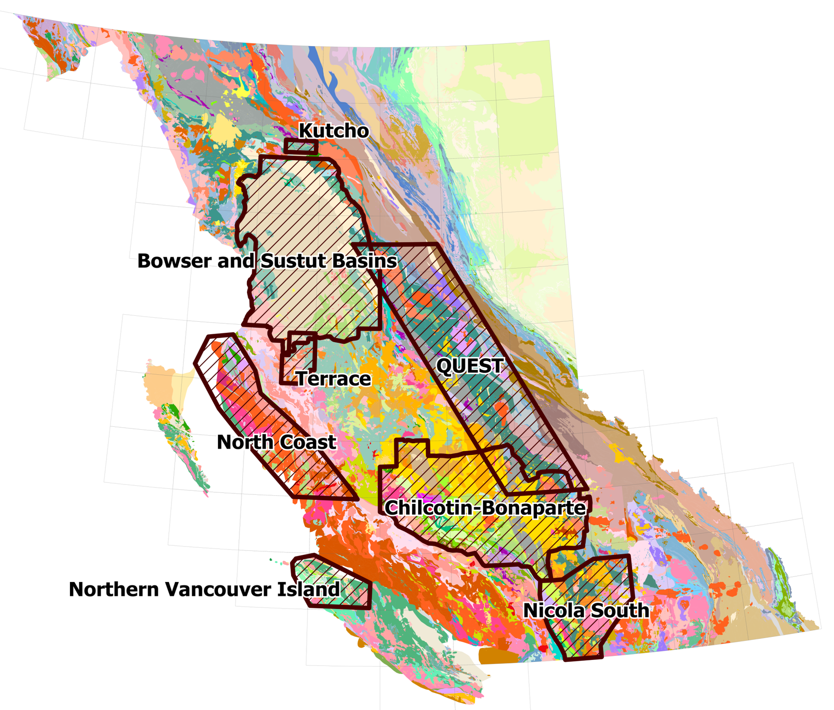

Figure 1. British Columbia bedrock geology and recent regional compilations and map integration.

Compilation and integration problems

Polygons are an attractive means to capture bedrock units in two-dimensional (2D) geological maps depicting surface expression (areal or polygonal features hereafter in the context of 2D maps) of three-dimensional rock bodies, in addition to the use of lines to capture the surface expression of quasi-planar features such as faults and contacts between bedrock units (or linear feature hereafter in the context of 2D maps). Digital maps using polygons can be difficult to update and integrate. Polygons are prone to introduce geometric and topological errors such as gaps, overlaps, slivers, and discontinuity from editing and edge matching in merging or integrating maps. Using polygons makes it time consuming to reconcile geometric differences at shared boundaries such as faults (Figure 2 and 3). Many of these errors are caused by rounding coordinates to the unit of precision during editing and transforming the data, e.g., map projection, convert data from systems with different units of precision (Figure 4 and 5).

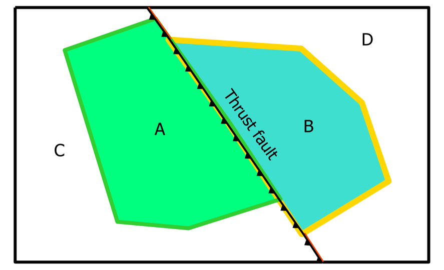

Figure 2. Shared boundaries among the thrust fault and the polygon boundaries for bedrock unit A and B.

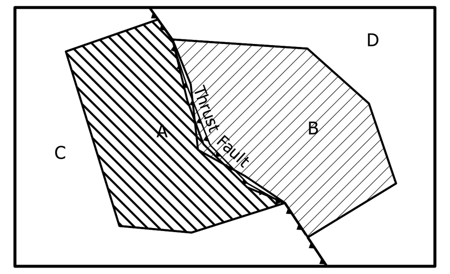

Figure3. Topological errors such as gaps and overlaps and other discontinuities are introduced among the thrust fault and bedrock units A and B.

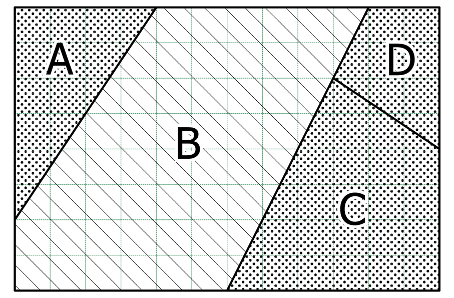

Figure 4. Shared boundaries among bedrock units A, B, C, and D. Lines in green represent the unit of precision that the geometries are stored, that is, coordinates beyond this precision are rounded to this unit of precision.

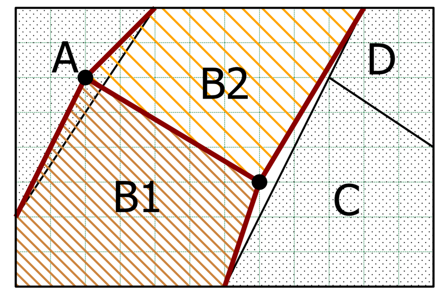

Figure 5. After unit B is divided into sub-units B1 and B2, overlaps are introduced between unit A and units B1 and B2; and a gap is formed between units B1, B2 and units C and D.

Solution: geospatial frame data model

To avoid the topological errors and simplify the map compilation, we developed a geospatial frame data (GFD) model that dispenses with polygons at the map compilation and integration stages. Instead, the GFD model consists only of two data components (Figure 6):

- centroids describing geological units, and
- lines defining geological boundaries

Polygons representing geological units are not part of the GFD but are generated from GFD at the data production stage in the finished map products (Figure 7).

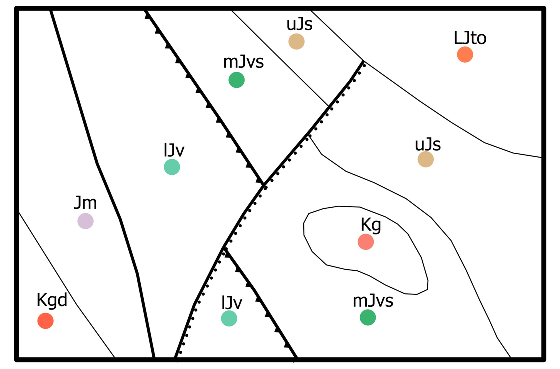

Figure 6. Geospatial frame data consists of lines delineating geological boundaries and centroids representing bedrock units.

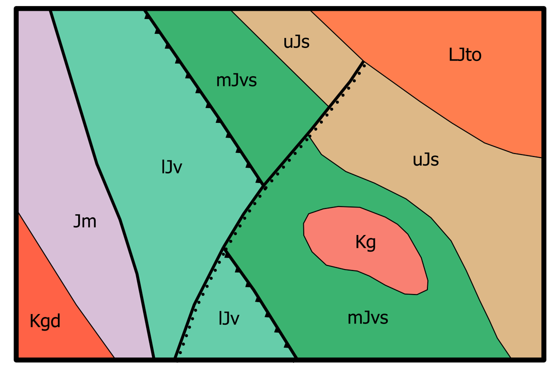

Figure 7. Bedrock geological map is created from the geospatial frame data.

Integration of geospatial frame data

To integrate digital geological maps, a common task is to fix overlaps, gaps, discontinuities, and other problems along mapsheet boundaries. The use of geospatial frame data (GFD) model allows us to develop a 'checking-out' process and an anchoring mechanism to fully automate the data integration, thus saving time by eliminating the task of edge matching.

Checking-out geospatial frame data with anchoring

When a new mapping project commences, a copy of the geospatial frame data is 'checked out' for the area with an extended regional context (Figures 8 and 9). The checking-out process sets up the GFD with anchoring tags (Figures 10):

1) The outermost boundaries of the GFD in the regional context are defined and tagged as 'anchorline' and the end points of anchor lines are defined as 'anchorpoint' (Figure 10 and 11).
2) Lines connected to anchorpoints are defined and tagged as 'rodeline'.
3) All other lines within the regional context are tagged as 'checked out for revision'.

Note: there is no crop or split of the linework in the GFD data. A complete 'checked-out' package would include the both the framework data and bedrock polygons (Figure 12).

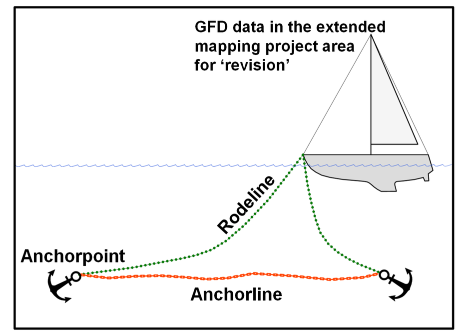

Figure 11. Definition of anchoring tags explained with nautical terms:

- Anchorline: guard map boundary
- Anchorpoint: guard nodes on map boundary
- Rodeline: line hooked to anchorpoint
- Revision: contents for update

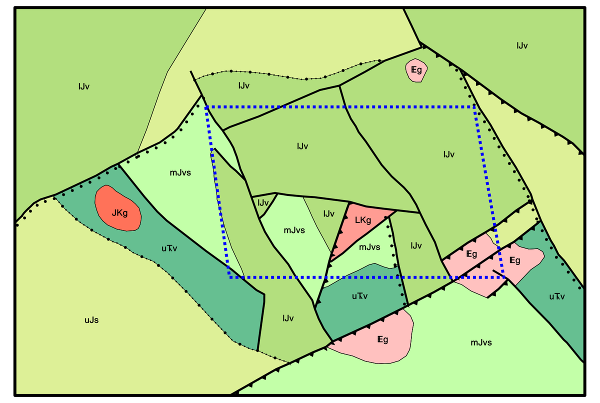

Figure 8. A new mapping project area is outlined by dotted line in blue.

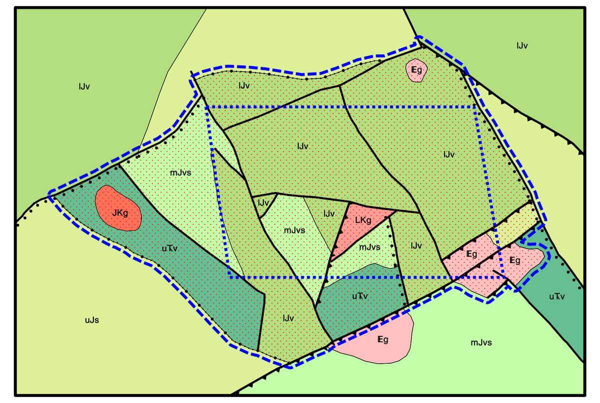

Figure 9. Selection of all data that intersect the limit of mapping for the new mapping project area; note that units JKg to the west and Eg to the north are included.

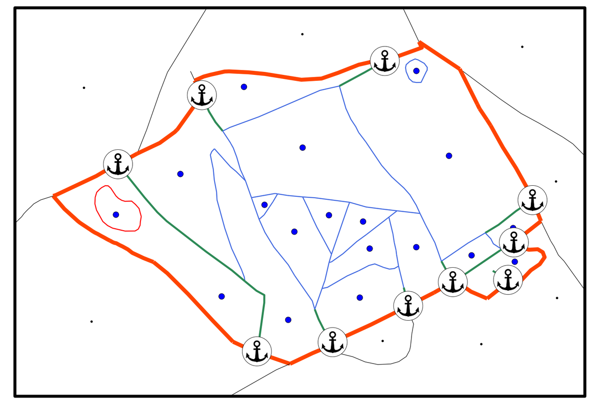

Figure 10. The selected GFD are tagged as anchorline (in red), rodeline (in green), and revision (in blue); also defined as anchorpoint on anchorline that connects end of a rodeline.

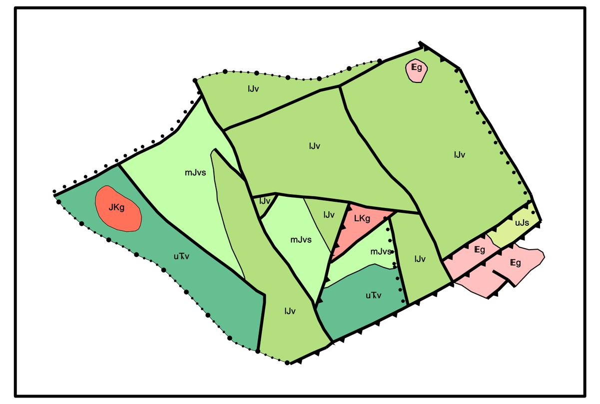

Figure 12. Extracted package for update (*checked out*), including project geospatial frame data (and bedrock polygons).

Updating bedrock geology in the extended project area

When the bedrock geology is updated (Figure 13), usually the anchorlines (highlighted in red) and anchorpoints will not be modified (Figure 14) with sufficient regional context of GFD data beyond the mapping project area. If new rodelines are added or existing rodelines are modified, they will be detected and handled at the data validation and integration stage.

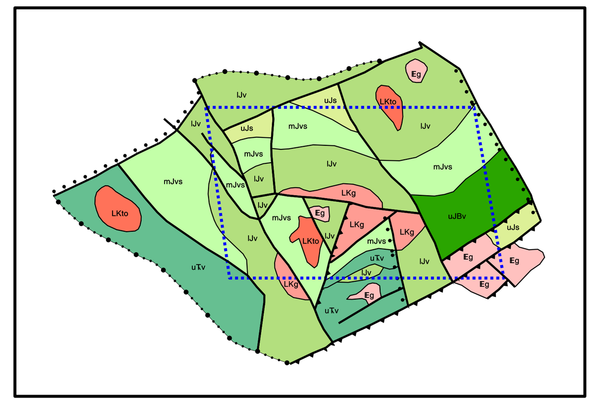

Figure 13. Updated bedrock geology in the extended regional compilation area. Note the age for unit JKg has been updated to LKto.

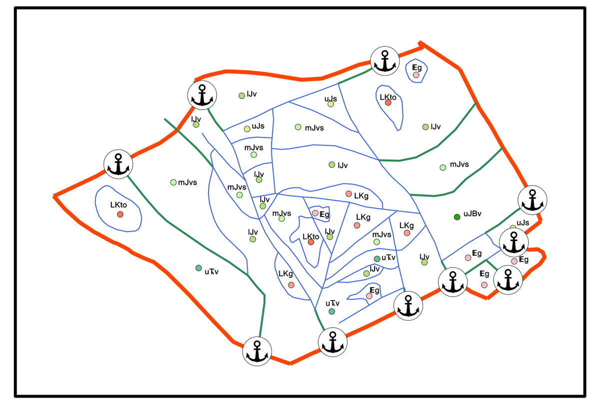

Figure 14. Updated project GFD data in the extended regional compilation area. Note three new rodelines without anchorpoints.

Checking-in: integrating updated project GFD data

When a mapping project is completed (Figure 12), the following steps are used to integrate the updates into the corporate GFD database:

1) After passing data quality checking, the bedrock polygons are not dropped (Figure 14) and only accepted project GFD data are admitted into the corporate GFD database after removing the anchorline (Figure 15).
2) Records tagged as 'rodeline' and 'checked out for revision' in the corporate GFD database are unlocked and retired.
3) The anchorpoints on the anchorlines in the corporate GFD database are used to snap the rodeline from the project GFD data (Figure 17 and 18). Note new anchorpoints in the corporate GFD database are created by intersecting new rodelines from the mapping project GFD data.
4) Lines in the regional context area are used to generate new bedrock polygons (Figure 19).
5) New bedrock polygons for the extended regional compilation area are attributed by the updated centroids in the project GFD data.

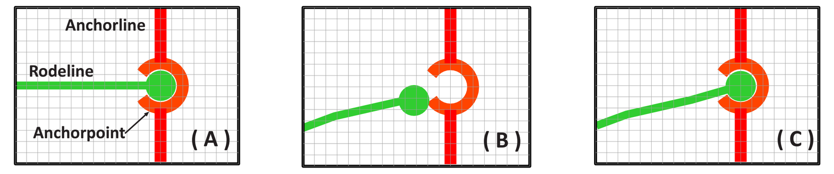

Figure 17. (A) before update: rodeline connected to anchorline at anchorpoint; (B) after update: rodeline drifted away from anchorpoint; and (C) after integration: rodeline snapped back to anchorpoint.

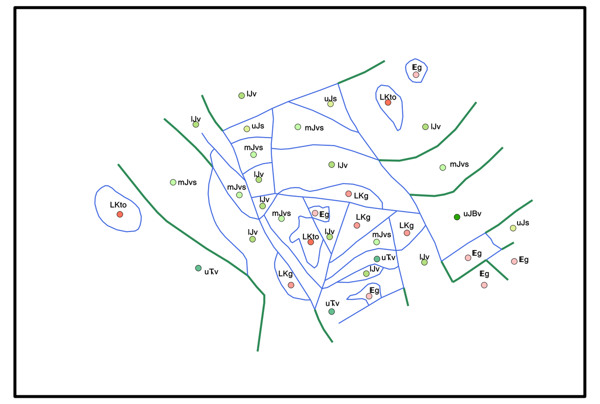

Figure 15. Remove anchorlines in the updated GFD data before integration.

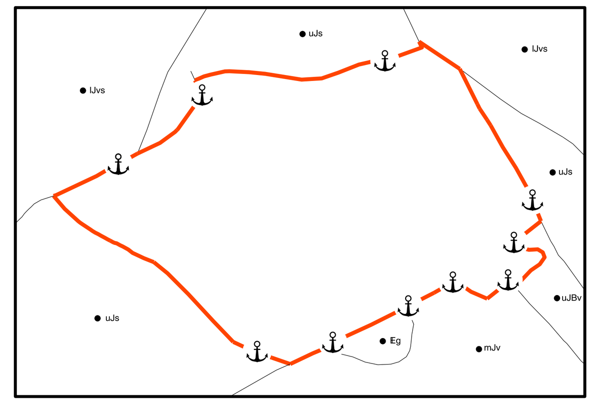

Figure 16. Retire out-dated GFD data in the corporate GFD database before accepting the updated GFD data.

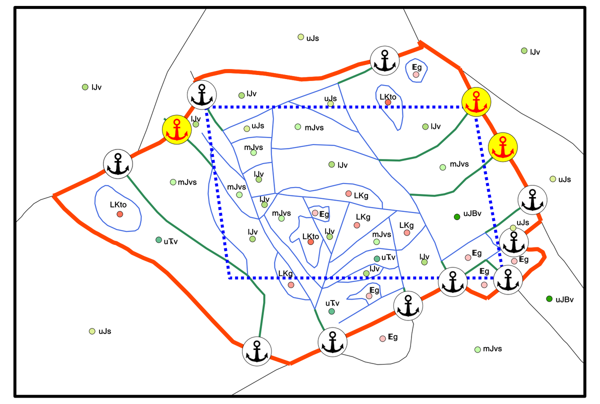

Figure 18. Updated project geospatial frame data are integrated into corporate GFD database (*checked in*). Note new anchorpoints (in red and yellow highlight) are created for new rodelines.

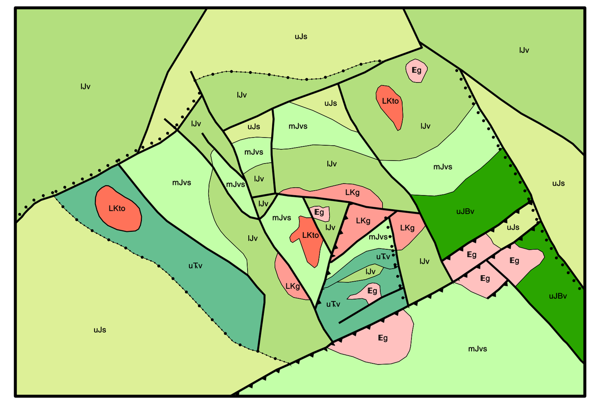

Figure 19. Updated provincial bedrock map.

An updated bedrock geological map for the entire province can be produced by applying the map styles and colour legend to the bedrock polygons, contacts, faults and other geological features (Figure 19), and adding other cartographic enhancements. This approach has been used to integrate recent regional compilations in the province of British Columbia (Figure 1).

Compilation and integration environment

System components

The geospatial frame data model is implemented in our Geoscience Operational Database Environment using spatial database PostgreSQL/PostGIS and desktop GIS Manifold System® (Figure 20), to fulfill the following tasks:

- Loading source data into the Observation Database after schema mapping and content standardization
- Carrying out data quality assurance, updating and integration in the Staging Database
- Archiving completed maps as the authoritative data sources in the Archive Database

This environment is capable of handling large volumes of data and multiple users to perform concurrent operations from both the front-end GIS tools or database-side manipulation.

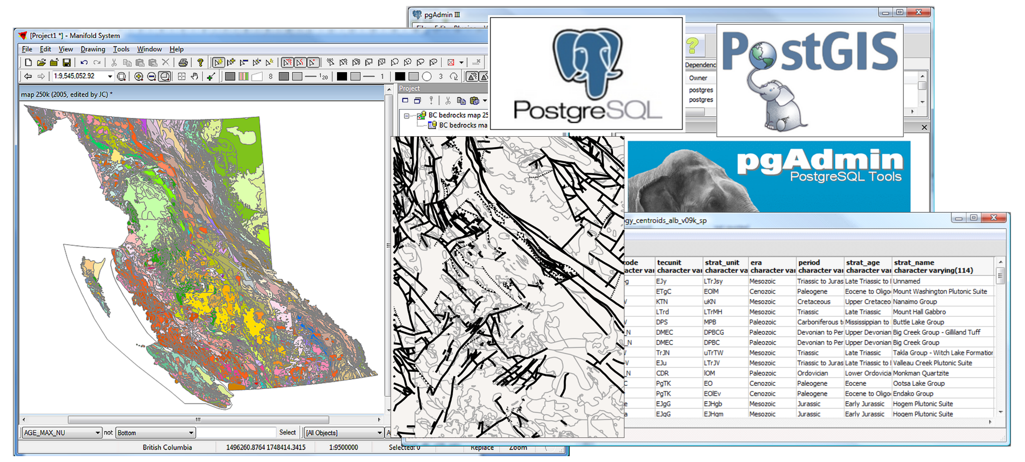

Figure 20. Geospatial frame data compilation and integration environment.

Database applications: production and publication

Most of the operations are automated or assisted through database applications developed in SQL, PL/pgSQL as functions, stored procedures, triggers, and database views:

- Schema mapping and content standardization for data loading service
- Data 'checking-out', framework data integration, and production of geological maps
- Change tracking and auditing on GFD: geometries and geological units
- Rules-driven data quality checking with rules and checking sequence stored in database
- Colour schemes and map legend for geological units adjusting after updates
- Production of custom geological maps

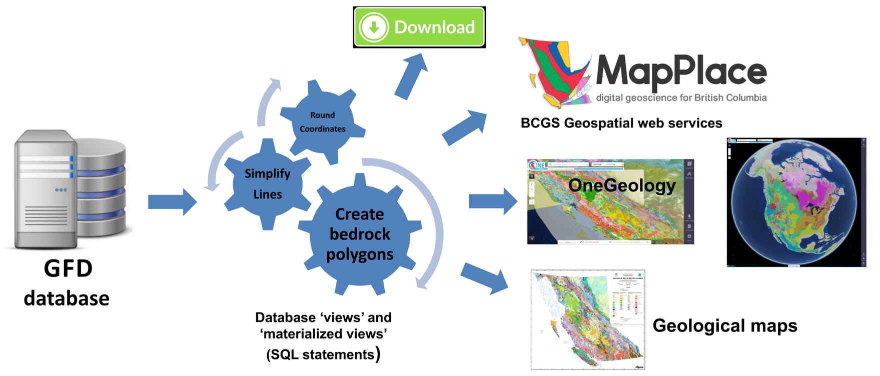

Figure 21. Database applications to support production and publication.

Summary

British Columbia Geological Survey updates and integrates digital geological maps by using a geospatial frame data model without polygons, a data 'checking-out' process, and an anchoring mechanism, implemented in a spatial database environment. This approach has helped us to streamline the data integration and delivery process. It:

- eliminates issues in shared boundaries and edge matching
- allows fully automatic data checking-out, anchoring and integration
- enables rule-driven data quality assurance and content standardization
- tracks and audits data revisions automatically
- permits multiple users to perform concurrent operations on large volumes of data
- automates updating of colour schemes and legends to produce customized maps
- shortens the time to deliver updated digital geology to clients through MapPlace

The approach and practices can be easily adopted by others using spatial database technology.