DIGITAL MAPPING TECHNIQUES 2019

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http://ngmdb.usgs.gov/info/dmt/

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

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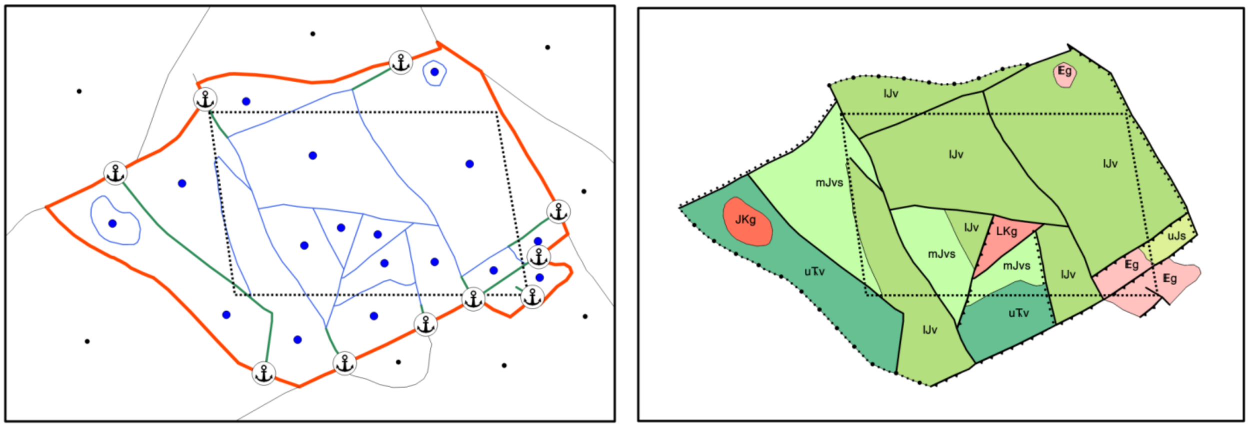
Since 2005, when the British Columbia Geological Survey first completed digital coverage of bedrock geology for the entire province, we have been faced with the challenge of integrating new field mapping into our corporate database. Digital maps in the Earth sciences have long used polygons to define 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 does not use polygons at the map compilation and integration stages. Instead, the GFD model consists of only 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 for the finished map products. The GFD model has no explicit topology for the lines, nodes, and centroids. The relationships among the GFD data components are geological. For example, overshoots and dangles are allowed to represent faults extending partially into a bedrock unit.

The GFD model defines a data 'checkout' process and 'anchoring' mechanism to update all geological units intersecting the limit of mapping, and to integrate data without the need of edge matching (Figures 1 and 2). The GFD data checkout process first intersects and selects bedrock geology that extends beyond the limits of new mapping to include all units and structures that may be affected. In the next step, all the selected features are tagged as the following: 1) 'anchor lines' to representing the outermost boundaries of the extended area, 2) 'anchor point' representing the nodes on outermost boundaries, 3) 'rode lines' representing the boundary features in the extended area directly connecting the anchor points, and 4) 'revision' for all the other features within the extended area (Figure 1A). Then, all the data within the extended area, including the GFD data components and the bedrock polygons, are extracted and packaged for update (Figure 1B). When update is complete and ready for integration, the first step is to retire the GFD data components in the corporate database. After anchor lines in the updated GFD package are removed, the new geology is then uploaded into the corporate database. Rode lines in the updates are snapped to the anchor points in the corporate database (Figure 2A). The geological map products with bedrock polygons are automatically updated when the database view or materialized view are refreshed from the updated corporate database (Figure 2B). The GFD data checkout process avoids introduction of topological errors because polygons are not split when data are extracted, and there is no edge matching between polygons in map integration. It also reduces the risk of introducing unit or structure discontinuities at the map boundaries.

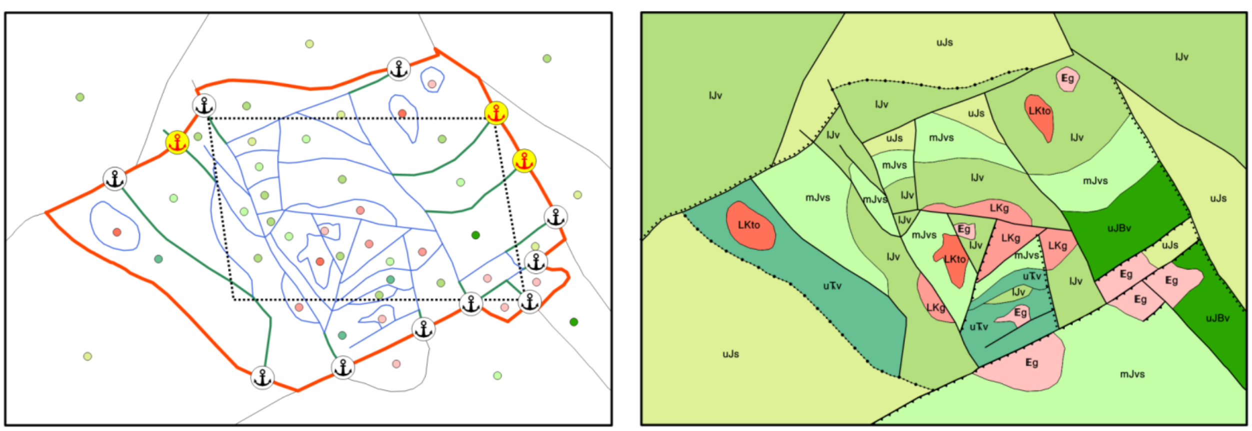
With only linework and point geometries, GFD also simplifies other processes, such as map generalization, without losing data integrity or introducing topological errors. Furthermore, the bedrock polygons in finished maps are the result of spatial database 'views' or 'materialized views' of the GFD data. 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 changing the source data in GFD.

The GFD model can be applied to any discipline that uses polygons and lines in digital mapping, such as topographic base maps, cadastres, land use, and soil maps. It is simple enough that it can be implemented in any desktop GIS or spatial database system.



(A) (B)

Figure 1. (A) GFD data ‘checkout’ step 1: proposed limit of mapping (shown as black dotted line) is used to intersect the GFD data components (bedrock units as points, and geological boundaries as lines), and affected data components (including those extending beyond the limit of new mapping) are tagged as 1) anchor lines in red, 2) anchor points shown as anchors in black, 3) rode lines in green, and revision as points and lines in blue; and (B) GFD data ‘checkout’ step 2: the GFD data package (and bedrock polygons) are extracted for geologists to update.



(A) (B)

Figure 2. (A) GDF data integration step: 1) out-dated data within the anchor lines in the corporate database are retired and removed, 2) updated project GFD data are loaded into the corporate database (except the anchor lines), 3) rode lines from project data are snapped to anchor points in the corporate database, and 4) new nodes (new anchor points as anchors in red highlighted by yellow circles) are formed to connect new rode lines; and (B) geological map production steps: 1) bedrock polygons are formed from GFD geological boundaries, 2) descriptions for bedrock polygons are transferred from GFD centroids through spatial overlay, 3) further data processing and symbolization can be applied to complete the cartographic representation of the geological map, including bedrock colours, unit labels, line styles for different fault types, legend, scale bar and map title.

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

Yao Cui, P.Geo.
British Columbia Geological Survey

Digital Mapping Techniques Workshop
Butte, Montana
May 19-22, 2019

Reducing complexity and eliminating topological errors in map compilation and integration

- Solution: geospatial frame data (GFD) model
- Problem: using polygons

Problems of using polygons

- Shared boundaries
- Edge matching

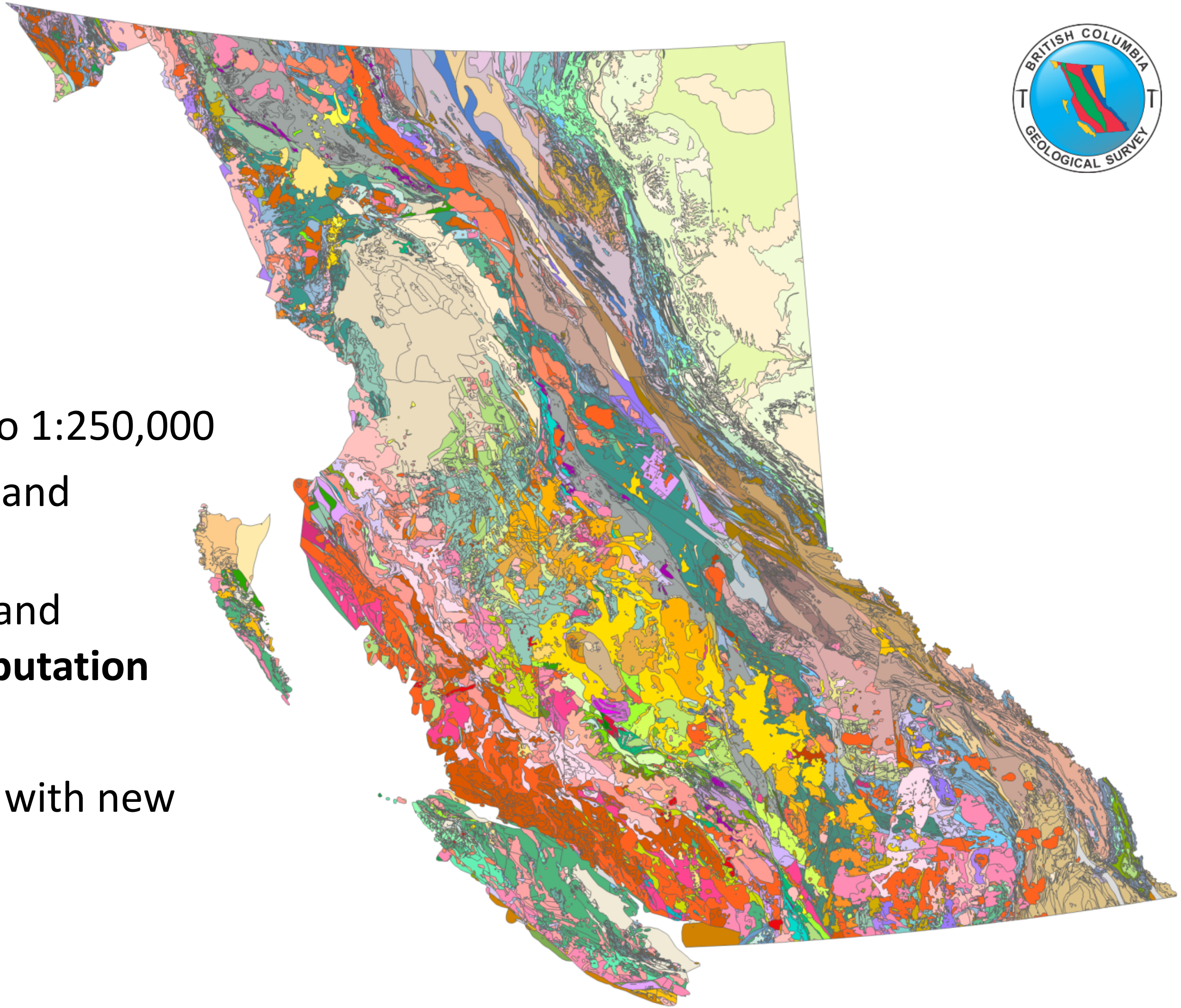
British Columbia

Bedrock Geology

Digital geology

- authoritative data source
- all details from 1:50,000 to 1:250,000
- seamless digital coverage and updatable
- consistent nomenclature and encoding to support **computation**

Challenge: how to update it with new mapping projects?



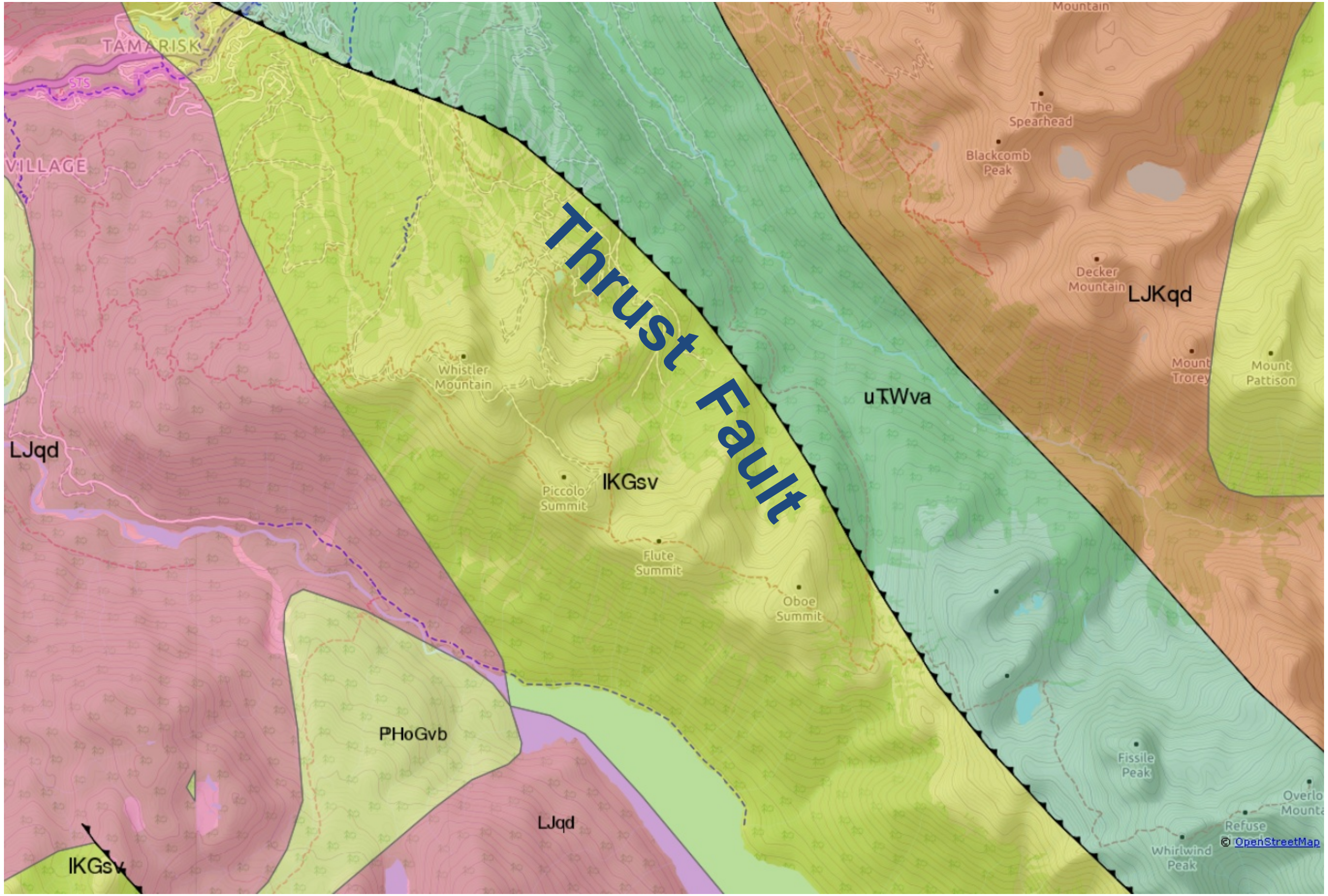
Shared boundaries (mapping surface 2D expression of 3D features)

- Polygonal/areal
- Linear

Thrust fault (linear)

Unit **lKGsv** (polygonal)

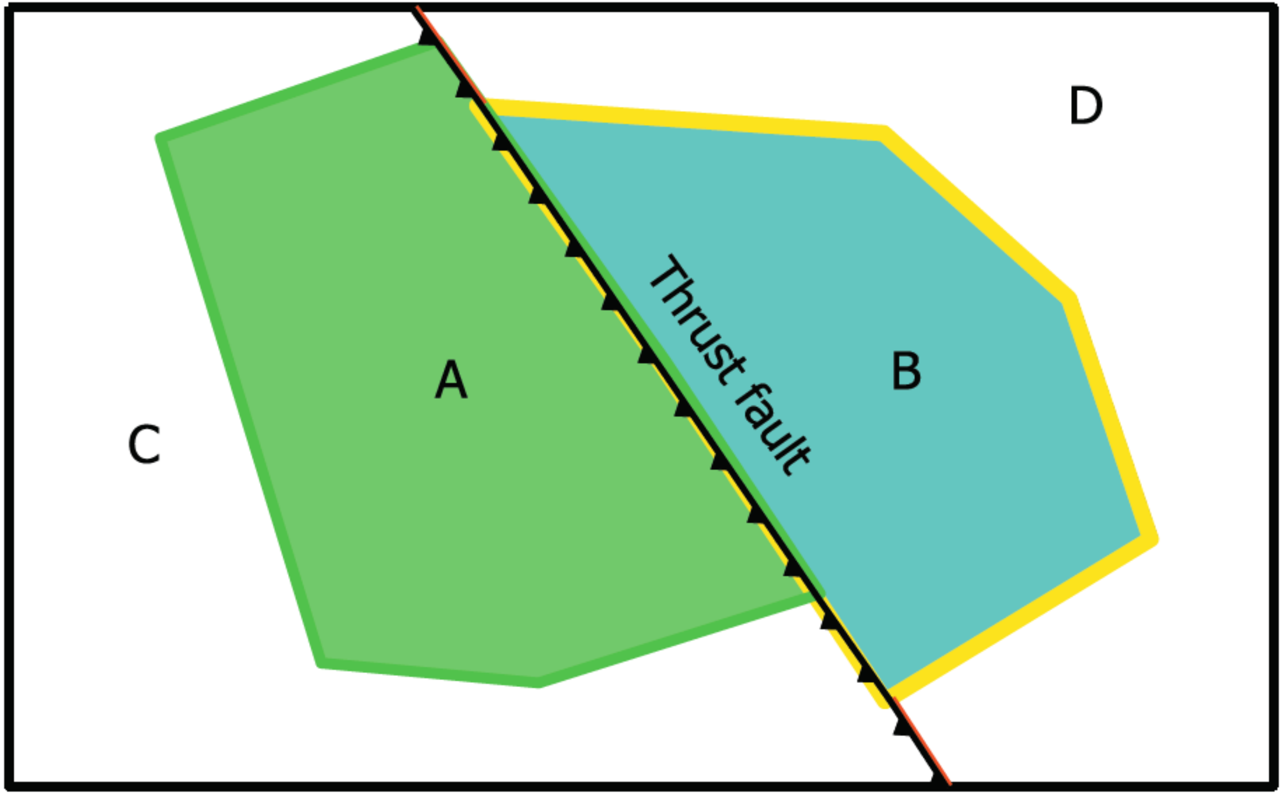
Unit **uTrWsa** (polygonal)



Shared boundary problems in map compilation

Between polygonal boundaries of bedrock units

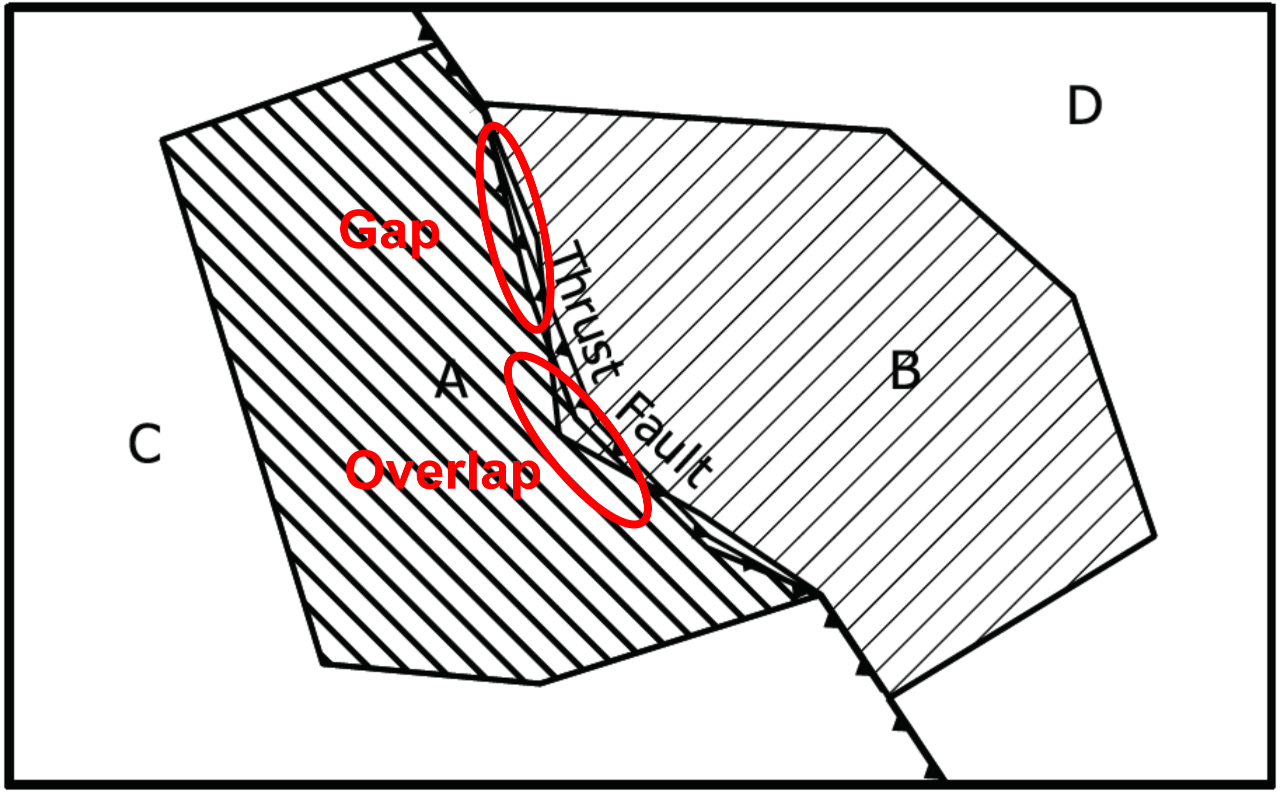
Between bedrock units and fault or contact



Errors introduced to shared boundaries

After editing boundaries

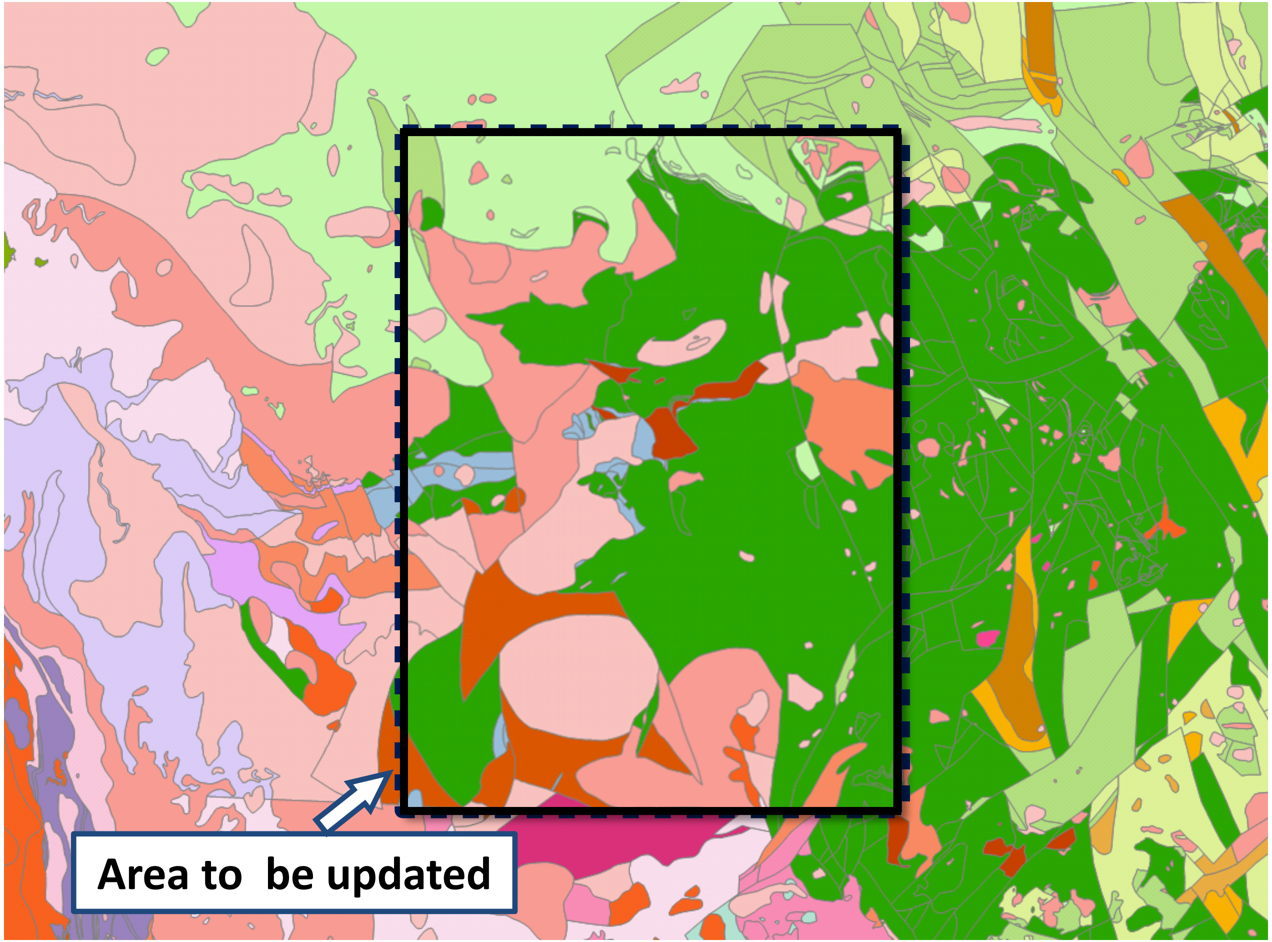
- overlaps
- gaps
- slivers
- discontinuity



Edge matching in map integration

Topological errors along map borders after a map is cropped and a new map is merged in:

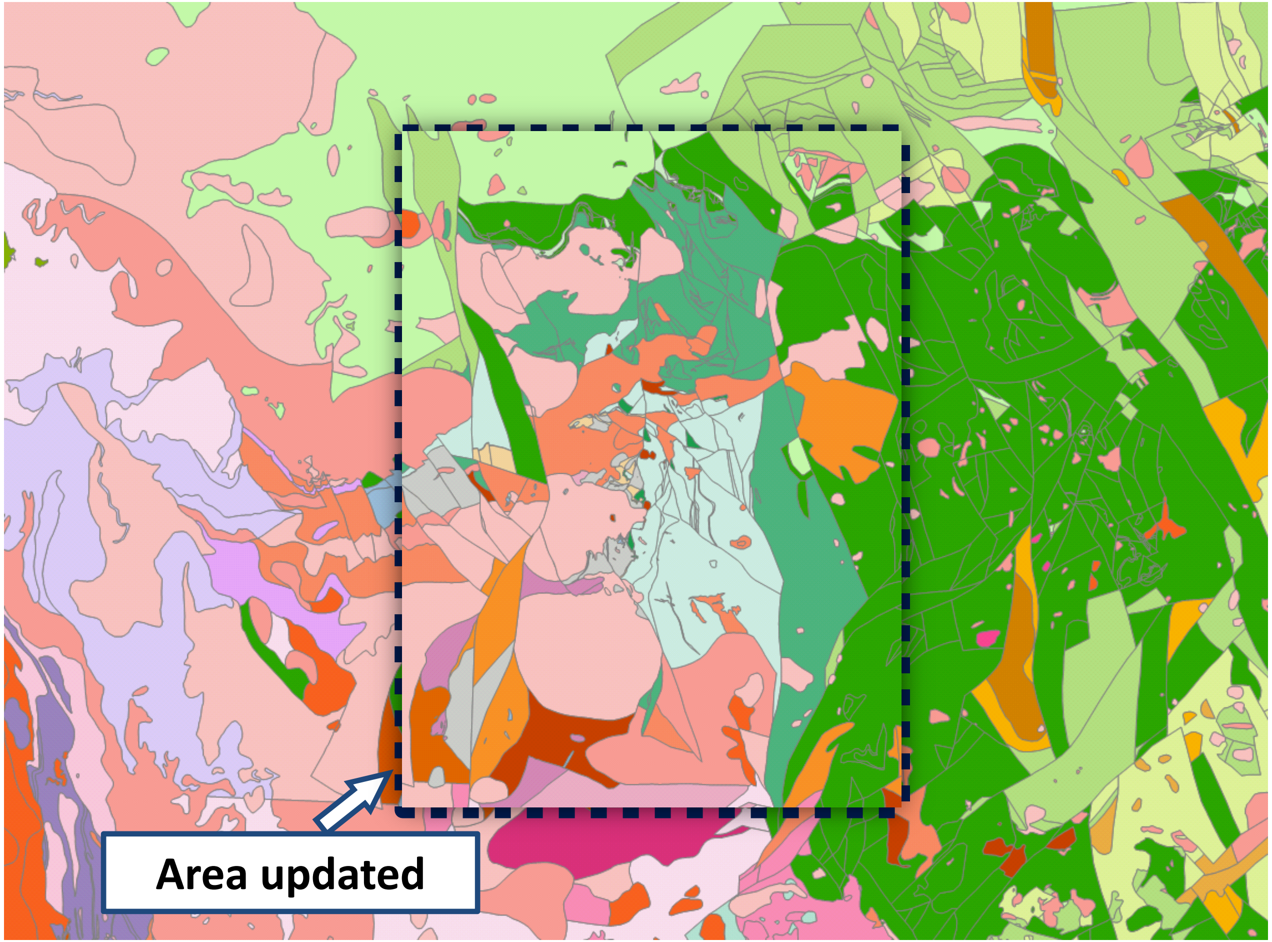
- overlaps
- gaps
- slivers
- discontinuities



Edge matching introduces topological errors

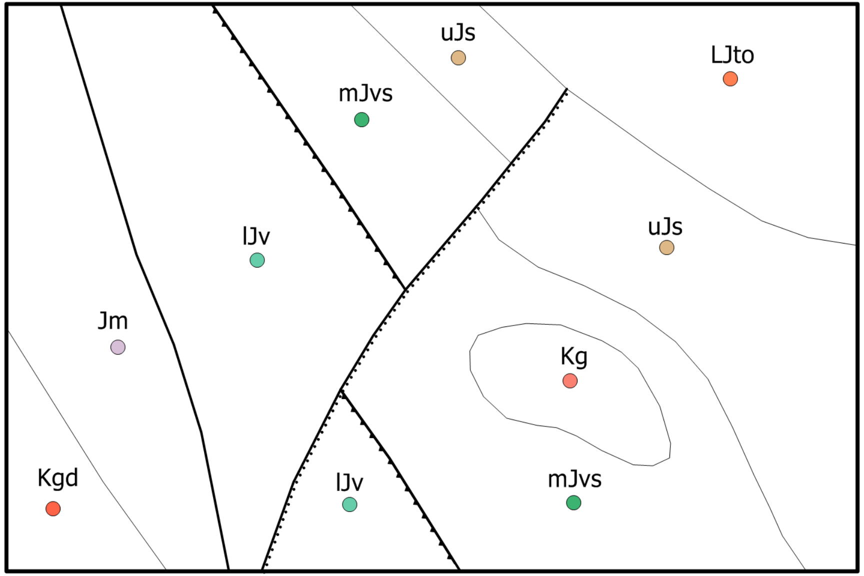
Topological errors along map borders after a map is cropped and a new map is merged in:

- overlaps
- gaps
- slivers
- discontinuities



Geospatial frame data model (GFD)

Geospatial Frame Data (GFD)



Two tables in a spatial database

- **Lines**: geological boundaries (contacts and faults)
- **Centroids**: attributes describing bedrock units (age, lithology, group, formation, etc.)

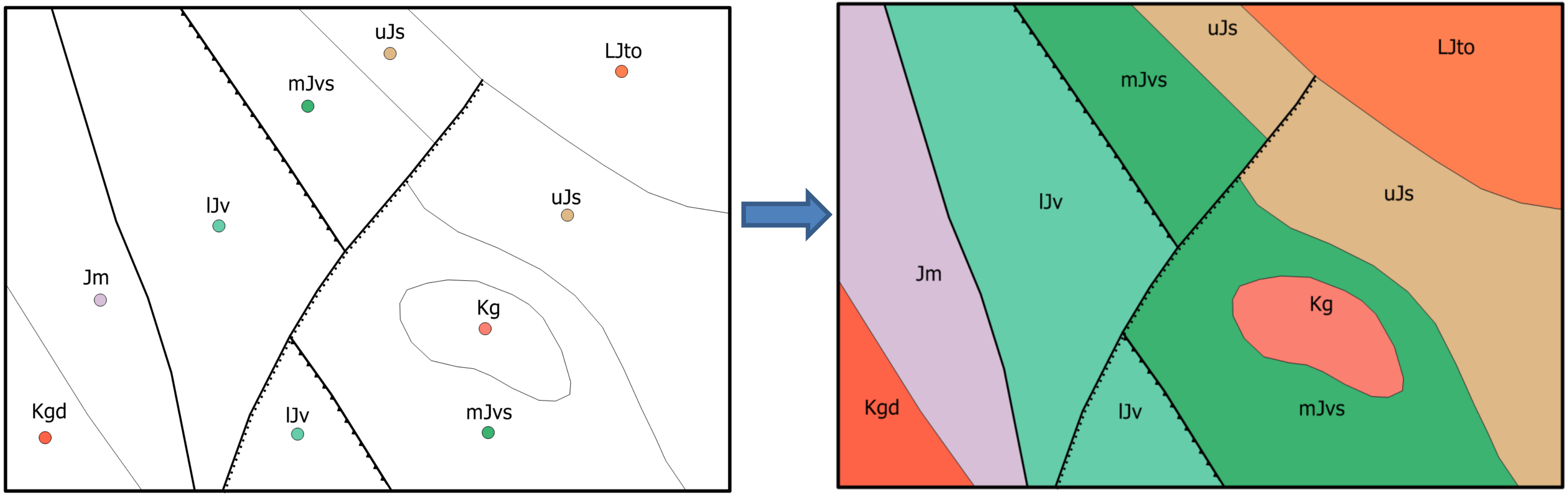
GFD is for compilation, editing, data quality and content validation, and integration

GFD boundaries are single and simple OGC lineStrings, fully noded, no overlaps, no crossing

From GFD to Geological Map

GFD: lines and centroids

Geological map



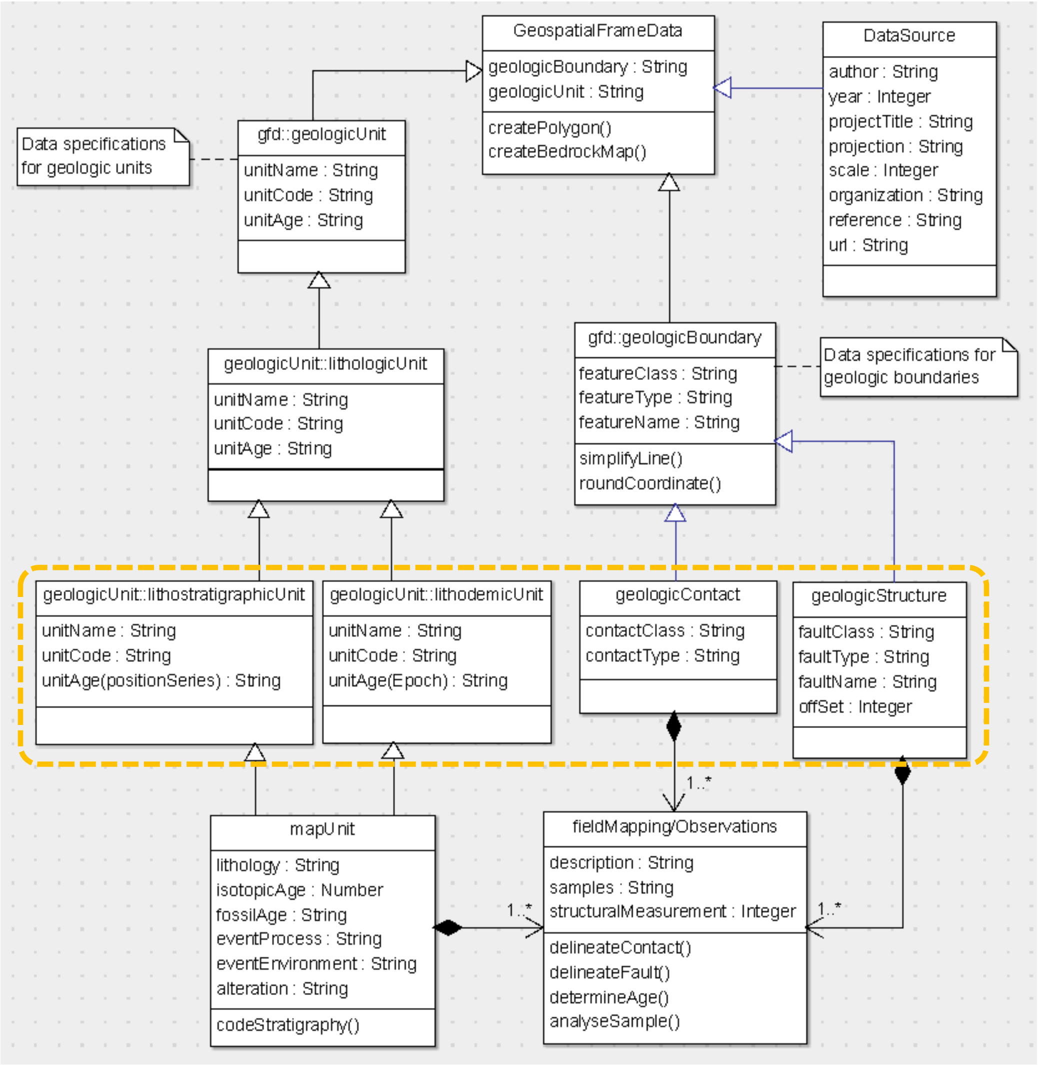
1. Generating bedrock polygons from GFD linework for geological boundaries
2. Populating bedrock attributes to the polygons from the GFD centroids

GFD in UML class diagram

GFD components

1) **Geological boundaries**
- contact types
- fault types
- topographic feature types
- *lineation types?*
- *foliation types?*

2) **Geological units**
- stratigraphic unit: name and label
- age
- lithology
- event process
- event environment
- alteration and mineralization



Geospatial Frame Data model

- GFD is for map compilation and data integration
- GFD stores digital geology as data source for map products
- Bedrock polygons are not part of GFD and are not maintained
- Cartographic representations with bedrock polygons are derivative products from GFD

GFD to simplify map integration

GFD data checkout

GFD data checking in

Anchoring mechanism

Eliminating topological errors in edge matching

No overlaps

No gaps

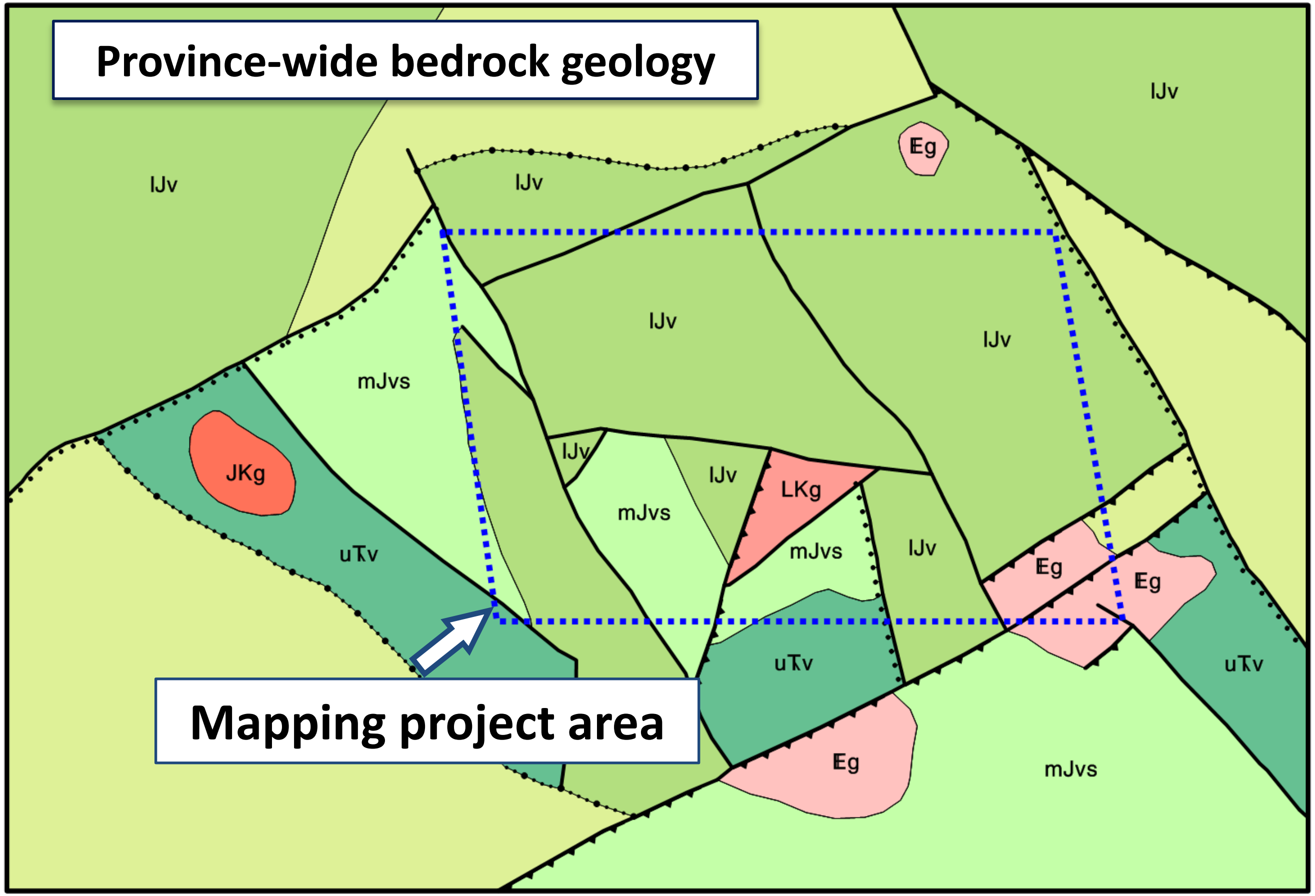
No sliver

Preventing new map boundary issues

Scenario: update bedrock geology

Mapping project

To update bedrock geology in the mapping project area (*limit of mapping* outlined by dotted line in blue)

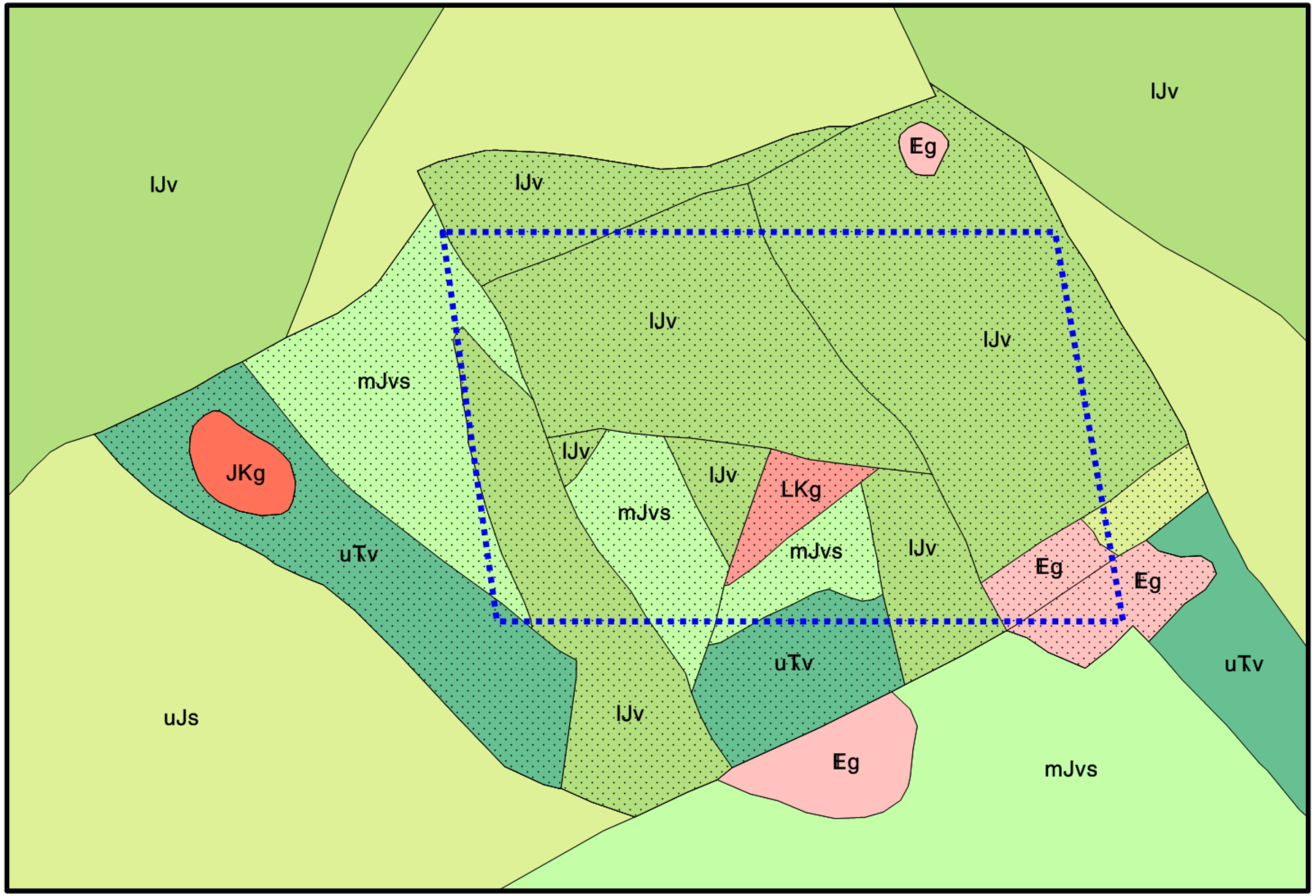


Data checkout: select bedrock units

Step 1:

Use the limit of mapping to intersect and select bedrock units (as polygons)

Note: unit ***Eg*** to the north and ***LKto*** to the west are missed in the initial process.

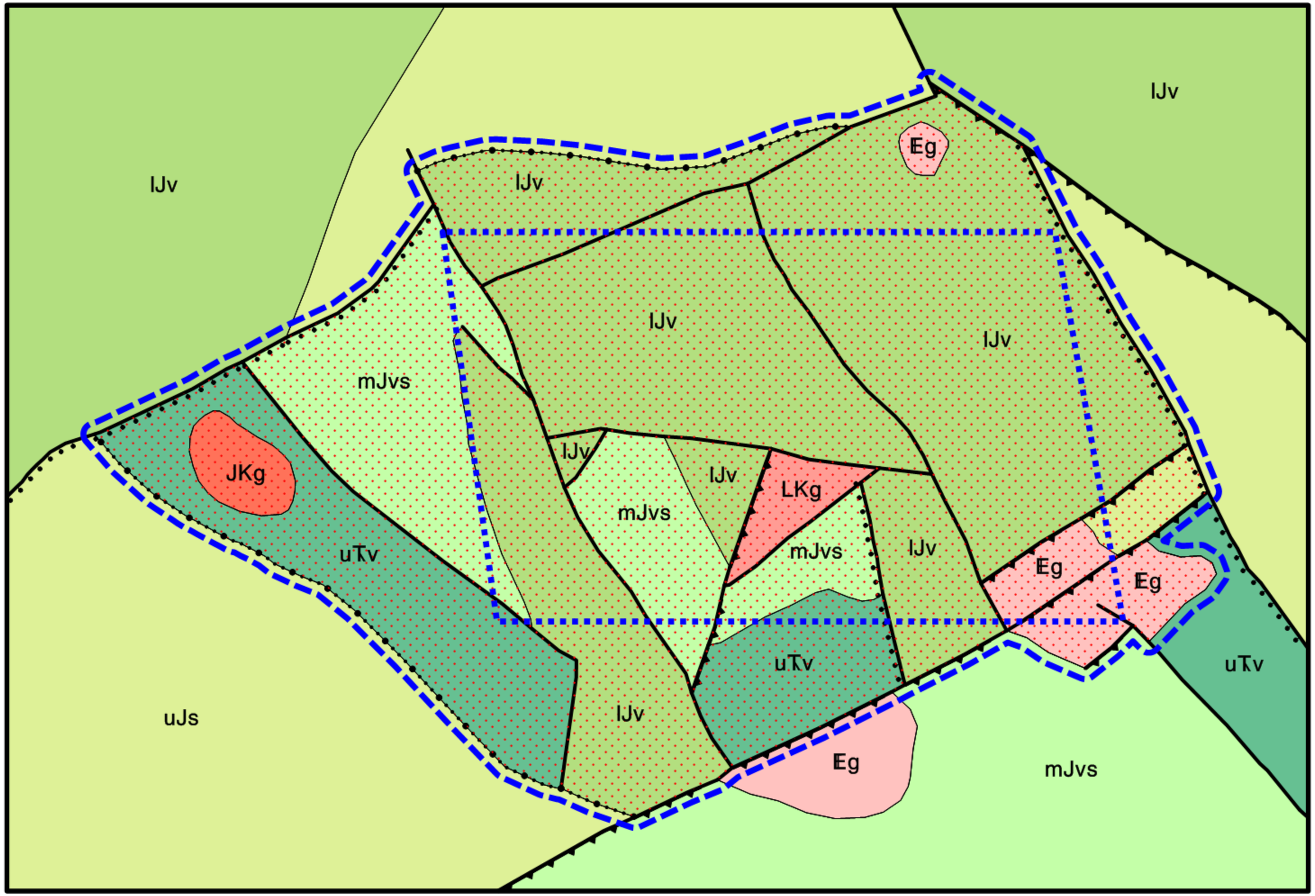


Data check-out: to include extended area

Step 2:

Create a buffer on the outermost boundary

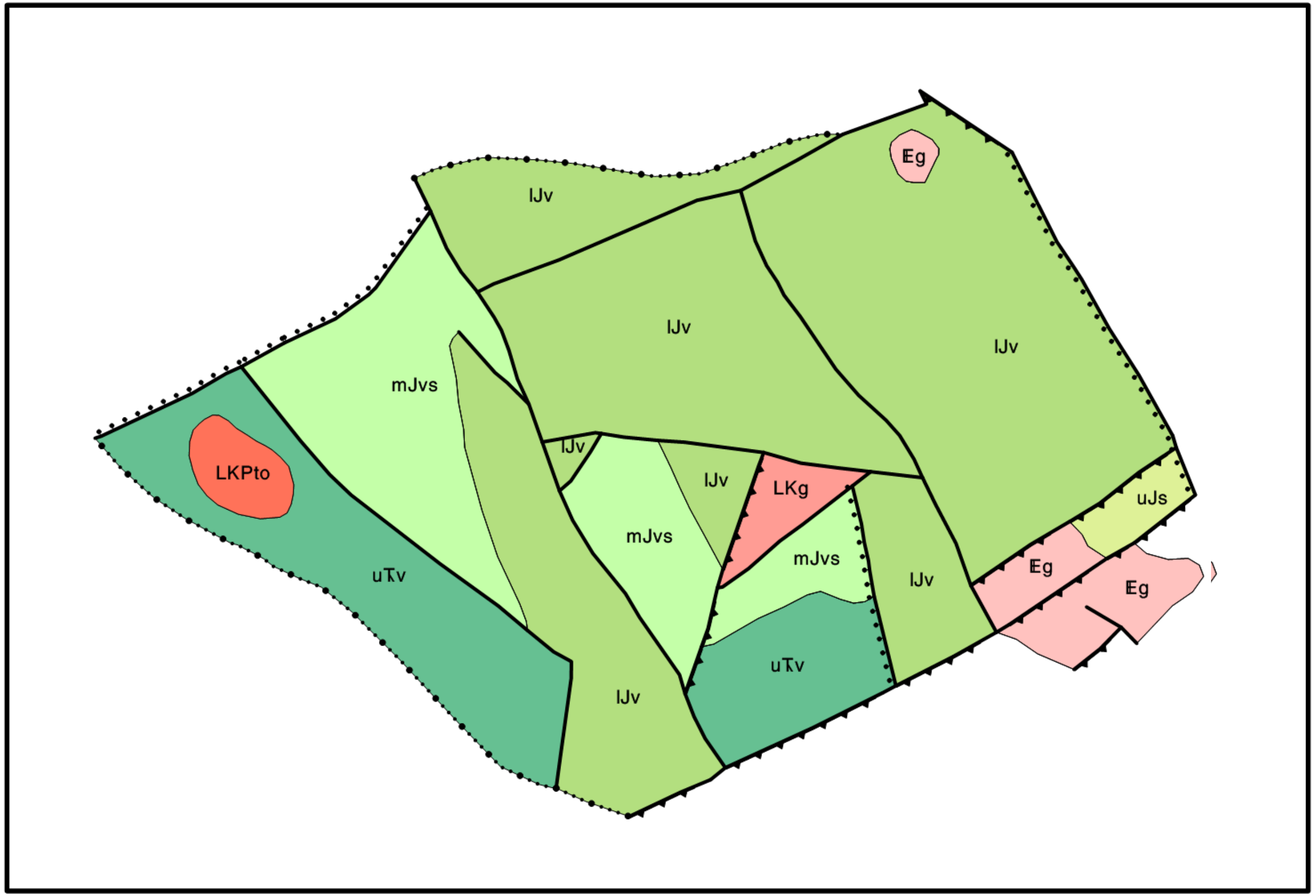
Use the buffer to select ALL the GFD data within the extended regional compilation area, including unit ***Eg*** to the north and ***LKto*** to the west



Data checkout: failed

Extracted data

Coordinates start to drift when the map is taken out and undergone transformation, e.g., re-projected



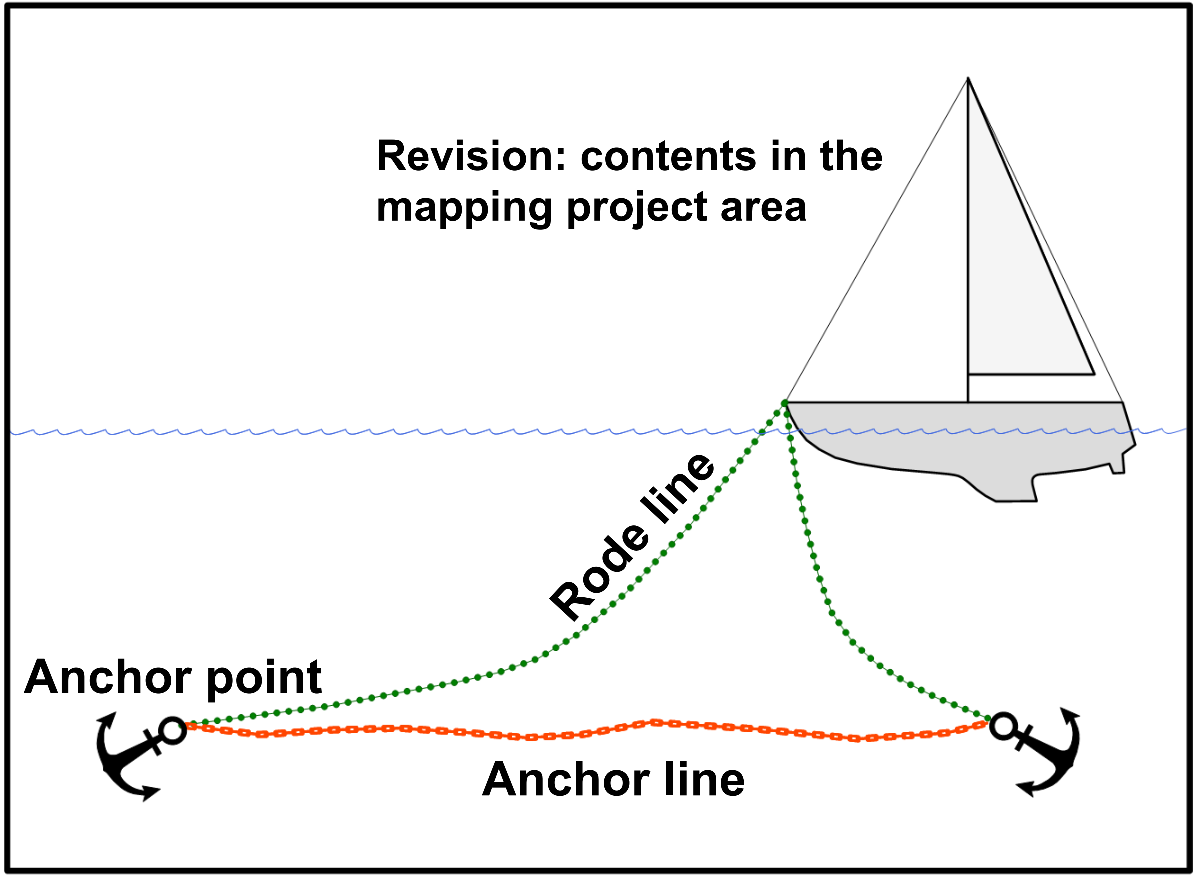
Nautical terms to *anchor* (or tag) the data properly

Anchor line
guarded map boundary

Anchor point
guarded nodes on map boundary

Rode line
line connect to anchor point

Revision
contents for update

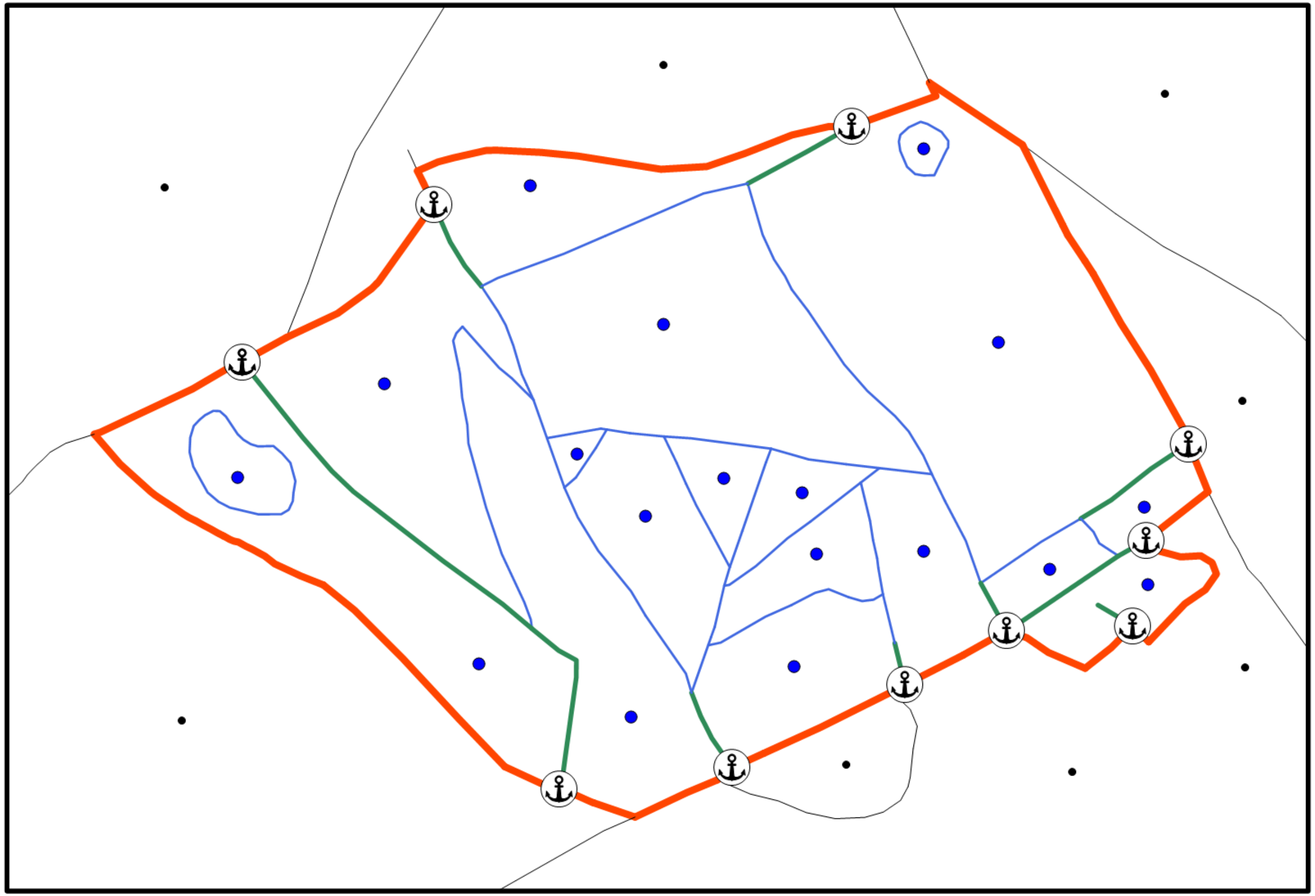


GFD checkout: tag selected GFD data with anchoring

Step 3:

Tag selected GFD data within the extended regional compilation area:

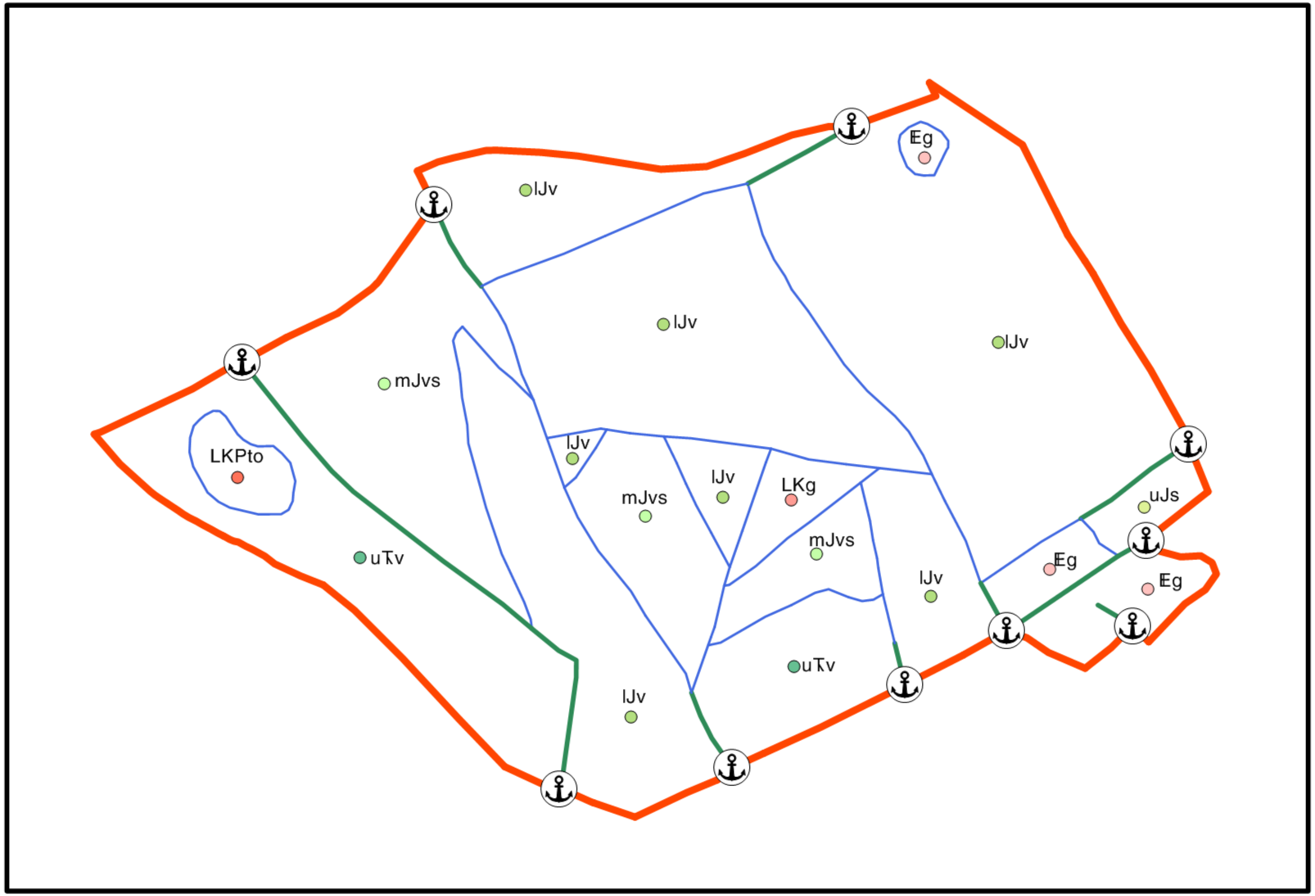
Anchor line in red
Rode line in green
Revision in blue (lines and bedrock units)



Data checkout: complete package for new mapping

Extracted data

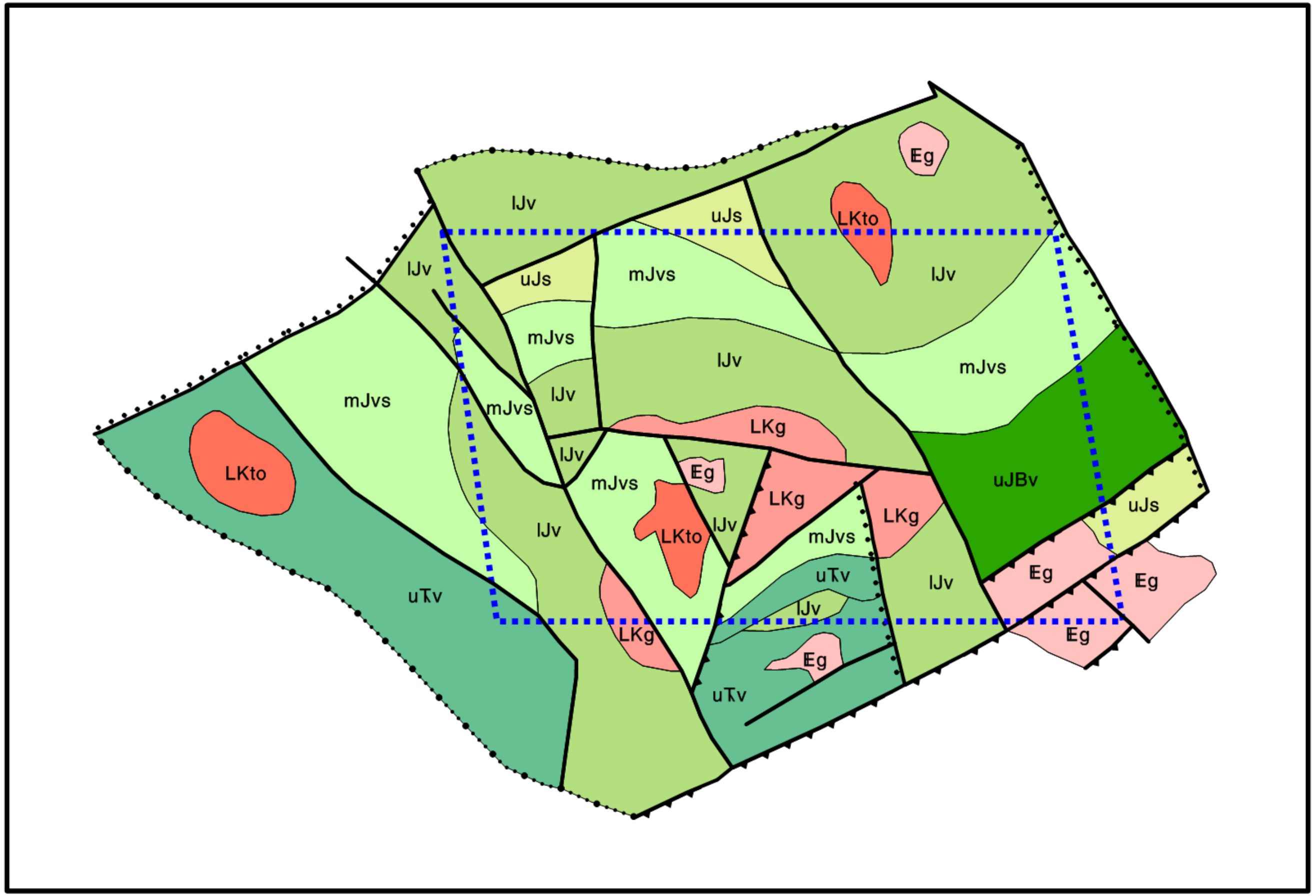
GFD lines
GFD centroids



Updated bedrock geology

Updates include:

- subdivision of units
- new intrusive units
- age constrains for the intrusive unit to the west
- new faults extended beyond anchor lines
- two new rode lines from subdivisions

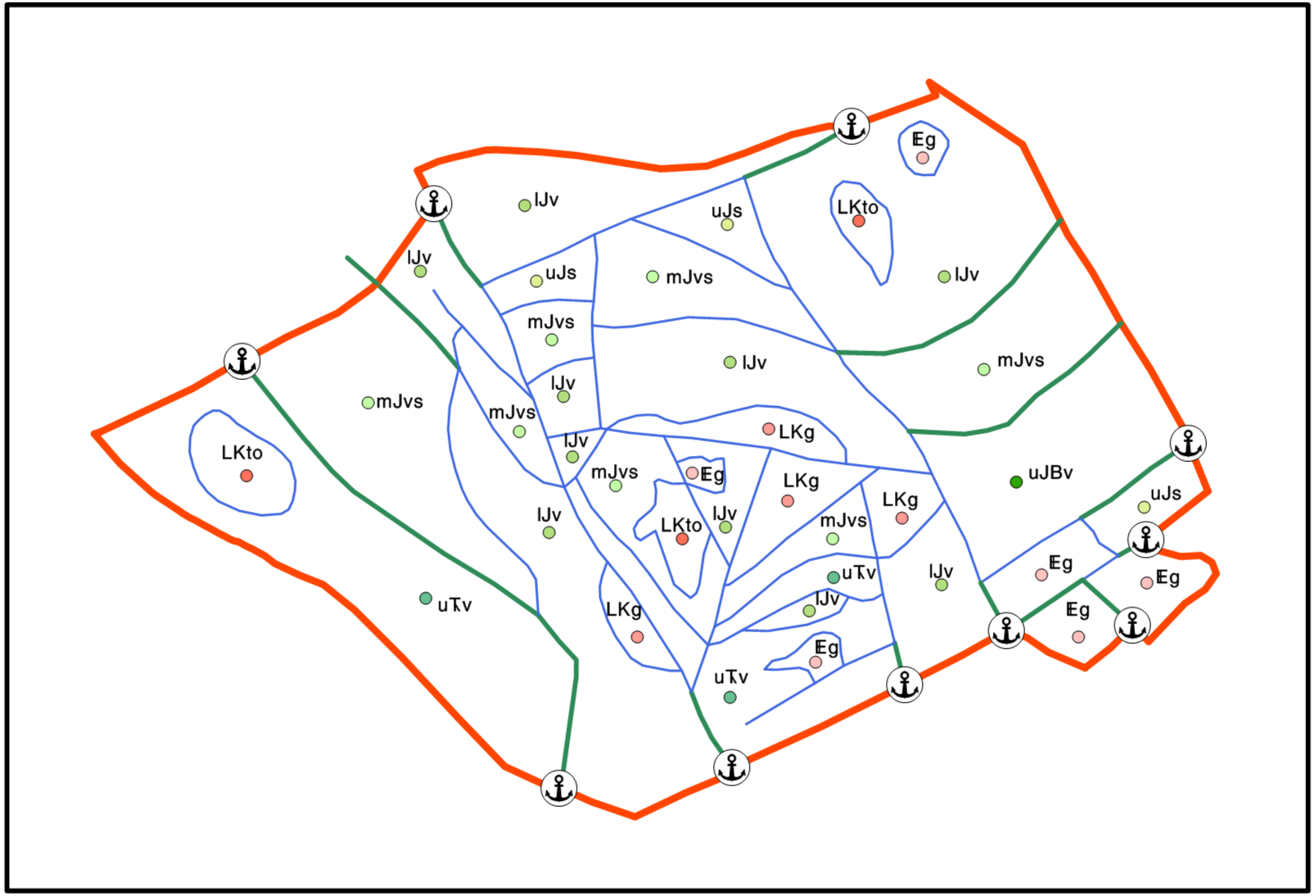


Updated bedrock geology

Validation and data quality assurance on GFD data, not on bedrock polygons

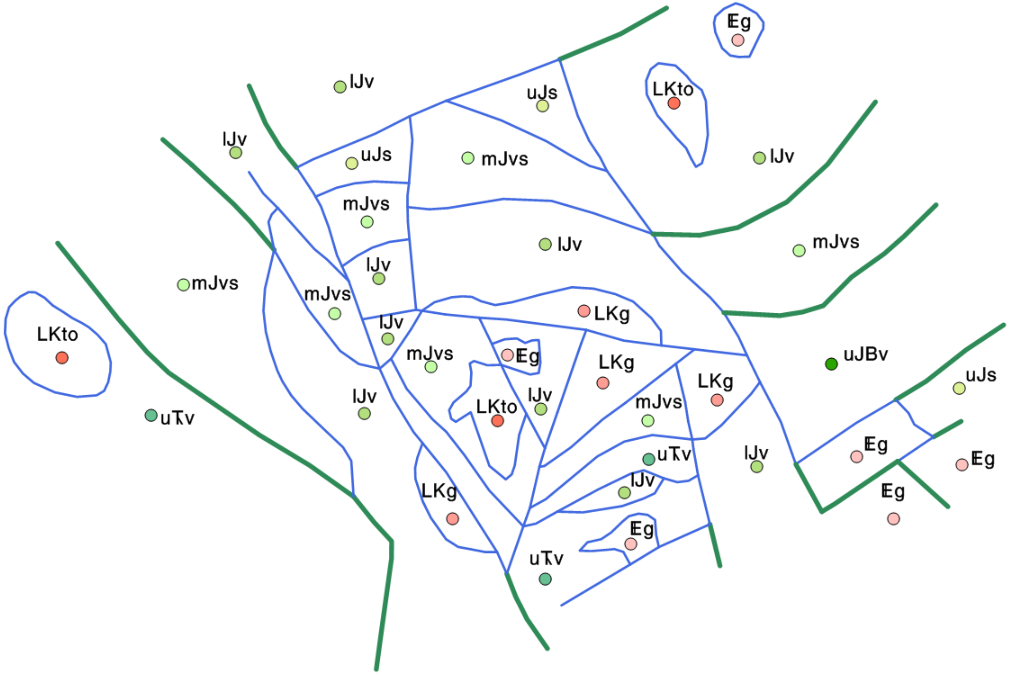
Note:

- a new fault extended beyond anchor line
- two new rode lines from subdivision of a unit



Updated bedrock geology ready for integration

Dropping anchor lines before uploading updates to the corporate database

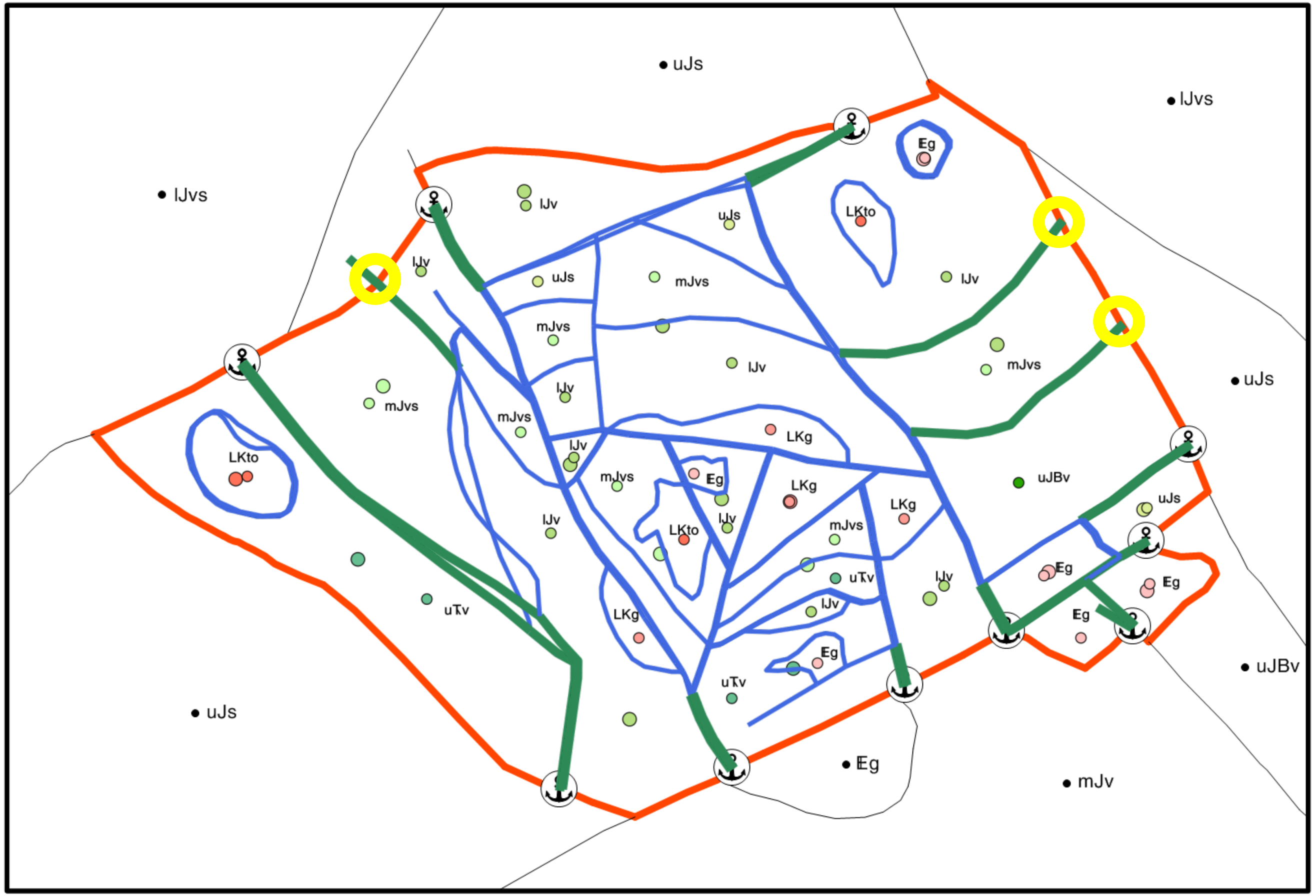


GFD project data checking in

1) Retiring out-dated GFD data to archival database

2) Admitting updated project GFD data

Yellow circles: new noding required

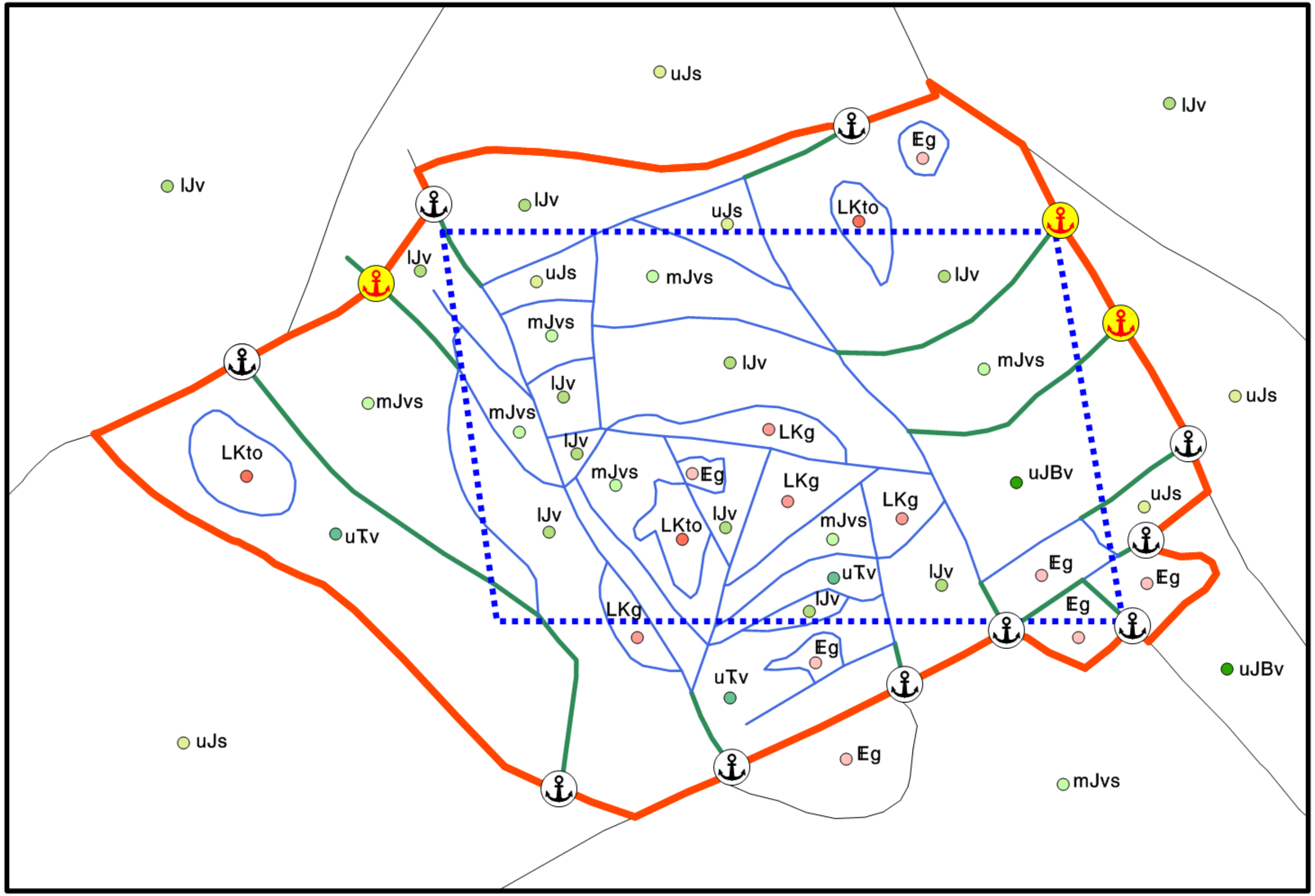


Integration without complex edge matching

GFD data from new mapping project are uploaded into corporate GFD database

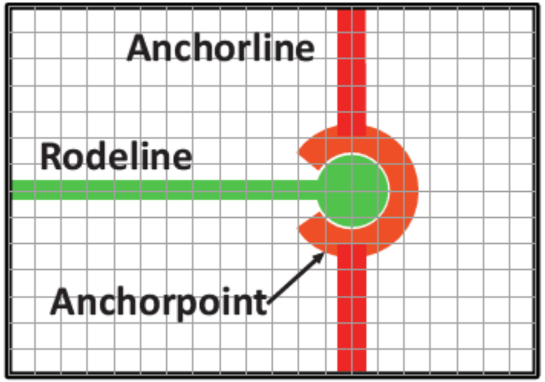
- Snap rode lines to anchor points
- Create new anchor points to connect new rode lines

Integration only requires rode lines connect to anchor points

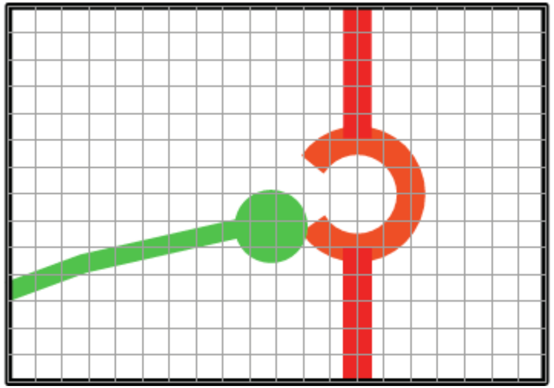


Rode lines connect to anchor points

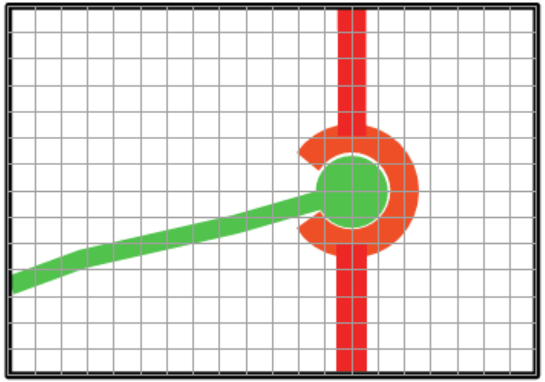
a simple geometric ‘snap’ with a given tolerance (e.g., 5 metres)



Before update
rode line connected to anchor point



During update:
rode line unhooked and drifted away from anchor point



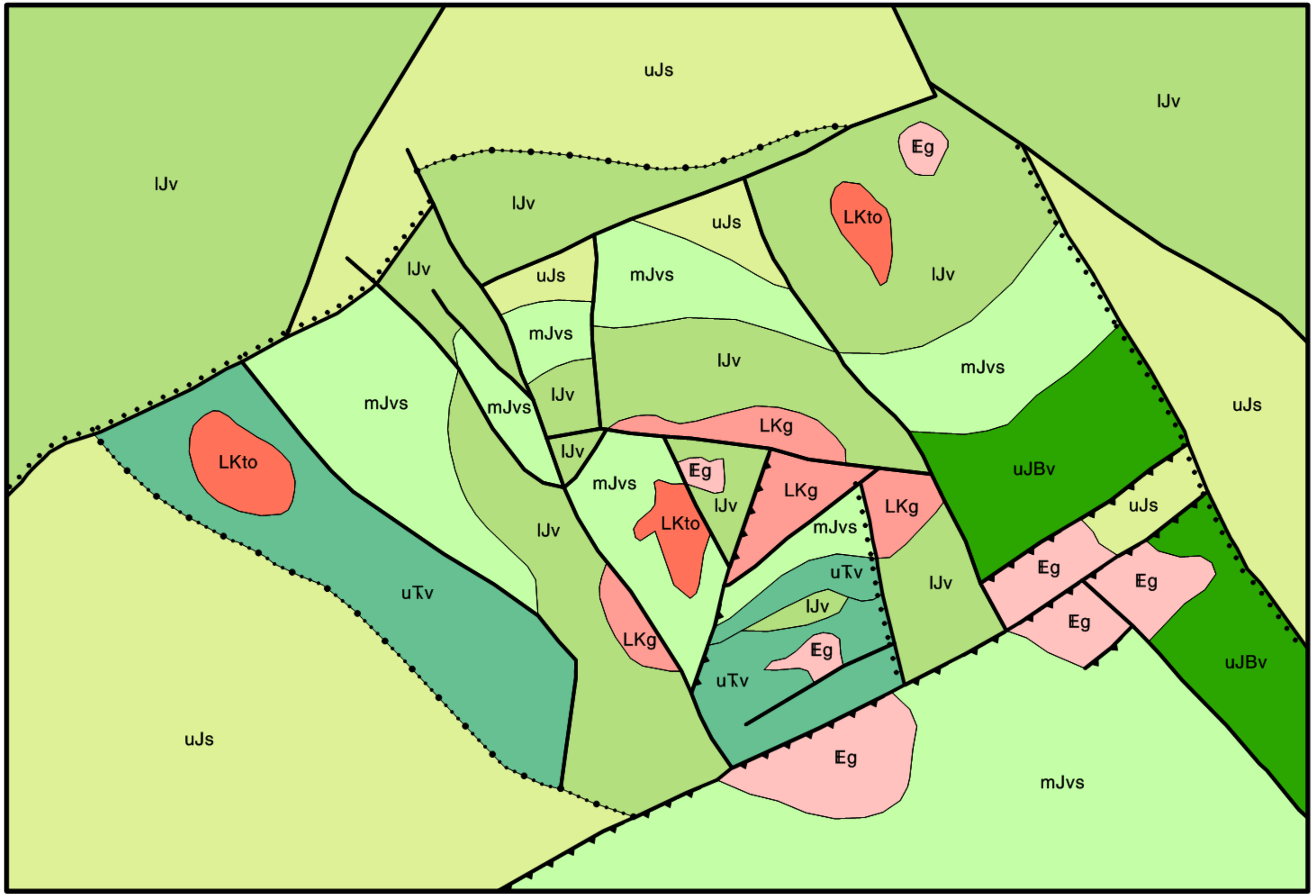
After integration
rode line snapped to anchor point in the corporate database

Create new geological map from updated GFD

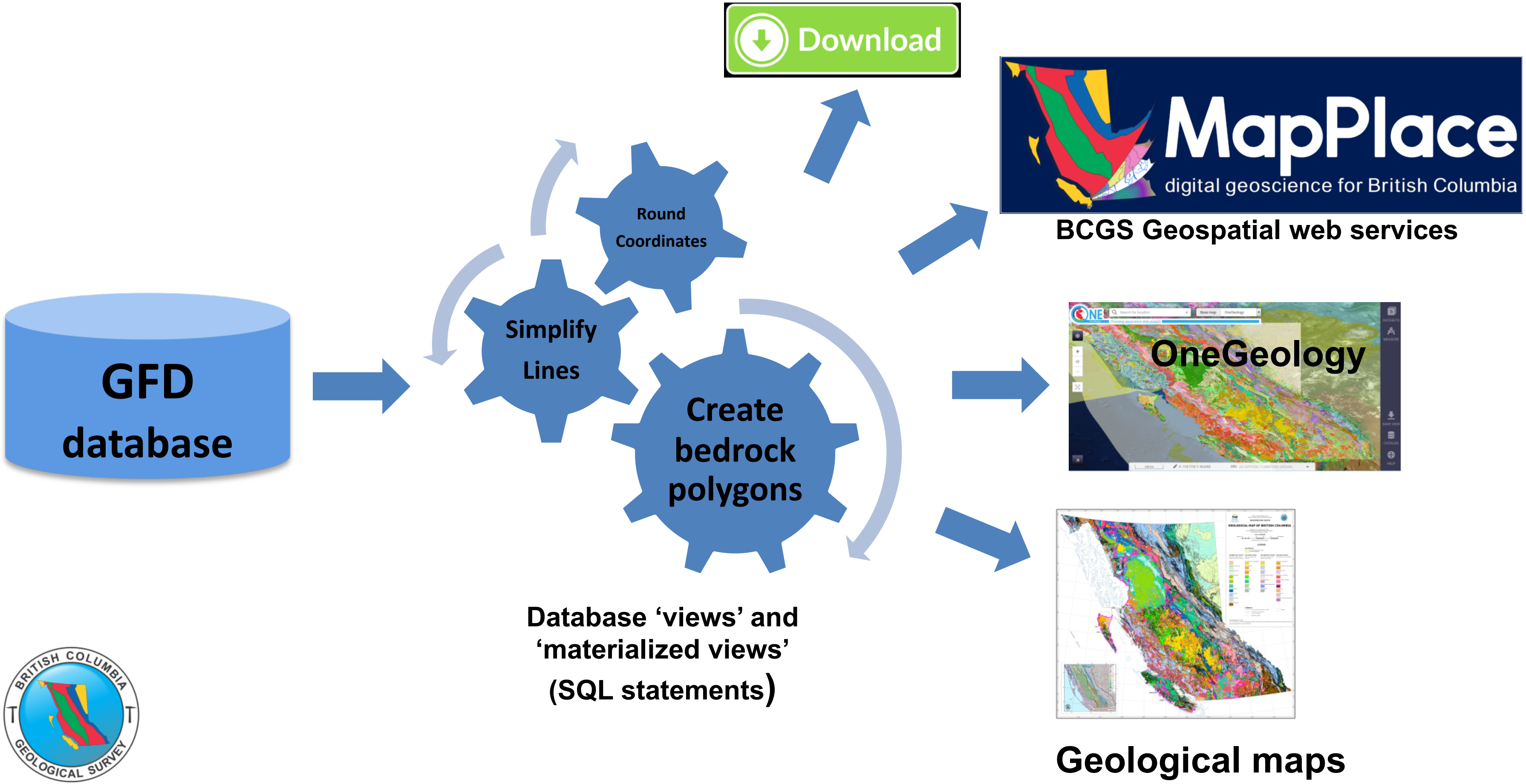
No topological errors:

- No gaps
- No overlaps
- No slivers
- No discontinuities or data boundaries

- Bedrock units are standardized (uniformed / harmonized)

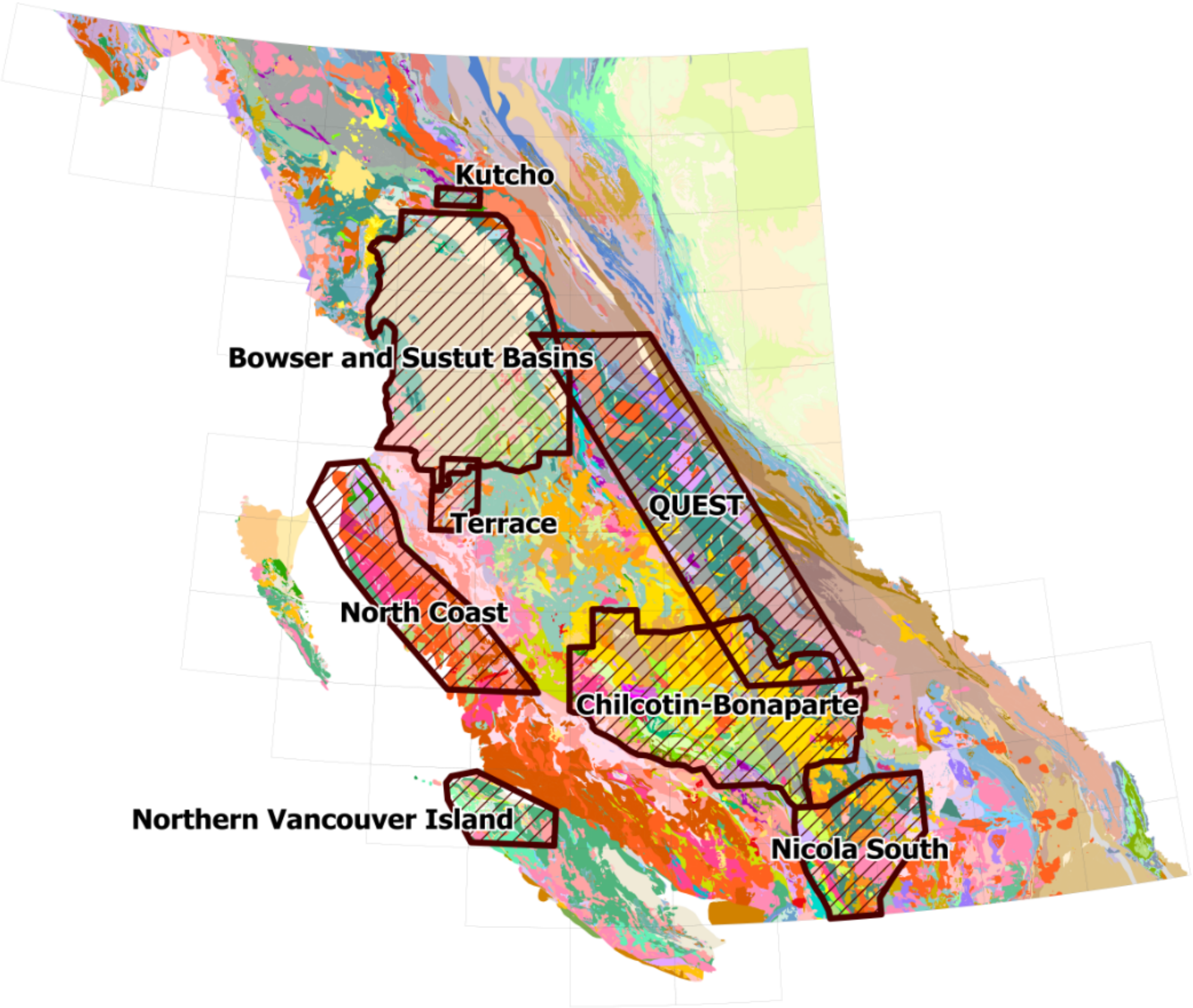


Bedrock geology production and publications



Open Format: GeoPackage

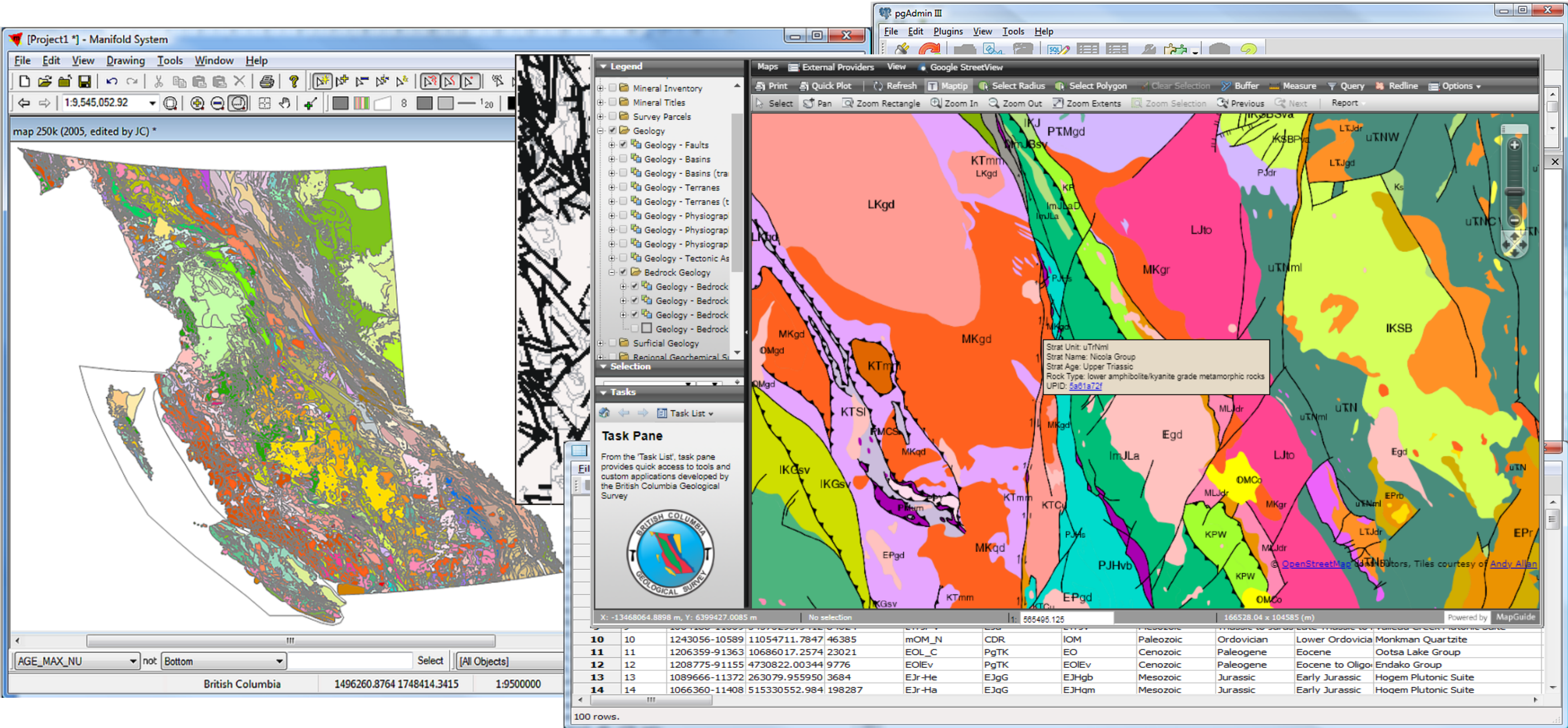
- OGC standard of Open Format
- Current version 1.2.1, published on 2018-09-06
- SQLite based
- Multiple maps
- Map styles: SLD
- No limitation of column names and size of files



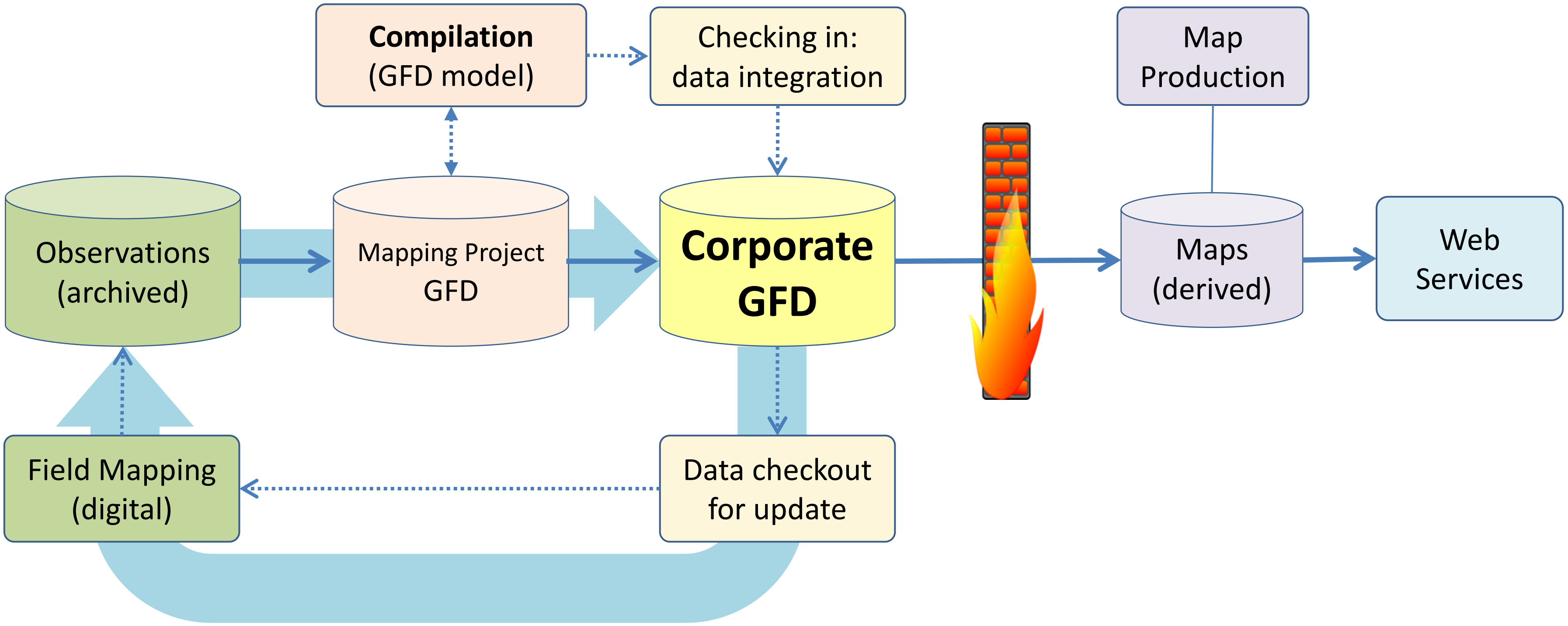
BRITISH COLUMBIA GEOLOGICAL SURVEY

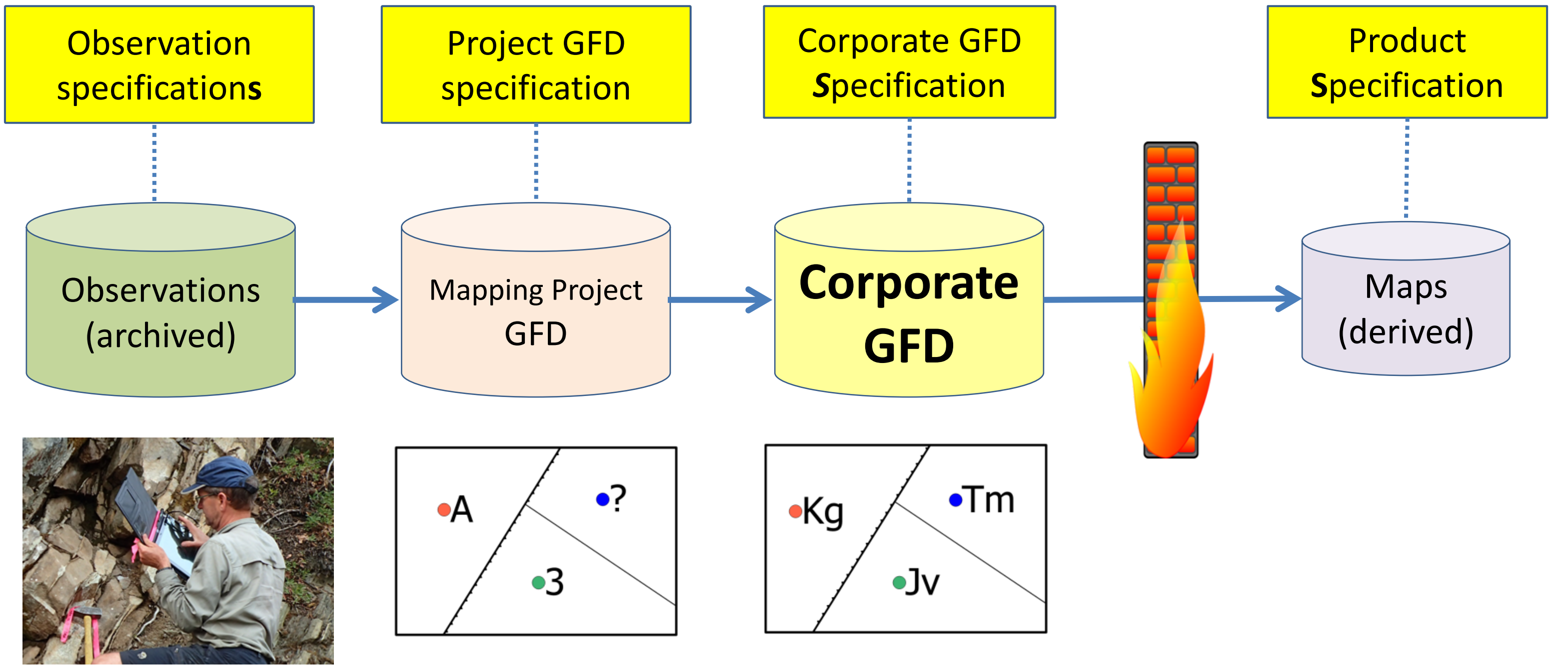
Implemented in Free and Open Software for Geospatial

PostgreSQL/PostGIS and MapGuide Open Source



Lifecycle of geospatial data




Observation specifications
Project GFD specification
Corporate GFD Specification
Product Specification
Observations (archived)
Mapping Project GFD
Corporate GFD
Maps (derived)
A
?
3
Kg
Tm
Jv

Causes of topological errors: unit of precision

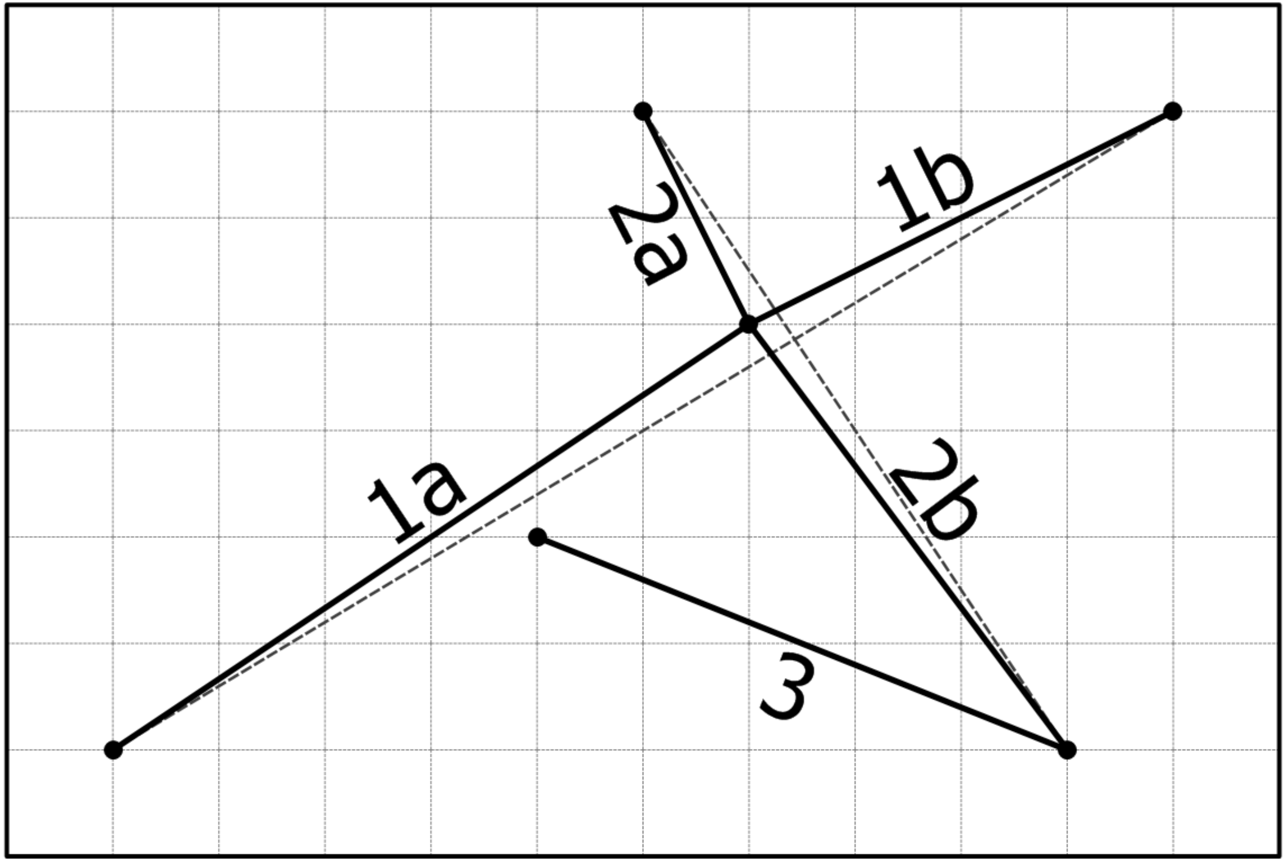
Rounding coordinates

- shift position
- change topology

Rounding after intersecting and adding coordinates

- change shapes
- alter topology

Grid in grey: unit of precision



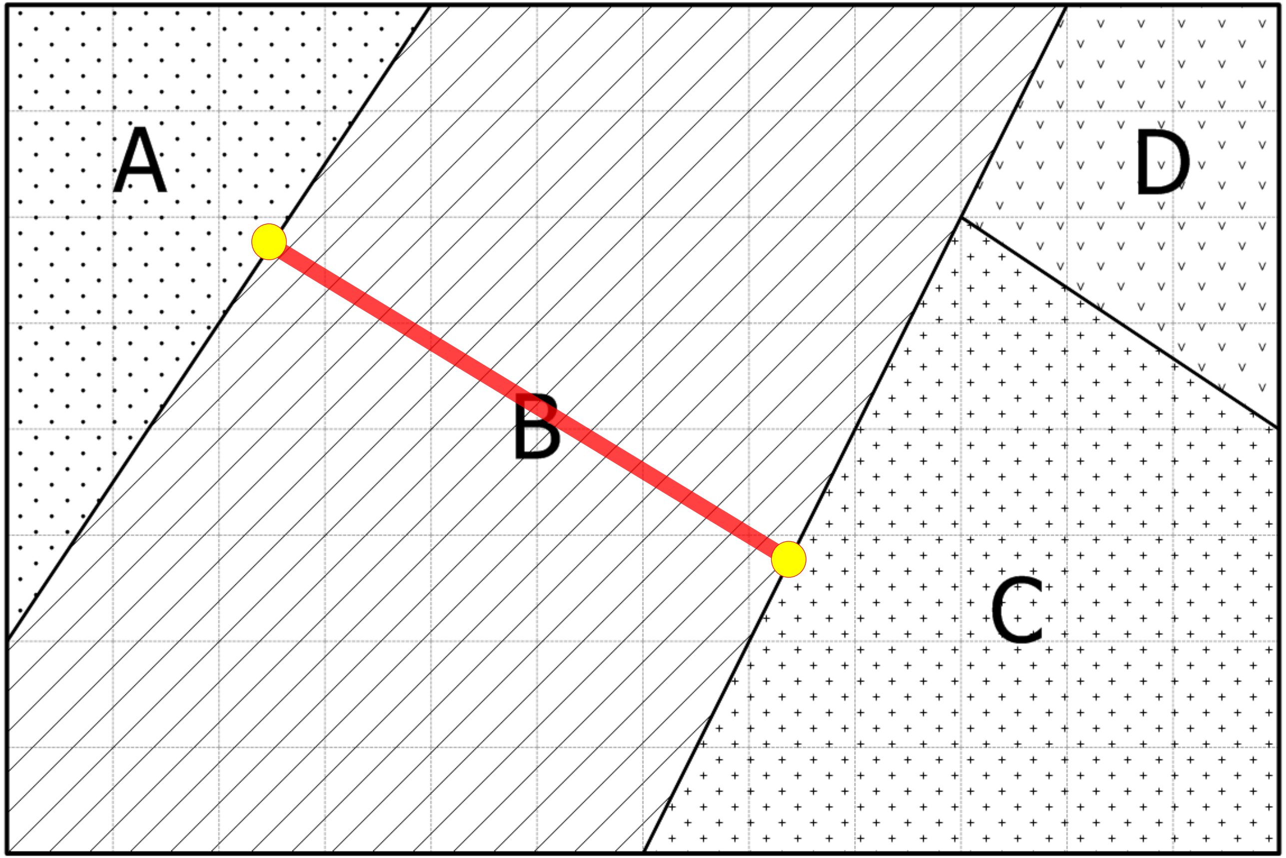
Topological errors from editing polygons

Bedrock unit B:
re-mapped and subdivided

● New nodes required to split unit B.

Note: new nodes are off precision grid

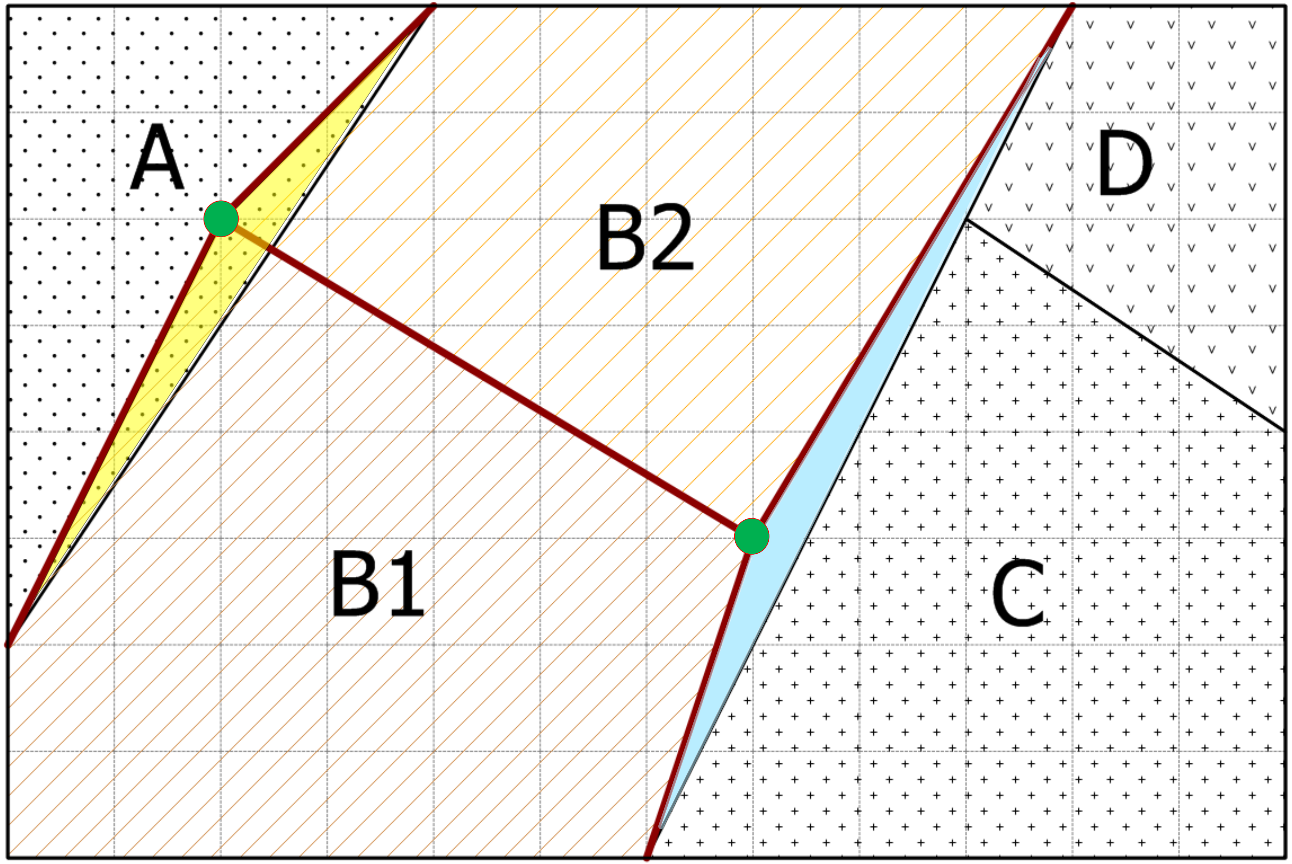
Grid in grey: unit of precision



Topological errors from editing polygons

After unit B sub-divided to B1 and B2

- New nodes form on precision grid
- Overlap between A and (B1, B2)
- Gap between (B1, B2) and (C, D)



Grid in grey: unit of precision

Summary

Geospatial Frame Data model, data checking out/in, and anchoring mechanism

- simplify map compilation and data integration
- eliminate problems in shared boundaries and edge matching
- shorten the time to deliver updated geology to clients
- streamline the processes of data quality assurance, generalization, and production
- ease to adopt with any spatial databases

Do not use polygons in map compilation and integration!

Thank you!

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