

DIGITAL MAPPING TECHNIQUES 2021

The following was presented at DMT'21
(June 7 - 10, 2021 - A Virtual Event)

The contents of this document are provisional

See Presentations and Proceedings
from the DMT Meetings (1997-2021)

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

DIGITAL GEOLOGY TO ENABLE ANALYTICS IN BRITISH COLUMBIA

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Data science and geospatial technology are advancing the mineral potential modelling that supports mineral exploration and land use planning in the province of British Columbia. As part of our digital transformation efforts to deliver analytical ready geoscience, the British Columbia Geological Survey (BCGS) is developing a strategy to identify opportunities and prioritize solutions for our future digital capabilities. We define 'digital capability' as the ability to enable analytics by improving data, processes, skills, and infrastructure to optimize the acquisition, management, and delivery of geological data products and services. We use 'analytics' as a general term for computational analysis of machine-readable data to discover patterns. To guide our efforts, we follow the FAIR principles (Findable, Accessible, Interoperable, and Reusable; more details available at <https://www.go-fair.org>). The DataBC Data Catalogue provides ISO 19115 metadata standard-compliant web services to find and access our geoscience data and services. We continue to update the province-wide seamless digital geology database by compiling and integrating new geological maps with the Geospatial Frame Data (GFD) model. The GFD model stores primitive feature components decomposed from bedrock units and geological boundaries. The primitive feature components allow semi-automation in schema mapping and transforming our data to the GeoSciML Lite model and matching to the CGI vocabularies. This provides interoperable data access and sharing via OGC Web Map Service (WMS) and Web Feature Service (WFS), also available on One Geology. The current WMS and WFS have achieved syntactic interoperability and formed the foundation towards semantic interoperability. Geological feature components should be extended to include (or associate with) the source data, possible to examine the details and how the bedrock models are constructed. The BCGS has made progress digitizing the source data, such as field stations, observation methods, structural measurements, isotopic data, geochemical data, and drill-hole data, and is considering adding alteration, mineralization, and petrographic analysis. To make our digital geology reusable, we want to improve feature-level metadata, such as mapping scales and appropriate presentation scales, assist automating generalized bedrock units and geological boundaries, assemble small-scale geological maps, or balance data density in machine learning. The BCGS is building a geoscience Spatial Data Infrastructure as a common foundation to improve digital capabilities; a spatial database management system is indispensable to streamline digital transformation of our geological maps.

This presentation provides an update on the compilation and integration of bedrock geology in the province of British Columbia, Canada, with highlights in digital transformation efforts to enable analytics, including techniques treating multi-levels of details and use cases of spatial databases.

Digital geology to enable analytics in British Columbia

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Sr. Geomatics Geoscientist
British Columbia Geological Survey

Digital Mapping Techniques
June 9, 2021

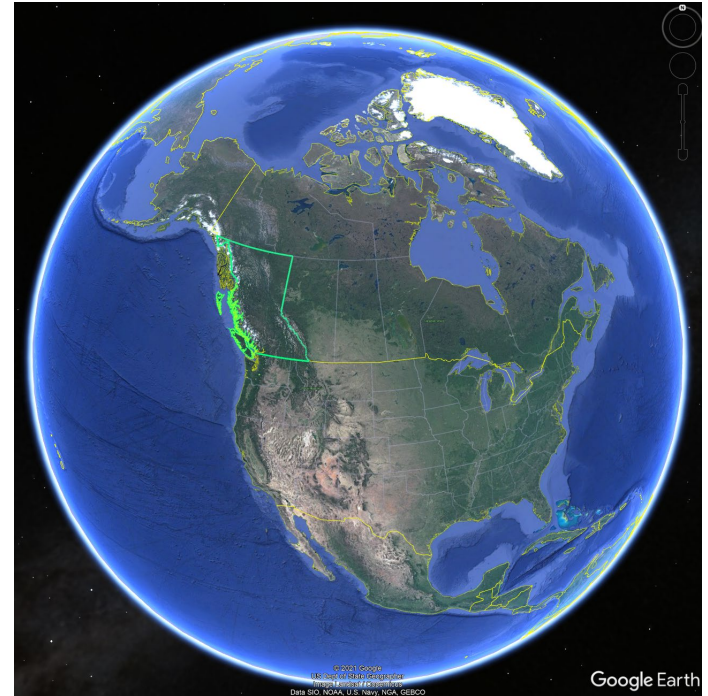


British Columbia Geological Survey

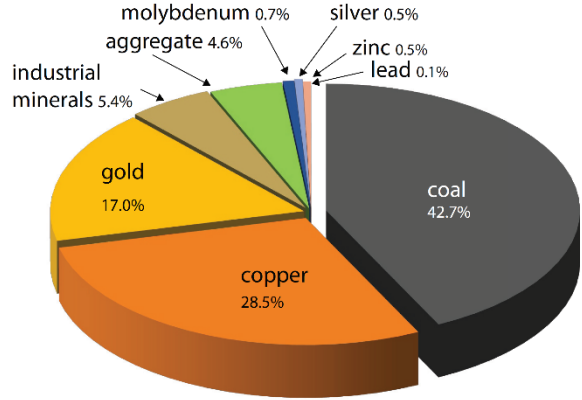


Outline

- Digital transformation to enable analytics
- Geologic mapping in British Columbia
- Update on progress
- Spatial database



Geoscience support mining and exploration



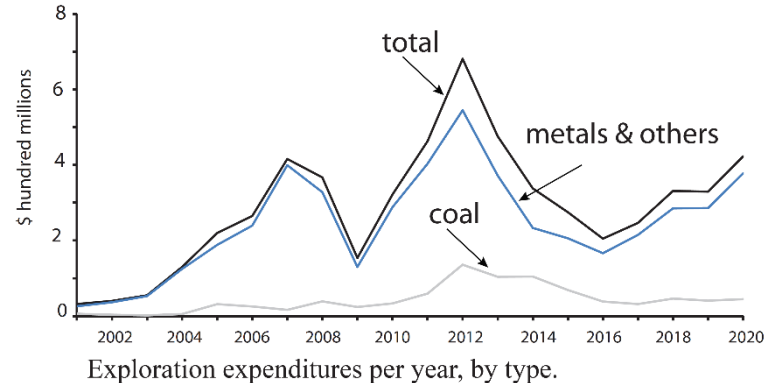
Mine production value in 2020: **\$9.28 billion**

- Largest copper and coal producer in Canada
- The only producer of molybdenum in Canada

Exploration expenditure in 2020

\$422.7 million total

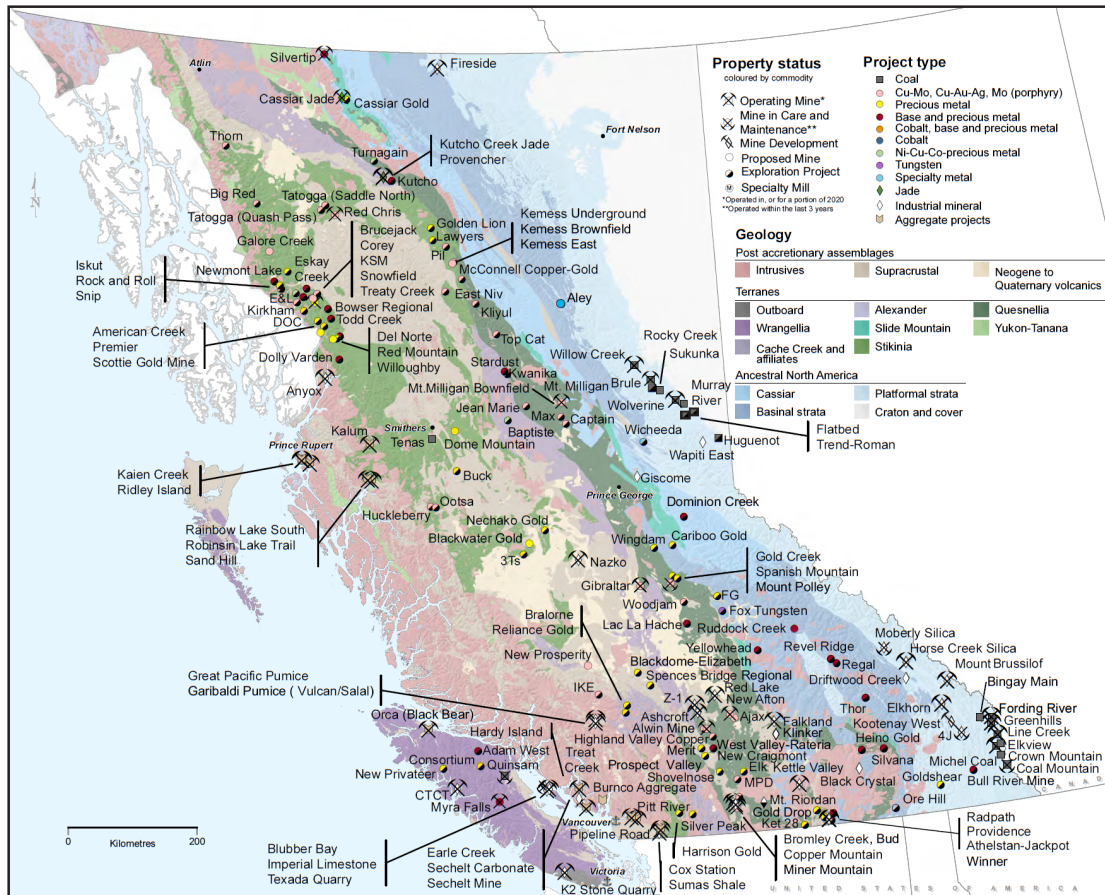
- \$378 million Metals + other
- \$44.7 million: Coal
- Increase of \$93.2 million vs. 2019



Source: Clarke et al., 2021, BCGS Information Circular 2021-01



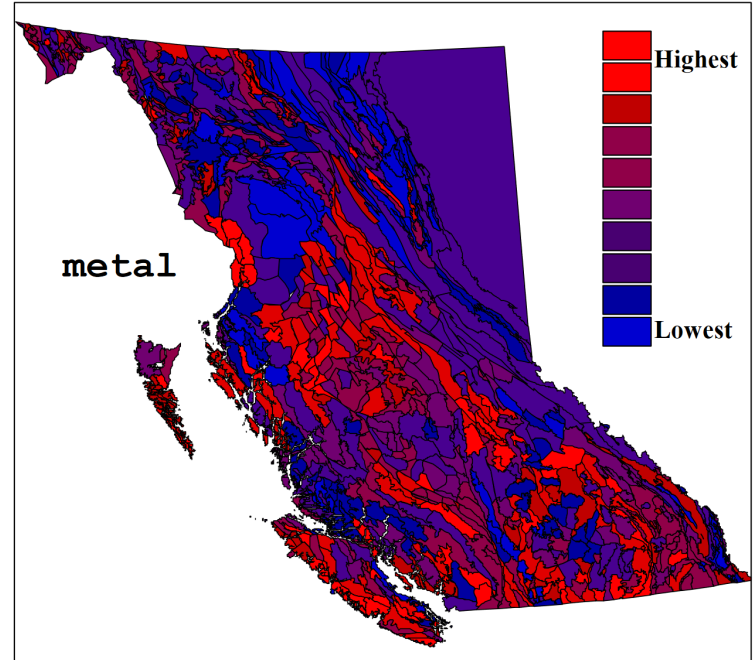
Geoscience to support mining and exploration



Geoscience to support land use planning



Land & Resource Management Plans by Natural Resource Regions in British Columbia.



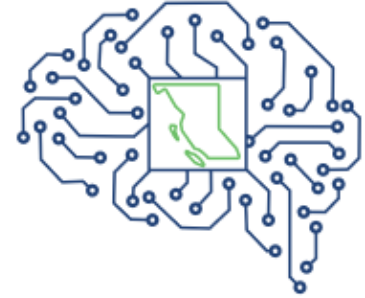
Relative ranking of metallic mineral assessment (Kilby, BCGS GeoFile 2004-02)

Why digital transformation of geoscience?

Data science, analytics, machine learning, ...

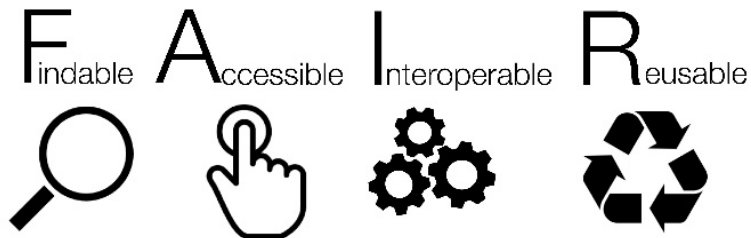
Enable analytics: solving scientific problems and carrying out predictive mineral potential modelling

- Mineral exploration and mining: target generation
- Land-use planning: mineral resource assessment



Guiding principles of digital transformation

- Develop **digital capabilities**: data, process, skills and infrastructure
- Follow the **FAIR** principles:



- Adopt the Open Geospatial Consortium (**OGC**) and ISO standards
 - GeoSciML, EarthResourceML, and IUGS/CGI vocabularies
 - OGC WMS and WFS

Findable...

DataBC Data Catalogue - ISO 19115 metadata

The screenshot shows the DataBC Data Catalogue interface. At the top, there is a search bar with the text "Search datasets...". Below the search bar, there are navigation links: "What is DataBC?", "Dataset Usage", "Geographic Services", "Blog", "Developers", "Contact", and "Log in". The main content area displays the search results for "geology", showing "85 datasets found for 'geology'". The results are ordered by "Relevance". The first result is "Bedrock Geology", which is described as "British Columbia Digital Geology is the data source used for the seamless province-wide, up-to-date, and detailed bedrock geology. The bedrock geology is standardized with...". It is published on 2014-12-15 and has various format options: other, xml, wms, shp, kml. The second result is "Geology Faults", described as "Geology faults are part of the British Columbia Digital Geology, which is the data source used for the seamless province-wide, up-to-date, and detailed bedrock geology. The...". It is published on 2011-03-09 and has format options: other, wms, shp, kml. The third result is "Surficial Geology Map Index", described as "Presented here is a surficial geology map index for British Columbia, which is published as BCGS Open File 2019-03. The 241 maps indexed were produced by the British Columbia...". It is published on 2016-04-21 and has format options: pdf, kmz, zip, csv. The fourth result is "Surficial Geology - Kootenay Region", described as "Surficial Geology for the Kootenay Region (qgeo_r4)". It has a format option: other. On the left side, there are filters for "Access Only (59)", "Open Government Lic... (26)", "Sectors" (Natural Resources (85)), "Dataset types" (Geographic Dataset (71), Application (8), Dataset (6)), "Format" (fgdb (57), shp (56), e00 (52), wms (40), kml (40)), and "Organizations" (BC Geological Survey (43), Knowledge Management (14)).



BCGS Publication Catalogue CGKN data catalogue standard

The screenshot shows the BCGS Publication Catalogue interface. At the top, there is a search bar with the text "Search datasets...". Below the search bar, there are navigation links: "Home > Farming, natural resources and industry > Mineral Exploration & Mining > British Columbia Geological Survey >". The main content area displays the search results for "geology", showing "85 datasets found for 'geology'". The results are ordered by "Relevance". The first result is "Bedrock Geology", which is described as "British Columbia Digital Geology is the data source used for the seamless province-wide, up-to-date, and detailed bedrock geology. The bedrock geology is standardized with...". It is published on 2014-12-15 and has various format options: other, xml, wms, shp, kml. The second result is "Geology Faults", described as "Geology faults are part of the British Columbia Digital Geology, which is the data source used for the seamless province-wide, up-to-date, and detailed bedrock geology. The...". It is published on 2011-03-09 and has format options: other, wms, shp, kml. The third result is "Surficial Geology Map Index", described as "Presented here is a surficial geology map index for British Columbia, which is published as BCGS Open File 2019-03. The 241 maps indexed were produced by the British Columbia...". It is published on 2016-04-21 and has format options: pdf, kmz, zip, csv. The fourth result is "Surficial Geology - Kootenay Region", described as "Surficial Geology for the Kootenay Region (qgeo_r4)". It has a format option: other. On the left side, there are filters for "Access Only (59)", "Open Government Lic... (26)", "Sectors" (Natural Resources (85)), "Dataset types" (Geographic Dataset (71), Application (8), Dataset (6)), "Format" (fgdb (57), shp (56), e00 (52), wms (40), kml (40)), and "Organizations" (BC Geological Survey (43), Knowledge Management (14)).

Home > Farming, natural resources and industry > Mineral Exploration & Mining > British Columbia Geological Survey >

Publications

The British Columbia Geological Survey is custodian of all public provincial geoscience data. Reports and maps produced since 1895 can be searched for, and downloaded from, our publication catalogue.

[Search publication catalogue](#)

The Survey currently publishes geological Papers, Open Files, GeoFiles, Geoscience Maps, and Information Circulars

- Papers**
Reserved for reviews and final thematic or regional works. Geological Fieldwork, our annual review of field activities and current research is released as the first Paper of each year.
- Geoscience Maps**
The British Columbia Geological Survey's vehicle for publishing final maps.
- Open Files**
Present the interim results of ongoing research, particularly mapping projects.
- GeoFiles**
Enable rapid release of extensive data tables from ongoing geochemical, geochronologic, and geophysical work. GeoFiles serve the same function as data repositories provided by many journals, providing immediate access to raw data from specific projects.
- Information Circulars**
Provide accessible geoscience information to a broad audience in government, industry, and the general public. Included are the annual Provincial Overview of Exploration and Mining in BC, and the Coal Industry Overview.
- Digital Geoscience Data**
Current versions of digital datasets that are regularly updated.

The names of our publications have changed through the years. Although recast in different formats, the substance of earlier generations of publications has remained.

- Bulletins**
The Bulletin series was started in 1896 for formal publications of the British Columbia Geological Survey. Because of increasing digital delivery of publications, this series has been retired.
- Preliminary Maps**
Discontinued in 1990, the Preliminary Map series delivered early drafts of maps intended for ultimate publication in Bulletins. Preliminary maps are now released digitally in the Open File series.
- Mineral Potential**
Mineral Resource Assessments; Mineral Potential Maps (1992 - 1993) evaluate the mineral potential of an area based on 1:50 000-scale geological mapping, integrated geochemical and geophysical data, and economic geology models.

Current series

Historical series

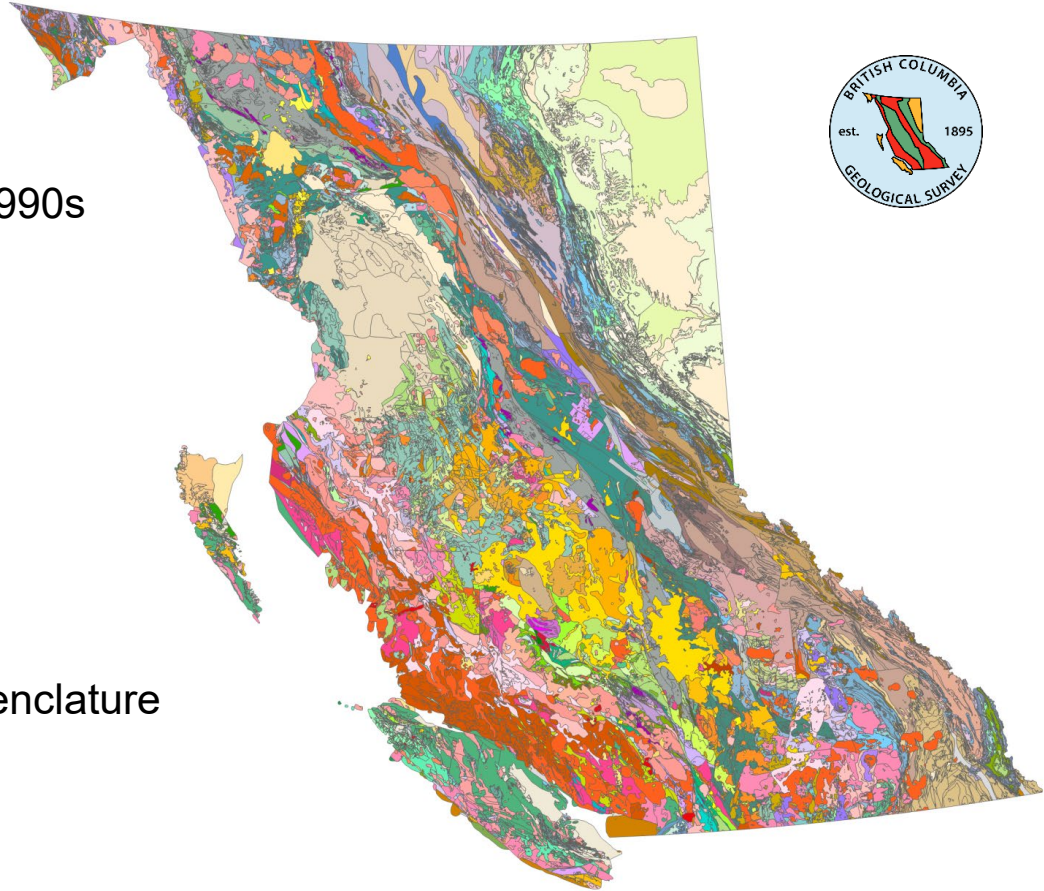
Geological Mapping in British Columbia

Maps to digital geology...

- Digital compilation since 1980s
- BC-wide seamless coverage in mid-1990s (funded by BC Land & Resource Management Plans)

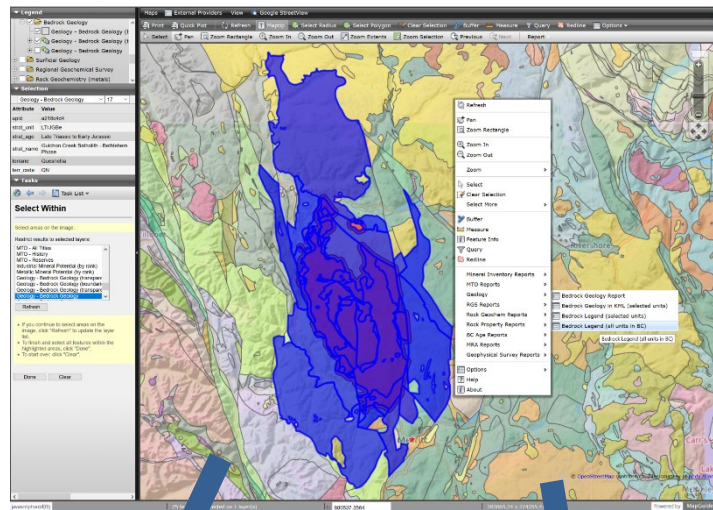
BC digital geology

- Authoritative data source
- Details from 1:50,000 to 1:250,000
- Seamless and updatable
- Analytical ready, with consistent nomenclature and encoding to support computation



Accessible, interoperable

- Available to query on MapPlace since 1997
- OGC GeoSciML Lite, WMS/WFS, OneGeology since 2018
- Syntactic interoperability?



Challenges:

- Updating digital geology
- Machine-readable (semantic interoperability)

MapPlace Geology Legend

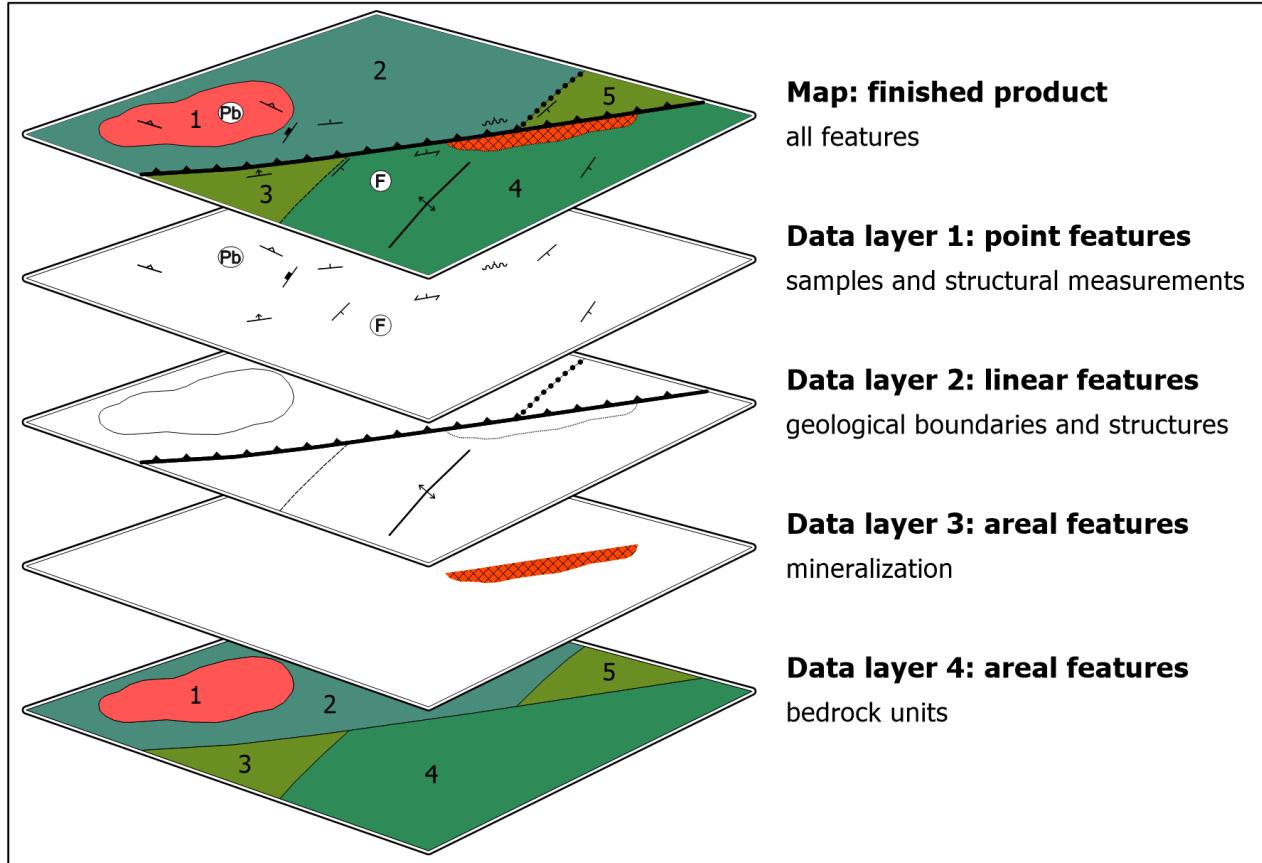
- Miscellaneous: EKAa basaltic volcanic rocks
- Eocene: EKAa undivided volcanic rocks; EKAa undivided sedimentary rocks; EKAa undivided volcanic rocks; EKAa undivided volcanic rocks
- Anastage Group: EKAa undivided volcanic rocks; EKAa undivided volcanic rocks; EKAa undivided volcanic rocks; EKAa undivided volcanic rocks
- Finniss Formation: Finniss Formation: undivided volcanic rocks; Finniss Formation: undivided volcanic rocks; Finniss Formation: undivided volcanic rocks
- Lower Jurassic to Middle Jurassic: Lower Jurassic to Middle Jurassic: undivided volcanic rocks; Lower Jurassic to Middle Jurassic: undivided volcanic rocks
- Lower Cretaceous: Lower Cretaceous: undivided volcanic rocks; Lower Cretaceous: undivided volcanic rocks
- Upper Cretaceous: Upper Cretaceous: undivided volcanic rocks; Upper Cretaceous: undivided volcanic rocks

MapPlace Summary of Bedrock Geology

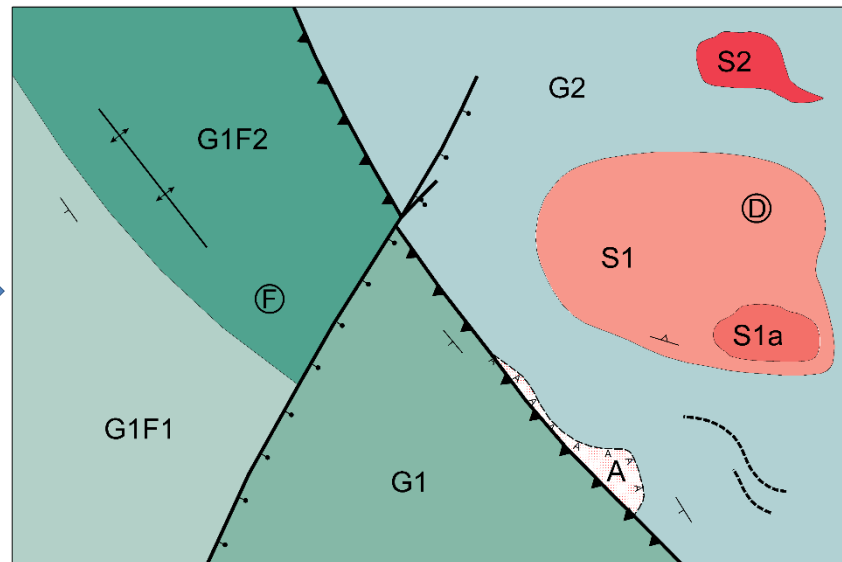
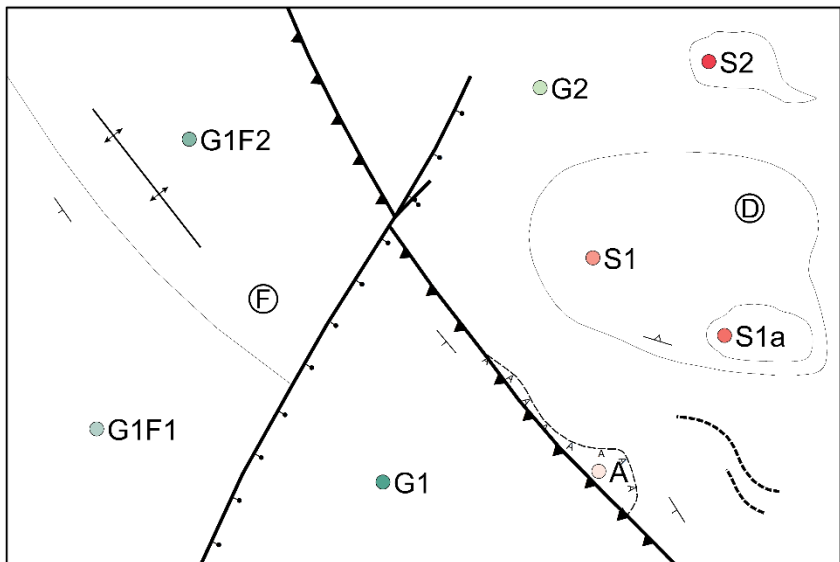
Unit ID	Unit Name	Period	Map Area	Rock Class	Rock Type	Age/Institution	Notes	Project	Status
EKAa	basaltic volcanic rocks								
EKAa	undivided volcanic rocks								
EKAa	undivided sedimentary rocks								
EKAa	undivided volcanic rocks								
EKAa	undivided volcanic rocks								
EKAa	undivided volcanic rocks								



Challenges in compilation and integration



Geospatial Frame Data (GFD) model



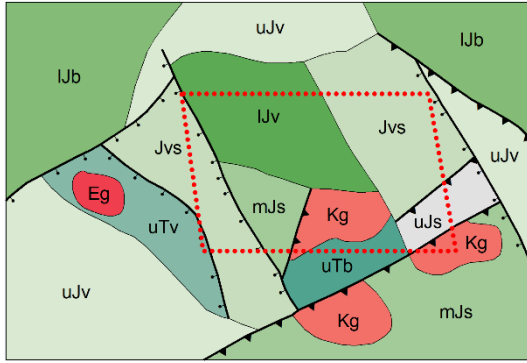
GFD database (data source, not a map)

- **GFD Lines:** geological boundaries (attributed)
- **GFD Centroids:** bedrock units (attributed)

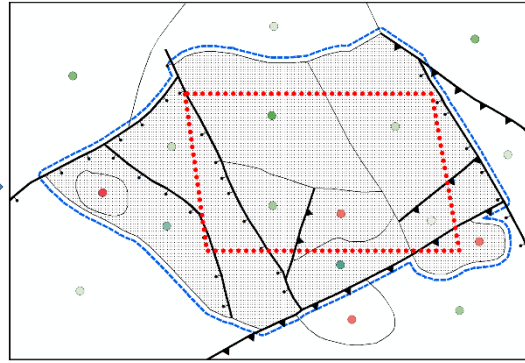
Derived geological map from the GFD data source

1. Generating bedrock polygons from geological boundaries
2. Populating bedrock attributes to the polygons from the centroids by overlay

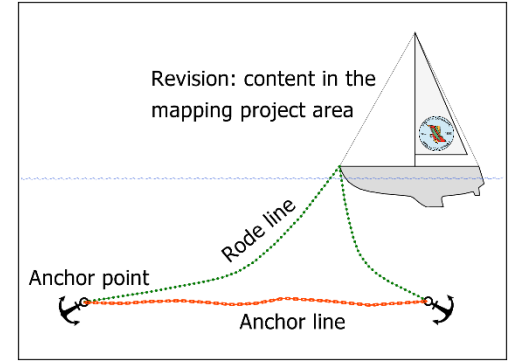
GFD data checkout and anchoring for integration



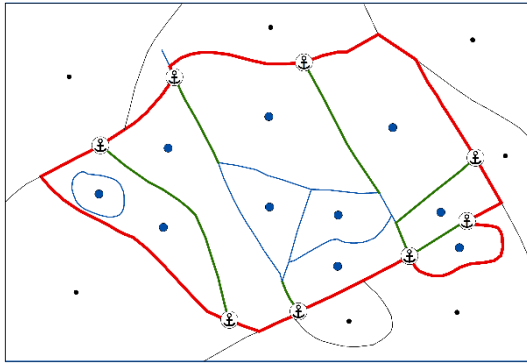
1) Area to update within limit of mapping (dotted line in red)



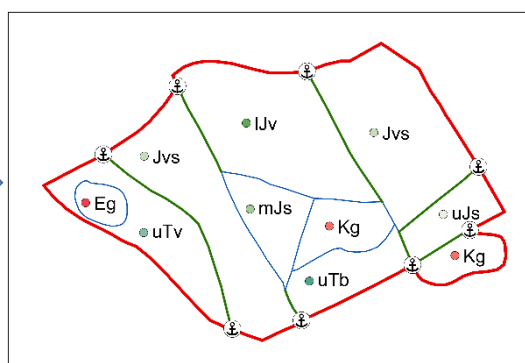
2) Data selection: extended to include entire features



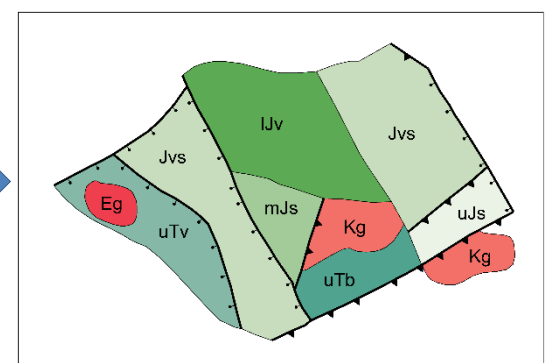
3) Anchoring concept: anchor line (red), anchor point, and rode line (green)



4) Anchoring applied to guard boundaries and intersections

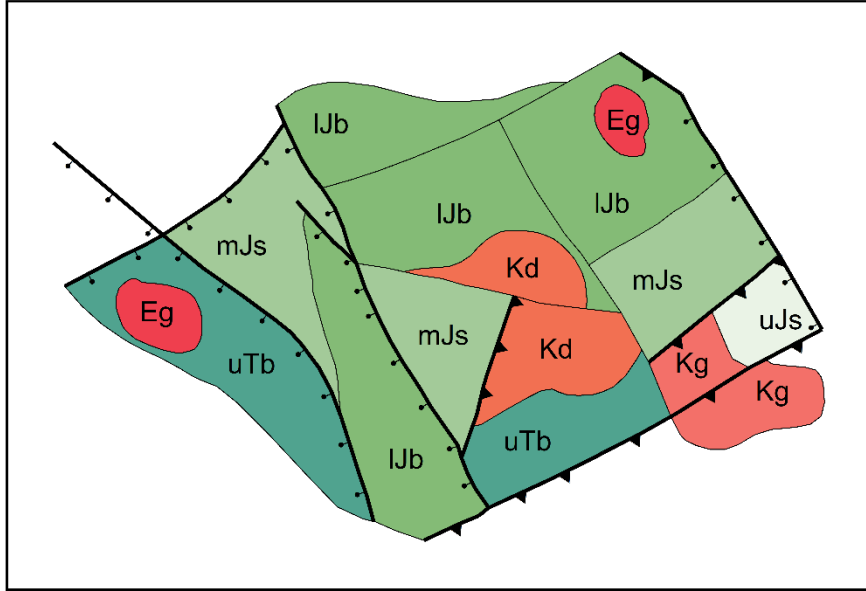


5) Data checked out: GFD feature components to update

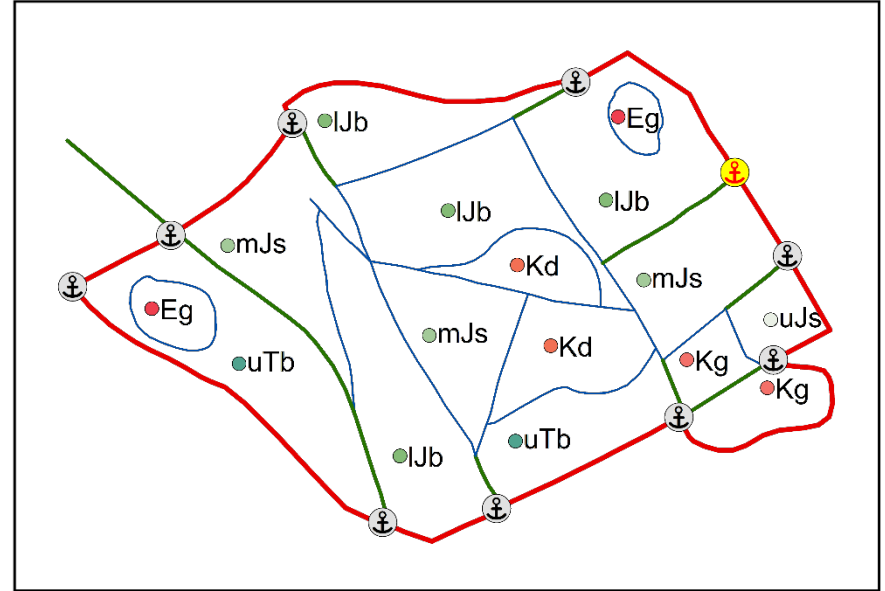


6) Data checked out: data package styled as a map with polygons

GFD update and integration (1/3)

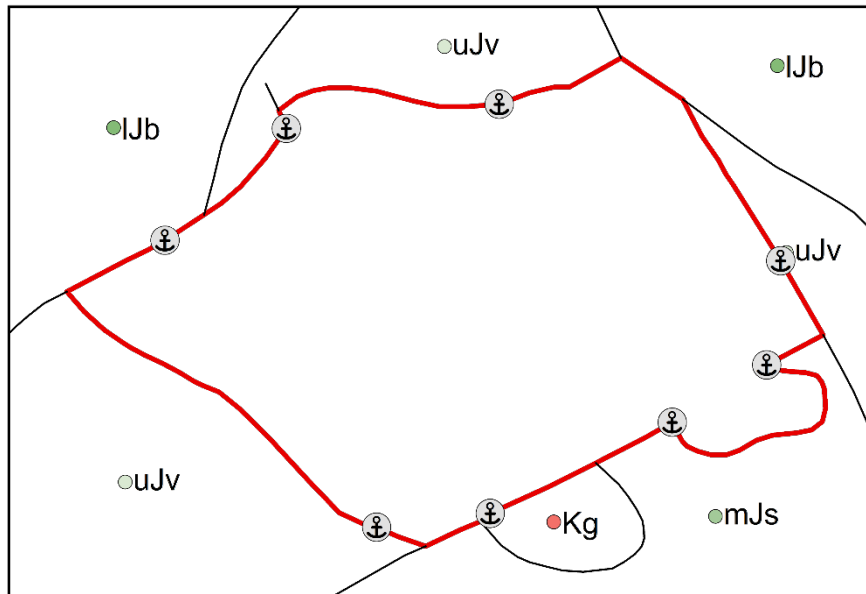


1) A new mapping project is complete and submitted for integration

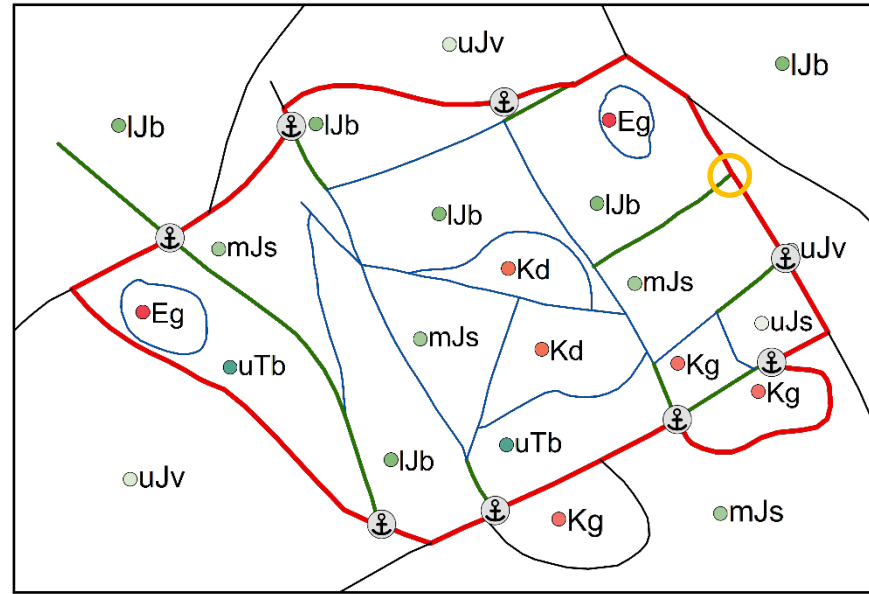


2) Only new GFD feature components are validated against the GFD specifications (note that a new anchor point in red and yellow highlight is flagged)

GFD update and integration (2/3)

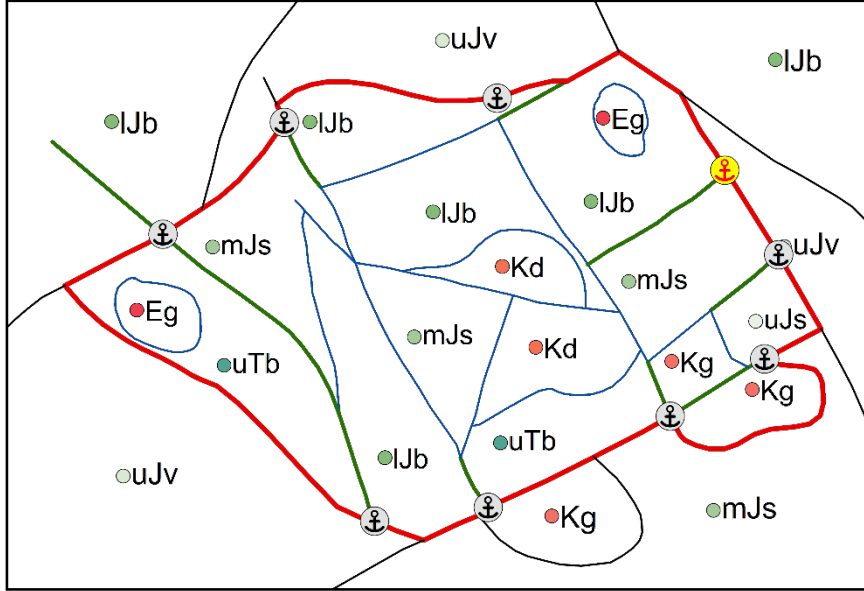


3) In the corporate GFD database, outdated feature components are retired before admitting updates

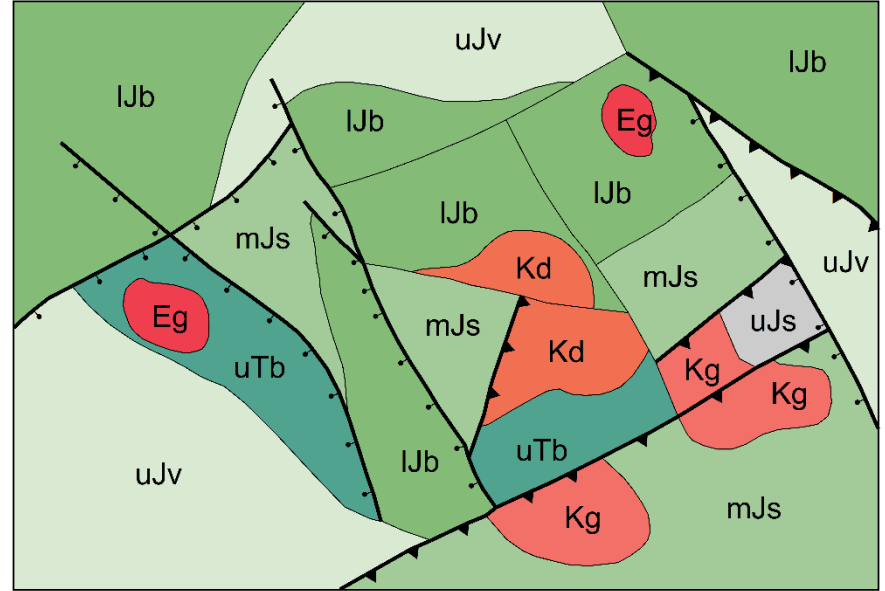


4) After updates are admitted, rode lines are snapped to anchor points, except a new rode line that has no anchor point (highlighted by a circle in orange color)

GFD update and integration (3/3)

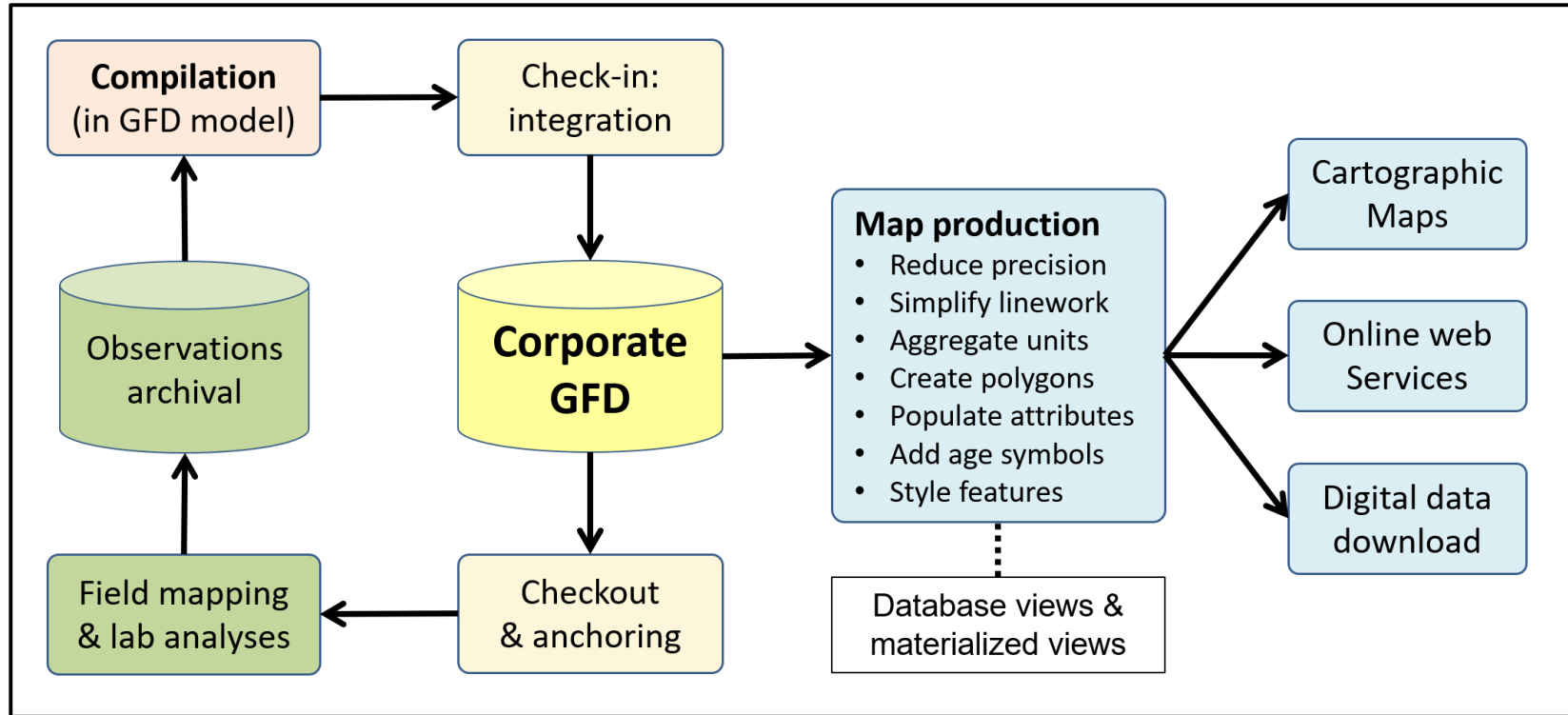


5) A new anchor point (in red and yellow highlight) is added to complete the integration

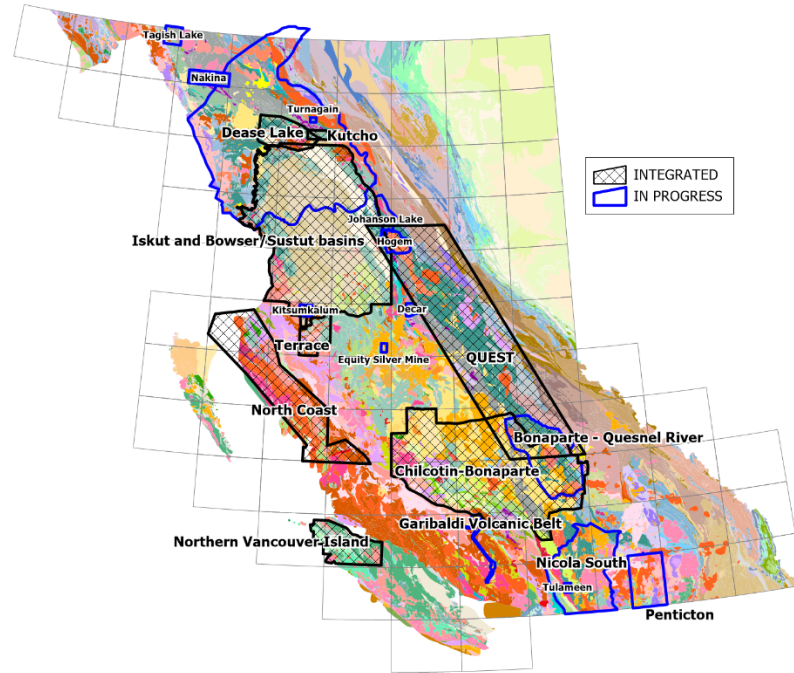


6) A finished geological map derived from the feature components in the corporate GFD database

Flow chart of GFD: from data checkout, update to check-in

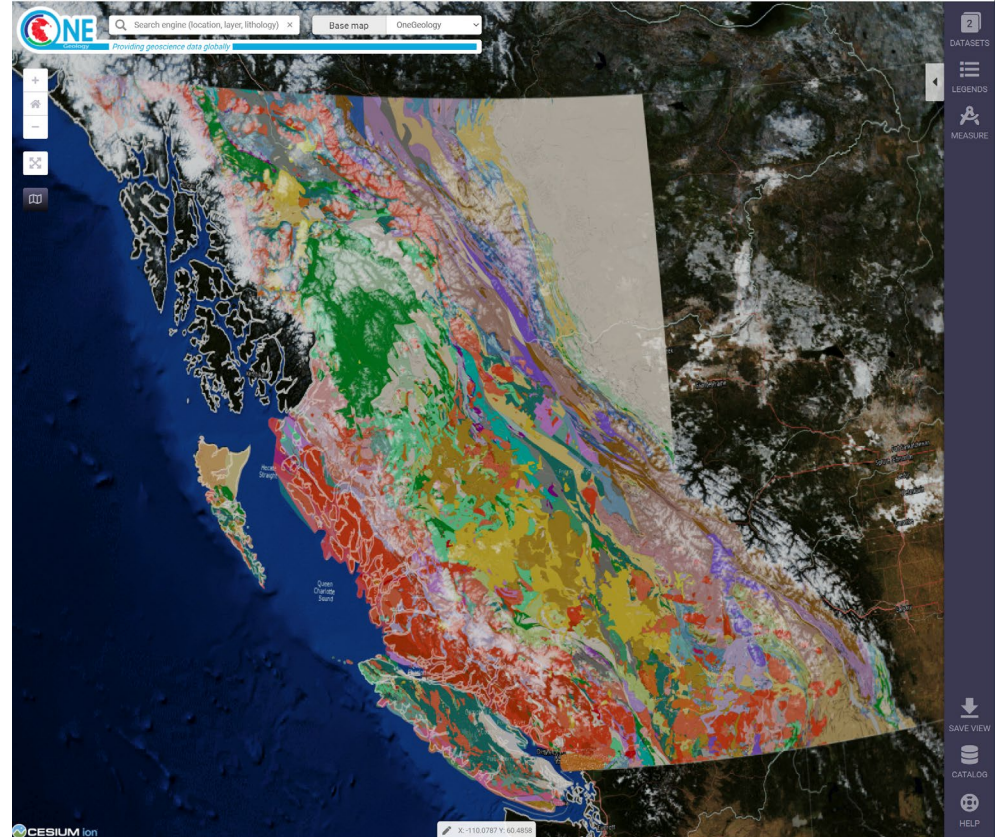


GFD compilation and integration progress in BC



Syntactic interoperability?

- GeoSciML Lite
- IUGS-CGI vocabularies
- OGC WMS/WFS



What is ‘interoperability’?

Interoperability is a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, in either implementation or access, without any restrictions.

-- <http://interoperability-definition.info/en/>

Syntactic interoperability:

- Data models and formats: e.g., GeoSciML, GeoPackage; WKT/SDO geometry
- System (interface/protocols): e.g., WMS, WFS

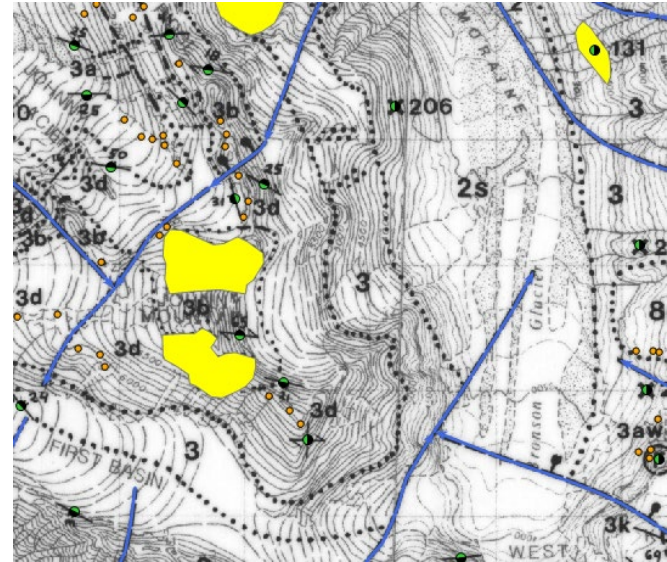
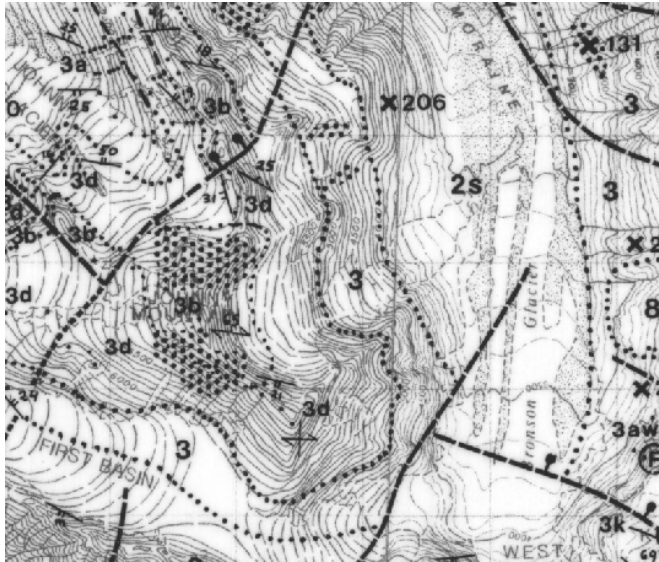
Semantic interoperability: shared **meaning** of data among systems

- Classifications/profiles to taxonomy
- Descriptions/terms/jargons to controlled vocabularies
- Geoscience to ontology



How it is known?

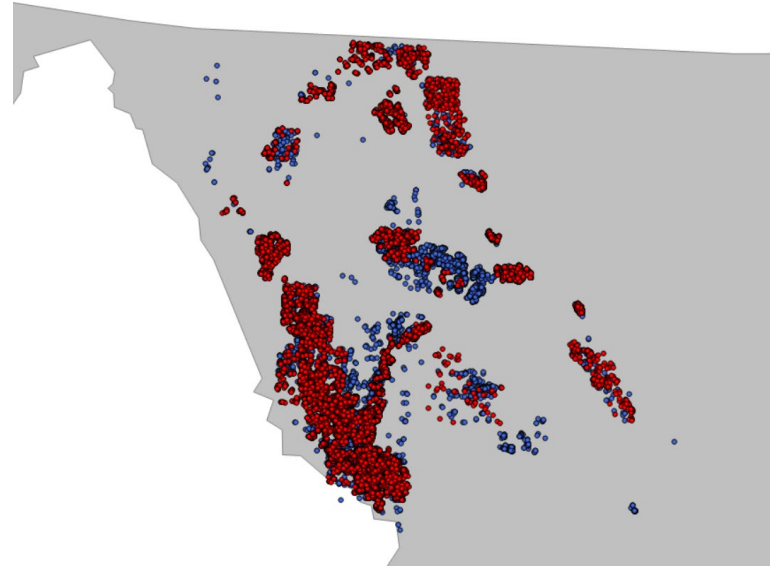
- Feature-level metadata: marker units, mapping scales, presentational scales
- Field data: observation methods, structural measurements, alteration, samples, photos
- Laboratory analyses: litho-geochem, drill-hole assay, isotopic data, petrography
- Spatiotemporally associated features: mineralization, mineral systems



Field data digitization

Currently compilation

- Field stations: 21,000
- Structure measurements: 19,000
- Other features (examples):
 - outcrops
 - folds
 - dykes
 - alteration zones
- Preserves all original data



Red= structures
Blue = field stations



Why spatial database?

- **Performance:** indexing, partitioning, parallel processing
- **Security:** authentication/permission, transactional, triggers, back-up
- **Multi-users:** concurrent editing, locking, roll-back, versioning
- **Multi-clients:** ODBC, OLE DB, JDBC
- **SQL queries:** standards based

Spatial database: PostgreSQL/PostGIS

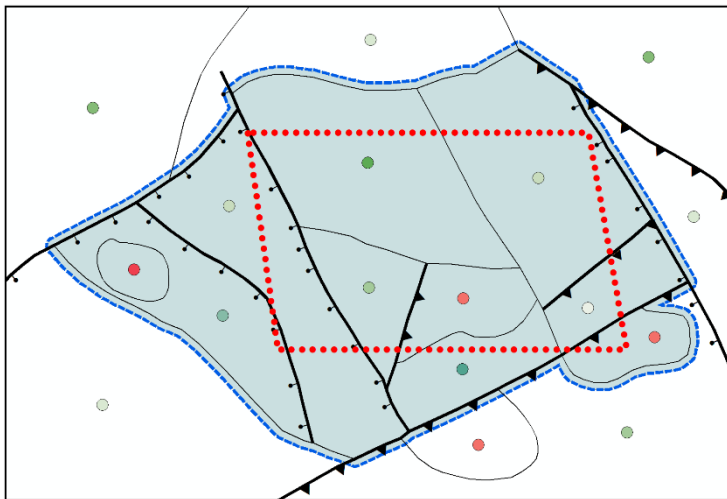
- **OGC standard simple features:**
 - geometry types, binary predicates, spatial functions and SQL
- **Foreign Data Wrapper**
 - integration of distributed databases



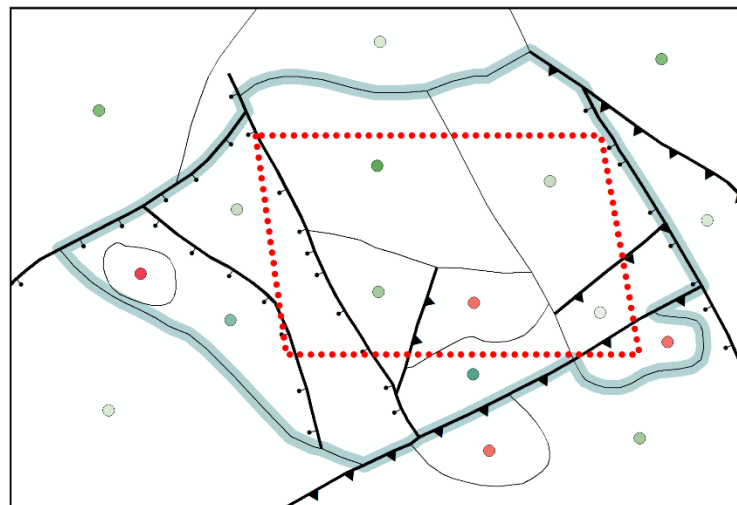
SQL statement for data checkout (snippet)



```
SELECT ST_Buffer(ST_BuildArea(ST_ExteriorRing(ST_Union(a.geom))), 1) geom_buff_aoi
,ST_Buffer(ST_ExteriorRing(ST_Union(a.geom)), 1) geom_buff_anchorline
FROM (SELECT a.geom FROM mv_bedrock_poly a LEFT JOIN mp_areas_poly b
ON ST_Intersects(a.geom, b.geom) WHERE b.mp_id = 'my_map_project_id') AS foo;
```

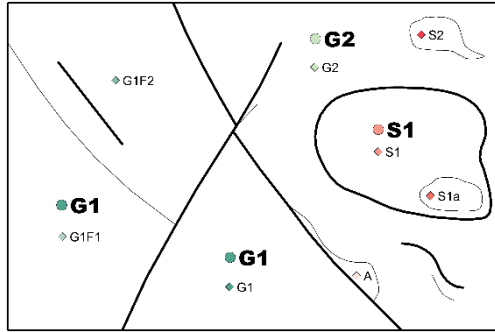


1) Create buffer [geom_buff_aoi] to tag feature components that intersect the mapping project area

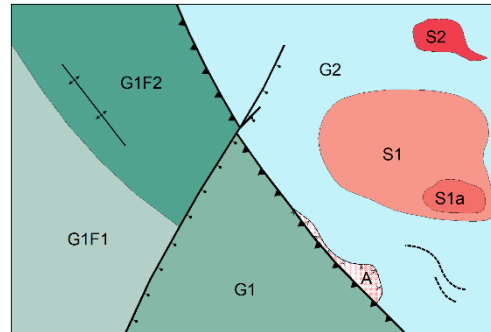


2) Create buffer [geom_buff_anchorline] to tag anchorlines, anchorpoints, rodelines and the rest for revision.

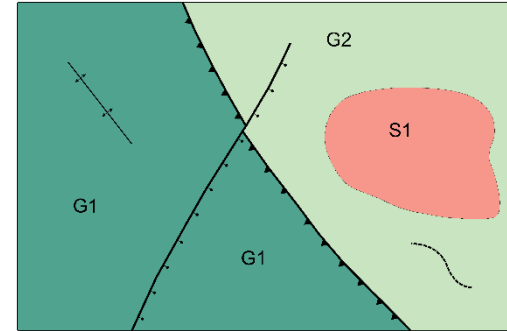
Database *views* and *materialized views* to create maps



1) GFD source data with levels of details



2) Map at a scale of 1:50,000



3) Map at a scale of 1:250,000

- a) All the line and unit label as diamond, presentational scale: 1:50,000;
- b) Thick line and unit label as circle, presentational scale: 1:250,000

- Database *views*: virtual or in memory result sets of stored queries
- Database *materialized views*: database objects containing result sets of stored queries

-- SQL View to **simplify bedrock boundaries** by a tolerance of 5 metres

```
CREATE OR REPLACE VIEW v_geobnd_line_simplified_5m AS
SELECT gid, f_type, f_name, ...
ST_SimplifyPreserveTopology(geom, 5) AS geom
FROM geobnd_line;
```

-- SQL Materialized View to **form polygons** from above View and **populate bedrock attributes** from centroids

```
CREATE MATERIALIZED VIEW mv_bedrock_poly AS
SELECT a.gid, a.strat_unit, a.strat_age, a.strat_name, a.rock_type, b.src_url, d.geom
FROM centroid_point a, lut_data_sources b,
(SELECT g.geom::geometry(Polygon,3005) AS geom
FROM (SELECT ST_Dump(ST_Polygonize(v_geobnd_line_simplified_5m.geom))) .geom AS geom
WHERE v_geobnd_line_simplified_5m.f_type <> 'alternation'
AND v_geobnd_line_simplified_5m.presentation_scales LIKE '%250,000%') g) d
WHERE a.src_id = b.src_id AND bedrock_centroid.presentation_scales LIKE '%250,000%'
AND bedrock_centroid.rock_type <> 'alternation' AND ST_Contains(d.geom, a.geom) WITH DATA;
```

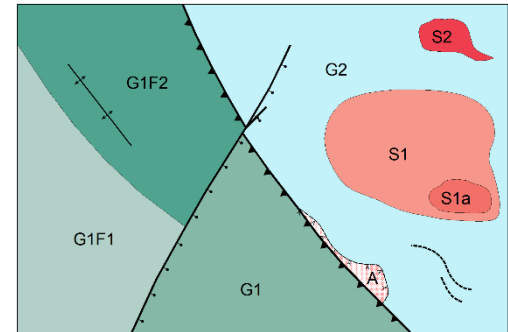
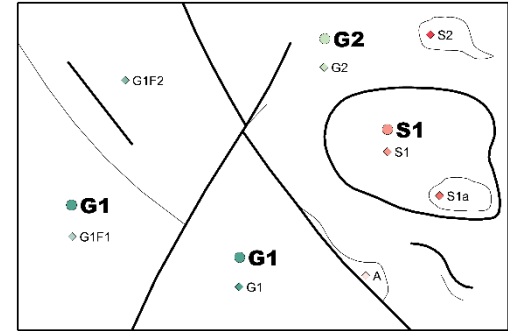


Trigger and function to refresh a Materialized View

```
-- Triggers to refresh materialized view after changes
-- Trigger: refresh materialized view on change to boundary
CREATE TRIGGER refresh_mat_view_on_bndy
AFTER INSERT OR UPDATE OR DELETE OR TRUNCATE
ON gfd_bndy_lines
FOR EACH STATEMENT
EXECUTE PROCEDURE refresh_mat_view();

-- Trigger: refresh materialized view on change to centroid
CREATE TRIGGER refresh_mat_view_on_centroid
AFTER INSERT OR UPDATE OR DELETE OR TRUNCATE
ON gfd_centroids
FOR EACH STATEMENT
EXECUTE PROCEDURE refresh_mat_view();

-- Function: refresh_mat_view()
CREATE OR REPLACE FUNCTION refresh_mat_view()
RETURNS trigger AS
$BODY$
begin
    refresh materialized view mv_bedrock_poly;
    return null;
end $BODY$
LANGUAGE plpgsql VOLATILE
COST 100;
```



Styled views by XML stored in database tables and applied to the views automatically

Trigger and function to track versioning

Trigger function to track changes on:

- **Insert:** adding new features
- **Delete:** retiring deleted features
- **Update:** modifying existing features

- **Validate:** quality assurance (QA, also including standardization) and status: passed, failed, and pending (e.g., resolution of issues)

Tracking revision and QA history

- **What:** insert, delete, update, or validate
- **when:** time-stamp
- **Who:** database username
- **why:** reasons of change

```
-- Trigger: track change to boundary
CREATE TRIGGER track_change_bndy
  BEFORE INSERT OR DELETE OR UPDATE
  ON gfd_bndy_lines
  FOR EACH ROW
  EXECUTE PROCEDURE track_change();

-- Trigger: track change to centroid
CREATE TRIGGER track_change_centroid
  BEFORE INSERT OR DELETE OR UPDATE
  ON gfd_centroids
  FOR EACH ROW
  EXECUTE PROCEDURE track_change();

-- Function: track_changes()
CREATE FUNCTION track_changes()
  RETURNS trigger
  LANGUAGE 'plpgsql'
  COST 100
  VOLATILE NOT LEAKPROOF
  AS $BODY$

DECLARE ...;

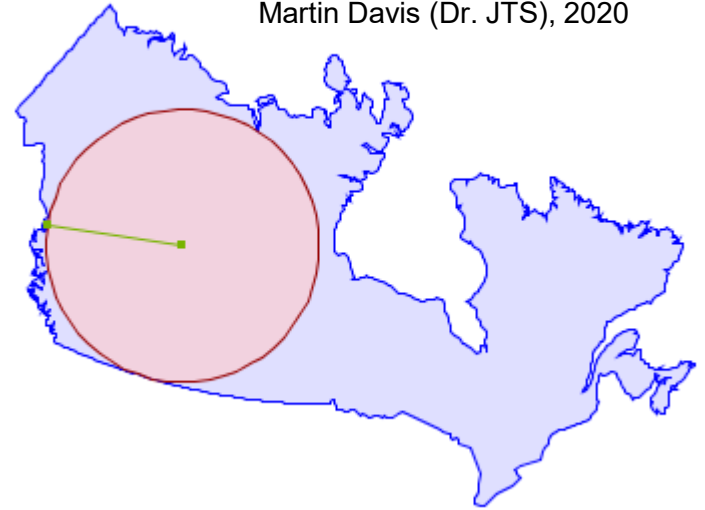
.....
```



SQL: spatial functions

Martin Davis (Dr. JTS), 2020

- Compute maximum inscribed circle
- Adjust centroid locations to the centres (`geom_centroid`)
- Compute unique ID (`pid`): repeatable (and meaningful?)
- Create cartographic text labels, sized by `radius`



```
SELECT radius,  
       ST_AsText(center) AS center,  
       ST_AsText(nearest) AS nearest  
FROM ST_MaximumInscribedCircle('POLYGON ((50 50, 150 50, 150 150, 50 150, 50 50))')
```

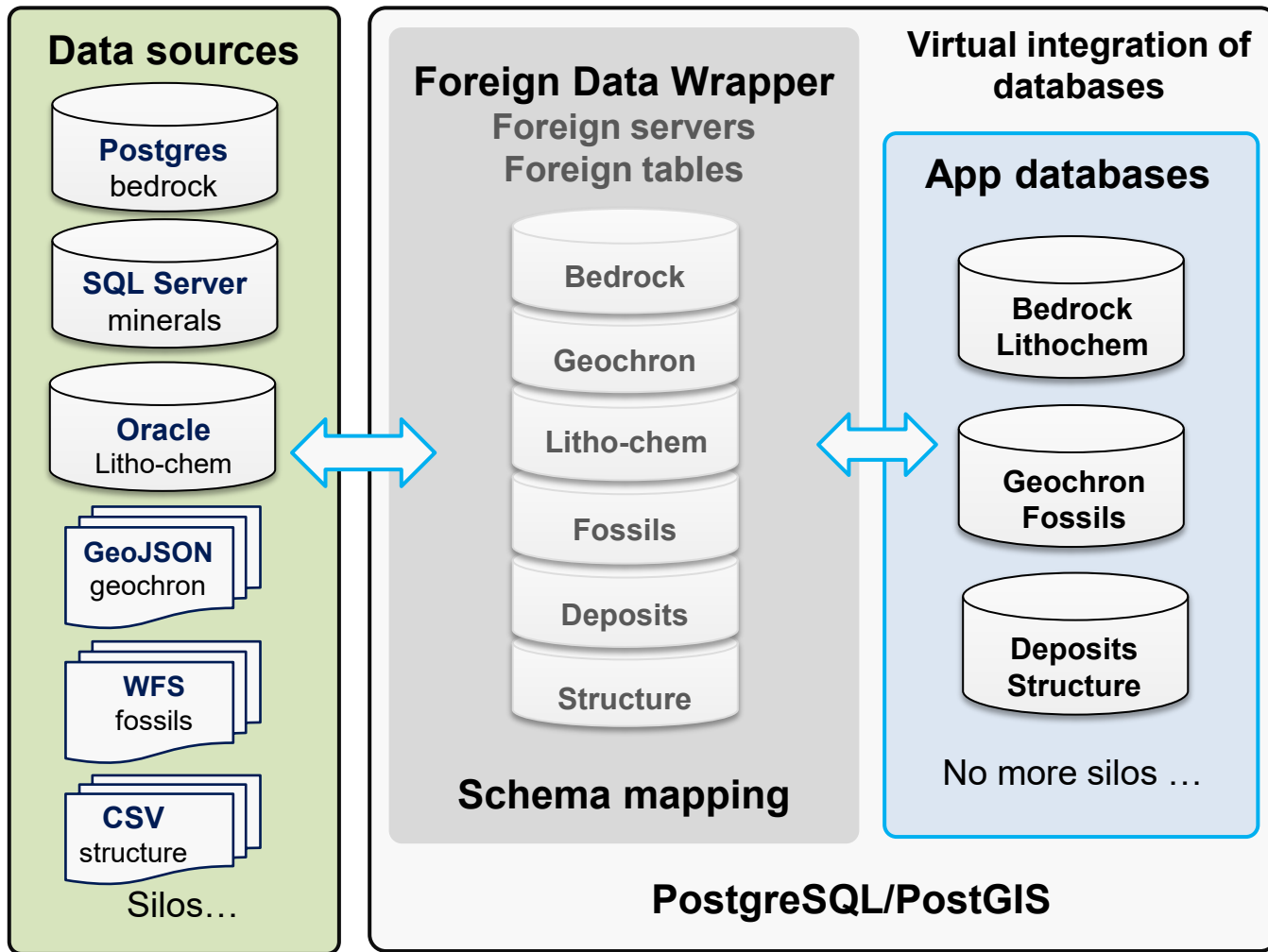
```
SELECT (ROUND(ST_X(center(ST_MaximumInscribedCircle(the_geom)))) || '-'  
       || ROUND(ST_Y(center(ST_MaximumInscribedCircle(the_geom))))),  
       ST_AsText(nearest(ST_MaximumInscribedCircle(the_geom))) AS pid,  
       ST_AsText(center(ST_MaximumInscribedCircle(the_geom))) AS geom_centroid,  
       strat_unit, stra_name, strat_age,  
       radius(ST_MaximumInscribedCircle(the_geom)/x AS label_font_size, ...  
FROM mv_bedrock_poly;
```



Foreign Data Wrapper

Supported by Postgres

It is used to build our application database, to virtually integrated data from various data sources.



Thank you!



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