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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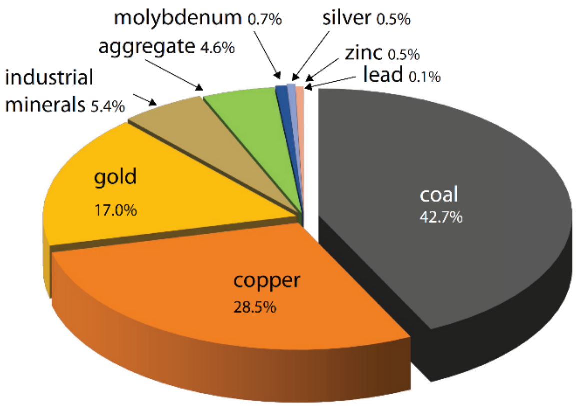
British Columbia Geological Survey

Digital Mapping Techniques
June 9, 2021

Outline

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

Geoscience support mining and exploration



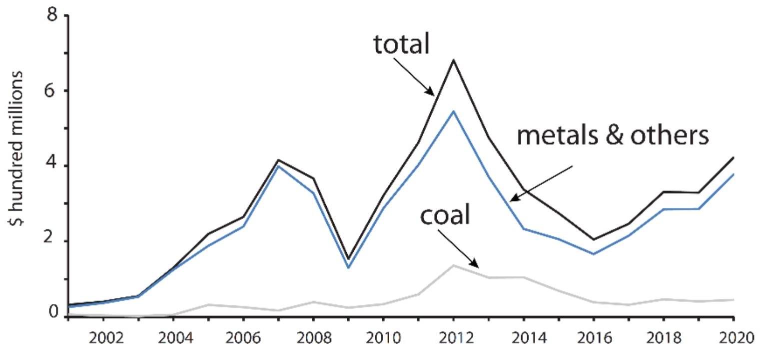
Mine production value in 2020: **$9.28 billion**

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

Exploration expenditure in 2020

$422.7 million total

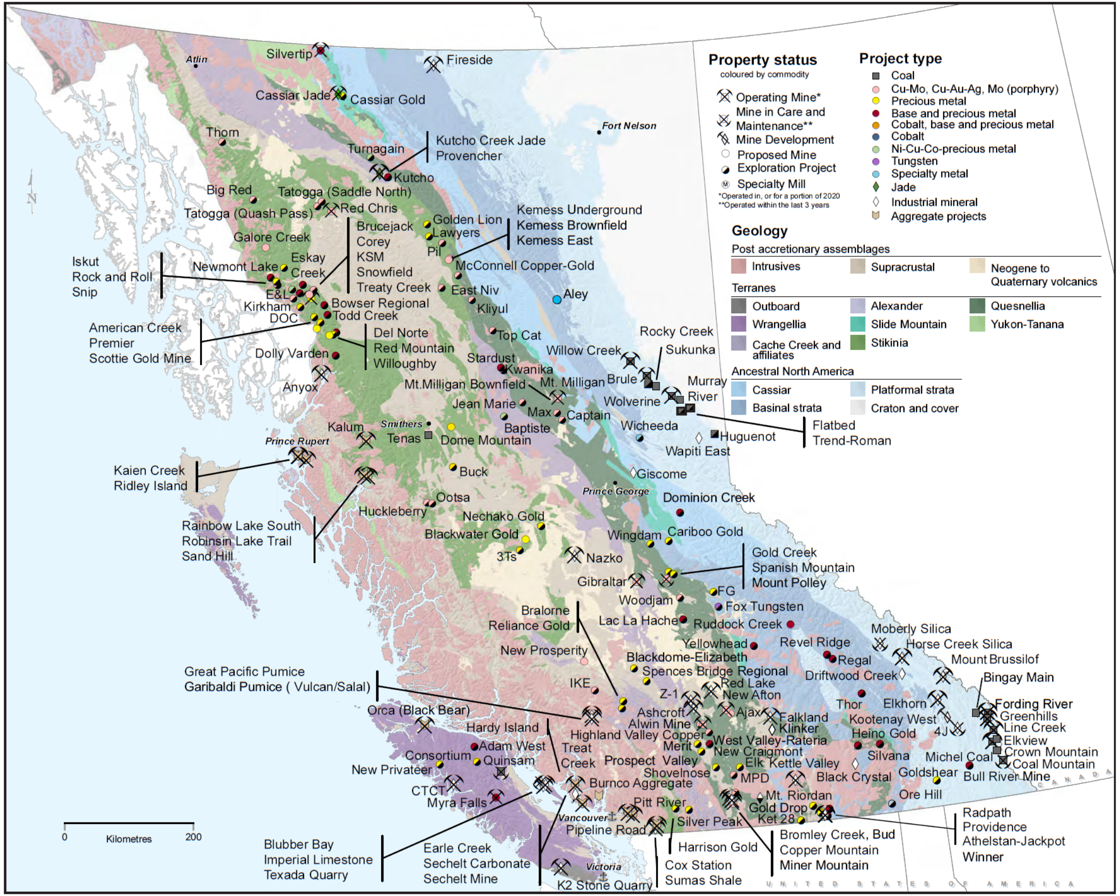
- $378 million Metals + other
- $44.7 million: Coal
- Increase of $93.2 million vs. 2019



Exploration expenditures per year, by type.

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

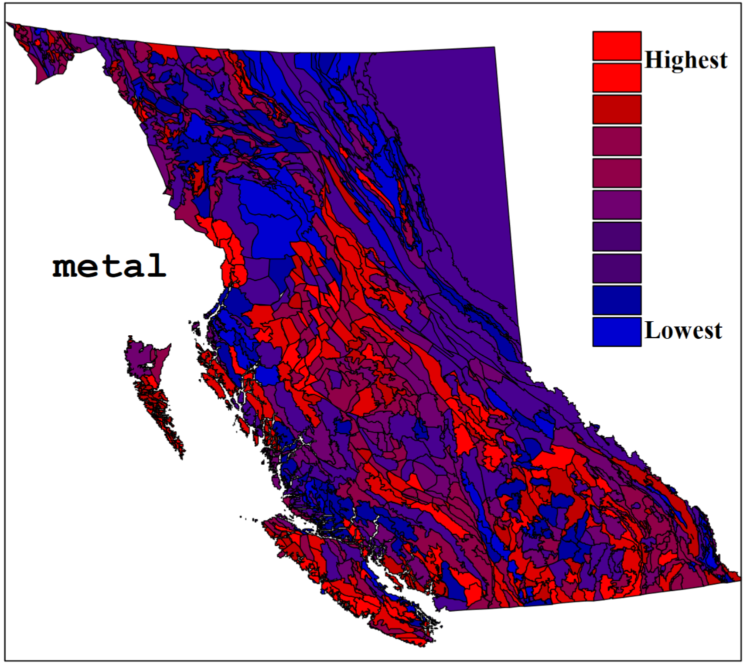
Geoscience to support mining and exploration



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

Geoscience to support land use planning

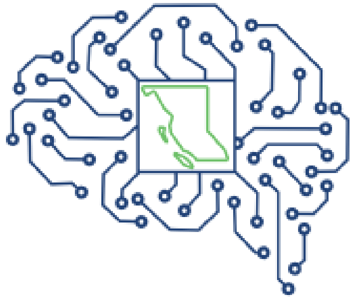
Land & Resource Management Plans by Natural Resource Regions in British Columbia.



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

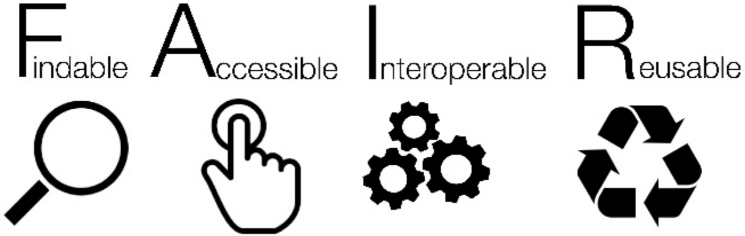
- Mineral exploration and mining: target generation
- Land-use planning: mineral resource assessment

data science community

BRITISH COLUMBIA GEOLOGICAL SURVEY est. 1895

Guiding principles of digital transformation

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

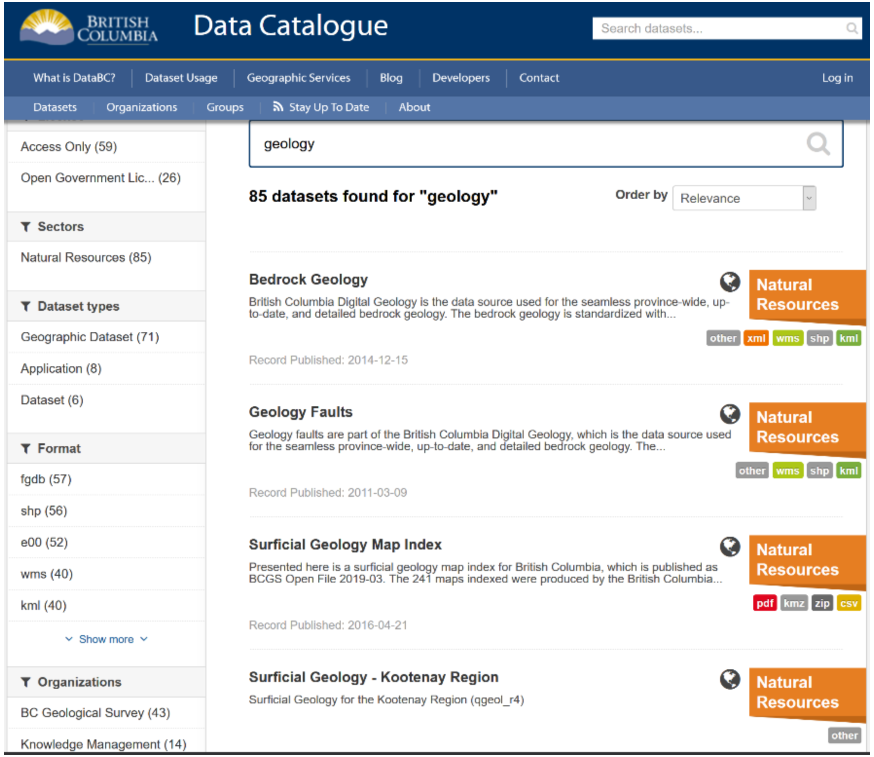


https://www.go-fair.org

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

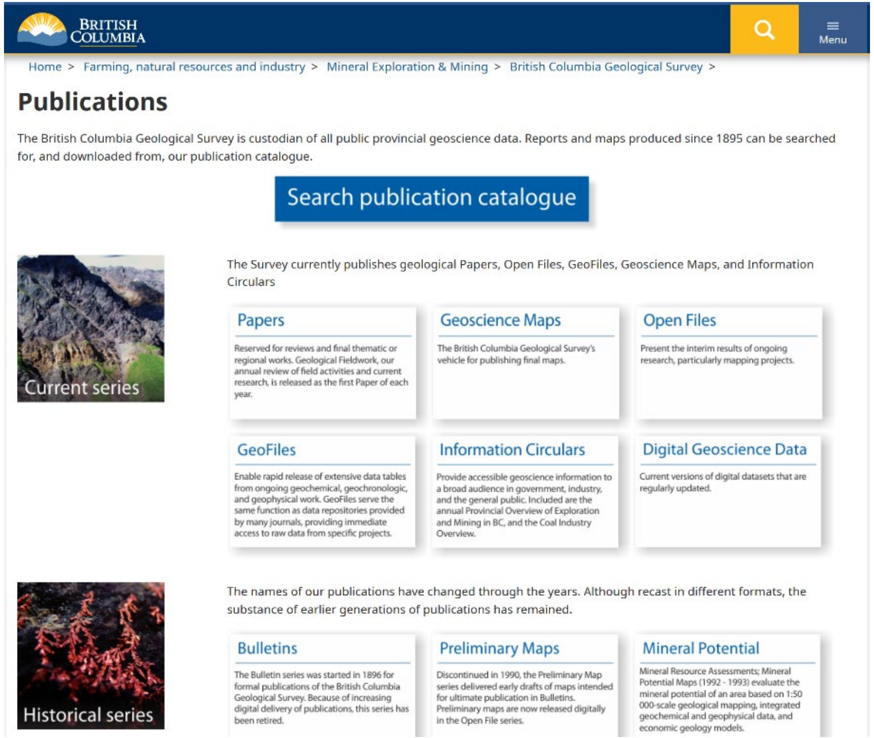
Findable…

DataBC Data Catalogue
- ISO 19115 metadata



BCGS Publication Catalogue

CGKN data catalogue standard



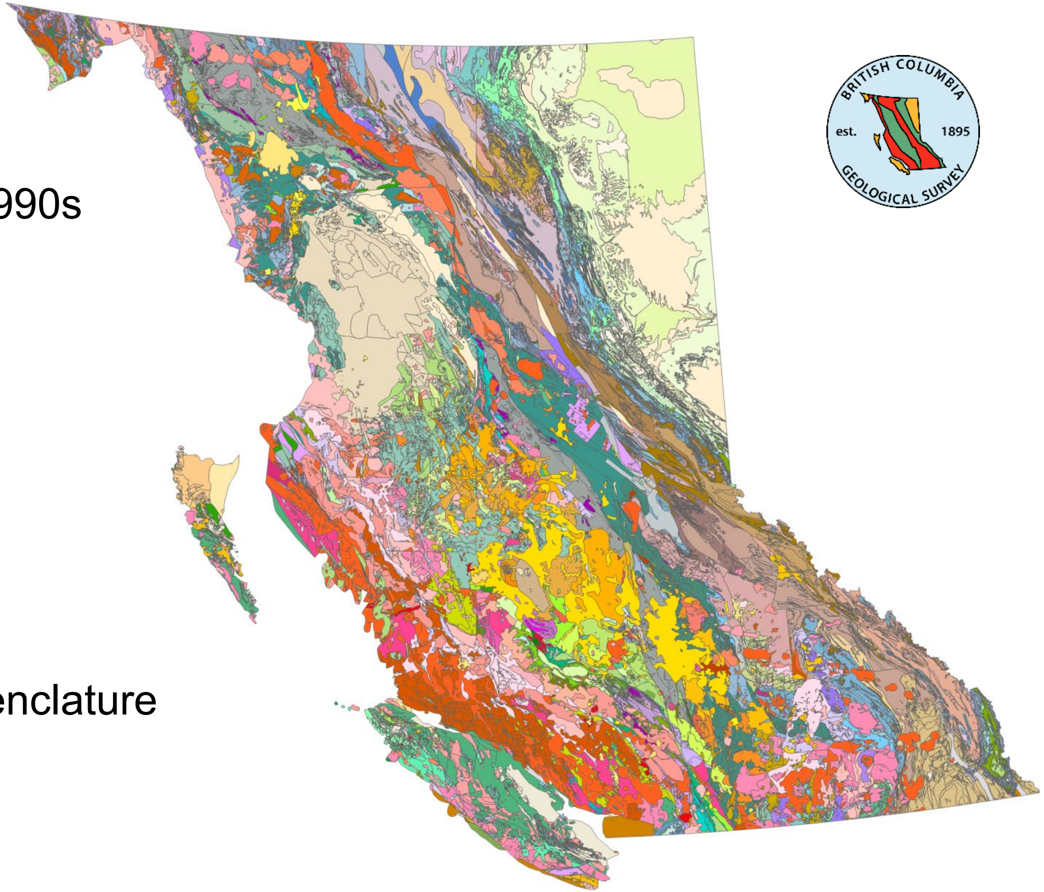
Geological Mapping in British Columbia

Maps to digital geology…

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

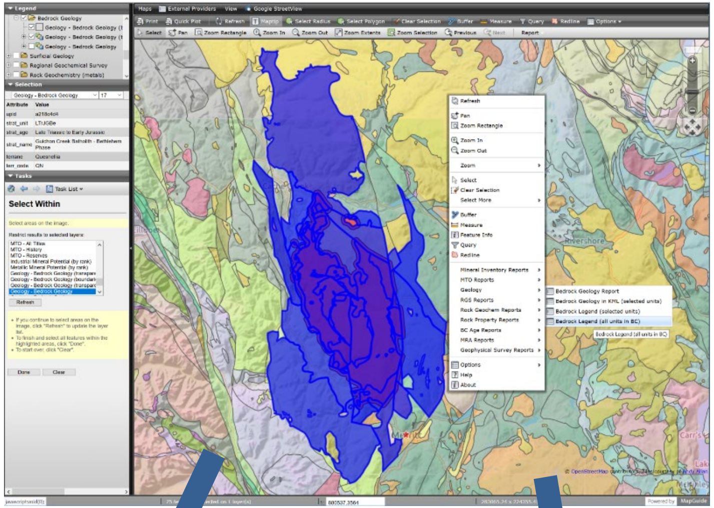
BC digital geology

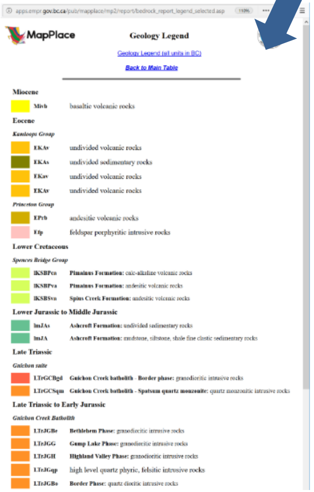
- Authoritative data source
- Details from 1:50,000 to 1:250,000
- Seamless and updatable
- Analytical ready, with consistent nomenclature and encoding to support computation

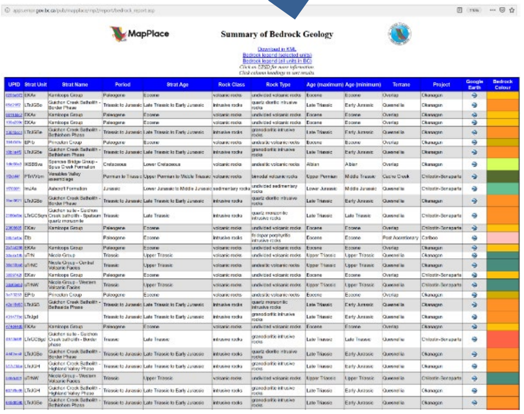


Accessible, interoperable

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







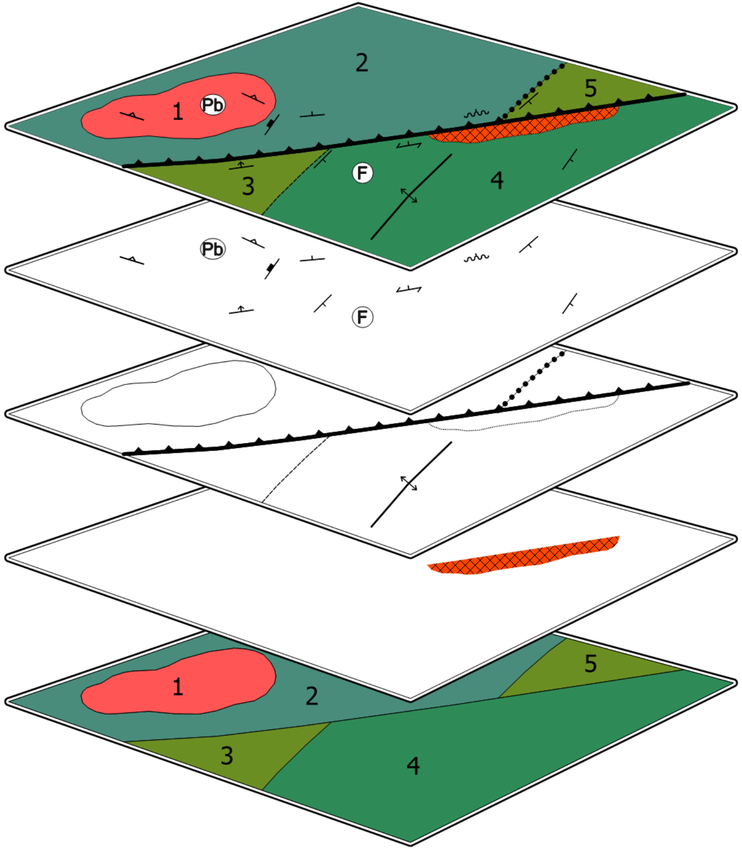
Challenges:

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

est. 1895 British Columbia Geological Survey

MapPlace digital geoscience for British Columbia

Challenges in compilation and integration



Map: finished product
all features

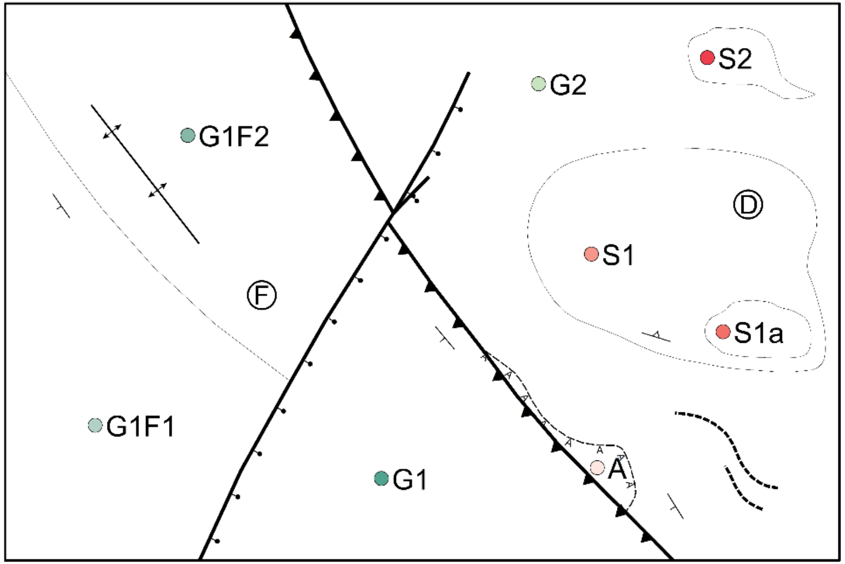
Data layer 1: point features
samples and structural measurements

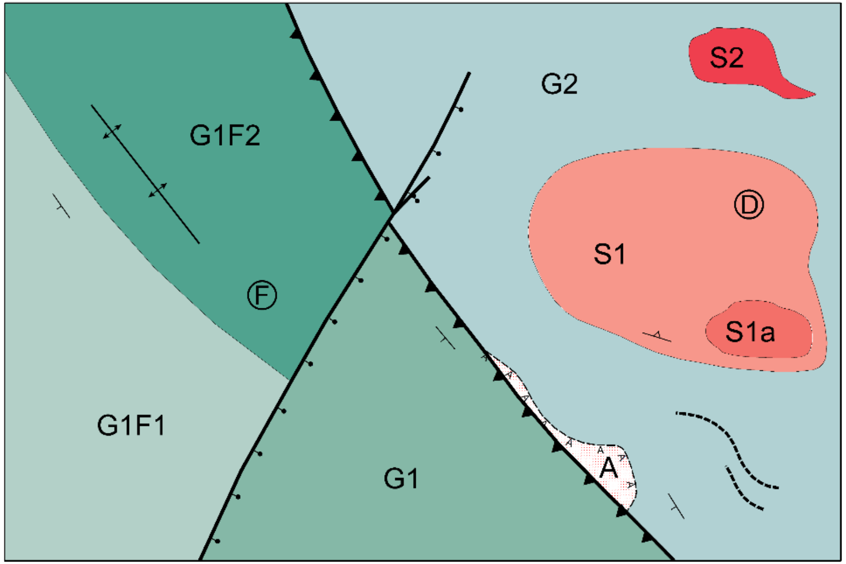
Data layer 2: linear features
geological boundaries and structures

Data layer 3: areal features
mineralization

Data layer 4: areal features
bedrock units

Geospatial Frame Data (GFD) model





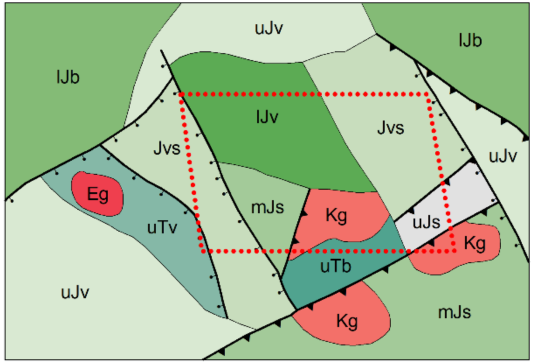
GFD database (data source, not a map)

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

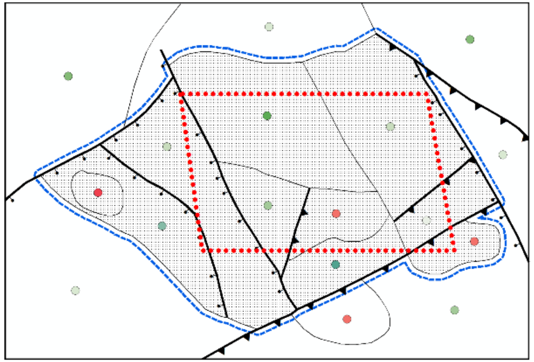
Derived geological map from the GFD data source

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

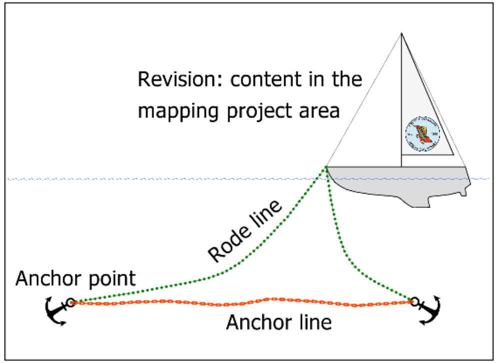
GFD data checkout and anchoring for integration



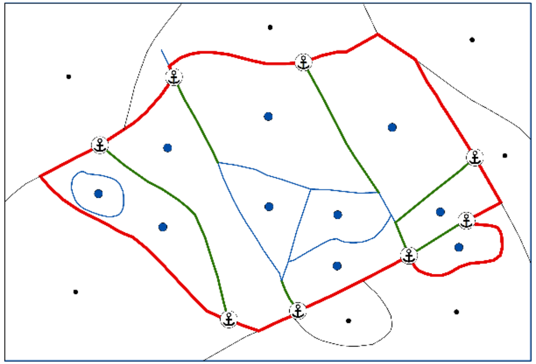
1) Area to update within limit of mapping (dotted line in red)



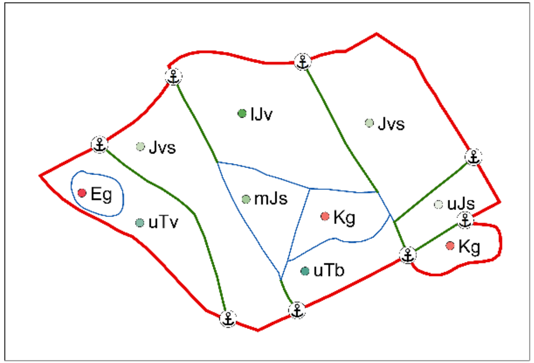
2) Data selection: extended to include entire features



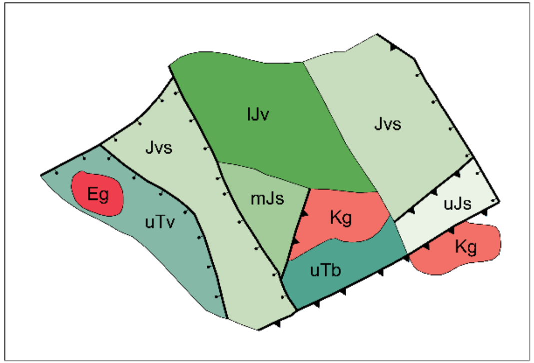
3) Anchoring concept: anchor line (red), anchor point, and rode line (green)



4) Anchoring applied to guard boundaries and intersections

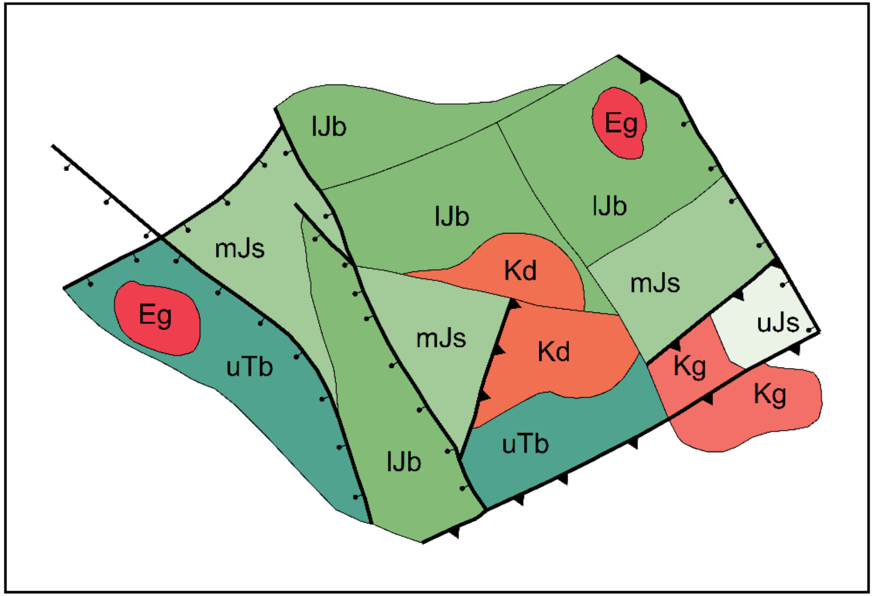


5) Data checked out: GFD feature components to update

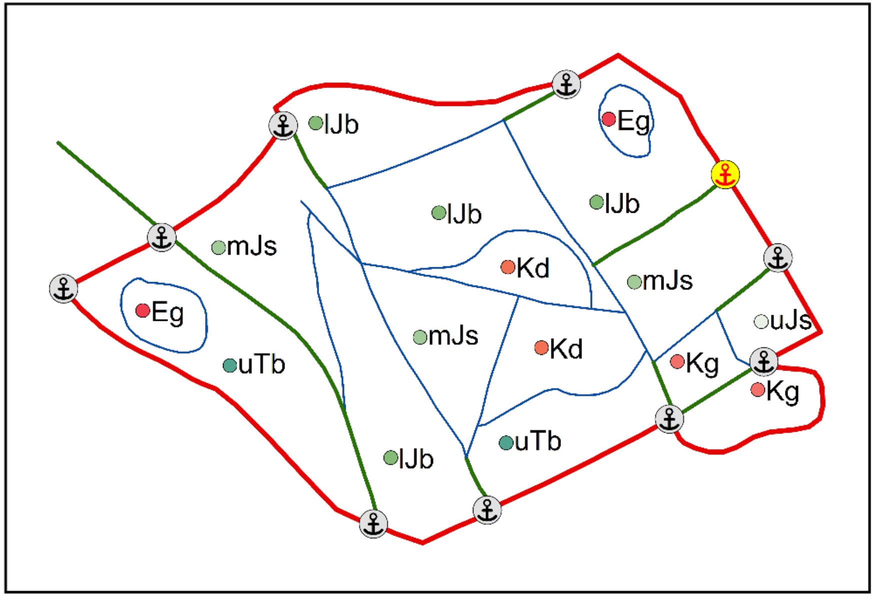


6) Data checked out: data package styled as a map with polygons

GFD update and integration (1/3)

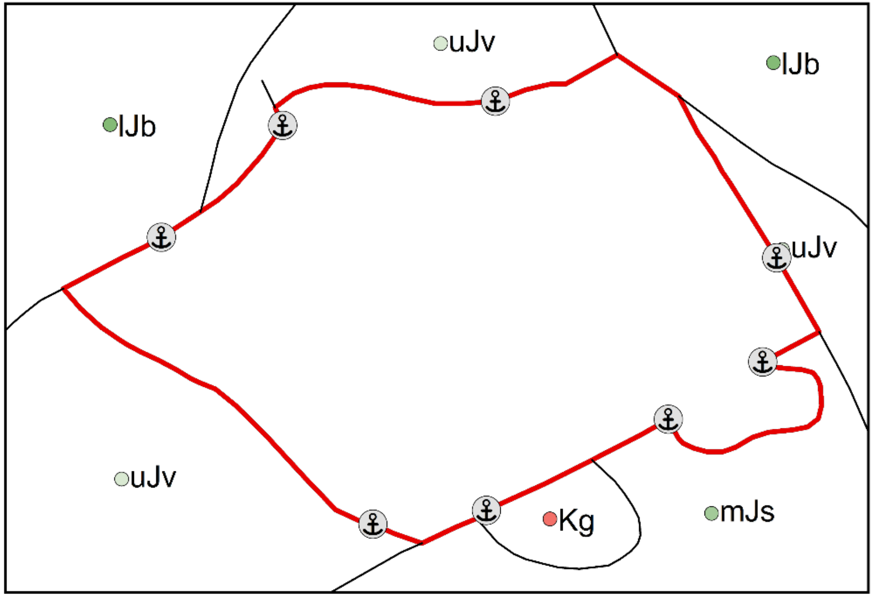


1) A new mapping project is complete and submitted for integration

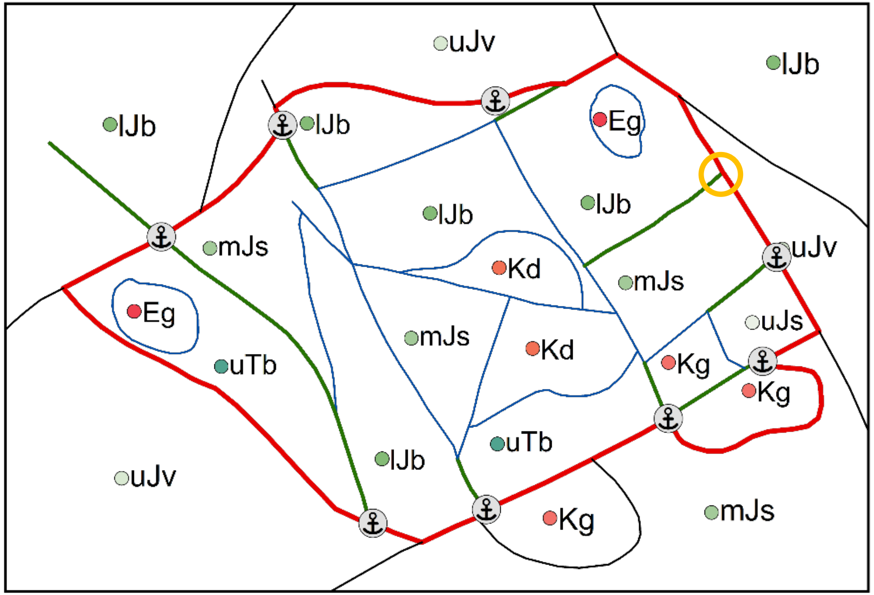


2) Only new GFD feature components are validated against the GFD specifications (note that a new anchor point in red and yellow highlight is flagged)

GFD update and integration (2/3)

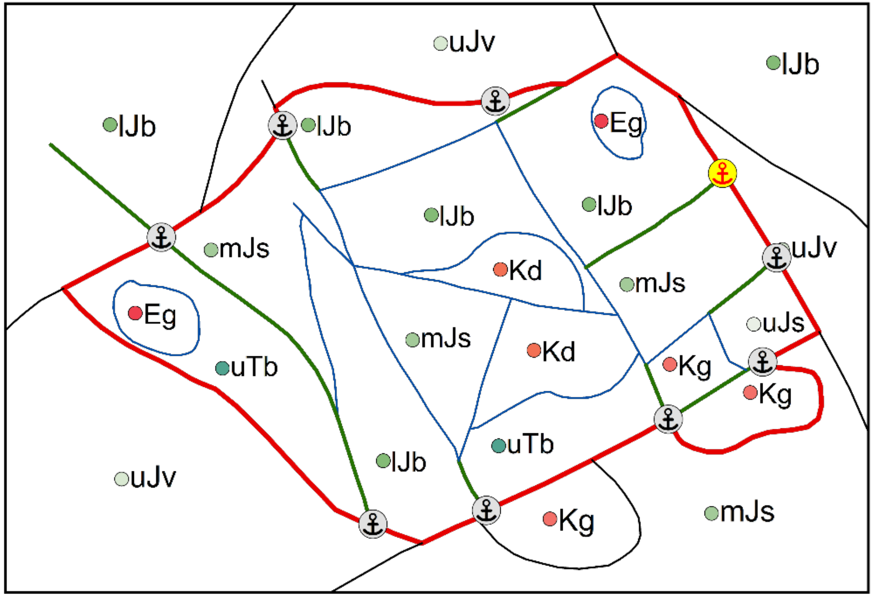


3) In the corporate GFD database, outdated feature components are retired before admitting updates

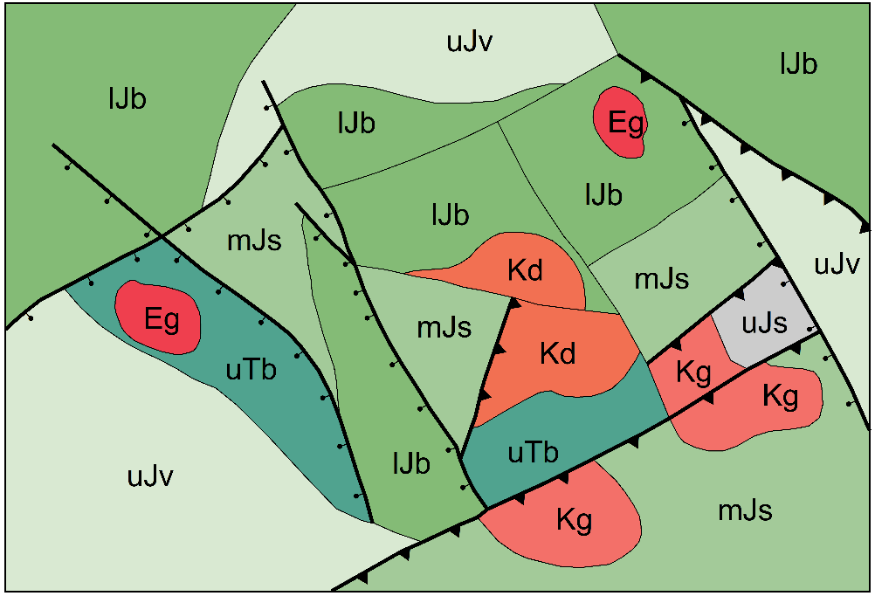


4) After updates are admitted, rode lines are snapped to anchor points, except a new rode line that has no anchor point (highlighted by a circle in orange color)

GFD update and integration (3/3)

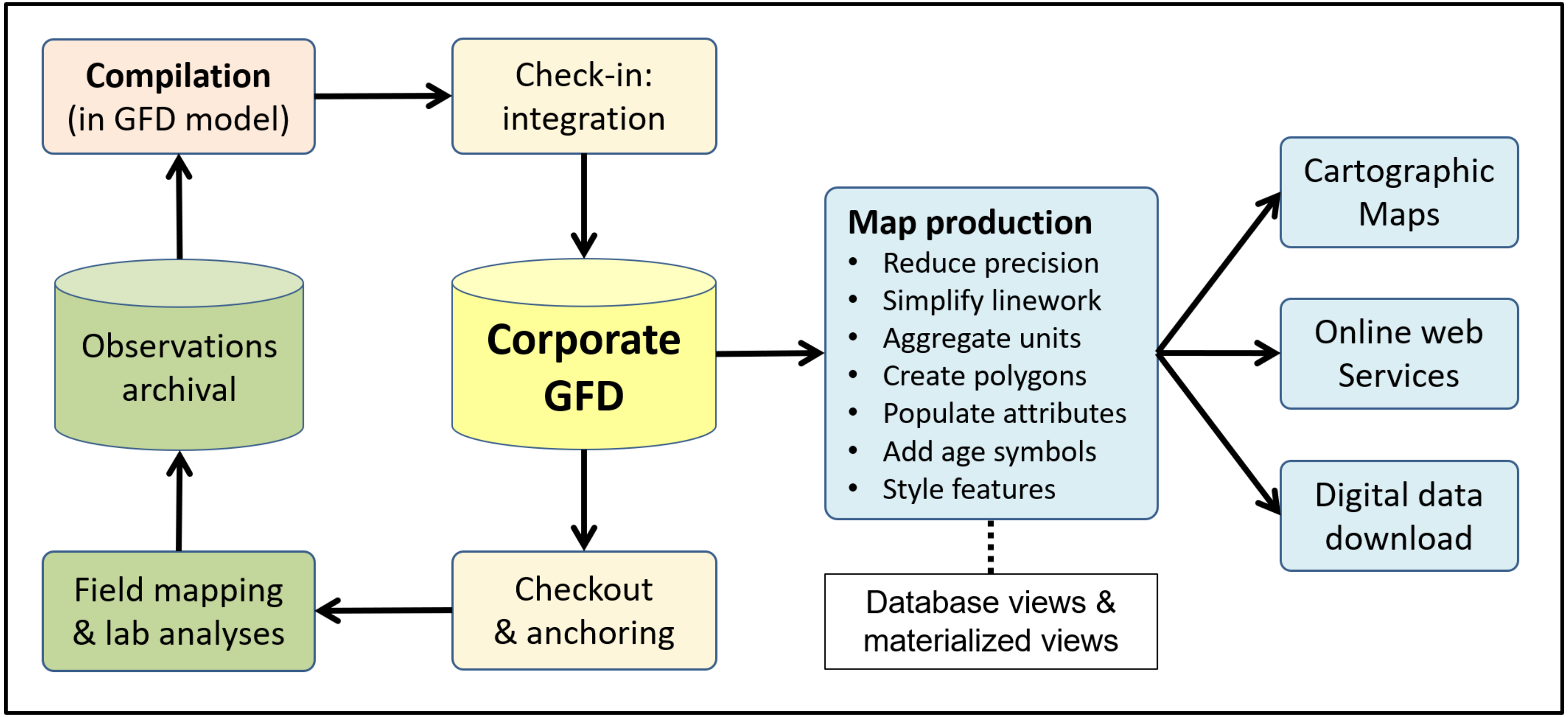


5) A new anchor point (in red and yellow highlight) is added to complete the integration

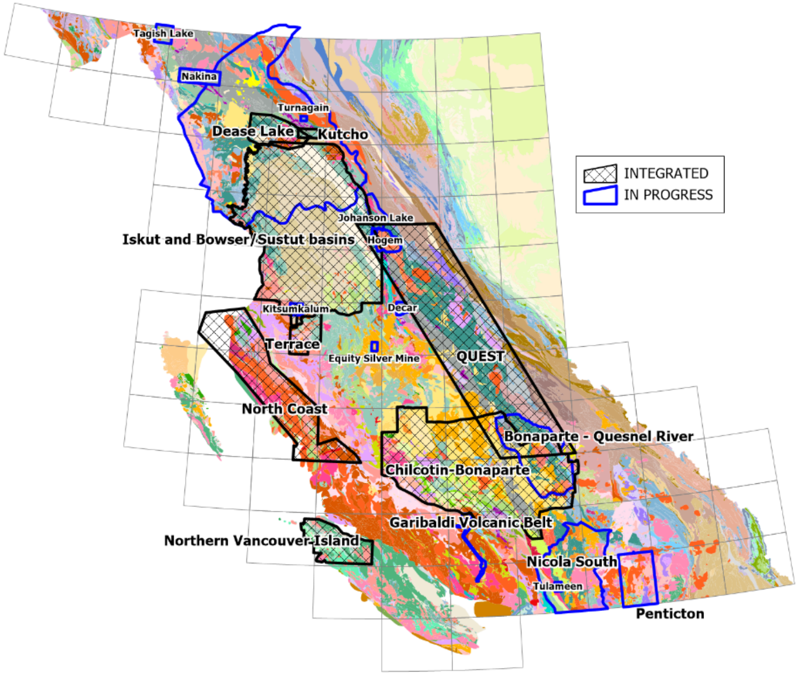


6) A finished geological map derived from the feature components in the corporate GFD database

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

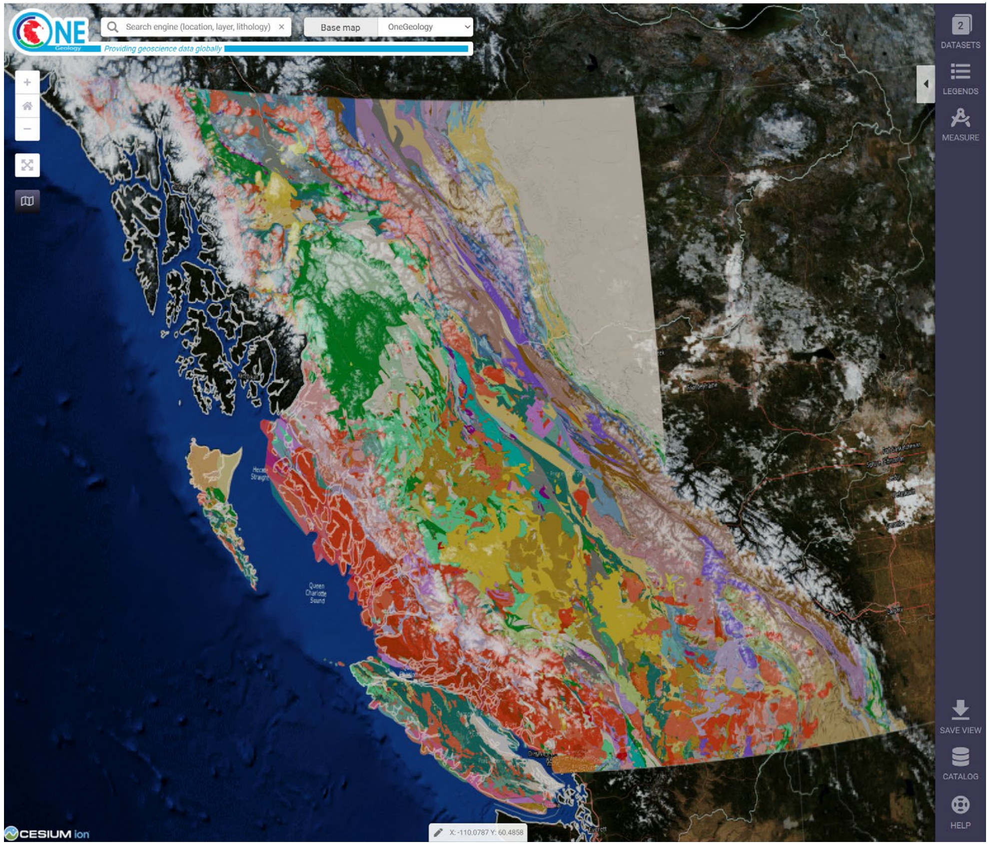


GFD compilation and integration progress in BC



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/

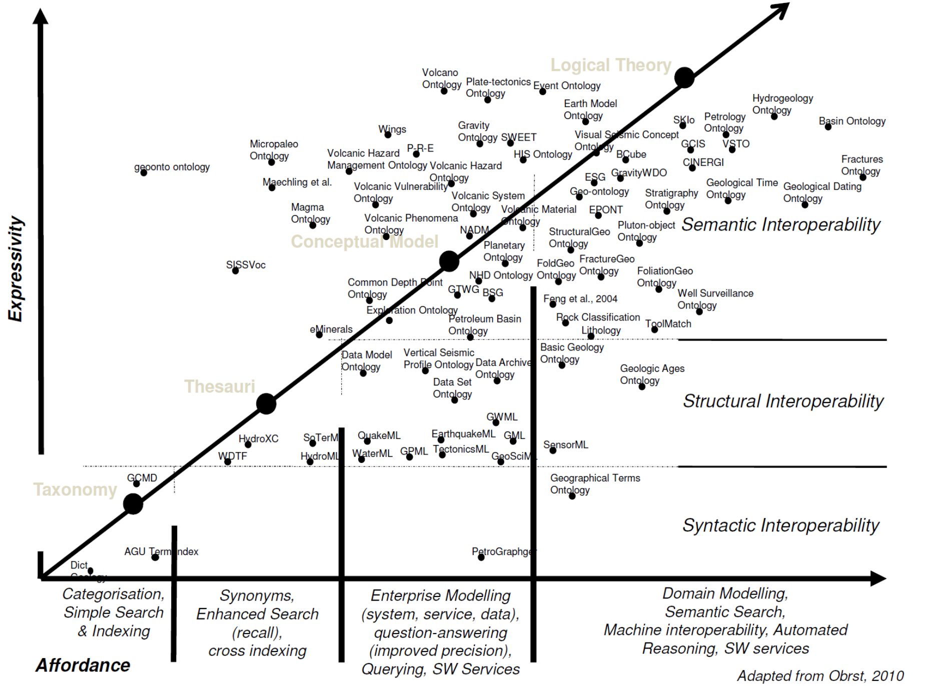
Syntactic interoperability:

- 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

Semantic interoperability, and feature-level metadata



Adapted from Obrst, 2010

a case for *deep* semantics

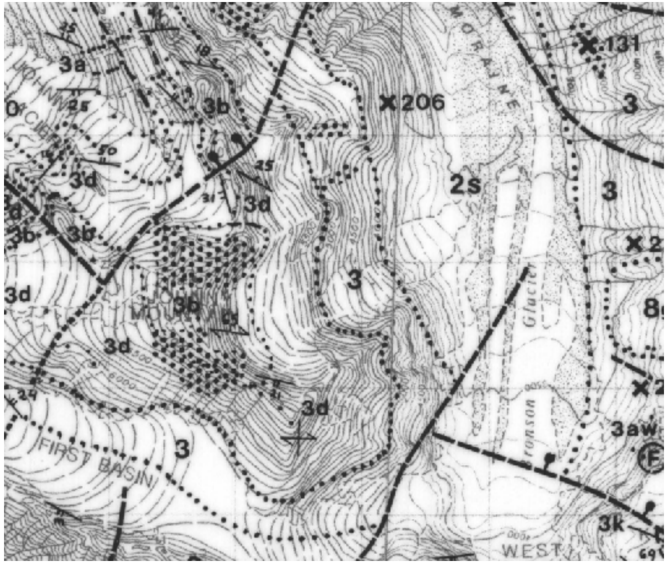
In the geosciences, it is not only important to capture and formalise *what* is known, but *how* it is known.

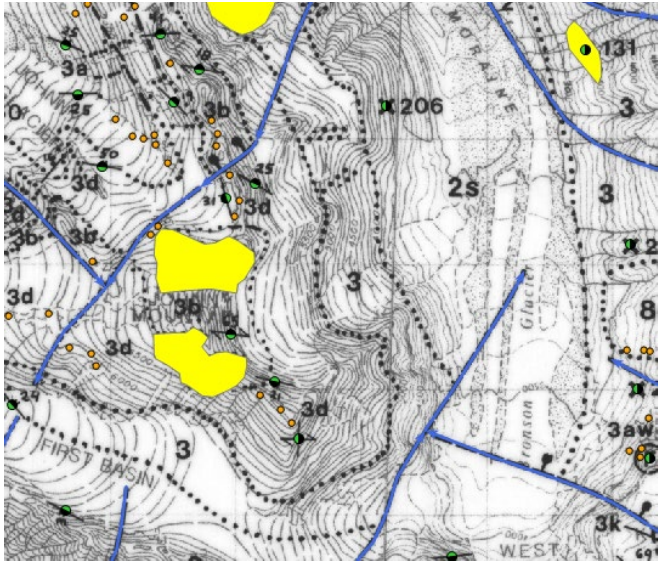
deep- as in deeply examining the conceptual structure and complexities of the domain in order to provide enough specificity in the concepts and relations that they are useful terms to differentiate complex but real situations (as they are found in research artefacts).

Brandon Whitehead (2012, 2016)

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

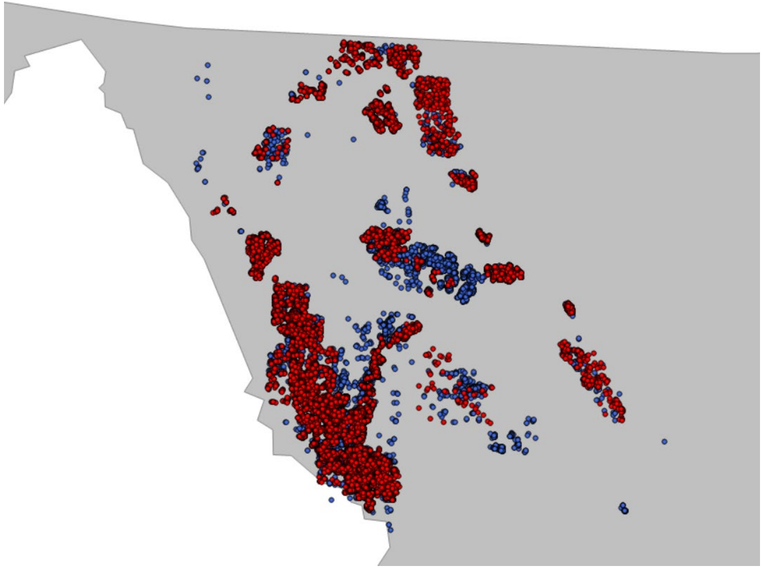




Field data digitization

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?

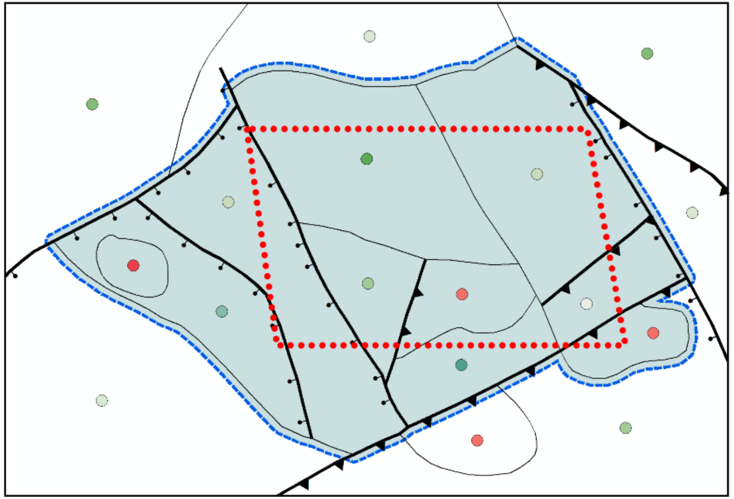
- **Performance**: indexing, partitioning, parallel processing
- **Security**: authentication/permission, transactional, triggers, back-up
- **Multi-users**: concurrent editing, locking, roll-back, versioning
- **Multi-clients**: ODBC, OLE DB, JDBC
- **SQL queries**: standards based

Spatial database: PostgreSQL/PostGIS

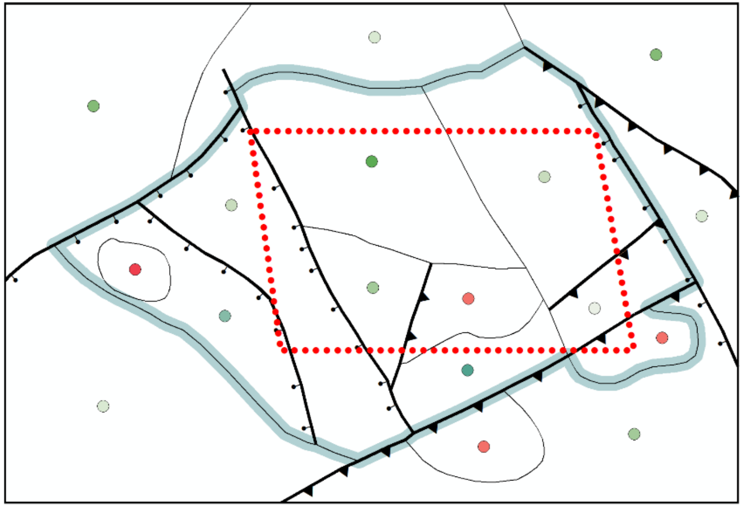
- **OGC standard simple features**:
    - geometry types, binary predicates, spatial functions and SQL
- **Foreign Data Wrapper**
    - integration of distributed databases

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;
```

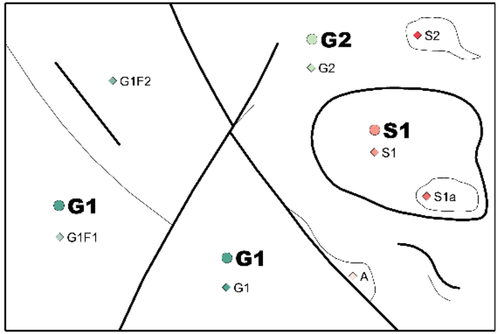


1) Create buffer [geom_buff_aoi] to tag feature components that intersect the mapping project area

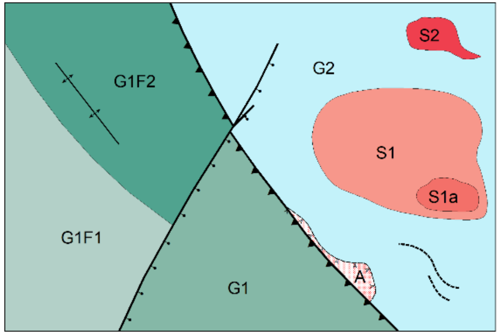


2) Create buffer [geom_buff_anchorline] to tag anchorlines, anchorpoints, rodelines and the rest for revision.

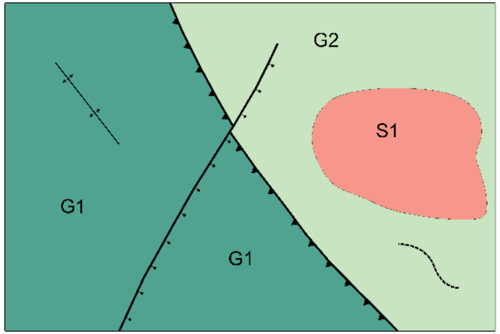
Database *views* and *materialized views* to create maps



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

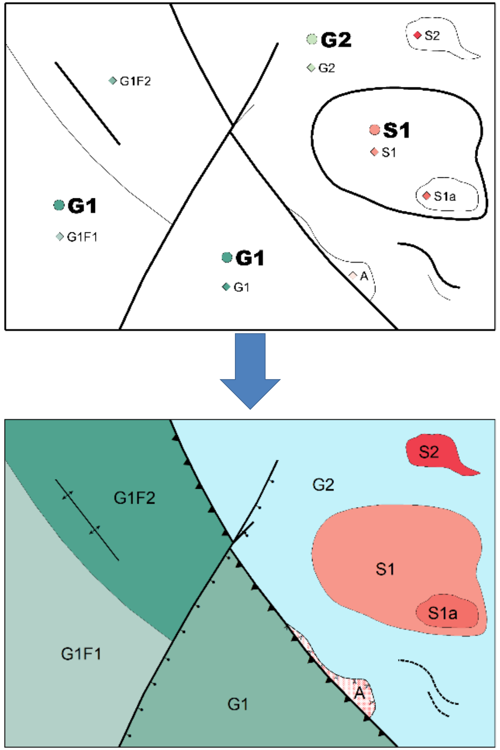
```
CREATE MATERIALIZED VIEW mv_bedrock_poly AS
 SELECT a.gid,a.strat_unit,a.strat_age,a.strat_name,a.rock_type,b.src_url,d.geom
   FROM centroid_point a, lut_data_sources b,
    (SELECT g.geom::geometry(Polygon,3005) AS geom
       FROM (SELECT ST_Dump(ST_Polygonize(v_geobnd_line_simplified_5m.geom))).geom AS geom
               FROM v_geobnd_line_simplified_5m
              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;
```

PostGIS
Spatial PostgreSQL

BRITISH COLUMBIA
est. 1895
GEOLOGICAL SURVEY

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

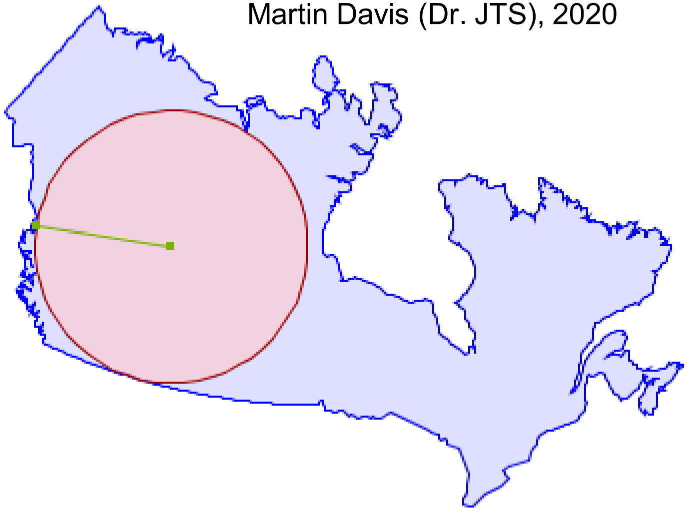
- ***Validate***: quality assurance (QA, also including standardization) and status: passed, failed, and pending (e.g., resolution of issues)

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

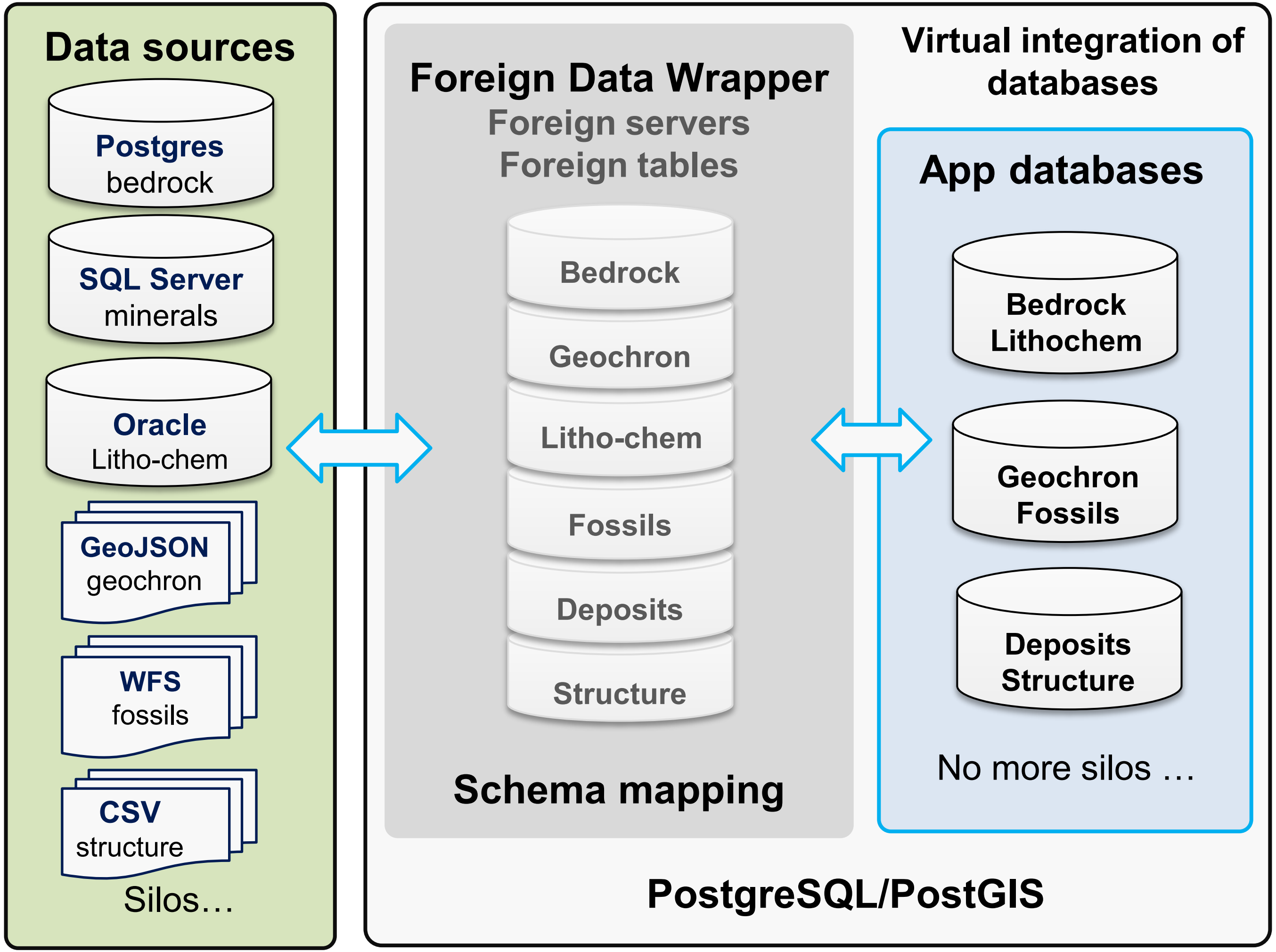
```
SELECT radius,
       ST_AsText(center) AS center,
       ST_AsText(nearest) AS nearest
  FROM ST_MaximumInscribedCircle('POLYGON ((50 50, 150 50, 150 150, 50 150, 50 50))')
```

```
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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