

# **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

**CUI**, Yao, British Columbia Geological Survey, 1810 Blanshard Street, Victoria, British Columbia, Canada, V8W 9N3; yao.cui@gov.bc.ca

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

Yao Cui, P.Geo. Sr. Geomatics Geoscientist British Columbia Geological Survey

> Digital Mapping Techniques June 9, 2021



British Columbia Geological Survey



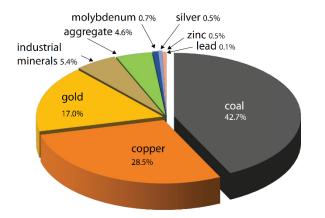
# Outline

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





# **Geoscience support mining and exploration**



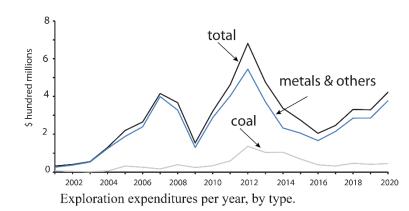
#### Mine production value in 2020: **\$9.28 billion**

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

## Exploration expenditure in 2020

#### \$422.7 million total

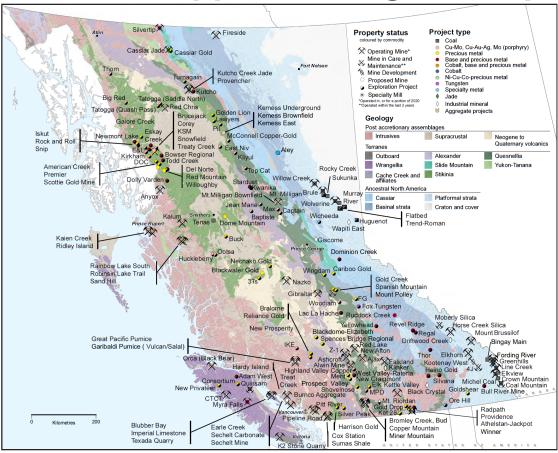
- \$378 million Metals + other
- \$44.7 million: Coal
- Increase of \$93.2 million vs. 2019



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



## Geoscience to support mining and exploration



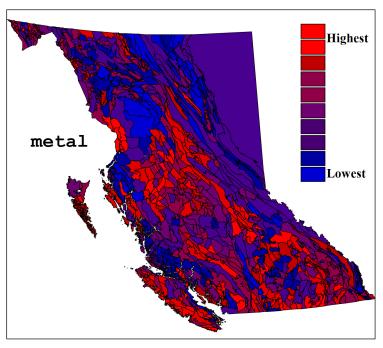


Source: Clarke et al., 2021, BCGS Information Circular 2021-01

## 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

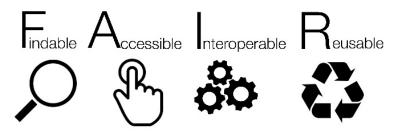






# **Guiding principles of digital transformation**

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





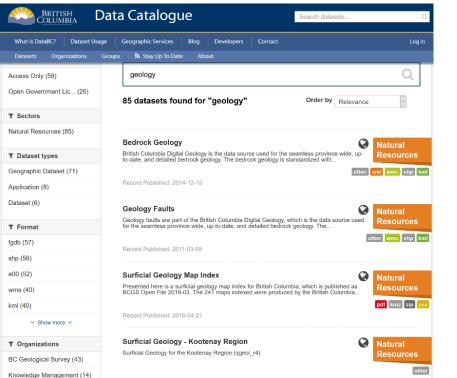
- Adopt the Open Geospatial Consortium (OGC) and ISO standards
  - GeoSciML, EarthResourceML, and IUGS/CGI vocabularies
  - OGC WMS and WFS



## Findable...



## **DataBC** Data Catalogue - ISO 19115 metadata



#### BCGS Publication Catalogue

#### CGKN data catalogue standard

Home > Farming, natural re	sources and industry > Mineral Explorati	on & Mining > British Columbia Geo	logical Survey >
Publications			
The British Columbia Geologica for, and downloaded from, our	I Survey is custodian of all public provincia	al geoscience data. Reports and maps	produced since 1895 can be s
	Search public	ation catalogue	
	The Survey currently publishes geo Circulars Papers	logical Papers, Open Files, GeoFiles, G Geoscience Maps	Seoscience Maps, and Informa
Current series	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.	The British Columbia Geological Survey's vehicle for publishing final maps.	Present the interim results of ongoing research, particularly mapping projects
	GeoFiles	Information Circulars	Digital Geoscience Da
	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.	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.	Current versions of digital datasets that regularly updated.
	by many journals, providing immediate	and Mining in BC, and the Coal Industry	
E & 1 2	The names of our publications have substance of earlier generations of	e changed through the years. Althoug publications has remained.	h recast in different formats



#### The Bulletin series was started in 1896 for Di formal publications of the British Columbia see Geological Survey, Because of increasing for digital delivery of publications, this series has been retired.

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 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.

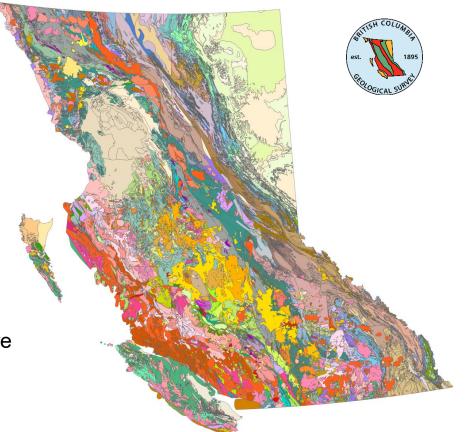
# **Geological Mapping in British Columbia**

#### 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)

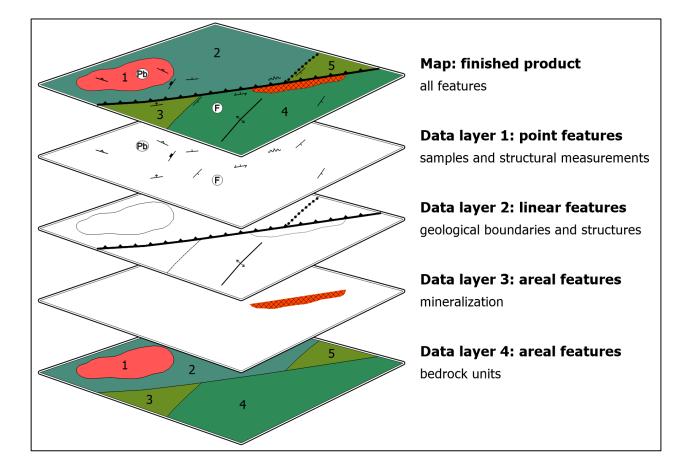




> LTr/GG LTr/GH LTr/Gp LTr/Gp

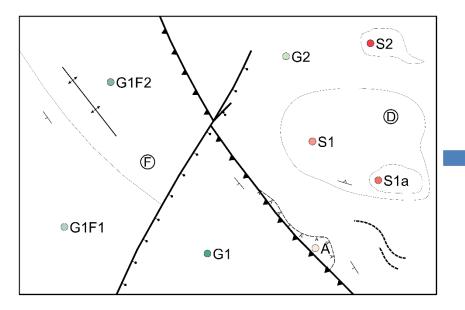
Legend     Sectors Geology	Haps 🔚 External Provi	ders View  Geogle Street	Witte	and the second	-	- Columbury - Collinson		T Ouery 📕 Redi						
Bedrogy - Bedroo B 🖉 🖓 Geology - Bedroo		Zeom Rectangle ( Zeom In	Q Zeam	Out Zeom Exte	nta 🔯 Zoern	Selection C Previous	Ca ness	Report .			_			
+ Caslogy - Bedree	Ceningy		-0	15	-	2150		ANK	111	SA	1	12		
<ul> <li>Surficial Geology</li> <li>Regional Geochemical</li> </ul>	in the second	Na /		-0	81.	V.	m.	N.	10	AN	0	0		
🕤 🔂 Rack Geochemistry (m	(1 / · · (64)	191	3	50	Bar	0	51	6	-	Nr	A			
Geology - Bedrock Geology	-17 - L	The st			37	1-3	à		1.	0	1 73			
Attribute Velue upit a21804cH	S PARA VC	AN A		1	R	Q Retred		15 3	10	2 Ca	Nor 1	6		
strat_unit LTUGBe	A mark	OUN C-		- 70	VP.	Zoom I	lectangle	1 43	( Ve	670	ZA			
atrat_age Late Trianate to Early Jo shiat_name Guidhan Creek Behall Phone	Entieten	100			98	Town:		0	1-1	des	Lac	-		
Icriane Photo Icriane Queanelia	A-TELSP	9 1 V			R	Q Zusm	Jat	0.0	131	N/Mar	-	-		
terr code QN	124		24. 1	and a	of for	Zoom		. 26	21-1	M	157	-		
• Taska		12/200	2	-	11	A Souce		68	14	11-	100	XI		
🛷 💠 🌼 🛄 Task List -	Rek.		101	1-	1 and	Char Select	More	. 50	1.1	112	In	St		
Select Within	11/2/10	AITTIN		22-		y Butter		1000	n	N	VZ	Ser.		
Select areas on the image.	The IST	The bot	de	1 con	T	Hese.		0.0	A	CV.	20	C.		
Readict results to selected layers: MTD - All Titles		AND A	03	A A		C Quary	Ente	20 FO	er hore	-	NB			
MID - AT This MID - AT This MID - Haise MID - Haisey MID - Reserves Industrial Mineral Potential (by trait) Metalik Mineral Potential (by trait) Centry, - Rethoot Gesting (have Centry, - Rethoot Gesting (have	NHM	The all	B	5	M	B Resine		20h	-4		118	50		
Metallo Moveal Potential (by tark) Geology - Bedrook Geolisos (hange		1221		C2S	YK		Inventory Re	parts >			117	5		
Georogy - Bedrock Geology (bound) Georogy - Bedrock Geology (bursp)		11 12 1		5 SUP	311	HTO &			k Geology Re	02	Pr	mal and		
Refresh			1.	1 ph	M	RGS R	iports	> Eedro	k Geology in I	CPG. (selected	unite)	and a		
· Management in paint many on		91900 F	1	V RA	200		eochem Report		tk Legend (sei tk Legend (all	octed units)	1	Na		
<ul> <li>If you continue to select awas on image, click "Refears" to update t but.</li> </ul>		NPA -				BC Apr	Reports	, /A		ck Legend (all ur	inka0	6		
<ul> <li>To finish and select at lealanes w biginigmed areas, olick "Door".</li> <li>To start ever, dick "Clear".</li> </ul>	In De	He Martin	5	4cm	AT	MRA R	sports sicel Survey F	:15	AST	17 - 1 F	Ę	20		
· resultive, one Gear.	FELE		3	The				apens Per	125	and	13	21		
Dane Gese	7000		5	A	An	TE Help		1114	57	-0	Y	50		
	3432	1 hours	73	A DA		About 1			955	205	0	~		
	- 1 - 1 - 1	1.00					0/1	1/>	he	2	1R	and P		
	1822	ALT 2	8 2.	30	< N		AC		30	NO A	ar	9 /		
	the second	15 15	~	-	Mer	In Janto		Jan B	THE	103	al Col	1		
	2 6 PI													
	1	GAL VAR	31		2 7	(SAD)	P	Da.	Shor	TA	- PI	Lanse		
		C VI	3		17	Stor	P	0 ~	Pit -	Stores .	n	Lak		
			2		2	1 the	P	0 ~	Developmentar	and	2 Star	Lake		
K		XC	から	×	K	The	C		conservation Diff	And a	2 Sta	Laki		
C jenerativnik(t))			から	20557-2564	K	1 the	C		Derection and the	A A A A A A A A A A A A A A A A A A A	Powered by	Laki		
د پارلیسی پر این کرد. پارلیسی پر این کرد کرد.	Laboration (1980)		から	Re1557.3564		1 the	L		Consideration of the	A C	Powered by	Lak		
	Leveration (1990)		ろう	002557,3564		12be			Designment Har	A A A A A A A A A A A A A A A A A A A	Fowered by	Lak Lak Rosen Reserve		
:0 Geology Legend			から	R01007-2564	K	1 the			and a second s	A	Powered by			
Geology Legend			から			The second			Providence of the	AA	Powered by			
:0 Geology Legend				1 appeler og for en gift	postbedick se	PTAP	2		personantes	a dank a dank	Powered by	Lak Room Room Room	(798) -	6 2
Geology Legend							And a second		Contents	a desta d	Powered by		(786) -	- 6 2
Geology Legend			Scenar por B		postedesk neg		Summ	arry of Bedrock	Geology	and	Powered by		(1986) -	- 6 2
Geology Legend Geology Legend Geology Legend Geology Legend Have to Main Table			Scenar goed					Described in KM.		A A A A A A A A A A A A A A A A A A A	Powered by		(198) -	- 6 t
Cectory Legend Geotory Legend Islands Back to Men Table baselite volcanic reeks			Scenar De B	<b>x s</b> ajulimajulistensis			0	Described in KM. office learned indexted or office learned into the learned to a UPID, for even splere of column learning in some	nte nte nte	and the second second	Powered by	Lak Lak regioner	(1986) -	@ \$
Geology Legend     Geotogy Legend     Geotogy Legend     Geotogy Legend     Geotogy Legend     bandta to ffan Tabe      bandta volensie recks  undivided volensie recka			91at Unit	x (a) dereg size op be	Na Na	pPlace MatAge	Cia Cia Reck Class	Described in KM, officer learned isotrand on officer learned isotranticity is on UDID, Sie wore leffen of officer learner leafen of officer learner learner Rock Type	nte EC: orte ruch Age (maimur		Powered by	Lak Lak transform transform	Gorgie	- G (
e Geology Legend Geolog, Legend Backta, Iener, List Junia Backta Man, Table bundla: volcanie rocks undivided volcanie rocks		UPD Stars	2 8101 Unit	Kalpdarosysteerapin Kalpdarosysteerapin Kalese Guo	Na Na	pPlace MatAge	Cia Cia Reck Class	Described in KM, officer learned isotrand on officer learned isotranticity is on UDID, Sie wore leffen of officer learner leafen of officer learner learner Rock Type	nte EC: orte ruch Age (maimur	Soure	Overag	Lak Lak Industry Varyouth	Gorgis Earth	n @ d Badaad
Geology Legend     Geotogy Legend     Geotogy Legend     Geotogy Legend     Geotogy Legend     bandta to ffan Tabe      bandta volensie recks  undivided volensie recka			0101044 2 004 2 1055e 2 106e	Kalphinnspinning) Kalphinnspinning) Kalphing Kal	Period Period Princero Transic Ic Janual Diseapero	pPlace	Chi Chi Reck Class values robs Hituales robs values robs	Described in KM. Description isotration of provide learned later when its end of 2000 Services system 2 relatives Availage on some 2 relatives Availage on some 2 relatives Availage on some parts charitie structure relation insolutions visionarie modelle	App province Econo Econo Lato Tanaic Econo	Eonro Esty Arank Eooro	Overag Queend is Overag	Olanagat Olanagat	Congle Earth G G G G G G G	n 🕞 🖞 Dedrych Colour
e Geology Legend Geolog, Legend Backta, Iener, List Junia Backta Man, Table bundla: volcanie rocks undivided volcanie rocks		0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000000	0101044 2 004 2 1055e 2 106e	Kalphinnspinning) Kalphinnspinning) Kalphing Kal	Period Period Princero Transic Ic Janual Diseapero	PPlace Stat Age Economic Later Transic to Early Jonanic	Chi Chi Rock Class Vitaric Cost Marane rock Marane rock	Described in KM. Description isotration of provide learned later when its end of 2000 Services system 2 relatives Availage on some 2 relatives Availage on some 2 relatives Availage on some parts charitie structure relation insolutions visionarie modelle	App province Econo Econo Lato Tanaic Econo	Easty Arank	Overap Querrella	Okaragan.	Corgle Earth 	n (a) d Dathack
Geology Legend Geitra Laveri II alle at der La fallen Laveri handlier volknais recks undrividet volknaise recks undrividet volknaise recks undrividet volknaise recks			Contractions Contr	Boad Name Restored States Assessed States Boad Prease Boad Prease	Action Resource Prinse to Januarie Prinse to Januarie Prinse to Januarie	Stat App Science Late Transit to Early Longent Econom Econom Econom Econom	Rock Class characteristic scha	Description of the SML provide Basered SML of the To- ported Basered SML of the To- test (2000) SML and the SML of the Particular of Academy in Sector Rock Topo and the SML of the SML of the party during in SML of the Academy of the SML of the Interference of the Interference of the Interference of the Interference of the Interference of the Interference of the Inter	Ago presinue Econo	Fourn Eafy Arank Fourn Fourn Fafy Arauk Fourn	Overag Queend is Overag	Olanagan Olanagan Olanagan Olanagan Olanagan	Congle Earth G G G G G G G G G G G G G G G G G G G	• G 2
e Goolog Legend Contra Lance du min u <u>Rock an Amit Zook</u> handhir vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck			3101Un2         600x           210250         210250           21050x         200x	California Constantia Sector Sector Sector Sector Sector The Sector Sector Sector The Sector Sector Sector The Sector Sector Parallel Constantia Sector The Sector Sector Sector The Sector Sector Sector Sector The Sector Sector Sector Sector The Sector Sector Sector Sector Sector The Sector Sector Sector Sector Sector The Sector	Period Pe	Bost Age Rosse Rosse Rosse Las Transe Is Daty Losses Rosse Las Transe Is Daty Losses	Reck Costs veloarie reola veloarie reola kiloarie reola kiloarie reola kiloarie reola kiloarie reola	Described in KM, proce heard backbody in Jore 2 to start 200 (see see hybrid collars headed) and the part dealer they in Jore 2 part dealer they in Jore 2 p	App presidence Econes Lan Transic Econes Eco	Eoore Eaty Aroust Eoore Eoore Faty Aroust Eoore Eoore Eoore Eoore Eoore	Overap Queenella Overap Querap Querap Querap Queenella	Okanagan Okanagan Okanagan Okanagan Okanagan Okanagan	Cingle Earth 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	n G (
Geology Legend Geitra Laveri II alle at der La fallen Laveri handlier volknais recks undrividet volknaise recks undrividet volknaise recks undrividet volknaise recks		Cardina Constant Cons	<ul> <li>Stottune</li> <li>Stottune</li> <li>Chuise</li> <li>Chuise</li> <li>Stote</li> <li>Chuise</li> <li>Chuise</li> <li>Chuise</li> <li>Chuise</li> </ul>	Bit Anne Frankrikernsternste Sentense Sea Gaber Cear Sentense Sea Sentense Sea Sentense Sea Sentense Sea Sentense Sea Sentense Sea	Period Period Periode Periode and Periode and Periode Peri	PPlace Barrow Law Trans to Entry Jonato Frome Law Trans to Entry Jonato Konne Law Trans to Entry Jonato Konne Law Trans to Entry Jonato	Rock Class editaria colos editaria colos editaria colos editaria colos editaria colos editaria colos	Described in FXM, proves in spectral in performance in the control in the control in the control interaction of the control in the control in the control in the control in the particular distance model protection in the control in the protection of the control in the control in the protection of the control in the control in the protection of the control in the control in the control in the protection of the control in the control in the control in the protection of the control in the control in the control in the control in the control in the control in the control in the control in the control in the control in the control in the control in the control in the control in the control in	Ago presidente focores Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes Econes	Eosre Esty Arank Eosre Eosre Eosre Eosre Eosre Eosre Eety Arank Aber	Overap Overap Overap Overap Overap Overap Overap Overap	Olanagan Olanagan Olanagan Olanagan Olanagan	Circyle Earth 9 9 9 9 9 9 9 9 9 9 9 9 9 9	G 2
e Goolog Legend Contra Lance du min u <u>Rock an Amit Zook</u> handhir vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck undridad vulkanis eeck			<ul> <li>Stottune</li> <li>Stottune</li> <li>Chuise</li> <li>Chuise</li> <li>Stote</li> <li>Chuise</li> <li>Chuise</li> <li>Chuise</li> <li>Chuise</li> </ul>	Entrahama Second Second	Period Pe	Bost Age Rosse Rosse Rosse Las Transe Is Daty Losses Rosse Las Transe Is Daty Losses	Reck Costs veloarie reola veloarie reola kiloarie reola kiloarie reola kiloarie reola kiloarie reola	Described In FOR construction of periodic National Construction of the Construction of the Construction of	App presidence Econes Lan Transic Econes Eco	Eoore Eaty Aroust Eoore Eoore Faty Aroust Eoore Eoore Eoore Eoore Eoore	Overap Queenella Overap Querap Querap Querap Queenella	Olaragan Olaragan Olaragan Olaragan Olaragan Olaragan	Cingle Earth 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	•• @ 2
Geolog: Legend Geiten Leenel in einen Acc. In Hen. Jaho Mandher volknist recks undvickel volknister recks undvickel volknister recks undvickel volknister recks undvickel volknister recks ankösiter volknister recks machielter prophyticie intensive recks		Cardina Constant Cons	<ul> <li>STOLUNE</li> <li>STOLUNE</li> <li>STOLE</li> </ul>	Back Rome Received Frances Frances Received Frances Recei	Period Péragore Telesgore	Place Builde Bui	Receive costs interaction inte	Described in FVM. centres inspect inspection inspections and inspection of the inspections inspection of the inspections inspection of the inspections of the inspection inspections of the inspection inspections inspections inspections in the inspection inspections in the inspection inspection in the inspection in the inspection inspection in the inspection in the inspection inspection in the inspection in t	Ago prosinuo Econo entre Econo	Ecore Esty Arasic Ecore Toure Faty Arasic Ecore Esty Arasic Alter Mode frame	Overap Cavanella Overap Coetap Coetap Cavanella Overap Cavanella Cavanella	Changan Changan Changan Changan Changan Changan Changan Changan Changan	Cingle Earth 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	er e t
e Geologi Legend Genter, Leeret ein einer Back an Reitz Zeite handler volknasie recks underkielt soklamistere geoks underkielt volknasie recks underkielt volknasie recks underkielt volknasie recks underkielt volknasie recks underkielt volknasie recks Underkielt volknasie recks		Cardina Constant Cons	StotUne CRA CRA 2 DAs 2 DAs 2 DAs 3 DAs 3 DAs 4	Back Rome Received Frances Frances Received Frances Recei	Period Péragore Telesgore	Place book tank tank tank tank tank tank tank tan	Rest Coss Citization Bittache rocks Schenic most Schenic	Described In FOR construction of periodic National Construction of the Construction of the Construction of	App province App province App province Excess Law Thank Excess Excess Exam Exam Exam Exam Exam Exam Exam Exam	Ecore Esty Aranic Ecore Ecore Esty Aranic Esty Aranic Abar Node Trave Node James	Overap Questella Overag Overag Questella Overag Questella Overag Questella	Changes Changes Changes Changes Changes Changes Changes Changes Changes Changes Changes	Cingle Earth 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	G 2
Cooking Legend     Control     Contro     Control     Control     Control     Contro			Constants	Kabylanostranosti Brankano Markano M	Partial Pressore Pres	Dest Age Linese Lan Trans to Early course: Transmotories And Transmotories Lane Transmoto	Control of the second of	Chargened In FAM. Chargened Internal Internal Internal Chargened Internal Internal Internal Chargened Internal Interna	App Products App Products Excess Ex	Ecore Enty Arunik Ecore Ecore Ecore Enty Arunik Alter Midde Frank Midde Frank Ecore	Overag Coverag Overag Overag Coverag Coverag Coverag Coverag Coverag Coverag Coverag Coverag Coverag Coverag Coverag Coverag Coverag	Diangan Dianga	Congle Certh O O O O O O O O O O O O O O O O O O O	G 2
Geologi Legend     Grante, samed an arise     Back an Arat. Take     Markini vulkanisi: meks     undridad vulkanis: meks     undridad vulkanis: meks     undridad vulkani: meks     undri     undridad vulkani: meks     undridad vulkan			<ul> <li>Statust</li> </ul>	Carlo Annes Van Starres Van Starres V Note Rever Carlos Constantino (Carlos Carlos Car	Packel Processor	PPIace Prove Late Teach	Rect Costs Colored revolu- tioned re	Concretel in CM. Exercised in Concrete to CODE in Concrete in Concrete Concrete in CODE in Concrete In Code in Code in Concrete In Code Information Code Information (Code Information Code Information (Co	App produces forces forces forces forces forces forces forces forces tain Theoric forces tain Theoric forces tain Theoric forces tain Theoric forces tain Theoric forces tain Theoric forces fo	Eoore Early Ansaic Eoore Eoore Eoore Early Ansaic Eoore Early Ansaic Alter Mode Transe Mode Transe Early Ansaic Early Ansaic Early Ansaic Early Ansaic	Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay	Okangan Okangan Okangan Okangan Okangan Okangan Okangan Chosin-dor apate Okangan Okangan Okangan Okangan Okangan Okangan Okangan Okangan Okangan Okangan Okangan Okangan	Congle Earth 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	Endersk
Cooking: Legend     Control			Statume C Rose C	Kalp Long Francisco Bard Nation Franken Case Case - Case Jacket Schere Case - Case Case - Case Jacket Schere Case - Case Case - Case Jacket Schere Case - Case Jacket Schere Case - Cas	Period Period Period Periogra Tanak to Jaranic Periogra Tanak to Jaranic Colomas Jaranic Tanak Tanak Tanak Tanak Periogra Periogra	PPlace Provide	Rect Case Participation of the semant roots semant root	Constraints in a filler state of the second state of the seco	Ap protecture Ap protecture Economic Econom	Eosre Eny Ansaic Eosre Fary Ansaic Eosre Fary Ansaic Eary Ansaic Adar Node Jonese Eary Ansaic Eary Ansaic Eary Ansaic Eary Eosre Eosre Eosre	Overag Ov	Okangan	Cingle Darth 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	
e Goolog Legend Generation Learner of a strike Rack at RAT Zales Insulisien volkanie recks undrickel volkanie recks Underscher volkanie recks Underscher volkanie recks Underscher volkanie volken etwa Nation Formatie under volken etwa Nation Formatie under volken etwa Nation Formatie under scheller winner sech Math Termite under scheller denstrameters			gint Livit           gint Livit         Gibbs	A defailed annual former of the method	Partical Photopro Transic to Jaraneli Photopro Transic to Jaraneli Photopro Transic to Jaraneli Transic To Jaraneli Transic To Jaraneli Transic Transic Transic Transic Transic Transic Transic Transic Transic Transic Transic Transic Transic	bord Age bord Linear	Rect Cost	Descend LPAL methods and the provided of the pro- terior of the provided of the pro- terior of the provided of the pro- terior of the pro- pro- terior of the pro- terior of the pro- terior of the pro- terior of the pro- terior of the pro- pro- terior of the pro- terior of the pr	App produces forces forces forces forces forces forces forces forces tain Theoric forces tain Theoric forces tain Theoric forces tain Theoric forces tain Theoric forces tain Theoric forces fo	Eoree Early Arauk Eoree Forre Farly Arauk Early Arauk Akar Node Trank Early Arauk Lafe Trank Eoree Eoree Eoree	Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay Overay	Okangan		Enderski
Cooking Legend     Control     Contro     Control     Control     Control     Contro			gint Livit           gint Livit         Gibbs	A defailed annual former of the method	Parked Person Pe	PPlace Provide	Rect Case Participation of the semant roots semant root	December 2015 of the second and a second a second and a second and a second a	App Product Eco Construction Co	Eosre Eny Ansaic Eosre Fary Ansaic Eosre Fary Ansaic Eary Ansaic Adar Node Insaic Eary Ansaic Eary Ansaic Eary Ansaic Eary Eosre Eosre Eosre	Overag Ov	Changer Danger Danger Danger Danger Danger Danger Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer		er Cardonal
e Goolog Legend Generation Learner of a strike Rack at RAT Zales Insulisien volkanie recks undrickel volkanie recks Underscher volkanie recks Underscher volkanie recks Underscher volkanie volken etwa Nation Formatie under volken etwa Nation Formatie under volken etwa Nation Formatie under scheller winner sech Math Termite under scheller denstrameters			90010000           20001           20000           2000	Exclusion Exclusion	Passol Respon Passers Jonaic Passyne Passyne Passyne Danaic Jonaic Passyne Namic Jonaic Passyne	PPIace Part Age Energy Late Street Late Street Lates The Street Late Street Lates Part Late Street Lates Part	Control of the second of	Constraint of an office of the second of a second of the s	Age produces Economic Age produces Economic Age produces Economic Age and Age	Eoree Enty Armite Corpee Eoree Eoree Enty Armite Alter Midde Transe Alter Midde Transe Enty Armite Enty Armite Enty Armite Eaty Armite Eatropee Eoree	Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray Oueray	Okanagan Okanagan	Original         Original	
e Goolog Legend Generation Learner of a strike Rack at RAT Zales Insulisien volkanie recks undrickel volkanie recks Underscher volkanie recks Underscher volkanie recks Underscher volkanie volken etwa Nation Formatie under volken etwa Nation Formatie under volken etwa Nation Formatie under scheller winner sech Math Termite under scheller denstrameters			gint Livit           gint Livit         Gibbs	East Annue East Annue Contractor Strate Contractor Strate Contractor Strate Contractor Strate Contractor Con	Parted Record Record Teases to Jonaic Passages Passages Passages Danaics To Jonaics Da	Becker Bergener	Rectause of the second second	Constraint of an office of the second of a second of the s	App Product Eco Construction Co	Eonre Enty Annuis Eonre Eonre Eavy Annuis Eonre Enty Annuis Attar Node Trane Eonre Eonre Eonre Eonre Eonre Aper Tosole Liper Tosole	Oueray Oueray	Changer Danger Danger Danger Danger Danger Danger Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer Changer		
e Cooky Lyand Generation Look and an American Back to the Mark State and American Cooky Cooky Cooky Cooky and American Cooky Cooky Cooky Cooky and American Cooky Cooky Cooky Cooky and American Cooky Cooky Cooky Cooky American Cooky Co	EG a a a a a a a a a a a a a		1011 (Mill           2         2004	Call Jones Team (1999)     Call Jones Team	Parted Penage Penages Deserve Penages Deserve Penages Deserve Penages	In the second se	Control of the second of	Descendant status en anarchistophilica e a service en anarchistophilica e a service en anarchistophilica e a service e a servi	Age produced Encode	Conve Conve Conve Conve Conve Conve Conve Cely Annois Cely Annois Cely Annois Cely Annois Cely Annois Conve	Operany Queense (Series) Queense (Series	Changes     C		Enducida
Goolog: Legend Control Legend Control Legend and the Reck at Refs Zoole andreide volkniste recks underside volkniste recks Macht Zool Karlster undersite volkniste reck Macht Zool Karlster undersite volknister, recks Macht Zool Karlster undersite volknister recks Macht Zool Karlster undersiter volknister recks Macht Zool Karlster volkn	EG a a a a a a a a a a a a a		90010000           9000000           9000000           9000000           9000000           9000000           9000000           90000000           90000000           9000000000           9000000000           90000000000           900000000000           900000000000000           9000000000000000000000000000000000000	Add Johnson Harmonika Mark Association Market School Market School	Prind Pengan Teast is Journel Neasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeasyne Yeast Yeasyne Yeast	Bender Bereiten Der Stehnen Stehnen Anstehn Stehnen	Control     C	Descendant 2016. The stand of cardinal sector of the stand of cardinal sector of the stand of t	Age produces Research Re	Easy Armaic Easy Armaic Eoree Eoree Fary Armaic Eorre Easy Armaic After Mode France Easy Armaic Eoree Easy Armaic Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree Eoree	Oueray Oueray	Search           Charach	Oright         Oright           Seth         9           9         9      10         9	
Cooking Legand     Contact Legand     Contact Legand     Contact Legand     Contact Legand     Contact Legand     Contact	EG a a a a a a a a a a a a a		93/01 (bold)           2         93/04 (bold)           2         93/04           3         93/04           3	Callo de construir de la	Pachol Record Telescone Te	Bondard Bon	Control of	Consequences and a solution of the solution of	Age productor Age productor Exercise Exerci	Europe Europe Eourope Eourope Europe Rand Anano Rand Anano Mada Junane Rand Anano Mada Junane Europe Rand Anano Lako Tunane Europe Nanore Nanore Nanore Nanore Nanore Nanore Nanore Nanore Nanore Nanore Sano	Operation Conserva	Search	Complete         Complete	
Control Legend     Control	EG a a a a a a a a a a a a a		Phot Units           12         1000           12         1000           12         1000           12         1000           13         1000           14         1000           15         1000           16         1000	Carl Annual Control Contente Control Control Control Control Control Control Control Cont	Parket Program	estador est	Control 100     Control 1	Description of the sector	Termina and a second se	Eoree Estry Arrent Estry Arrent Estry Arrent Estry Arrent Estry Arrent Atter Midde Transe Estry Arrent Estry Arrent Estry Arrent Estre Estre Estre Estre Estre Estre Estre Estry Arrent Arrent	Openant Gamma Channa Ch	Image: Section 2000           Image:	Diright           Can           Can           O <td< td=""><td></td></td<>	
Control Legand     Control	EG		Phot Units           12         1000           12         1000           12         1000           12         1000           13         1000           14         1000           15         1000           16         1000	Carl Annual Control Contente Control Control Control Control Control Control Control Cont	Parket Program	estador est		Alexandromerican a statistican a statis	A series of the	Euror Euror Euror Euror Euror Euror Alter Media Laruna Media Laruna Media Laruna Media Laruna Media Laruna Media Laruna Media Laruna Euror	Ouevas Ou	Image: Section of the sectio		
Coolog: Legent Control Legent C	ES a a a a a a a a a a a a a		Bear Loss           2         2000		Particle Pharperson Ph	escher seic			A provide a second seco	Evere Every Arouse Every Arouse Every Arouse Every Arouse Every Arouse Adde Every Adde Every Adde Every Every Arouse Every Eve	Newson Carents	Paramatan           Paramatan <td< td=""><td></td><td></td></td<>		
Control Legand     Control	ES a a a a a a a a a a a a a		Bear Loss           2         2000		Particle Pharperson Ph	estador est		Description of the sector	A series of the	Euror Euror Euror Euror Euror Euror Alter Media Laruas Media Laruas Media Laruas Media Laruas Media Laruas Media Laruas Media Laruas Euror	Ouevas Ou	Image: Section of the sectio		Part Colores

# **Challenges in compilation and integration**



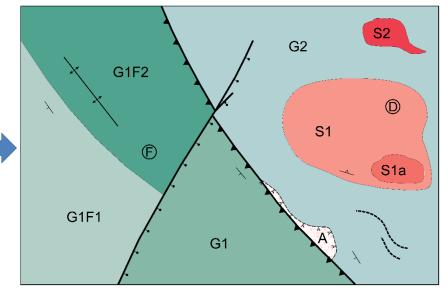


## **Geospatial Frame Data (GFD) model**



GFD database (data source, not a map)

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

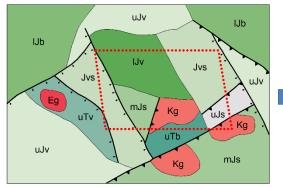


Derived geological map from the GFD data source

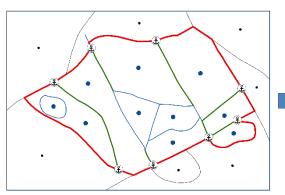
- 1. Generating bedrock polygons from geological boundaries
- 2. Populating bedrock attributes to the polygons from the centroids by overlay



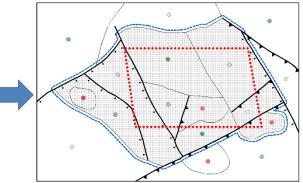
## GFD data checkout and anchoring for integration



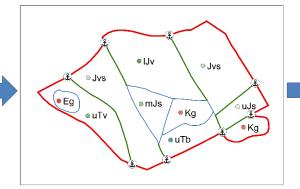
1) Area to update within limit of mapping (dotted line in red)



4) Anchoring applied to guard boundaries and intersections

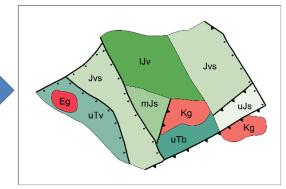


2) Data selection: extended to include entire features



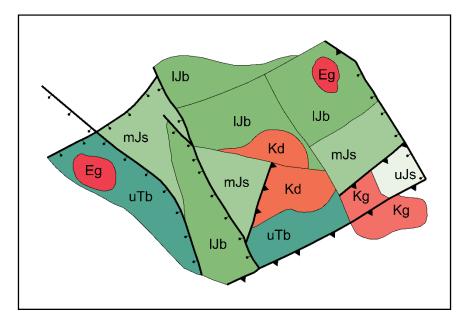
5) Data checked out: GFD feature components to update

- Revision: content in the mapping project area
- 3) Anchoring concept: anchor line (red), anchor point, and rode line (green)

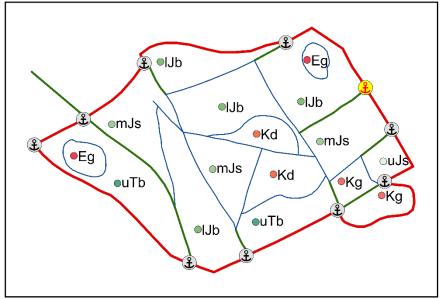


6) Data checked out: data package styled as a map with polygons

## GFD update and integration (1/3)



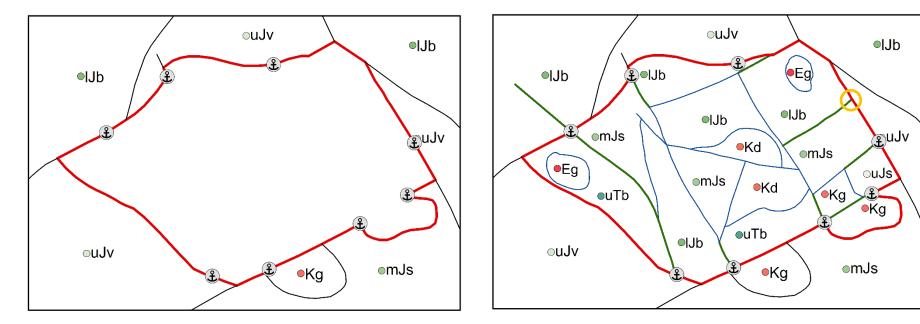
1) A new mapping project is complete and submitted for integration



 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)

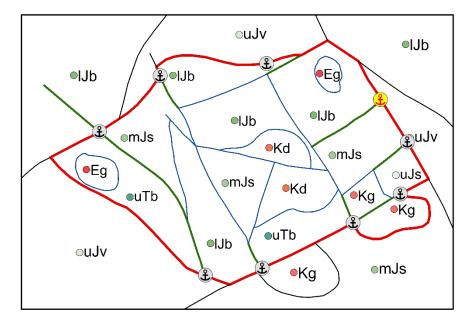


3) In the corporate GFD database, outdated feature components are retired before admitting updates

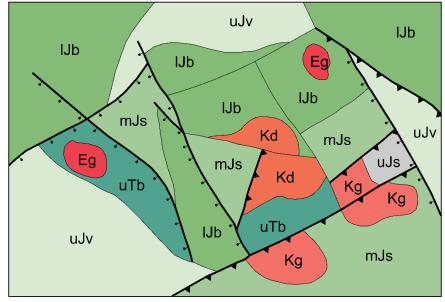


4) After updates are admitted, rode lines are snapped to anchor points, except a new rode line that has no anchor point (highlighted by a circle in orange color)

## GFD update and integration (3/3)



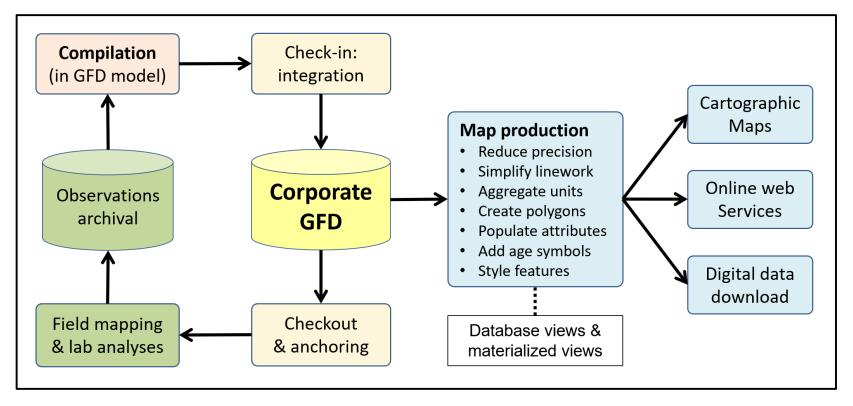
5) A new anchor point (in red and yellow highlight) is added to complete the integration



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

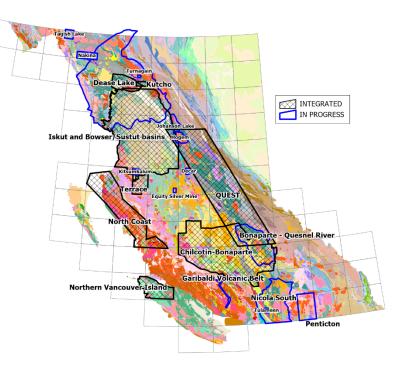


### Flow chart of GFD: from data checkout, update to check-in





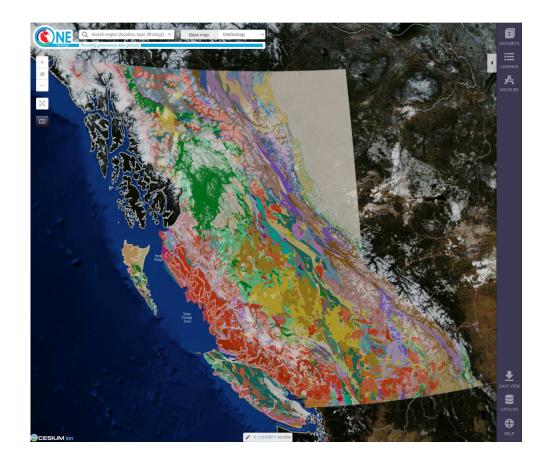
#### **GFD compilation and integration progress in BC**





# 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:

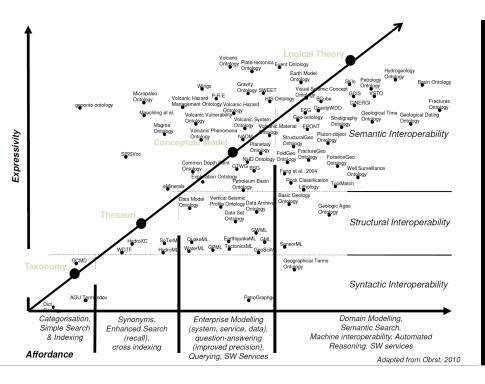
- Data models and formats: e.g., GeoSciML, GeoPackage; WKT/SDO geometry
- System (interface/protocols): e.g., WMS, WFS

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



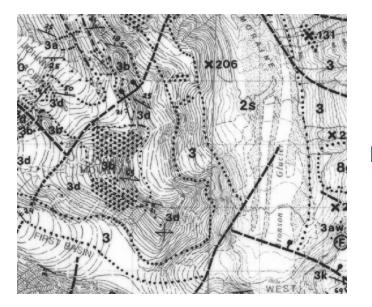
#### a case for *deep* semantics

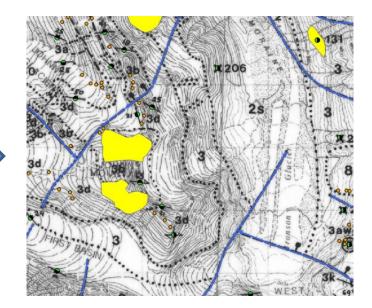
In the geosciences, it is not only important to capture and formalise *what* is known, but *how* it is known.

*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).

## 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



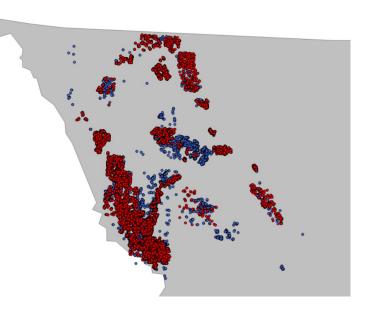




## **Field data digitization**

## 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

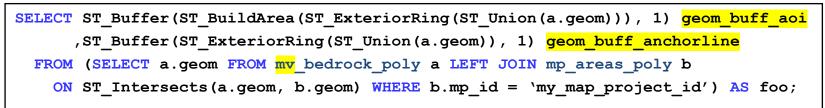
#### Spatial database: PostgreSQL/PostGIS

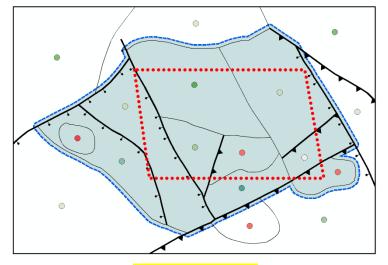
- OGC standard simple features:
  - o geometry types, binary predicates, spatial functions and SQL
- Foreign Data Wrapper
  - o integration of distributed databases



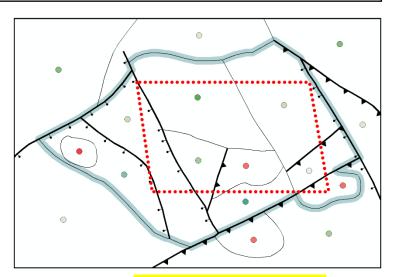


### SQL statement for data checkout (snippet)





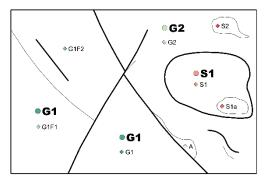
1) Create buffer [geom\_buff\_aoi] to tag feature components that intersect the mapping project area



2) Create buffer [geom\_buff\_anchorline] to tag anchorlines, anchorpoints, rodelines and the rest for revision.



#### Database views and materialized views to create maps

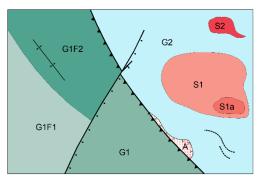


1) GFD source data with levels of details

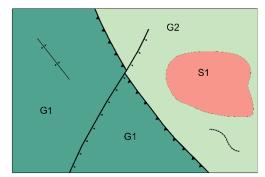
```
a) All the line and unit label as diamond, presentational scale: 1:50,000;b) Thick line and unit label as circle, presentational scale: 1:250,000
```

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

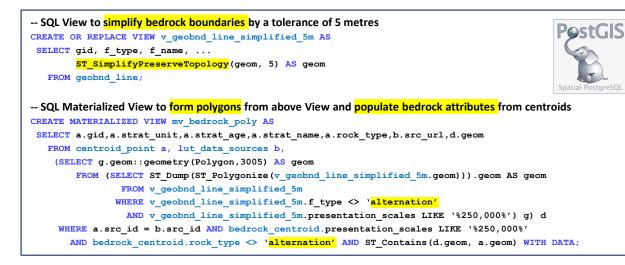




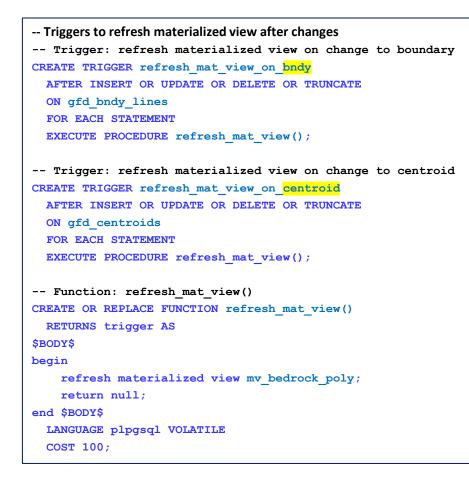
2) Map at a scale of 1:50,000

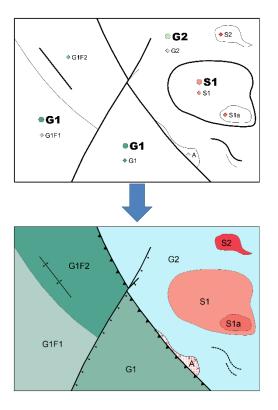


3) Map at a scale of 1:250,000



### Trigger and function to refresh a Materialized View





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

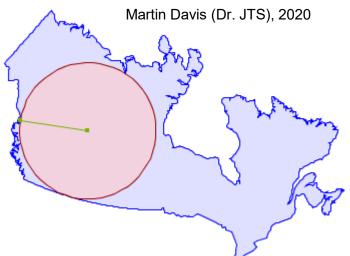
VOLATILE NOT LEAKPROOF

AS $BODY$

DECLARE ...;
```

## **SQL:** spatial functions

- 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))')
```

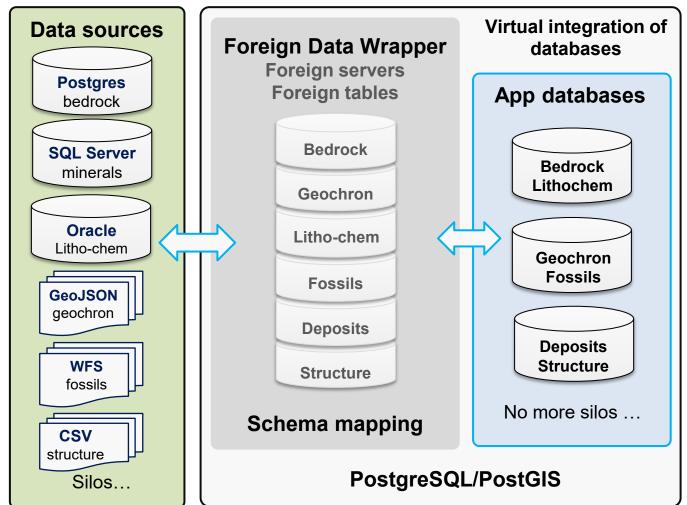


#### Foreign Data Wrapper

Supported by Postgres

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





## Thank you!



E-mail: yao.cui@gov.bc.ca Telephone: 1+250-952-0440