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Critical Minerals Mapping Initiative

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Data-driven prospectivity models for basin-hosted mineral systems and their critical raw materials

Canada

Critical mineral mapping initiative (CMMI)

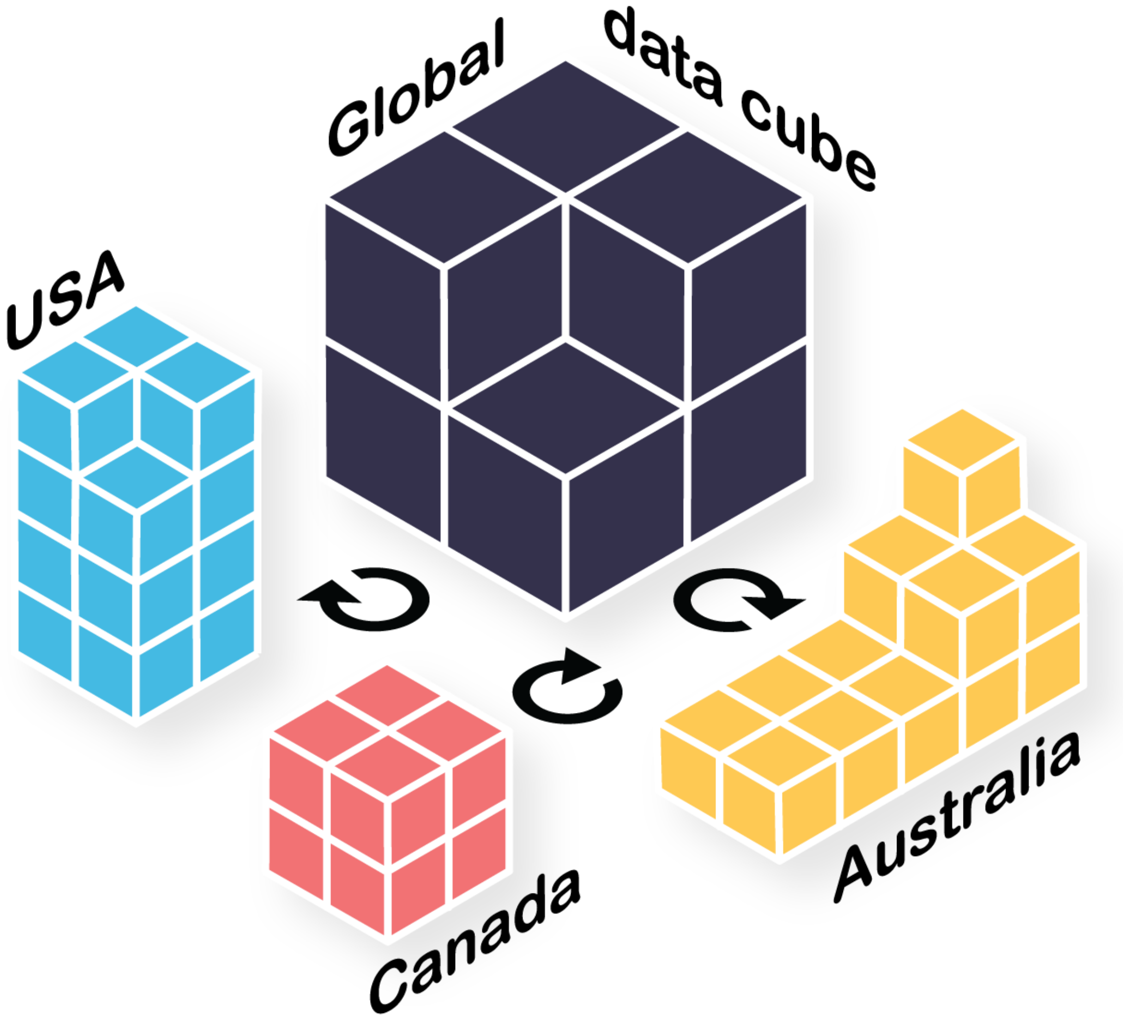
Goals

1. Knowledge sharing
   e.g., co-develop conceptual mineral systems models;

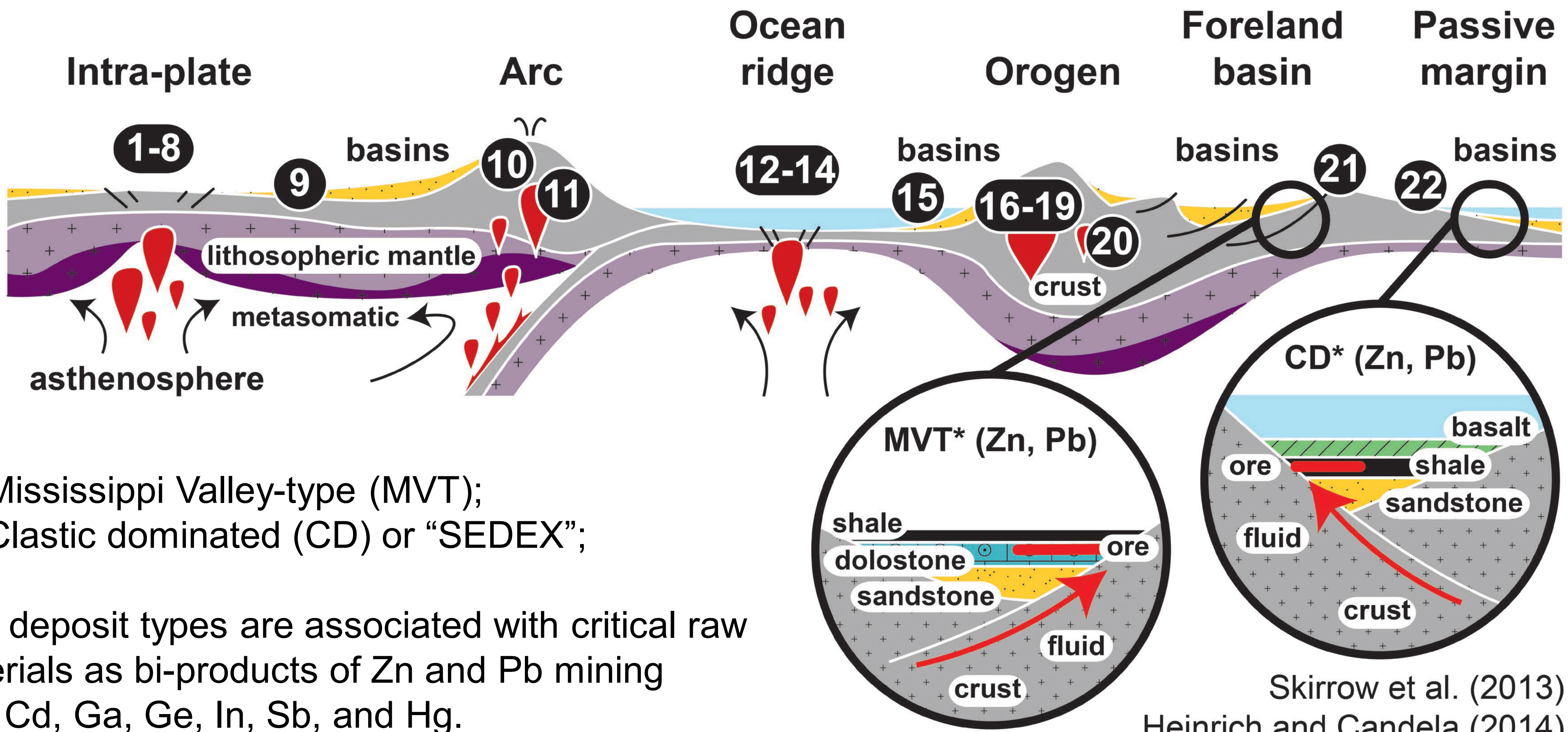
2. Data sharing
   e.g., leverage our national datasets for mutual benefit and support critical mineral discovery;

3. Communicating critical mineral research,
   e.g., AGI Critical Mineral Forum;

This presentation reports on the **data sharing**, **data integration**, and prospectivity modelling aspects of the CMMI collaboration.



Geological settings for critical minerals



21. Mississippi Valley-type (MVT);
22. Clastic dominated (CD) or “SEDEX”;

Both deposit types are associated with critical raw materials as bi-products of Zn and Pb mining e.g., Cd, Ga, Ge, In, Sb, and Hg.

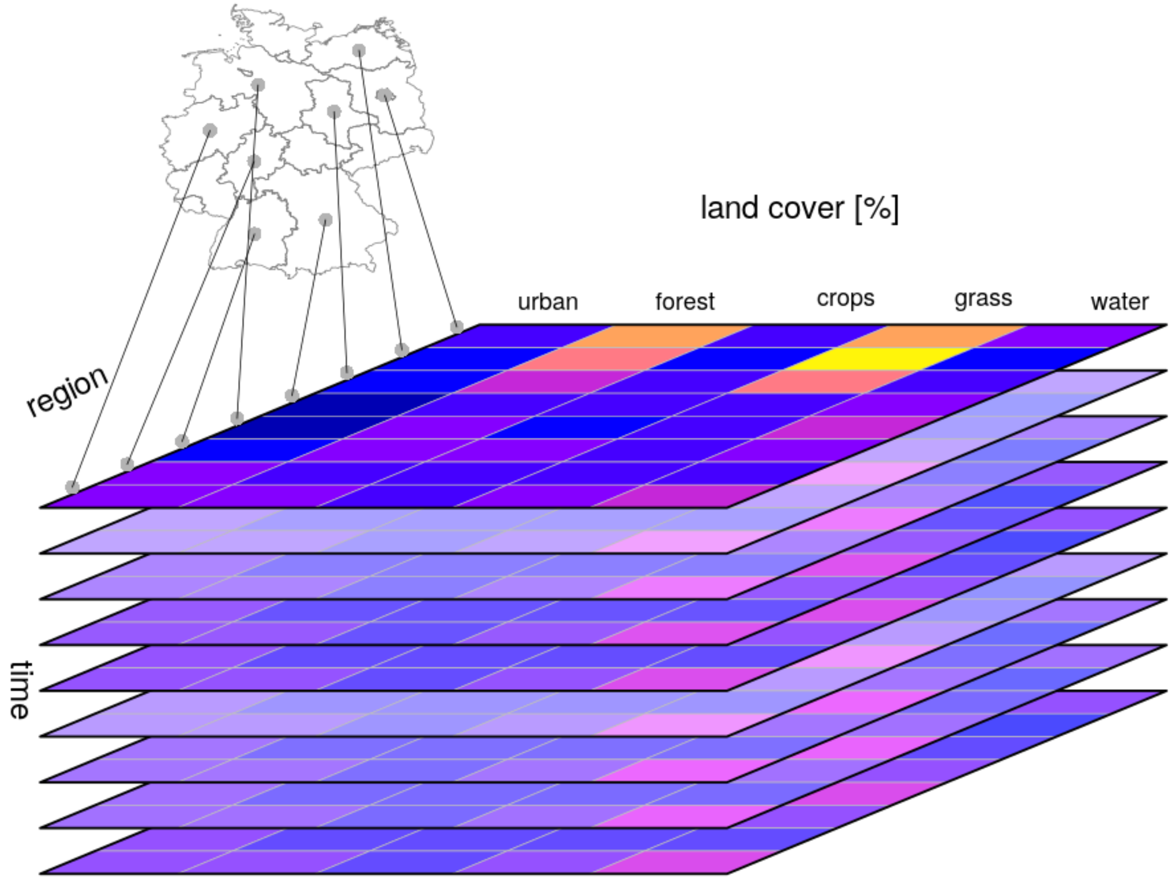
Skirrow et al. (2013)
Heinrich and Candela (2014)

Spatial indexing of geological data

1. Data cubes are multi-dimensional arrays, e.g., EO data. Can also create data cubes from irregular grids and or more varied datasets comprising text and numbers;

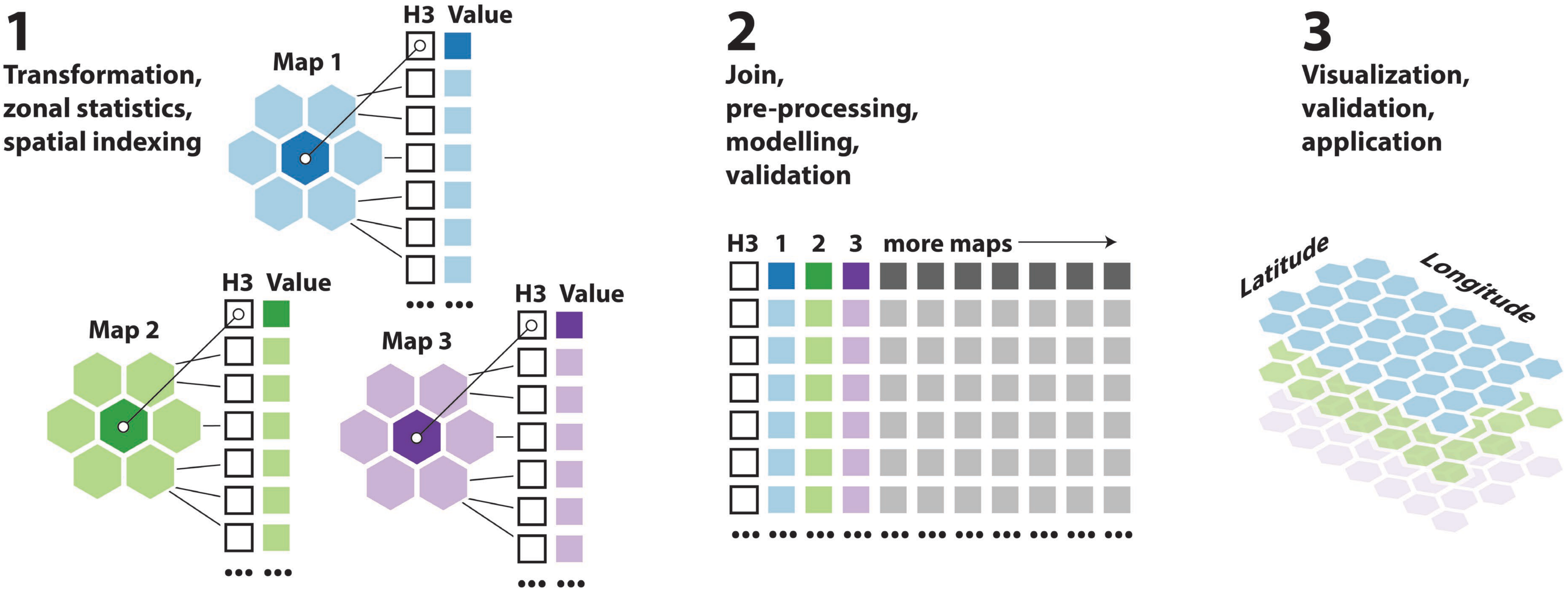
2. Zonal statistics and spatially indexing are two of the processes for combining disparate datasets together;

3. Data in this form can be used with artificial intelligence platforms to generate predictive models.



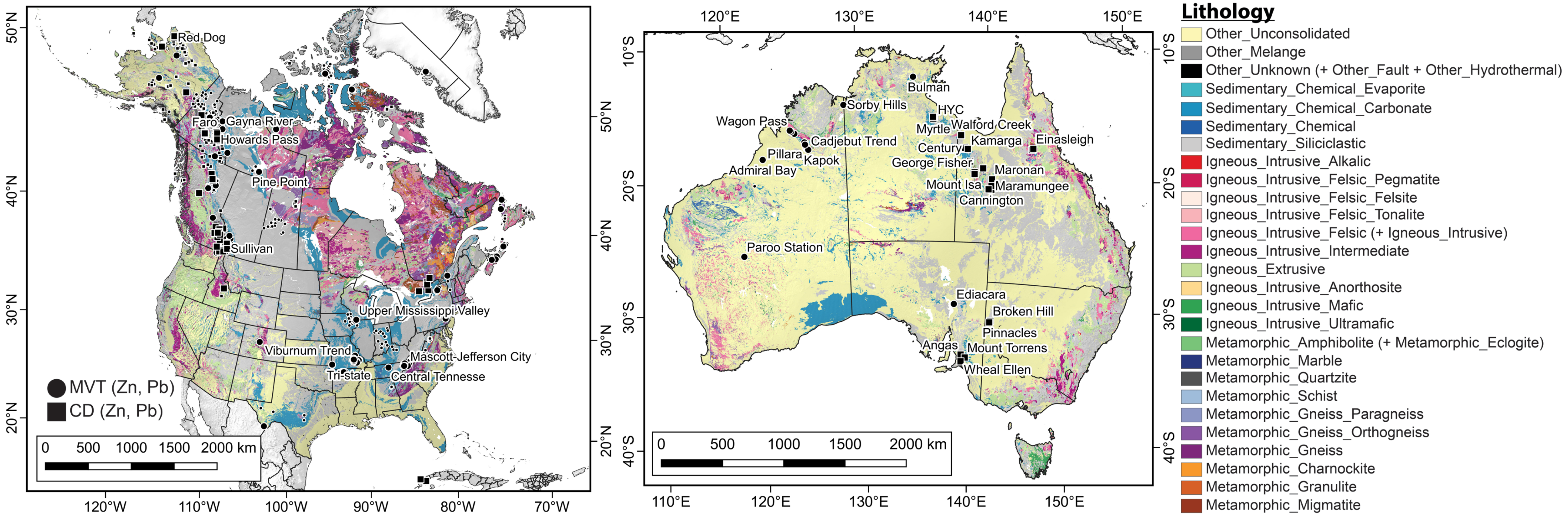
Pebesma et al., stars package

Modelling workflow



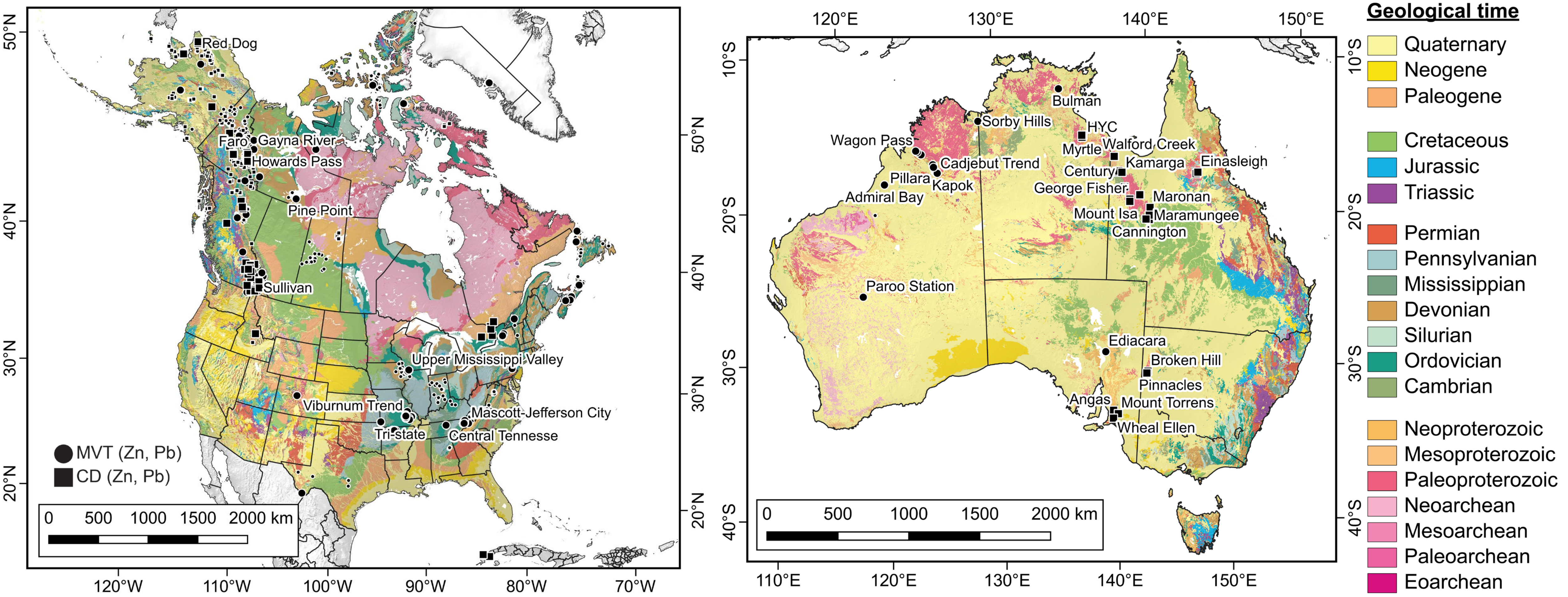
1. Uber developed H3 for fast geospatial indexing of global datasets (Apache 2.0 License);
2. Advantages are: (a) Global extent; (b) hierarchical; (c) neighbourhood tools; (d) share with anyone;
3. Each “cell” is associated with a “H3 address”.

New data highlights: consistent lithology



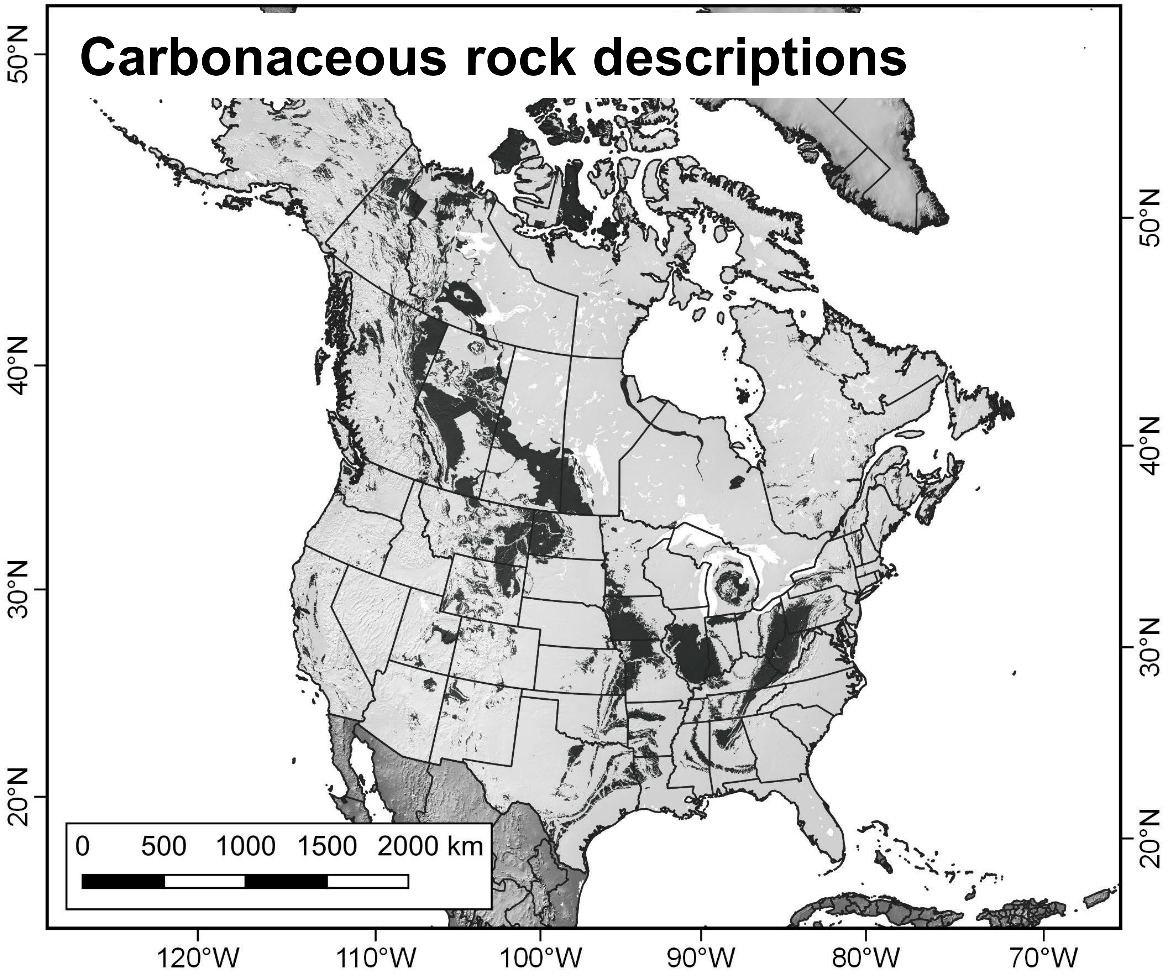
1. Assembled provincial, territorial, and state geological datasets (first time for Canada; 23 maps total);
2. New hierarchical rock legend with consistent formatting across all three countries;
3. Geology is one of the most important inputs for prospectivity modelling.

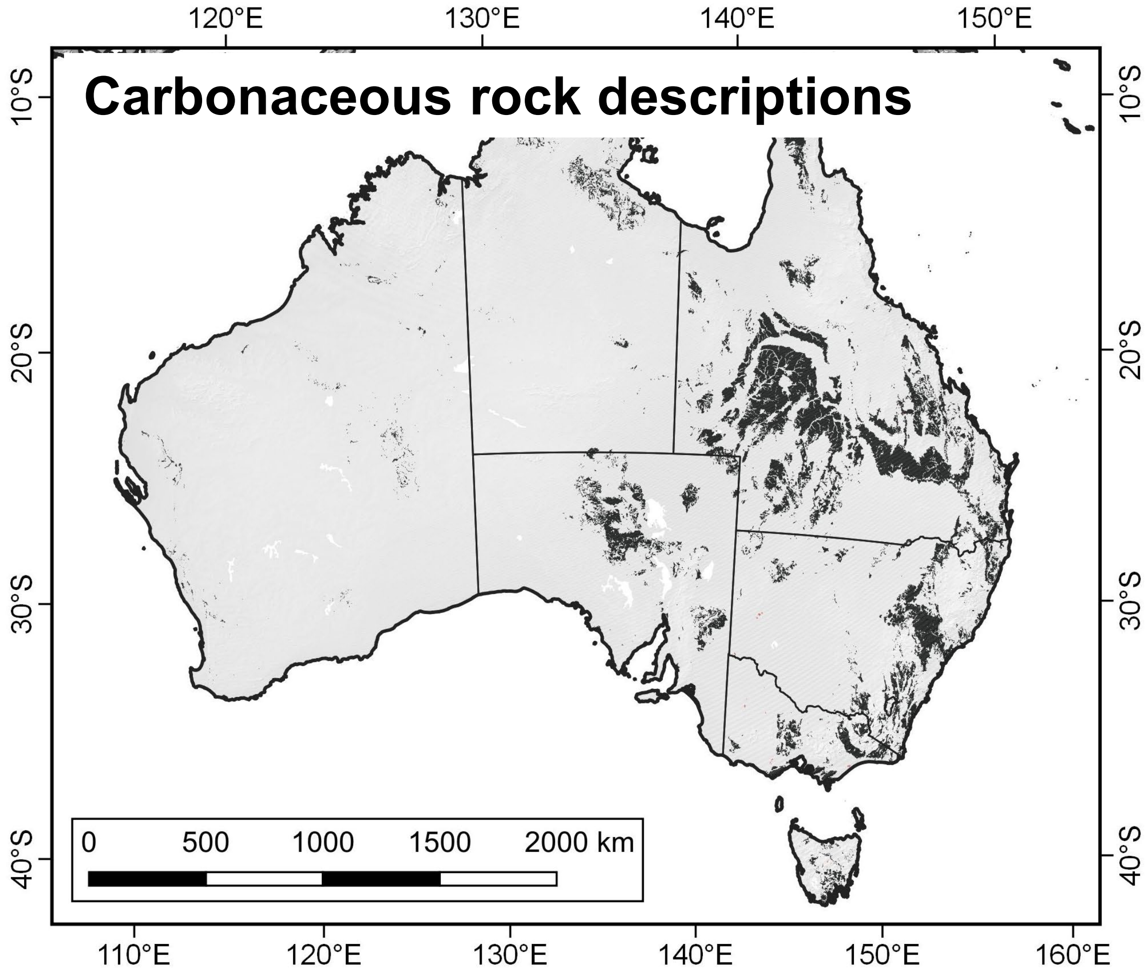
New data highlights: consistent ages



1. Consistent age formatting across Canada, the U.S., and Australia;
2. Geological time used to map pre-enriched source rocks.

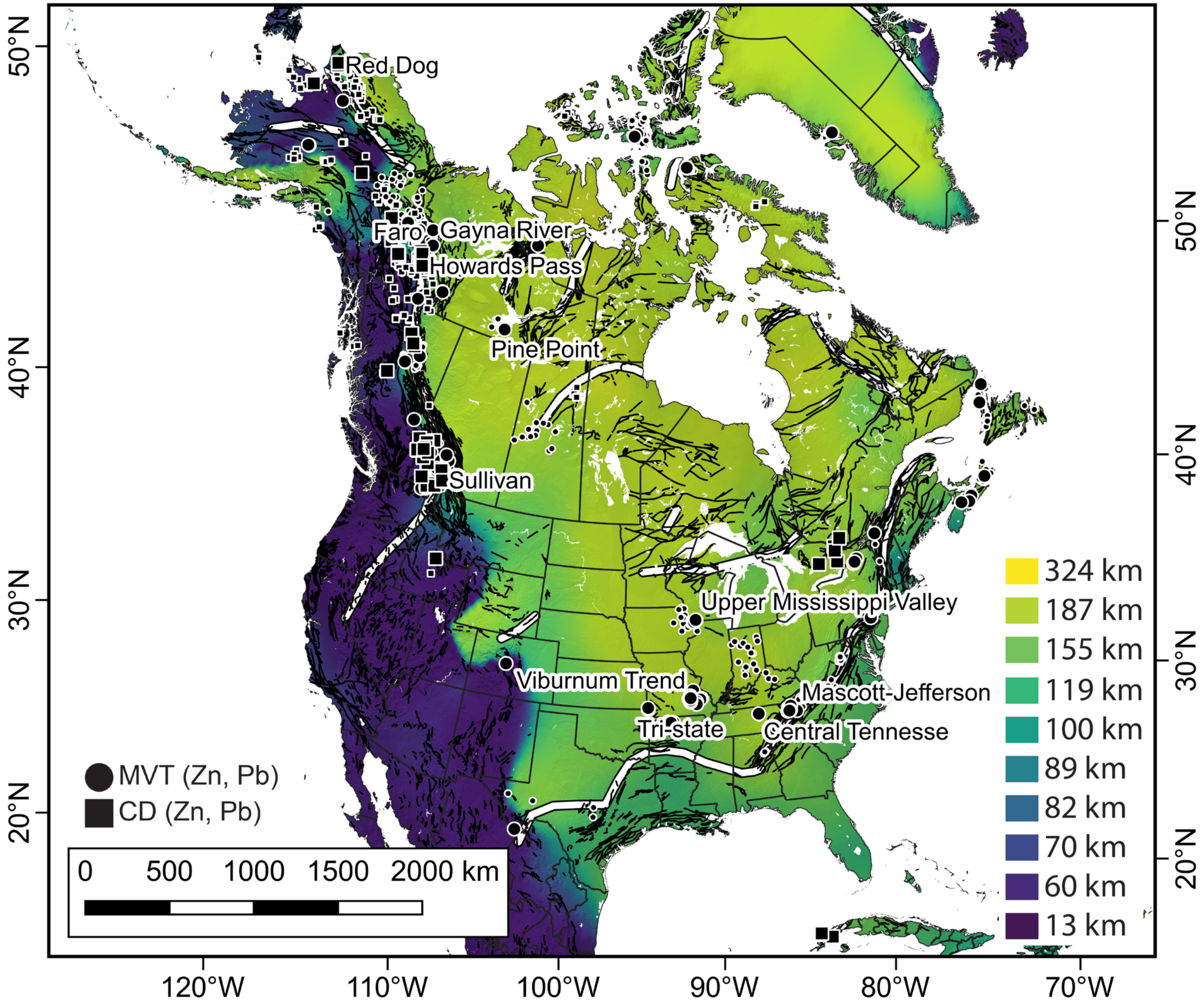
New data highlights: map properties

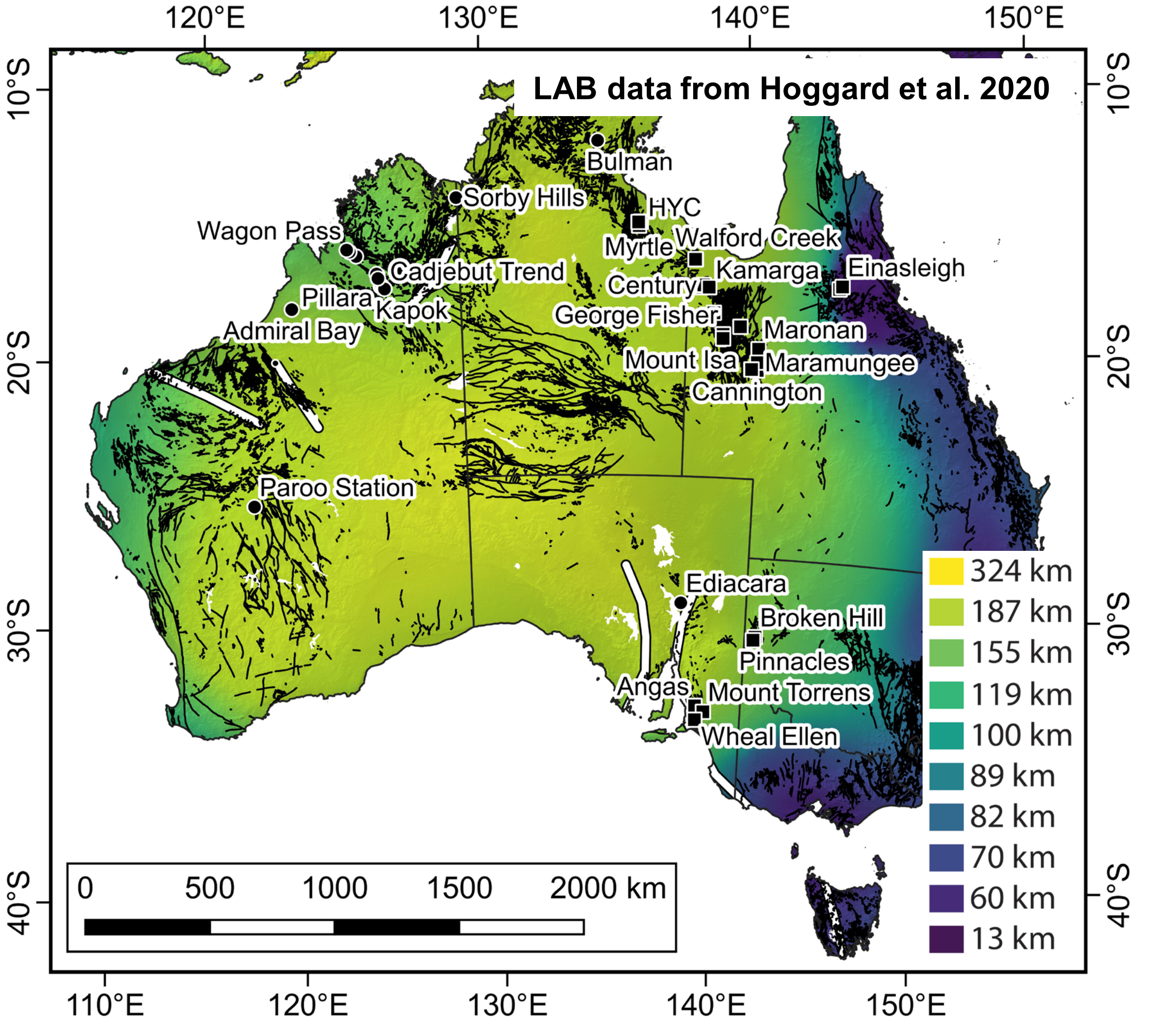




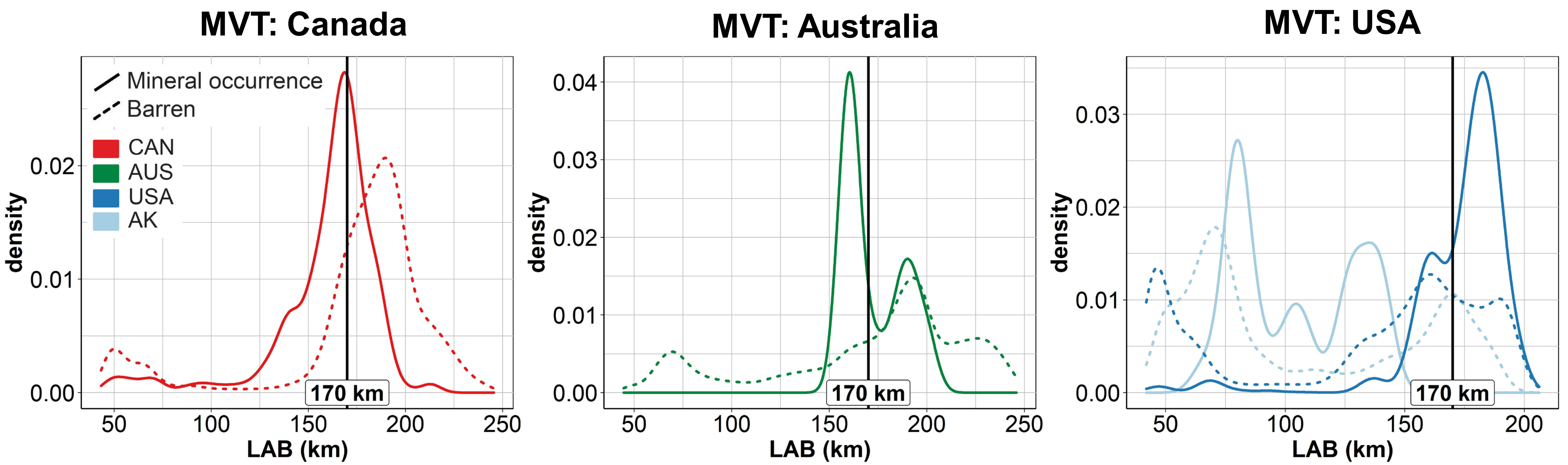
1. Dictionaries used to extract 17 different geological properties from unstructured rock descriptions

Mineral system pathways: LAB





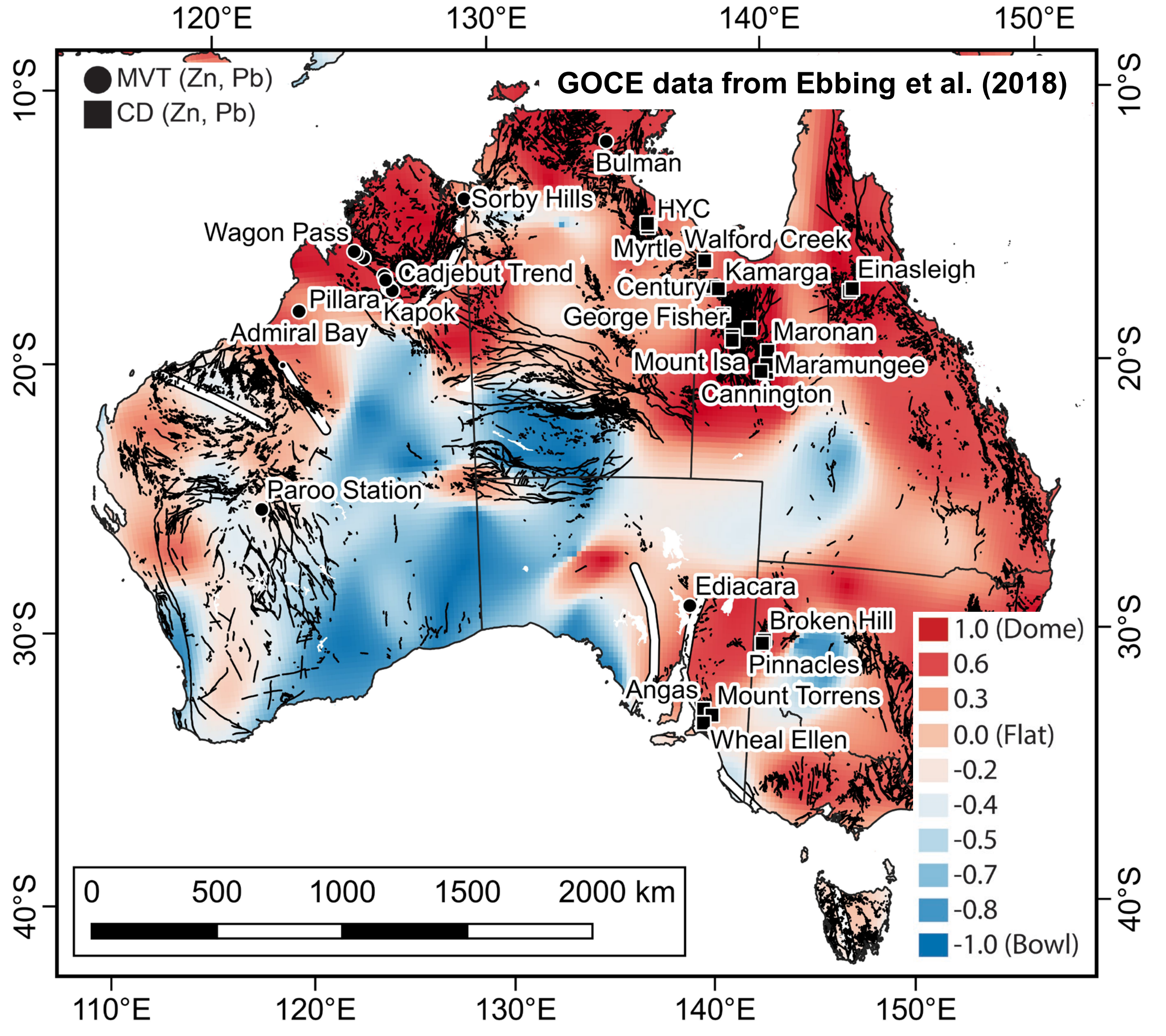
Mineral system pathways: LAB



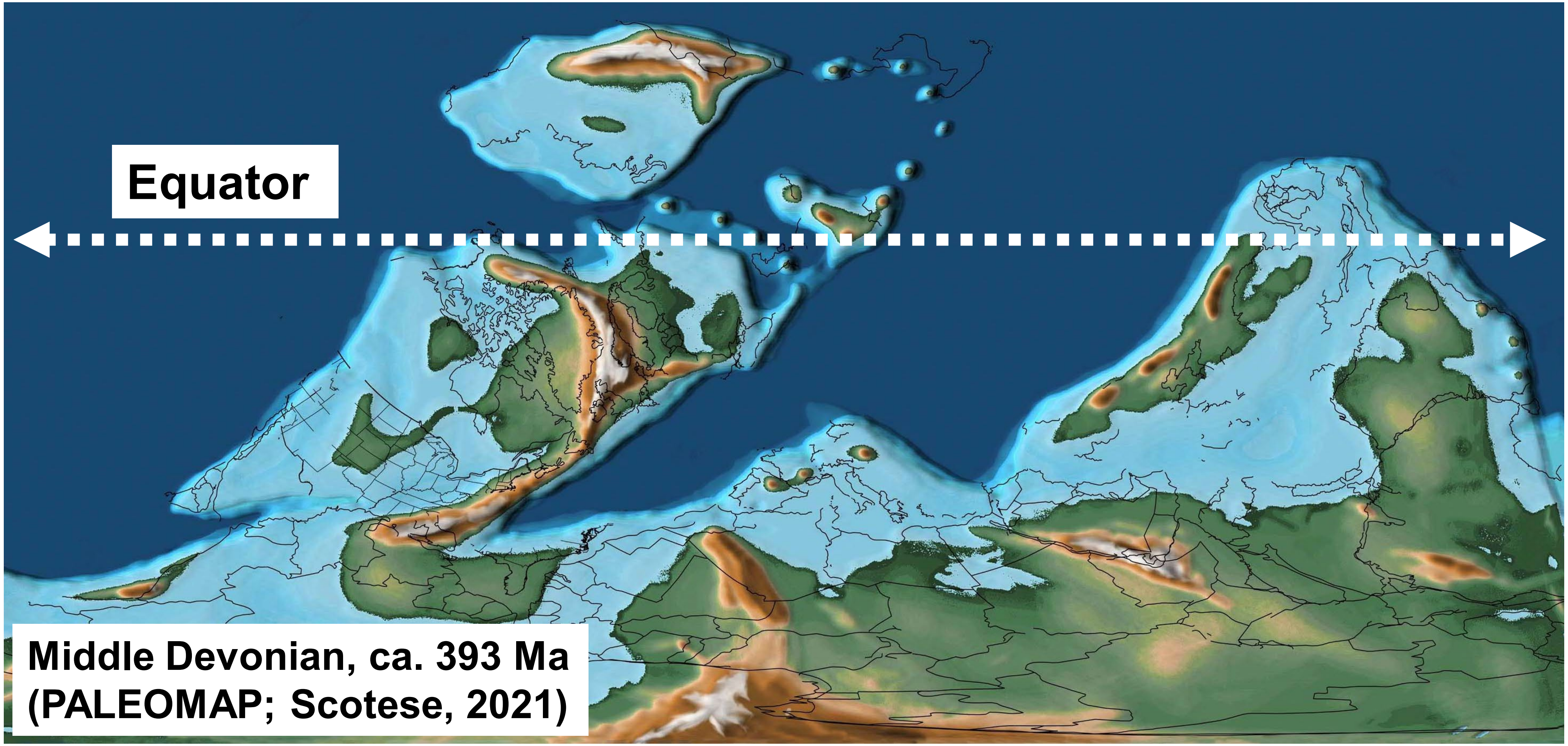
1. Overall association with edges of thickened lithosphere;
2. Prospective LABs are distinct for each region;
3. Regional differences are important to understand for modelling;

Pathways: GOCE satellite gravity data

1. Satellite gravity data can be interpreted with seismic-based methods to image the lithosphere;
2. Mass-deficit, or "bowls", correspond to cratonic areas;
3. Mass-surplus, "or domes" correspond to orogens and anomalous density sources in the crust and/or uppermost mantle (e.g., mafic under-plating);
4. Basin-hosted mineral systems tend to occur at the edges of "domes".



Paleo-latitude important for: (1) carbonate platforms and (2) evaporites

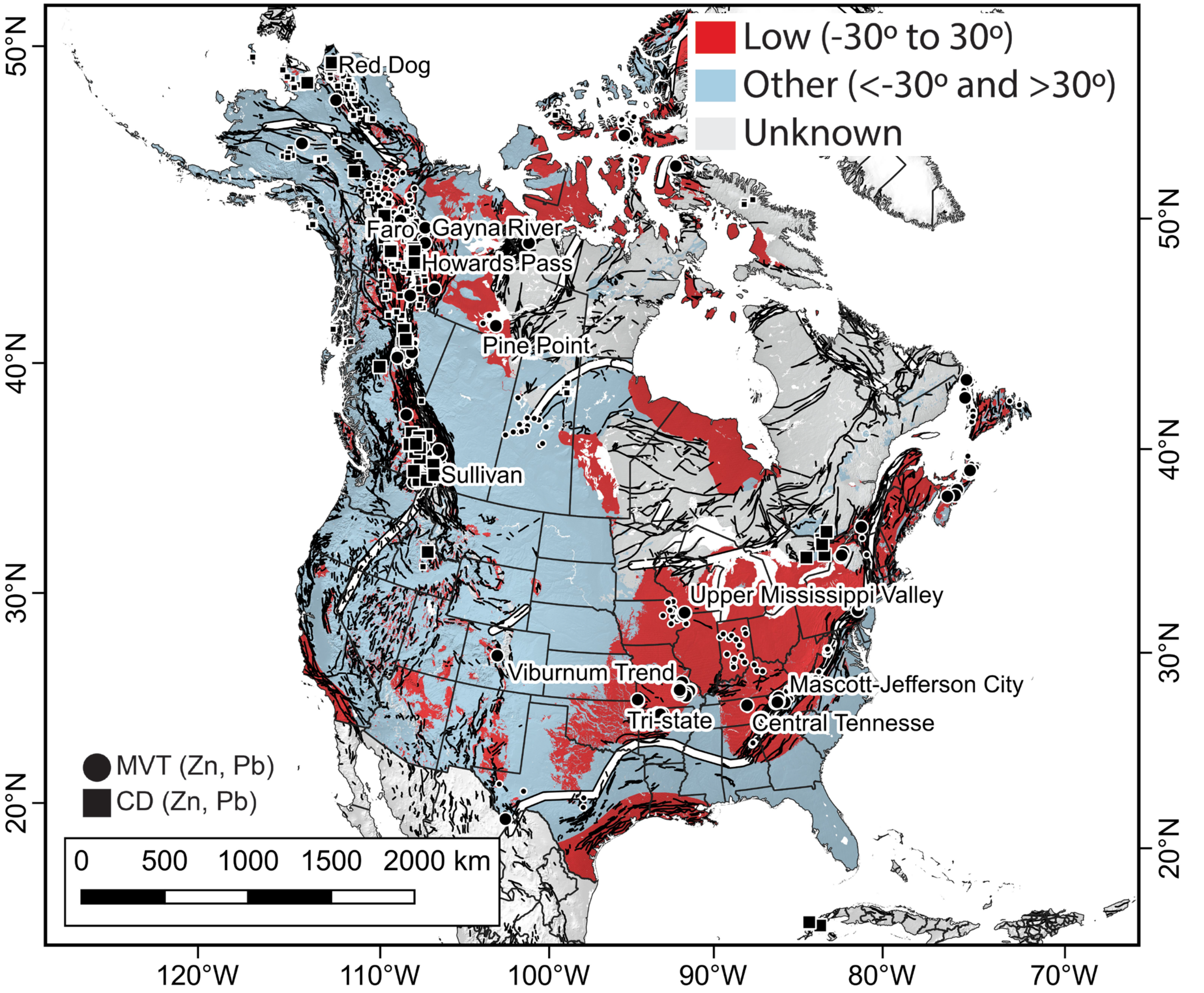


Potential brine-generating regions

1. Paleo-latitude estimated from rock ages, tectonic plate ID, paleo-geographic reconstructions (i.e., PLALEOMAP, Scotese, 2021), and tracked through time using the GPlates API;

2. Saline brines are generated at evaporative latitudes (red in figure);

3. Because saline brines can effectively strip and transport base metals and some critical elements from underlying oxidized strata, they are critical for transporting ore-forming components to depositional sites at MVT and CD deposits.



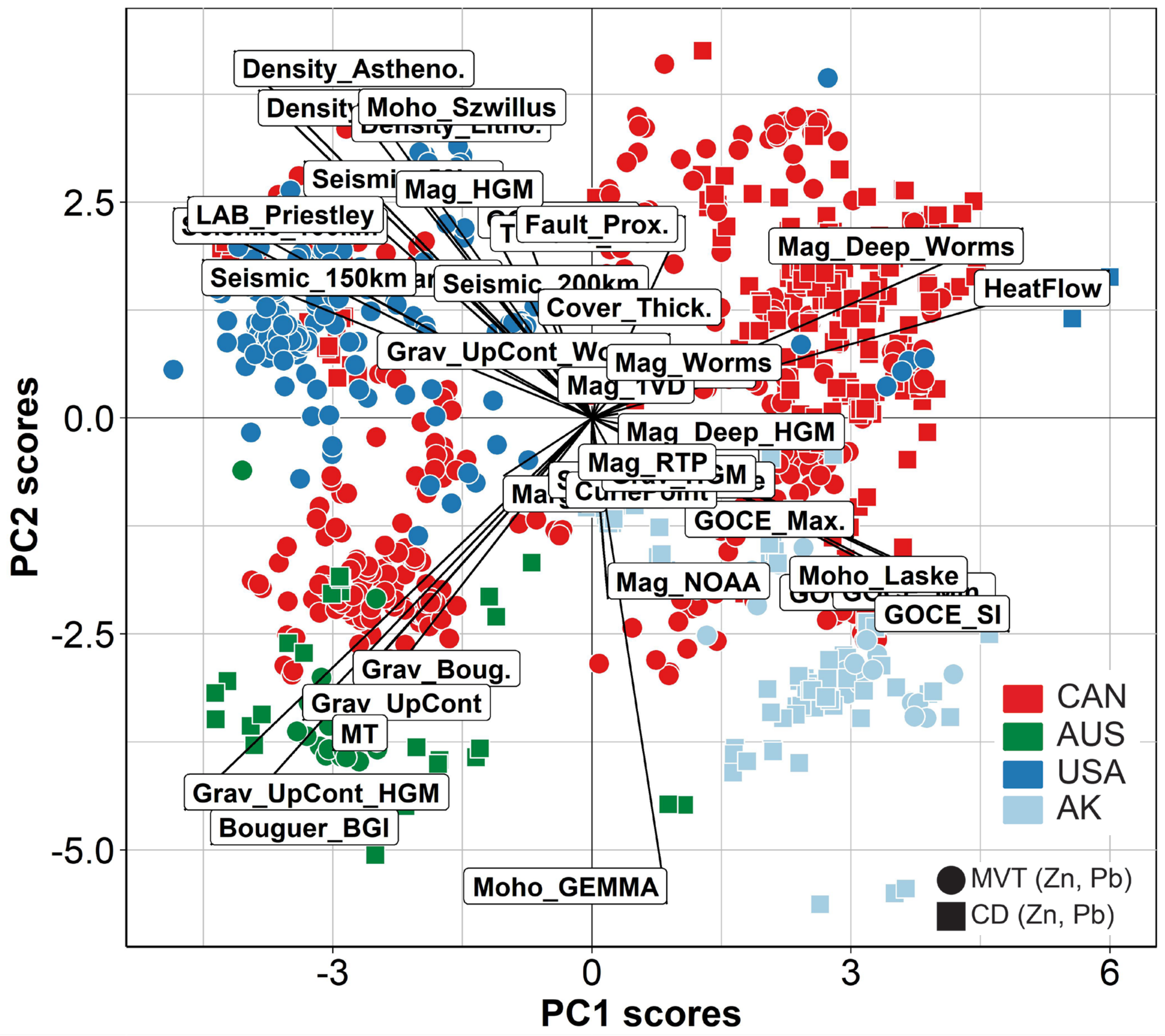
Geological "nature" versus "nurture"

1. Disparate regions yield disparate geophysical signatures (e.g., gravity, magnetic, seismic, MT);

2. Regional signatures likely represent the confluence of similar geological processes ("nature") operating on different geological domains with disparate histories ("nurture");

3. Data integration provides important clues on how we should proceed with training models.

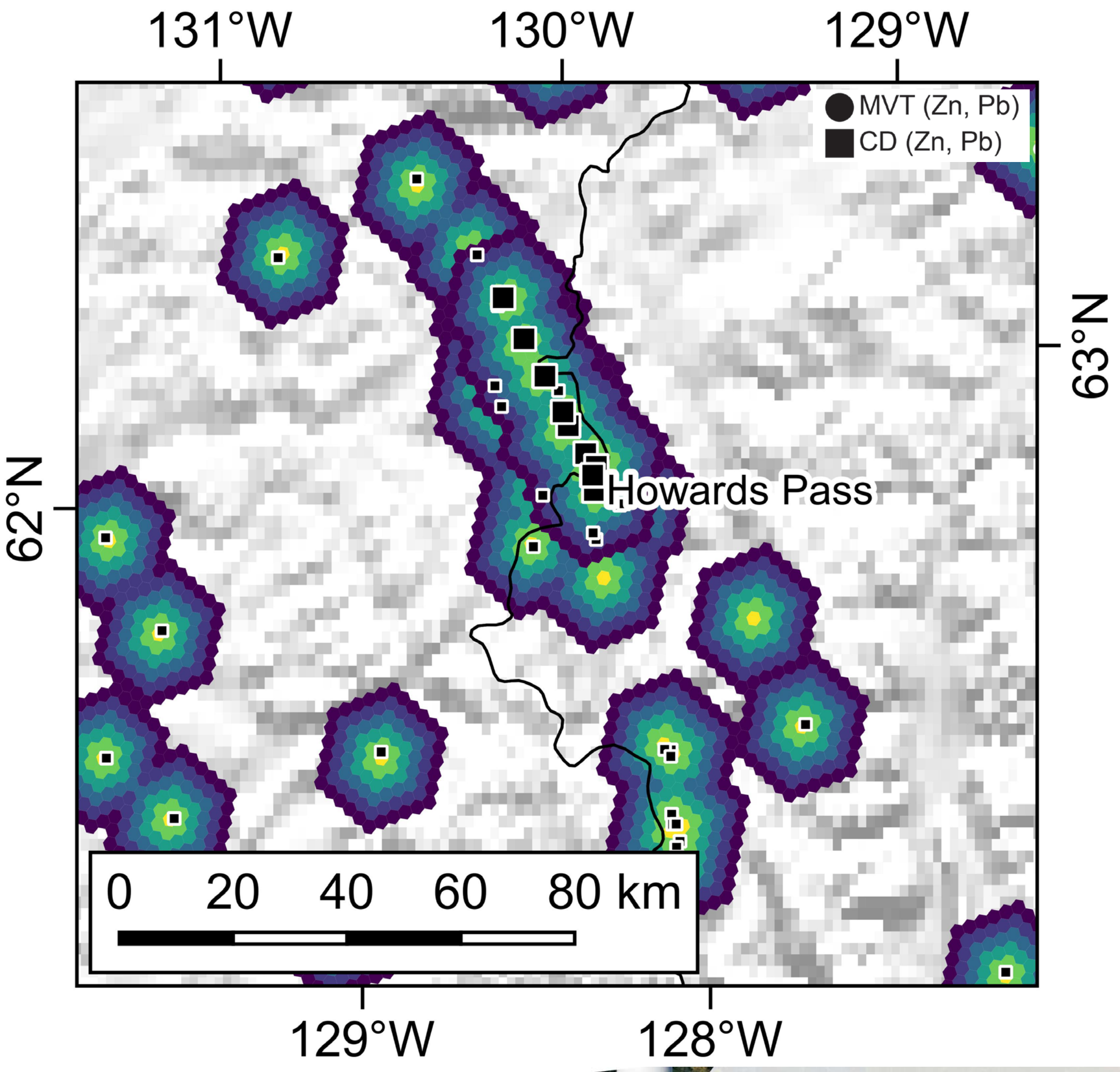
PCA Biplot: Deposits and mineral occurrences



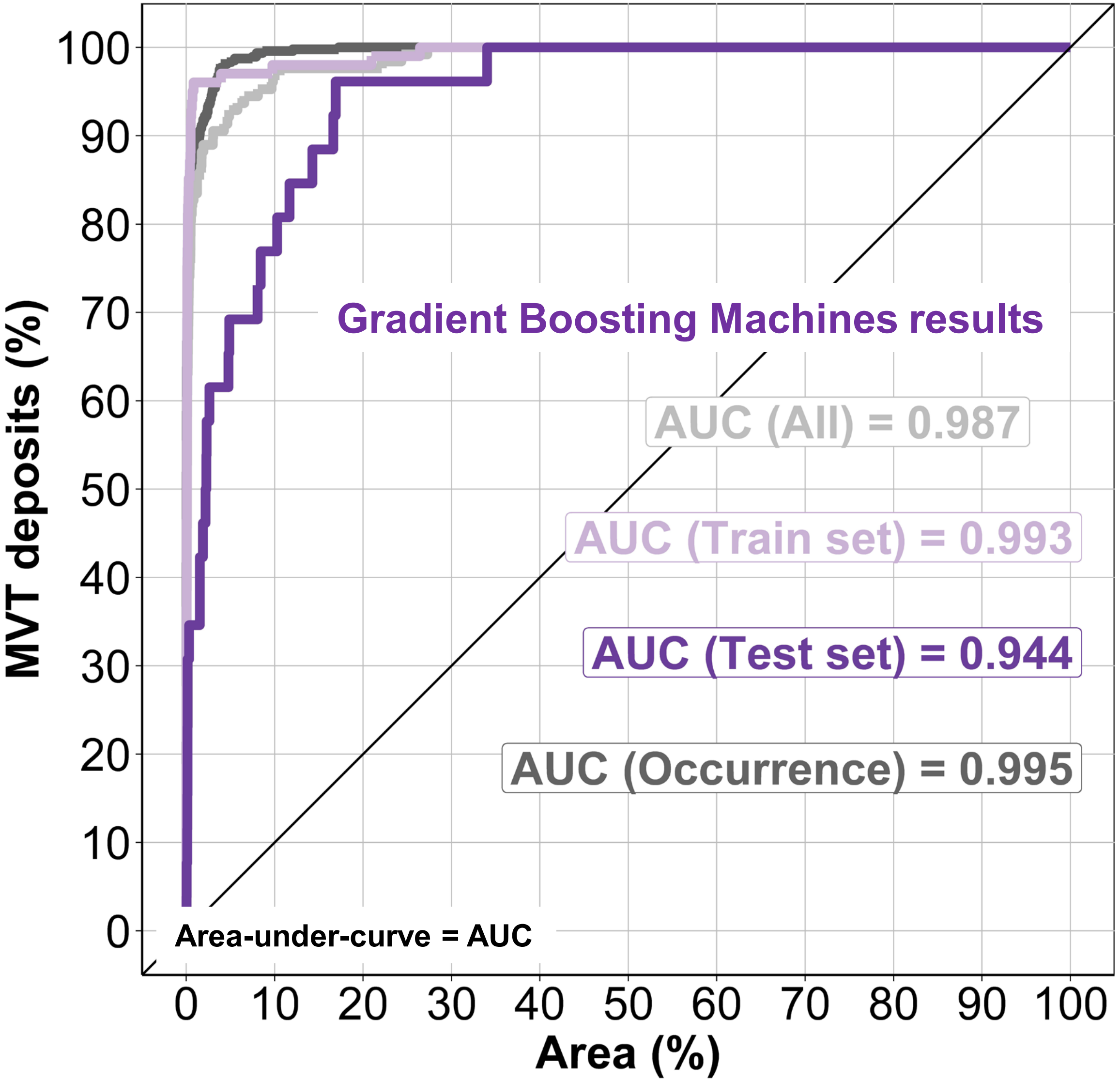
Model training & machine learning competitions

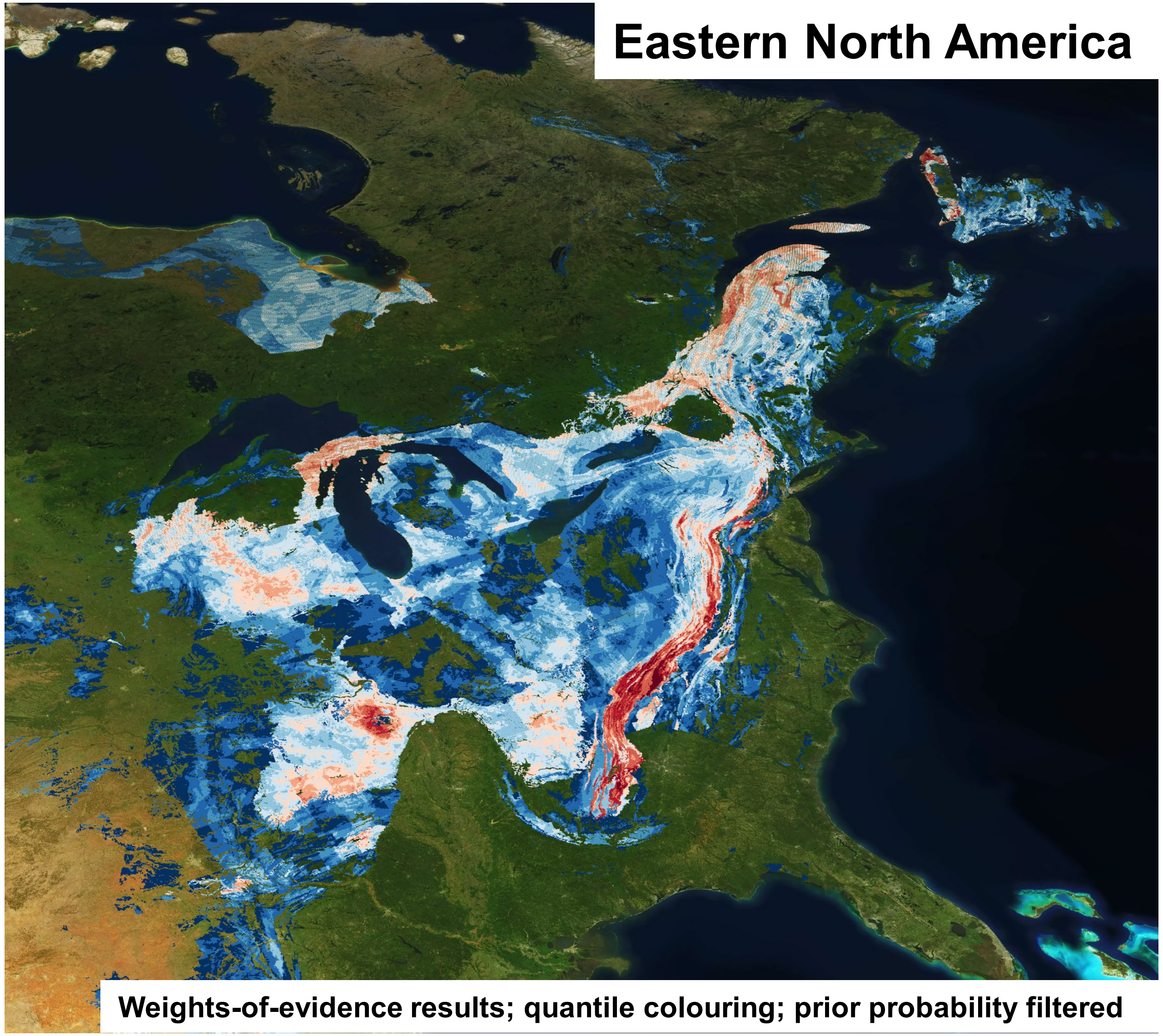
- Mineral deposits are **rare**;
- Mineral occurrences are still **rare**;
- Can we use neighbours?

1. We want the closest neighbours;
2. We want neighbours next to “deposits” more than mineral occurrences;
3. We want the neighbours next to the largest deposits more than smaller deposits;
4. We want to know the attributes of the source hexagon.

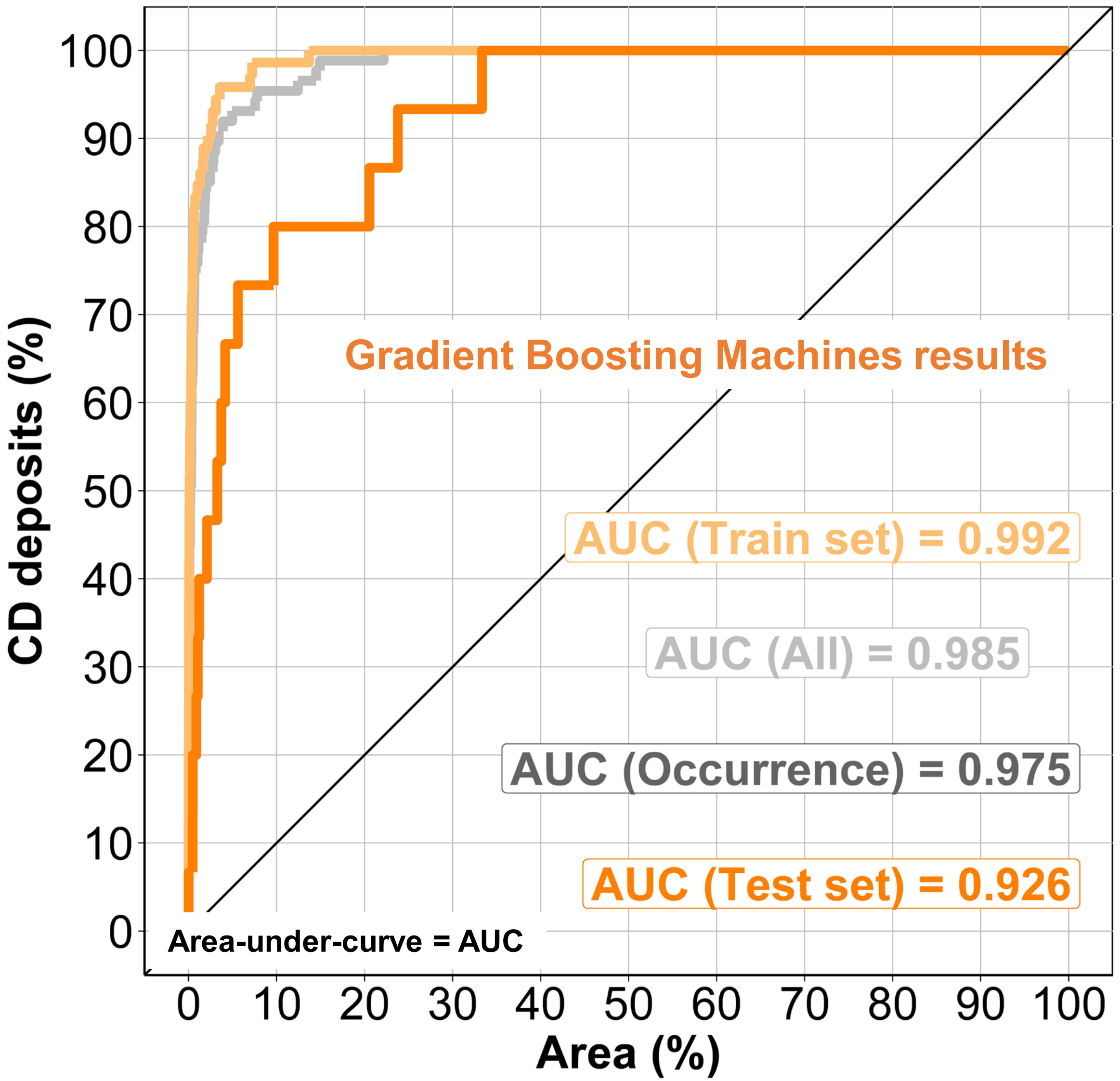


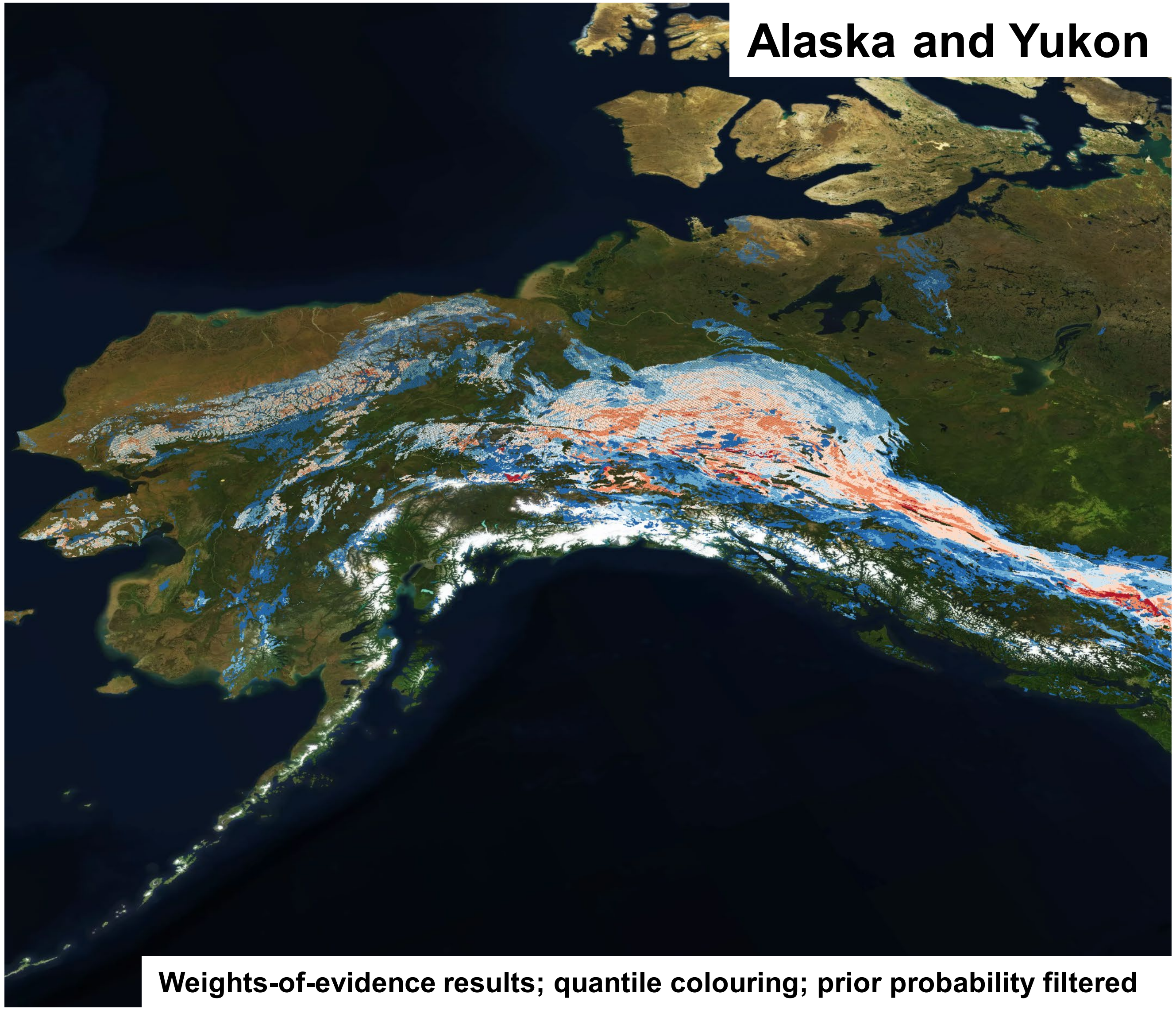
Preliminary MVT model results





Preliminary CD model results



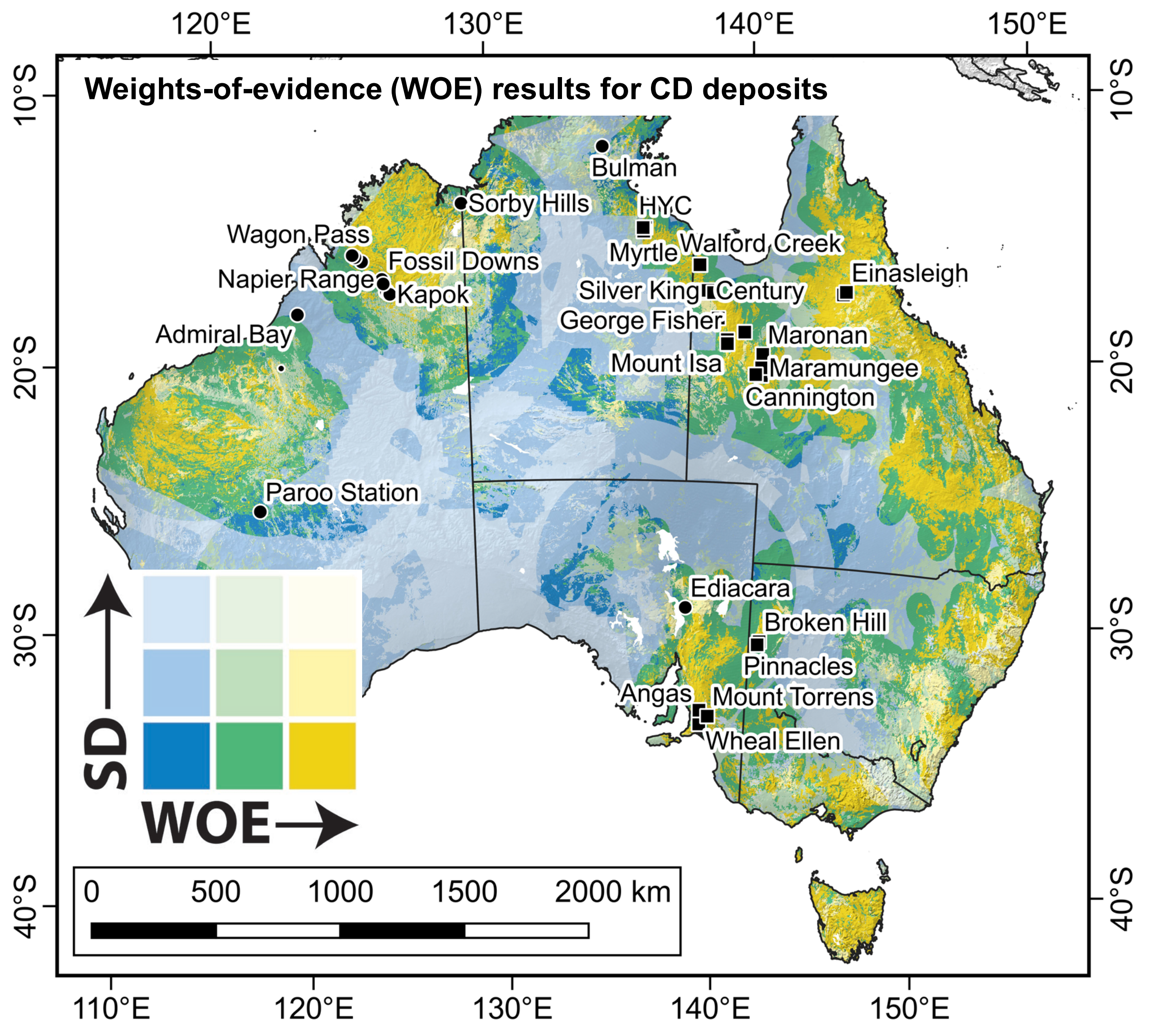


Estimating model "uncertainty"

1. Prospectivity models are associated with multiple sources of uncertainty
(e.g., errors, sample bias, model methods);

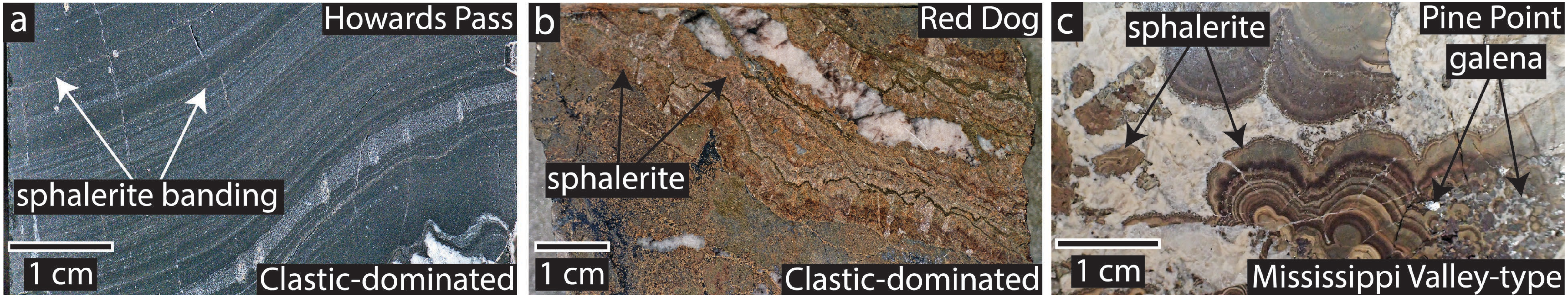
2. Regions with mostly positive evidence yield low uncertainty and high posterior probabilities
(i.e., low standard deviation, SD; dark yellow colour);

3. Regions with mixed evidence tend to yield higher uncertainty and lower posterior probabilities
(i.e., high SD; blue and green colours).



Conclusions

1. Data-sharing offers a number of advantages for prospectivity modelling
   (e.g., seamless maps, study processes at multiple scales, address major un-answered questions);
2. Data-driven modelling is now focused on improving performance in unknown areas
   (e.g., machine learning competitions are on-going);
3. Knowledge-driven prospectivity modelling is happening in parallel and both methods are complementary;
4. Prospectivity modelling also complements other critical mineral research as part of CMMI, such as the newly released portal, to identify the most favourable settings for critical raw materials.



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