Integrating Interdisciplinary Data: The EMERGE Database and its Broader Lessons for Data Management Best Practices

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Introduction

- Interdisciplinary research enables the exploration of emergent phenomena, broadening the horizons of scientific discovery.
- To enable different disciplines to effectively "speak" to one another, interdisciplinary research data must be organized, integrated, and shared based on **FAIR principles** (Findable, Accessible, Interoperable, Reusable).
- Interdisciplinary data integration faces several major challenges:
  - Broader scale, more interdisciplinary projects = larger, more numerous, and more heterogeneous datasets.
  - Different disciplines and labs use different terminologies.
  - Multiple levels of data processing, each representing different information "quality"; and these vary across disciplines.

EMERGE (EMergent Ecosystem Response to ChanGE)

- An in-depth interdisciplinary study of ecosystem-climate feedbacks in the thawing permafrost peatland Stordalen Mire (northern Sweden).
- Builds on a over a decade of work:

Data heavily leveraged by EMERGE.

10-year DOE-funded study of permafrost-carbon feedbacks at Stordalen

3-year NASA-funded study scaling IsoGenie findings to regional and pan-Arctic levels

… plus numerous other projects, including climate data spanning over a century

The **EMERGE Database (EMERGE-DB)**, the project's central data archive, accomplishes the **essential tasks** of data management:

Data Storage on fully-RAIDed OSU server

Data Sharing via web portal

while also offering more **advanced functionality** to facilitate interdisciplinary collaboration:

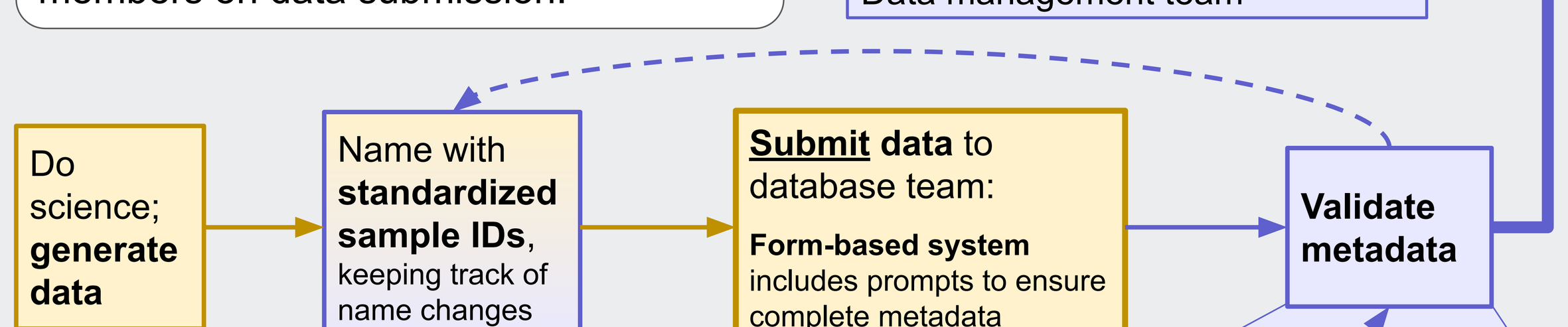
Data Integration within one graph framework

Data Exploration with complex custom queries

Data import workflow

EMERGE has a **Data Policy** that further explains this process and guides project members on data submission.

KEY - Roles & responsibilities:
Project members / data generators
Data management team



Once submitted, all source datasets are:

- Assigned basic file metadata in consultation with data generators:
  - title, authors & contact info, version #, quality level, access rights
- Recorded in the EMERGE-DB's Metadata nodes for sharing via the website's Downloads page.
- Shared via external repositories (for publication-ready data).

Submitted sample metadata is standardized for cross-dataset consistency.

These **standardized properties** (indicated with "__") then guide detailed data import.

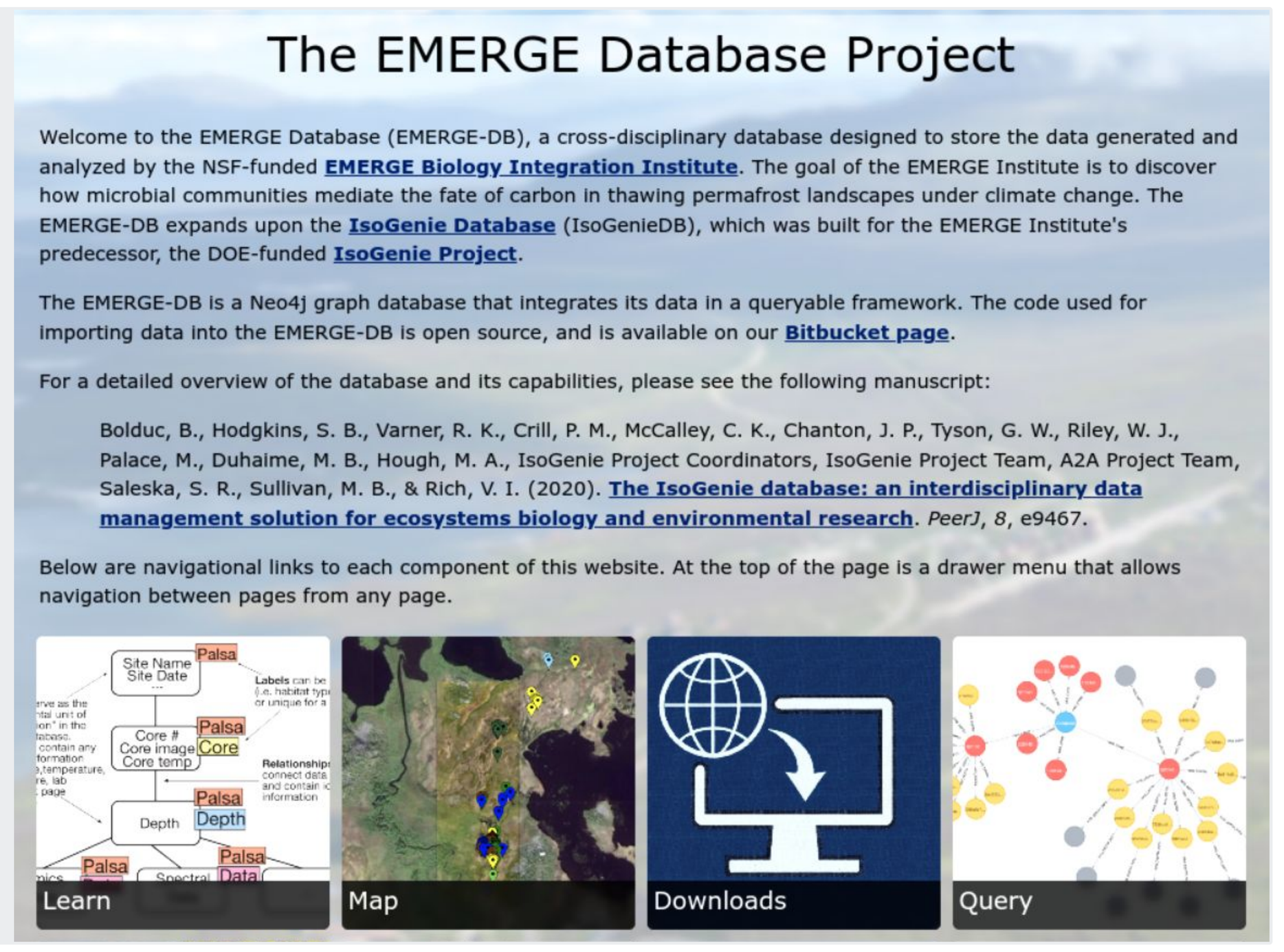
SampleID__	Site__	Core__	Date__	DepthMin__	DepthMax__	Habitat__	…
MainAutochamber.202107_P_3_30to34	Palsa Autochamber Site	3	2021-07-18	30	34	Palsa	
MainAutochamber.202107_S_1_1to5	Sphagnum Autochamber Site	1	2021-07-26	1	5	Bog	
IncubationMaterial.202107_IncE_2_10to14	Inc-Eriophorum	2	2021-07-23	10	14	Fen	

Import data (python)

Web Portal

emerge-db.asc.ohio-state.edu

- Provides both public and within-project data access.
- Different pages provide different "views" of the data (see screenshots connected from Graph Database below).



Graph Database

- Connects data thematically in a flexibly-structured network, **mirroring physical or conceptual relationships** between entities.
- Neo4j-powered framework enables efficient custom querying.

sample metadata

measurement data

file metadata

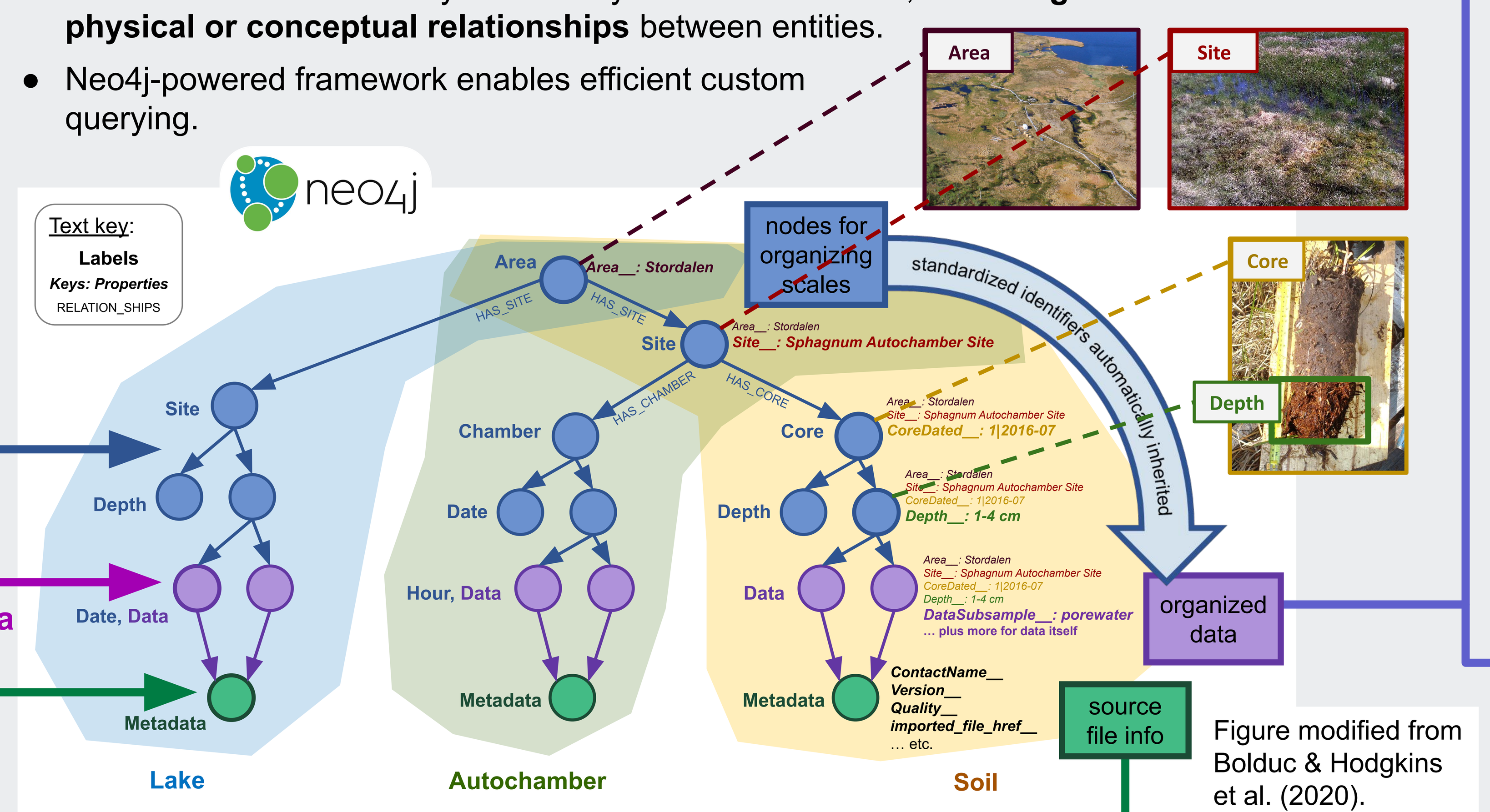


Figure modified from Bolduc & Hodgkins et al. (2020).

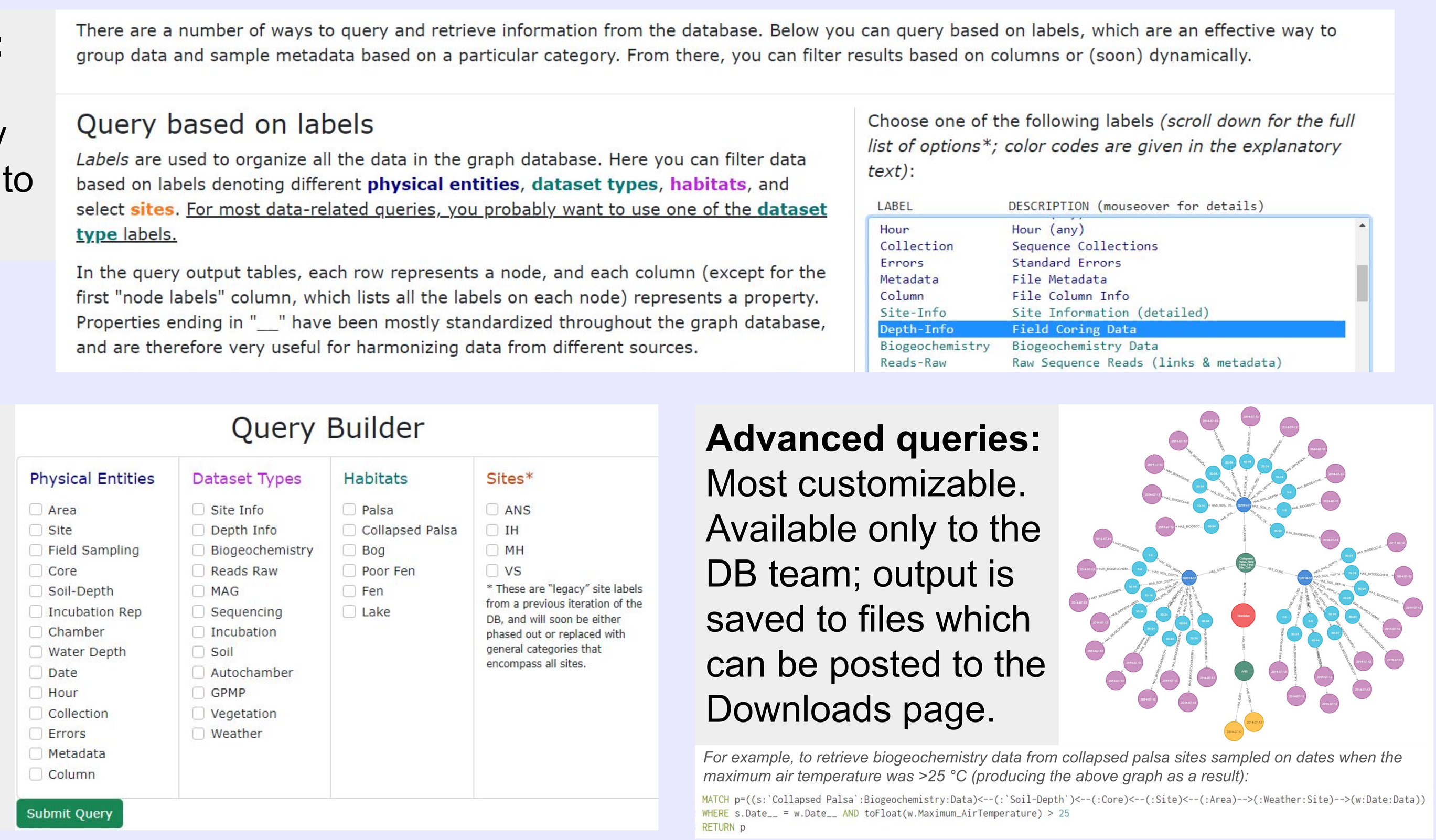
auto-population of Downloads page from **Metadata** nodes

Queries: Retrieve subsets of integrated data

Cached queries: Snapshots of single-label query results; available to the public.

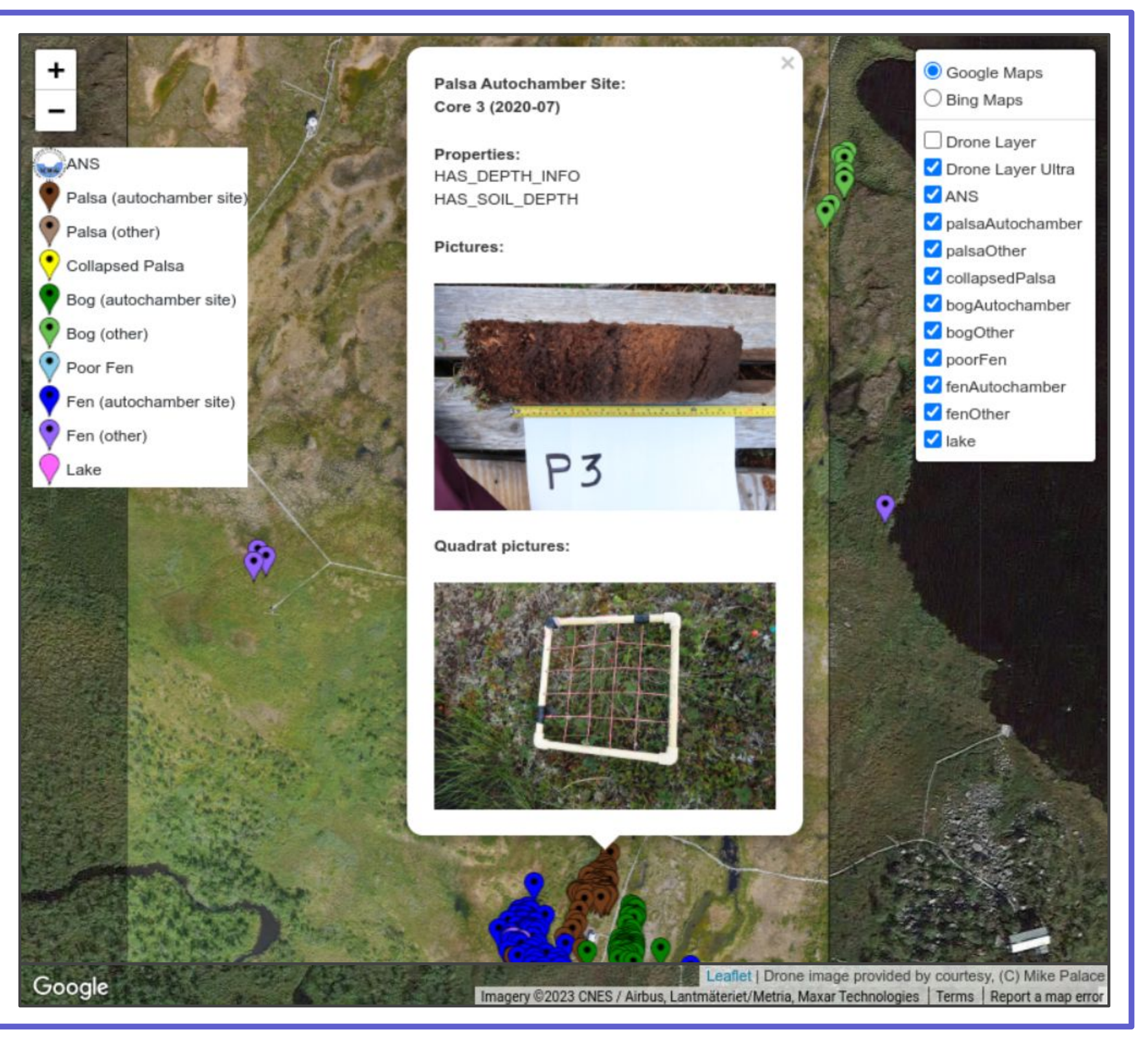
Live queries: Real-time queries on one or more labels. Available to EMERGE members (public access is forthcoming).

Advanced queries: Most customizable. Available only to the DB team; output is saved to files which can be posted to the Downloads page.



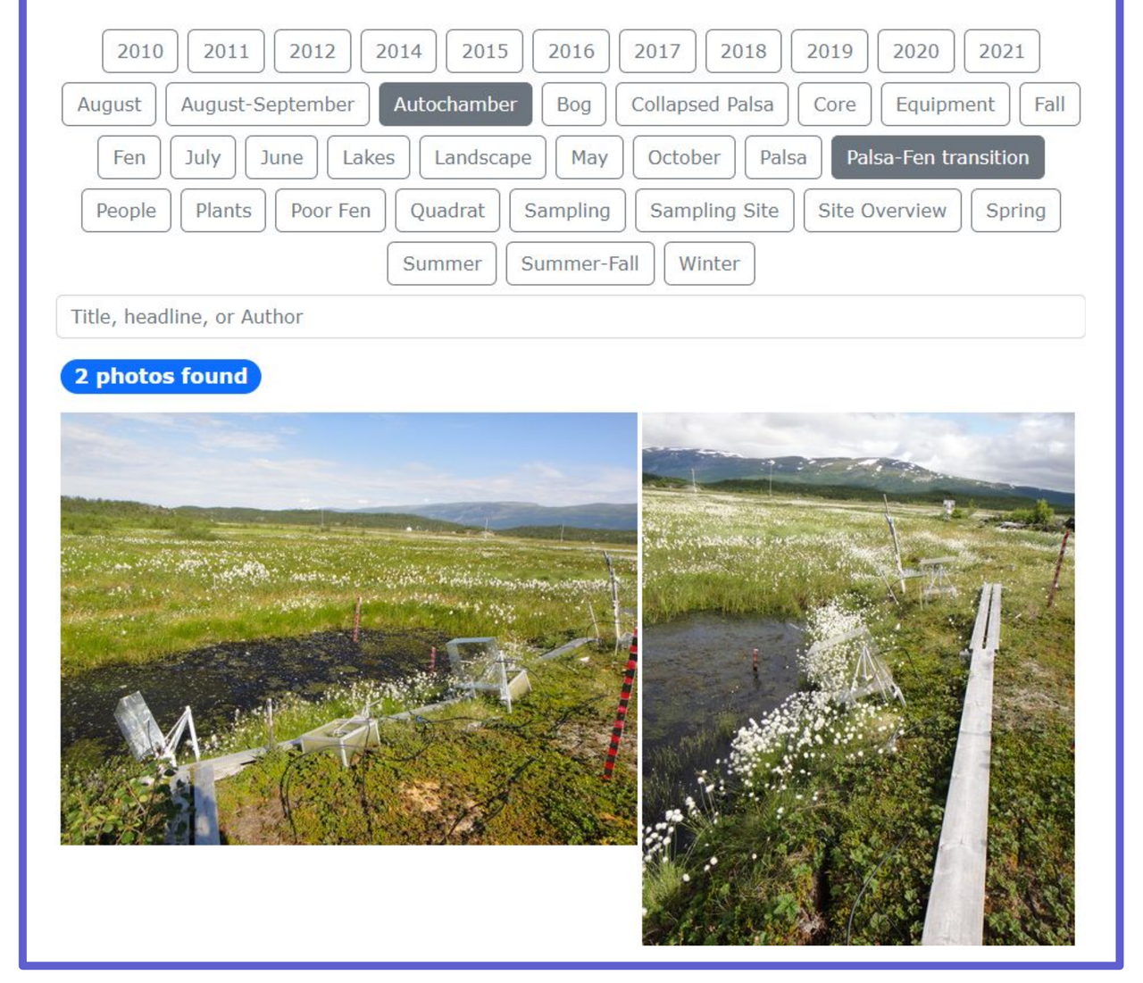
Map:

Graphical information on cores and other geo-referenced entities.

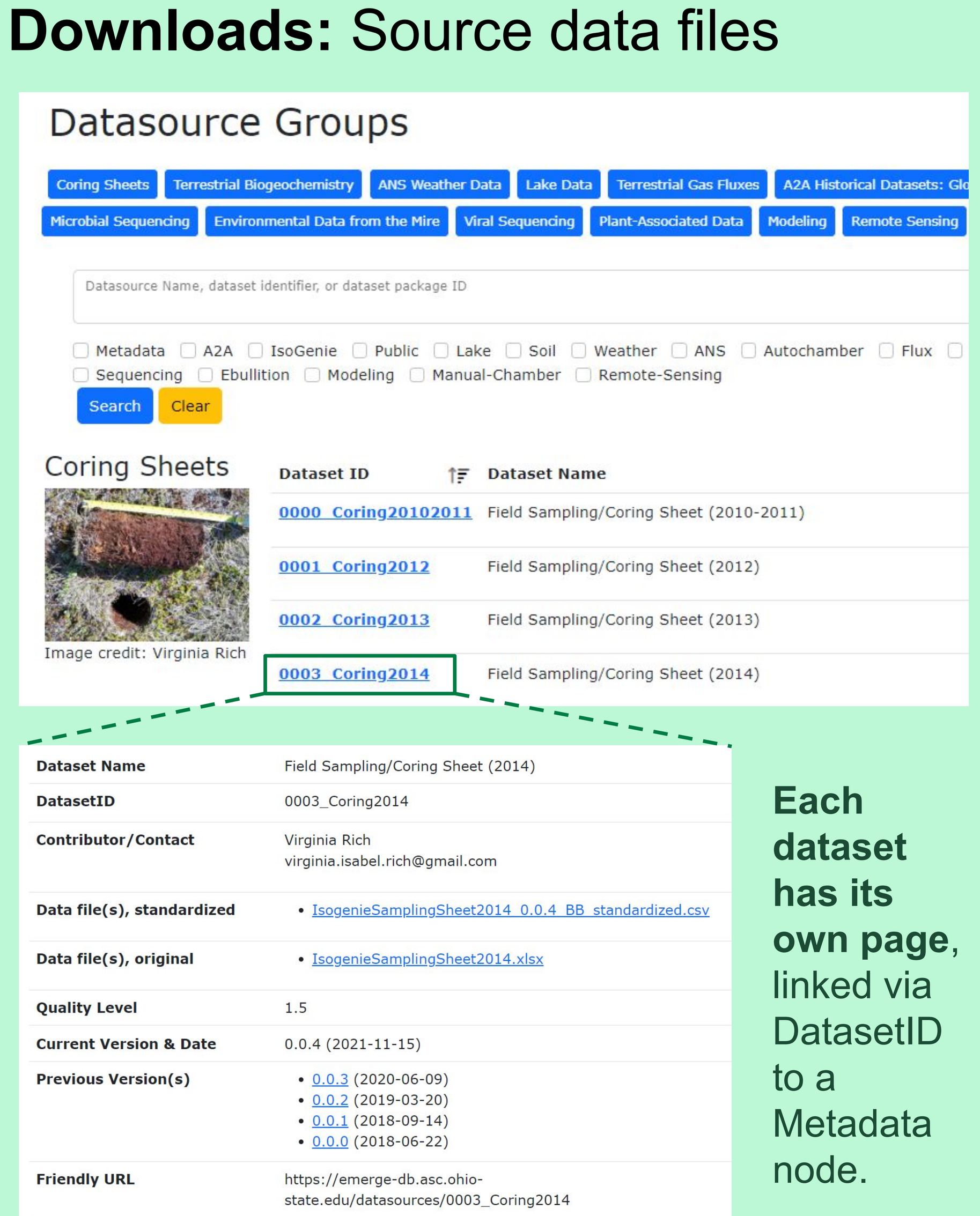


Pictures:

- Interactive repository of tagged field site photos.
- Downloadable image files include embedded metadata.



Downloads: Source data files



Each dataset has its own page, linked via DatasetID to a Metadata node.

Where applicable, Downloads pages include links to community data repositories.

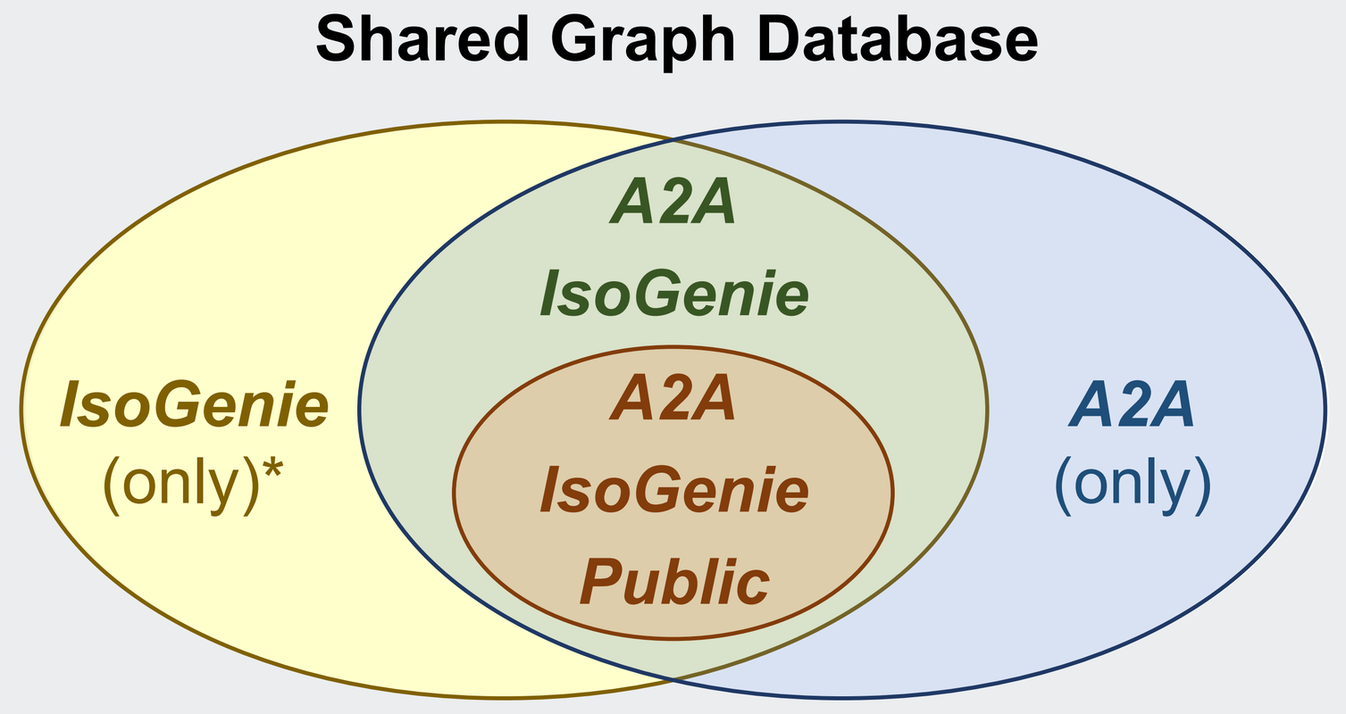
From EMERGE Data Management Plan:

"The EMERGE-DB is the hub of the DMP, while public data repositories and partner institutions' internal databases are the spokes."

GitHub · NCBI National Center for Biotechnology Information · zenodo · ProteomeXchange · Stockholm University | Bolin Centre for Climate Research

Managing Data Access

- The EMERGE-DB framework is shared by multiple related projects with both public and private data, necessitating a system for managing data access.
- **Access labels** are assigned to all nodes and used by the website to filter shared data by access rights.



* For historical reasons, **EMERGE** data uses the **IsoGenie** access label.

Figure modified from Bolduc & Hodgkins et al. (2020).

Conclusions

- Flexible data integration can be balanced with long-term data sharing via:
  - **Metadata standardization workflows** to facilitate data interoperability & reusability for integration.
  - **A central integrated data structure** that can be explored with custom queries.
  - **Links to records in community repositories** for long-term accessibility of the original datasets.
  - **A web portal providing access** to both the integrated data and the versioned original datasets, improving their findability.
- These broadly-applicable lessons for data management best practices from the EMERGE-DB team can provide a roadmap for other interdisciplinary teams building data management systems.

Reference

- Bolduc, B., Hodgkins, S. B., … & Rich, V. I. (2020). The IsoGenie database: an interdisciplinary data management solution for ecosystems biology and environmental research. *PeerJ*, *8*, e9467. https://doi.org/10.7717/peerj.9467

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