Mining Canada with GIS

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ABSTRACT

The Historical Canadian Mines Data Hub and Visualization Centre is an open-access on-line GIS application for learning about the mining history of Canada. This platform is a collection of information about Canadian mines and quarries, including operational and production details of mines that operated in Canada as long ago as 1774. Using the map tabs and filter settings, users can visualize trends in mining operations across the country over time, or view details on specific mines of interest. The initial mines dataset was collected mainly from provincial geological databases and was put into the public domain in May 2022. Moving forward, the goal is to enrich the historical mining data by adding basic technical information about the mining operations including dates of operation. The framework applied facilitates continuous updates and additions to the current dataset, including volunteered data from users. The mines hub is a valuable tool with a wide range of applications, from classroom teaching to informing policy. In the next stages of this project, collaborative storytelling will be enabled by attaching crowdsourced data to mine locations in PDF format.

1. Introduction: Historical Canadian Mines Data Hub

Mining of natural resources has played an integral role throughout Canada's history, influencing trends in settlement, the economy, policy and politics, and more. Two key books describe mining throughout Canada's history. The first describes the first 100 years of the development of Canada's minerals industries (Udd, 2000). The second tells stories of the towns, the workers, and significant mines from every period of mining in Canada (Sandlos and Keeling, 2021). Both are impressive chronicles of the development of Canada through mining, but they are targeted towards a narrow audience of those that are keenly interested or involved in the industry. As well, each book's content is constrained by an approximate 200-page limit, while accessibility to the information they contain is likewise constrained by the availability of existing printed copies.

The use of geological maps for showing the distribution of geologic features, the locations of mines and minerals, and landslide and erosion sites is common. However, with the rapid advancement of spatial data visualization techniques and tools in the field of Geographic Information Systems (GIS) over the past three decades, interactive geological maps are increasingly developed to visualize spatio-temporal patterns. In parallel with advancements in GIS and GITechnology, active debates arose within the scientific community around access and elitism in GIS, and questions around how GIS might be democratized became central in the nascent field of participatory GIS (PGIS), sometimes also referred to as public participation GIS (PPGIS) (e.g., Obermeyer, 1998; Carver et al., 2001; Sieber, 2006). At the same time, advancements were being made in the development of spatial decision support systems (SDSS): frameworks for decision-making that account for spatial elements or attributes important to a given decision-making process. While the definition of SDSS has been criticized for being loose and inconsistently applied (Keenan, 2003), scholars have agreed early on that GIS and SDSS as descriptive categories inevitably overlap to some degree (Carver et al., 2001; Keenan & Jankowski, 2019). Despite

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ongoing debate surrounding accessibility and democratization of GIS, online interactive mapping has become mainstream in recent years due to promises of broad and instantaneous user access, ease of maintaining data currency, and myriad opportunities for public engagement and participation, among others. Whether part of their central purpose or not, online mapping tools and applications often function as SDSSs, PGISs, or both. As technology continues to evolve in these fields, scholars and end users continue to recognize the nearly endless potential uses of online interactive mapping tools.

In Canada, the federal government provides an interactive digital map which collates producing mines across the country but only by location and commodity (The Atlas of Canada – Minerals and Mining). To obtain more information about particular mines, one must access the maps provided by the provinces, where each jurisdiction tracks different types of operations data. This project aims to capture and present standardized mining operation data for all of Canada in a single platform: the Historical Canadian Mines Data Hub and Visualization Centre (Mines Hub). The Mines Hub, which is now publicly accessible via the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) website, provides a national-level historical mining database that includes technical information and is publicly accessible to a broad audience. A similar example of a mines database that captures the spatial location along with consistent details is the New Mexico Uranium Mines Dashboard (arcgis.com). Like the Mines Hub, the New Mexico Uranium Mines Dashboard provides mine production years; unlike the Mines Hub, it does not allow the user to identify operating mines by year(s) of interest. The consolidation of existing data on Canadian historical mines could aid in academic research, training, education, business analysis, and policy development purposes.

The specific purpose of this research was to develop an interactive web-based dashboard for accessing, storing, visualizing, and continuing collection of information on mines in Canada throughout history and up to the present day. The threefold objectives are as follows: 1) the collation, and long-term presentation and preservation, of historical mining information in Canada, 2) enriching the historical mining data by adding technical information about mining operations and dates of operation, and 3) developing an interactive integrated historical mines dashboard to display the actual mining locations and associated descriptive statistics with the option to search and filter data. This paper is focused on the development of the interactive historical mines dashboard and its key functions.

2. Methods and Mines Data

2.1 Identifying Data for Collection

In teaching mining engineering courses at the University of Saskatchewan (USask), the lead author discovered that no one has collated a list of mining operations in Canada. An inspirational book for collecting data for the project was by Ryan Silke (2009). He developed a template to collate information including location, stage of development, descriptions of mine workings, details of the operations and equipment, and references. Other books such as the 2007 edition (Canadian Mining Journal, 2007) provide further support that it is reasonable to collect engineering data to describe mines.

Columns were created in an Excel file, including: mine name, alias (mines can change ownership often), province, type of operation, latitude, longitude, GIS reference for location, shaft depth (if applicable), processing method, production (tonnes), use of commodity, last stage of development, commodities, and dates of operation. Currently, the database covers 1774 to 2019, the year that data collection was completed. Additional columns including mining method, tailings impoundment type, and tailings facility type were added upon discovery that the Global

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Tailings Portal (Global Tailings Portal, 2022) currently has 229 mines identified in Canada. This type of information is of value as demonstrated by the importance of mining in Canada's history and the limited ways to access it presently. The Mines Hub may eventually help the Global Tailings Portal to add to their data and help to extend the project's reach to new audiences. Finally, the database allows users to attach pdf files to each data point. In future phases of this project, we plan to use this feature to increase the detail and information available about these mines via collaborative storytelling. Table 1 shows the current information presented (dependent on availability) for each data point within the Mines Hub.

2.2 Data Sources

Data incorporated into the mines database originates from multiple open-access sources as outlined in Table 2. For each data point, the mine name, location, and commodities produced are included at minimum. After an extensive and systematic internet search, geological databases were identified across Canada as the best initial source. These were reviewed to find all operations described as mines or quarries. A framework was created to present the data in a digital format that allows for the addition of technical data through crowdsourcing. If other information identified for collection existed, that data was also downloaded and copied into the appropriate columns within the provincial dataset in Excel format. In many cases, this required reading text entries to extract additional information such as dates of operation. Throughout this process, multiple sources of data including the 900A map series (Geological Survey of Canada, 1947 to 2016) were consulted and dates of operation for many mines were manually extracted.

2.2 Data Preparation and Integration

The available information on Canadian mines as per Columns 2 and 3 of Table 1 was initially compiled by province in Excel sheets. These provincial data files were merged into a single Excel spreadsheet for further data cleaning and data transformation. Data checks were performed to identify outliers. Some data points initially appeared to be located outside Canadian borders due to coordinate errors, and when possible, their coordinates were corrected.

Information about mine commodities is recorded in eight separate columns (only two are shown in lines 35 and 36 of Table 1 due to space constraints). A formulaic column (Commodities) was created to consolidate all commodities produced at a single mine site into a single column to facilitate searching and filtering within the dashboard. Based on the commodity type, mines were categorized into groups (including fuel, geothermal, mineral, rock/stone, unconsolidated material, or other) and sub-groups. Initially, the years of production were recorded in separate columns. There are 254 columns for specifying the active year(s) of production for each mine, starting from 1770. A new column (999) for mines with missing years of operation/production, and four calculated columns to summarize the years of operation information (e.g., total production years, first and last production year, etc.) were added. Column 4 of Table 1 provides a brief description of variable types and Excel formulas used to organize the data.

The initial data arrangement for years of production in separate year columns did not support searching mines by specific years of operation and required restructuring. Using the Power Query tool in Excel, a group of year columns (from 1970 – 2025, with 999 for missing year information) were transformed into one variable group (Year) and saved in a new file. Lastly, two interrelated csv files were prepared for storing: 1) mine information including geographic coordinates, commodity groups; and 2) restructured years of production in single year column. The tables were linked using a one-to-many relationship based on a common Mine Identifier (MUID) column.

Table 1: Sample Record for a Canadian Mine

Sr	Variable Name	Data Sample	Description/Status/formula
1	Data_File	BC	Provincial file information/identifier
2	MUID	BC970	Unique identifier
3	Mine_Name	Comox	Mine name
4	Alias	Cumberland	Mine alias
5	Province	British Columbia	Province full name
6	Type_Code	U	Initially used for data recording
7	Type	Underground	Mining type
8	Latitude	49.631388	Geographic coordinate (WGS84)
9	Longitude	-125.03805	Geographic coordinate (WGS84)
10	Location		Basic description of mine location (no data)
11	GIS_Source	BC-1	GIS data source
12	GIS_Source_Link	https://min-file.gov.bc.ca/	GIS data URL
13	GIS_Source_Ref	092F 315	Topographic sheet number
14	Mining_Method		Categorical
15	Shaft	N/A	[yes; no; na]
16	Shaft_Depth		(data will be collected in next round)
17	Access_Type		no data (data will be collected in next round)
18	Processing_Method	N/A	Categorical
19	Mine_Production	>10,000,000 Tonne	Categorical
20	Mill_OnSite		no data (data will be collected in next round)
21	Mine_Backfill		no data (data will be collected in next round)
22	Tailings_Facility_Type		no data (data will be collected in next round)
23	Tailings_Impound-ment_Type		no data (data will be collected in next round)
24	Use_Commodity		Diverse options
25	LastStage_Development	Producer	Categorical
26	Date_Operation_Known	Yes	[yes; no; na]; [IF(AG3=0, "N/A", "Yes")]
27	Years of Known Operation	58	Count; [COUNTIF(AX3:KM3, "X")]
28	Production_Start	1888	Year; [IFERROR(INDEX($AX$1:$KS$1,MATCH(TRUE,IN-DEX(AX2:KS2<>"",),0)),"")]
29	Production_End	1953	Year; [IFERROR(LOOKUP(2, 1/(AX2:KS2<>""),$AX$1:$KS$1), "")]
30	Commodity_Classification	Fossil Fuels	4 Groups (fossil fuels, metals, non-metals, others)
31	Commodity_Group	Fuel	5 Groups (fuel, mineral, rock, unconsolidated material, other)
32	Commodity_subGroup	Coal	16 subgroups
34	Commodities	Coal, Fireclay	List; [TEXTJOIN(", ", TRUE, AP2, AQ2,AR2,AS2,AT2,AU2,AV2,AW2)]
35	Commodity1	Coal	Primary commodity
36	Commodity2	Fireclay	commodity
43	999		Missing year information
44	1770		Starting year
162	1888	X	
163	1889	X	
164	1890	X	
165	1891	X	
166	1892	X	
167	1893	X	
168	1894	X	
169	1895	X	
170	1896	X	
171	1897	X	
172	1898		

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Table 2: Province and Data Source

Province	Data Source
British Columbia	B.C. MINFILE, Ministry of Energy, Mines and Petroleum Resources
Alberta	Alberta Energy Regulator (2015); Alberta Government Oil Sands Information Portal, Mychaluk et al (2001)
Saskatchewan	Saskatchewan Mineral Deposit Index
Manitoba	Manitoba Mineral Resources, Mineral Inventory Cards
Ontario	Ontario Ministry of Mines, Abandoned Mines
Quebec	Énergie et Ressources Quebec, Système d'information géominière du Québec
New Brunswick	New Brunswick Natural Resources and Energy Development, Mineral Occurrences and Industrial Minerals Databases
Nova Scotia	Nova Scotia Natural Resources, The Nova Scotia Mineral Occurrence Database; Nova Scotia Department of Lands and Forestry, 2020. Nova Scotia Abandoned Mine Openings Database; Adams (1991)
Newfoundland and Labrador	Newfoundland and Labrador Department of Natural Resources, Mineral Occurrence Data System Database
Northwest Territories	Silke (2009)
Nunavut	Wikipedia
Yukon	Yukon, Minefile

2.4 Developing the Dashboard

The final step was to develop the historical mining dashboard. For visualization, we considered Tableau and Microsoft Power BI, but eventually opted for ESRI's ArcGIS Dashboard App. ESRI's online platform is intuitive to program with, and it has customizable data handling and geo-visualization features. After considering various options for storing and updating data at regular intervals, the authors chose to store the data using enterprise geodatabase in SQL Server database and published the data as an ArcGIS feature service (mine location layer, and mine year of production) via ArcGIS Server which offers high functionality and an optimal visualization format. An ArcGIS web map was then created where these feature layers were added along with other data layers. In addition to the actual mine locations, the mining and geology exhibits across Canada that have potential for tourism are included. The number of mines by regional municipalities and surficial geology are included as separate layers in the web map. The second and third authors have previous experience in developing online mapping dashboards (see Ingram et al., 2021), and were able to draw on this throughout to enhance the design and functionality of the Mines Hub.

2.5 Stakeholder Feedback on Mines Hub

The Canadian Institute of Mining, Metallurgy and Petroleum (CIM) was formed in 1898 via an Act of Parliament of Canada. The Mines Hub directly supports CIM's vision, to be "the trusted authority & collective source for advancing mineral industry knowledge, guidelines & best practices" (CIM, 2022). Hence, CIM Magazine highlighted this project as a 2022 Editors' pick (CIM Magazine, 2022). Further, CIM has taken the opportunity to provide a direct link to the Mines Hub on their website (https://www.cim.org/the-hub/).

Since the launch of the Mines Hub dashboard, we have received interest from several early users, and have engaged in online interactions with three governmental bodies as a result: the Provinces of British Columbia and Nova Scotia, and Natural Resources Canada. The value of Canada's mineral production reached $55.5 billion in 2021 (Government of Canada, 2022), so it is in the

best interest of Canadian governments that mining remains strong if this financial base is to continue. “It sometimes is said that it takes 500-1,000 grassroots exploration projects to identify 100 targets for advanced exploration, which in turn lead to 10 development projects, 1 of which becomes a profitable mine” (Eggert, 2010). Furthermore, it is not uncommon for mines to take between 10 and 20 years to get from the discovery to production phase. All mines have finite resources so exploration must continue. The provinces provide searchable open-source geological databases (Table 2) to support the mineral industry of their jurisdiction. The Mines Hub is one universal application that standardizes data into a common format so that users can compare various attributes of mines nationwide.

The lead author and CIM Magazine posted on the social media platform *LinkedIn* to request additional data. Responses to these posts allowed the authors to expand the list of mining museums across Canada from 12 to 42. Additional historical books on mining in Canada were added as the result of another targeted post. The authors have not yet received volunteered information from mine employees regarding missing mines or missing data on mines included in the database. Informal conversations with engineers from mining companies suggest that this is due to onerous internal approvals processes required to release this information. The information being requested (Table 1) is general in nature and is mostly to the benefit of post-secondary students studying mining. To raise awareness around this issue, the lead author published an article in the Canadian Mining Journal entitled “Mining engineering hit a roadblock” (Beneteau, 2022).

Students and professors in postsecondary academic settings have been among the first active users of the Mines Hub. For example, a graduate student at University of Saskatchewan used the database to identify where sulfide producing minerals may be found in Canada, while another graduate student from Laurentian University reached out to learn more about the location of Canadian mines to support their research project. The Mines Hub has also facilitated connections among users: the lead author and a University of Saskatchewan humanities researcher have begun sharing resources upon realizing that they are both working on projects that examine similar materials. Finally, the Mines Hub has already received uptake as a learning tool. Use of the database has been built into an energy related research project for first-year engineering students at the University of Saskatchewan. Students will be required to conduct basic data analysis on Mines Hub data by taking advantage of the download formats and analysis tools available via the interface.

The Mines Hub will be updated on a continuous basis with write-ups, photos, and other mining related research and literature sourced from users. When the database was launched, we were provided with enhanced data on the Patience Lake Mine from Toby Cote of Saskatoon, who had documented her father’s (Harvey Laberge) experience starting the mining operation as a driller. We were also able to add a *Canadian Geographical Journal* article (Burke, 1961) to the site based on user feedback. The article describes mining in the Haliburton, Ontario area from the perspective of a Canadian geography teacher. Canada’s mining industry has a long history of contributing to local and regional economies and capturing a broad array of citizen and worker perspectives is integral to a deeper understanding of mining throughout Canada’s history.

3. Results and Discussion

3.1 Historical Mining Data and ArcGIS Web Map

The first dataset included 14,211 unique data points, each with a location in Canada. As per Table 3, Ontario has the most at 6166 and Nunavut the least at 10. Underground mines are the most common of all the mine types, with 5017 mines identified as underground. This is partly due to

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the large number of coal mines in Alberta and Saskatchewan. In Table 3, zeroes suggest that no mines within a given category have yet been identified. These findings are subject to change as the initial dataset is improved by crowdsourced data and additional sources.

For display purposes, the historical mines were presented in four different layers, each layer differently classified using commodity groups (6 categories), mine type (17 types in total), production size (<1 Tonne, 1 to 10 Tonne, >10 to 100 Tonne, >100 to 1000 Tonne, >1000 to 10,000 Tonne, >10,000 to 100,000 Tonne, >100,000 to 1,000,000 Tonne, >1,000,000 to 10,000,000 Tonne, >10,000,000 Tonne, N/A), and number of known years of production (no data, 1-25 years, 26-50 year, 51-100 years, and more than 100 years). Out of 14,211 mines, 7591 are currently missing years of operation/production data, which we will seek to update over time.

Table 3: Breakdown of Records by Province

Province/Territory	Fuel	Mineral	Rock	Unconsolidated material	Other	Total Mines
Newfoundland and Labrador	4	141	51	4	0	200
Nova Scotia	104	173	29	1	1	308
New Brunswick	0	59	30	0	2	91
Quebec	0	790	6	6	1,134	1,936
Ontario	7	4,427	929	52	751	6,166
Manitoba	9	107	22	5	0	143
Saskatchewan	407	132	0	2	5	546
Alberta	2,510	5	0	8	3	2,526
British Columbia	95	1,751	235	47	6	2,134
Nunavut	0	9	0	0	1	10
Northwest Territories	0	89	0	0	1	90
Yukon	8	52	0	0	1	61
Total (Canada)	3,144	7,735	1,302	125	1,905	14,211

3.2 Historical Canadian Mines Dashboard

The dashboard incorporates six main features as shown in Figure 1. Users can apply filters (Figure 1, Area A) to select mines based on features such as years of production, commodity, mine type, region, and mine tonnage. For example, one can click on the tonnage (>100,000 to 1,000,000 tonnes) and only the highest producing mines in the history of Canada will appear. The date feature (Figure 1, Area B) adds further value to this project by allowing users to display only those mines operating within a chosen range of years. Filters can be applied contemporaneously. For example, if 2019-2019 is selected as the date range while the previous high-tonnage filter is still active, only the highest producing mines operating in Canada in 2019 are displayed. The database offers easy navigation and the opportunity to be updated to reflect current realities, in contrast to the existing records in books and inconsistent provincial databases.

The database accounts for differences among mines by documenting individual descriptors of each mine and making them searchable. For example, someone may be interested in knowing the locations of surface pits, shaft openings, or mining properties where tailings have been reprocessed. There are 17 different types of mines identified by the Mines Hub. Mines are not searchable by individual commodities in other Canadian mining databases (e.g., Natural Resources Canada, 2022) because commodities are typically included only in combination. This has made it previously impossible to simply search “gold” to find all gold mines in Canada because

this would not return mines that produce more than just gold (e.g., gold, gold-silver, gold-copper, etc.). In the Mines Hub database, searches can be done on primary commodities, allowing users to identify all mines that have produced a given commodity of interest.

Subcategories of commodities are shown in Figure 1, Area C, and are organized into fuel, geothermal, minerals, rock/stone, unconsolidated material, and other. Figure 1, Area D is used to toggle layers on and off, and to select the preferred base map. The interactive window can be changed by toggling between tabs in Area E, and charts showing alternative data visualization options can be selected in Area F. A safety warning at the top of the window reminds users to stay out of abandoned mines.

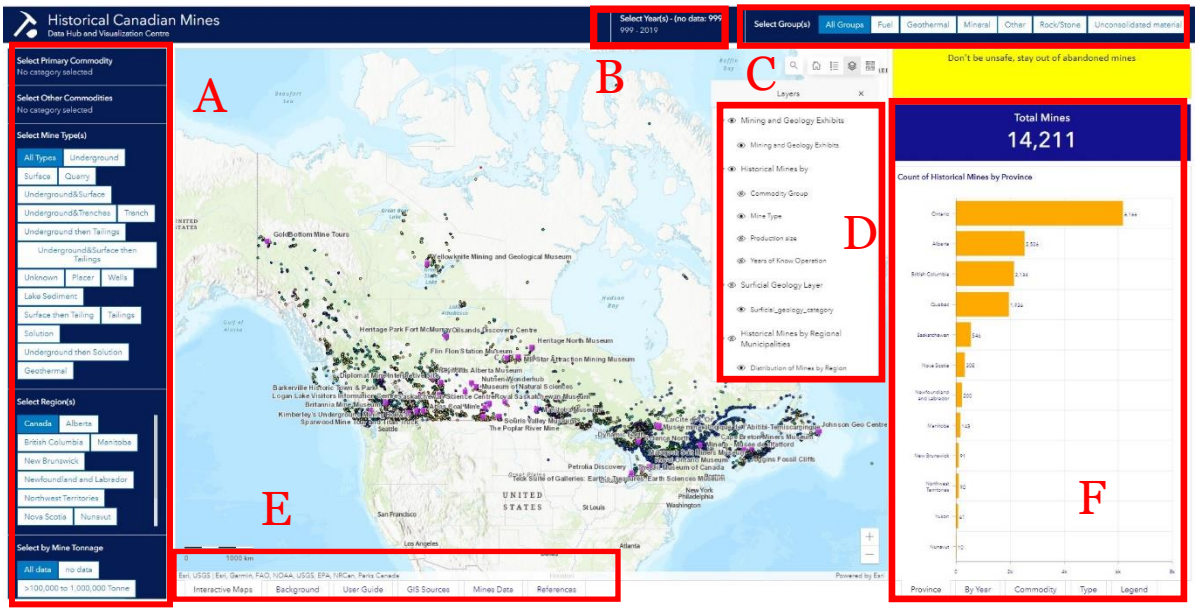

Figure 1: Interactive map window identifying features, including: A) data filter; C) commodity filters D) tabs that control display in window; E) page filter; and F) charts. Dashboard link: [Canadian Historical Mines (arcgis.com)]

3.3 Additional Resources

A key way to learn about mining in Canada is to visit museums and geology exhibits across the country. We have identified 42 public venues to date, primarily through crowdsourcing information on LinkedIn. This layer can be toggled on and off using the features in Figure 1, Area D. Tourist associations have been contacted across the country to assist in identifying other educational mining exhibits.

Historical books on Canadian Mining can be difficult to find as many are out of print. The authors are currently crowdsourcing information on historical books that may provide further information to continue to build the database. A tab can be accessed in Figure 1, Area E where pdf versions of these books will be made available in this area of the Mines Hub upon receiving consent from publishers.

4. Conclusion

The platform is designed to collect and present information about historical and currently operating mines across Canada, as well as information about relevant museums, exhibits, and books. In the future, we plan to enhance this application by adding pdf attachments to data points which will offer users greater detail about mining operations. Using collaborative storytelling

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through crowdsourced data, the Mines Hub will be able to offer personal accounts and stories about mines alongside the technical data. The data contained within the Mines Hub will continue to grow and will represent a more comprehensive view of Canada's mining history over time through crowdsourcing and the addition of information from the Atlas of Canada.

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