Development of a Database of Rare-Earth Element Occurrences and Characteristics for the East Kootenay Coalfields of Southeastern British Columbia (NTS 082G/10, 15): Proposed Work

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Introduction

Rare-earth elements (REE) are a group of 17 elements in the periodic table that include 15 lanthanides and two chemically similar transition metals—scandium and yttrium. Using their atomic number, REE are classified as heavy or light, with elements from Tb to Lu and Y belonging to the former group, and La to Gd and Sc belonging to the latter group (Moldoveanu and Papangelakis, 2013; Zhang et al., 2015). With the emergence of new clean energy and defence-related technologies, consumption of REE has increased rapidly (Tse, 2011). For example, it is projected that the demand for dysprosium will increase by as much as 2600% by 2025 (Standing Committee on Natural Resources, 2014). In addition to increased demand, it is expected that traditional rare earth ore deposits will be exhausted in the near future (Seredin and Dai, 2012). Based on this projected increased demand and dwindling supply, the United States (U.S.) and the European Union have classified REE as critical elements, due to their importance in clean energy and defence applications (U.S. Department of Energy, 2010; European Commission, 2017). The National Energy Technology Laboratory (NETL) in the United States has conducted a prospective analysis of coal deposits as a source of REE using the coal database of the U.S. Geological Survey (USGS), which contains concentrations of rare-earth elements from coalfields across the United States (Bryan et al., 2015). The NETL has launched the ‘Feasibility of Recovering Rare Earth Elements’ program to demonstrate the technological and economic (techno-economic) feasibility of developing domestic technologies for separation of REE from coal and/or its byproducts. The study uses samples that contain a minimum of 300 ppm total REE and attempts to concentrate the REE to a level greater than or equal to 2% (by weight) in processed streams (U.S. Department of Energy, 2016). The program will focus on areas of research such as resource sampling and characterization, separation technology development, REE sensor development, process and systems modelling, and techno-economic analyses (U.S. Department of Energy, 2016).

The presence of REE has been documented in some Canadian coal deposits, especially in British Columbia (BC) coalfields (Goodarzi, 1988; Birk and White, 1991; Goodarzi et al., 2009); however, there is no proper quantification of their concentration, nor is there characterization or extraction analysis currently available for coal deposits in BC, or for coal deposits in other parts of Canada. Therefore, the first objective of this study is to develop a database of REE occurrences in the East Kootenay coalfields of southeastern BC (Figure 1), using samples collected in the field, and to identify the potential best coal sources of REE in the area. Using the data collected in the first phase, Phase 2 of the study will explore the possibility of extracting the REE from these sources. Some of the initial results of the study were reported previously (Kumar et al., 2018; Kuppusamy and Holuszko, 2019).

Background

U.S. Geological Survey’s COALQUAL Database

During the 1970s energy crisis, the USGS developed the National Coal Resources Data System (NCRDS), which is a comprehensive database of coal resources in the United States (Finkelman et al., 1994). The USCHEM (United States geochemical database) is an interactive digital version of the NCRDS that contains information for more than 13 000 samples from major coal basins in the United States (Palmer et al., 2015). The COALQUAL database, which is a subset of 7430 samples from the USCHEM database (Bragg et al., 1994), was published in 1994. For each sample in the COALQUAL database, 136 parameters were collected, including coal type, proximate analysis data, ulti-

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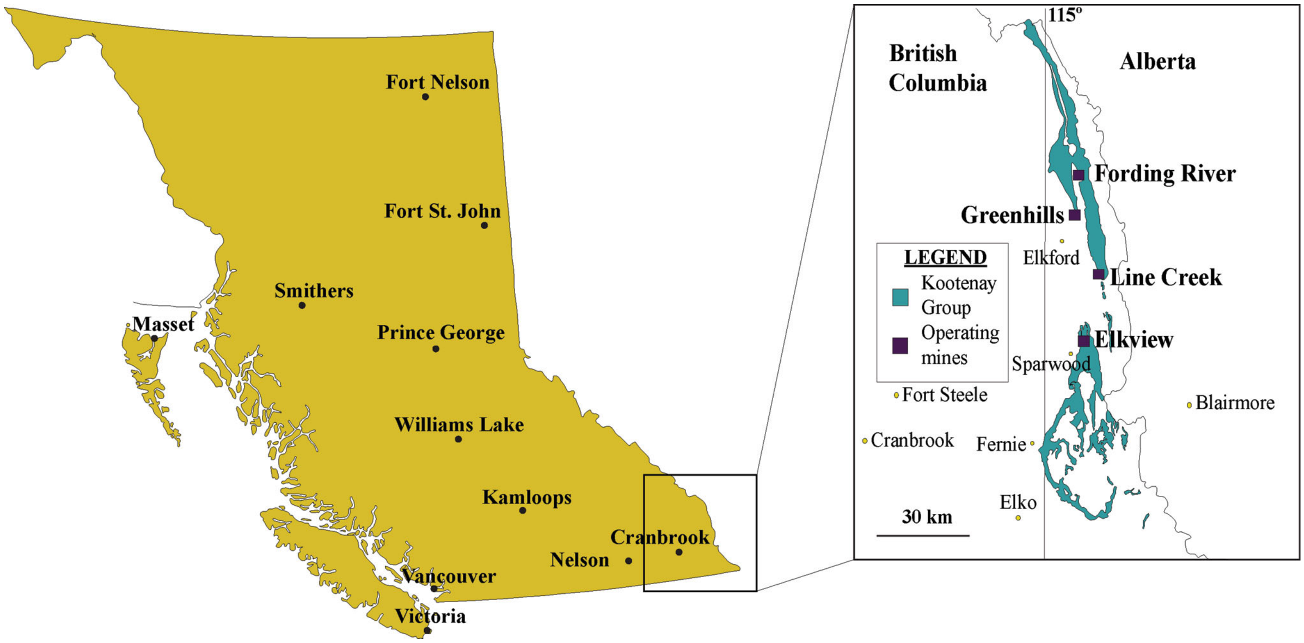

Figure 1. Location of East Kootenay coalfields and operating coal mines in southeastern British Columbia (adapted from BC Geological Survey, 2019).

mate analysis data, and major-, minor- and trace-elements analysis data (Finkelman et al., 1994). Figure 2 is an example of a COALQUAL sample detail page.

In 2015, an updated version (3.0) of the COALQUAL database was published, with 7657 samples (Palmer et al., 2015). Using the original database as a guideline, further investigations had been carried out to characterize and physically enrich the data on REE from coal-related feedstocks (e.g., produced coals, coal waste, coal ash from power plants) in the United States (Akdogan and Ghosh, 2014; Honaker et al., 2015; Miskovic, 2015; Soundarrajan et al., 2015).

Project Description

The purpose of this investigation is to assess BC coal deposits as possible sources of REE for extraction. During the first phase of the project, a database of REE distribution in the East Kootenay coalfields of southeastern BC will be created, one similar to the USGS COALQUAL database, but more simplified in terms of number of parameters collected and focusing on characteristics of REE in the study area. To develop the database, various samples of coal will be collected from different mines in the study area and analyzed for their REE concentration using inductively coupled plasma–mass spectrometry.

Further, stratigraphic variation in REE concentration has been reported in some United States coal deposits (Hower et al., 1999; Rozelle et al., 2016). Figure 3 shows the stratigraphic variation in REE concentration in samples from the West Kentucky No. 13 coal seam. To capture possible similar stratigraphic variations in REE content in the study area, for each coal seam sample collected, the associated roof, floor and partings waste rock samples will also be collected and analyzed for their REE concentration. Understanding these variations in REE concentration is important, since the mined coal is generally processed to remove undesirable impurities, such as deleterious minerals and sulphur, to meet market quality requirements. During coal processing, REE tend to concentrate in clean coal or waste tailings, depending on the nature of the REE association in the feed (Kumar et al., 2018; Kuppusamy and Holuszko, 2019); REE in coal can occur in several different modes, such as ion-adsorbed minerals, aluminosilicate minerals, accessory minerals, authigenic minerals, submicron minerals and in organic association (Hower et al., 1999, 2018; Dai et al., 2002; Seredin and Finkelman, 2008; Seredin and Dai, 2012; Zhang et al., 2015). To identify the nature of the REE mineral carriers in the study area, a select few samples will be characterized using techniques such as X-ray diffraction analysis, scanning electron microscope–energy dispersive spectrometry, and electron probe microanalyzer.

This first phase of work, which consists of database development and preliminary characterization of REE in the samples collected, is currently being carried out and is anticipated to be completed by March or April 2020. Based on the results, the second phase of the project will focus on advanced characterization of selected samples, and lab-scale extraction of the REE in the coal-related feedstocks. This will enable an assessment of the possibility of using BC coal deposits as potential resources for REE extraction.

USGS science for a changing world — COALQUAL Database

Sample Detail for W218790

View Definitions of Qualifiers and Parameters

Sample Description	
Sample ID	W218790
State	Kentucky
County	CLAY
Latitude	37.2203
Longitude	-83.8561
Province	EASTERN
Region	CENTRAL APPALACHIAN
Field	
District	SOUTHWESTERN
Formation	BREATHITT
Group	
Bed	MANCHESTER
Member	
Coal Zone	
Depth (in)	0
Thickness (in)	9.4
System	Pennsylvanian
Series/Epoch	
Literature	
Comments	
Map	MANCHESTER (7.5')
Collector	KYGS-CURRENS J C
Mine/Power Plant	SURFACE MINE
Drill Core No	
Point Id	KGS 698
Submit Date	12/16/1982
Sample Description	BITUMINOUS COAL
Estimated Rank	BITUMINOUS
Apparent Rank	High volatile A bituminous
Analytical Labs	GT and USGS
Sample Type	Channel
Analysis Type	As Received
Values Represent	Single sample
Township	
Range	

Proximate & Ultimate	
Sample ID	W218790
Moisture	3.53
Moisture Q	
Volatile Matter	39.99
Volatile Matter Q	
Fixed Carbon	52.34
Fixed Carbon Q	
Standard Ash	4.14
Standard Ash Q	
Proximate Validation	Acceptable
Hydrogen	5.38
Hydrogen Q	
Carbon	77.2
Carbon Q	
Nitrogen	1.8
Nitrogen Q	
Oxygen	7.39
Oxygen Q	
Sulfur	0.56
Sulfur Q	
Ultimate Validation	Excellent
Btu	13915
Btu Q	
Sulfate Sulfur	0.01
Sulfate Sulfur Q	
Pyritic Sulfur	0.03
Pyritic Sulfur Q	
Organic Sulfur	0.52
Organic Sulfur Q	
Ash Deformation	2800
Ash Deformation Q	G
Ash Softening	2800
Ash Softening Q	G
Ash Fluid	2800
Ash Fluid Q	G

Oxide	
Sample ID	W218790
Remnant Moisture	1.23
Remnant Moisture Q	r
GSAsh	4.1
GSAsh Q	
SiO_2	49.2
SiO_2 Q	o
Al_2O_3	32.7
Al_2O_3 Q	o
CaO	1.65
CaO Q	o
MgO	0.764
MgO Q	o
MnO	0.0057
MnO Q	
Na_2O	0.932
Na_2O Q	o
K_2O	1.26
K_2O Q	o
Fe_2O_3	3.27
Fe_2O_3 Q	o
TiO_2	1.49
TiO_2 Q	o
P_2O_5	
P_2O_5 Q	B
SO_3	
SO_3 Q	B
LOI	

Trace Element	
Sample ID	W218790
GS Ash Dry	4.15
GS Ash Dry Q	
Si	9550
Si Q	
Al	7180
Al Q	
Ca	490
Ca Q	
Mg	191
Mg Q	
Na	286
Na Q	
K	436
K Q	
Fe	951
Fe Q	
Ti	370
Ti Q	
TS	
TS Q	B
Ag	0.0145
Ag Q	
As	0.506
As Q	
Au	0.29
Au Q	L
B	17.4
B Q	
Ba	15.4
Ba Q	
Be	2.78
Be Q	
Bi	0.42
Bi Q	L

Figure 2. Example of a ‘Sample Detail’ page from the U.S. Geological Survey’s (USGS) COALQUAL database.

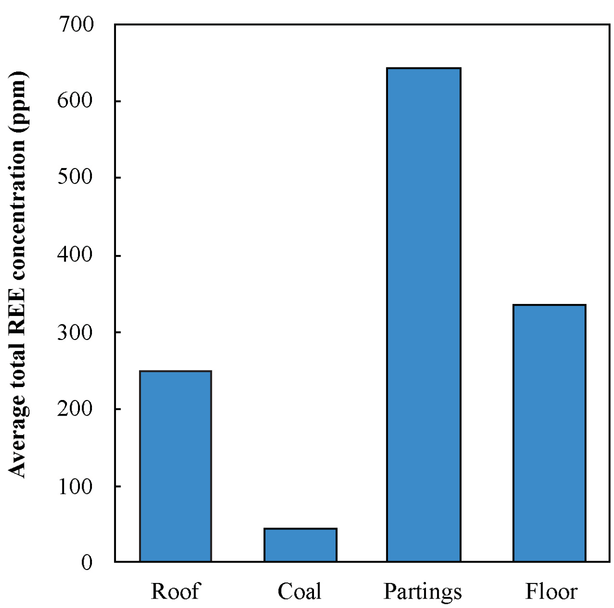

Figure 3. Average rare-earth element (REE) concentration (whole-coal basis, ppm) in roof, coal, partings and floor core samples from the West Kentucky No. 13 seam (data used is from Yang et al., 2019).

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