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Invited research article

Elemental concentration and organic petrology of unique liptinite-rich humic coal, canneloid shale, and cannel coal of Devonian age from Arctic Canada

Fariborz Goodarzi[a], Thomas Gentzis[b,*]

[a] FG & Partners Ltd., Calgary, AB, T3G 3J4, Canada
[b] Core Laboratories, 6316 Windfern Road, Houston, TX 77040, USA

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ABSTRACT

Seventeen coal and carbonaceous shale samples taken from eight stratigraphic sections of the Devonian Hecla Bay and Weatherall formations in Arctic Canada, were examined using reflected light microscopy, instrumental neutron activation analysis (INAA), and inductively coupled plasma emission spectroscopy (ICPES). Samples consist of humic coal with 62–79 vol% vitrinite, liptinite-rich humic coal with 42 vol% liptinite, and cannel coal with 52–81 vol% sporinite content. Carbonaceous shale has 46–73 vol% mineral matter and canneloid shale has 30–42 vol% mineral matter as well as 22–38 vol% sporinite content. Most were deposited in areas characterized by minor channel cut-and-abandonment and lake and bay infills peripheral to distributary complexes. A fresh water environment is indicated by Boron (18–71 ppm), low inertinite (0–7.8 wt%), and high sporinite content (30–81 vol%). The ratio of Na/K versus liptinite content shows that coals and associated sediments from the Hecla Bay Formation experienced a more rapid rate of sedimentation than the carbonaceous shales from the Weatherall Formation. The highest total REEs and LREE (La-Gd) was in the liptinite-rich humic coal, followed by humic coal and carbonaceous shale. The concentration of REEs and LREEs in the cannel coals is half of that measured in the liptinite-rich humic coal. The PAAS normalized for oil shales follows two different patterns: 1) the liptinite-rich coal samples display a sharp increase from Nd to Ho, then maintain a similar pattern up to Lu; and 2) samples of other lithologies increase from Nd to Dy, and then maintain a flat trend up to Lu. Hierarchical cluster analysis shows that canneloid and liptinite-rich coal exhibit the greatest similarity with each other whereas humic coal and liptinite-rich coal show the greatest dissimilarity with carbonaceous shale.

1. Introduction

Bituminous coals occur in all geological provinces in the Canadian Arctic Archipelago, with the exception of the Arctic Coastal Plain (Ricketts and Embry, 1984). The Devonian clastic wedge contains the oldest coals found in the western Arctic Islands and extends across the Arctic Islands representing the final phase of deposition in the Franklinian Basin (Embry and Klovan, 1976; Goodarzi and Goodbody, 1990a; Goodarzi and Goodbody, 1990b). The clastic wedge is interpreted as a regressive succession that contains submarine fan, marine-slope, marine-shelf, deltaic, and fluvial deposits (Embry and Klovan, 1976). In the western Arctic Islands, coal seams are found in the Hecla Bay, Beverley Inlet, and Parry Islands formations, which include all the fluvio-deltaic strata of the wedge in this region (Goodarzi and Goodbody, 1990a; Goodarzi and Goodbody, 1990b). The Devonian coal seams are thin (20-30 cm), stratigraphically widely spaced, and their lateral extent is unknown. These coals are subbituminous C to high volatile bituminous B in rank (Fortier et al., 1963; Goodarzi and Goodbody, 1990a; Goodarzi et al., 1993; Goodarzi and Goodbody, 1990b; Ricketts and Embry, 1984; Tozer and Thorsteinsson, 1964). The oldest coals found in Canada are of Devonian age and include cannel coals (Goodarzi and Goodbody, 1990a; Goodarzi et al., 1993; Goodarzi and Goodbody, 1990b). Many of the coals in Melville Island that will discuss in this study are cannel coals.

This research is part of a major program on energy deposits, such as oil shales and liptinite-rich (i.e., cannel) coal aimed to characterize their potential for hydrocarbon extraction as well as the possible environmental impact during extraction of hydrocarbon in *ex situ* (i.e., mining/retorting) and *in situ* (i.e. underground) operations. The purpose of the present study is to report on: 1) the elemental composition of Devonian coals from Melville Island (Figs. 1 and 2) to relate the variation of elements of these coals to their environment(s) of

* Corresponding author.
E-mail addresses: fgoodarzi@shaw.ca (F. Goodarzi), thomas.gentzis@corelab.com (T. Gentzis).

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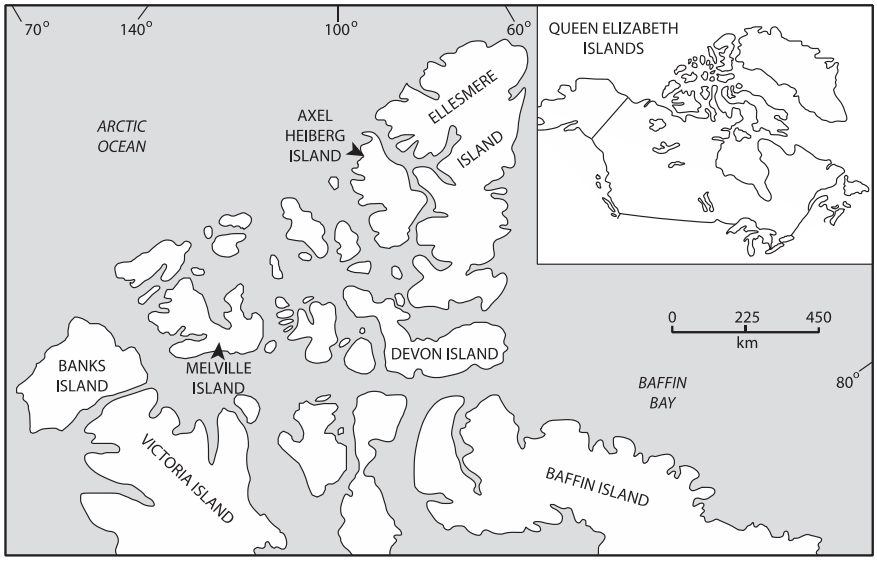

Fig. 1. Location of Melville Island, Arctic Canada.

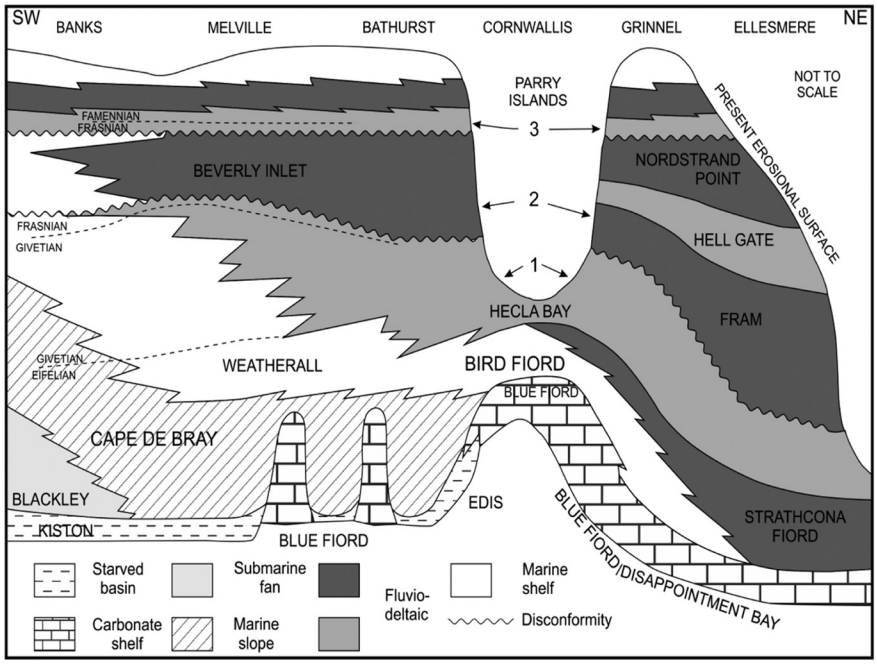

Fig. 2. A cross section of Devonian classic wedges containing coals, Hecla Bay (1), Beverly Inlet (2) and Perry Islands (3) in the Canadian Arctic Islands (after (Goodarzi and Goodbody, 1990a; Goodarzi and Goodbody, 1990b)).

deposition.

1.1. Cannel coal

Cannel coals are considered to be terrestrial oil shales deposited in stagnant, oxygen-depleted water on land. They are composed of organic matter derived primarily from corky tissues, plant resins and waxes, pollen grains, and spores of vascular plants. Cannel coals can be divided into two varieties: cutinite-rich or sporinite-rich. The cutinite-rich cannel coals are similar to the 'leaf coal', as described by Teichmüller (1962) for the soft brown coal from Germany and by Ammosov (Ammosov, 1964) for the Devonian leaf coal from Germany and the Devonian coal from Barzas, Russia. Those coals contain up to 50 vol% cutinite that originates from the thick cuticles of psilophytes. The Moscow 'leaf coal' is Carboniferous in age and has a thickness of up to 1 m (Ammosov, 1964). Carboniferous leaf coals were also found in Upper Silesia, Germany, northern France, in the Pottsville Formation of Indiana, USA, and in Queensland, Australia (Bode, 1931; Cook and Taylor, 1963; Duparque, 1927; Guennel and Neavel, 1959). On the other hand, sporinite-rich cannel contains both megasporinite and microsporinite (tenuisporinite and crassisporinite, respectively) (Goodarzi and Goodbody, 1990a; Goodarzi and Goodbody, 1990b; Stach, 1982). Part of the energy deposits in Arctic Canada include oil shale of Carboniferous to Ordovician age and the Devonian cannel and canneloid deposit of Melville Island.

1.2. Depositional environment

During the Givetian, submerged plants (psilophytes) grew in shallow lagoons. Thin coal layers derived from such plants are known,