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Unusual resinite-rich coals found in northeastern Greenland and along the Norwegian coast: Petrographic and geochemical composition

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ABSTRACT

Middle Jurassic coals unusually rich in resinite/liptinite are known in northeastern Greenland from a few outcrops and from several erratic pieces. In addition, since the mid-1800's a number of loose pieces of resinite-rich coal, the so-called Kvæfjord coal, have been found along the Norwegian coast in or close to the shore zone in places where it would have been impossible for the coal to originate from passing ships. This study presents a comprehensive organic petrographic and geochemical investigation of two new pieces of resinite-rich coal found on Store Koldewey in northeastern Greenland, a resinite-rich core sample from the Norwegian island Andøya, and two pieces of the Norwegian Kvæfjord coal. The coals are thermally immature and contain an extraordinary high content of liptinite and in particular resinite (34.2–93.6 vol.%). The two coal pieces from Store Koldewey and the core sample from Andøya are compositionally comparable to the resinite/liptinite-rich Middle Jurassic coals that crop out on Hochstetter Forland and Kuhn Ø in northeastern Greenland. The two loose pieces of Kvæfjord coal are exceptionally rich in resinite and appear to be slightly different from the other coals, albeit they are compositionally related. The documentation of *in situ* resinite/liptinite-rich coals on Andøya and the finding of loose pieces along the Atlantic coast of Norway indicate that formation of these unusual coals occurred regionally in the pre-rift North Atlantic region, probably in peat-forming mires with a yet unknown strongly resin-producing vegetation established at the margins of a gradually northward prograding embayment formed during Middle Jurassic rifting between Greenland and Norway. The unique maceral composition makes the coals excellent potential petroleum source rocks with HI values >400 mg HC/g TOC, but the sketchy knowledge of the regional distribution of the coals combined with the probably restricted areal extent of the coal deposits limits their significance as an additional source rock in the North Atlantic area.

1. Introduction

Unusual Middle Jurassic resinite/liptinite-rich coals are known from northeastern Greenland, where coal beds of the Muslingebjerg Formation crop out on Kuhn Ø, on Hochstetter Forland, and at Kulhøj, western Germania Land. Resinite/liptinite-rich coals are known *in situ* from Kuhn Ø and Hochstetter Forland, whereas only erratic pieces have been found further north on Store Koldewey, and at Kulhøj/Germania Land and Hertugen af Orleans Land (Bojesen-Koefoed et al., 1996, 2012; Petersen et al., 1998) (Fig. 1). Apart from these relatively well-known coal occurrences in northeastern Greenland, a number of loose pieces of resinite-rich coal have been found along the Norwegian coast since the mid-1800's. The finding sites were in or close to the shore zone in places where it would have been impossible for the coal to originate from passing ships (Horn, 1931; Øverland and Solbakk, 2009).

This study reports a detailed organic petrographic and geochemical investigation of five samples of resinite-rich coal found on Store Koldewey in northeastern Greenland, on the Norwegian coast, and in a well drilled on the Norwegian island Andøya. The aims are to document the coals' highly unusual composition, to determine their thermal maturity, and to discuss their similarity and possible distribution in the North Atlantic region related to the Middle Jurassic palaeogeography.

1.1. Historical background of the Norwegian Kvæfjord coal

In 1867, a local farmer discovered coal *in situ* on the farm of Ramså on Andøya in Nordland County (Helland, 1897). During a visit to the site by superintendent of mines Tellef Dahll in 1868 a section of sedimentary rocks consisting of sandstone, clay, and coal was uncovered. The fossil content in the sediments was dated to the Jurassic (Norborg et al., 1997). On 14 November 1869, the Tromsø Stiftstidende newspaper reported a new discovery of coal in Hemmestad in Kvæfjord Municipality in Troms County (Anon., 1869). During the clearing of a new field in the summer of 1869, several big black pieces were found,

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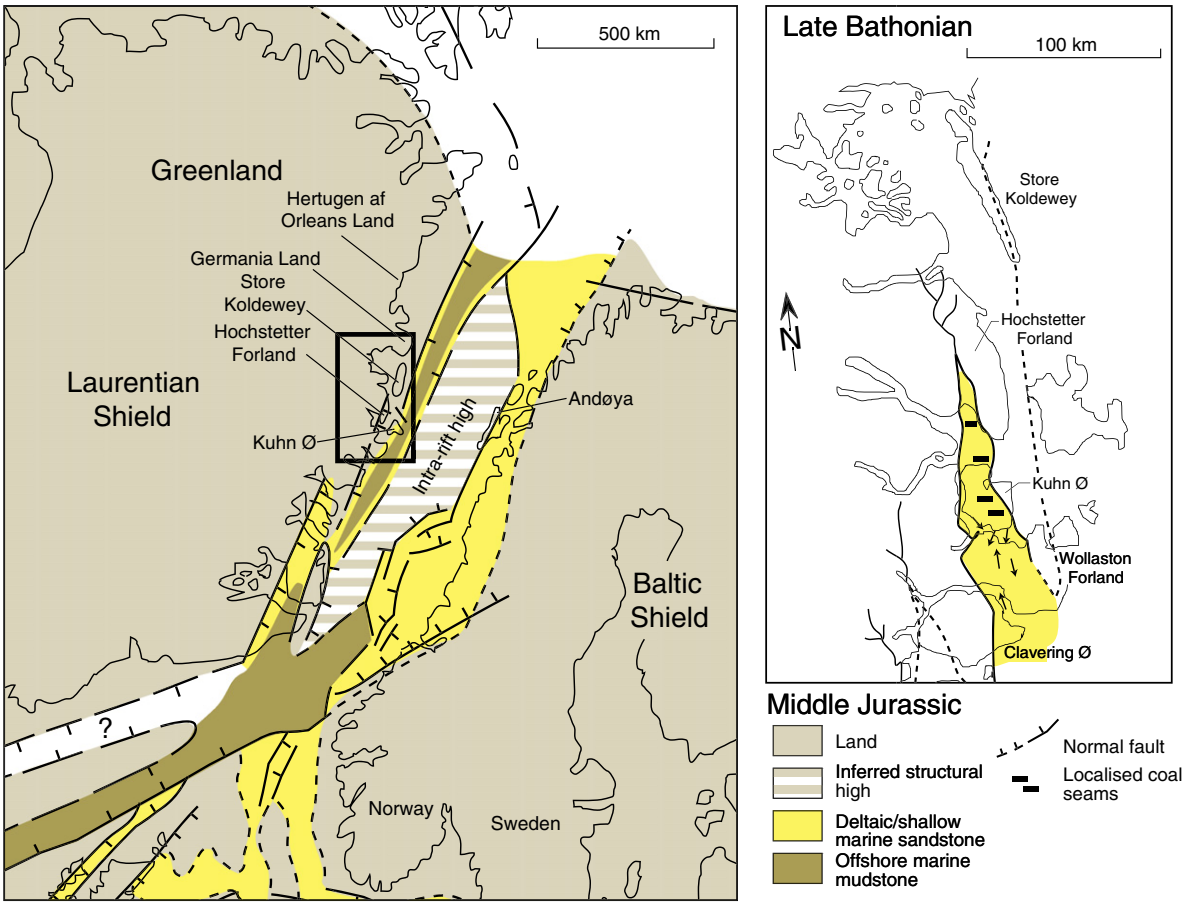

Fig. 1. North Atlantic Middle Jurassic pre-rift palaeogeography with indication of present-day outcrops of resinite/liptinite-rich coals of the Middle Jurassic Muslingebjerg Formation in northeastern Greenland and the Middle Jurassic Ramså Formation on the Norwegian island Andøya where an onshore well encountered resinite/liptinite-rich coal at a depth of 491.35 m. Frame shows the area enlarged to the right.: Middle Jurassic palaeogeography of the Hochstetter Forland area showing embayments with supposed coal formation. Modified from Surlyk (2003).

that "to the uninitiated looked like the petrified remnants of a whale". Prof. Kjerulf at the University of Oslo identified one of the pieces as coal, and stated: "It cannot here be any doubt of the occurrence of coal layers – and of a very valuable type!!". After receiving another piece Kjerulf carried out detailed analyses of the coal. In a meeting of The Norwegian Academy of Science and Letters on 11 February 1870, Kjerulf (1871) presented the previously unknown coal type, results of the analyses, and comparisons to other coal types. The measurement of the specific gravity (s.g.) showed that the coal would float in sea water, this made Kjerulf realise that the coal piece "was a foreign product, that once floated to Hemmestad" (Anon., 1870; Kjerulf, 1870). Pettersen (1874), during geological mapping of Troms County, re-examined the location, but was unable to find any coal.

The coal type identified by Kjerulf was given the name Kvæfjord coal (Kjerulf, 1870, 1871). Examples of this coal type have been found as loose pieces along the western and northern coastline of Norway (Fig. 2). The discoveries of Kvæfjord coal are rare, only 16 discoveries can be confirmed (Table 1). No discoveries after the 1930s are known to the authors. The origin of the Kvæfjord coal was an enigma that interested several Norwegian geologists up to 1940. In addition to Kjerulf (1871), the major source for our understanding of the Kvæfjord coal is Horn's (1931) comprehensive and thorough review. Important contributions have also been made by Corneliussen (1891), Holmsen (1924), Havnø (1932, 1933), and Isachsen (1940). Kjerulf (1871) regarded the Kvæfjord coal as a new coal type, which did "not resemble any other commonly known coal in all properties". Holmsen (1924) presumed that the Kvæfjord coal was a solid hydrocarbon, although he was unable to identify any type of hydrocarbon that corresponded to the coal. Horn (1931) defined the Kvæfjord coal as a boghead coal, based on comparison with the characteristics of other, particularly Australian, boghead coals. Prior to his description of the Kvæfjord coal Horn (1931) gave a general overview of boghead coal and discussed the possible content of this coal type. Generally he observed "that the algae-nature of the yellow bodies are however quite questionable". He cited Conacher (1917), who was of the opinion that the yellow bodies in boghead coals were "simply grains and fragments of resin, and the supposed cell structure are merely the effects of physical and mechanical processes incident to geological action". Horn found this hypothesis "very plausible". It can be deducted that Horn's use of the term boghead coal did not necessarily indicate a coal consisting of algae macerals, and, moreover, that Horn looked upon a resin-source as a possibility for the Kvæfjord coal. Horn (1931) distinguished between two types of Kvæfjord coal based on morphological differences: the Kvæfjord type had brownish black colour, yellow streak, and resin-like surface; while the Bindal type had brown to greyish brown colour, yellowish white/grey streak, and dull surface. Both types of coal are often partly covered by a lighter coloured weathering crust (plate I, pictures 1, 2 in Horn, 1931; reproduced in Øverland and Solbakk, 2009). Horn's (1931) identifications of type are given under comments in Table 2. Based on the premises given by Horn (1931) the discoveries 14 Fræna (Fig. 3A) and 15 Tromsø (Fig. 3B) are of the Bindal type, whereas 16 Bø are of the Kvæfjord type. Fragments of conifer needles are observed in 5 Bindal (Heer, 1877), 6 Lødingen, 14 Fræna, and 15 Tromsø. In retrospect, it is worth noting the use of references to respectively amber and resin in descriptions of the Kvæfjord coal: Discovery 3 North Møre was labelled "amber" (Anon., 1870), alternatively given as "amber-like mineral"