The petrology and provenance of coal artifacts from Thule settlements in north-eastern Greenland

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Coal petrographic techniques have been used to trace the origin of coal used to produce artifacts by the Thule people in north-eastern Greenland. The coal artifacts were collected from the north-east coast settlements between 76°55'–80°18'N and date back to the 15th century A.D. The petrographic data suggest that they have a common source, the Middle Jurassic coals outcropping south of 75°15' in north-eastern Greenland. It is thus evident that the Thule people used local material rather than bringing the coal from the known “mines” in Arctic Canada. It also implies that contemporaneous Thule people groups along the east coast of Greenland were in contact and traded.

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Coal petrographic techniques have over the past years successfully been used to identify the provenance of coal artifacts excavated by archaeologists. Teichmüller (1992) studied coal ornaments from Roman and Celtic grave sites and was able to trace some of the materials to sources in southern Germany, Bohemia and the Czech Republic. Smith (1996, 1997) studied coal relics collected from Roman sites in Britain and found that nearly all the specimens originated from the nearest outcrops of coal seams.

In the Canadian Arctic, Alaska and Greenland, coal artifacts are occasionally found in excavated winter house ruins from the Thule culture period (McCullough 1989; Steffian 1992; Kalkreuth *et al*. 1993), representing an early phase of Inuit occupation. Previous examinations of coal artifacts from the Bache Peninsula region of eastern Ellesmere Island and Axel Heiberg Island in Arctic Canada, including the analysis of beads and a possible labret (lip piercing piece), showed that the artifacts consisted of a variety of coal and organic-rich shale types (lignite, boghead coal, cannel shale), some of which could be traced to nearby outcrops (Kalkreuth *et al*. 1993; Kalkreuth & Sutherland 1998). Boghead coal appears to have been particularly suitable for making delicate ornaments and carvings; however, the origin of the boghead coal used for some of the coal artifacts from Ellesmere Island and Axel Heiberg Island is still uncertain.

The Thule culture came to Greenland from the northern part of the Bering Strait. The timing of the arrival is heavily debated and ranges from the early 12th century A.D. to the late 13th century A.D. (McCullough 1989; McGhee 2000; Schledermann & McCullough 2003; Friesen & Arnold 2008; Jensen 2009). They settled in the Thule area in northwest Greenland and later some Thule culture groups migrated eastwards to north-eastern Greenland while others moved southward along the west coast of Greenland (Fig. 1). The migration into north-eastern Greenland went along the north coast and south into J.P. Koch Fjord and eastwards through Wandel Dal and Midsommersøer in southern Peary Land (Fig. 2; Grønnow & Jensen 2003). Migration must have been fast since there are no winter houses known between Hall Land (ca. 81°N/60°W) and Amdrup Land (Fig. 2), where the northernmost winter houses on the northeast coast of hunting society at the Northeast Water Polynia, which offered access to marine hunting of whales, walrus, narwhale and seals with some possibilities of hunting musk ox and caribou. Six to seven settlements are known around the polynia (Andreasen 1997), but so far only few excavations have been undertaken. The migration continued southwards along the east coast, where we see many settlements in the Dove Bugt area (Grønnow & Jensen 2003) and from ca. A.D.1400 there was also substantial settlement at and around Clavering Ø (Sørensen 2010).

When the migrants came to north-eastern Greenland they brought along tools, clothes and raw material from the Thule area. Objects of coal are not known from the Thule area. In north-eastern Greenland, large pieces of coal have recently been found at three Northeast Water sites: Sophus Müller Næs, Eskimonæs, and the southern of the small islands Henrik Krøyer Holme (Fig. 2). Farther south, in Dove Bugt, objects of coal are known from the large Rypefjeldet site (Fig. 2), and in addition a few very small coal pieces were excavated by members of the Danmarks Ekspeditionen in 1906–08 (Thostrup 1911): L3059 from Grave 321 at Stormbugt Øst, L3060 from Snenæs House, and seven beads, L3064, from grave 529 at Rypefjeldet (Thomsen 1917), and later two beads were found in ruin group II, house 2 at Dødemandsbugten on Clavering Ø (Larsen 1934).

The present study focuses on the petrographic examination of five coal artifacts collected from Thule settlements in north-eastern Greenland (Fig. 2), believed to date back to the 15th century A.D. The results are compared with existing data from coal seams outcropping in north-eastern Greenland in order to determine if these coal seams may be the sources for the artifacts.

Table 1. Information on sample location, sample identification, and sample type

Location	Coordinates		Sample id.	Sample type
Eskimonæs, Holm Land	80°25´11˝N	15°41´21˝W	KNK 2071x1	coal, female figurine
Henrik Krøyer Holme	80°36´23˝N	13°58´19˝W	KNK 2073x47	coal, preform to a figurine
Henrik Krøyer Holme	80°36´23˝N	13°58´19˝W	KNK 2073x52	lump of coal
Sophus Müller Næs, Amdrup Land	*c.* 80°47´N	*c.* 14°10´W	L1 5696	coal, drop-like shape (amulet?)
Rypefjeldet, Dove Bugt	*c.* 76°11´N	*c.* 20°20´W	L1 5794	lump of coal

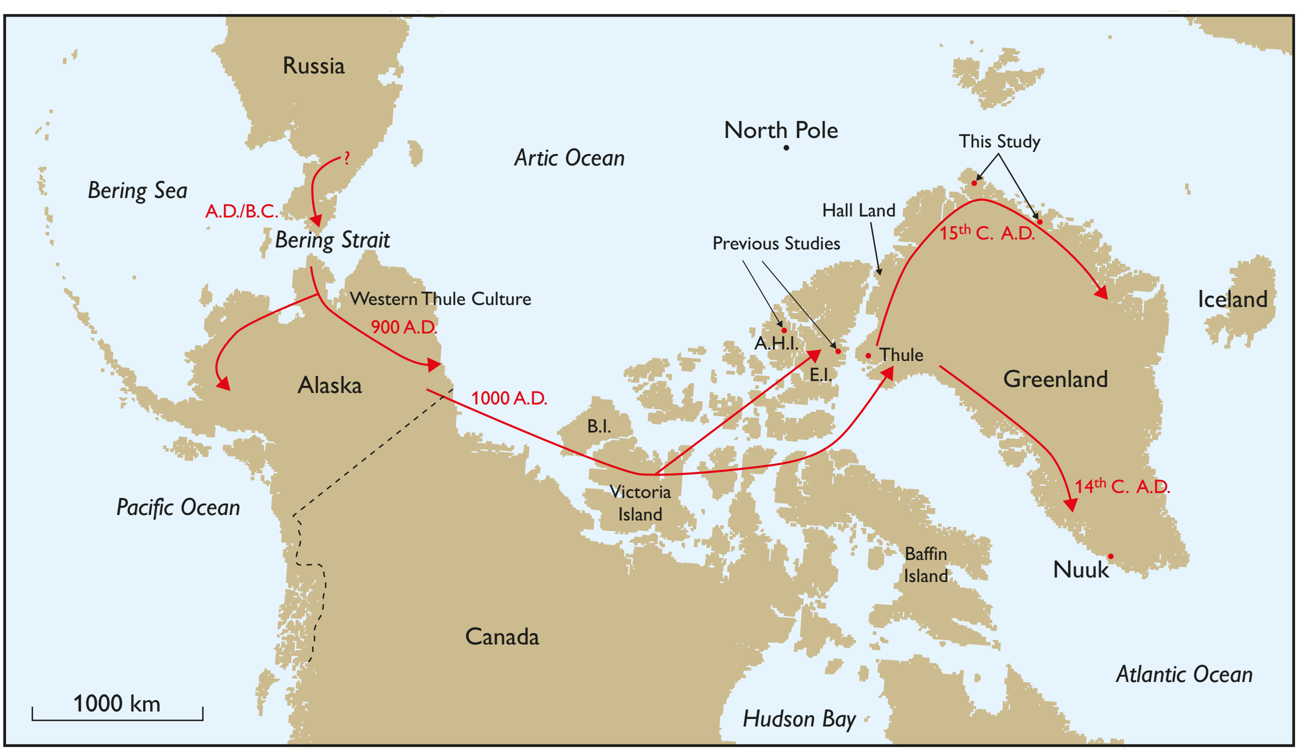

Fig. 1. Map showing migration routes of the early Thule Culture and the locations of previous and the present coal artifact studies. See text for discussion of migration. B.I.= Banks Island, E.I.= Ellesmere Island, A.H.I.= Axel Heiberg Island.

Sampling, sample preparation and analytical methods

Sampling

The coal artifacts examined in this study all come from north-eastern Greenland (Fig.2; Table 1).

Sample KNK 2071x1 was found on the surface at Eskimonæs on Holm Land (Fig. 2) in 1996 and most likely represents the same settlement phase as the excavated features, i.e. around A.D. 1400 (Andreasen 1997). Coal artifacts KNK 2073x47 and KNK 2073x52 were collected in 1993 as surface samples from Henrik Krøyer Holme (Fig. 2). Material from this location has not been dated, but it is, however, most likely that they have the same age as the material found at Eskimonæs. Coal artifact L1 5696 was excavated in a house ruin at Sophus Müller Næs, Amdrup Land (Grønnow & Jensen 2003), whereas coal artifact L1 5794 was collected much farther to the south at Rypefjeldet, Dove Bugt (Fig. 2).

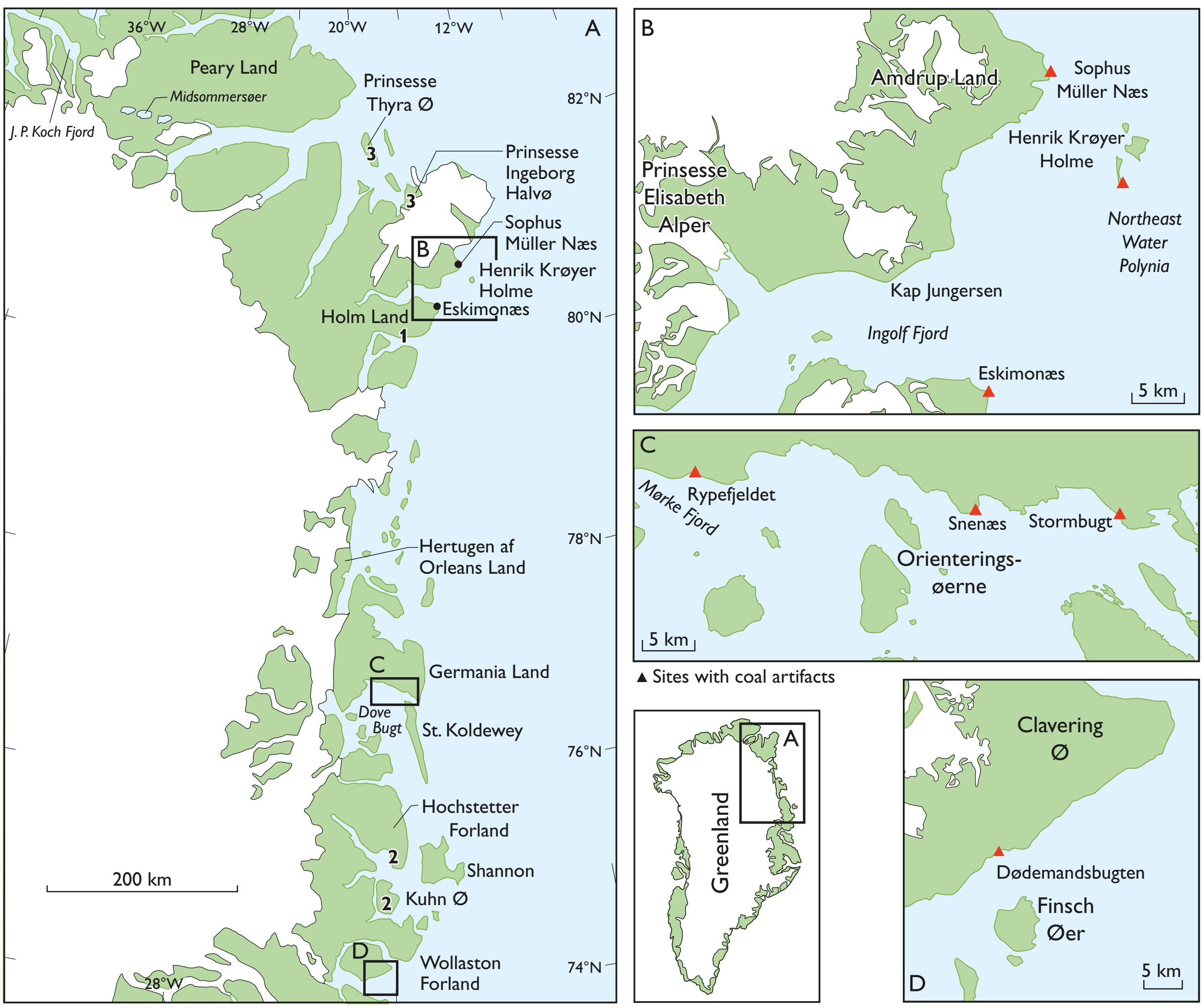

Fig. 2. Maps of north-eastern Greenland. The coal artifacts were collected at Eskimonæs (KNK2071x1), Henrik Krøyer Holme (KNK 2073x47, KNK 2073x52), Sophus Müller Næs, (L1 5696) and at Rypefjeldet, Dove Bugt (L1 5794). Numbers in A indicate outcrops of coal-bearing strata: (1) in the Lower Carboniferous Sortebakker Formation on southern Holm Land, (2) in the Middle Jurassic Muslingebjerg Formation at Hochstetter Forland and Kuhn Ø - erratic blocks of the Middle Jurassic Muslingebjerg Formation are known also from Germania Land and Hertugen af Orleans Land -, and (3) in the Palaeogene (?) Thyra Ø Formation on Prinsesse Thyra Ø and on Prinsesse Ingeborg Halvø.

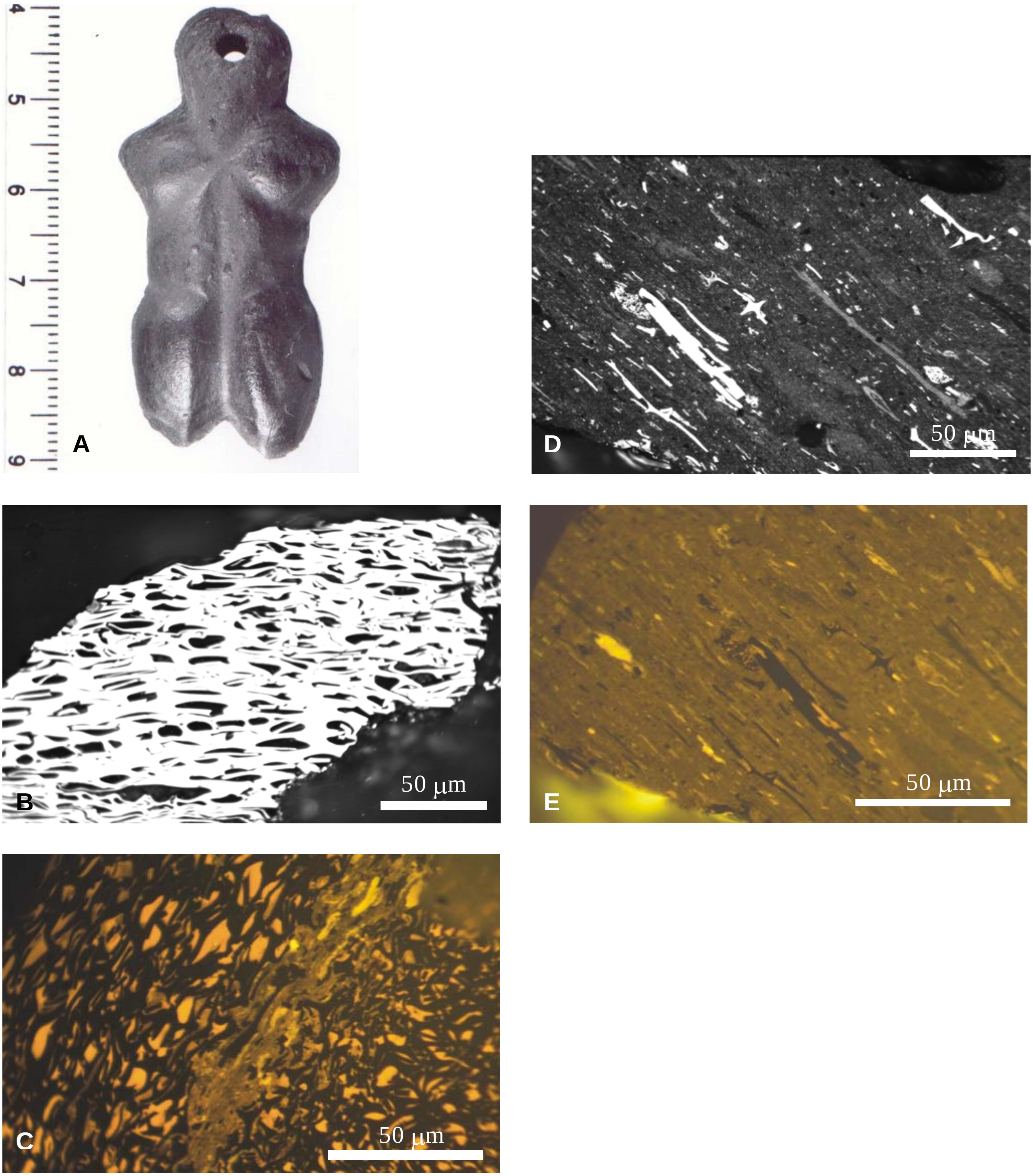

Fig. 3. **A**, coal artifact KNK 2071x1, Eskimonæs, Holm Land. Specimen has been carved in the shape of a female figurine. For details see text. **B–E**, photomicrographs in oil immersion of coal artifact KNK 2071x1; B and D shown in white reflected light, C and E shown in fluorescence-inducing blue light illumination. **B,** fusinite with well-preserved botanical cell-structure. **C**, yellowish fluorescing exsudatinite filling cell lumen of fusinite. Centre of image shows fluorescing groundmass associated with sporinite. **D,** fine-grained clay mineral matrix associated with inertodetrinite. **E**, fluorescing groundmass associated with sporinite and non-fluorescing inertinite.

Sample preparation and analytical methods

Due to the precious nature of the coal artifacts, sample material was obtained by carefully scraping small fragments off the original specimen. The material was mounted in epoxy resin, and grinding and polishing procedures were applied as routinely used for coal and other organic material (Bustin *et al*. 1989).

Analytical methods applied include microscopical examination of the sample material in reflected white- and fluorescence-inducing blue light to study the petrographic characteristics using the nomenclature of the International Committee for Coal and Organic Petrology (ICCP) (1963, 1971, 1998, 2001). Vitrinite (huminite) reflectances were measured in random mode to determine the thermal maturity (rank) of the organic material by standard petrographic routines (Bustin *et al*. 1989).

Results

Petrographic analyses

Coal artifact KNK 2071x1

This artifact is a polished piece of stratified coal that has been carved in the shape of a female figurine (Fig. 3A), measuring 50×25×10 mm.

Petrograhic analysis shows the predominance of fusinite and sporinite macerals associated with a fluorescing groundmass of clay minerals. The fusinite particles are characterized by a well-preserved botanical cell-structure (Fig. 3B). When applying blue-light excitation it becomes apparent that almost all open cell luminae of the fusinite particles are filled with yellowish fluorescing exsudatinite (Fig. 3C). Sporinite macerals are enriched in the fluorescing groundmass (Fig. 3D, E).

Vitrinite (huminite) reflectance measurements (Table 2) indicate a mean value of 0.31 $\%R_{random}$. In terms of coal rank this corresponds to lignite.

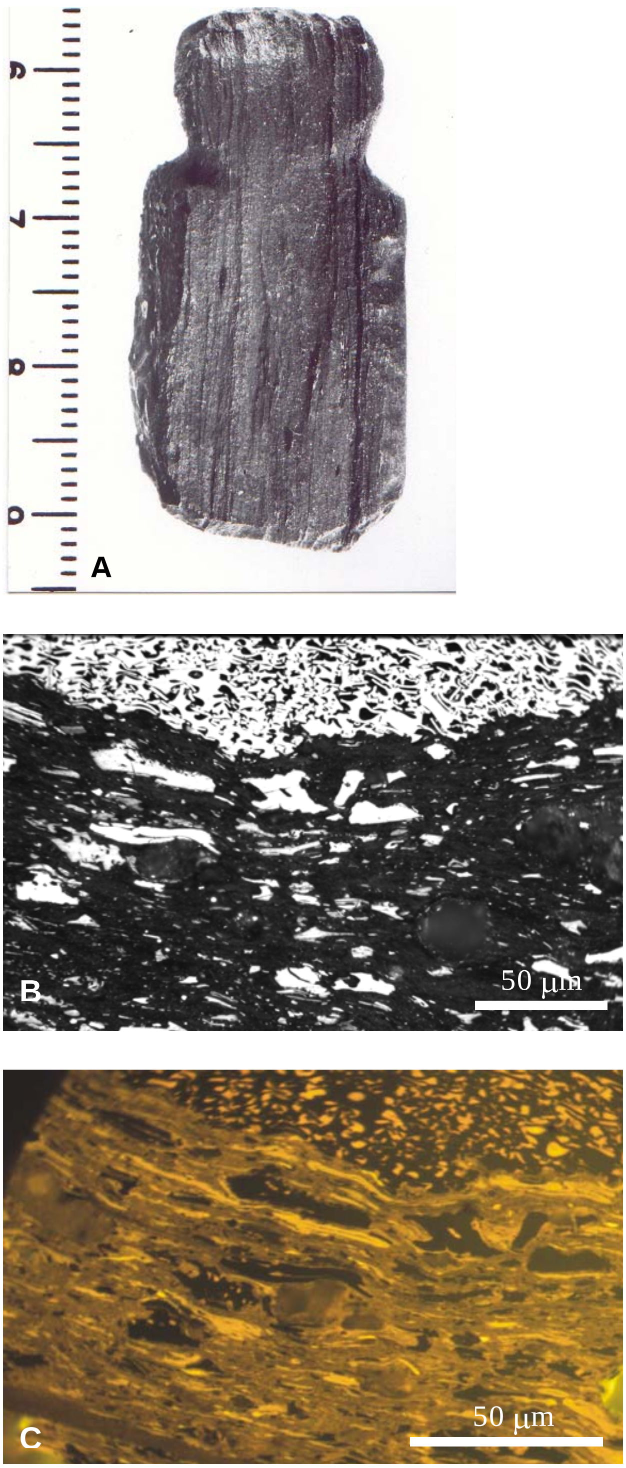

Fig. 4. **A**, coal artifact KNK 2073x47, Henrik Krøyer Holme. Specimen has been carved and may present a preform to a figurine. For details see text. **B** and **C**, photomicrographs in oil immersion of coal artifact KNK 2073x47; B shown in white reflected light, C shown in fluorescence-inducing blue light illumination. **B,** fusinite showing typical "Bogen" structure (top of image) and mineral matrix (clay minerals and quartz) associated with inertodetrinite in centre and lower part of image. **C**, yellowish fluorescing exsudatinite filing cell lumen of fusinite associated with fluorescing groundmass enriched in sporinite.

Coal artifact KNK 2073x47

This artifact is a piece of stratified coal that has been carved and may represent a pre-form to a figurine (Fig. 4A), measuring 40×20×10 mm.

Petrographic analysis in white light shows the predominance of fusinite and inertodetrinite macerals associated with clay minerals and quartz (Fig. 4B). Blue light excitation shows enrichment of sporinite in the fluorescing groundmass (Fig. 4C), and exsudatinite filling the cell lumen of fusinite.

Vitrinite reflectance measurements indicate a mean value of 0.40 $\%R_{random}$ (Table 2), corresponding to sub-bituminous rank.

Coal artifact KNK 2073x52

This artifact is a piece of stratified coal (Fig. 5A), measuring 70×50×20 mm. One plane parallel to bedding has macroscopically identifiable remnants of fusain. Fusain is principally considered to be derived from forest fires (Scott 1989; Scott & Jones 1994) near or at the site of organic matter accumulation. Microscopic analysis in white light shows the predominance of fusinite and inertodetrinite macerals (Fig. 5B) associated with quartz and clay minerals. Blue light excitation shows exsudatinite filling the cell lumen of fusinite (Fig. 5C) and enrichment of sporinite in the fluorescing groundmass (Fig. 5D).

Vitrinite (huminite) reflectance measurements indicate the existence of two reflectance populations (Table 2), with means of 0.29 and 0.53 $\%R_{random}$ respectively. These values correspond to a rank of lignite and sub-bituminous A, respectively.

Coal artifact L1 5696

This artifact is a piece of polished coal that has been carved into a drop-like shape, possibly representing an amulet (Fig. 6A), measuring 35×20×10 mm.

Petrographic analysis shows that the organic matter is dominated by sporinite and vitrinite macerals (Fig. 6B, C). Inertinite macerals as shown in Fig. 6B are rare.

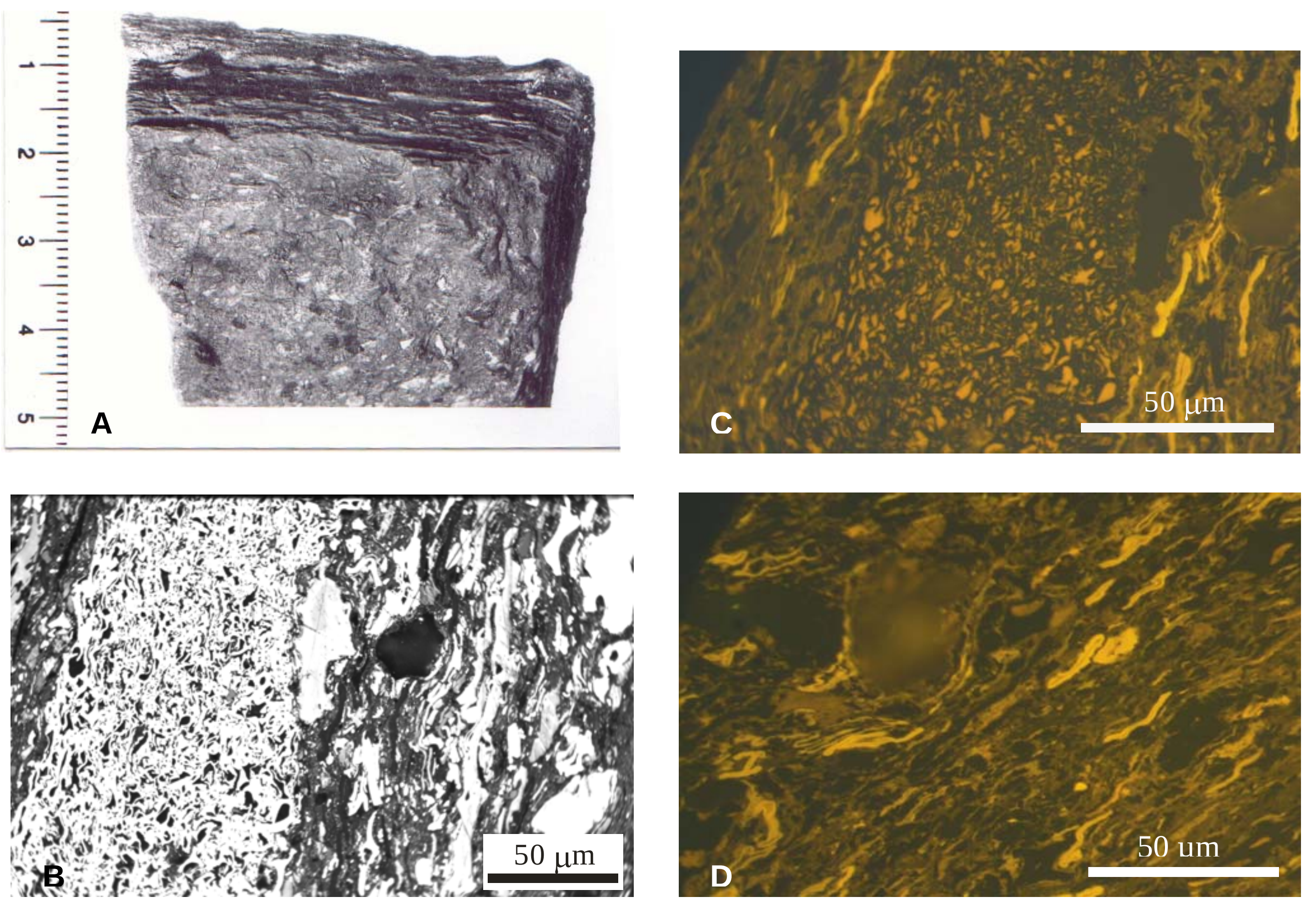

Fig. 5. **A**, coal artifact KNK 2073x52, Henrik Krøyer Holme. Specimen represents a lump of coal, for details see text. **B–D**, photomicrographs in oil immersion of coal artifact KNK 2073x52; B shown in white reflected light, C and D shown in fluorescence-inducing blue light illumination. **B**, enrichment of fusinite and inertodetrinite macerals with sporinite (dark elongated stringers). **C**, yellowish fluorescing exsudatinite filling cell lumen of fusinite (centre of image) associated with fluorescing groundmass containing brightly fluorescing sporinite. **D**, fluorescing groundmass showing enrichment of sporinite.

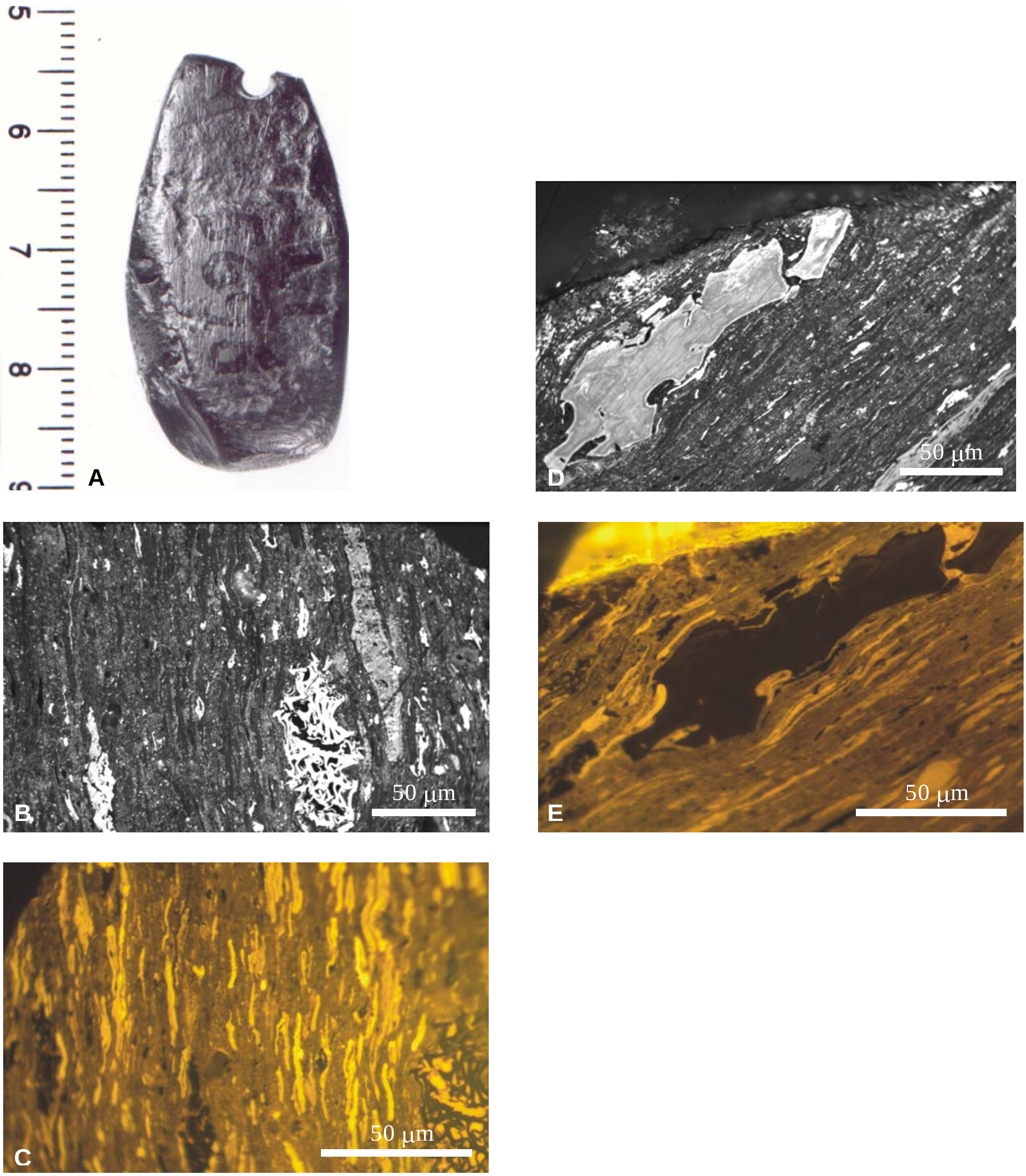

Fig. 6. **A**, coal artifact L1 5696, Sophus Müllers Næs, Amdrup Land. This piece has been carved into a drop-like shape and possibly represents an amulet; for details see text. **B–E**, photomicrographs in oil immersion of coal artifact L1 5696. B and D shown in white reflected light, C and E shown in fluorescence-inducing blue light illumination. **B**, fine-grained mineral matrix with inclusions of fusinite, inertidetrinite, vitrinite and sporinite (elongated dark stringers). **C**, fluorescing groundmass with abundant occurrences of strongly fluorescing sporinite. Exsudatinite fills cell lumen of fusinite (right base of image). **D**, relict of fish bone/tooth (?) associated with fine grained mineral matrix containing inertodetrinite and sporinite (dark elongated stringers). **E**, fish bone/tooth (?) in fluorescing matrix associated with abundant sporinite.

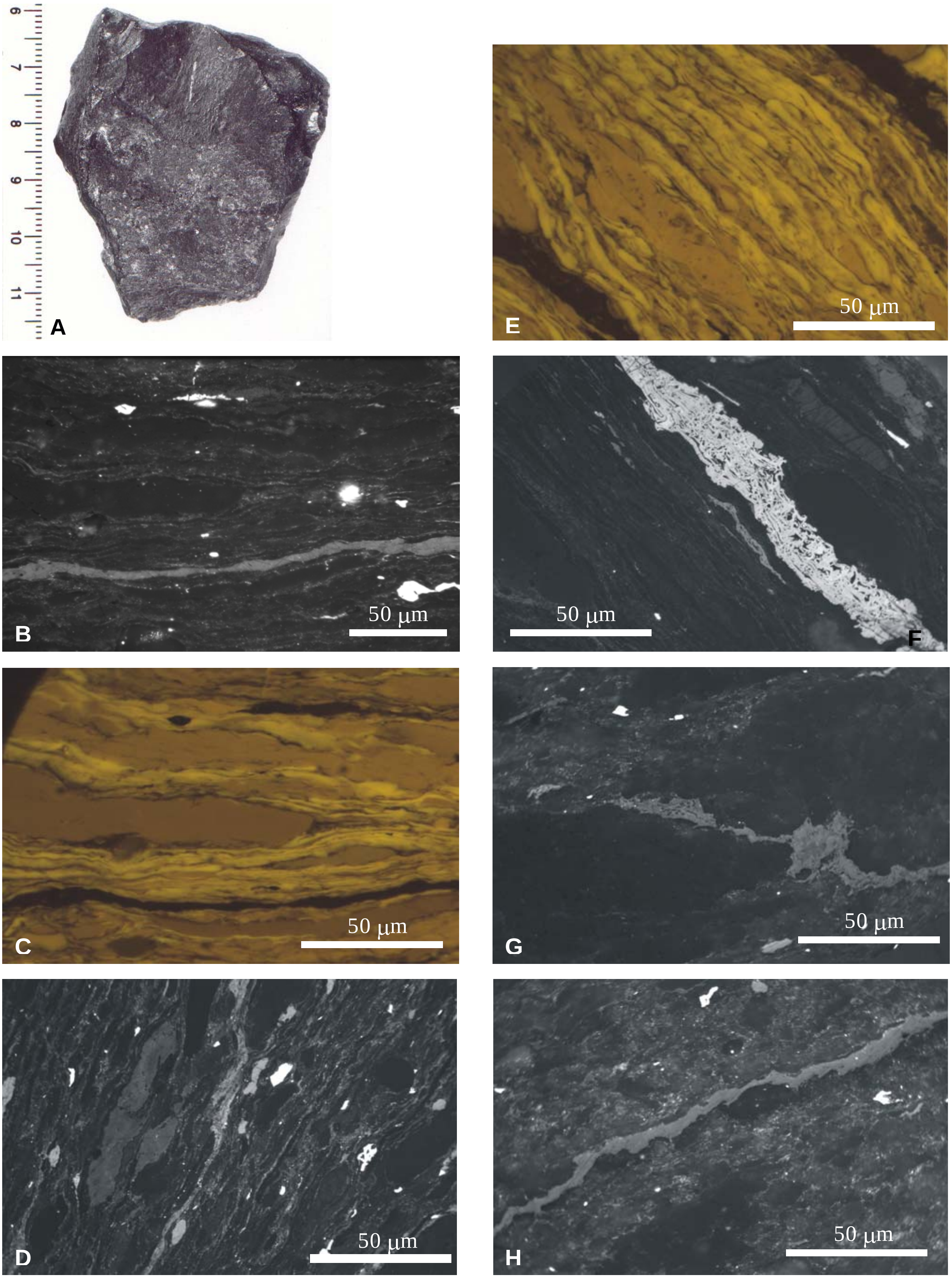
A
E
50 µm
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Table 2. Summary of petrographical characteristics of the coal artifacts

Sample id.	Comments on petrographic composition	$\%R_{random}$	Std.	N
KNK 2071x1	fluorescing groundmass, rich in sporinite, fusinite, exsudatinite filling cell lumen of fusinite	0.31	0.02, 0.08	14, 6
KNK 2073x47	fluorescing groundmass, rich in sporinite and inertinite with exsudatinite in cell lumens of fusinite	0.40	0.03	5
KNK 2073x52	fluorescing groundmass, rich in liptinite and inertinite with exsudatinite in cell lumens of fusinite	0.29, 0.53	0.03, 0.12	6, 8
L1 5696	rich in liptinite (sporinite) and vitrinite, rare inertinite, fragment of fish bone/tooth (?) associated with sporinite	0.33	0.03	10
L1 5794	extremely rich in liptinite (resinite, cutinite, liptodetrinite), rare inertinite	0.25	0.03	20

$\%R_{random}$: mean random vitrinite reflectance
Std.: standard deviation
N: number of measurements

Figure 6D and 6E show sporinite macerals associated with a large fragment of fish bone (?).

The mean vitrinite (huminite) reflectance value is 0.33 $\%R_{random}$ (Table 2), corresponding to a rank of lignite.

Coal artifact L1 5794

This artifact is a piece of coal of irregular shape, measuring 50×50×25 mm (Fig. 7A).

Petrographic analysis shows that the sample is enriched in liptinite macerals. The most abundant component is resinite (Fig. 7B, C, D, E), followed by sporinite and cutinite. Inertinite macerals such as fusinite (Fig. 7F) are rare, whereas the vitrinite content is moderate (Figs 7F and 7G). Petrographic characteristics of this specimen also include the occurrence of vitrinized (?) medium gray elongated stringers with morphological characteristics of sporinite or cutinite (Fig. 7H).

The mean value of vitrinite (huminite) reflectance is 0.25 $\%R_{random}$ (Table 2), corresponding to a rank of lignite.

Summary of the petrographic characteristics of the coal artifacts

From a coal petrographic point of view the artifacts form two distinct groups:

The first group consists of samples collected at Eskimonæs (KNK 2071x1) and Henrik Krøyer Holme (KNK 2073x47 and KNK 2073x52). These artifacts are all characterized by the relative high amounts of inertinite (fusinite, inertodetrinite) associated with sporinite. Typically the open spaces of fusinite particles are filled with exsudatinite, considered to be a secondary maceral (Teichmüller 1974a,b; Kalkreuth & Macauley 1987), believed to be formed during the bituminization process, filling pores and fractures in coal. The high amount of exsudatinite observed in the coal artifacts from Greenland is, however, rather unusual. Macroscopic similarities such as stratification, dimensions and thicknesses of the specimens as well as very similar petrographic characteristics suggest that coal artifact KNK 2073x52 and the carved coal artifact KNK 2073x47 were derived from the same coal piece.

The second group of samples consists of the artifacts collected at Sophus Müller Næs (L1 5696) and Rypefjeldet (L1 5794), which are characterized by the dominance of sporinite and resinite respectively, whereas inertinite macerals are rare.

The vitrinite (huminite) reflectances determined in the coal artifacts range from 0.25 to 0.53 $\%R_{random}$, corresponding to coal ranks ranging from lignite to high volatile A bituminous coal. However, all specimen are enriched in liptinite macerals, and it is well known that vitrinite reflectances may be considerably lowered by the presence of liptinite macerals (Kalkreuth 1982; Petersen & Vosgerau 1999), and may thus not indicate the 'true' level of coal rank.

◀ Fig. 7. **A**, coal artifact L1 5794, Rypefjeldet, Dove Bugt. This specimen is an irregular coal lump; for details see text. **B–F**, photomicrographs in oil immersion of coal artifact L1 5794. B, D and F–H shown in white reflected light, C and E shown in fluorescence-inducing blue light illumination. **B**, vitrinite stringer associated with liptinite (resinite, liptodetrinite). **C**, large bodies of brownish-orange fluorescing resinite associated with cutinite and sporinite macerals. **D**, vitrinite and inertodetrinite associated with resinite and cutinite. **E**, enrichment of yellowish fluorescing cutinite and resinite. **F**, occurrence of rare fusinite with well-preserved botanical cell-structure associated with sporinite and resinite. **G**, vitrinite associated with resinite. **H**, elongated medium grey particle with morphological characteristics typical of sporinite or cutinite (vitrinized ?).

Coal occurrences in north-eastern Greenland

Palaeogene, Middle Jurassic and Lower Carboniferous coal-bearing strata are exposed in localised areas along the coast in north-eastern Greenland from Kuhn Ø at ~74°43'N, 20°15'W to Prinsesse Thyra Ø at 82°05'N, 19°16'W (Fig. 2). The Middle Jurassic coals have been thoroughly investigated by the Geological Survey of Denmark and Greenland, whereas the knowledge about the Lower Carboniferous and Palaeogene coals is less detailed.

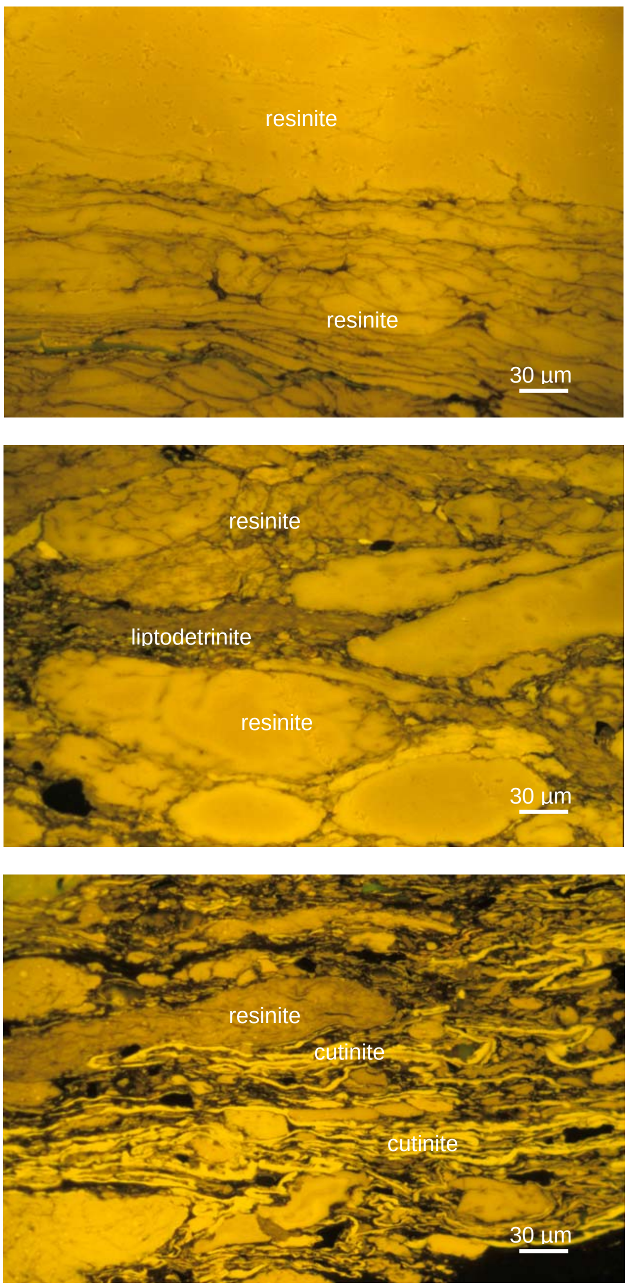

Fig. 8. Photomicrographs of liptinite-rich coals from the Muslingebjerg Formation at Payer Dal, Kuhn Ø. The coals are extraordinarily rich in resinite, but also cutinite and liptodetrinite (reflected light microscopy, blue light excitation).

Palaeogene coal occurrences

Palaeogene coal occurs in the Upper Paleocene to ?lowermost Eocene Thyra Ø Formation at Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø (Fig. 2) in the vicinity of Station Nord (~81°30'–82°05'N, 16°48'–19°16'W; Lyck & Stemmerik 2000). The formation consists of interbedded fine-grained sandstones, siltstones and coal, but generally the formation is poorly exposed with most information provided by isolated outcrops along rivers on southern Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø. A coal from the Thyra Ø Formation is characterised by a dominance of huminite, some liptinite and minor amounts of inertinite. The liptinite appears mainly to be composed of liptodetrinite, sporinite and thin cutinite, whereas resinite is largely absent. The vitrinite reflectance is 0.51 $\%R_{random}$, corresponding to subbituminous A rank.

Middle Jurassic coal occurrences

Middle Jurassic coal beds of the Muslingebjerg Formation are known from outcrops on Kuhn Ø and the southern coast of Hochstetter Forland in north-eastern Greenland (~74°43'–75°14'N, 20°00'–20°15'W), and erratic blocks are known farther north from Germania Land to Hertugen af Orleans Land at *c.* 78°N, 21°W (Fig. 2). Vitrinite reflectance values of 0.49–0.53 $\%R_{random}$ show that the coals are of subbituminous A rank (Petersen & Vosgerau 1999). In Bastian Dal on Kuhn Ø, the Muslingebjerg Formation is up to 11 m thick and contains three 1–2 m thick coal beds interbedded with fluvial sediments (Alsgaard *et al.* 2003). The coals are mineral-poor and on a mineral matter free basis (mmf) composed of 42–98 vol.% huminite, 2–55 vol.% inertinite and 0–31 vol.% liptinite, although the majority contain less than 7 vol.% liptinite (Petersen *et al.* 2002). In Payer Dal on Kuhn Ø samples from a 15 cm thick coal bed are dominated by liptinite (Fig. 8). On a mineral matter free basis these coals contain 53–87 vol.% liptinite, which principally is composed of resinite (32–70 vol.%, mmf) followed by liptodetrinite and cutinite (Petersen & Vosgerau 1999). The composition is comparable to that of the dull coal facies in the Muslingebjerg Formation in the coastal cliff at Kulhus, Hochstetter Forland approximately 40–50 km north of Kuhn Ø (Fig. 2). At Kulhus, the coal-bearing succession is *c.* 20 m thick. Due to faulting the succession is repeated along the coast. It consists of a sandstone-dominated 'shoreface facies association' and a 'coastal plain facies association' containing silt- and sandstones and four coal beds of which only three, 1.15–3.45 m thick, are exposed (Clemmensen & Surlyk 1976; Bojesen-Koefoed *et al*. 1996; Petersen *et al*. 1998). Each coal bed consists of three coal facies (dulling-upward) cycles recording increasing flooding of the precursor mires and thus repeated outpacing of peat formation by the rising water table. The dull coals towards the top of the coal beds are extraordinarily enriched in liptinite, particularly resinite, due to selectively removal of huminitic organic matter during flooding (Petersen *et al*. 1998). They contain (mmf) generally 35–60 vol.% huminite, less than 20 vol.% inertinite, and more than 35 vol.% liptinite. The liptinite is dominated by resinite, up to more than 50 vol.% (mmf) of the maceral composition, followed by liptodetrinite and cutinite. The bright and banded coals, characteristic of the lower and middle parts of the coal facies cycles, consist generally of more than 60 vol.% huminite, less than 20% vol.% inertinite and less than 30 vol.% liptinite on a mineral matter free basis.

The liptinite-enriched coals from both Kulhus and Payer Dal have strongly suppressed vitrinite reflectance values, yielding reflectances down to 0.30 $\%R_{random}$ corresponding to reflectance suppression of up to 0.23 $\%R_{random}$ (Petersen & Vosgerau 1999).

Lower Carboniferous coal occurrences

Coal beds occur in the non-marine Lower Carboniferous Sortebakker Formation at Sortebakker, southern Holm Land (~80°09'N, 17°44'W; Fig. 2) (Dalhoff *et al*. 2000). The formation is estimated to be about 1 km thick and is mainly composed of fluvial sediments forming stacked fining-upward cycles of sandstones and shales (Dalhoff & Stemmerik 2000). The coal occurs in mud-dominated coal and coaly shale beds, usually <1 m thick. Sparse rootlets have been observed and the coal is described as black to brownish (Dalhoff & Stemmerik 2000). A coal sample from the Sortebakker Formation has a T_{max} value of 572°C, corresponding to a vitrinite reflectance of above 3 $\%R_{random}$ and thus anthracite rank. This high thermal maturity agrees with the assumption that the Sortebakker Formation was exhumed and that up to 2 km of sediments have been removed by erosion.

Discussion: origin of the coal artifacts

Palaeogene coal source ?

The Palaeogene coals exposed at Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø (Fig. 2) occur relatively close to the artifacts collected at Eskimonæs and Henrik Krøyer Holme (KNK 2071x1, KNK 2073x47, KNK 2073x52) and could potentially be the source for the artifacts. Although the vitrinite reflectance reported for the Palaeogene coals (0.51 $\%R_{random}$) is comparable to the reflectance (0.53 $\%R_{random}$) from coal artifact KNK 2073x52, the maceral composition of the Palaeogene coal is dominated by huminite macerals, and the coal does not show the fluorescing groundmass, abundance of inertinite and exsudatinite as observed in coal artifact KNK 2073x52 and in the other artifacts. It appears unlikely that the Palaeogene coals were the source for the artifacts.

Middle Jurassic coal source ?

The petrographic composition and the vitrinite reflectance values of the liptinite-enriched dull coal layers from Kulhus on Hochstetter Forland and Payer Dal on Kuhn Ø (Petersen *et al*. 1998; Petersen & Vosgerau 1999) are comparable to that of the coal artifact L1 5794 collected at Rypefjeldet, Dove Bugt. Petrographically, sample L1 5794 is essentially composed of resinite, cutinite and liptodetrinite, with rare occurrences of vitrinite and inertinite (Fig. 7), which is strikingly similar to the liptinite composition (Fig. 8) of the dull coal layers from Kulhus and Payer Dal (Petersen & Vosgerau 1999). Coal with liptinite-enriched maceral composition and extraordinary amounts of resinite and exsudatinite is highly unusual, not only in Greenland but also elsewhere around the world, suggesting that coal artifact L1 5794 could have been collected from Middle Jurassic coals at Kulhus, Payer Dal or perhaps at other outcrops in north-eastern Greenland. In addition, the vitrinite reflectance of 0.25 $\%R_{random}$ obtained from coal artifact L1 5794 is close to the suppressed values reported for the liptinite-enriched coal layers at Kulhus and Payer Dal, which are also located relatively close to Rypefjeldet, Dove Bugt, where coal artifact L1 5794 was found. However, there need not have been any visits at all to the outcrops. Loose blocks of liptinite-rich coals such as those found at Kulhus and Payer Dal have been reported far from the outcrops, for instance in Germania Land and on Store Koldewey (Bojesen-Koefoed *et al*. 1996). These loose blocks may represent particularly robust parts of coals suited for carving, and such coal pieces will naturally catch the eye in a region otherwise dominated by basement rocks.

The coals from Bastian Dal, Payer Dal and Kulhus can also be rather rich in inertinite and/or sporinite, which may agree with the abundant inertinite macerals (fusinite, inertinite) and sporinite observed in the coal artifacts (KNK 2071x1, KNK 2073x47, KNK 2073x52 and L1 5696). This group of coal artifacts is characterized by depressed vitrinite reflectances typical for liptinite rich coals as they have been reported for the Middle Jurassic coals in north-eastern Greenland (Bojesen-Koefoed *et al*. 1996; Petersen *et al*. 1998; Petersen & Vosgerau 1999).

Considering the above discussion it is suggested that the coal artifacts have a common source in the Middle Jurassic coals in north-eastern Greenland.

Lower Carboniferous coal source ?

Lower Carboniferous coals from the Sortebakker Formation are anthracites, and because of this they are excluded as the source of the coal artifacts, since these are all characterized by significantly lower rank levels.

Conclusions

Based on petrographic characteristics it is evident that the coal outcropping closest to the Thule settlements around the Northeast Water Polynia, the Palaeogene coal at Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø and the Carboniferous coal at southern Holm Land, are unlikely as a source for the coal artifacts. The investigated Thule culture coal artifacts are suggested to have a common source which is the Middle Jurassic coals found at Kulhus, Hochstetter Forland, on Kuhn Ø, and as loose blocks other places in north-eastern Greenland (Fig. 2). There are some Thule settlements in this area, but the main settlements are to the east and south on Shannon, Clavering Ø and Wollaston Forland (Sørensen 2010). The Thule people migrated from the north down the east coast of Greenland, so the presence of Jurassic coal from south of 75°15'N in the settlements at Dove Bugt and the Northeast Water Polynia (located between 76°55'N and 80°18'N) suggests that a group of people might have been moving northwards again from the 'coal area' or that contemporaneous groups in the north and south were in contact and traded. If the coal was collected from Middle Jurassic coal beds in north-eastern Greenland, this study presents the first indication that a local raw material in north-eastern Greenland was moved by Thule people from south to north against the main migration direction in prehistoric time. Alternatively, loose blocks found farther north were the source of the artifacts. In either case, the more precise nature of this movement of material and/or carvings or ideas in north-eastern Greenland in the 15th century A.D. remains to be explored in an archaeological context.

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