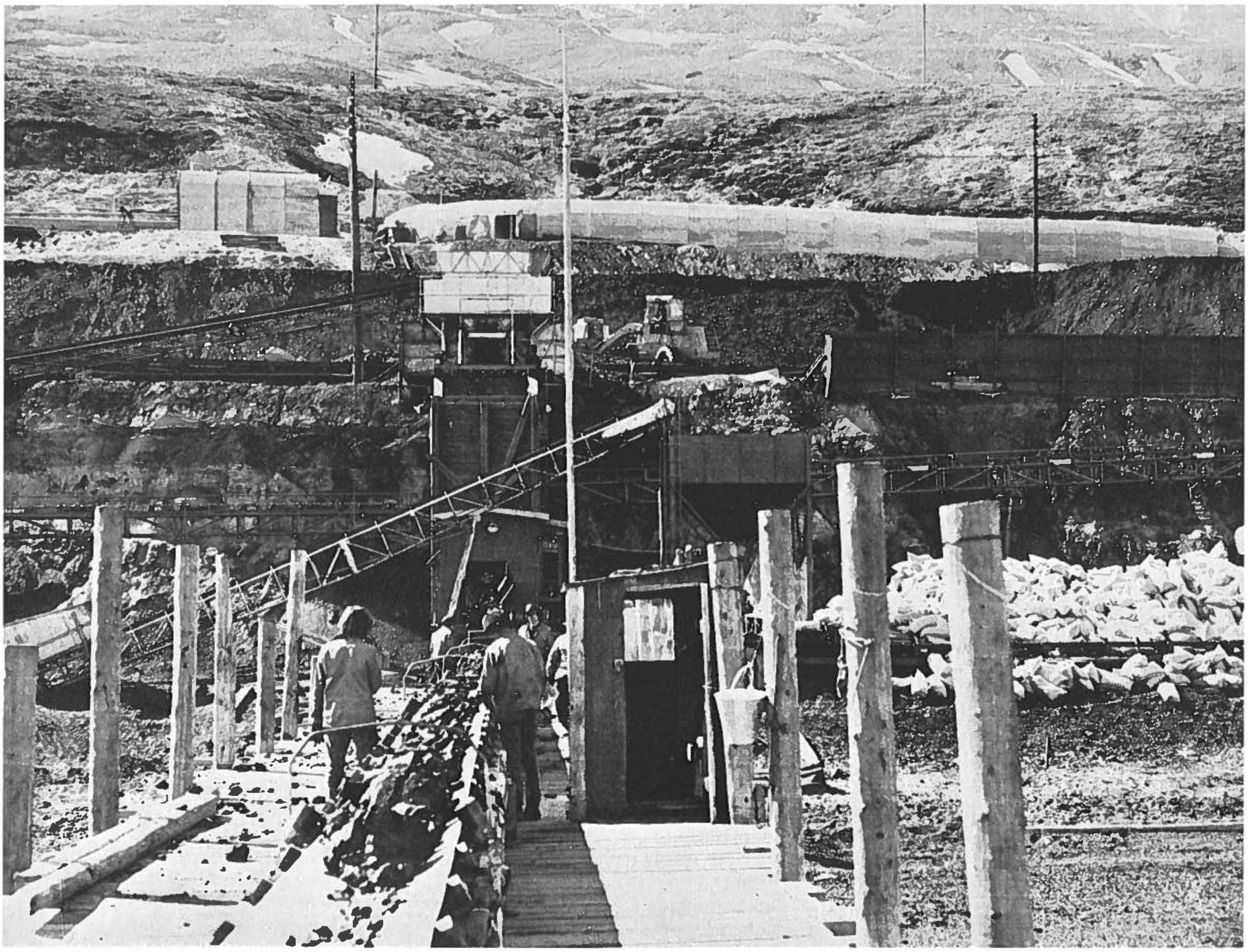


Coal geology

Elmar J. Schiener

Fig. 408. View of the entrance to the now abandoned coal mine at Qutdligssat. Photo: K. Dockner.

Introduction

The coals of Greenland come from many stratigraphic levels ranging from Lower Carboniferous to Tertiary. Of the ice-free areas of Greenland only a small proportion can be considered as prospective. In order of the degree of exploration and economic importance in the past, these areas are:

(1) Central West Greenland (Disko, Nûgssuaq, Hareøen).

(2) East Greenland (Jameson Land, Kap Hope, Wegener Halvø, Hudson Land, Wollaston Forland, Kuhn Ø).

(3) North-East Greenland (Hochstetter Forland, Holm Land, Kronprins Christian Land.

Historical review of coal mining

From the early days of colonisation coal deposits in West Greenland attracted the attention of travellers, although it seems unlikely that the Viking settlers of Erik the Red utilised the seams on 'Eysunes' as suggested by Steenstrup (1874). European whalers probably were the first to replenish their fuel supplies for blubber boiling from coal outcrops on Disko and Hareøen, and M'Clintock (1859) reports taking on 8–9 tons of coal from outcrops east of Godhavn both in 1857 and 1858.

In Greenland coal was mostly used for housewarming. According to Galster (1942), as early as 1777 the Royal Greenland Trade Department sent a German coal mining expert to the Umanak colony in order to establish mining for local use; from 1780 to 1830 annual production there was between 90 t and 140 t.* From another mine, supplying the colony of Ritenbenk, Steenstrup (1874) reports production of a total of 605 tons for the nine years from 1863 to 1872. Comparison of the price of imported English coal in 1872 at 21 Mark/tønde with the 3 Mark/tønde for indigenous coal makes the use of the Greenland product even more understandable. More details on the earlier history of coal mining can be found in Petersen (1921).

Mining in those days was done haphazardly from well-exposed seams with easy access, mostly near the shore. Once operations became difficult, the workings were abandoned and the primitive open cast activity moved to a new site. The small quantities produced were transported by dog sledge in winter or by the universal umiak in summer. Larger vessels had great difficulties owing to rather unsafe anchorages in the coal producing regions. According to Bøgvad (1950), state mining operations up to their closure in 1833 were run not much differently from private activities, with resulting poor efficiency.

In 1905 renewed efforts were made with the opening of the underground state mine at Qaersuarssuk (north coast of Nûgssuaq). After initial difficulties production started in 1908 from seams totalling 1.2 m with intercalated thin stone bands. Until 1924, when a major fault halted the near horizontal workings, output was between 1200 t/a and 1500 t/a. Private activity continued well into the 1950s, though on a small scale (approx. 600 t/a). Shipping facilities were at all times beset with adverse conditions, fast currents and numerous icebergs.

Preliminary exploration had been carried out since around 1920 in the Qutdligssat area on Disko and near Atanikerdluk on south Nûgssuaq, places where coal had been mined on a small scale for a long time (Bøgvad, op. cit.). In 1924 the new state mine started in a 1 m thick, near horizontal seam at Qutdligssat, the site of the old Ritenbenk colony's mine. Modern coal extraction methods had finally reached Greenland, when a mechanisation programme was introduced in 1929. Significant production increases however were first achieved in 1954 (fig. 412).

East Greenland coal deposits, owing to the severe environmental difficulties encountered along that coast, did not receive much attention. The first reports of coal showings were by the 2nd German North Pole Expedition under Koldewey (1869–1870). The expeditions under Lauge Koch utilised the coal for bunkers and even staked a claim for the Danish state in 1931 (Frebold, 1932). In the only sedimentary area with settled Greenlander population, the Scoresby Sund region, coal had been mined on a very small scale for local use (Rosenkrantz, 1942) since the founding of the Scoresbysund settlement in 1924.

* The quotation in Galster of 400 t/a to 600 t/a is most likely caused by direct conversion from the measure of volume 'tønde' to metric tons; 1 tønde = 170 l = 230 kg coal.

Central West Greenland

Stratigraphic position

The exact stratigraphic position for some of the coal-bearing strata is still a matter of uncertainty. Faunal control for the greatest part of the non-marine succession is poor and elements of the fossil flora do not allow a closer zonation. The Kome Formation (Aptian–Barremian), in which seams have been worked on the north coast of Nûgssuaq, and the Atane Formation (Upper Turonian–Upper Senonian), which contains most of the coal on southern Nûgssuaq and Disko, are the main Cretaceous coal-bearing strata (Koch & Pedersen, 1960; Koch, 1964; Rosenkrantz, 1970). Interbasaltic sediments of presumably late Eocene age (Koch, 1955, 1964) contain coal seams on Hareøen and on western Nûgssuaq (Steenstrup, 1874).

Facies

The strata of the Kome and Atane Formations total approximately 1000–1500 m in thickness. They consist characteristically of alternating light-coloured, quartz-feldspar arenites and dark, micaceous-carbonaceous lutites. Sand/shale ratios, depending on position with regard to basin margin, vary from around 5.5 to 0.45. Thickness of individual units can vary from a few centimetres up to several tens of metres. Wedging of beds is common even in outcrop range, and correlation over longer distances is impossible, even for more regularly and evenly bedded units. Medium scale cross-bedding with both planar and festoon foresets are the most common sedimentary structures in the sandstones with dewatering convolutions an additional characteristic (fig. 409).

Cementation varies greatly. The sandstones range from very dense to friable and are far from uniform even within an individual sedimentation unit; hardpans of hydrated iron oxides and iron carbonates are common at sandstone-shale boundaries (fig. 409).

The lutites show all transitions from quartz-rich siltstones with average 1–2 % total organic carbon to shaly coal of 30–35 % total organic carbon.

X-ray diffractometry showed a predominance of mixed layer (muscovite-illite) clays over kaolinite. Pyrite is common, disseminated as well as in framboidal aggregates of varying sizes, which are also found frequently in the sandstones. Concretionary carbonate occasionally forms more or less continuous horizons within outcrop range. Sedimentary structures are of low energy type; parallel lamination and low angle ripple drift lamination with occasionally occurring scour-and-fill structures are typically developed in centimetre-thick silt to fine sand intercalations. Coal seams of greatly varying thickness occur in both of the framework lithologies. Most commonly they are associated with carbonaceous siltstone-shale in a configuration as shown in fig. 409.

In the exposed parts of the section along the south coast of Nûgssuaq a maximum total of around 2 % of the column is relatively pure coal. The number of workable seams (taken at > 50 cm) however, rarely exceeds four or five over 500 m of vertical exposure. Shallow penetration seismic work, carried out by The Geological Survey of Greenland (Denham, 1974) indicates the probable existence of additional seams below fjord bottom in the Vaigat.

Exposure conditions prevent direct correlation of seams, but considering facies and depositional environment it seems unlikely that individual seams would persist over long distances. Splitting and pinching is too commonly a characteristic in outcrop range.

The development of seat-earth horizons is conspicuously lacking. Most seams follow immediately upon sand or are intercalated in well and evenly laminated siltstone-shale, as shown in fig. 409. In some of the less carbonised seams the composition is of very uniformly sized leaves, obviously washed together. It seems reasonable therefore to consider most of the coal as of allochthonous origin.

Petrographical investigations (Bergbau Forschung GmbH, 1974) on coal samples from Nûgssuaq and from some seams encountered in the former mine at Qutdligssat show a predominance of tissue derived macerals over resinous or bituminous macerals (fig. 410). The close intergrowth of all three maceral types would indicate some degree of allochthony for the plant debris, where changeable water levels might be responsible for the formation of the more oxidised inertinite fraction. These findings correspond well with the envisaged model of the depositional environment for the coal-bearing sequence.

The regional aspect of the Upper Cretaceous rocks on Nûgssuaq indicates in broad outline a delta system with approximately SW–NE depositional

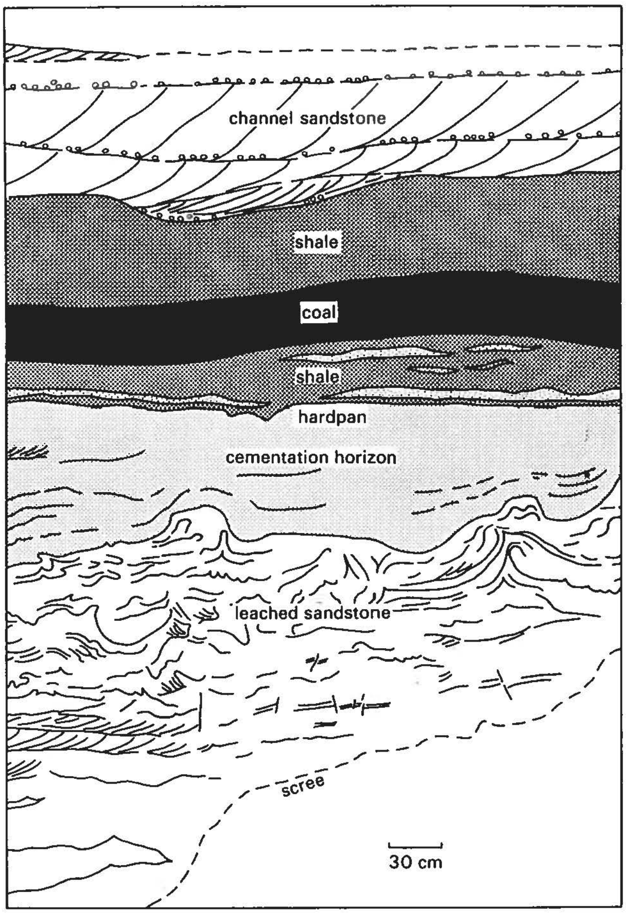
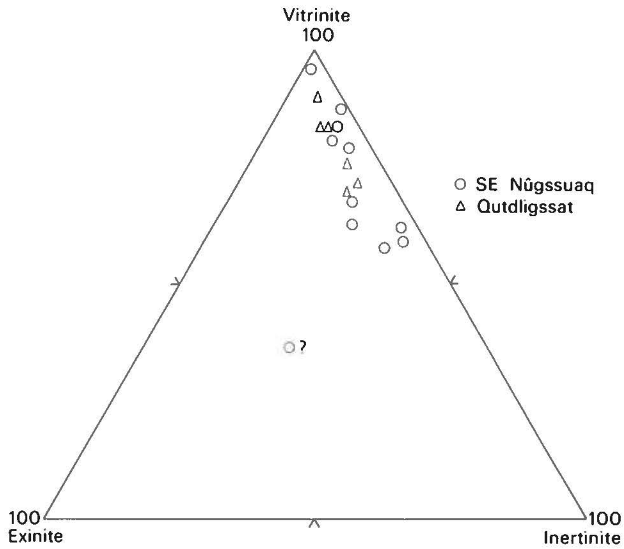


Fig. 409. Characteristic sedimentary features in the coal-bearing strata of West Greenland, (drawn from photograph).

Fig. 410. Plot of vitrinite-inertinite-exinite ratios (mineral-free) on coal samples from Nûgssuaq and Disko.



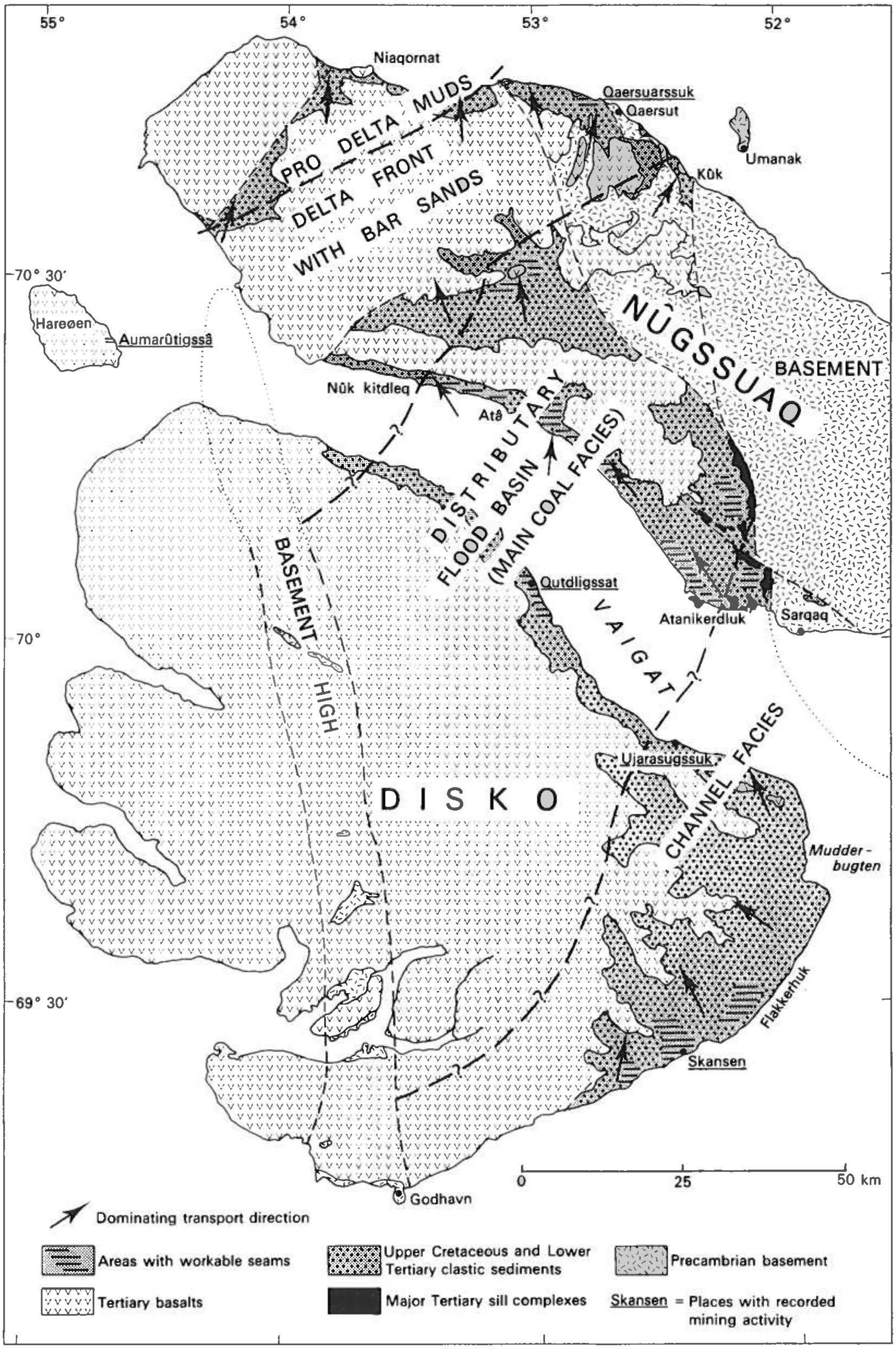


Fig. 411. Central West Greenland, areal distribution of strata with major coal seams, transport directions and facies distribution for Upper Cretaceous – Lower Tertiary sediments.

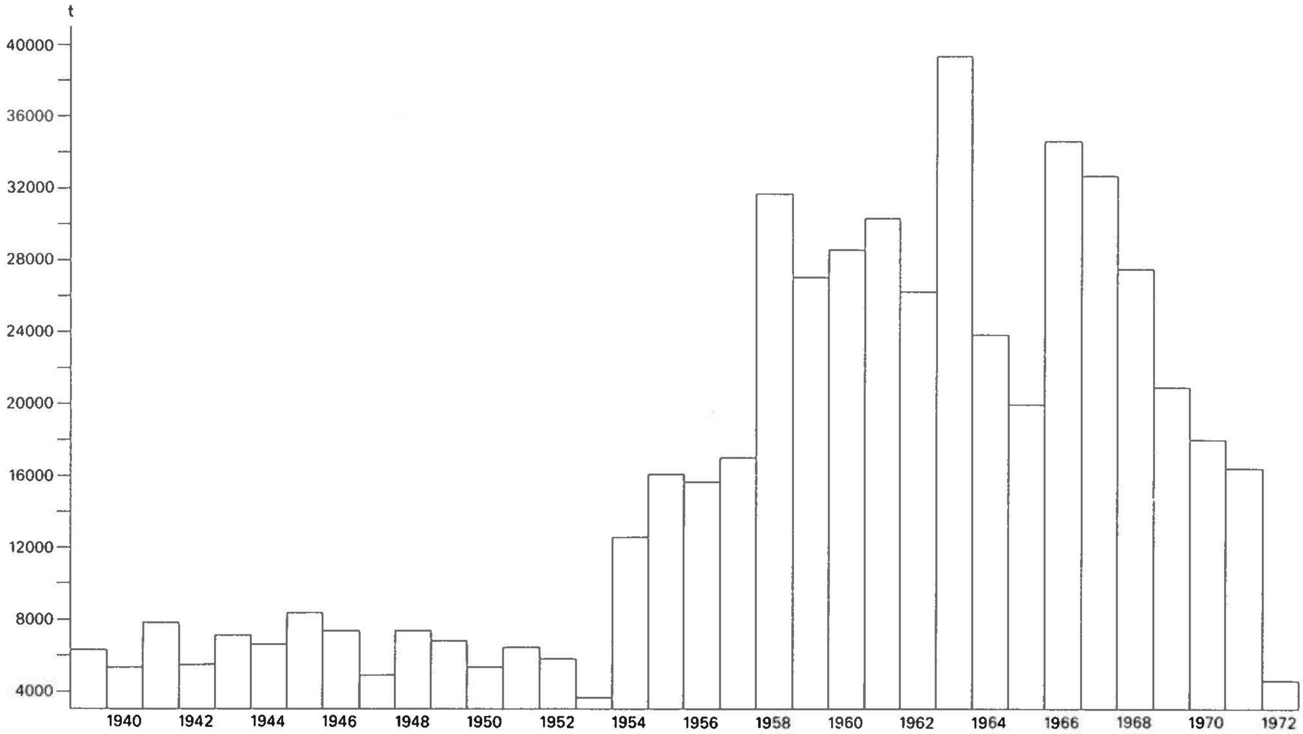


Fig. 412. Production figures from the Qutdligssat Mine (compiled from reports by the Greenland Technical Organization).

palaeostrike. The marine shales on north Nûgssuaq are thought to represent the prodelta facies, the southward adjoining sandstones with minor shales would indicate delta-front deposits with development of bars. Landward follows the distributary flood basin facies where shales and coal represent interdistributary deposition which further up-dip is replaced by sand and gravel dominated channel facies (fig. 411).

The Qutdligssat Mine

The underground workings at Qutdligssat were opened in 1924 in a gently outward dipping seam of approximately 1 m thickness. According to Bøgvad (1950) the mine proved to be free of fire-damp, and ambient temperatures were below freezing. The output of an average 4000 t/a over the 15 years until 1939 was shipped for Greenland consumption during

Table 24. Analyses of coals from the south coast of Nûgssuaq and from Qutdligssat

	Moisture %		Ash %	Dry Ash Free Volatile matter %	Dry Ash Free Fixed carbon %	Calorific value kcal/kg	Effective calorific value kcal/kg	S %	H %	C %	N %	O %
	Total	Inherent										
1	17.6	2.6	13.0	47.6	52.4	6360	4310	1.1	3.6	52.1	1.1	13.0
2	18.0	3.7	7.5	48.7	51.3	6350	4630	0.34	3.8	55.0	0.95	14.4
3	28.3	3.3	8.4	50.6	49.4	5900	3570	0.3	3.0	47.0	1.48	12.8
4	12.7	1.7	6.6	48.0	52.0	6000	4760	0.4	4.5	61.9	1.2	15.1
5	13.25	–	6.8	40.5	59.5	7151	–	0.6	4.5	74.8	1.5	18.6
6	13.91	–	6.5	41.5	58.5	7142	–	1.1	5.1	75.4	1.0	17.4

From unpublished report, prepared for the Greenland Technical Organization.

1 Atâ.
2 Igpigsarssuk.
3 Pautût.
4 Atanikerdluk.
5, 6 Qutdligssat, Disko.

the summer months. Strong tidal currents and drifting icebergs prevented the establishment of efficient loading facilities. Except for minor modifications, loading methods had not changed significantly when the mine and settlement were closed in 1972. They consisted in essence of loading by crane/conveyor into barges, which were brought alongside ship by tugs, where the coal was transferred by ship's gear into the holds. Environmental conditions made this system extremely vulnerable.

After 1939 operations were transferred to about 1 km south-east of the old mine, where a 50–60 cm seam was developed and mined first in room and pillar fashion, later in longwall advance.

Exploration in the years after World War II included some diamond core drilling and proved additional workable seams mainly below the then mined level, with minimum reserves around two million tons. Development on the shallowest seam, totalling 1.5 m of clean coal with two 15 cm shale intercalations, started in 1966 with longwall advance mining, which later was changed to shortwall rises. The output figures for the years from 1939 are shown in fig. 412.

The raw coal on average separated into three fractions, 59 % of household grade (> 25 mm), 19 % of stoking grade (> 20 mm) and 22 % of fines (< 20 mm). Since markets for stoking and fine coals were rather limited in Greenland, some of the product was shipped to Denmark. Briquetting trials were carried out on the fine coal; despite good results no further steps were undertaken (Anon., 1962).

Further prospects

Analyses of West Greenland coals (table 24) indicate their high volatile, sub-bituminous character. The high ash content makes them unsuitable for technical purposes (e.g. coking) but does not impede their use as household, stoking or steaming coal. Calorific values lie below English or Polish bituminous coals, but this factor should be offset by the transport advantage for use in Greenland.

The absence of methane in the mines despite the high volatile content of the coal is most likely due to the rather shallow depth (< 300 m) of the workings, to the high average permeability of the country rock and the vicinity of the deep fjord. The latter's thaw zone might facilitate gas escape into the fjord water whereas permafrost further landward inhibits gas migration upwards. The presence of methane producing mud volcanoes in most of the large river valleys (Rosenkrantz, *in* Kühnel, 1958) is most likely connected to the presence of coal-bearing strata at depth. A full review of features connected with West Greenland mud volcanoes can be found in Henderson (1969).

Additional reserves on the south coast of Nûgssuaq were assumed by Rosenkrantz (*in* Kühnel, 1958) to be in the range of hundreds of million tons. A more conservative estimate, based on the maximum of five seams thicker than 80 cm, observed in a 500 m high profile, would indicate minimum possible reserves between 20 and 30 million tons.

Here the steep terrain and the longer distance to the coast would require greater efforts in engineering and thus in investment. The presence of a natural harbour at Atanikerdluk might to some extent offset the disadvantages mentioned.

East Greenland

Stratigraphic position and facies

The oldest coal-bearing sediments mentioned in the literature are, according to Frebold (1932), of Lower Carboniferous age and were found by H. Backlund in the Moskusoksefjord area on Hudson Land. Koch (1929) mentions possible Upper Carboniferous coal-bearing shales, overlain by fossiliferous limestones, from the Kap Brown area and Trümpy (1969) reports on a sandstone-shale facies with coal of Namurian B–Westphalian C age on Wegener Halvø. No detailed accounts of facies, number of seams or estimates of reserves are available.

The Rhaeto–Liassic Kap Stewart Formation (Rosenkrantz, 1929; Surlyk *et al.*, 1973) outcropping at Kap Hope and around Kap Stewart (fig. 413) has coal seams associated with carbonaceous lutites intercalated in variously cemented arkosic arenites. The arenites commonly contain carbonised plant fragments or thin coal laminae and characteristically form cross-bedded and well cemented roofs over the lutite-coal horizons. According to the determinations by Harris (1937), the coal seams occur in the Rhaetic.

Table 25. Analyses of coal from Kuhn Ø, East Greenland

Moisture %	Inherent Moisture %	Ash %	Effective calorific value kcal/kg	S %	H %	C %	N %	O %
1.53	0.43	11.94	6081	0.43	6.4	67.8	0.64	13.39

From Bauer, 1874

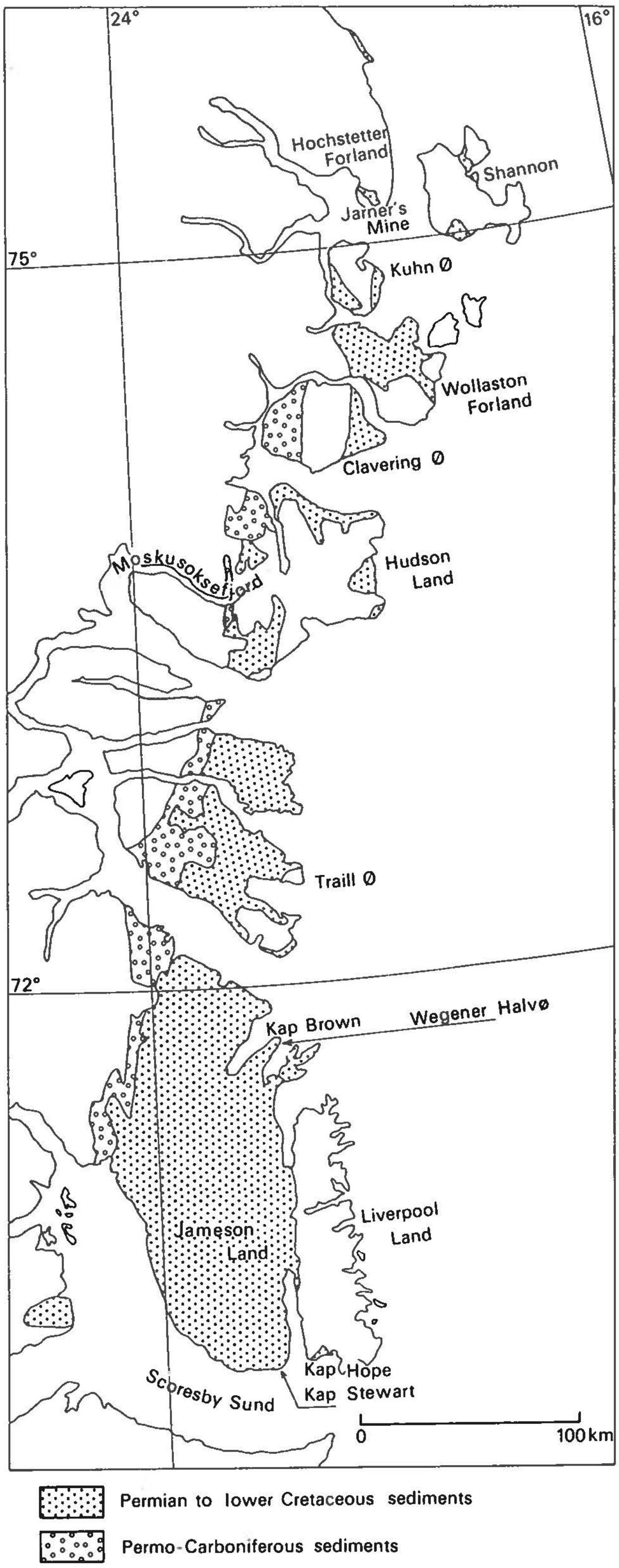


Fig. 413. East Greenland, distribution of post-Caledonian sediments from Tectonic/Geological Map of Greenland.

On the southern part of Wollaston Foreland coarse-grained, brownish sandstones are interlayered with clay and half-inch thick lignite layers. Suspected age is Jurassic (Frebold, 1932). According to Vischer (1943) and Maync (1949) their age is Tertiary.

On the south coast of Kuhn Ø thicker coal seams were found in Middle Jurassic sandstones. An analysis in Bauer (1874) (table 25) indicates lignite rank.

Kap Hope workings

Rosenkrantz (1942) investigated the occurrences at Kap Hope in some detail; the following account is largely based on his descriptions.

Coal seams occur in a small down-faulted outlier to the east of Kap Hope. Outcrops are discontinuous and the seams appear to be lenticular. Gentle dips prevail in the series, which shows several dolerite sills. One seam pinches out within 40 m of the coastal section, attaining a maximum thickness of 53 cm. The roof-rock is coarse-grained, well cemented sandstone, at least 2 m to 3 m thick. Removal of this overburden is the only alternative to underground extraction of the coal.

From table 26 can be seen that one sample has a somewhat lower rank than the other two. Rosenkrantz (1942) ascribes this fact to the different tectonic setting of the sample localities. The very high ash content together with high specific gravity and low volatile matter seems to indicate primary mud contamination. The figures from table 26 seem to indicate that the samples for analysis were taken from weathered parts. The volatile content is too low, as is the (N+O)/H ratio, in comparison with calorific values and total carbon content. Using the latter two values alone, the samples could be classified as sub-bituminous coal (Patteisky & Teichmüller, 1960).

Since resettling of the area in 1924 the Kap Hope occurrences as well as contemporaneous deposits around Kap Stewart have been worked occasionally on a small scale to supplement imported coal.

North-East Greenland

Stratigraphic position and facies

With the exception of the Jurassic deposits on the south-western tip of Hochstetter Forland, which were thoroughly investigated and described by Frebold (1932), little can be written about coal-bearing strata in North-East Greenland.

Table 26. Analyses of coal from Kap Hope, East Greenland

Specific gravity	Inherent moisture %	Ash %	Volatile matter %	Fixed carbon %	Effective calorific value kcal/kg	Calorific value ash-free basis kcal/kg	S %	H %	C %	N %	O %
1.45	2.4	10.6	38.5	48.5	6810	7117	1.03	5.5	71.2	1.00	8.3
1.53	2.0	15.9	39.7	42.4	6583	6857	1.72	5.0	66.5	0.87	8.0
1.72	3.6	29.3	24.4	42.7	4866	5061	0.76	3.3	53.0	0.64	9.4

From Rosenkrantz, 1942

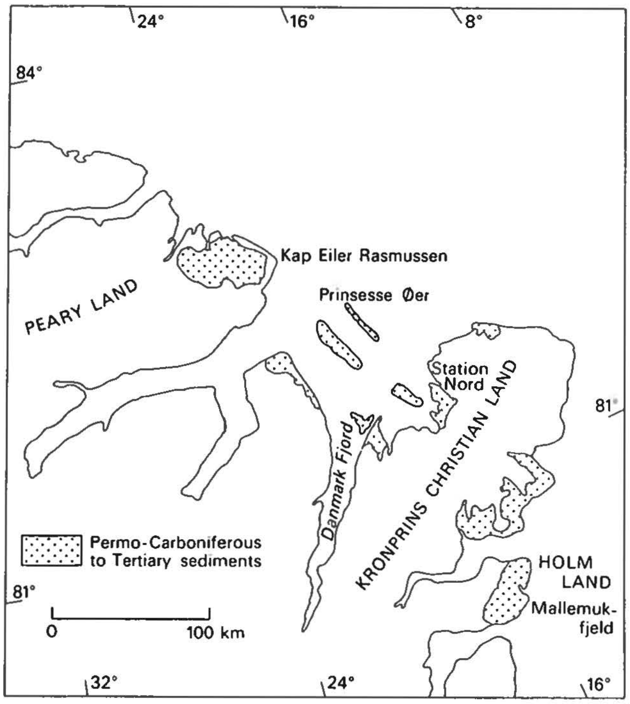


Fig. 414. North-East Greenland, distribution of Permo-Carboniferous to Tertiary sediments (from Tectonic/Geological Map of Greenland).

The occurrence of continental Carboniferous developed as sandstones and shales with several excellent coal seams up to half a metre thick is reported by Nielsen (1941) from the southern part of Holm Land, south-west of Mallemukfjeld (fig. 414). This 'Terrestrial group' had been identified by Nathorst (1911) as of Lower Carboniferous age. Coal-bearing sediments were also observed on the Prinsesse Øer; their age apparently is Tertiary (P. R. Dawes, personal communication).

'Jarner's Mine'

This locality on Hochstetter Forland was discovered by J. Payer (Koldewey, 1874), rediscovered by H. H. Jarner in 1907 and first described shortly by Koch (1929). In 1931 the area was staked by Koch, claimed for the Danish State and named after Jarner (Frebold, 1932). Frebold as a member of the 1931 East Greenland Expedition investigated the coal-bearing sediments and gave a thorough description (Frebold, 1932) which provided the basis for the compilation below. A recent investigation by Surlyk & Clemmensen (1975) resulted in some corrections of the regional relationships and a detailed facies analysis.

The coal-bearing strata occur as down-faulted blocks in the coastal outcrops. The sediments are locally strongly disturbed by faulting, but have general coastward dip (SW dip).

The stratigraphic position was determined from a marine band containing lamellibranchs; the sediments were assigned to the Callovian or Lower Oxfordian, possibly Upper Oxfordian.

The three coal seams are interlayered with friable quartz arenites, locally rich in pyrite, and subordinate carbonaceous lutites. The sequence is apparently repeated by folding and faulting. Fig. 415 shows the reconstructed distribution and thickness of the seams.

Coal analyses (table 27) indicate a rank transitional from lignite to sub-bituminous coal. Durain, vitrain and fusain, in order of importance, are the main macerals, with fusain only weakly represented. Pyrite is common and is in places strongly concentrated.

The seams are well exposed at beach level (fig.

Table 27. Analyses of coal from 'Jarner's Mine' Hochstetter Forland, North-East Greenland

Moisture %	Ash %	Calorific value kcal/kg	S %	H %	C %	$O_2 + N_2$ %
3.05	13.6	7060				
3.2	17.1	6400				
	8.1	6980		6.2	65.2	
2.48	17.2	6900	1.39	8.47	60.3	10.16
4.5	8.6	6750	1.96	7.95	65.0	12.99

From Frebold, 1932

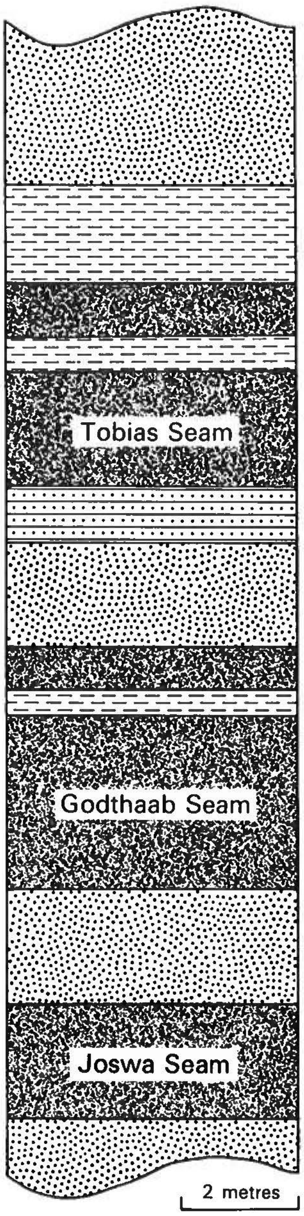


Fig. 415. Distribution of coal seams in 'Jarner's Mine', Hochstetter Forland (after Frebold, 1932).

416). The interlayered sandstones are weakly to non-cemented and thus easily removable. When the expedition's vessel *Godthaab* obtained bunker from the exposures 34 tons of clean coal were mined and transported in 240 man-hours.

Minimum reserves are estimated at 25 000 tons, referring to the coastal fault-blocks only.

Fig. 416. Coal seams exposed at 'Jarner's Mine', Hochstetter Foreland. Photo. A. Rosenkrantz.

References

Anon. 1962: Betænkning vedrørende Kulbrydning i Grønland. København: Kulbrudsudvalget, Ministeriet for Grønland. 85 pp.

Bauer, A. 1874: Analysen einiger Gesteine aus Ostgrönland. *In* Koldewey, K. *Die Zweite deutsche Nordpolarfahrt in den Jahren 1869 und 1870 under der Führung des Kapitän Karl Koldewey.* **2,** 508–511. Leipzig: Brockhaus.

Bergbau Forschung GmbH 1974: Kohlenpetrographische Untersuchungen an Kohlen aus West- und Ost-Grönland. GGU, internal report.

Bøgvad, R. 1950: Grønland som mineralproducerende Land. *In* Birket-Smith, K., Mentze, E. & Friis Møller, M. (edit.) *Grønlands Bogen* **2,** 95–117, København: Schultz Forlag.

Denham, L. R. 1974: Offshore geology of northern West Greenland. *Rapp. Grønlands geol. Unders.* **63,** 24 pp.

Frebold, H. 1932: Geologie der Jurakohlen des nördlichen Ostgrönland. *Meddr Grønland* **84,** 5, 65 pp.

Galster, J. 1942: Minedrift og Teknik i Grønland. *Danmark* **3,** 6–11.

Harris, T. 1937: The fossil flora of Scoresby Sound East Greenland. 5. Stratigraphic relations of the plant beds. *Meddr Grønland* **112,** 2, 114 pp.

Henderson, G. 1969: Oil and gas prospects in the Cretaceous–Tertiary basin of West Greenland. *Rapp. Grønlands geol. Unders.* **22,** 63 pp.

Koch, B. E. 1955: Geological observations on the Tertiary sequence of the area around Atanikerdluk, West Greenland. *Bull. Grønlands geol. Unders.* **9** (also *Meddr Grønland* **135,** 5) 50 pp.

Koch, B. E. 1964: Review of fossil floras and nonmarine deposits of West Greenland. *Bull. geol. Soc. Amer.* **75,** 535–548.

Koch, B. E. & Pedersen, K. R. 1960: Geological map of Atanikerdluk and environs. *Bull. Grønlands geol. Unders.* **23** (also *Meddr Grønland* **162,** 4) 38 pp.

Koch, L. 1929: Geology of East Greenland. *Meddr Grønland* **73** (2), 1–204.

Koldewey, K. 1874: *Die Zweite deutsche Nordpolarfahrt in den Jahren 1869 und 1870 unter Führung des Kapitän Karl Koldewey.* Leipzig: Brockhaus.

Kühnel, O. 1958: Hundrede millioner tons kul i Grønland. *Dansk tekn. Tidsskr.* **82,** 2, 21–25 & 40 only.

Lenz, O. 1874: Specielle Darstellung der geologischen Verhältnisse Ostgrönlands. *In* Koldewey, K. *Die Zweite deutsche Nordpolarfahrt in den Jahren 1869 und 1870 unter Führung des Kapitän Karl Koldewey.* **2,** 481–496. Leipzig: Brockhaus.

M'Clintock, F. L. 1859: *The voyage of the 'Fox' in the Arctic seas.* 403 pp. London: John Murray.

Nathorst, A. G. 1911: Contributions to the Carboniferous flora of north-eastern Greenland. *Meddr Grønland* **43,** 337–346.

Nielsen, E. 1941: Remarks on the map and the geology of Kronprins Christians Land. *Meddr Grønland* **126,** 2, 34 pp.

Patteisky, K. & Teichmüller, M. 1960: Inkohlungsverlauf, Inkohlungsmassstäbe und Klassifikation der Kohlen auf Grund von Vitrit Analysen. *Brennstoff Chemie,* **41,** 99–134.

Petersen, S. 1921: De grønlandske Kul. *Naturens Verden* **5,** 228–243.

Rosenkrantz, A. 1929: Preliminary account of the geology of the Scoresby Sund district. *Meddr Grønland* **73**(2), 1, 135–154.

Rosenkrantz, A. 1942: The lower Jurassic rocks of East Greenland II. The Mesozoic sediments of the Kap Hope area, southern Liverpool Land. *Meddr Grønland* **110,** 2, 56 p.

Rosenkrantz, A. 1970: Marine Upper Cretaceous and lowermost Tertiary deposits in West Greenland. *Meddr dansk geol. Foren.* **19,** 406–453.

Steenstrup, K. J. V. 1874: Om de kulførende Dannelser paa Øen Disko, Hareøen og Syd-Siden af Nûgssuak's Halvøen i Nord-Grønland. *Vidensk. Meddr dansk naturhist. Foren. Kbh.* **3–7,** 76–112.

Surlyk, F., Callomon, J. H., Bromley, R. G. & Birkelund, T. 1973: Stratigraphy of the Jurassic–Lower Cretaceous sediments of Jameson Land and Scoresby Land, East Greenland. *Bull. Grønlands geol. Unders.* **105** (also *Meddr Grønland* **193,** 5) 76 pp.

Trümpy, R. 1969: Notes on Triassic stratigraphy and paleontology of north-eastern Jameson Land (East Greenland). II. Lower Triassic ammonites from Jameson Land (East Greenland). *Meddr Grønland* **168,** 2, 77–116.