Chapter 8

Timing of thermal episodes

F. G. Christiansen and K. Hansen

The two previous chapters have demonstrated a consistent pattern of thermal maturity and a distribution of bitumen occurrences suggesting that significant amounts of hydrocarbons were once generated and expelled with possible later migration. The timing of this migration has important economic aspects, especially in relation to the formation of traps and the degradation of accumulated hydrocarbons.

Precise dating of hydrocarbon generation, migration and accumulation is difficult unless these processes are clearly related to specific geological events such as: (1) formation of diagenetic minerals, which may be dated isotopically (e.g. smectite, illite, glauconite); or (2) magmatic events which may be dated isotopically (e.g. granite or dolerite intrusion). Indirect evidence, often producing relatively narrow time constraints, may be obtained from: (1) the subsidence history deduced from stratigraphic and sedimentological data; (2) drastic changes in thermal maturity or maturity patterns across unconformities; or (3) the thermal history (especially uplift) deduced from fission track age determinations and fission track length distributions.

Franklinian subsidence and Ellesmerian orogeny

Stratigraphic and sedimentological knowledge of the Franklinian basin in North Greenland, recently described in detail by Higgins *et al.* (in press), provides a good background for the consideration of the Early Palaeozoic subsidence history and its thermal maturity effect on the source rocks.

Shelf carbonates deposited along the southen margin of the Franklinian basin seem particularly suitable for calculation of the subsidence history. Preliminary determinations by M. Sønderholm (GGU, unpublished) suggest slow steady subsidence with a slightly decreasing rate of 15–20 mm/1000 y from Early Cambrian to Early Silurian time. Estimated rates for the Late Silurian indicate much higher values around 125–150 mm/1000 y. The sediments in the northern part of the region were laid down in a deep-water trough and indicate considerably higher subsidence rates throughout the Early Palaeozoic (especially in the Early Cambrian), apparently also with increasing values in the Silurian.

Little is known of possible continued subsidence as Devonian sediments are known only in the Canadian part of the Franklinian basin. However, it is clear that the Cambrian source rocks in the northernmost areas (north of the Navarana Fjord Escarpment), and probably also some of the Silurian shales, were already buried so deeply by Late Silurian or Early Devonian time that hydrocarbon generation took place. In the central and southern parts of the region it is not known whether the burial history can account for such an early generation of hydrocarbons.

The Late Palaeozoic Ellesmerian orogeny brought sedimentation in the Franklinian basin to a close (Trettin & Balkwill, 1979). In North Greenland it gave rise to the North Greenland fold belt, which has an E–W trend across most of the northern part of the region and roughly coincides with the trend of the deep-water trough. The rocks affected by deformation are mainly turbiditic sandstones and shales of Cambrian to Early Silurian age, and exhibit an increasing intensity of deformation and metamorphism towards the north (see fig. 60; Dawes, 1976; Higgins *et al.*, 1982, 1985; Soper & Higgins, 1987).

The youngest known sediments affected by the Ellesmerian orogeny in North Greenland are of latest Silurian, possibly earliest Devonian age (Peel, 1982; Higgins *et al.*, in press), whereas the oldest post-Ellesmerian sediments which unconformably overlie folded rocks are of Late Carboniferous age (Håkansson & Stemmerik, 1984; Stemmerik & Håkansson, in press). Rb-Sr isotopic dating of whole rocks and clay mineral fractions suggests a Late Devonian to Early Carboniferous age for the Ellesmerian metamorphism (Springer, 1981; N. Springer & J. D. Friderichsen, personal communication, 1988).

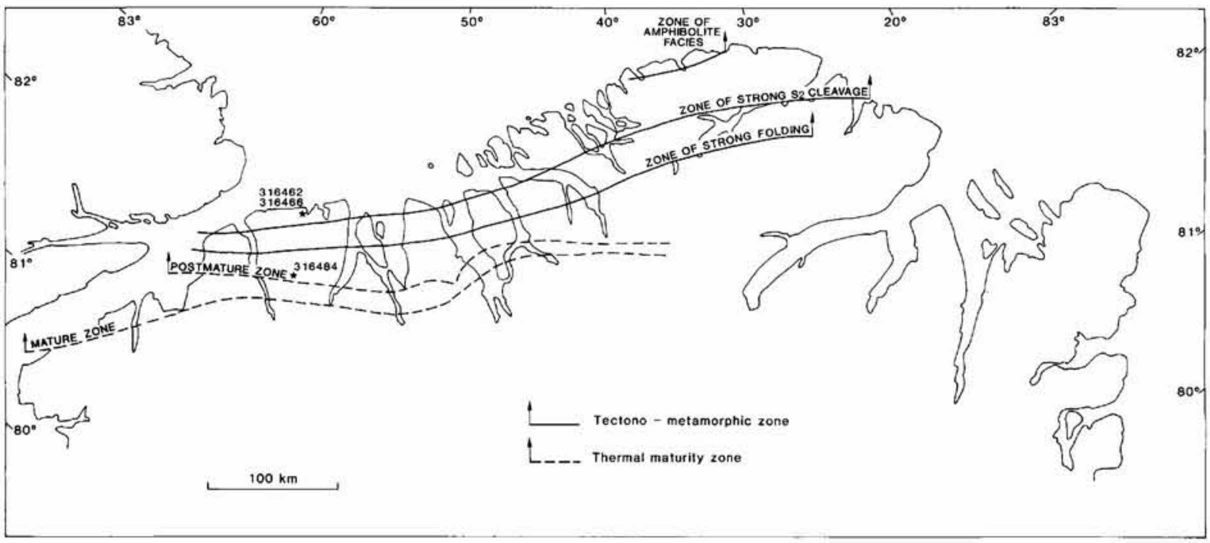

Fig. 60. Map of Ellesmerian tectono-metamorphic zones. Modified after Dawes (1976) and Higgins *et al.* (1982, 1985). The thermal maturity zonation is modified from Chapter 6. The locations of samples studied by the fission track method are indicated by stars.

The striking parallelism of the Ellesmerian tectono-metamorphic zones and the thermal maturity pattern (fig. 60) suggests that the strong thermal effect in the Early Palaeozoic source rocks is largely Ellesmerian. The thermal maturity increases markedly from thermally immature/early mature source rocks in the south to postmature source rocks over south–north distances of only 10–30 km as the fold belt is approached. A marked contrast in thermal maturity is observed in eastern Peary Land between thermally postmature or low metamorphic Silurian source rocks and overlying thermally immature or early mature Upper Palaeozoic and Mesozoic rocks (fig. 48; Christiansen *et al.*, in press). This implies at least two periods of burial or thermal events, one pre- or syn-Ellesmerian and one post-Ellesmerian, separated by a period of uplift.

Late Palaeozoic and Mesozoic sedimentation

Late Palaeozoic and Mesozoic sediments are restricted in North Greenland to relatively small areas in the northern and eastern parts of Peary Land (fig. 61; Dawes, 1976; Håkansson & Stemmerik, 1984). They rest unconformably on older rocks, or occur as fault-bounded inliers. In western North Greenland Late Palaeozoic and Mesozoic sediments have not been preserved, and it is not known where they were deposited. However, rocks of this age are widely preserved in northern Ellesmere Island (Trettin & Balkwill, 1979).

The absence of post-Ellesmerian sediments in western North Greenland may indicate that the area was subjected to uplift during Late Palaeozoic and Mesozoic time, while deposition in the Peary Land region may have been confined to fault-controlled basins.

Cretaceous–Tertiary magmatic and tectonic events

Cretaceous to Tertiary magmatic and tectonic activity is widespread in the eastern and northern part of North Greenland (fig. 61) (Soper *et al.*, 1982; Higgins *et al.*, 1985; Friderichsen & Bengaard, 1985). It is referred to the Eurekan orogeny, which affected the Canadian Arctic Islands as well as North Greenland (Trettin & Balkwill, 1972; Trettin *et al.*, 1979).

Dolerite dykes were intruded in dense N–S trending swarms along the north coast of Greenland, in north Peary Land and Nansen Land. Further south dykes are less frequent and have E–W to SE–NW trends (fig. 61). Geochemically the dykes are of alkaline type ('within-plate') (Soper *et al.*, 1982). The dykes cross-cut early Cretaceous sediments and are post-dated by the Kap Washington Group peralkaline volcanics and interbedded sediments which have a latest Cretaceous to earliest Tertiary age (Larsen *et al.*, 1978; Batten *et al.*, 1981; Batten, 1982; Larsen, 1982; Soper *et al.*, 1982). Friderichsen & Bengaard (1985) noted two dyke generations in Nansen Land, an early generation of densely distrib-

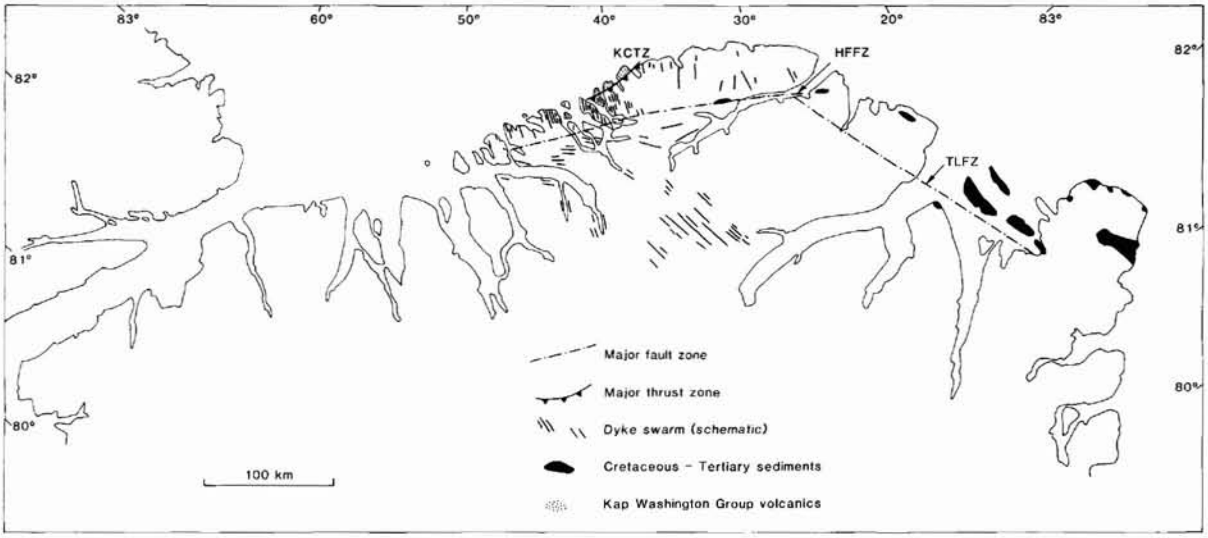

Fig. 61. Map of North Greenland showing Cretaceous–Tertiary magmatic and tectonic features. Modified after Soper *et al.* (1982). KCTZ: Kap Cannon thrust zone, HFFZ: Harder Fjord fault zone, TLFZ: Trolle Land fault zone.

uted N–S oriented dykes, and a later generation of scattered NW–SE to WNW–ESE oriented dykes.

Lower Palaeozoic metasediments of the North Greenland fold belt are thrust over the Kap Washington Group volcanics along the Kap Cannon thrust zone (fig. 61; Soper *et al.*, 1982). Isotopic ages suggest a Paleocene to Eocene age for the thrust event (Soper *et al.*, 1982).

Due to the limited occurrence of post-Ellesmerian sediments in North Greenland it is often difficult to distinguish Eurekan structures and events from those of Ellesmerian age. The most important Eurekan events are the northward thrusting on the Kap Cannon thrust zone and movements along the Harder Fjord and Trolle Land fault zones (fig. 61). In the Freuchen Land and inner J. P. Koch Fjord region, the scattered dolerite dykes are probably responsible for local anomalous thermal effect on the source rocks of the Henson Gletscher Formation (Chapter 6; Christiansen *et al.*, 1987).

Fission track analysis

A total of 15 samples from two profiles through thermally immature to postmature areas were prepared for fission track analyses, but only three of these yielded apatite grains of the appropriate size fraction (see details of preparation and analytical technique in Chapter 3).

All three samples are from Nyeboe Land (fig. 60); samples 316462 and 316466 are from turbiditic sandstones in the upper part of the Early Silurian Merqujôq Formation, whereas sample 316484 is from a sandstone in the Late Silurian Wulff Land Formation. The two first samples come from a thermally postmature to low metamorphic area in the steeply inclined Nyeboe Land linear belt (Dawes, 1982) where a cleavage is developed in the interlayered mudstone beds. The third sample is from a thermally postmature area, apparently undeformed, situated 50 km to the south (fig. 60).

The two northernmost samples, 316462 and 316466, show similar apatite fission track ages (Table 5). The

Table 5. Fission track ages of apatite and zircon

Sample	Ma ± 1 σ	No. grains	Ns	Ni	X^2(P%)
Apatite fission track ages					
316462	206.79±22.14	9	253	165	96.4
316466	207.18±21.53	9	275	179	89.2
316484	224.45±17.24	16	435	463	99.2
Zircon fission track ages					
316462*	457.73±45.40	8	552	125	4.9
	411.11±41.41	8	528	130	7.3
316484	347.74±34.30	9	482	141	88.8

*Two determinations; the very low probability of the chi-squared test (X^2(P%)), indicates that the interpretation of this age is difficult.

mean track lengths and track length distributions fall in the field of mixed and bimodal distributions of Gleadow *et al.* (1986) indicating a complex thermal history (Table 6; fig. 62). The bimodal character of 316462 and the broad based character of 316466 may be ascribed to a heating event in the 70–130°C range (Gleadow *et al.*, 1983) which only partly annealed earlier tracks. This event took place later than the age of 207 Ma. The southern sample, 316484, shows a slightly older age of 224 Ma and longer mean track length indicating a very limited late thermal overprint. This fission track age is expected to reflect the age of uplift through the 100°C isotherm.

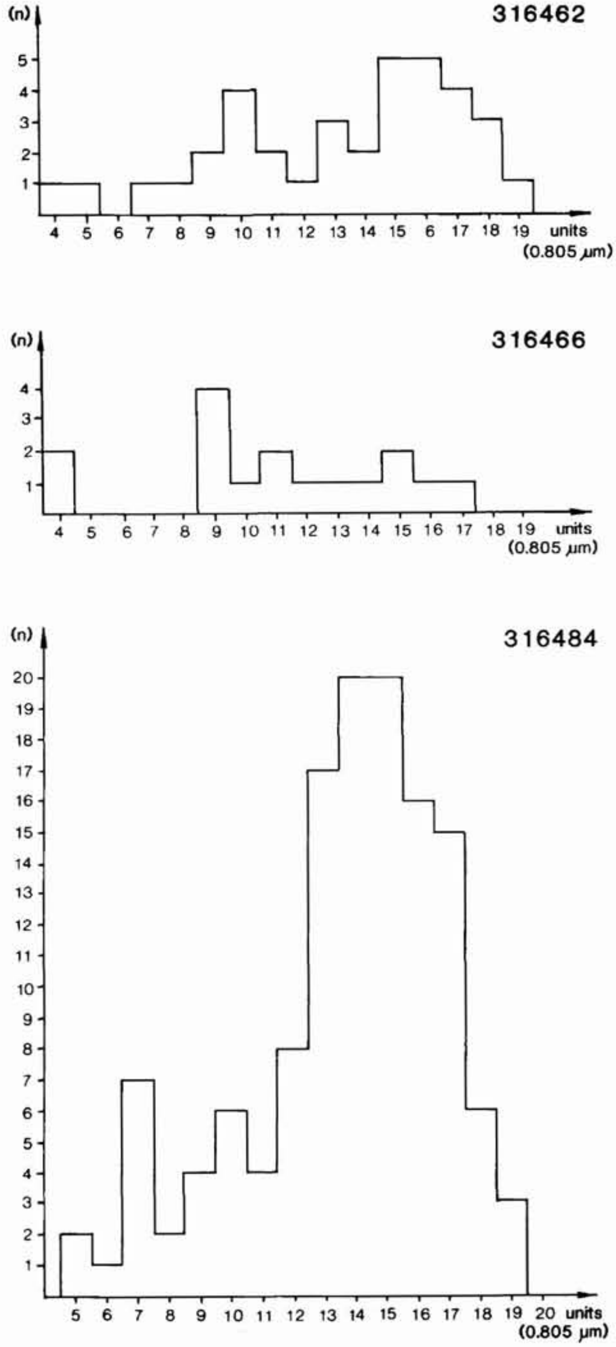

Fig. 62. Fission track length distributions. See details in Tables 5 and 6.

Table 6. Confined track lengths of apatites

Sample	$t_{mean} \pm 1\ \sigma$ (µm)	No.	Type	Quality
316462	10.62±3.11	35	bimodal	?good
316466	9.01±3.19	15	mixed	poor
316484	10.99±2.53	130	mixed	good

Fission track zircon age determinations were performed on two of the samples (Table 5). The obtained fission track ages are significantly different from each other. The northern sample, 316462, was reanalysed, but in both cases gave a low probability of the chi-squared test. The individual zircon grain ages of the sample are close to, or older than, the time of deposition (*c.* 280–700 Ma) and may imply that pre-sedimentary fission tracks were only partly annealed in the temperature interval around 240 ± 50°C (Hurford, 1986). The southern sample, 316484, is of much better analytical quality as expressed by the high probability of the chi-squared test, and the fission track age of 348 Ma obtained probably corresponds to the time of uplift through the 240°C isotherm.

A possible time-temperature history of the analysed samples is illustrated in fig. 63. All three sandstones were deposited in the Silurian and subjected to rapid subsidence shortly after deposition. During this subsidence and the following Ellesmerian orogeny the sandstones reached temperatures well above the apatite annealing range (100 ± 30°C) and possibly also close to the zircon annealing temperature (240 ± 50°C). Uplift through the 240°C isotherm took place shortly after the Ellesmerian orogeny, whereas uplift through the 100°C isotherm occurred in Late Triassic to Early Jurassic time. A possible late thermal overprint in the northern area was probably associated with Cretaceous to Tertiary magmatic activity.

Calculated cooling rates for sample 316484 give 8.9°C/Ma in the 240°C to 100°C interval and 4.5°C/Ma in the 100°C to 0°C interval. Using a geothermal gradient of 30°C/km, these values correspond to uplift rates of 36 m/Ma and 15 m/Ma, respectively. Such rates are comparable with post-Caledonian vertical movements in the

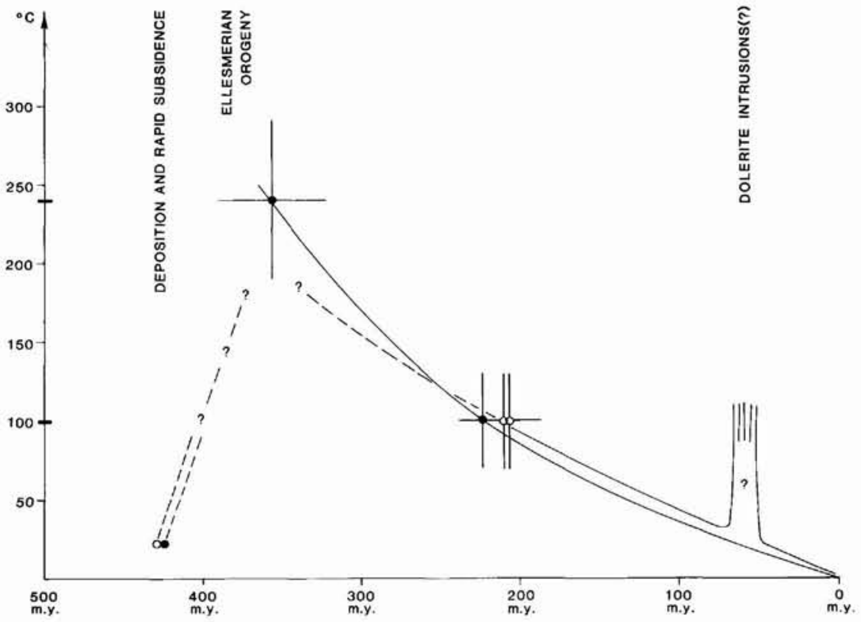

Fig. 63. Synoptic diagram showing the thermal tectonic history of the Silurian sediments in northern Nyeboe Land.

Scoresby Sund region of East Greenland (Hansen, 1985).

Implications

The thermal history as outlined by geological considerations, the thermal maturity pattern, and the age determinations of thermal episodes and uplift, is consistent with a simple model of hydrocarbon generation and possible accumulation. Both the Middle to Late Cambrian and the Early Silurian source rocks were subjected to rapid subsidence in the Late Silurian and suffered a strong thermal alteration during this subsidence and the subsequent Ellesmerian deformation. Most of the potential hydrocarbons were probably already generated at this time. After the Ellesmerian orogeny, uplift and cooling prevailed throughout most of the Mesozoic, possibly with local heating in the northernmost part of the region in the Cretaceous and Tertiary in association with the intense dyke intrusion.

References

Aldridge, R. J., Dorning, K. J., Hill, P. J., Richardson, J. B. & Siveter, D. J. 1979: Microfossil distribution in the Silurian of Britain and Ireland. *In* Harris, A. L., Holland, C. H. & Leake, B. E. (edit.) The Caledonides of the British Isles – reviewed. *Spec. Publ. geol. Soc. Lond.* **8**, 433–438.

Allaart, J. H. 1965: The Lower Paleozoic sediments of Hall Land, North Greenland. Unpubl. intern. GGU rep., 11 pp.

Allman, M. & Lawrence, D. F. 1972: *Geological laboratory techniques*, 335 pp. London: Blandford Press.

Armstrong, H. A. & Dorning, K. J. 1984: Silurian palynomorphs from the Chester Bjerg Formation, Hall Land, western North Greenland. *Rapp. Grønlands geol. Unders.* **121**, 97–103.

Bally, A. W. & Snelson, S. 1980: Reals of subsidence. *Bull. Can. Petrol. Geol.* **28**, 9–75.

Batten, D. J. 1981: Palynofacies, organic maturation and source potential for petroleum. *In* Brooks, J. (edit.) *Organic maturation studies and fossil fuel exploration*, 201–223. London: Academic Press.

Batten, D. J. 1982: Palynology of shales associated with the Kap Washington Group volcanics, central North Greenland. *Rapp. Grønland geol. Unders.* **108**, 15–23.

Batten, D. J. 1984: Identification of amorphous sedimentary organic matter by transmitted light microscopy. *In* Brooks, J. (edit.) Petroleum geochemistry and exploration of Europe. *Spec. Publ. geol. Soc. Lond.* **12**, 275–287.

Batten, D. J., Brown, P. E., Dawes, P. R., Higgins, A. K., Koch, B. E., Parson, I. & Soper, N. J. 1981: Peralkaline volcanicity on the Eurasia basin margin. *Nature* **294**, 150–152.

Berry, W. B. N. & Wilde, P. 1978: Progressive ventilation of the oceans – an explanation for the distribution of the Lower Paleozoic black shales. *Am. J. Sci.* **278**, 257–275.

Bertrand, R. & Héroux, Y. 1987: Chitinozoan, graptolite, and scolecodont reflectance as an alternative to vitrinite and pyrobitumen reflectance in Ordovician and Silurian strata, Anticosti Island, Quebec, Canada. *Bull. Am. Ass. Petrol. Geol.* **71**, 951–957.

Bishop, R. S., Gehman, H. M. Jr., Young, A. 1983: Concepts for estimating hydrocarbon accumulation and dispersion. *Bull. Am. Ass. Petrol. Geol.* **67**, 337–348.

Bjerreskov, M. 1986: Silurian graptolites from N Greenland. *In* Hughes, C. P. & Rickards, R. B. (edit.) Palaeoecology and biostratigraphy of graptolites. *Spec. Publ. geol. Soc. Lond.* **20**, 181–189.

Bois, C., Bouche, P. & Pelet, R. 1982: Global geologic history and distribution of hydrocarbon reserves. *Bull. Am. Ass. Petrol.* **66**, 1248–1270.

Bryant, I. D. & Smith, M. P. 1985: Lowermost Ordovician sandstones in central North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 25–30.

Buchardt, B. & Cederberg, T. 1987: EFP-83 projekt: Stabil isotop geokemi i moderbjergarter, olie og gas i Danmark, afsluttende rapport. Geologisk Centralinstitut, København, 33 pp.

Buchardt, B., Clausen, J. & Thomsen, E. 1986: Carbon isotope composition of Lower Palaeozoic kerogen: Effects of maturation. *In* Leythaeuser, D. & Rullkötter, J. (edit.) Advances in organic geochemistry 1985. *Org. Geochem.* **10**, 127–134.

Burgess, J. D. 1974: Microscopic examination of kerogen (dispersed organic matter) in petroleum exploration. *Spec. Pap. geol. Soc. Am.* **153**, 19–30.

Bustin, R. M., Barnes, M. A. & Barnes, W. C. 1985a: Diagenesis 10. Quantification and modelling of organic diagenesis. *Geoscience Canada* **12**, 4–21.

Bustin, R. M., Cameron, A. R., Grieve, D. A. & Kalkreuth, W. D. 1985b: Coal petrology, its principles, methods, and applications. *Geol. Ass. Can. Short Course Notes* **3**, 230 pp.

Christiansen, F. G. (edit.) 1988: Petroleum geology of North Greenland. Final report – 'Nordolie'. Unpubl. intern. GGU rep., Part I (text) 231 pp., part II (figures) 101 pp., Appendix I (previously completed papers 43 + 95 pp., Appendix II (key data) 87 pp.

Christiansen, F. G. & Nøhr-Hansen, H. 1989: The Silurian shales of central and western North Greenland: evaluation of hydrocarbon source rock potential. *Rapp. Grønlands geol. Unders.* **143.**

Christiansen, F. G. & Rolle, F. 1985: Project 'Nordolie': hydrocarbon source rock investigations in central North Greenland. *Rapp. Grønlands geol. Unders.* **125**, 17–21.

Christiansen, F. G., Nøhr-Hansen, H., Rolle, F. & Wrang, P. 1985: Preliminary analysis of the hydrocarbon source rock potential of central and western North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 117–128.

Christiansen, F. G., Nykjær, O. & Nøhr-Hansen, H. 1986: Source rock investigations and shallow core drilling in central and western North Greenland – project 'Nordolie'. *Rapp. Grønlands geol. Unders.* **130**, 17–23.

Christiansen, F. G., Nøhr-Hansen, H. & Nykjær, O. 1987: The Cambrian Henson Gletscher Formation: a mature to postmature hydrocarbon source rock sequence from North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 141–157.

Christiansen, F. G., Piasecki, S. & Stemmerik, L. in press: Petroleum, North Greenland. *In* Trettin, H. P. (edit.) *The Innuitian Orogen and Arctic platform: Canada and Greenland. The geology of North America* **E**. Ottawa: Geological Survey of Canada.

Christie, R. L. 1979: The Franklinian geosyncline in the Canadian Arctic and its relationship to Svalbard. *Norsk Polarinstitutt, Skrifter* **167**, 263–314.

Christie, R. L. & Dawes, P. R. in press: A history of exploration and geology in the Innuitian region. *In* Trettin, H. P. (edit.) *The Innuitian Orogen and Arctic platform: Canada and Greenland. The geology of North America* **E**. Ottawa: Geological Survey of Canada.

Christie, R. L. & Ineson, J. R. 1979: Precambrian–Silurian geology of the G. B. Schley Fjord region, eastern Peary Land, North Greenland. *Rapp. Grønlands geol. Unders.* **88**, 63–71.

Christie, R. L. & Peel, J. S. 1977: Cambrian–Silurian stratigraphy of Børglum Elv, Peary Land, eastern North Greenland. *Rapp. Grønlands geol. Unders.* **82**, 48 pp.

Clayton, J. L. & Swetland, P. J. 1978: Subaerial weathering of sedimentary organic matter. *Geochim. cosmochim. Acta* **42**, 305–312.

Clementz, D. M. 1979: Effect of oil and bitumen saturation on source rock pyrolysis. *Bull. Am. Ass. Petrol. Geol.* **63**, 2227–2232.

Clemmensen, L. B. 1979: Notes on the palaeogeographical setting of the Eocambrian tillite-bearing sequence of southern Peary Land, North Greenland. *Rapp. Grønlands geol. Unders.* **88**, 15–22.

Collinson, J. D. 1979: The Proterozoic sandstones between Heilprin Land and Mylius-Erichsen Land, eastern North Greenland. *Rapp. Grønlands geol. Unders.* **88**, 5–10.

Collinson, J. D. 1980: Stratigraphy of the Independence Fjord Group (Proterozoic) of eastern North Greenland. *Rapp. Grønlands geol. Unders.* **99**, 7–23.

Combaz, A. 1964: Les palynofacies. *Rev. Micropaleontol. Paris* **7**, 205–218.

Curiale, J. A. 1986: Origin of solid bitumens, with emphasis on biological marker results. *In* Leythaeuser, D. & Rullkötter, J. (edit.) Advances in organic geochemistry 1985. *Org. Geochem.* **10**, 559–580.

Davies, W. E. 1972: Landscape of northern Greenland. *Spec. Rep. Cold Reg. Res. Engng. Lab.* **164**, 67 pp.

Davis, N. C. & Higgins, A. K. 1987: Cambrian – Lower Silurian stratigraphy in the fold and thrust zone between northern Nyeboe Land and J. P. Koch Fjord, North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 91–98.

Dawes, P. R. 1971: The North Greenland fold belt and environs. *Bull. geol. Soc. Denmark* **20**, 197–239.

Dawes, P. R. 1976: Precambrian to Tertiary of northern Greenland. *In* Escher, A. & Watt, W. S. (edit.) *Geology of Greenland,* 248–303. Copenhagen: Geol. Surv. Greenland.

Dawes, P. R. 1982: The Nyeboe Land fault zone: a major dislocation on the Greenland coast along northern Nares Strait. *In* Dawes, P. R. & Kerr, J. W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 177–192.

Dawes, P. R. 1984a: Operation Grant Land 1965–1966; a geological exploration programme in Ellesmere Island and North Greenland. *Rapp. Grønlands geol. Unders.* **121**, 5–17.

Dawes, P. R. 1984b: Programme NordGrøn (PNG) 1983–1985: regional mapping and geological studies in western and central North Greenland. *Rapp. Grønlands geol. Unders.* **120**, 18–24.

Dawes, P. R. & Christie, R. L. 1982: History of exploration and geology in the Nares Strait region. *In* Dawes, P. R. & Kerr, J. W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 19–36.

Dawes, P. R. & Christie, R. L. in press: Geomorphic regions of the Innuitian region. *In* Trettin, H. P. (edit.) *The Innuitian Orogen and Arctic platform: Canada and Greenland. The geology of North America* **E**. Ottawa: Geological Survey of Canada.

Dawes, P. R. & Haller, J. 1979: Historical aspects in the geological investigation of northern Greenland. Part 1: New maps and photographs from the 2nd Thule Expedition 1916–18 and the Bicentenary Jubilee Expedition 1920–1923. *Meddr Grønland* **200**(4), 38 pp.

Dawes, P. R. & Kerr, J. W. (edit.) 1982: Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 392 pp.

Dawes, P. R. & Peel, J. S. 1981: The northern margin of Greenland from Baffin Bay to the Greenland Sea. *In* Nairn, A. E. M., Churkin, M. & Stehli, F. G. (edit.) *The ocean basins and margins* **5**, 201–264. New York: Plenum Publ. Corp.

Dawes, P. R. & Soper, N. J. 1970: Geological investigations in northern Peary Land. *Rapp. Grønlands geol. Unders.* **28**, 9–15.

Dawes, P. R. & Soper, N. J. 1973: Pre-Quaternary history of North Greenland. *In* Pitcher, M. G. (edit.) Arctic geology. *Mem. Am. Ass. Petrol. Geol.* **19**, 117–134.

Dawes, P. R. & Soper, N. J. 1979: Structural and stratigraphic framework of the North Greenland fold belt in Johannes V. Jensen Land, Peary Land. *Rapp. Grønlands geol. Unders.* **93**, 40 pp.

Dawes, P. R. & Soper, N. J. 1973: Pre-Quaternary history of North Greenland. *In* Pitcher, M. G. (edit.) Arctic geology. *Mem. Am. Ass. Petrol. Geol.* **19**, 117–134.
W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 89–104.

Deines, P. 1980: The isotopic composition of reduced organic matter. *In* Fritz, P. & Fontez, J. Ch. (edit.) *Handbook of environmental isotope geochemistry*. Vol. **1**, *The terrestrial environment,* 329–407. Amsterdam: Elsevier.

Demaison, G. 1984: The generative basin concept. *In* Demaison, G. & Murris, R. J. (edit.) Petroleum geochemistry and basin evaluation. *Mem. Am. Ass. Petrol. Geol.* **35**, 1–14.

Dorning, K. J. 1987: The organic palaeontology of Palaeozoic carbonate environments. *In* Hart, M. B. (edit.) *Micropalaeontology of carbonate environments*, 256–265. Chichester, England: Ellis Horwood Ltd.

Dow, W. G. 1977: Kerogen studies and geological interpretations. *J. geochem. Expl.* **7**, 79–99.

Duffield, S. L. 1985: Land-derived microfossils from the Jupiter Formation (Upper Llandoverian) Anticosta Island, Québec. *J. Paleont.* **59**, 1005–1010.

Durand, B. (edit.) 1980: *Kerogen. Insoluble organic matter from sedimentary rocks*, 519 pp. Paris: Editions Technip.

Ellitsgaard-Rasmussen, K. 1955: Features of the geology of the folding range of Peary Land, North Greenland. *Meddr Grønland* **127**(7), 56 pp.

Embry, A. F., Powell, T. C. & Mayr, U. in press: Petroleum resources, Arctic Islands. A. Petroleum. *In* Trettin, H. P. (edit.) *The Innuitian Orogen and Arctic platform: Canada and Greenland. The geology of North America* **E**. Ottawa: Geological Survey of Canada.

Epstein, A. G., Epstein, J. B. & Harris, L. D. 1977: Conodont color alteration – an index to metamorphism. *Prof. Pap. U.S. geol. Surv.* **995**, 27 pp.

Epstein, S., Buchsbaum, R., Lowenstam, H. A. & Urey, H. C. 1951: Carbonate-water isotopic temperature scale. *Bull. geol. Soc. Am.* **62**, 417–425.

Escher, J. C. & Larsen P.-H. 1987: The buried western extension of the Navarana Fjord escarpment in central and western North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 81–89.

Espitalié, J., Laporte, J. L., Madec, M., Marquis, F., Leplat, P. 1977: Methode rapide de caracterisation des roches mères de leur potentiel pétrolier et de leur degré d'évolution. *Revue Inst. fr. Pétrole* **32**, 23–42.

Espitalié, J., Madec, M. & Tissot, B. 1980: Role of mineral matrix in kerogen pyrolysis: influence on petroleum generation and migration. *Bull. Am. Ass. Petrol. Geol.* **64**, 59–66.

Espatilié, J., Makadi, K. S. & Trichet, Y. 1984: Role of the mineral matrix during kerogen pyrolysis. *Org. Geochem.* **6**, 365–382.

Evans, R. J. & Felbeck, Jr. G. T. 1983: High temperature simulation of petroleum formation – II. Effects of inorganic sedimentary constituents on hydrocarbon formation. *Org. Geochem.* **4**, 145–152.

Folk, R. L. 1968: *Petrology of sedimentary rocks*, 170 pp. Austin, Texas: Hemphill's.

Forsberg, A. & Bjorøy, M. 1983: A sedimentological and organic geochemical study of the Botneheia Formation, Svalbard, with special emphasis on the effects of weathering on the organic matter in shales. *In* Bjorøy, M. *et al.* (edit.) *Advances in organic geochemistry 1981*, 60–68. London: Wiley & sons Ltd.

Foscolos, A. E., Powell, T. G. & Gunther, P. R. 1976: The use of clay minerals and inorganic and organic geochemical indicators for evaluating the degree of diagenesis and oil generating potential of shales. *Geochim. cosmochim. Acta* **40**, 953–966.

Friderichsen, J. D. & Bengaard, H.-J. 1985: The North Greenland fold belt in eastern Nansen Land. *Rapp. Grønlands geol. Unders.* **126**, 69–78.

Friderichsen, J. D., Higgins, A. K., Hurst, J. M., Pedersen, S. A. S., Soper, N. J. & Surlyk, F. 1982: Lithostratigraphic framework of the Upper Proterozoic and Lower Palaeozoic deep water clastic deposits of North Greenland. *Rapp. Grønlands geol. Unders.* **107**, 20 pp.

Frisch, T. 1974: Metamorphic and plutonic rocks of northernmost Ellesmere Island, Canadian Arctic Archipelago. *Bull. geol. Surv. Can.* **229**, 87 pp.

Galimov, E. M. 1980: $^{13}C/^{12}C$ in kerogen. *In* Durand, B. (edit.) *Kerogen*, 271–300. Paris: Editions Technip.

Gleadow, A. J. W. & Lovering, J. F. 1978: Thermal history of granitic rocks from western Victoria: a fission track dating study. *J. Geol. Soc. Aust.* **25**, 323–340.

Gleadow, A. J. W., Duddy, I. R. & Lovering, J. F. 1983: Fission track analysis: a new tool for the evaluation of thermal histories and hydrocarbon potential. *Austr. Petrol. Expl. Assoc. J.* **23**, 93–102.

Gleadow, A. J. W., Duddy, I. R., Green, P. F. & Lovering, J. F. 1986: Confined fission track lengths in apatite: a diagnostic tool for thermal history. *Contr. Mineral. Petrol.* **94**, 405–415.

Glensen, P. G. & Andrews, H. N. 1987: The evolution of early land plants. *American Scientist* **75**, 478–489.

Glickson, M., Gibson, D. L. & Philp, R. P. 1985: Organic matter in Australian Cambrian oil shales and Lower Palaeozoic shales. *Chem. Geol.* **51**, 175–191.

Goodarzi, F. & Norford, B. S. 1985: Graptolites as indicators of the temperature history of rocks. *J. geol. Soc. Lond.* **142**, 1089–1099.

Goodarzi, F., Snowdon, L. R., Gunther, P. R. & Jenkins, W. A. M. 1985: Preliminary organic petrography of Palaeozoic rocks from the Grand Banks, Newfoundland. *Marine Petrol. Geol.* **2**, 254–259.

Grahn, Y. & Nøhr-Hansen, H. 1989: Chitinozoans from Ordovician and Silurian shelf and slope sequences from North Greenland. *Rapp. Grønlands geol. Unders.* **144.**

Grantham, P. J. 1986: The occurrence of unusual C_{27} and C_{29} sterane predominance in two types of Oman crude oil. *Org. Geochem.* **9**, 1–10.

Grønlands Fiskeri- og Miljøundersøgelser 1986: Biologiske miljøundersøgelser i Nordgrønland 1984–85. Unpubl. rep., 113 pp.

Gutjahr, C. C. M. 1983: Introduction to incident-light microscopy of oil and gas source rocks. *Geol. Mijnbouw* **62**, 417–425.

Håkansson, E. & Stemmerik, L. 1984: Wandel Sea Basin – The North Greenland equivalent to Svalbard and the Barents Shelf. *In* Spencer, A. M. *et al.* (edit.) *Petroleum geology of North European margin,* 97–107. Norwegian Petroleum Society.

Hansen, B. T., Kalsbeek, F. & Holm, P. M. 1987: Archaean age and Proterozoic metamorphic overprinting of the crystalline basement at Victoria Fjord, North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 159–168.

Hansen, K. 1985: Fission track age determinations of vertical movements in the crust caused by continental rifting: a fission track age study of the Scoresby Sund area; method and results. Unpublished lic.scient. thesis, Univ. Copenhagen, 119 pp.

Hatch, J. R., Jacobsen, S. R., Witzke, B. J., Risatti, J. B., Anders, D. E., Watney, W. L., Newell, K. D. & Vuletich, A. K. 1987: Possible late Middle Ordovician organic carbon isotope excursion: evidence from Ordovician oils and hydrocarbon source rocks, Mid-Continent and East-Central United States. *Bull. Am. Ass. Petrol. Geol.* **71**, 1342–1354.

Henderson, G. 1976: Petroleum geology. *In* Escher, A. & Watt, W. S. (edit.) *Geology of Greenland*, 489–505. Copenhagen: Geol. Surv. Greenland.

Henriksen, N. 1985a: Systematic 1:500 000 mapping and regional geological studies in central and western North Greenland. *Rapp. Grønlands geol. Unders.* **125**, 9–17.

Henriksen, N. 1985b: Systematic geological mapping in 1984 in central and western North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 5–10.

Henriksen, N. 1986: Completion of field work for the 1:500 000 mapping and regional geological studies in central and western North Greenland. *Rapp. Grønlands geol. Unders.* **130**, 9–17.

Henriksen, N. 1987: Systematic geological mapping in 1985 in central and western North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 5–12.

Henriksen, N. & Jepsen, H. F. 1985: Precambrian crystalline basement at the head of Victoria Fjord, North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 11–16.

Henriksen, N. & Peel, J. S. 1976: Cambrian – Early Ordovician stratigraphy in southwestern Washington Land, western North Greenland. *Rapp. Grønlands geol. Unders.* **80**, 17–23.

Heroux, Y. Chagnon, A. & Bertrand, R. 1979: Compilation and correlation of major thermal maturation indicators. *Bull. Am. Ass. Petrol. Geol.* **63**, 2128–2144.

Higgins, A. K. 1986: Geology of central and eastern North Greenland. *Rapp. Grønlands geol. Unders.* **128**, 37–54.

Higgins, A. K. & Soper, D. J. 1985: Cambrian – Lower Silurian slope and basin stratigraphy between northern Nyeboe Land and western Amundsen Land, North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 79–86.

Higgins, A. K., Mayr, U. & Soper, N. J. 1982: Fold belts and metamorphic zones of northern Ellesmere Island and North Greenland. *Rapp. Grønlands geol. Unders.* **130**, 9–17.

Higgins, A. K., Soper, N. J. & Friderichsen, J. D. 1985: North Greenland fold belt in eastern North Greenland. *In* Gee, D. G. & Sturt, B. A. (edit.) *The Caledonide Orogen – Scandinavia and related areas,* 1017–1029. London: John Wiley & Sons Ltd.

Higgins, A. K., Ineson, J. R., Peel, J. S., Surlyk, F. & Sønderholm, M. in press: The Franklinian basin in North Greenland. *In* Trettin, H. P. (edit.) *The Innuitian Orogen and Arctic platform: Canada and Greenland. The geology of North America* E. Ottawa: Geological Survey of Canada.

Hills, I. R., Whitehead, E. V., Anders, D. E., Cummins, J. J. & Robinson, W.E. 1966: An optically active triterpane, gammacerane in Green River, Colorado, oil shale bitumen. *Chem. Commun.* **20**, 752–754.

Horsfield, B. 1984: Pyrolysis studies and petroleum exploration. *In* Brooks, J. & Welte, D. (edit.) *Advances in petroleum geochemistry* **1**, 247–298. London: Academic Press.

Horsfield, B., Dembicki Jr, H. & Ho, T. T. Y. 1983: Some potential applications of pyrolysis to basin studies. *J. geol. Soc. Lond.* **140**, 431–443.

Huang, W.-Y. & Meinschein, W. G. 1976: Sterols as ecological indicators. *Geochim. cosmochim. Acta* **40**, 323–330.

Hunt, J. M. 1979: *Petroleum geochemistry and geology*, 615 pp. San Francisco: W. H. Freeman and Co.

Hurford, A. J. 1986: Cooling and uplift patterns in the Lepontine Alps, South Central Switzerland and an age of the vertical movement on the Insubric fault line. *Contrib. Miner. Petrol.* **92**, 413–427.

Hurford, A. J. & Green, P. F. 1983: The zeta age calibration of fission track dating. *Isotope Geosci.* **1**, 285–317.

Hurst, J. M. 1980a: Silurian stratigraphy and facies distribution in Washington Land and western Hall Land, North Greenland. *Bull. Grønlands geol. Unders.* **138**, 95 pp.

Hurst, J. M. 1980b: Paleogeographic and stratigraphic differentiation of Silurian buildups and biostromes of North Greenland. *Bull. Am. Ass. Petrol. Geol.* **64**, 527–548.

Hurst, J. M. 1981: Platform edge and slope relationships: Silurian of Washington Land, North Greenland and comparison to Arctic Canada. *Bull. Can. Petrol. Geol.* **29**, 408–419.

Hurst, J. M. 1984: Upper Ordovician and Silurian carbonate shelf stratigraphy, facies and evolution, eastern North Greenland. *Bull. Grønlands geol. Unders.* **148**, 73 pp.

Hurst, J. M. & Peel, J. S. 1979: Late Proterozoic (?) to Silurian stratigraphy of southern Wulff Land, North Greenland. *Rapp. Grønlands geol. Unders.* **91**, 37–56.

Hurst, J. M. & Surlyk, F. 1982: Stratigraphy of the Silurian turbidite sequence of North Greenland. *Bull. Grønlands geol. Unders.* **145**, 121 pp.

Hurst, J. M. & Surlyk, F. 1983: Initiation, evolution and destruction of an early Paleozoic carbonate shelf, eastern North Greenland. *J. Geol.* **91**, 671–691.

Hurst, J. M., McKerrow, W. S., Soper, N. J. & Surlyk, F. 1983: The relationship between Caledonian nappe tectonics and Silurian turbidite deposition in North Greenland. *J. geol. Soc. Lond.* **140**, 123–132.

Illich, H. A. 1983: Pristane, phytane, and lower molecular weight isoprenoid distributions in oils. *Bull. Am. Ass. Petrol. Geol.* **67**, 385–397.

Ineson, J. R. 1985: The stratigraphy and sedimentology of the Brønlund Fjord and Tavsen Iskappe Groups (Cambrian) of Peary Land, eastern North Greenland. Unpublished Ph.D. thesis, University of Keele, U.K., 310 pp.

Ineson, J. R. & Peel, J. S. 1980: Cambrian stratigraphy in Peary Land, eastern North Greenland. *Rapp. Grønlands geol. Unders.* **99**, 33–42.

Ineson, J. R. & Peel, J. S. 1987: Cambrian platform – outer shelf relationship in the Nordenskiöld Fjord region, central North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 13–26.

Ineson, J. R. & Peel, J. S. in press: Cambrian shelf stratigraphy of the Peary Land region, central North Greenland. *Bull. Grønlands geol. Unders.*

Jacob, H. 1983: Recent studies on the genesis of natural solid oil bitumens. *Geol. Jahr. Reihe D* **59**, 61 pp.

Jacob, H. 1985: Disperse, feste Erdölbitumina als Migrations- und Maturitätsindikatoren im Rahmen der Erdöl-/Erdgas-Prospektion. Eine Modellstudie in NW-Deutschland. *Deutsche Gesellschaft Mineralölwissenschaft und Kohlechemie E.V., Forschungsbericht* **267**, 54 pp.

Jensenius, J. 1987: Fluid inclusion and stable isotope studies of diagenetic calcite and dolomite associated with seeping asphalt, North Greenland, 28 pp. *In* Jensenius, J. 1987: Fluid inclusion microthermometry and stable isotope studies applied to the diagenesis of sedimentary rocks. Unpublished lic. scient. thesis, University of Copenhagen.

Jepsen, H. F. 1971: The Precambrian, Eocambrian and early Palaezoic stratigraphy of the Jørgen Brønlund Fjord area, Peary Land, North Greenland. *Bull. Grønlands geol. Unders.* **96**, 42 pp.

Jones, R. W. 1987: Organic facies. *In* Brooks, J. (edit.) *Advances in petroleum geochemistry* **2**, 1–90. London: Academic Press.

Katz, B. J. 1983: Limitations of 'Rock-Eval' pyrolysis for typing organic matter. *Org. Geochem.* **4**, 195–199.

Kerr, J. W. 1967: Nares submarine rift valley and relative rotation of North Greenland. *Bull. Can. Petrol. Geol.* **15**, 483–520.

Kerr, J. W. 1980: A plate tectonic contest in Arctic Canada. *In* Strangway, D. W. (edit.) The continental crust and its mineral deposits. *Spec. Pap. geol. Ass. Can.* **20**, 457–486.

Kingston, D. R., Dishroon, C. P. & Williams, P. A. 1985: Global basin classification system. *Oil Gas J.* **83**(18), 238–262.

Kisch, H. J. 1980: Incipient metamorphism of Cambro-Silurian clastic rocks from the Jamtland Supergroup, central Scandinavian caledonides, western Sweden: illite crystallinite and 'vitrinite' reflectance. *J. geol. Soc. Lond.* **137**, 271–288.

Klemme, H. D. 1971: What giants and their basins have in common. *Oil Gas J.* **69**(9), 85–90.

Koch, C. J. W. 1987: Preparation and characterization by X-ray diffraction of kerogen from Cambrian and Silurian sedimentary rocks from North Greenland. Unpubl. intern. GGU rep., 13 pp.

Koch, L. 1925: The geology of North Greenland. *Am. J. Sci.* **9**, 271–285.

Koch, L. 1929: Stratigraphy of Greenland. *Meddr Grønland* **73**(2), 205–320.

Kontorovich, A. E. 1984: Geochemical methods for the quantitative evaluation of the petroleum potential of sedimentary basins. *In* Demaison, G. & Murris, R. J. (edit.) Petroleum geochemistry and basin evaluation. *Mem. Am. Ass. Petrol. Geol.* **35**, 79–109.

Krebs, W. & Macqueen, R. W. 1984: Sequence of diagenetic and mineralization events, Pine-Point lead-zinc property, Northwest Territories, Canada. *Bull. Can. Petrol. Geol.* **32**, 434–464.

Larsen, N. H. 1985: Cambrian endolithic alga from North Greenland. Sec. Int. Phycol. Congr., Book of abstracts, 88. Copenhagen.

Larsen, N. H. 1989: Fossil algae from North Greenland. *Open File Ser. Grønlands geol. Unders.* **89/3**, 32 pp. + 42 figs.

Larsen, O. 1982: The age of the Kap Washington Group volcanics, North Greenland. *Bull. geol. Soc. Denmark* **31**, 49–55.

Larsen, O., Dawes, P. R. & Soper, N. J. 1978: Rb/Sr age of the Kap Washington Group, Peary Land, North Greenland, and its geotectonic implications. *Rapp. Grønlands geol. Unders.* **90**, 115–119.

Larsen, P.-H. & Escher, J. C. 1985: The Silurian turbidite sequence of the Peary Land Group between Newman Bugt and Victoria Fjord, western North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 47–67.

Larsen, P.-H. & Escher, J. C. 1987: Additions to the lithostratigraphy of the Peary Land Group (Silurian) in western and central North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 65–80.

Larsen, P.-H., Edwards, D. & Escher, J. C. 1987: Late Silurian plant megafossils from the Peary Land Group, North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 107–112.

Legall, F. D., Barnes, C. R. & Macqueen, R. W. 1981: Thermal maturation, burial history and hotspot development, Paleozoic strata of southern Ontario–Québec, from conodont and acritarch colour alteration studies. *Bull. Can. Petrol. Geol.* **29**, 492–539.

Leggett, J. K., McKerrow, W. S., Cocks, L. R. M. & Richards, R. B. 1981: Perodicity in the early Palaeozoic marine realm. *J. geol. Soc. Lond.* **138**, 167–176.

Lewan, M. D. 1983: Effects of thermal maturation on stable organic carbon isotopes as determined by hydrous pyrolysis of Woodford Shale. *Geochim. cosmochim. Acta* **47**, 1471–1479.

Lewan, M. D. 1986: Stable carbon isotopes of amorphous kerogens from Phanerozoic rocks. *Geochim. cosmochim. Acta* **50**, 1583–1591.

Leythaeuser, D. 1973: Effects of weathering on organic matter in shales. *Geochim. cosmochim. Acta* **37**, 113–120.

Link, W. K. 1952: Significance of oil and gas seeps in World oil exploration. *Bull. Am. Ass. Petrol. Geol.* **36**, 1505–1540.

Macauley, G., Snowdon, L. R. & Ball, F. D. 1985: Geochemistry and geological factors governing exploitation of selected Canadian oil shale deposits. *Pap. geol. Surv. Can.* **85–13**, 65 pp.

Mackenzie, A. G. 1984: Applications of biological markers in petroleum geochemistry. *In* Brooks, J. & Welte, D. H. (edit.) *Advances in petroleum geochemistry* **1**, 115–214. London: Academic Press.

Macqueen, R. W. & Powell, T. G. 1983: Organic geochemistry of the Pine Point lead-zinc ore field and region, Northwest Territories, Canada. *Econ. Geol.* **78**, 1–15.

Marcussen, C., Christiansen, F. G., Larsen, P.-H., Olsen, H., Piasecki, S., Stemmerik, L., Bojesen-Koefoed, J., Jepsen, H. F. & Nøhr-Hansen, H. 1987: Studies of the onshore hydrocarbon potential in East Greenland 1986–87: field work from 72° to 74°N. *Rapp. Grønlands geol. Unders.* **135**, 72–81.

McKerrow, W. S. 1979: Ordovician and Silurian changes in sea level. *J. geol. Soc. Lond.* **136**, 137–145.

McKirdy, D. M., Aldridge, A. K. & Ypma, P. J. M. 1983: A geochemical comparison of some crude oils from Pre-Ordovician carbonate rocks. *In* Bjoroy, M. *et al.* (edit.) *Advances in organic geochemistry 1981*, 99–107. London: Wiley & Sons Ltd.

McKirdy, D. M., Kantsler, A. J., Emmett, J. K. & Aldridge, A. K. 1984: Hydrocarbon genesis and organic facies in Cambrian carbonates of the eastern Officer basin, South Australia. *In* Palacas, J. G. (edit.) Petroleum geochemistry and source rock potential of carbonate rocks. *Am. Ass. Petrol. Geol. Stud. Geol.* **18**, 13–31.

Miller, B. M. 1986: Resource appraisal methods, choice and outcome. *In* Rice, D. D. (edit.) Oil and gas assessment. *Am. Ass. Petrol. Geol. Stud. Geol.* **21**, 1–23.

Moldowan, J. M. Seifert, W. K. & Gallegos, E. J. 1985: Relationship between petroleum composition and depositional environment of petroleum source rocks. *Bull. Am. Ass. Petrol. Geol.* **69**, 1255–1268.

Moore, L. V. 1984: Significance, classification of asphaltic material in petroleum exploration. *Oil Gas J.* **82**(41), 109–112.

Nassichuk, W. W. 1983: Petroleum potential in Arctic North

America and Greenland. *Cold Regions Science and Technology* **7**, 51–88.

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

Norford, B. S. 1972: Silurian stratigraphic sections at Kap Tyson, Offley Ø and Kap Schuchert, northwestern Greenland. *Meddr Grønland* **195**(2), 40 pp.

Nøhr-Hansen, H. & Koppelhus, E. B. 1988: Ordovician spores with trilete rays from Washington Land, North Greenland. *Rev. Palaeobot. Palynol.* **56**, 305–311.

O'Connor, B. 1979: The Portfjeld Formation (?early Cambrian) of eastern North Greenland. *Rapp. Grønlands geol. Unders.* **88**, 23–28.

Ogunyami, O., Hesse, R. & Héroux, Y. 1980: Pre-orogenic and synorogenic diagenesis and anchimetamorphism in Lower Paleozoic continental margin sequences of the northern Appalachians in and around Quebec City, Canada. *Bull. Can. Petrol. Geol.* **28**, 559–577.

Ourisson, G., Albrecht, P. & Rohmer, M. 1979: Paleochemistry and biochemistry of a group of natural products: the hopanoids. *Pure Appl. Chem.* **51**, 709–729.

Østfeldt, P. 1987a: Oil-source rock correlation in the Danish North Sea. *In* Brooks, J. & Glennie, K. (edit.): *Petroleum geology of North West Europe,* 419–429. London: Graham & Trotman.

Østfeldt, P. 1987b: Organic geochemistry of North Greenland samples. Unpubl. intern. GGU rep., 43 pp.

Parrish, J. T. 1982: Upwelling and petroleum source beds, with reference to Paleozoic. *Bull. Am. Ass. Petrol. Geol.* **66**, 750–774.

Parrish, J. T. 1987: Palaeo-upwelling and the distribution of organic-rich rocks. *In* Brooks, J. & Fleet, A. J. (edit.) Marine petroleum source rocks. *Spec. Publ. geol. Soc. Lond.* **26**, 199–205.

Peel, J. S. 1979: Cambrian – Middle Ordovician stratigraphy of the Adams Gletscher region, south-west Peary Land, North Greenland. *Rapp. Grønlands geol. Unders.* **88**, 29–39.

Peel, J. S. 1980: Cambrian and Ordovician geology of Warming Land and southern Wulff Land, central North Greenland. *Rapp. Grønlands geol. Unders.* **101**, 55–60.

Peel, J. S. 1982: The Lower Paleozoic of Greenland. *In* Embry, A. F. & Balkwill, H. R. (edit.) Arctic geology and geophysics. *Mem. Can. Soc. Petrol. Geol.* **8**, 309–330.

Peel, J. S. 1985: Cambrian – Silurian platform stratigraphy of eastern North Greenland. *In* Gee, D. G. & Sturt, B. A. (edit.) *The Caledonide Orogen – Scandinavia and related areas,* 1077–1094. London: John Wiley & Sons Ltd.

Peel, J. S. & Christie, R. L. 1982: Cambrian–Ordovician stratigraphy, correlations around Kane basin. *In* Dawes, P. R. & Kerr, J. W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 117–135.

Peel, J. S. & Hurst, J. M. 1980: Late Ordovician and early Silurian stratigraphy of Washington Land, western North Greenland. *Rapp. Grønlands geol. Unders.* **100**, 18–24.

Peel, J. S. & Wright, S. C. 1985: Cambrian platform stratigraphy in the Warming Land – Freuchen Land region, North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 17–24.

Peel, J. S., Dawes, P. R., Collinson, J. D. & Christie, R.L. 1982: Proterozoic – basal Cambrian stratigraphy across Nares Strait: correlation between Inglefield Land and Bache Peninsula. *In* Dawes, P. R. & Kerr, J. W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 105–115.

Perregaard, J. 1979: Organic geochemistry of sedimentary organic matter from Greenland: a petroleum source rock evaluation. Unpubl. intern. GGU rep., 81 pp. + appendix.

Philp, R. P. & Lewis, C. A. 1987: Organic geochemistry of biomarkers. *Ann. Rev. Earth Planet. Sci.* **15**, 363–395.

Poty, B., Leroy, J. & Jachimowicz, 1976: A new device for measuring temperatures under microscope: the Chaixmeca microthermometry apparatus. *In* Roedder, E. & Kozlowski, A. (edit) *Fluid inclusion research* **9**, 173–178.

Powell, T. G. 1978: An assessment of the hydrocarbon source potential of the Canadian Arctic Island. *Pap. geol. Surv. Can.* **78–12**, 82 pp.

Powell, T. G., Macqueen, R. W., Barker, J. F. & Bree, D. G. 1984: Geochemical character and origin of Ontario oils. *Bull. Can. Petrol. Geol.* **32**, 289–312.

Procter, R. M., Tayor, G. C. & Wade, J. A. 1984: Oil and gas resources of Canada. *Pap. geol. Surv. Can.* **83–31**, 59 pp.

Radke, B. M. & Mathis, R. L. 1980: On the formation and occurrence of saddle dolomite. *J. sed. Petrol.* **50**, 1149–1168.

Rayer, F. G. 1981: Exploration prospects and future petroleum potential of the Canadian Arctic Islands. *J. petrol. Geol.* **3**, 367–412.

Reed, J. D., Illich, H. A. & Horsfield, B. 1986: Biochemical evolutionary significance of Ordovician oils and their sources. *In* Leythaeuser, D. & Rullkötter, J. (edit.) Advances in organic geochemistry 1985. *Org. Geochem.* **10**, 347–358.

Rice, D. D. (edit.) 1986: Oil and gas assessment. *Am. Ass. Petrol. Geol. Stud. Geol.* **21**, 267 pp.

Robert, P. 1974: Analyse microscopique des charbons et des bitumen dispersés dans roches et mesure de leur pouvoir réflecteur. Application à l'étude de la paléogéothermie des bassins sédimentaires et de la genèse des hydrocarbures. *In* Tissot, B. & Bienner, F. (edit.) *Advanced organic geochemistry,* 549–569. Rueil-Malmaison.

Rogers, M. A., McAlary, J. D. & Baily, N. J. L. 1974: Significance of reservoir bitumens to thermal-maturation studies, Western Canada basin. *Bull. Am. Ass. Petrol. Geol.* **58**, 1806–1824.

Rolle, F. 1981: Hydrocarbon source rock sampling in Peary Land 1980. *Rapp. Grønlands geol. Unders.* **106**, 99–103.

Rolle, F. & Wrang, P. 1981: En foreløbig oliegeologisk vurdering af Peary Land området i Nordgrønland. Unpubl. intern. GGU rep., 21 pp.

Rullkötter, J., Meyers, P. A., Schaefer, R. G. & Dunham, K. W. 1986: Oil generation in the Michigan Basin: a biological marker and carbon isotope approach. *In* Leythaeuser, D. & Rullkötter, J. (edit.) Advances in organic geochemistry 1985. *Org. Geochem.* **10**, 359–375.

St. John, B., Bally, A. W. & Klemme, H. D. 1984: Sedimentary provinces of the world – hydrocarbon productive and nonproductive. *Am. Assoc. Petrol. Geol. Map Library,* 36 pp. + maps.

Schoell, M. 1984: Wasserstoff- und Kohlenstoffisotope in organischen Substanzen, Erdölen und Erdgassen. *Geol Jahrb. Reihe D.* **67**, 167 pp.

Schopf, T. J. M. 1983: Paleozoic black shales in relation to continental margin upwelling. *In* Thiede, J. & Suess, E. (edit.) *Coastal upwelling, its sediment record, part B: Sedimentary records of ancient coastal upwelling,* 570–596. New York: Plenum Press.

Scotese, C. R., Bambach, R. K., Barton, C., Van der Voo, R. & Ziegler, A. M. 1979: Palaeozoic base maps. *J. Geol.* **87**, 217–278.

Sikander, A. H. & Pittion, J. L. 1978: Reflectance studies on organic matter in Lower Paleozoic sediments of Quebec. *Bull. Can. Petrol. Geol.* **26**, 132–151.

Sluijk, D. & Nederlof, M. H. 1984: Worldwide geological experience as a systematic basis for prospect appraisal. *In* Demaison, G. & Murris, R. J. (edit.) Petroleum geochemistry and basin evaluation. *Mem. Am. Ass. Petrol. Geol.* **35,** 15–26.

Smith, M. P., Sønderholm, M. & Tull, S. J. 1989: The Morris Bugt Group (Middle Ordovician – Early Silurian) of North Greenland and its correlatives. *Rapp. Grønlands geol. Unders.* **143**.

Sønderholm, M. & Due, P. H. 1985: Lower and Middle Ordovician platform carbonate lithostratigraphy of Warming Land, Wulff Land and Nares Land, North Greenland. *Rapp. Grønlands geol. Unders.* **126**, 31–46.

Sønderholm, M. & Harland, T. L. 1989a: Franklinian reef belt, Silurian, North Greenland. *In* Geldsetzer, H. J. J., James, N. P. & Tebbutt, G. E. (edit.) Reefs, Canada and adjacent area. *Mem. Can. Soc. Petrol. Geol.* **13,** 356-366.

Sønderholm, M. & Harland, T. L. 1989b: Latest Ordovician – earliest Silurian reef mounds in western North Greenland. *In* Geldsetzer, H. J. J., James, N. P. & Tebbutt, G. E. (edit.) Reefs, Canada and adjacent area. *Mem. Can. Soc. Petrol. Geol.* **13,** 241-243.

Sønderholm, M., Harland, T. L., Due, P. H., Jørgensen, L. N. & Peel, J. S. 1987: Lithostratigraphy and depositional history of Upper Ordovician – Silurian shelf carbonates in central and western North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 27–40.

Soper, N. J. & Higgins, A. K. 1987: A shallow detachment beneath the North Greenland fold belt: implications for sedimentation and tectonics. *Geol. Mag.* **124**, 441–450.

Soper, N. J., Dawes, P. R. & Higgins, A. K. 1982: Cretaceous–Tertiary magmatic and tectonic events in North Greenland and the history of adjacent ocean basins. *In* Dawes, P. R. & Kerr, J. W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 205–220.

Springer, N. 1981: Preliminary Rb-Sr age determinations from the North Greenland fold belt, Johannes V. Jensen Land, with comments on the metamorphic grade. *Rapp. Grønlands geol. Unders.* **106**, 77–84.

Springer, N. (compiler) 1987: Conventional core analysis for GGU. Cambrian sandstones from North Greenland (Nordolie). Unpubl. intern. GGU rep., 17 pp.

Sproule, J. C. 1966: Oil and gas prospects of the Canadian Arctic Islands. *Proc. 8th Commonwealth Mining and Metallurgical Congress, Australia and New Zealand 1965,* Vol. **5** (Petroleum), 57–64.

Staplin, F. L. 1969: Sedimentary organic matter, organic metamorphism, and oil and gas occurrence. *Bull. Can. Soc. Petrol. Geol.* **17**, 47–66.

Stemmerik, L. & Håkansson, E. 1989: Stratigraphy and depositional history of the Upper Palaeozoic and Triassic sediments in the Wandel Sea Basin, eastern North Greenland. *Rapp. Grønlands geol. Unders.* **143**.

Stoneley, R. 1981: Petroleum: the sedimentary basin. *In* Tarling, D. H. (edit.) *Economic geology and geotectonics,* 51–71. London: John Wiley & Sons Ltd.

Stouge, S., Thomsen, E. & Guvad, C. 1988: Reflected light microscopy of graptolite periderm material of Ordovician/Silurian strata in North Greenland. Unpubl. intern. GGU rep., 58 pp.

Strother, P. K. & Traverse, A. 1979: Plant microfossils from Llandoverian and Wenlockian rocks of Pennsylvania. *Palynology* **3**, 1–21.

Stuart-Smith, J. H. 1970: Hydrocarbon potential of northern Greenland. *Bull. Am. Ass. Petrol. Geol.* **54**, 2507 only.

Stuart-Smith, J. H. & Wennekers, J. H. N. 1977: Geology and hydrocarbon discoveries of Canadian Arctic Islands. *Bull. Am. Ass. Petrol. Geol.* **61**, 1–27.

Surlyk, F. 1982: Nares Strait and the down-current termination of the Silurian turbidite basin of North Greenland. *In* Dawes, P. R. & Kerr, J. W. (edit.) Nares Strait and the drift of Greenland: a conflict in plate tectonics. *Meddr Grønland Geosci.* **8**, 147–150.

Surlyk, F. 1983: Source rock sampling, stratigraphical and sedimentological studies in the Upper Palaeozoic of the Jameson Land basin, East Greenland. *Rapp. Grønlands geol. Unders.* **115**, 88–93.

Surlyk, F. & Hurst, J. M. 1983: Evolution of the early Paleozoic deep-water basin of North Greenland – aulacogen or narrow ocean? *Geology* **11**, 77–81.

Surlyk, F. & Hurst, J. M. 1984: The evolution of the early Paleozoic deep-water basin of North Greenland. *Bull. geol. Soc. Am.* **95**, 131–154.

Surlyk, F., Hurst, J. M., Marcussen, C., Piasecki, S., Rolle, F., Scholle, P. A., Stemmerik, L. & Thomsen, E. 1984: Oil geological studies in the Jameson Land basin, East Greenland. *Rapp. Grønlands geol. Unders.* **120**, 85–90.

Surlyk, F. & Ineson, J. R. 1987a: Aspects of Franklinian shelf, slope and trough evolution and stratigraphy of North Greenland. *Rapp. Grønlands geol. Unders.* **133**, 41–58.

Surlyk, F. & Ineson, J. R. 1987b: The Navarana Fjord Member (new) – an Upper Llandovery platform derived carbonate conglomerate. *Rapp. Grønlands geol. Unders.* **133**, 59–63.

Thickpenny, A. & Leggett, J. K. 1987: Stratigraphic distribution and palaeo-oceanographic significance of European early Palaeozoic organic-rich sediments. *In* Brooks, J. &

Fleet, A. J. (edit.) Marine petroleum source rocks. *Spec. Publ. geol. Soc. Lond.* **26**, 231-247.

Thomsen, E. & Guvad, C. 1987: Organic petrology and thermal maturity of Lower Palaeozoic deposits from western and central North Greenland. Unpubl. intern. GGU rep., part 1 (text) 40 pp. and part 2 (figures) 49 pp.

Tissot, B. P. & Welte D. H. 1984: *Petroleum formation and occurrence*, 699 pp. Berlin, Heidelberg, New York, Tokyo: Springer Verlag.

Trettin, H. P. 1987: Pearya: a composite terrane with Caledonian affinities in northern Ellesmere Island. *Can. J. Earth Sci.* **24**, 224–245.

Trettin, H. P. & Balkwill, H. R. 1979: Contributions to the tectonic history of the Innuitian Province, Arctic Canada. *Can. J. Earth Sci.* **16**, 748–769.

Trettin, H. P., Frisch, T. O., Sobczak, L. W., Weber, J. R., Law, L. R., Delaurier, I., Niblett, E. R. & Whitnam, K. 1972: The Innuitian Province. *In* Price, R. A. & Douglas, R. J. W. (edit.) Variation in tectonic styles in Canada. *Spec. Pap. geol. Ass. Can.* **11**, 83–179.

Troelsen, J. C. 1949: Contributions to the geology of the area round Jørgen Brønlunds Fjord, Peary Land, North Greenland. *Meddr Grønland* **149**(2), 29 pp.

Troelsen, J. C. 1950: Contributions to the geology of Northwest Greenland, Ellesmere Island and Axel Heiberg Island. *Meddr Grønland* **149**(7), 85 pp.

Tyson, R. V. 1987: The genesis and palynofacies characteristics of marine petroleum source rocks. *In* Brooks, J. & Fleet, A. J. (edit.) Marine petroleum source rocks. *Spec. Publ. geol. Soc. Lond.* **26**, 47–67.

Ungerer, P., Bessis, F., Chenet, P. Y., Durand, B., Nogaret, A., Chiarelli, A., Oudin, J. L. & Perrin, J. F. 1984: Geological and geochemical models in oil exploration; principles and practical examples. *In* Demaison, G. & Murris, R. J. (edit.) Petroleum geochemistry and basin evaluation. *Mem. Am. Ass. Petrol. Geol.* **35**, 53–77.

Vavrdová, N. 1984: Some plant microfossils of possible terrestrial origin from the Ordovician of Central Bohemia. *Věstnik Ústředniho ústavu geologického* **59**, 165–170.

Venkatachala, B. S. 1981: Differentiation of amorphous organic matter types in sediments. *In* Brooks, J. (edit.) *Organic maturation studies and fossil fuel exploration,* 177–200. London: Academic Press.

Waples, D. W. 1985: *Geochemistry in petroleum exploration,* 232 pp. Dordrecht: Reidel Publ. Com.

Wedeking, K. W. & Hayes, J. M. 1983: Carbonization of Precambrian kerogens. *In* Bjorøy *et al.* (edit.) *Advances in organic geochemistry 1981,* 546–553. London: Wiley & Sons Ltd.

Welte, D. H., Kalkreuth, W. & Hoefs, J. 1975: Age-trend in carbon isotopic composition in Palaeozoic sediments. *Naturwissenschaften* **62**, 482–483.

Welte, D. H. & Yukler, M. A. 1981: Petroleum origin and accumulation in basin evolution – a quantitative model. *Bull. Am. Ass. Petrol. Geol.* **65**, 1387–1396.

Yarbrough, S. C. 1986: Oil and gas developments in Europe 1985. *Bull. Am. Ass. Petrol. Geol.* **70**, 1578–1610.

Plate 1. Kerogen

A. Sample with a relatively low (0.21% TOC) kerogen content and a dominance of finely disseminated amorphous kerogen in a silica gel, Lafayette Bugt Formation, Nyeboe Land, GGU 316490–1, unsieved organic material.
B. As A., Lafayette Bugt Formation, Nyeboe Land, GGU 316490–2, sieved organic material (on 10 μm nylon mesh).
C. Sample with a relatively moderate (1.15% TOC) kerogen content and small to moderate amounts of large amorphous kerogen particles, Thors Fjord Member, Nares Land, GGU 318007–18–1 unsieved organic material.
D. As C., Thors Fjord Member, Nares Land, GGU 318007–18–2, sieved organic material (on 10 μm nylon mesh).
E. Sample with a relatively large (5.09% TOC) kerogen content and a dominance of large amorphous kerogen particles, Thors Fjord Member, Nares Land, GGU 318007–32–1, unsieved organic material.
F. As E., Thors Fjord Member, Nares Land, GGU 318007–32–2, sieved organic material (on 10 μm nylon mesh).

Scale bar: 20 μm.

Plate 2. Cambrian palynomorphs

A. Acritarch-like folded alga. Middle Cambrian Sydpasset Formation, Freuchen Land, MGUH 19334 from GGU 315873–2; 139.5–13.9.
B. Acritarch-like folded alga. Middle Cambrian Sydpasset Formation, Freuchen Land, MGUH 19335 from GGU 315873–2; 150.6–7.0.
C. Two acritarch-like folded algae. Middle Cambrian Sydpasset Formation, Freuchen Land, MGUH 19336 (large light body), MGUH 19337 (dark small body), both from GGU 315873–2; 122.0–15.3.
D. Acritarch-like folded alga. Middle Cambrian, Ekspedition Bræ Formation, Freuchen Land, MGUH 19338 from GGU 324217–2; 139.2–14.9.
E. Acritarch-like folded alga. Middle Cambrian, Ekspedition Bræ Formation, Freuchen Land, MGUH 19339 from GGU 324300–2; 131.2–13.4.
F. Acritarch-like folded alga. Middle Cambrian, Ekspedition Bræ Formation, Freuchen Land, MGUH 19340 from GGU 324217–2; 141.9–11.4.
G. Lump of algal or spore-like elements. Middle Cambrian, Ekspedition Bræ Formation, Freuchen Land, MGUH 19341 from GGU 324300–2; 127.8–14.4.
H. Diad-like lump of algal or spore-like elements. Middle Cambrian, Ekspedition Bræ Formation, Freuchen Land, MGUH 19342 from GGU 314300–2; 138.5–17.8.
I. Lump of alga or spore-like elements. Middle Cambrian, Ekspedition Bræ Formation, Freuchen Land, MGUH 19343 from GGU 324300–2; 157.7–14.7.

Scale bar: 20 μm.

Plate 3. Ordovician palynomorphs

A. Acritarch. Upper Ordovician Troedsson Cliff Member, Washington Land, MGUH 19344 from GGU 316968–2; 145.3–17.8.
B. Acritarch. Upper Ordovician – Lower Silurian Aleqatsiaq Fjord Formation, Washington Land, MGUH 19345 from GGU 316085–4; 124.1–21.3.
C. Graptolite fragment, Upper Ordovician Troedsson Cliff Member, Washington Land, MGUH 19346 from GGU 316968–2; 128.1–2.9.
D. Scolecodont, Upper Ordovician, Troedsson Cliff Member, Washington Land, MGUH 19347 from GGU 316968–2; 148.8–15.1.
E. Alga. Upper Ordovician – Lower Silurian Aleqatsiaq Formation, Nyeboe Land, MGUH 19348 from GGU 316103–2; 135.0–15.0.
F. Filamentous alga. Upper Ordovician – Lower Silurian Aleqatsiaq Formation, Washington Land, MGUH 19349 from GGU 316058–2; 135.1–4.2.
G.-L. Spores with trilete rays. Upper Ordovician, Troedsson Cliff Member, Washington Land (Nøhr-Hansen & Koppelhus, 1988).
G.-I. *Besselia nunaatica*, MGUH 17539 from GGU 316968–2; 125.5–8.3.
G. Distal view illustrating the minute ornamentation.
H. Equatorial view.
I. Internal proximal view.
J. *Besselia nunaatica*, two connected spores, internal proximal view, MGUH 17541 from GGU 316968–2; 155.1–11.9.
K.-L. *Besselia nunaatica*. MGUH 17542 from GGU 316968–2; 123.8–15.9.
K. Distal view illustrating the ornamentation.
L. Internal proximal view.

Scale bar: 20 μm.

Plate 4. Silurian palynomorphs

A. Chitinozoan, *Angochitina* cf. *A. elongata*. Upper Silurian Wulff Land Formation, Wulff Land, MGUH 19350 from GGU 315950–3; 136.9–17.2.
B. Chitinozoans, *Linochitina erratica*. Upper Silurian Wulff Land Formation, Wulff Land, MGUH 19351 from GGU 315950–2; 154.3–9.6.
C. *Retiolites*, graptolite fragment. Upper Silurian, Wulff Land Formation, Wulff Land, MGUH 19352 from GGU 315950–3; 155.1–11.1.
D. Graptolite fragment, Upper Silurian, Wulff Land Formation, Wulff Land, MGUH 19353 from GGU 315950–2; 127.3–5.7.
E.-H. Trilete spore-like bodies, figs E and F with a degraded bitumen-like appearance.
E. Lower Silurian Lafayette Bugt Formation, Washington Land, MGUH 19354 from GGU 211760–2; 143.3–17.2.
F. Upper Silurian Wulff Land Formation, Wulff Land, MGUH 19355 from GGU 315950–3; 15950–3; 155.5–8.2.
G. Upper Silurian Nyeboe Land Formation, Nyeboe Land, MGUH 19356 from GGU 319234–2; 119.3–11.0.
H. Upper Silurian Nyeboe Land Formation, Wulff Land, MGUH 19357 from GGU 319210–3; 130.6–21.4.
I. Spherical folded algae, acritarchs? Lower Silurian Lafayette Bugt Formation, Hall Land, MGUH 19358 from GGU 324157–2; 144.2–8.5.
J. Tubular structure. Upper Silurian Nyeboe Land Formation, Wulff Land, MGUH 19359 from GGU 319210–3; 146.6–16.5.
K. Tubular structure. Upper Silurian Nyeboe Land Formation, Nyeboe Land, MGUH 19360 from GGU 319234–2; 138.8–8.0.
L. Rounded drop-shaped palynomorphs. Lower Silurian Lafayette Bugt Formation, Washington Land, MGUH 19361 from GGU 316061–2; 137.1–14.8.

Scale bar: 20 μm.

Plate 1. Kerogen

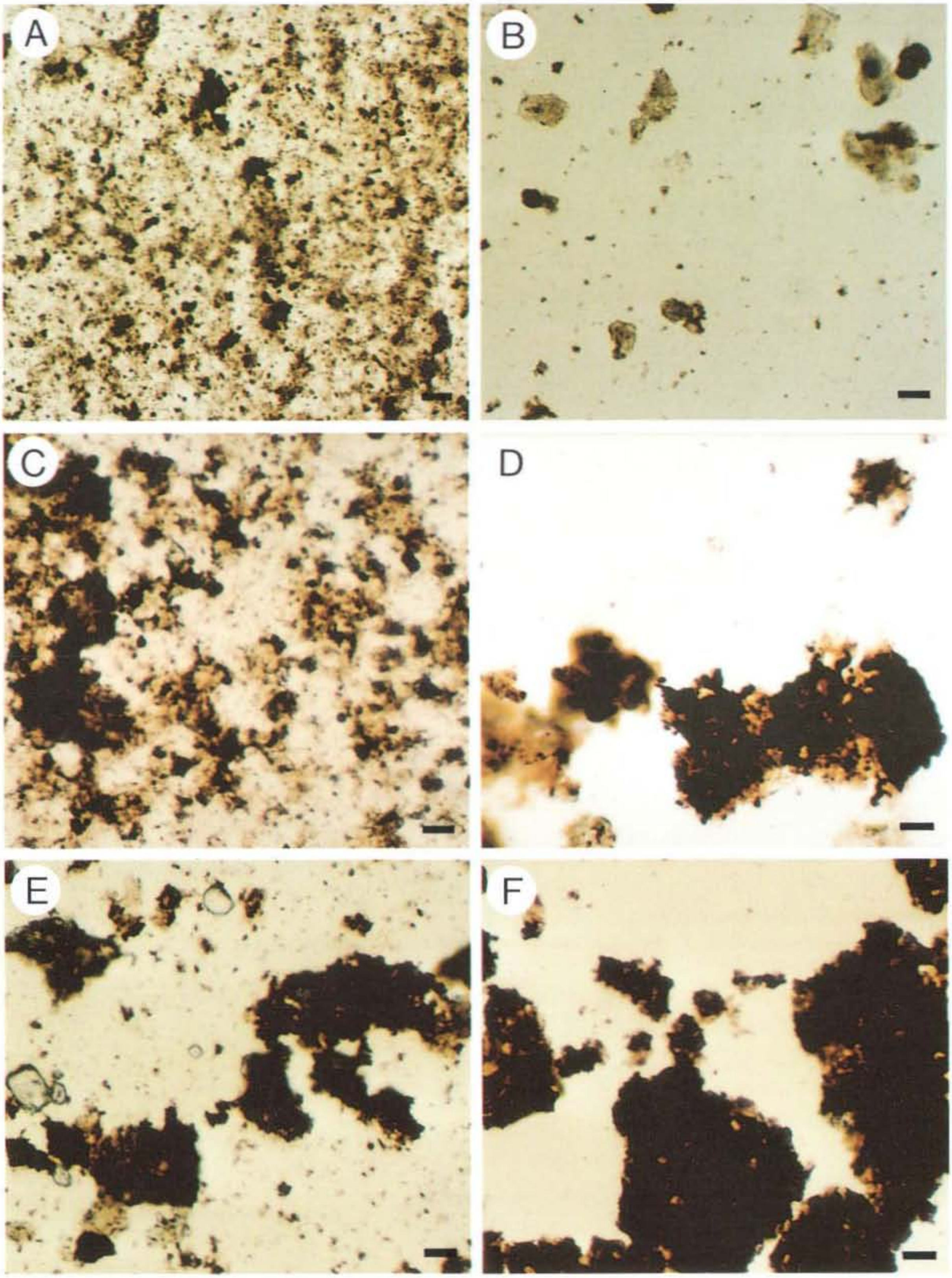

Plate 2. Cambrian palynomorphs

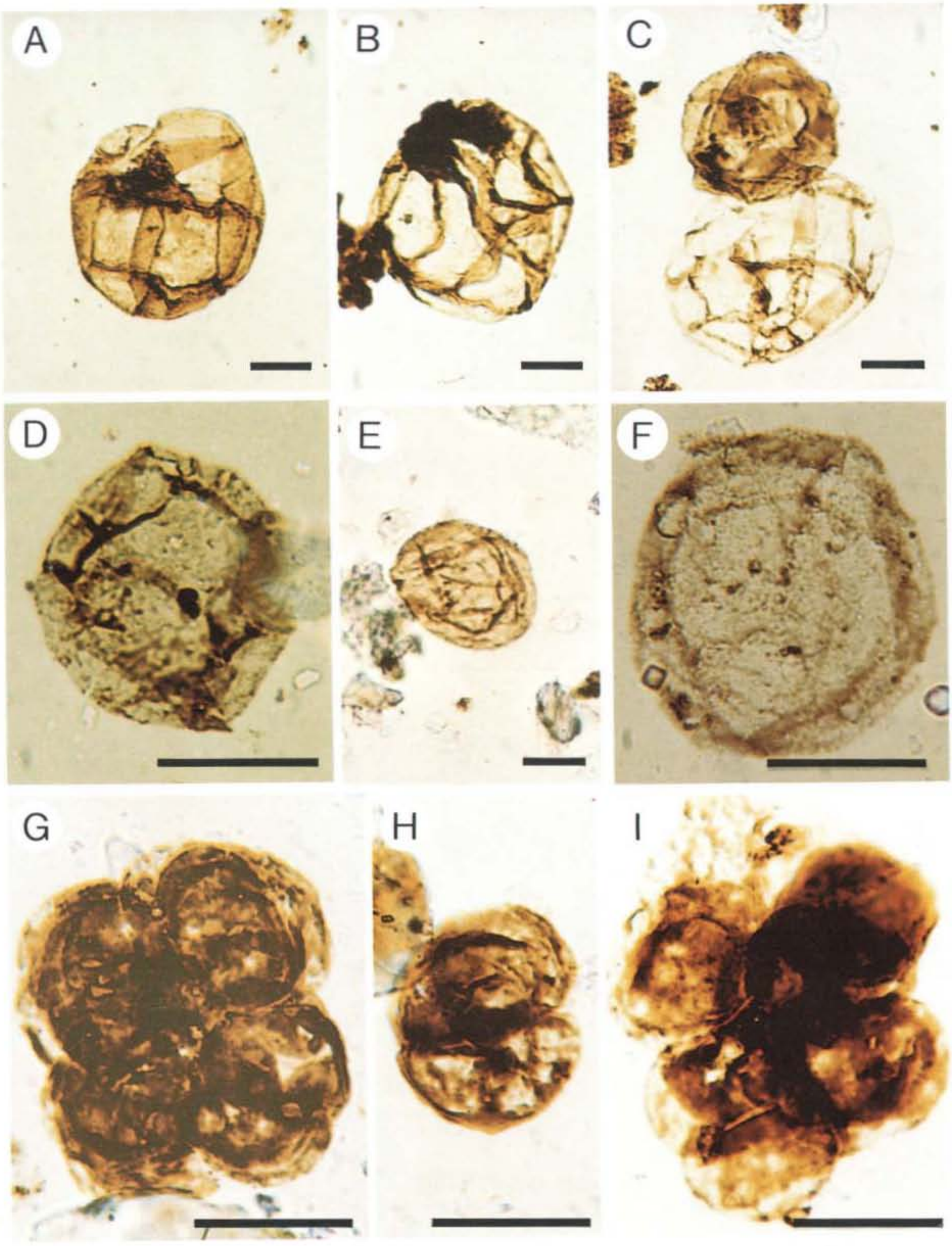

Plate 3. Ordovician palynomorphs

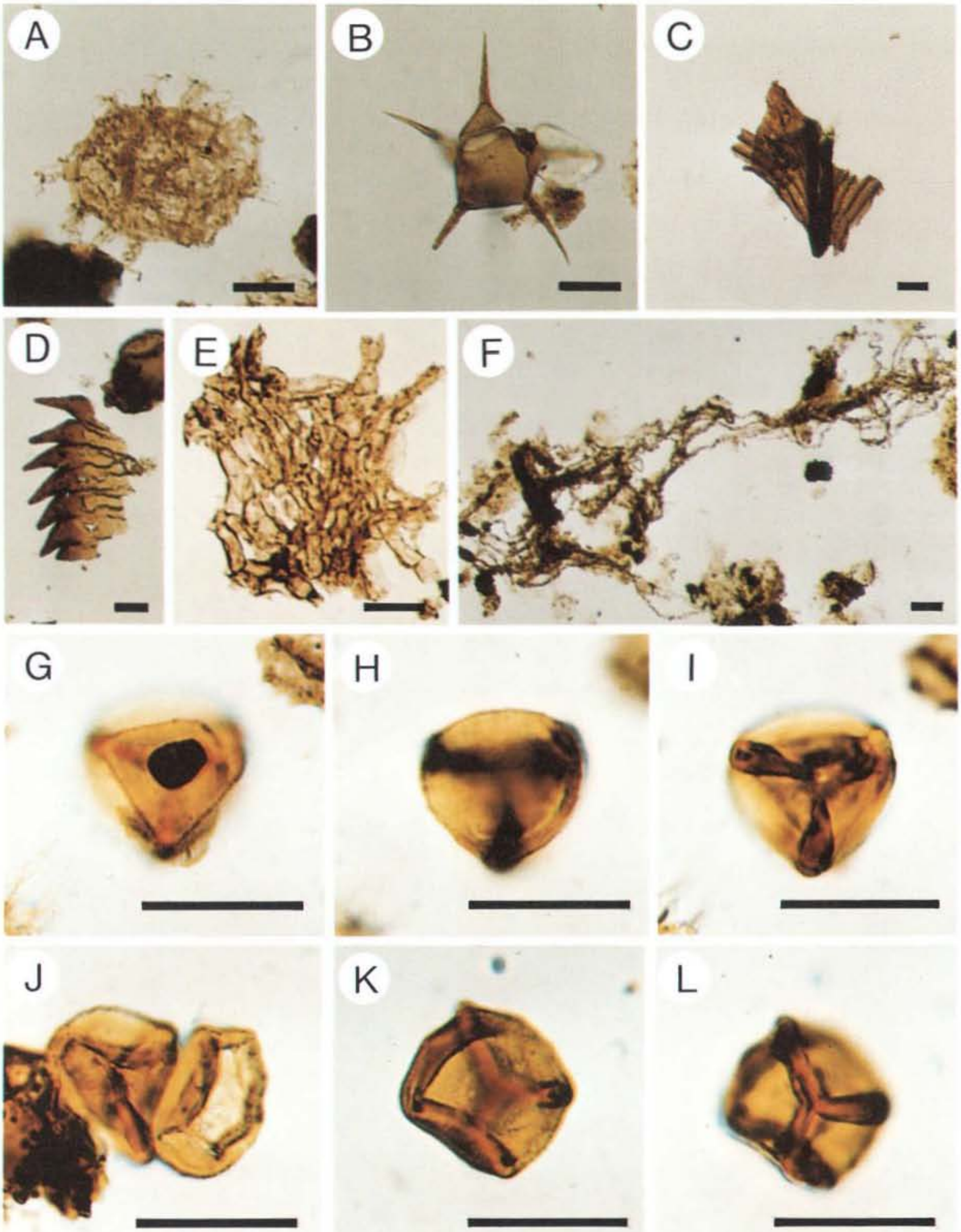

Plate 4. Silurian palynomorphs

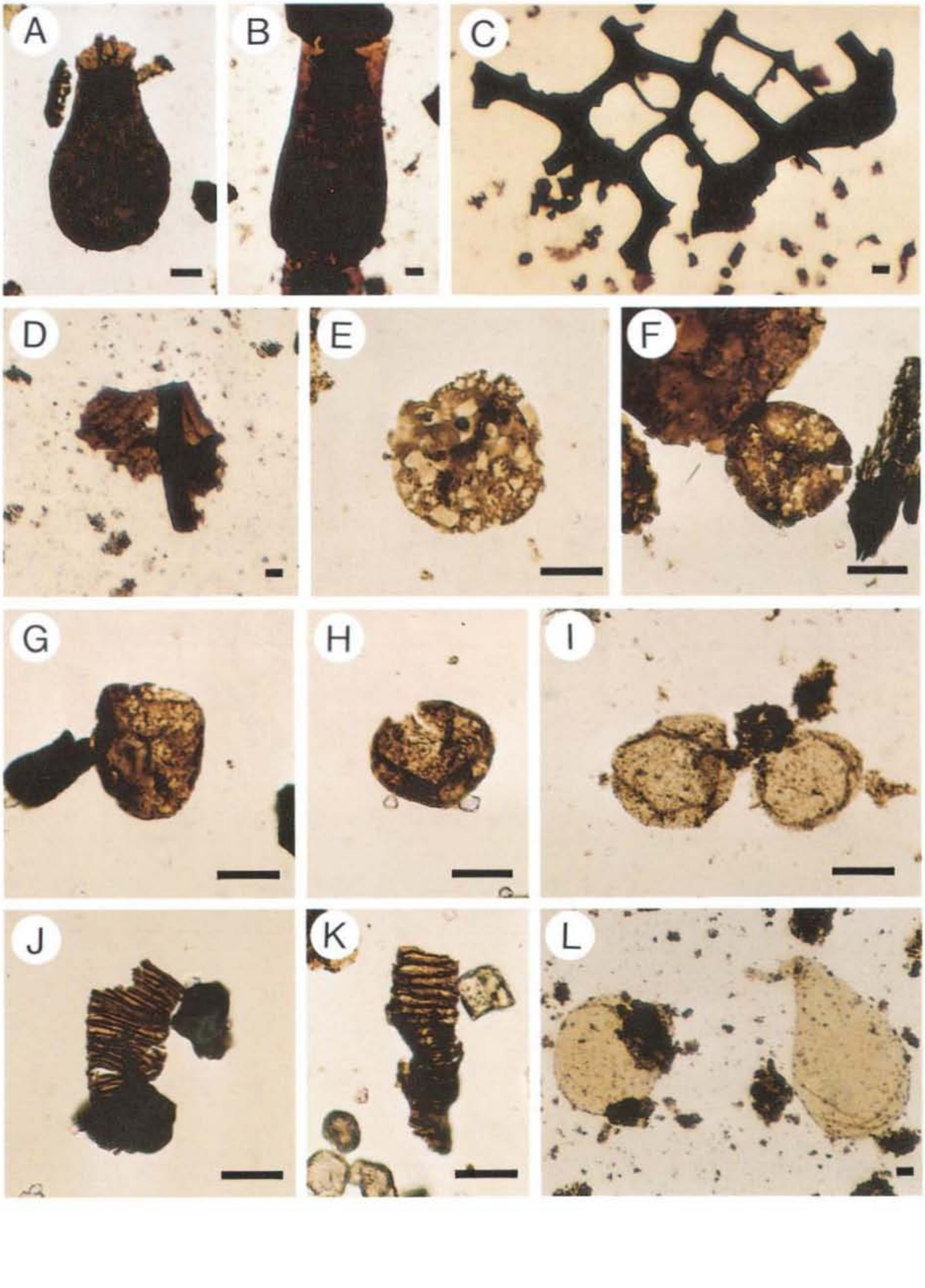

Plate 5. Progressive coloration of amorphous kerogen with increasing thermal alteration

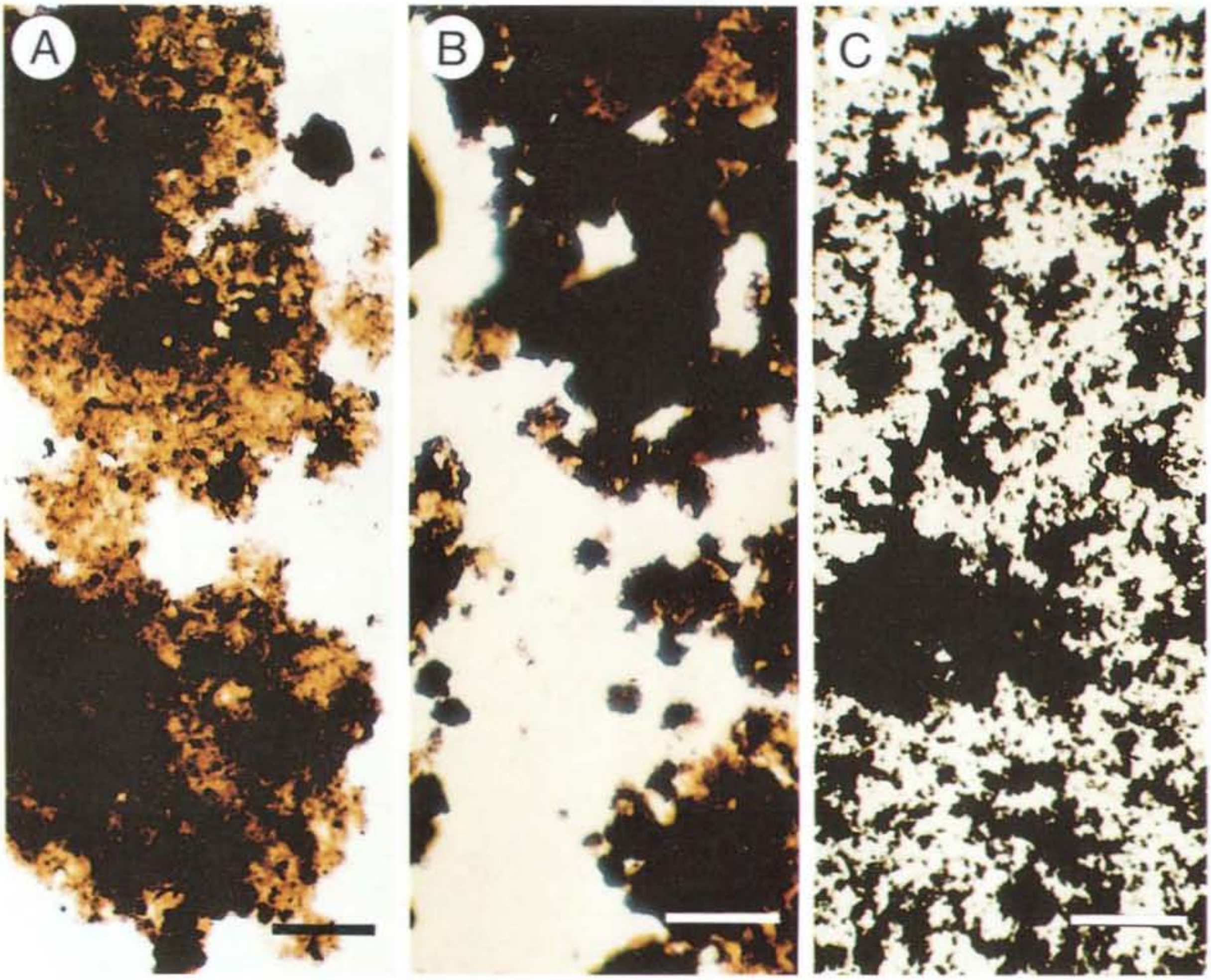

Plate 5. Progressive coloration of amorphous kerogen with increasing thermal alteration

Scale bar: 50 μm

A. TAI: (2)–2^+, GGU 211759–2. B. TAI: 2^+–(3^-), GGU 324405–2. C. TAI: 4^+, GGU 316475–1.

Plate 6. Change in structure of amorphous kerogen with increasing thermal alteration as observed in the scanning electron microscope

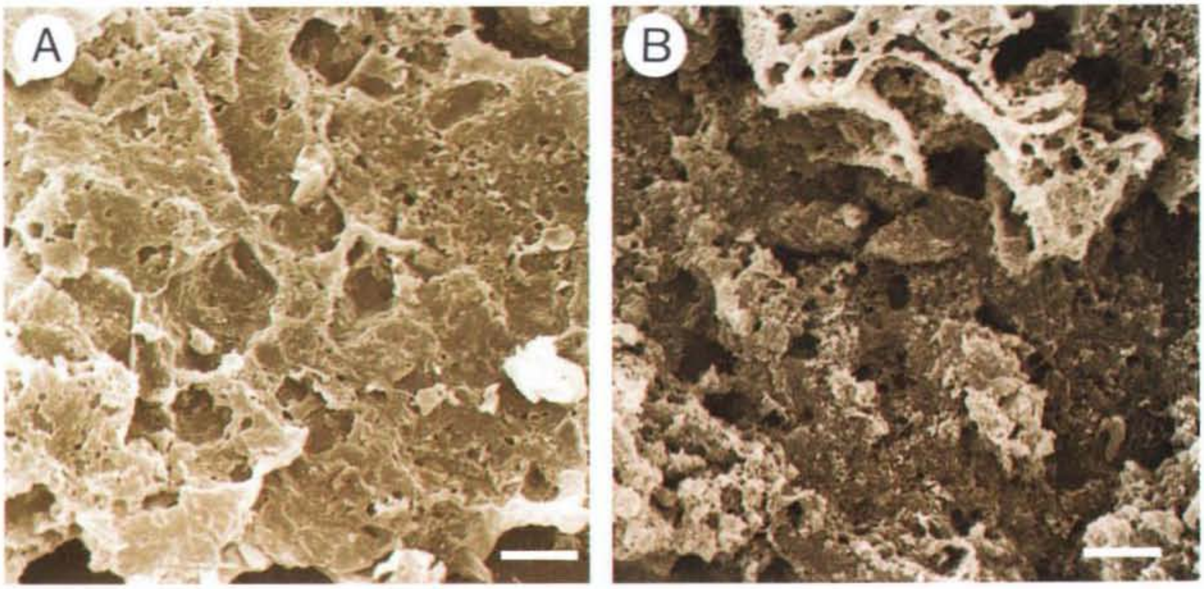

Plate 6. Change in structure of amorphous kerogen with increasing thermal alteration as observed in the scanning electron microscope

A. TAI: 2^+–(3^-), T_{max}: 446, GGU 324405–2, scale bar: 10 μm.

B. TAI: 4^+, T_{max}: n.d., GGU 316475–2, scale bar: 10 μm.

Plate 7. Field appearance of bitumen

A. Seeping asphalt from southern Wulff Land (equivalent to GGU 324200).

B. Hard solid bitumen in dolomite vug in the Sydpasset Formation (equivalent to GGU 324287–324299, core GGU 318003).

Plate 8. Macroscopic bitumen in slabs

A. Asphalt from seep in dolomite breccia. GGU 324200A.

B. Like A. Stained. D0, D1, D2, C1, C2 correspond to generations of dolomite and calcite.

C. Asphalt from seep in dolomite breccia. Stained. Same generations of carbonates as A and B. GGU 324200E.

D. Hard solid bitumen in vugs and veins in dolomite grainstone. DO: dolomite grainstone, D1: saddle dolomite. Core GGU 318003.

Plate 9. Bitumen in thin section

A. Bitumen in coral. GGU 324130B, Lafayette Bugt Formation, Nyeboe Land. Plane light, stained, C: calcite, Fe-C: Fe-rich calcite, B: bitumen, scale bar: 1 mm.

B. Bitumen in coral. GGU 316067, Lafayette Bugt Formation, Washington Land. Crossed nicols + gypsum plate. Q: quartz, C: calcite, B: bitumen, scale bar: 1 mm.

C. Bitumen-filled fracture in calcarenite. GGU 318013–09, Lafayette Bugt Formation, Nyeboe Land. Plane light, scale bar: 2 mm.

D. Two-phased bitumen (black and yellow) (B1, B2) in saddle dolomite veins (D1) cross-cutting dolomite grainstone (D0). See close-up (arrow) in Plate 11. GGU 318003–53, Henson Gletscher Formation, Freuchen Land. Plane light, scale bar: 2 mm.

E.-F. Saddle dolomite vein (D1) in dolomite grainstone (D0). Bitumen occurs as impregnation in DO (B1), as residual matter in the contact between D0 and D1 (B2, R_o: 0.92%) and in the centre of the vein (B3, R_o: 1.21%). GGU 318003–21, Sydpasset Formation, Freuchen Land. Plane light, scale bars: 1 mm.

Plate 10. Bitumen in palynologically prepared samples observed in microscope or in SEM

A. Bitumen with flaky appearance (note crystal impressions). GGU 315172–1. Ryder Gletscher Group Fm 6, Wulff Land. Scale bar: 25 μm.

B. Globular bitumen. GGU 315865–2, Aftenstjernesø Formation, Nares Land, scale bar: 50 μm.

C. Globular bitumen which has been extruded during and after sample preparation by the xylene-containing mounting medium. GGU 315199, Ryder Gletscher Group Fm 6, Warming Land. Scale bar: 12.5 μm.

D. Bitumen with flaky appearance (note crystal impressions). GGU 315172–1, Ryder Gletscher Group Fm 6, Wulff Land. Scale bar: 10 μm.

E. Bitumen mirroring imprints of crystals from coral space. GGU 316067–2, Lafayette Bugt Formation, Washington Land. Scale bar: 10 μm.

F. Thread-like bitumen. GGU 324453, Buen Formation, Wulff Land. Scale bar: 25 μm.

Plate 7. Field appearance of bitumen

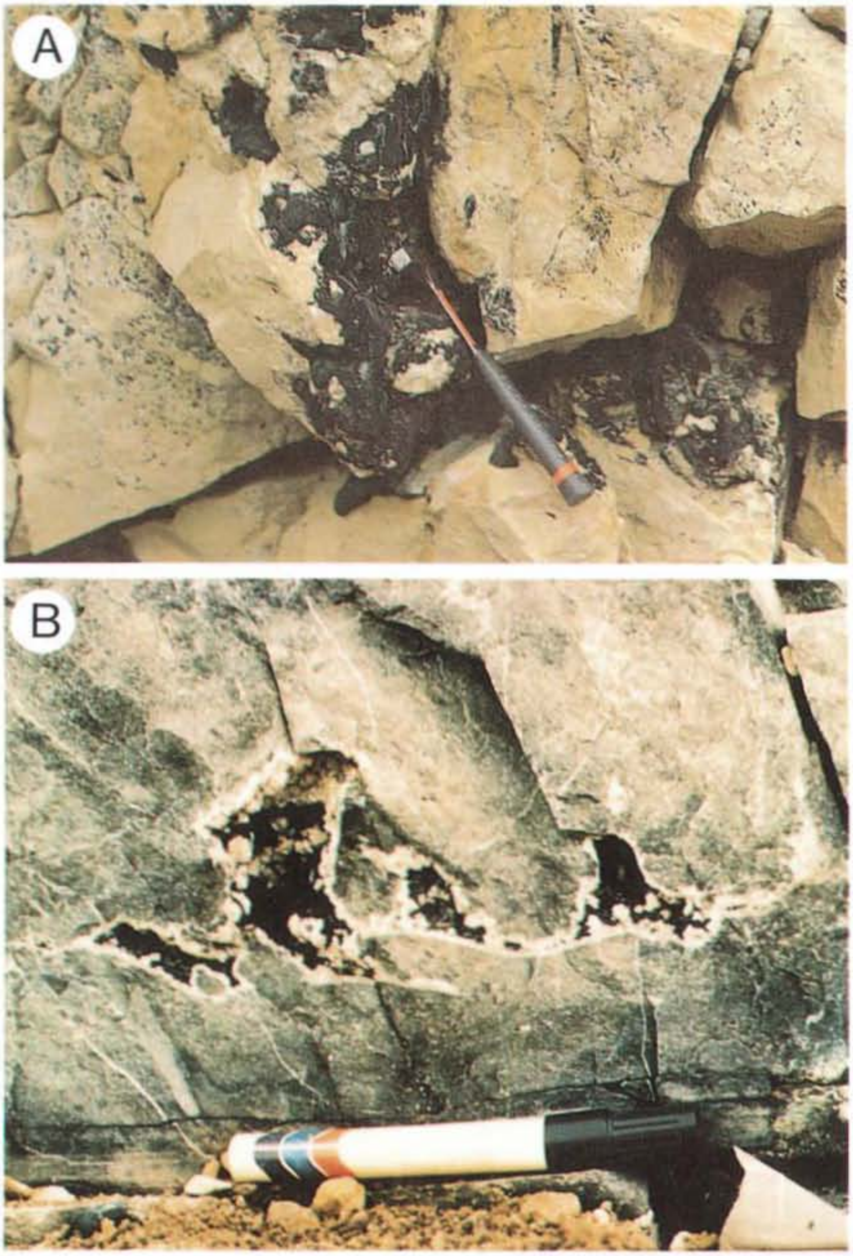

Plate 8. Macroscopic bitumen in slabs

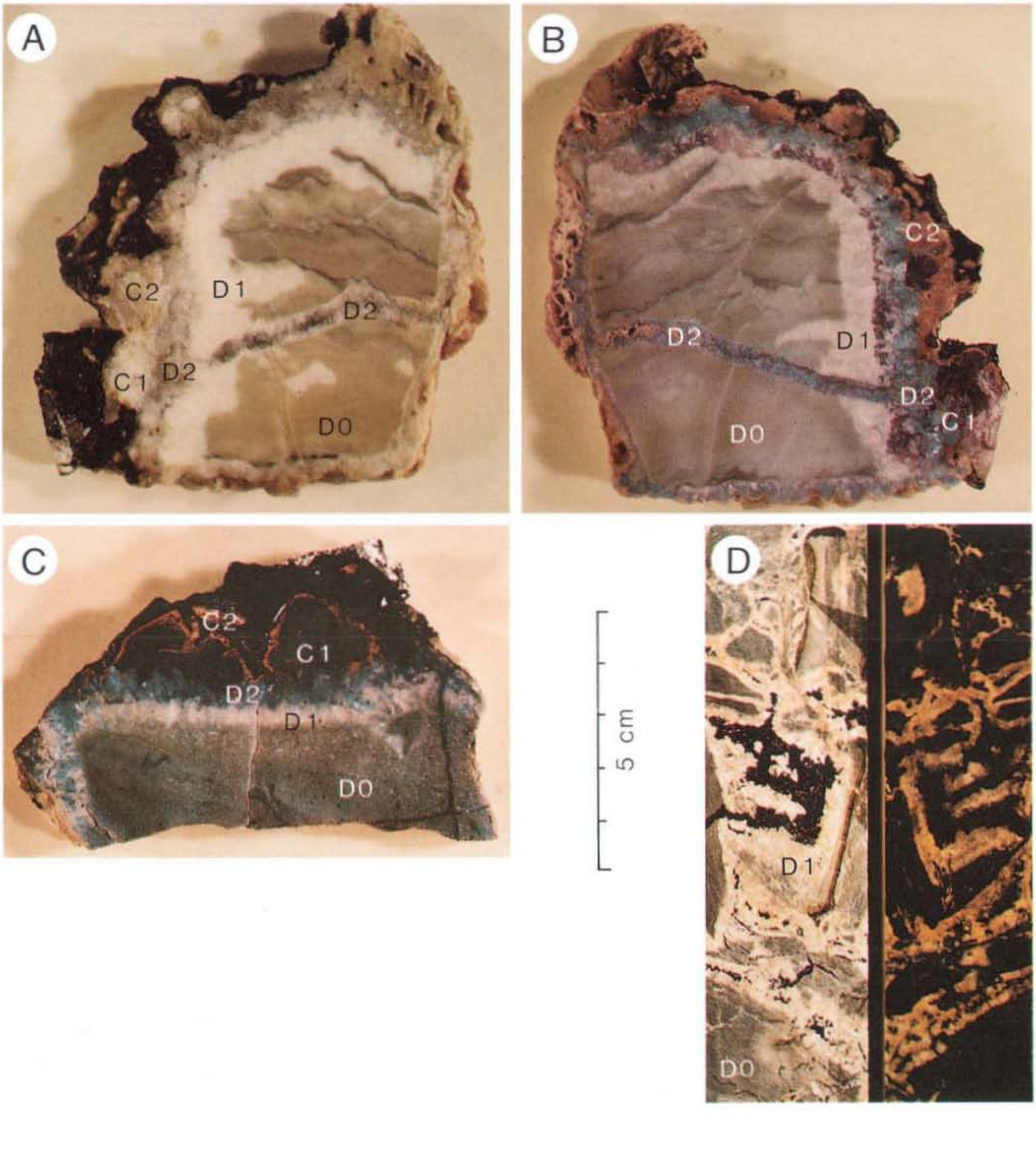

Plate 9. Bitumen in thin section

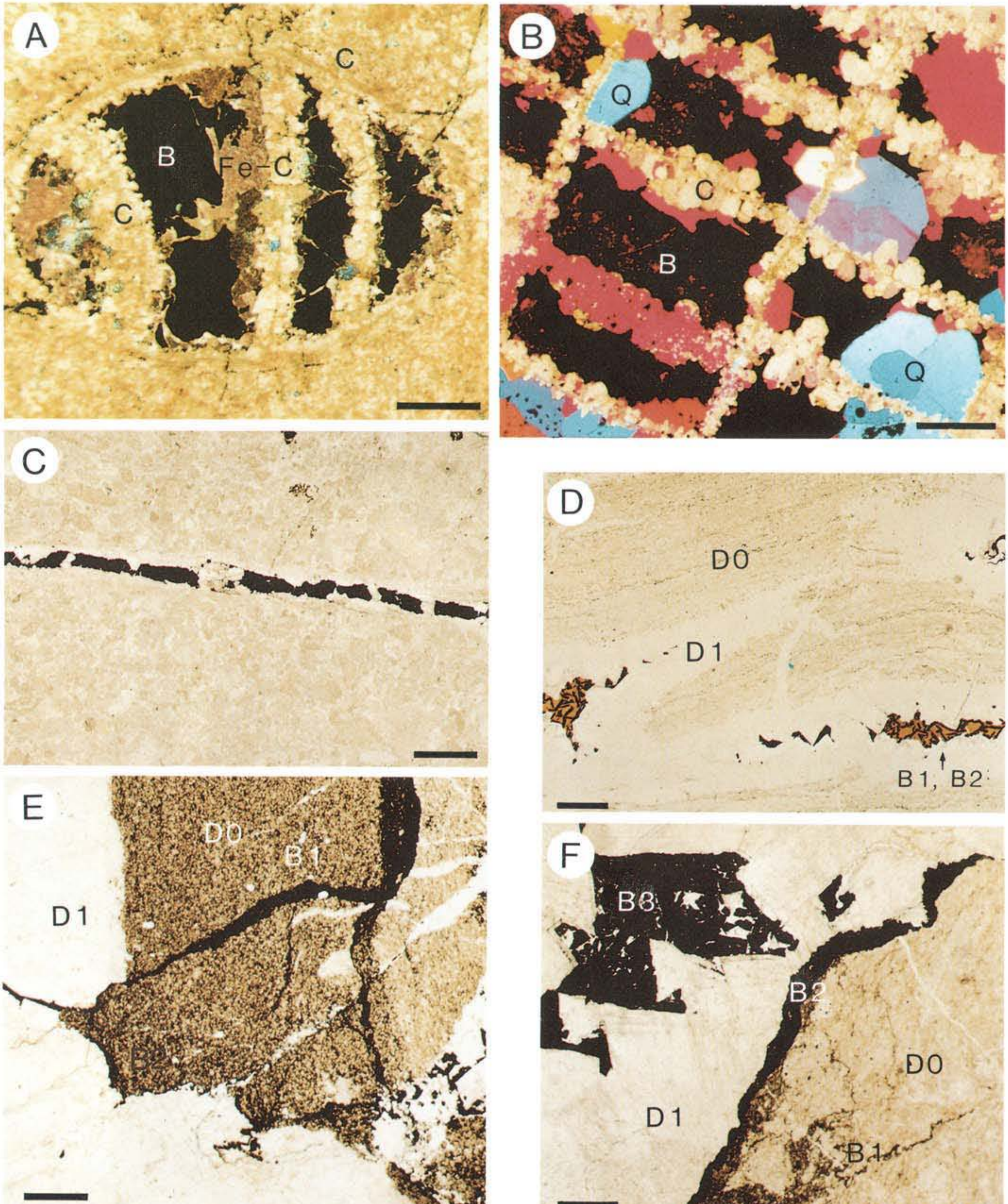

Plate 10. Bitumen in palynologically prepared samples observed in microscope or in SEM

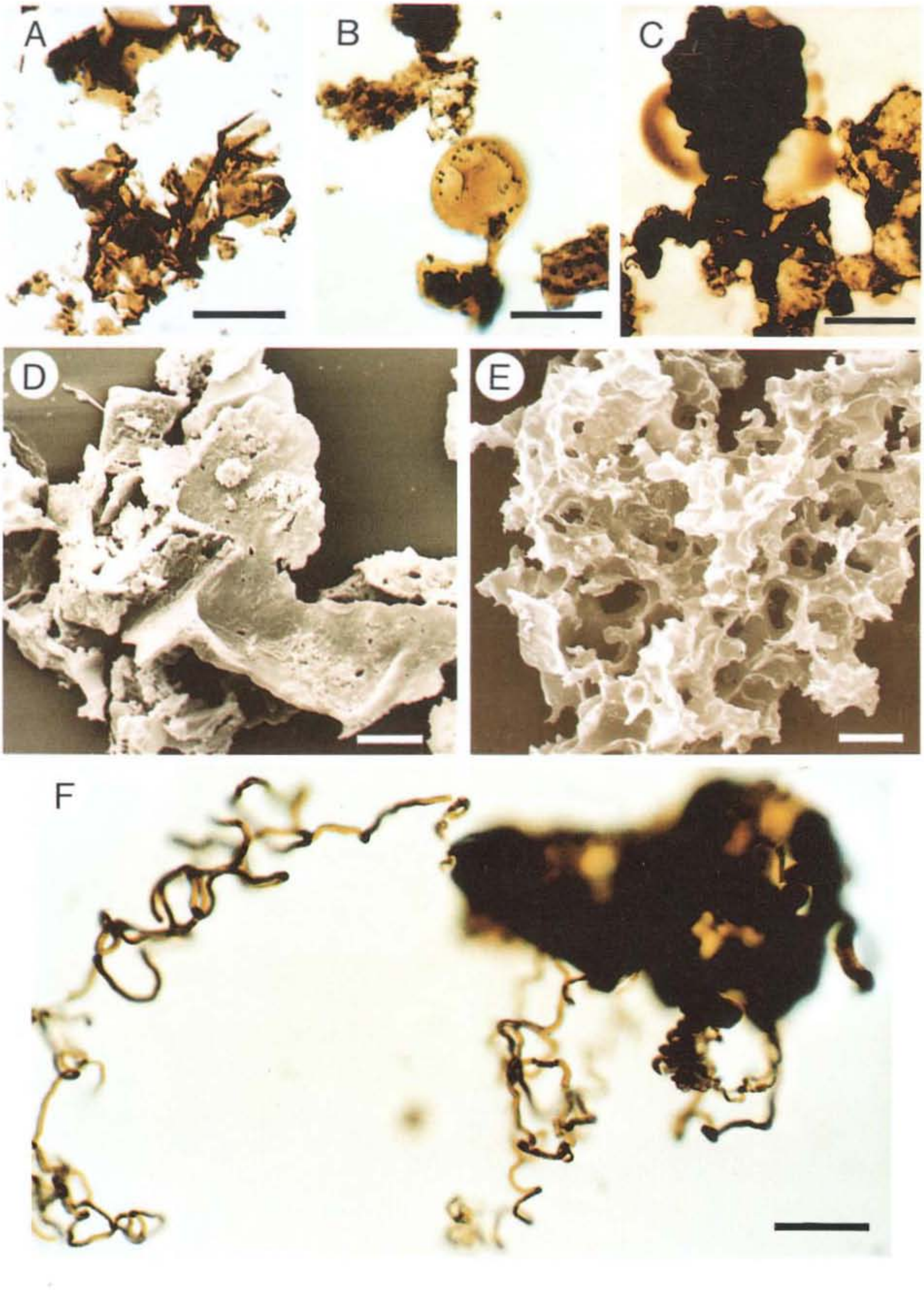

Plate 11. Bitumen in polished section

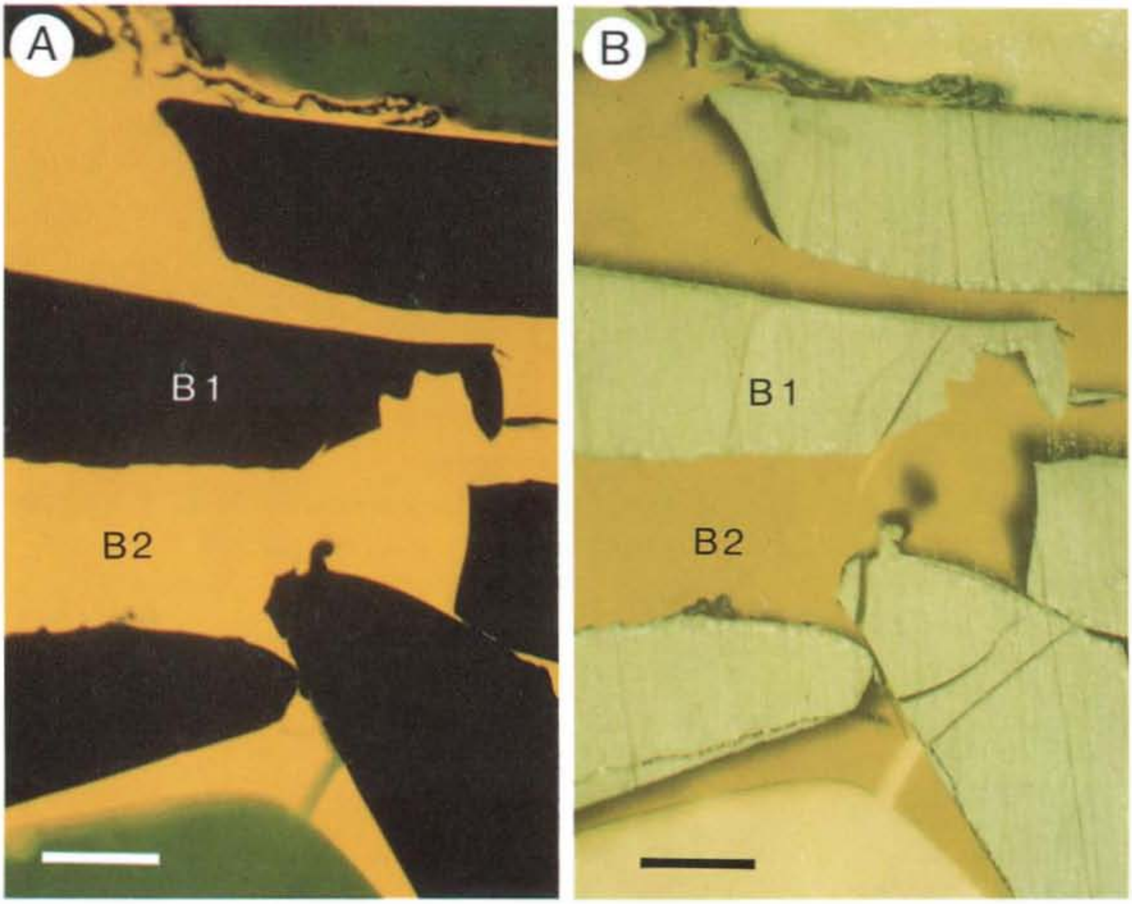

Plate 11. Bitumen in polished section

GGU 318003–53, Henson Gletscher Formation, Freuchen Land.
Scale bar: 50 μm

A. Fluorescent light photograph of two-phase bitumen.

B. Normal reflected light photograph of same field. The yellow-fluorescent low-reflecting bitumen (B2) has a R_o of 0.08% and the dark non-fluorescent high-reflecting bitumen (B1) a R_o of 1.17%.

Cover picture
Cambrian and Ordovician strata at Blue Cliffs, Wulff Land, North Greenland. Photo: J. Lautrup, GGU.