Chapter 9

Quantitative aspects and economic implications

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Many methods have been proposed for assessing the petroleum potential of a given region and each of these require different levels of information and knowledge (see numerous papers in Rice, 1986). Miller (1986) proposed a simplification into five basic categories of methodology:

1) Areal and volumetric yield, in combination with geological analogy.
2) Delphi or subjective consensus assessment.
3) Performance or behaviouristic extrapolation based on historical data.
4) Geochemical material balance.
5) Combinations of geological and statistical models.

These methods may be used during frontier to mature stages of exploration, either regionally, on single stratigraphic units or on specific plays or prospect types.

The present considerations of the hydrocarbon potential are based on the geochemical material balance approach. None of the other methods are adequate considering the stage of investigation and the available data.

The geochemical material balance approach is based on a stepwise evaluation of the hydrocarbon cycle (fig. 64):

1) Generative potential of source rocks.
2) Amount of hydrocarbons generated in source rocks.
3) Amount of hydrocarbons expelled from source rocks.
4) Loss during migration.
5) Amount of hydrocarbons trapped.
6) Loss during leakage, degradation.
7) Amounts of non-recoverable hydrocarbons in the reservoir.

This approach has been widely applied and is rapidly developing, thus increasing both the theoretical understanding and the sophistication of calculations (Welte & Yukler, 1981; Bishop *et al.*, 1983; Demaison, 1984; Kontorovich, 1984; Sluijk & Nederlof, 1984; Ungerer *et al.* , 1984).

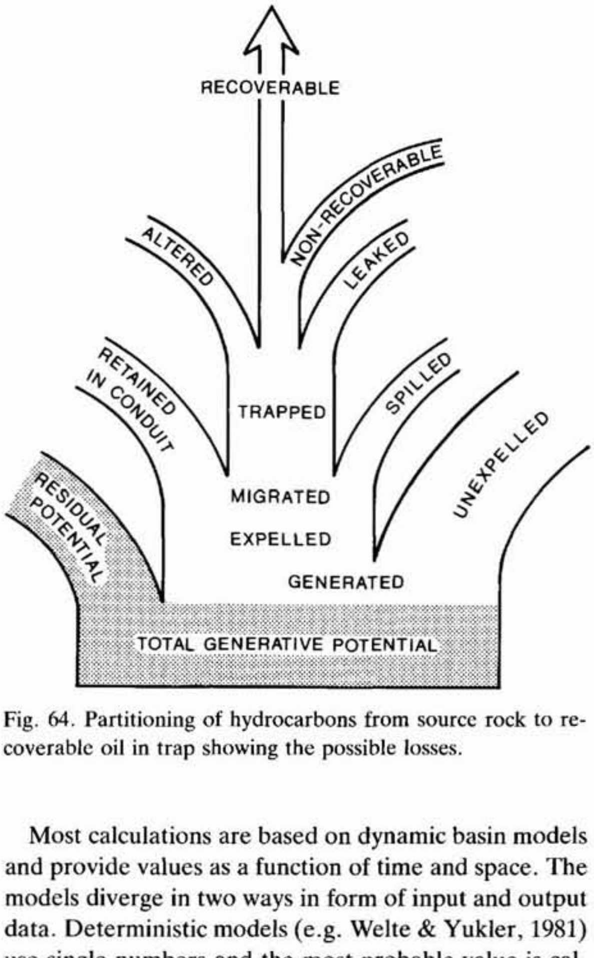

Fig. 64. Partitioning of hydrocarbons from source rock to recoverable oil in trap showing the possible losses.

Most calculations are based on dynamic basin models and provide values as a function of time and space. The models diverge in two ways in form of input and output data. Deterministic models (e.g. Welte & Yukler, 1981) use single numbers and the most probable value is calculated. Probablistic models (e.g. Bishop *et al.*, 1983; Sluijk & Nederlof, 1984) employ probability distributions for both input, calculation and output and are hence much more informative. However, very large databases and computer systems are necessary for utilizing this approach.

In the following preliminary appraisal of the hydrocarbon potential in North Greenland a simple deterministic non-dynamic calculation is used. Although the tectonic–sedimentological development of North Greenland is fundamentally well understood (Higgins *et al.*, in press), with a well established source rock distribution and thermal maturity pattern (Chapters 5 and 6), substantial data and work are still not available for detailed space-time-temperature modelling. Hence the main attempt in this chapter has been to estimate the order of magnitude by calculation of the ultimate potential of each source rock unit followed by discussion of generation and partitioning of hydrocarbons (see fig. 64).

Generative potential of source rocks

The hydrocarbon potential of source rocks is calculated using a simple material balance formula, either directly or summarized and integrated depending on the variation of input parameters:

Generated hydrocarbons =
drainage area × net thickness of source rock × density of source rock × yield × conversion constants.

The drainage area and net thickness are known from the preliminary studies of the two source rock units considered, the Henson Gletscher Formation (Christiansen *et al.*, 1987) and the Silurian shales (Christiansen & Nøhr-Hansen, 1988). The calculation only applies to the region between Hall Land and Freuchen Land (figs 65 and 66), where data control is good. Some of the source rocks are also distributed in Washington Land and Peary Land, but volumetric and geochemical values are not known in sufficient detail.

The yield of a given unit may be calculated as ultimate, residual or fractional (or by integration of subdivided units). The employed values are either recorded directly from the Rock Eval (S2 or S1 + S2) or from the TOC value (quantity) multiplied by either H/C (from elemental analysis) or Hydrogen Index (from Rock Eval) (quality). The conversion constant depends on the form of input data and the required output form (e.g. million barrels of hydrocarbon or million m^3 of hydrocarbon).

The calculations, as in other deterministic models, are based on a set of 'most likely' values. Calculations have also been performed on minimum and maximum values of area, thickness and yield in order to ascertain the sensitivity of the estimates.

In the Silurian succession the shales of Llandovery

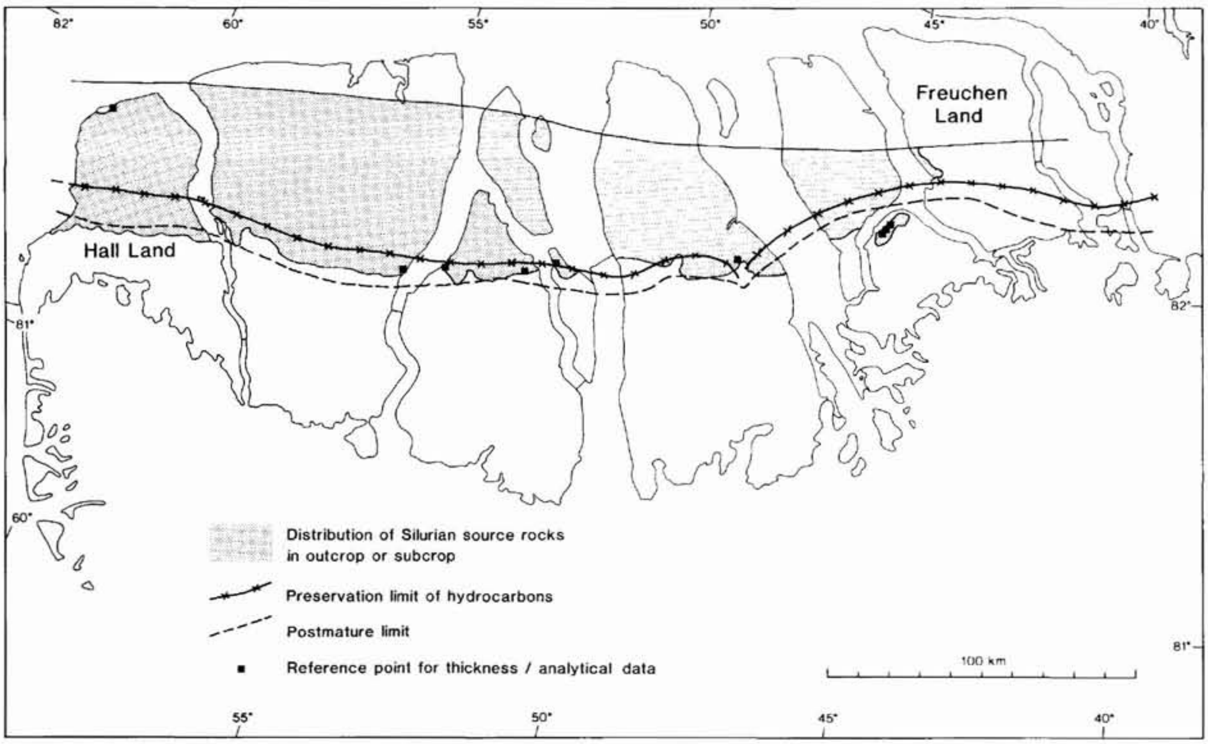

Fig. 65. Distribution of Silurian source rocks (shale groups A and B of Christiansen & Nøhr-Hansen, 1989) in outcrop and subsurface with reference points for measurements of thickness and analytical data. The preservation limit of hydrocarbons and the postmature limit of source rocks are indicated.

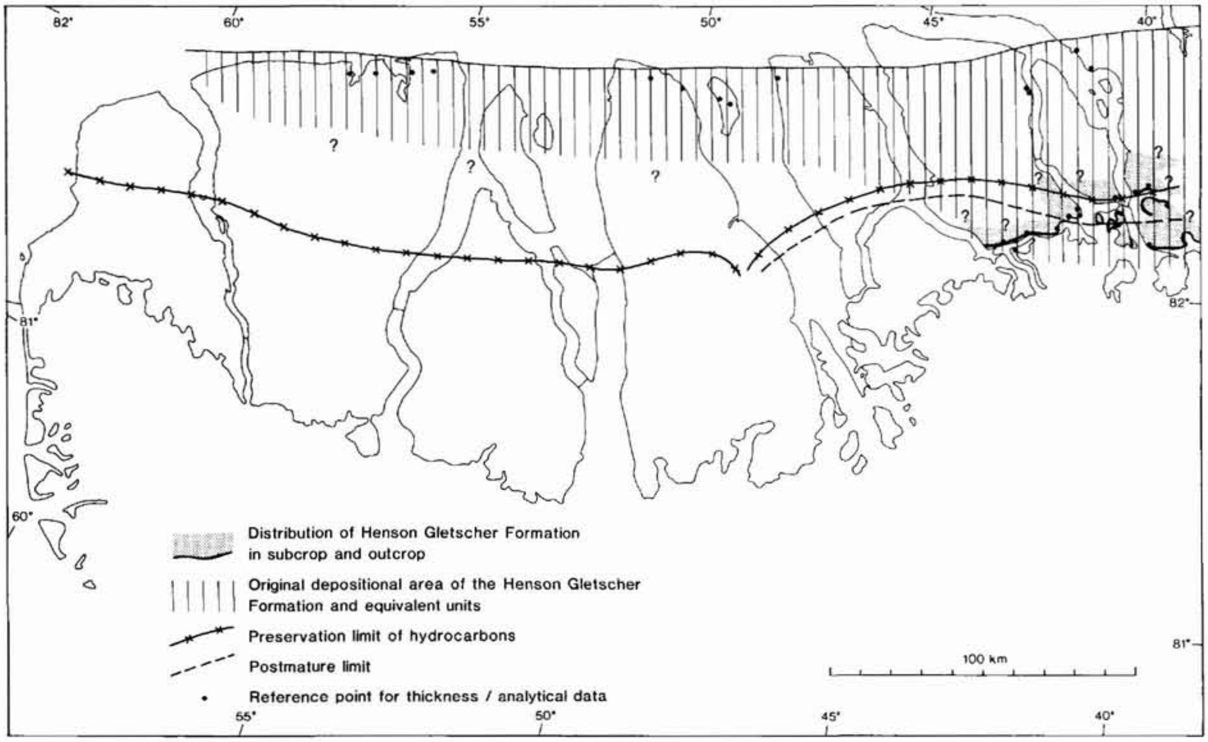

Fig. 66. Distribution of Cambrian source rocks with reference points for measurements of thickness and analytical data. The dark tone shows the outcrop and subcrop of the Henson Gletscher Formation (Christiansen *et al.*, 1987), and the vertical hatching indicates the total original depositional area of organic-rich rocks including unit 2 of the Cambrian – Lower Silurian starved basin sequence (Higgins & Soper, 1985; A. K. Higgins, personal communication 1987). The preservation limit of hydrocarbons and the postmature limit of source rocks are indicated.

age (group A and B of Christiansen & Nøhr-Hansen, 1989) have a significant potential. Organic-rich shales were apparently only deposited between the reef belt and the Navarana Fjord escarpment (fig. 65) covering an area of approximately 12 000 km^2 with tentatively estimated minimum and maximum values of 7500 km^2 and 17 500 km^2, respectively (Table 7).

In the Cambrian Henson Gletscher Formation estimates of the drainage area are more complex. The source rocks were traced in detail in a relatively small area until, due to the general shallow northerly dip, they disappear under younger strata (Christiansen *et al.*, 1987). The Henson Gletscher Formation outcrops over a distance of about 100 km (fig. 66) and an area of 3000 km^2 has been used in the calculation example (Table 7). However, the recent correlation between the Henson Gletscher Formation and unit 2 of the 'Cambrian – Lower Silurian starved basin sequence' (Higgins & Soper, 1985; Higgins *et al.*, in press) points towards a much wider distribution of organic-rich sediments, probably covering an area of approximately 15 000 km^2 (fig. 66, Table 7).

The applied net thickness values are also based on information from the two preliminary studies, in the Silurian case with a subdivision into a few intervals with certain average quantity and quality parameters of the organic matter.

The yield values are based on Rock Eval measurements. Due to the good correlation between percent TOC and generative potential (S1 + S2) for various ranks of maturity (figs 67 and 68) it has been possible to estimate the initial ultimate yield of the two units and to recalculate initial TOC values.

Typical immature Silurian shales with 2 and 4% TOC are expected to have generative potentials of 8 and 18 mg HC/g rock, respectively. At increasing maturity, e.g. at peak to late generation conditions of T_{max} between 445°C and 450°C, the generative potential is reduced to 3 and 7 mg HC/g rock, respectively (fig. 67). The Cambrian source rocks seem to have a slightly lower generative potential; the initial yield for shales and lime mudstones with 2 and 4% TOC is 7 and 16 mg HC/g rock, respectively.

Based on analyses of detailed measured sections and

Table 7. Calculation of generated hydrocarbons

	Drainage area km^2	Thickness (m) with initial TOC%	Initial yield mg HC/g rock	Generated HC 10^3 mill. m^3 HC	'Palaeo-potential' with 1% efficiency mill. barrels HC
Silurian					
Most likely	12 000	5 (5% TOC)	26		
		20 (3% TOC)	14	32.25	2029
		75 (1.5% TOC)	6		
Maximum	17 500	10 (5% TOC)	26		
		25 (3% TOC)	14	77.11	4850
		100 (2% TOC)	8		
Minimum	7 500	20 (3% TOC)	14		
				9.60	604
		60 (1.5% TOC)	6		
Cambrian					
Maximum	15 000	30 (3.5% TOC)	14	19.69	1239
Minimum	3 000	30 (2.5% TOC)	9	2.53	159

drill cores (see results in Christiansen & Nøhr-Hansen, 1989) the TOC distribution of the Silurian shales has been simplified to a 'most likely' thickness of 5 m with 5% initial TOC, 20 m with 3% initial TOC and 75 m with 1.5% initial TOC.

In the Cambrian sequence an average total source

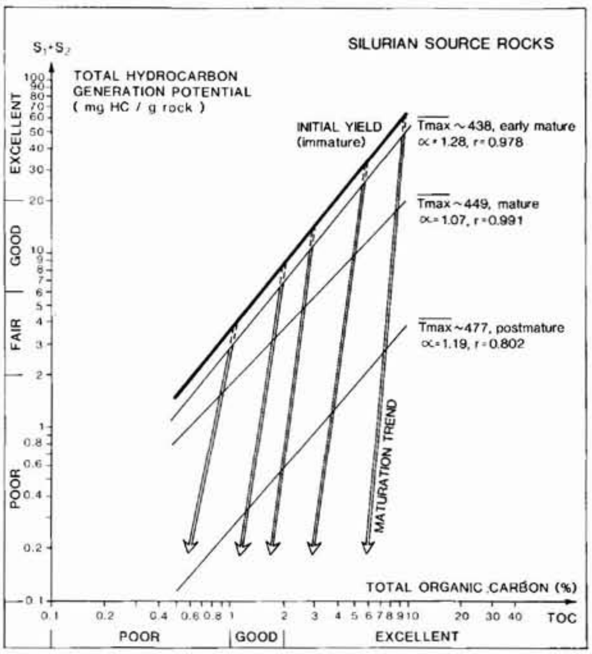

Fig. 67. Plot of %TOC versus generation potential (S1 + S2) for Silurian source rocks at various ranks of maturity. The linear relation is expressed as the slope (α) and the regression coefficient (r). The linear relation for an immature source rock is shown as a thick line, the maturation trend as double arrows.

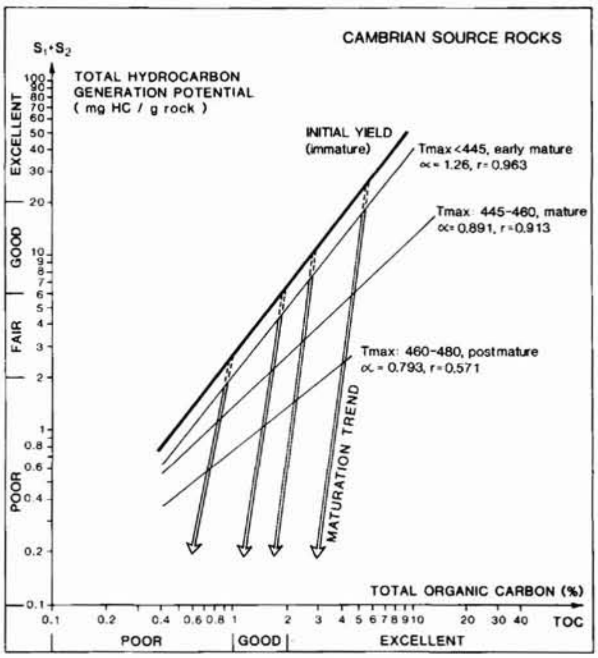

Fig. 68. Plot of %TOC versus generation potential (S1+S2) for Cambrian source rocks with various ranks of maturity. The linear relation is expressed as the slope (α) and the regression coefficient (r). The linear relation for an immature source rock is shown as a thick line, the maturation trend as double arrows.

rock thickness of 30 m has been applied in all calculations. Christiansen *et al.* (1987) mention a cumulative source thickness between 25 and 40 m (with an estimated average of 30 m) in the southern part of the region. Towards the north A. K. Higgins (personal communication, 1987) reports 10 measured sections with a formation thickness between 21 and 31 m (average 27 m); these values also include some sandstone intervals.

Only liquid hydrocarbons are considered in the calculations since any natural gas generated during the Ellesmerian orogeny will have leaked to the surface. The main potential of the source rocks is paraffinic crudes.

Amounts of hydrocarbons generated

Table 7 shows the amounts of hydrocarbons that would have been generated if all the studied source rocks had undergone a complete maturation history. Comparison of distribution and thermal maturity patterns (figs 65 and 66) not only suggests that most (> 90%) of the source rocks are completely mature but also that the major part have suffered such a strong thermal alteration that no hydrocarbons remain.

The calculated values are therefore considered as a reasonable estimate of the hydrocarbons generated during thermal maturation in Late Palaeozoic time. These estimates suggest that significant amounts of hydrocarbons were generated compared to many other petroliferous basins. This is further emphasized in the right column of Table 7, where the total 'palaeo-potential' is calculated assuming an efficiency of expulsion-migration-trapping-recovery of 1%. This 1% volume is close to the global percentage of generated hydrocarbons, which is considered economically recoverable (Durand, 1980). For comparison it should be noted that the production in Denmark and Norway in 1985 was 22 million barrels/year and 294 million barrels/year, respectively, and the reserves in the two countries 465 million barrels and 10 900 million barrels, respectively (Yarbrough, 1986). Nassichuk (1983) proposed reserves of approximately 500 million barrels in the Lower Palaeozoic basin of the Canadian Arctic based on volumetric yield considerations.

Conceptual plays

The present knowledge of basin evolution in North Greenland (e.g. Higgins *et al.*, in press) combined with the distribution and quality of source and reservoir rocks allow a tentative identification of a number of conceptual play models (fig. 69).

The most obvious Silurian play, also known from the Canadian Arctic (Rayer, 1981; Embry *et al.*, in press), is shelf margin limestones and reefs as reservoirs with juxtaposed shales acting as source and seal. The combination of source rocks with interbedded porous carrier beds (mainly carbonate conglomerates and calcarenites) favours a high migration efficiency. Table 8 illustrates some highly speculative calculations of the possible order of size of single fields. The available amounts of hydrocarbons are relatively easy to calculate; the efficiencies are not known but are suggested to be considerably higher for the organic-rich units than for the leaner parts. The maximum 'palaeo-potential' of the single reefs was probably in the range from a few tens to a few hundreds of million barrels, amounts which easily could have been trapped in the larger and probably also in the smaller reefs (Table 9).

Table 8. Calculation example, single field in Silurian reef

Drainage area km^2	Thickness (m) initial TOC%	Initial yield mg HC/g rock	Efficiency %	'Palaeo-potential' mill. barrels HC
400	5 (5% TOC)	26	5	
	20 (3% TOC)	14	2	113
	75 (1.5% TOC)	6	0.5	

Table 9. Calculation example, reservoir capacity in single Silurian reef

	Reef volume km^3	Porosity %	Capacity of reservoired HC mill. barrels
Maximum 10 km × 5 km × 0.5 km	25	20	31450
Minimum 1 km × 1 km × 0.3 km	0.3	10	190

The Silurian reef play is restricted by high thermal maturity and erosion level. Most of the reefs in the thermal mature zone are deeply eroded and are either exposed or shallowly buried down to only a few hundred metres of depth. The possible reefs further north, if present, occur down to 2 km below the surface, but are not likely to have any preserved hydrocarbons due to the high thermal maturity.

Two conceptual plays are suggested in the Cambrian sequence (fig. 69), both with their source in the Henson

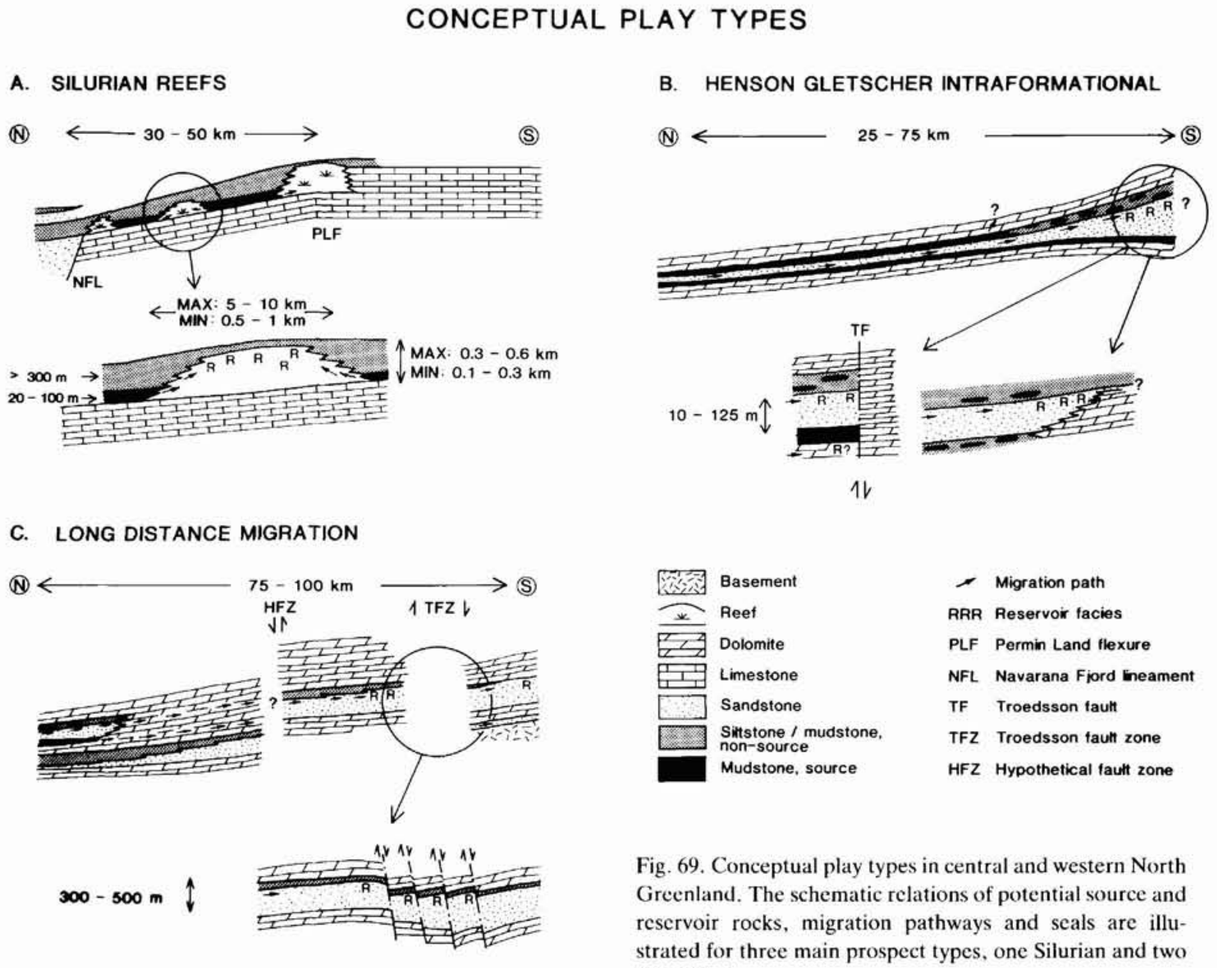

Fig. 69. Conceptual play types in central and western North Greenland. The schematic relations of potential source and reservoir rocks, migration pathways and seals are illustrated for three main prospect types, one Silurian and two Cambrian.

Gletscher Formation (or equivalent northern units). In both types the structural setting in the region with shallow northerly dip favours migration away from the most mature areas into thermally immature reservoirs towards the south.

The first play type includes intraformational reservoirs, especially sheet sandstones, but possibly also coarse-grained dolomites which are sealed by the enclosing source rocks. The nature of the middle siliciclastic unit is important for the migration history. Do the sheet sandstones form regionally continuous beds (blankets) which are highly efficient conduits, or do the sandstones laterally interdigitate with shale and lime mudstone? Trapping possibilities include both structural and stratigraphic types (fig. 69). Structural traps might have formed along major SW–NE trending faults or in nearby fault-induced anticlines. Stratigraphic traps might have formed where the reservoir sandstones of the Henson Gletscher Formation (or the Sæterdal Formation) interfinger with or laterally grade into impermeable intraformational bioturbated siltstones or into shallow-water dolomitized carbonates of the Ryder Gletscher Group. Due to the close association of source rocks with potential migration pathways, the efficiency of migration was probably high. This fact, combined with the large drainage areas, suggests that major accumulations could have formed at the time of maturation. However, the play is not prospective today. The areas where such stratigraphic traps were most likely to form are eroded and the areas with sufficiently buried potential traps are situated north of the inferred hydrocarbon preservation limit (fig. 66).

The second Cambrian play type includes reservoir rocks in strata older than the Henson Gletscher Formation, preferentially in the Lower Cambrian Buen Formation sandstones, but also Proterozoic sandstones or in possible but not yet recognized porous carbonates. This concept involves long distance migration, both laterally and along faults to older stratigraphic levels. Consequently the efficiency of migration is expected to be low (< 1%). The possibility of this play type, not only in Late Palaeozoic time but also today, is supported by the frequent staining of thermally unaltered bitumen in the potential reservoir rocks, the low thermal maturity of this part of the region, and the possible existence of subsurface structures. Both stratigraphic and structural traps are likely in this geological setting. The most simple prospective types would be that of fault-bounded reservoirs or large anticlines associated with major SW–NE faults (fig. 69).

Economic implications

The study of the hydrocarbon potential in central and western North Greenland has followed a stepwise evaluation of: (a) source rock deposition, (b) source rock quality and quantity, (c) thermal maturity history, and (d) generation products. Reservoir and trapping possibilities have not been considered in detail and only preliminary results are available. Several of these important factors provide positive indications of a petroleum potential. However, it is clear that the subsidence and thermal history of the source rocks are problematic. Most source rocks are thermally mature or postmature due to thermal alteration in Late Palaeozoic time. Hence the exploration prospectivity is considered limited, although clearly present.

Prospective plays involve generation of hydrocarbons more than 300 million years ago, long-distance migration and preservation in an uplifted and eroded basin. The expected limited cumulative efficiency of this playtype is partly compensated by the large amounts of generated hydrocarbons.

Among the most interesting results is the clear recognition of the regional thermal maturity pattern. Future petroleum geological activities can now be concentrated in relatively small areas outlined by the 'Nordolie' study. In addition examples of conceptual play types have been identified.

The present study also has implications for the petroleum assessment in the Canadian part of the Franklinian basin where the sedimentary succession is partly buried under Upper Palaeozoic and Mesozoic to Tertiary strata of the Sverdrup basin succession. The 'Nordolie' results may provide an important guideline for a re-evaluation of both source rocks (especially age, environment, quality and quantity, and thickness) and thermal history.

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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

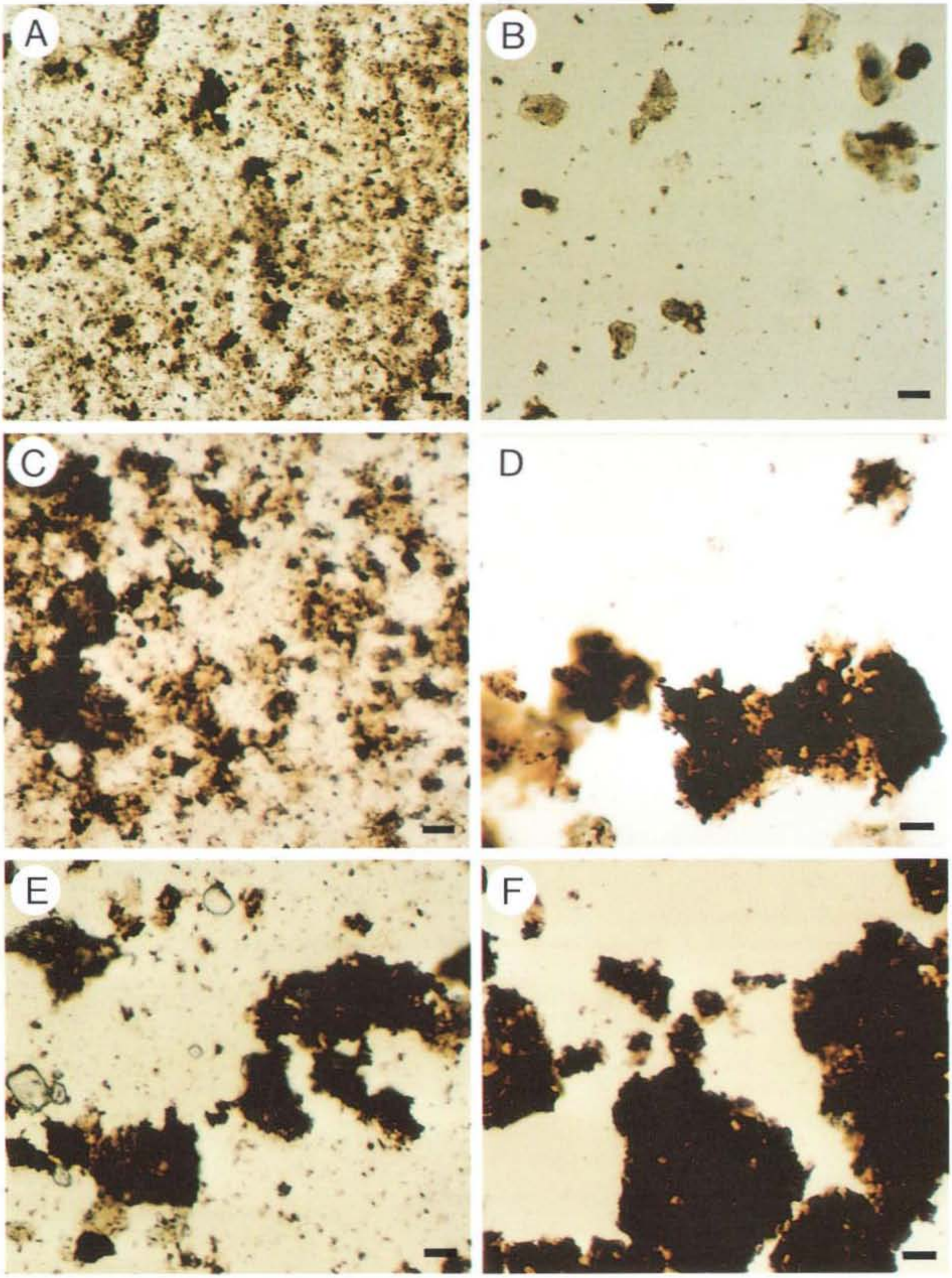

Plate 2. Cambrian palynomorphs

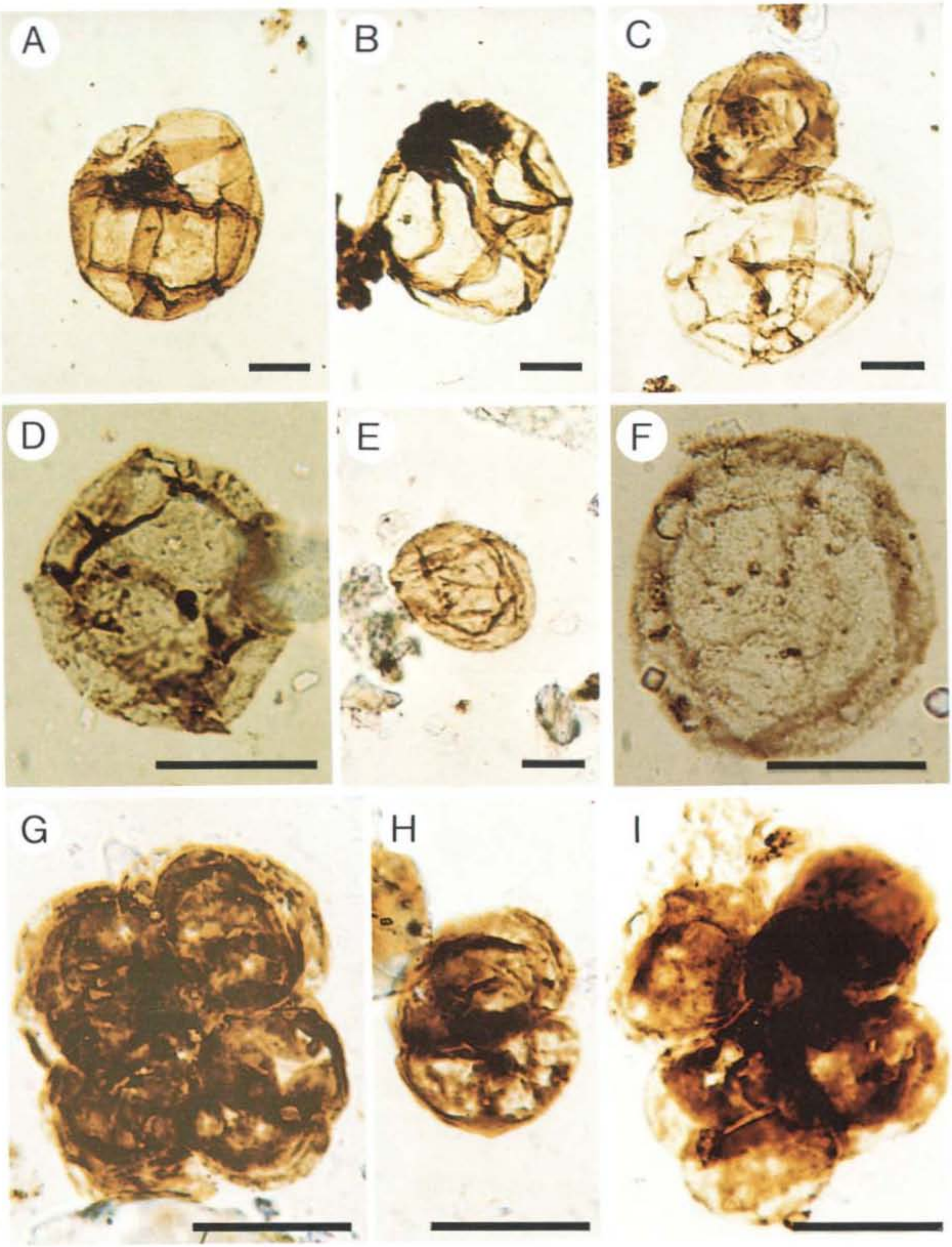

Plate 3. Ordovician palynomorphs

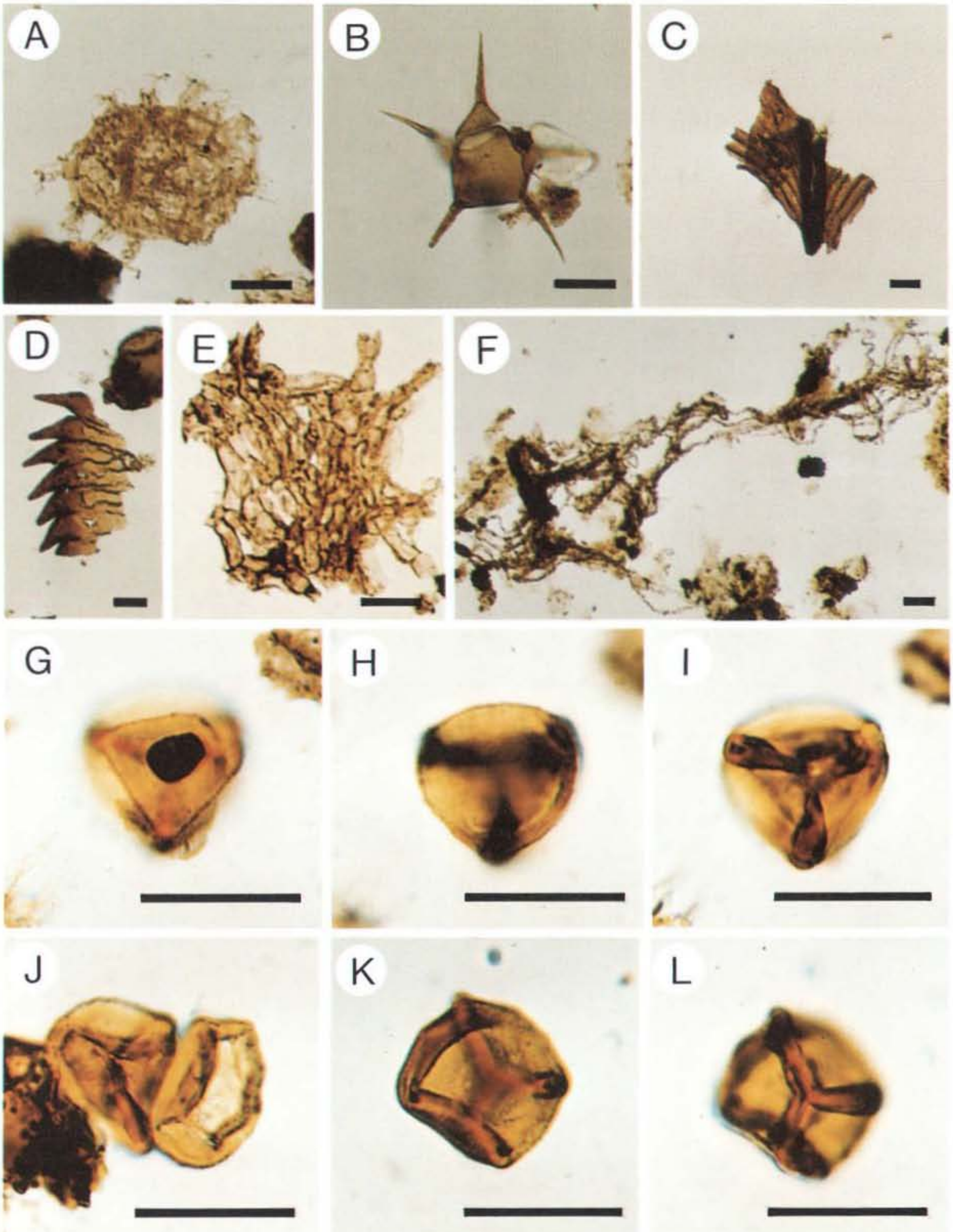

Plate 4. Silurian palynomorphs

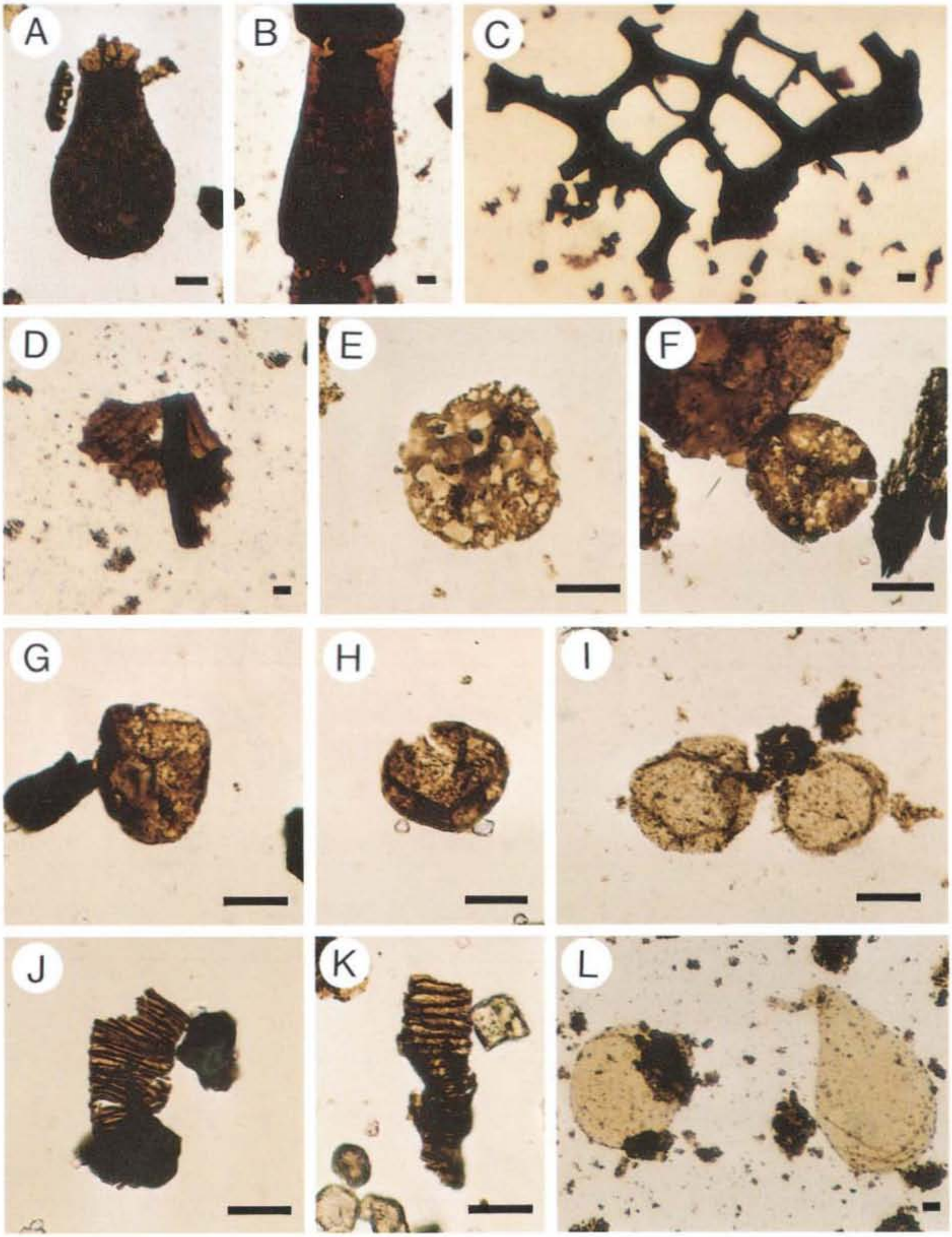

Plate 5. Progressive coloration of amorphous kerogen with increasing thermal alteration

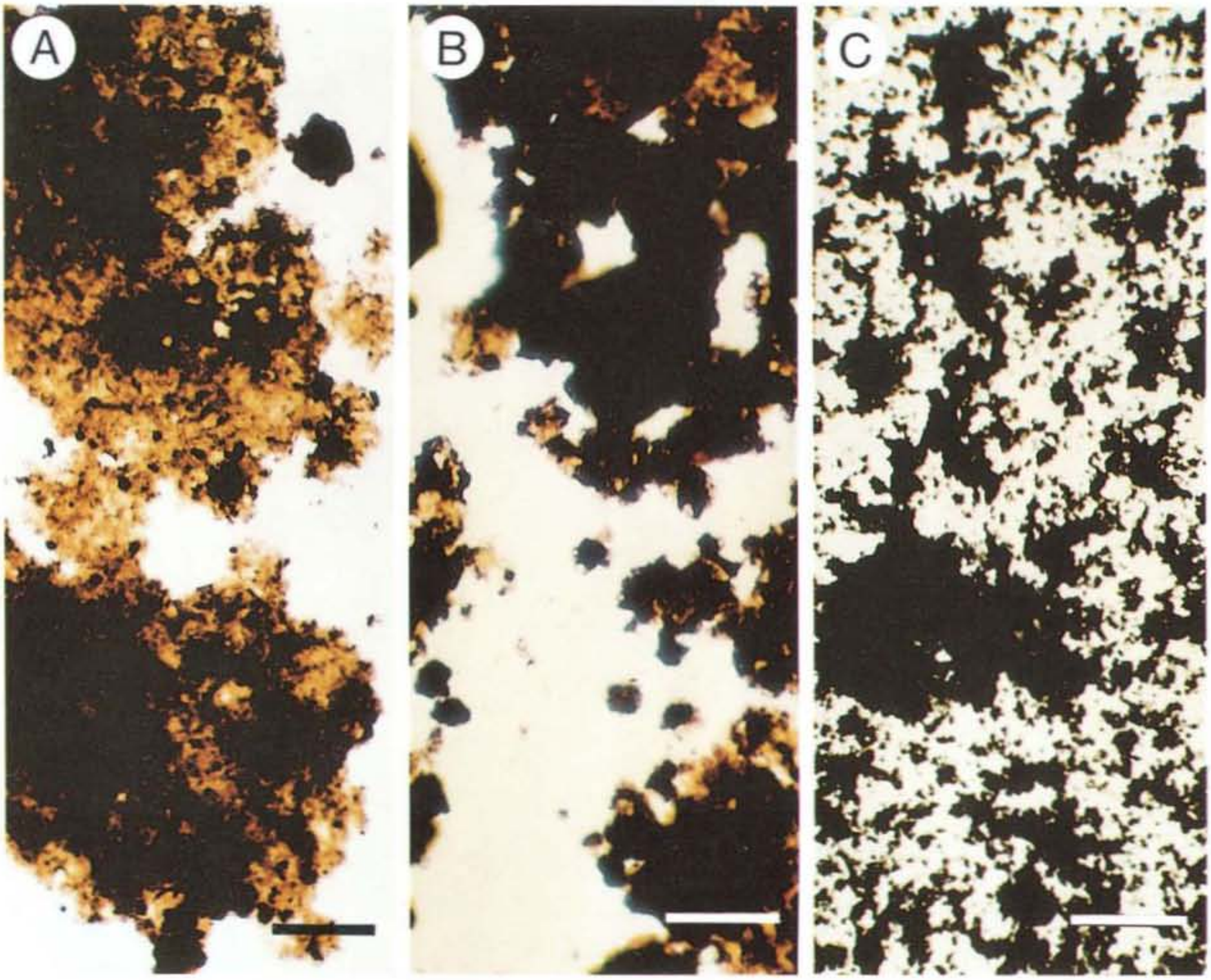

Plate 5. Progressive coloration of amorphous kerogen with increasing thermal alteration

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

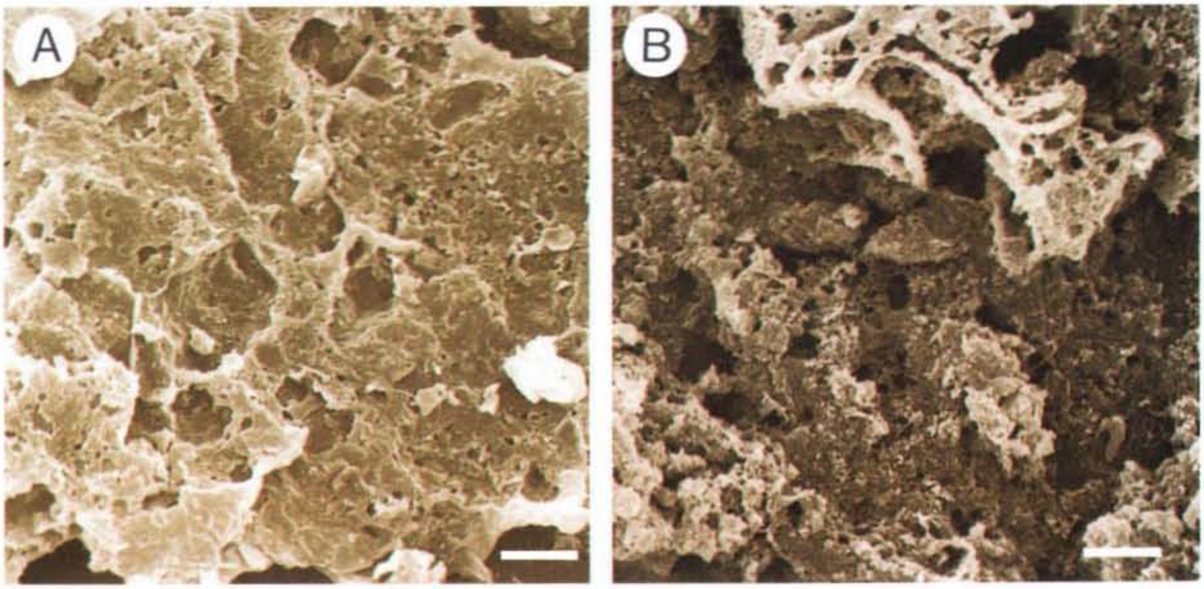

Plate 6. Change in structure of amorphous kerogen with increasing thermal alteration as observed in the scanning electron microscope

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).

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 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.

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

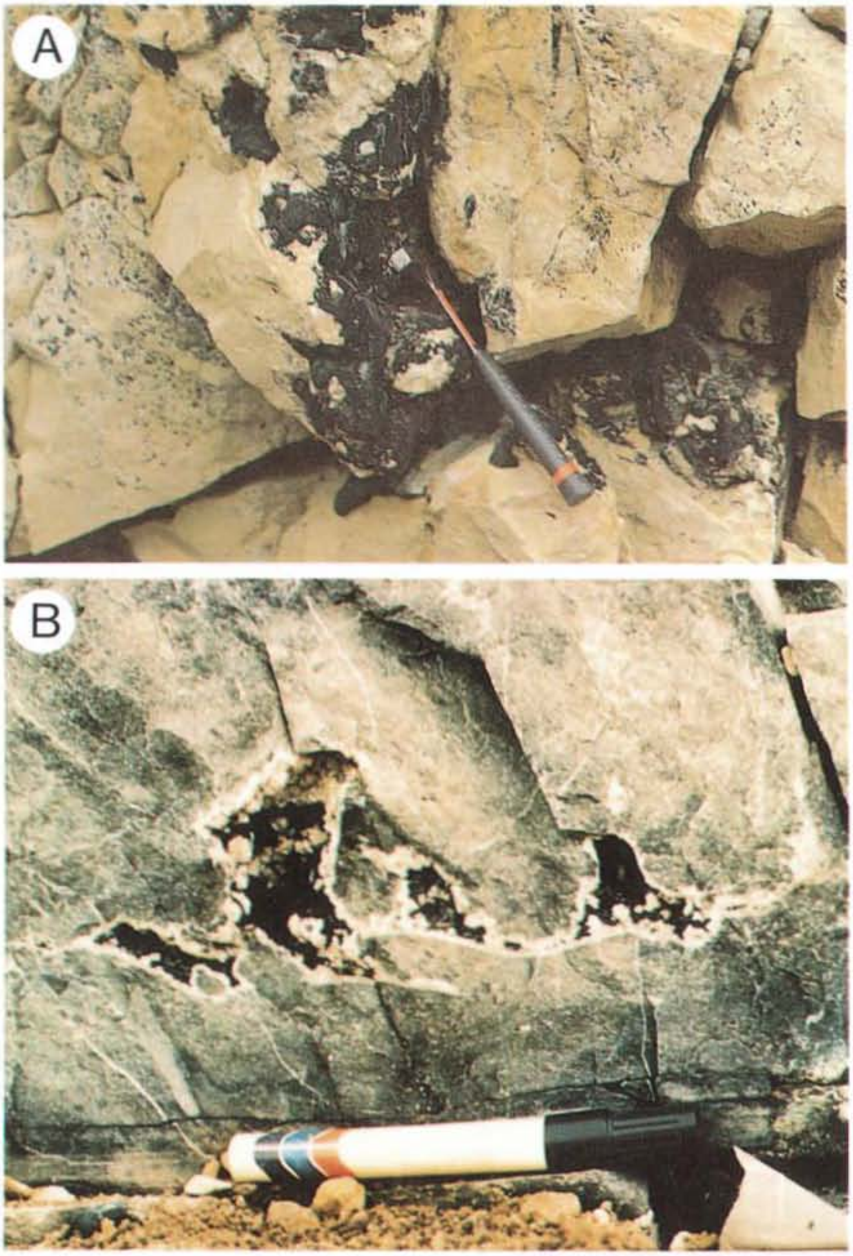

Plate 8. Macroscopic bitumen in slabs

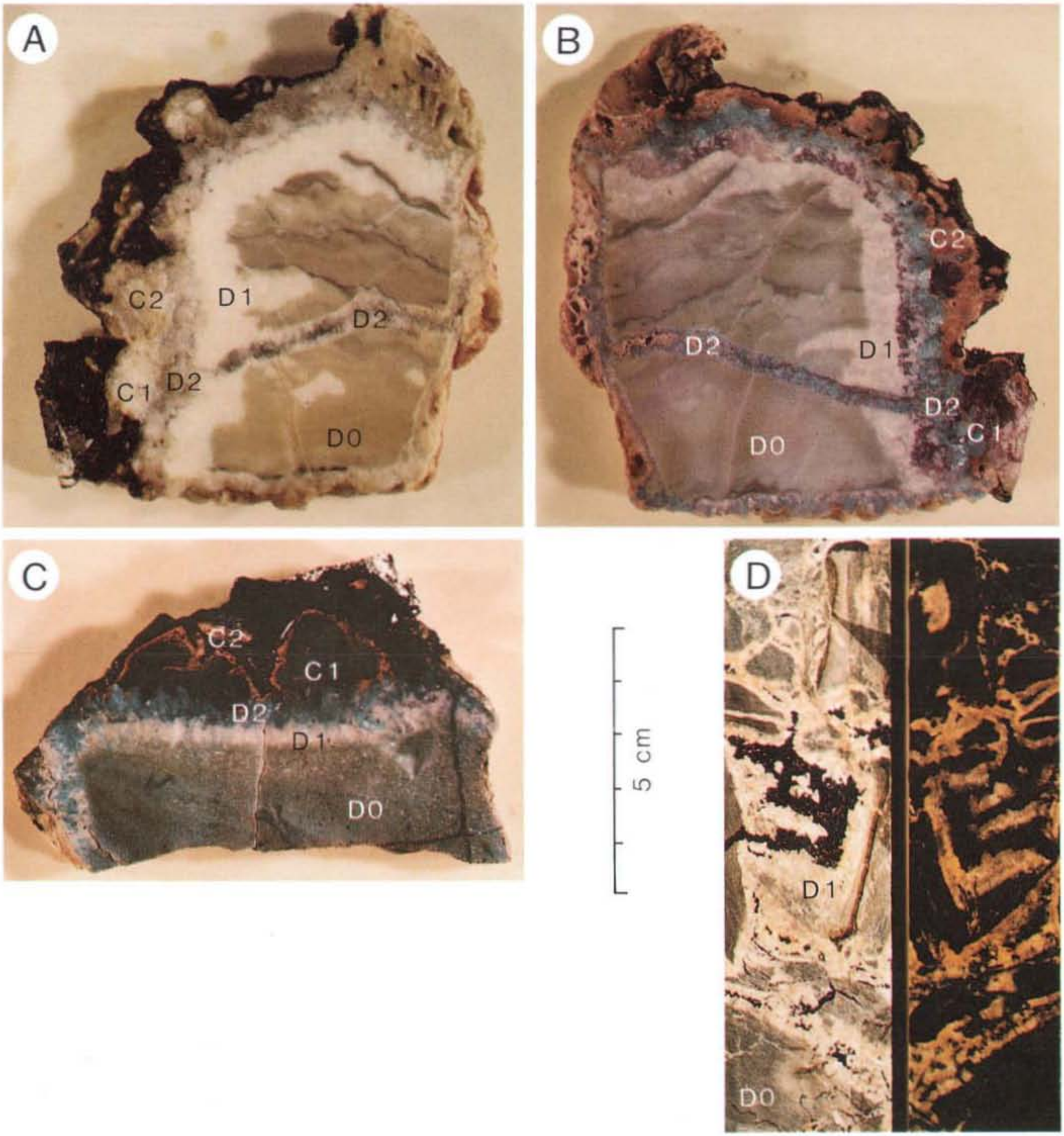

Plate 9. Bitumen in thin section

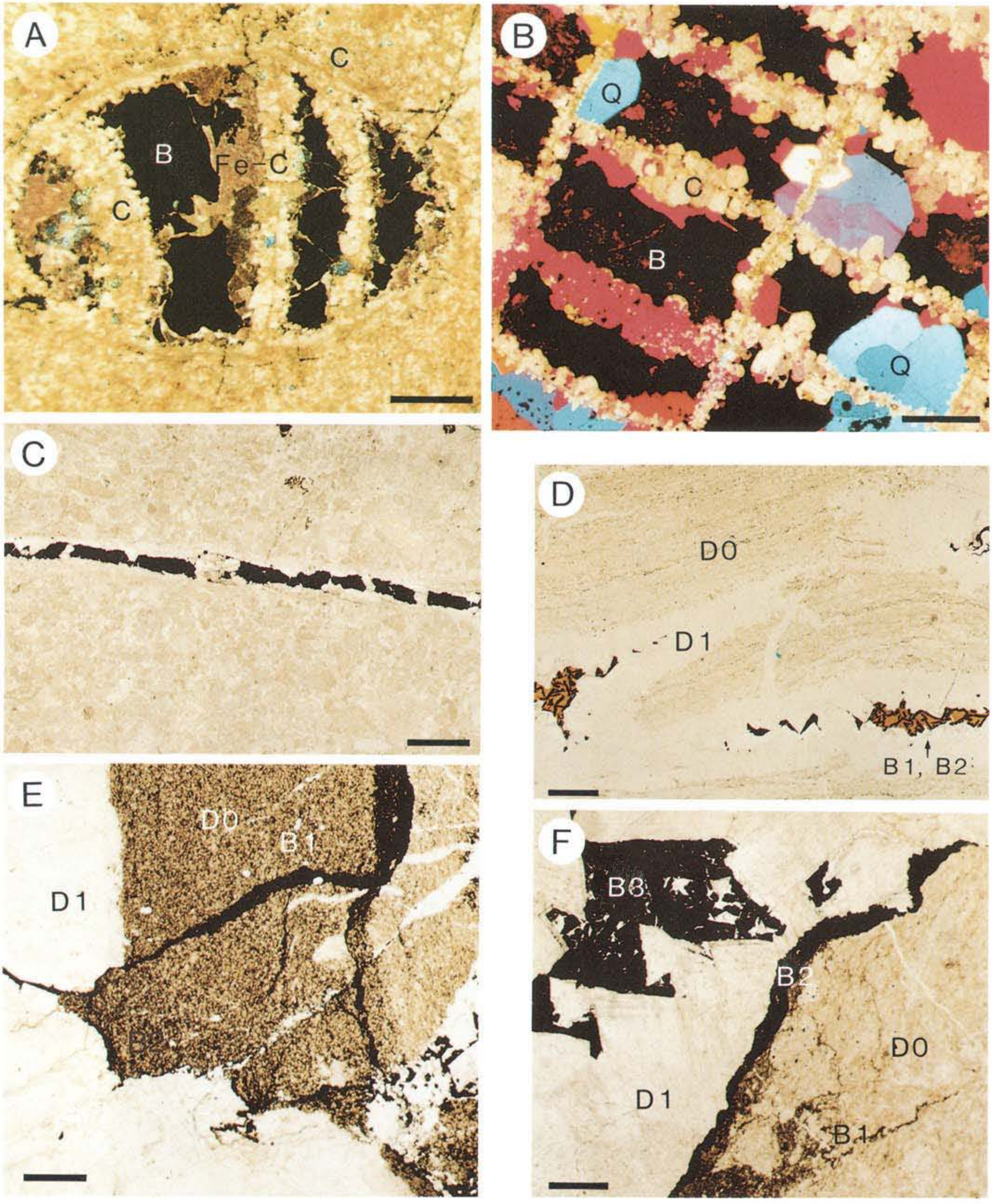

Plate 10. Bitumen in palynologically prepared samples observed in microscope or in SEM

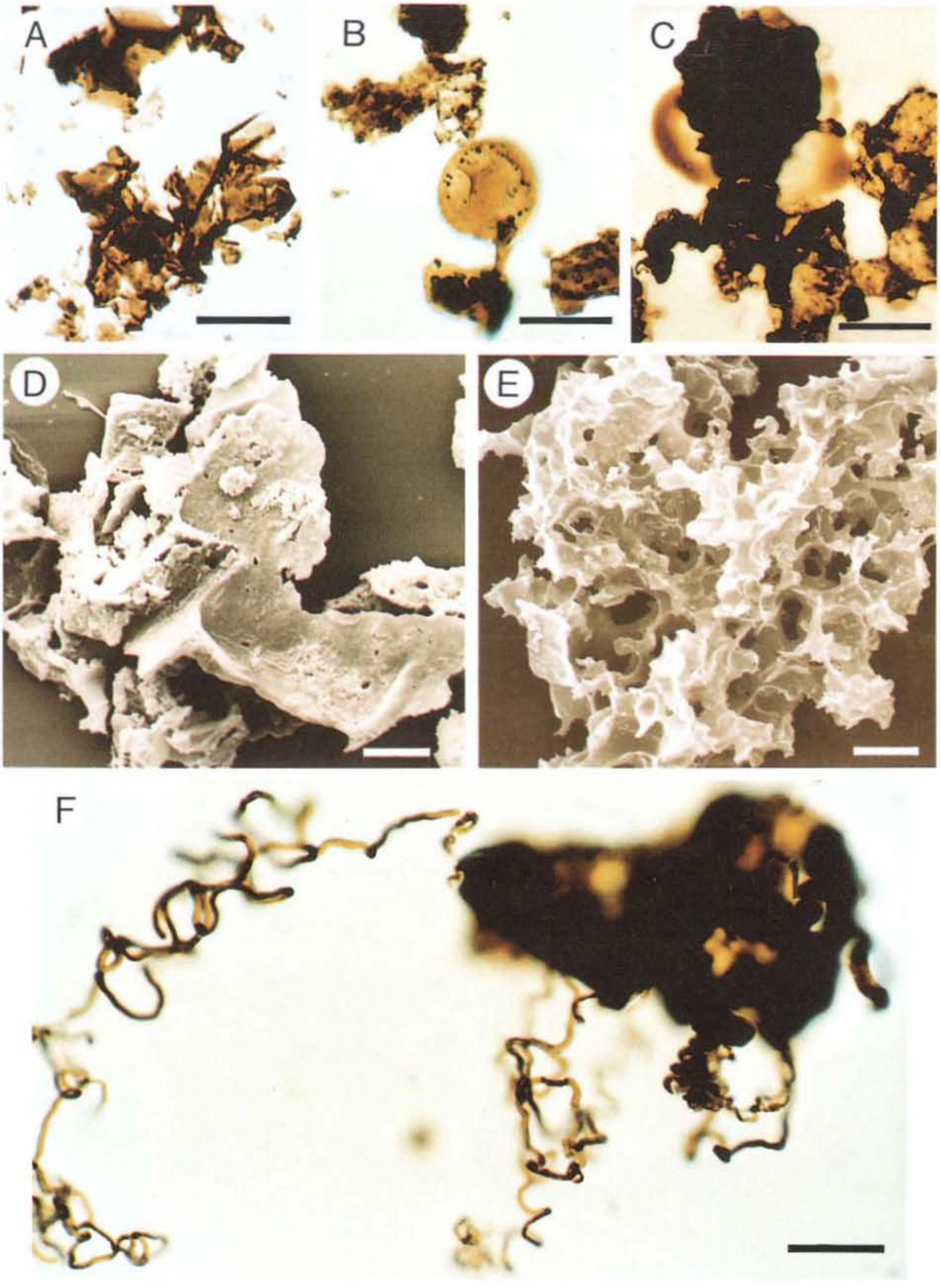

Plate 11. Bitumen in polished section

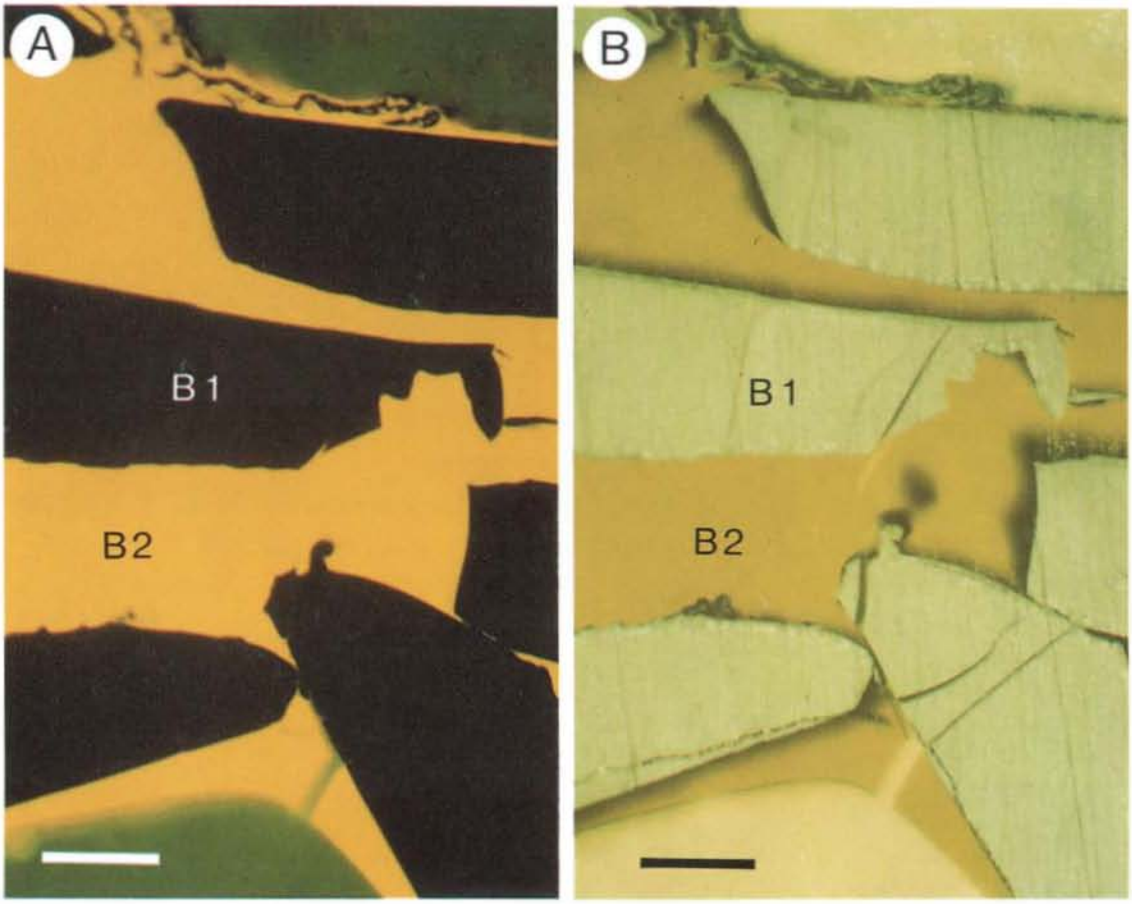

Plate 11. Bitumen in polished section

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.