Study of organic matter in Cretaceous–Tertiary sediments central West Greenland

E. J. Schiener

Source rock investigations have been carried out on behalf of GGU for a number of years. The primary objective was an evaluation of the oil generating potential of the dark shales of the Nûgssuaq peninsula (Henderson, 1969: Stevens *et al.*, 1974). Samples from East and North Greenland were also analysed for the same purpose (Stevens *et al.*, 1973; 1974).

During the last decade the formerly highly specialised fields of coal petrography and related organic geochemistry have, with the necessary modifications, expanded into widely accepted tools for the study of sedimentary basins. A great deal of the impetus has come from the ever increasing demand for fossil fuels which are genetically connected with sediments. With only the remote and inclement regions left for new exploration exhaustive study of available data is one way to reduce some of the high risks involved. For Denmark the risk aspect is still of secondary importance since these initial financial risks are borne exclusively by the concessionaires. It is, however, of greatest importance that gradually more specialised know how in all aspects of exploration for fossil fuels is accumulated. With this in mind, a regional evaluation on the onshore sediments, at present the only accessible parts of the West Greenland Basin (Henderson, 1976), had been initiated by GGU early in 1973 (Schiener, 1974). Initially work was directed towards establishing a sedimentation model for the Cretaceous–Tertiary sediments (Henderson *et al.*, 1976). To find additional support for this model geochemical analyses were carried out on broadly distributed shale samples. Their organic content was investigated simultaneously, while samples from some of the coal seams on Disko and Nûgssuaq were subjected to coal petrographic investigations.

In late 1973 the Danish Natural Science Foundation – Statens Naturvidenskabelige Forskningsråd (SNF) – approached GGU for proposals for energy related research topics. It was finally agreed in 1974 that SNF would fund a 'pilot-project' which by means of a combination of organic geochemistry, study of organic particles, clay mineralogy and geochemistry of a range of environment sensitive trace-elements would provide regionally representative data on a variety of parameters; the objective being primarily to demonstrate applicability of methods and secondarily to acquire more detailed knowledge of the depositional and post-depositional history of the sediments. This knowledge in turn will find its direct application in the evaluation of results from the wells to be drilled on the West Greenland shelf.

The importance of accumulating additional technical and scientific know how is best demonstrated by the fact that all analytical work had to be commissioned outside Denmark. This applies especially to organic geochemistry and coal petrography. It is pleasing to state that in the meantime SNF provisionally agreed to fund additional field investigations and to finance the establishment of an, albeit small, laboratory for organic geochemistry. GGU collaborated with the provision of a reflecting microscope; the combination of these facilities opens up a range of scientific and practical possibilities that will assist in the future evaluation of the fossil fuel potential of Greenland.

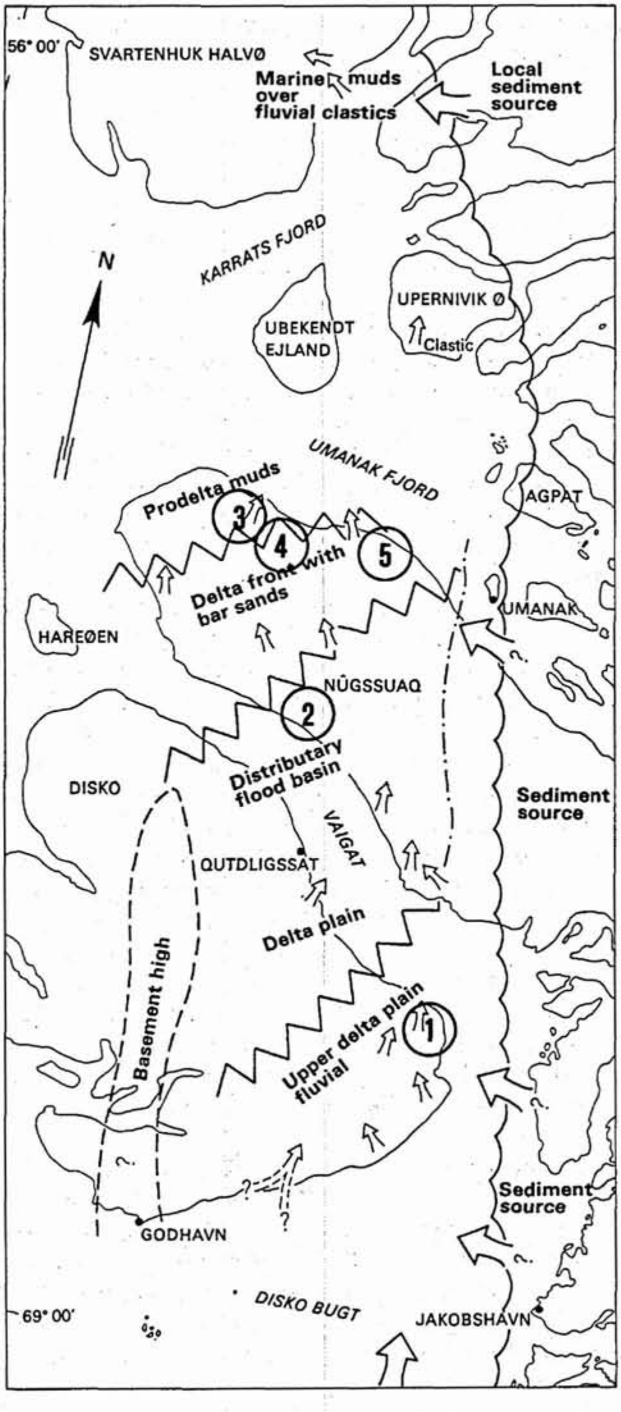

Fig. 13. Cretaceous–Tertiary facies distribution in the Disko–Svartenhuk Halvø region, central west Greenland. Circled numbers mark the location of the samples described in the text.

Purpose of the investigations

It would go beyond the scope of this report to explain in detail all the principles that form the scientific basis for the investigations. A short description of the geological and geochemical reasons will suffice.

The range of applied analytical procedures had two main geological objectives, both closely related to the practical applicability of the basin model. The first objective was to determine by means of combined organic-geochemical and coal petrographic methods, facies related changes in the composition of the organic matter in the dark shales. In fine-grained sediments deposited under predominantly marine conditions the organic matter will in most instances be dominated by hydrogen rich remains of phytoplankton. The opposite end member, oxygen and carbon rich organic matter, derived from higher land plants is found in dark shales of predominantly terrestrial origin (Philippi, 1974).

The second objective, equally important, was to determine the regional and stratigraphic variation in the degree of organic metamorphism or katagenesis (Vassoevitch *et al.*, 1970). The intense igneous activity in the Early Tertiary as well as some major fault zones should have found expression in the thermally very sensitive organic matter (Correia, 1969).

The geochemical objective was a first attempt at a regional evaluation of petroleum potential (Hitchon, 1974) aiming at a possible extrapolation into the offshore area (Schiener, 1975). The geochemical characterisation of possible source rock lithologies will allow rapid comparison with similar lithologies encountered in offshore wells, which in turn will facilitate economic appraisal by state authorities.

To cover the objectives samples were selected from (fig. 13):

(1) the fluviatile facies on south-east Disko; their stratigraphic range is presumably Cretaceous and Early Tertiary;

(2) the assumed transition between fluviatile and brackish-marine on the south coast of Nûgssuaq; stratigraphically presumed Cretaceous – Early Tertiary;

(3) the clearly marine deposits of Late Cretaceous – Early Tertiary age on the north coast of Nûgssuaq;

(4) the marine influenced deposits of Early Tertiary age in Tunorssuaq (north Nûgssuaq);

(5) the sediments interpreted as predominantly of terrestrial origin and of Early Cretaceous age on the north coast of Nûgssuaq east of Ikorfat.

Analytical methods

Only analyses pertaining predominantly to the study of the organic matter will be mentioned here. Inorganic geochemical work has been done on most of the samples, but detection of significant variations requires more elaborate treatment of the raw data. The analytical procedures were, apart from minor modifications, identical in both institutions involved: Institute of Geology and Geochemistry of Petroleum and Coals, Rheinisch Westfälische Hochschule, Aachen and Geochemistry-Mineralogy Division, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

Organic geochemistry

a. content of total organic carbon, after digestion of carbonates (TOC); measuring thermal conductivity of CO_2 originating during combustion in a Leco-analyser; (fig. 14).

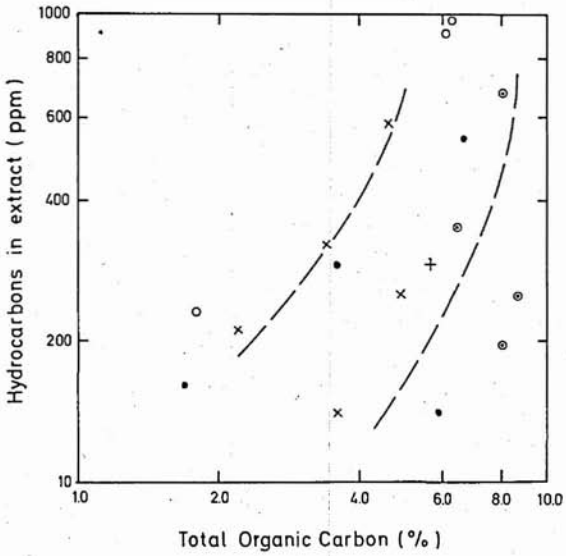

Fig. 14. Total organic carbon content (TOC) plotted against extract yield (solvent soluble organic matter). Symbols as in fig. 15.

b. content of solvent extractable organic matter (SOM), with di-chloro-methane as solvent in soxhlet columns; (fig. 14).
c. distribution of *n*-paraffins, aromatics and hetero components in the extract by liquid column chromatography; (fig. 15).
d. gas chromatography of paraffins with between 15 and 31 C-atoms per molecule (C_{15}–C_{31});
e. separation of paraffins into *n*-paraffins and iso + cyclo-paraffins by molecular sieving (Urea adduction).

Coal petrography

a. microscopic determination of the distribution of the three end members Liptinites (spores–cuticles–resins–algal remains), Vitrinites (gelified plant detritus) and Inertinites (oxidised plant detritus and fungal sclerotia); (fig. 15).
b. optical 'rank' determination of phytoclasts (Bostick, 1974) by the measurement of reflectance of vitrinite particles by means of a microscope photomultiplier (Kötter, 1960).

Conclusions – main trends

The combination of geochemical and microscopic methods for studying the dispersed organic matter in the limited number of samples gave results consistent with the geological setting described by Henderson *et al.* (1976).

The organic matter in the fluviatile delta top facies is derived almost exclusively from higher vascular land plants. In the marine influenced pro-delta environment indicated by well documented faunas, the phytoplanktonic marine elements (alginites) are subordinated owing to a marked diluting effect caused by the overabundantly transported detritus of land derived higher plants. These findings apply to both Late Cretaceous and Early Tertiary strata, although the latter show a less severe dominance by transported detritus (fig. 14).

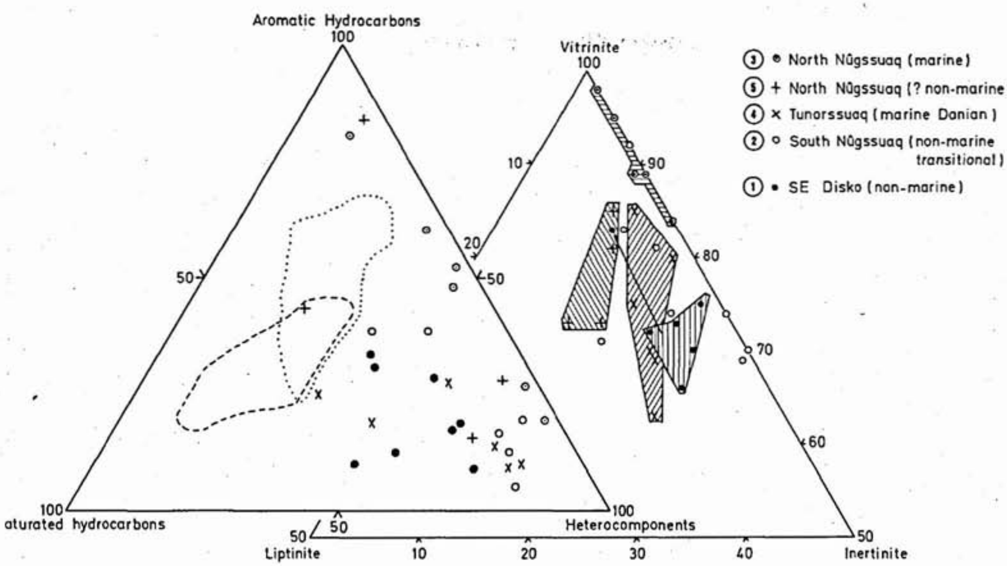

Fig. 15. *Left:* Relation between saturated hydrocarbons, aromatic hydrocarbons, aromatic hydrocarbons and heterocompounds in extracts. Encircled areas indicate clusters of points obtained by Baker (1962) from Cretaceous shales of Kansas and Oklahoma. *Right:* Relation between maceral types occurring as phytoclasts. Numbers refer to the localities marked on fig. 13.

The degree of thermal metamorphism (katagenesis) obtained from vitrinite reflectance and exinite colour (Staplin, 1969) shows some regional variation that in most cases can be related to geological events. Average values in shales uninfluenced by igneous heating are around $R_{oil} = 0.5$–0.6 %, but can be as low as $R_{oil} = 0.35$ %. Values in excess of $R_{oil} = 0.8$–1.0 % are encountered only where intrusive bodies or major fault zones are known to exist. The influence of the latter is not yet determined with sufficient certainty, although there are some indications of a preponderance of igneous heat (relatively short-lived but strongly elevated temperatures) from as yet undetected igneous bodies close to the surface.

Thermal effects of extrusive basalt flows have not yet been studied in detail. The sample material available was taken closely below pillow breccias only. There reflectance values are even slightly lower than those from samples lower in the section.

When the predominant type of organic matter (coaly in this case) is compared with the alteration or maturity stages of fig. 16, it appears that under the observed facies and burial conditions generation of wet and dry gas can be expected. With an increase of phytoplanktonic remains (predominantly of algal origin) as contributors to the organic matter, a trend already observed in the onshore region, (Henderson, 1969; Stevens *et al.*, 1974), regional aspects for the offshore area appear to improve. As an additional factor, increased depth of burial in the offshore equivalents of the studied sediments should be considered to have a beneficial effect on a regional evaluation of petroleum potential.

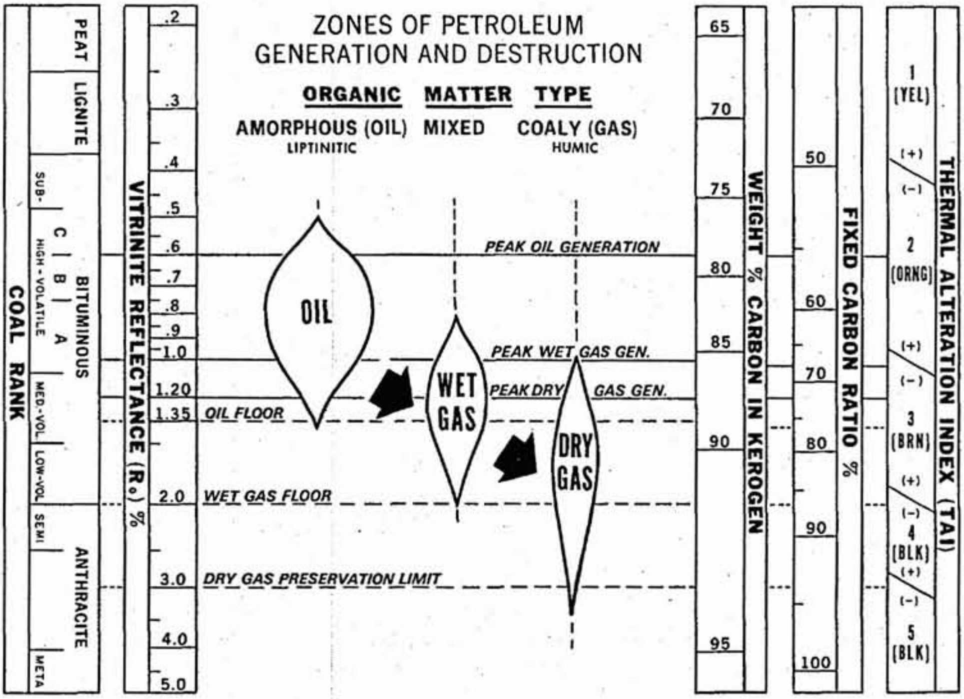

Fig. 16. Occurrence of hydrocarbon types in relation to type of organic matter and maturity. Published with kind permission of W. G. Dow, Superior Oil Co.

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Age relations of the Precambrian Mârmorilik Marble Formation, central West Greenland

Adam A. Garde and T. C. R. Pulvertaft

The Mârmorilik Formation is one of the most important metasedimentary formations in the Precambrian of Greenland. It is the host rock of the Sorte Engel (Black Angel) zinc-lead ore body, it is the largest potential source of calcite limestone in West Greenland, and it is a striking marker horizon which greatly facilitates the recognition of major structures in the Precambrian basement. The formation is composed almost entirely of carbonate rock (dolomite and calcite marbles), and the original depositional thickness of these rocks has been estimated to be more than 1 km (Henderson & Pulvertaft, 1967) an order of thickness that one of us (A.A.G.) has confirmed during recent detailed mapping south-east of Mârmorilik.