Preliminary report of fission track studies in the Jameson Land basin, East Greenland

Kirsten Hansen

Fission track (FT) analysis is especially suited to reveal and date low temperature events. The closure temperature of apatite (100 ± 30°C) and its annealing characteristics in the interval of 70–125°C are especially relevant to the study of the maturation of hydrocarbons (Gleadow *et al.*, 1983).

FT analyses were made on Permian to Cretaceous, quartzose sandstones and arkoses from the Jameson Land basin. Both FT ages and track length distributions for apatites were obtained for samples taken along the western and eastern margin of the basin (fig. 1 and Table 1) in order to study the tectonic and thermal history of the area. The investigation takes advantage of earlier FT work in the neighbouring Caledonian mountain belt which is believed to be the source of the terrigenous material, including the apatites, which make up the sediments (Hansen, 1985). A report of further investigations in this area is in preparation.

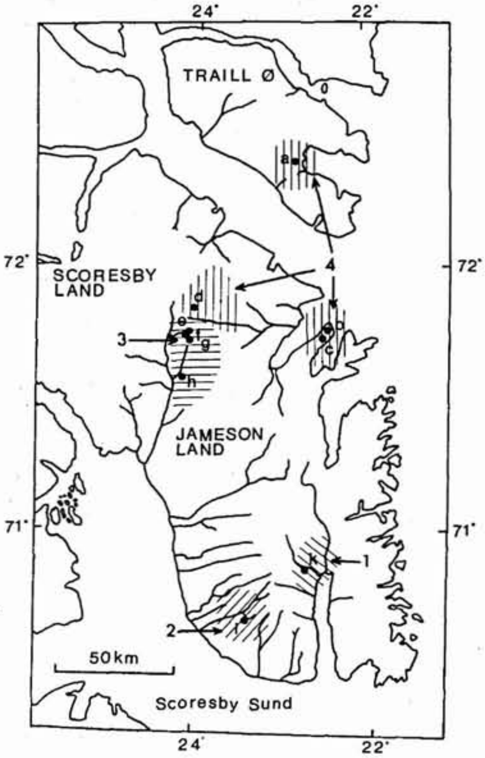

Fig. 1. Sample localities, Jameson Land, East Greenland. Shadings indicate different thermal type areas. Key to localities in Table 1.

Technique

Samples of *c.* half a kilogram were crushed and separated using magnetic and heavy liquid methods. Most samples yielded apatites. Polished and etched apatite mounts were irradiated together with mica detectors in the J1 facility of the HERALD reactor in Aldermaston, England, for age determinations. Specially polished and etched mounts were prepared for track length measurements. The measurements were carried out using a Zeiss-Jena microscope with a × 100 oil objective and a cover slip, and either a calibrated net or a scale bar inserted in the × 12.5 ocular. The calibration used in the age determinations follows the suggestions of Hurford & Green (1983). The NBS SRM612 and Corning CN1 and CN2 glasses were used as fluence monitors and the Fish Canyon and Mt. Dromedary apatites as age standards in the zeta calibration.

Results

Table 2 shows results of FT apatite age determinations and mean track length distributions. Table 3 shows track densities for glass standards for the two irradia-

Table 1. Basic data for sample localities, Jameson Land, East Greenland

Locality	area type	GGU sample no.	elevation m a.s.l.	sediment formation age
Traill Ø				
a	4	327371	880	Cretaceous
Wegener Halvø				
b	4	298343	490	Triassic
c	4	327546	880	Permian
West Jameson Land				
d	4	221247	1100	Upper Permian
e	3	292005	900	Upper Permian
f	3	248628	400	Lower Permian
g	3	293284	771	Upper Permian
h	3	293252	213	Lower Triassic
South Jameson Land				
i	2	292016	300	Upper Jurassic
Ugle Elv, east Jameson Land				
k	1	248652	500	Upper Jurassic

Deposition ages are obtained from Piasecki (personal communication, 1987).

Table 2. Mean track lengths and apatite fission track ages of sedimentary rocks from the Jameson Land basin, East Greenland

Sample GGU no.	Irr. no.	$\varrho_s \times 10^5$ (N_s)	$\varrho_i \times 10^5$ (N_i)	grain no.	age(Ma) ± 1σ	mean length (μm) ± 1σ(N)
Traill Ø						
327371	KH18	7.4369 (160)	51.500 (1108)	7	15.57 ±1.69	†
Wegener Halvø						
298343				†	†	12.28 ±3.34 (44)
327546	KH18	5.2455 (86)	29.643 (486)	9	19.23 ±2.59	10.64 ±3.76 (33)
West Jameson Land						
221247	KH18	7.4746 (31)	40.025 (166)	4	20.29 ±4.20	10.83 ±3.20 (28)
292005	KH17	57.029 (340)	50.320 (300)	8	135.56 ±14.01	10.01 ±2.49 (37)
248628*	KH17	25.658 (281)	45.290 (496)	8	70.23 ±9.49	10.55 ±2.95 (110)
293284	KH18	8.2379 (71)	8.0058 (69)	7	111.10 ±20.19	†
293252	KH17	29.628 (432)	45.677 (666)	9	77.93 ±7.05	10.05 ±2.75 (100)
South Jameson Land						
292016	KH17	15.630 (472)	34.406 (1039)	15	54.68 ±4.71	11.51 ±2.30 (100)
Ugle Elv, east Jameson Land						
248652*	KH18	29.176 (467)	16.931 (271)	10	205.30 ±31.39	†

* failed the chi-squared test. Ages calculated on the basis of individual grain ϱ_s/ϱ_i ratios.
† not determined.
ϱ_s and ϱ_i are track densities of spontaneous and induced tracks respectively, N_s and N_i similarly are the number of tracks counted and N represents the number of tracks measured.

tions and the zeta values which were employed. Fig. 2 shows the measured track length distributions.

Discussion

Apatite FT ages, except for the area in the south-east which is described below, are annealing ages modified by a post-sedimentary heating event (Table 2). This is shown by FT ages which are younger than the 150 Ma apatite cooling ages found for the neighbouring basement (Hansen, 1985) and also younger than the sediment deposition age of individual samples given in Table 1. The FT age distribution suggests that different parts of the area suffered different heating histories. The different parts of the area are shown in fig. 1 and are described below.

(1) Area type 1 is an area in the south-east which is only weakly annealed and probably slowly uplifted. It gives an apatite FT age of *c.* 200 Ma. The material for the sample representing this area may originate from the nearby Hurry Inlet granite of 425 Ma (Hansen & Steiger, 1971). The FT age for the granite yields 203 Ma for apatite for a surface sample (Gleadow & Brooks, 1979) taken to represent apatite FT ages at today's erosion level for the Hurry Inlet granite. This means that apatites in the sediment may range from 425 to 200 Ma for an unannealed sample. The actual age spread found for the sediment (Upper Jurassic) is between 80 and 330 Ma, i.e. lower than expected for unannealed samples, the youngest being younger than the sediment age indicating that the partial annealing was experienced after deposition. The mild annealing suggests that the temperature was close to the lower temperature limit of the annealing interval, e.g. *c.* 80°C, which is in accordance with vitrinite reflectance measurements found for the area (E. Thomsen, personal communication, 1987).

(2) Area type 2 is an area in the south which was probably almost totally annealed (close to 125°C) and was slowly uplifted at, or later than 55 Ma ago, the thermal activity perhaps being indirectly related to the Scoresby Sund igneous activity at 53–56 Ma (Watt *et al.*, 1986). A

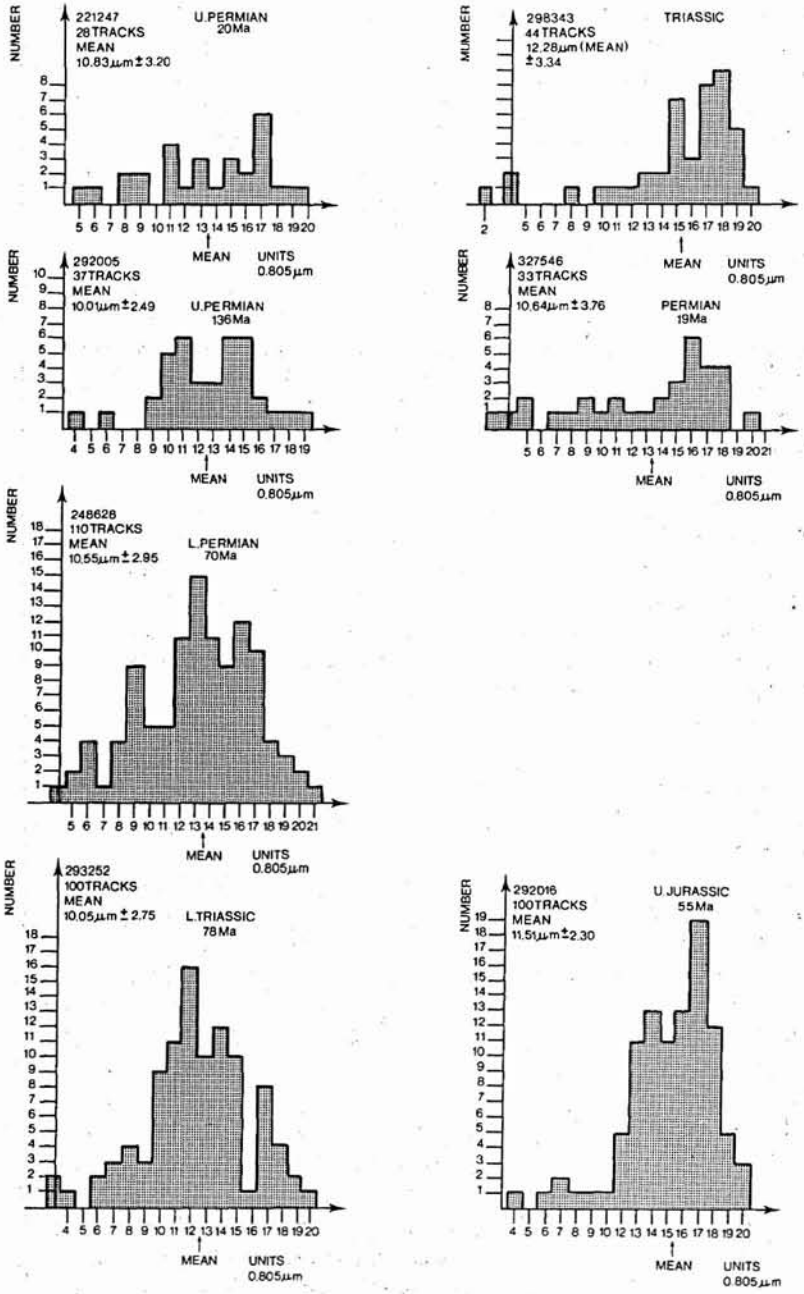

Fig. 2. Track length distributions, Jameson Land, East Greenland. Mean track lengths, uncertainties, deposition ages and apatite fission track ages are also given in the figure.

temperature not much lower than 125°C fits the maturity pattern revealed by, e.g. reflectance measurements (E. Thomsen, personal communication, 1987). This area could be related to the partly annealed area of type 3, representing a more deeply buried section.

(3) Area type 3 in the west shows varying ages, 70–135 Ma, which can be partly ascribed to different degrees of annealing due to different elevations (Table 1). Thus the samples from the highest levels cooled below the annealing interval first and also did not proceed so far into the annealing interval. Temperature differences at 30°C/km would be *c.* 15–20°C for differences in altitudes of *c.* 600 m which could produce marked age differences at temperatures around 100°C (Gleadow *et al.*, 1983). The time of the uplift may coincide with the uplift of the southern area. Hydrocarbon maturity measurements reveal a complex pattern with a major maturity shift between Lower and Upper Permian (Surlyk *et al.*, 1986) not found in the FT data.

(4) *Area type 4* in the north shows young uplift ages of *c.* 20 Ma which implie almost total annealing. The connection between the eastern and western part is unclear, as is the influence of the Werner Bjerge intrusion which also gives an apatite uplift age of 20.5 Ma (Gleadow & Brooks, 1979) and similar K-Ar ages (Schassberger, personal communication to C. K. Brooks). Maturity measurements also show these northern areas to be post-mature with respect to oil generation (Surlyk *et al.*, 1986).

The above findings are supported by track length distributions, mean track lengths, and their uncertainties (Table 2 and fig. 2). Heating into the annealing interval reduces track lengths, the track length distribution thus being diagnostic of the path through the heating interval (Gleadow *et al.*, 1986).

Track length distributions have so far been obtained for samples from the southern area (type 2), the western area (type 3), and the northern areas (type 4), although the restricted amount of material makes it difficult to obtain reliable results. However, the internal consistency of the few data allows a generalised description of track length distributions for three of the areas described.

The youngest area (type 4) shows the simplest track length distributions in its eastern part, where distributions are dominated by young tracks in a typical skewed uplift pattern (Gleadow *et al.*, 1986). However, the broad distribution and the low mean indicate a small admixture of pre-uplift age to the measured age. This means, as suggested above, that temperatures close to total annealing (125°C) were attained together with late uplift (after 20 Ma ago). The distribution for the sample taken close to the contact of Werner Bjerge intrusion (221247) does not reveal a typical uplift pattern. This may, however, be due to the difficult and restricted material and interpretation must await further determinations.

The track length distribution of the northern samples (area type 4) contrasts with the distribution for the western area (type 3) which shows a very broad symmetrical pattern. A symmetrical distribution is characteristic of partial annealing with only a small proportion of newly formed long tracks, i.e. the resulting mixed age is dominated by partly annealed old tracks and the uplift age is much younger than the mixed age. A temperature close to 100°C must be assumed as the maximum temperature experienced.

In the southern area (type 2) the track length distribution is narrower with a younger (55 Ma) age compared to the western area, but it still has an old component as shown by mean lengths and uncertainties; it is probably a result of further annealing due to deeper burial than found in the western area. This implies a temperature close to, but not exceeding, 125°C and a slow uplift, not much later than 55 Ma ago. The area has been uplifted together with the neighbouring areas which were never so deeply buried, as shown by their higher ages and greater spread in track lengths.

Table 3. Track density of glass standards, calibration factors

	ϱ_dSRM612 Number	ϱ_dCN1 Number	ϱ_dCN2 Number
KH17	8.089194×10^5 5242	24.86787×10^5 6446	22.96979×10^5 5954
KH18	7.100035×10^5 4601	21.90888×10^5 5679	21.64268×10^5 5610
ζ	288 ± (9.38%)	101 ± (4.95%)	105 ± (4.76%)

KH17 and KH18 are irradiation numbers, ϱ_d track densities of mica detectors for the respective glass standards and zeta calibration factors (Hurford & Green 1983) used for the age determination based on age standards.

Conclusions

In general the results support the maturity pattern found for the area by Surlyk *et al.* (1986). Assuming a geothermal gradient of 30°C/km, the maximum burial is constrained to be less than 3 km by by the maximum temperature experienced (less than *c.* 125°C), except perhaps to the north. During uplift, sediments in the southern part first passed the 100°C isotherm not much later than 55 Ma ago and were uplifted together with the less deeply buried neighbouring areas. To the north, uplift led to the passing of the 100°C isotherm much later, around 20 Ma ago. The reasons for the young ages to the north, compared to more southern areas could be delayed uplift followed by a rapid uplift during the last 20 Ma. The rapid uplift is not likely to have proceeded for a longer time span than the 20 Ma as this would lead to exposure of sedimentary rocks of higher formation age to the north compared to the rest of the area, and this did not occur. Alternatively, younger ages could also result from a higher geothermal gradient which would be likely to accompany the Tertiary intrusive activity. Finally a combination of the two explanations is possible.

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Institut for Petrologi,
Øster Voldgade 10,
DK-1350 Copenhagen K,
Denmark.

Studies of the onshore hydrocarbon potential in East Greenland 1986–87: field work from 73° to 76°N

C. Marcussen, P.-H. Larsen, H. Nøhr-Hansen, H. Olsen,
S. Piasecki and L. Stemmerik

The study of the Devonian to Cretaceous sequence in central and northern East Greenland was continued in 1987. Field work was carried out from early July to mid August covering the region between Ymer Ø and Hochstetter Forland (fig. 1). This was the second year of a two-year field work programme (Marcussen *et al.*, 1987) which forms part of a regional programme comprising sedimentological, stratigraphic, structural, and petroleum geological studies of the sedimentary basin in central East Greenland (e.g. Surlyk, 1983; Surlyk *et al.*, 1984, 1986a,b).

Stordal in Hudson Land, which offers a natural landing strip for STOL aircraft, was used as base camp for the 1987 expedition. The expedition group of 15 included four to five geological field parties and five supporting personnel, including a helicopter pilot and mechanic. In addition a five-man British-Danish East Greenland 'vertebrate–paleontological' expedition (Bendix-Almgreen, 1988) and a group from GGU planning the 1988 expedition to North-East Greenland were present. Two teams (led by P.-H. Larsen and H. Olsen) studied the tectonics and sedimentology of the Devonian succession. Two teams (led by L. Stemmerik and S. Piasecki) investigated the Carboniferous, Permian and Triassic sedimentology of the region. The Jurassic and Cretaceous sequences were studied by two teams (led by S. Piasecki and in the late half of the season by H. Nøhr-Hansen). All the teams collected material for source rock analyses and a large number of samples were also collected for determining reservoir rock properties.

Devonian

Sedimentological studies. The field work in 1987 was concentrated on Ymer Ø, Gauss Halvø, Moskusokselandet and Strindberg Land (figs 1, 2). Detailed facies analyses were made by vertical facies logging and 2-

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