DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1998/87

Modelling of uplift history from maturity and fission track data, Nuussuaq, West Greenland

EFP-95 Project: Final Report
ENS Journal No. 1313/95-0004

Anders Mathiesen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

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Contents

1. Introduction

The background for this project is a series of petroleum geological activities by GEUS in the Disko-Nuussuaq-Svartenhuk Halvø region of central West Greenland, - activities that have created many important break-troughs during the 90'ties:

- Discovery of oil seeps in basalts at Marraat (1992) e.g.(Christiansen, 1993)
- Documentation of thick sedimentary succession (6-8 km) by onshore seismics (1994) e.g. (Christiansen et al., 1995)
- Discovery of oil impregnation in sediments underlying volcanics (1995)
- Documentation of large rotated faults by offshore seismics (1995-1997) e.g. (Chalmers et al., 1999a)
- Discovery of extensive oil seepage with many different oil types (1996-1997) e.g.(Bojesen-Koefoed et al., 1999)
- Documentation of fair to good reservoirs (1997) e.g.(Sønderholm and Dam, 1998)

The discovery of oil in this region revised the widespread rumours that the whole of the Labrador Sea - West Greenland region was gas-prone and the 5 wells (GANW#1,GANE#1,GANK#1,GANT#1 and GRO#3) that were drilled in 1995-1996 have given a number of positive evidence of oils and oil-prone source rocks.

The main focus of this report is to present a conceptual model and numerical framework for modelling of the Nuussuaq Basin and the adjacent areas (Fig.2.1). This report presents the first quantitative basin models for those parts of Nuussuaq that, based on structural, stratigraphic and direct hydrocarbon indicators, have the best possibilities for discovering accumulations of hydrocarbons.

Basin modelling is, as used here, the integration of models for tectonism, magmatism, sedimentation, organic geochemistry into a timeframe based on precise age dating and biostratigraphy. Further use of maturity data and regional seismic data basin modelling provides an important hydrocarbon exploration tool. Results from basin modelling are in this study combined with fission track data analysis and modelling to add important constraints to the uplift and erosion history of the area. In an area like the Nuussuaq Basin, where the data is limited and thus the geological understanding, problems with quantifying geological information, degree of freedom of input parameters and what final concept and strategy to use becomes critical. This study deal with these problems.

The report is the final report of the Energy Research Project (EFP No. 1313/95-0004) entitled "Modelling of uplift history from maturity and fission track data, Nuussuaq, West

Greenland" supported by the Danish Ministry of Environment and Energy (through the Energy Research Program).

The report combines ongoing research projects dealing with the geology of West Greenland and focuses on results from subsidence, uplift and erosion and the implications for hydrocarbon generation and preservation. An attempt to distinguish the tectonic part of the uplift from the actual uplift and erosion is also presented.

A large number of papers and reports on the sedimentology, volcanology, biostratigraphy, petrophysics and organic geochemistry of the sediments, oils and gases from these wells and outcropping rocks published by GEUS have been used e.g. (Christiansen et al., 1996b); (Dam, 1996a; Dam, 1996b; Dam, 1996c); (Kristensen and Dam, 1997); (Nøhr-Hansen, 1997a); (Storey et al., 1998; Pedersen et al., 1996). Furthermore, this project is closely linked with seismic studies in the Disko Bugt-Uummannaq Fjord region (Bate et al., 1994).(Chalmers, 1998; Chalmers et al., 1999b; Chalmers et al., 1999a)

2. General geological setting and stratigraphy

The West Greenland margin is a rifted continental margin, formed in connection with the opening of the Labrador Sea in Late Mesozoic - Early Cenozoic time. A complex of linked sedimentary basins stretching from the Labrador Sea to the northern Baffin Bay (Chalmers et al., 1993; Whittaker et al., 1997) extend onshore on central West Greenland (Chalmers et al., 1993). The Labrador Sea is flanked by typical Arctic continental shelves with banks less than 200 m deep separated by glacially eroded channels (Chalmers et al., 1993). The onshore part of these basins in West Greenland, the Nuussuaq Basin, extends from Disko to the south, across most of Nuussuaq, to Svartenhuk Halvø in the north (Fig.2.1). The Nuussuaq Basin is bounded against basement in the east by an extensional fault system, parts of which have been active several times during the Late Mesozoic and Early Cenozoic. This faulted contact consists of Precambrian gneisses and metasediments (Pedersen and Pulvertaft, 1992). Generally the basin is characterised by major N–S and NW–SE faults with E- and NE dipping fault blocks (Chalmers et al., 1999a).

The structural and sedimentological evolution of the Nuussuaq Basin initiated with rifting of the Greenland-Canada continent probably as early as 138 Ma, based on an age determination of a sample from the coast parallel dike swarm in SW Greenland.

The sedimentary succession on Nuussuaq is in places 6–8 km thick (Christiansen et al., 1995) (Chalmers et al., 1999b) of which the uppermost 2.5 km Lower Cretaceous (Albian) to Paleocene succession is exposed. The both marine and terrestrial sediments are typically overlain by 1.5–2 km of picritic hyaloclastites and continental flood basalts (Pedersen and Pulvertaft, 1992; Dam and Sønderholm, 1994). The age and character of the deepest offshore sediments are still not known (Chalmers et al., 1999b; Whittaker, 1995). A recent onshore study based on seismic and especially gravity and magnetic data have provided new information of the deep structures in the Nuussuaq basin. Interpretation of gravity data suggests that maximum depth to basement is in the order of 8-10 km in the western part of the region, whereas it is much shallower under eastern Disko and Disko Bugt where the maximum depths to basement are between 2 and 3 km (Chalmers et al., 1999b). Seismic reflection lines and gravity maps indicate that the sediments continues into offshore areas to the north, west and south (Whittaker, 1996).

From Albian until Late Campanian or Early Maastrichtian, sediments where deposited in a fluvial- and wave dominated delta environment and consists of fluviatile clastics in the south changing to marine mudstones in the north reflecting the change from upper deltaic plain in the south to deeper marine conditions in the north. The delta sediments fanned out to the west and north-west from a point east of Disko island, reaching into deeper water in the position of the present-day north-west Nuussuaq and Svartenhuk Halvø. Pre- and syn-rift fluvial sandstones with minor mudstone and coal seams characterise the south and east of the outcrop area. To the north-west these are replaced by stacked, typical deltaic, coarsening-upwards successions, often ending with a coal layer, while further north-west dark mudstones were deposited in a purely marine environment (Pedersen and Pulvertaft, 1992).

Between latest Campanian and mid-Maastrichtian the area became tectonically unstable, tectonic uplift and/or a eustatic fall in sea level led to a drastic change in sedimentation. Deep valleys were incised in the underlying sediments. On Nuussuaq there is evidence that at least three phases of uplift during the Maastrichtian and Early Paleocene were each followed by incision of valleys in the underlying sediments (Kristensen and Dam, 1997; Dam et al., 1998). Conglomerates and both turbiditic and fluvial sands and mudstones of Late Maastrichtian age to Middle Paleocene age filled the valleys, while on the fault-controlled slope to the west more than 2.5 km of turbidite channel sandstones alternating with marine mudstones were deposited on the submarine slope to the west around the Itilli Valley (Dam and Sønderholm, 1994; Dam and Sønderholm, 1998). As the relative sea level rose again during Early Paleocene time the incised valleys became filled with debris flow paraconglomerates, turbidite sands and mudstones.

Following the Late Maastrichtian – Early Paleocene transgression and accompanying valley-fill, slope and shelf sedimentation, there was a renewed fall in relative sea level, probably caused by tectonic uplift. A new major valley system was then incised along the south coast of present day Nuussuaq and was filled with fluvial and estuarine sand, while in central and northern Nuussuaq a low-stand shoreline developed. Renewed transgression coincided with the final infilling of the valleys, and fluvial-estuarine sandstones are abruptly overlain by shelf mudstones (Dam and Sønderholm, 1994; Dam et al., 1998).

The Valley incision was followed by rapid major subsidence associated with up to 2 km or more volcanic consisting of picritic hyaloclastites and continental flood basalts e.g. (Pedersen, 1985; Pedersen et al., 1993). The eruption of Paleogene basalts began at the end of Early Paleocene in subaqueous environment, contemporaneously with the deposition of marine, limnic and fluviatile clastic sediments in the northern and eastern part of Nuussuaq. The earliest basalts, the Vaigat Formation, occur to the west, and were erupted in a subaqueous environment, as the lowest volcanic rocks consist of hyaloclastite basalt breccias that build up Gilbert-type delta structures with cross-bedding sets up to 700 m. During eruption, the lavas flowed eastward into a deep water-filled basin, presumably of tectonic origin, where they formed huge eastward-prograding hyaloclastite fans. In south-east Nuussuaq lacustrine mudstones rest unconformably on tilted fluvio-deltaic sediments of the Atane Formation (Pulvertaft, 1989). With time the water-filled basin was filled up and plateau lavas spread further east, finally overlapping onto Precambrian basement (Pedersen et al., 1998; Pedersen et al., 1996). The stratigraphically lowermost volcanic sample dated yields an age of 60.4 ± 0.5 Ma (Storey et al., 1998).

The Vaigat Formation is overlain by the Maligât Formation, which reaches a maximum thickness on Disko in excess of 2 km. Age determination from flows gave ages of 60.5 ± 0.4 Ma to 59.4 ± 0.5 Ma (Storey et al., 1998). These ages are within magnetochron 26r, while the lowermost lavas of the Vaigat Formation show normal magnetisation and most therefore have been erupted during Chron 27n (Riisager and Abrahamsen, 1997; Riisager and Abrahamsen, 1998)

At present it is difficult to establish a coherent picture of the timing and duration of the volcanism and the interplay between volcanism and the Early Paleocene sedimentation. One of the main reasons is because not all sediments contain fossils suited for biostratigraphic work, and because many contacts between volcanics rocks and sediments are poorly exposed. Furthermore, discrepancies between the biostratigraphic work and $^{40}Ar/^{39}Ar$-geochronology complicates the absolute age relation between the sediments and volcanic rocks (e.g. (Nøhr-Hansen, 1997a) vs. (Storey et al., 1998)).

2.1 Structure

The depositional pattern in the Nuussuaq Basin seems to be strongly structurally controlled. The present-day onshore eastern boundary is marked by a system of N-S and NW-SE –trending faults where most of the movement took place after the deposition of the Atane Formation (Fig.2.1) (Chalmers et al., 1999b).

Field mapping and seismic surveys around Nuussuaq have identified a major N-S trending normal fault zone (Kuugannguaq Fault) stretching from the Kuugannguaq valley on Disko, across the Vaigat and Nuussuaq (Fig.2.1) (Chalmers et al., 1999b). The Kuugannguaq Fault acted as a major morphological feature throughout most of the Late Cretaceous – Paleocene. Deltaic deposition took place east of the fault e.g. (Pedersen and Pulvertaft, 1992), whereas, deposition in a major turbidite slope complex took place west of the fault e.g. (Dam and Sønderholm, 1994). This suggest that a N-S fault-controlled slope occurred along the Kuugannguaq Fault throughout most of the Late Cretaceous. The fault downthrow the basalts 200-350 m to the west.

Another significant N-S fault (Gassø Fault) with downthrow to the west occurs east of Marraat and is interpreted to run just west of the GRO#3 well (Fig.2.1 and Fig.2.2). Inland the total post-Vaigat Formation downthrow of this fault is in the order of 900 m. At three localities (e.g. Nuuk Killeq, Fig.2.1) on the south coast of Nuussuaq and in the north coast of Disko the surface on which the hyaloclastite breccias accumulated rises abruptly eastwards 400-500 m. These steps in the subsurface are regarded as expressions of fault scarps formed during the rapid subsidence that preceded the extrusion of the breccias (Chalmers et al., 1999b; Pedersen et al., 1993). Another N-S trend defines the Disko Gneiss Ridge (Fig.2.1). Its effect on the basalts shows that faulting was active on the western margin of the Disko Gneiss Ridge at a late stage in basin development. The fault system that defines the present-day boundary of sedimentary outcrops to the east also trend N-S, but are later offset by faults that trend WNW-ESE, giving a overall NNW-SSE trend to this fault system. The trend between WNW-ESE and NW-SE is the trend of several shear zones in the Precambrian basement east of Disko Bugt, suggesting that these old shear zones exerted an influence on later faulting.

The Itilli fault zone is a structural feature trending 37° from the south-east corner of Hareøen to the north coast of Nuussuaq and with a downthrow to the north-west. The net vertical displacement is up to 3 km, much of which is uplift in the axial zone of a eastwards-plunging anticline, the Ukalersalik anticline, rather than downthrow. This compressional anticline together with other extensional features around the Itilli fault zone are considered to be evidence in support of the suggestion that the Itilli fault zone is a left-lateral splay formed during major transpression in Late Eocene or Early Oligocene time from the northern extension of the Ungava Fracture Zone (Chalmers et al., 1993; Chalmers et al., 1999b). Furthermore, it is responsible for the outcrop of the Itilli succession in the core of the anticline. On Hareøen (Fig.2.1) the basalt stratigraphy requires a downthrow of more that a kilometre. The Itilli fault zone, with tilting of the basalts north-west of the fault zone, is regarded as a relatively young feature (Chalmers et al., 1999b). No other SW-NE orientated faults have been identified in the Nuussuaq Basin south-east of the Itilli fault.

2.2 Exploration potential

Since 1992 widespread oil seepage and staining have been observed in lavas and hyaloclastites in the lower part of the volcanic succession and in the top of the sedimentary succession on north-western Disko and western Nuussuaq e.g.((Bojesen-Koefoed et al., 1997a; Bojesen-Koefoed et al., 1999)). The discovery of live oil in the Nuussuaq Basin both in outcrops of volcanics over an area of at several hundred km^2 and in volcanics and underlying sediments that were penetrated in several slim core holes proves that the Nuussuaq Basin is a petroliferous basin (Christiansen et al., 1994; Christiansen et al., 1996a; Christiansen et al., 1996b). During field work in 1997 the area of oil seepage and staining was extended to outcropping volcanics on Hareøen, Ubekendt Ejland, Schades Øer and Svartenhuk Halvø and below an unconformity between Upper Cretaceous shallow marine sandstones and Paleocene marine mudstones at Asuk on the northern side of Disko (GEUS, unpublished data) (Fig.2.1 and Fig.2.2). Seepage and staining mainly occur within vesicular lava flow tops, and are often associated with mineral veins in major fractures (Bojesen-Koefoed et al., 1997b), but have also been reported in Paleocene sediments in cores (Christiansen et al., 1996b; Dam, 1996a; Dam, 1996b; Dam, 1996c)).

Chemical analyses of the oil seeps and shows, suggest the existence of several petroleum systems in the Cretaceous and Paleocene fluviodeltaic and marine sediments, including at least five distinct oil types (Bojesen-Koefoed et al., 1999). Biomarkers in some of the oil samples are characteristic of Paleocene deltaic oils, indicating that the source for these oils is in the underlying uppermost Maastrichtian-lower Paleocene sediments. Other surface samples have a more complex origin. Evidence of a deeper source rock has also been obtained on the north side of the Nuussuaq where wet gas was encountered in 1994 in fractured Upper Cretaceous mudstones during drilling for Ni and Pt minerals (Serfat, Fig.2.1). North of Nuussuaq on Svartenhuk Halvø there is evidence of wet gas in the Umiivik-1 well, which indicates the existence of a good but now postmature Cenomanian-Turonian source rock (Dam, 1997). Distribution oil seeps and shows are important for the exploration models in the West Greenland region.

Reservoirs in the Nuussuaq Basin may be either within mid to Upper Cretaceous fluvio-deltaic sandstones or Upper Maastrichtian-Lower Paleocene turbidite sandstones, as have been documented in the GRO#3, GANE#1 and GANT#1 cores (Sønderholm and Dam, 1998; Dam, 1996a) and (Dam and Nøhr-Hansen, 1995; Dam, 1996c). The sandstones are associated with the deep valley incision and subsequent infilling with possible reservoir sandstones found on the south coast of Nuussuaq (Kristensen and Dam, 1997; Sønderholm and Dam, 1998; Dam et al., 1998).

2.3 Offshore the Disko-Nuussuaq-Svartenhuk Halvø area

Offshore the Disko-Nuussuaq-Svartenhuk Halvø area the Paleogene basalts exposed onshore continue offshore where they have been mapped from seismic and magnetic data over the entire shelf area from 68° to 78°N (Whittaker, 1996; Whittaker, 1995; Chalmers et al., 1999b). In the eastern part of the offshore area the basalts are exposed at sea-bed (Fig.2.1), but to the west they become increasingly buried under a cover of Eocene and younger sediments. While the upper surface of the basalts can be mapped easily from the seismic data, the base of the basalts usually cannot be interpreted and there are seldom distinct reflections from the underlying presumed sedimentary formations (Whittaker, 1995). The discovery of live oil onshore Nuussuaq has lead to a much more positive assessment of the offshore area:

1. There are both tilted fault blocks and inversion anticlines that affect the basalts and underlying sediments (Whittaker, 1995) and to some extent also the lower Eocene; some of these structures could provide structural traps.
2. The oil discovered on Nuussuaq is so widespread and includes so many types of oil that more than one effective source rock must occur below the basalts. This could source both sub-basaltic plays and, if the oil has migrated through the basalts, reservoirs in the overlying Eocene. South-west offshore the Nuussuaq area, there is also the possibility that source rocks were deposited in restricted basins above the basalts.

Recent interpretation of seismic data offshore has shown the presence of a closed structure at top basalt level with bright spot features and indicate the presence of hydrocarbon that have migrated through the basalts from deeper source rocks and trapped in the sediments above the basalts (Skaarup et al., 1999).

3. Stratigraphic and tectonic framework

In an area with a complex geological setting it is important to integrate or compile all available information using the same timeframe in order to establish the most consistent numerical basin model. It is of particular importance for basin modelling to date and to estimate the time span of the geological events, and to estimate amount of subsidence and uplift relative to the same reference surface (i.e. the sea level). Therefore, relevant geological information and knowledge on stratigraphy, tectonics and source rock potential, which has been used as input data for the event definition of the Nuussuaq Basin (see Section 6) are summarised in this section.

The description of the geological setting and numerical model concept focus especially on the Nuussuaq Basin in a strictly sense, but incorporates available data and other information from the Svartenhuk Halvø and Disko areas, whenever they are sufficient and relevant.

The structural and sedimentological evolution of the onshore Nuussuaq Basin initiated with rifting of the Greenland-Canada continent probably as early as 138 Ma, and today comprises a succession of Upper Cretaceous - Lower Paleogene sediments. In Early Paleogene time, during North Atlantic break-up, the basin was covered by volcanic rocks of a total of up to 3-5 km. Subsequently uplift and erosion took place in the whole region; parts of the volcanic cover was later removed and in some areas the erosion cut deeply into the underlying sediments.

The onshore Nuussuaq Basin, which is one of the many basin in the Labrador - West Greenland region, is to the east underlain and tectonically bordered by Precambrian quartzo-feldspathic gneiss's and metasediments of Archaean to Mid-Proterozoic age (Henderson and Pulvertaft, 1987) (Fig.2.1). The basement on the western part of Nuussuaq is overlain by a stratigraphic succession which can be divided into four groups:

1. Pre-Volcanic Sedimentation
2. Volcanism
3. Post-volcanic igneous activity and sedimentation
4. Uplift and Erosion

As it is emphasised in the following, the timing of the change from sedimentary dominated deposits (= Pre-Volcanic Sedimentation) to the more volcanic succession (= Volcanism) is not quite clear. Figure 3.1 summarises the latest accepted stratigraphic relation between the Pre-Volcanic Sedimentation and the Volcanic succession, while Figure 3.2 is a new composite geological profile along Vaigat fjord area.

Appendix 1 is a schematic cross-section through all wells and areas with relevant geological information using the same depth reference. Timeframe, stratigraphic framework and tectonic events and other important information combined with a simplified cross-section compiling geological information and stratigraphic relationship for the Nuussuaq Basin and the areas west of Nuussuaq is given in Appendix 2.

3.1 Pre-Volcanic sedimentation

The oldest known sediments in the basin, both onshore and offshore, are of presumed Early Cretaceous age. On Disko and in southern and central Nuussuaq the Cretaceous sediments include fluvial, deltaic, and marine deposits of the Atane Formation (Pedersen and Pulvertaft, 1992). The Atane Formation is dated as Albian?-Cenomanian to latest Santonian on the basis of palynomorphs and rare marine invertebrates (Nøhr-Hansen, 1996). In Central Nuussuaq the Atane Formation is erosively overlain by marine shales of Late Cretaceous age (Nøhr-Hansen, 1994). There is a general tendency for outcrops of the Atane Formation to become younger towards the northwest although the dip directions are mostly to north-east. This requires the presence of faults with downthrow to the west (Chalmers, 1998).

The basin was affected be considerable tectonic movements in latest Cretaceous to earliest Paleogene (Rosenkrantz and Pulvertaft, 1969; Henderson, 1973; Pulvertaft, 1979; Pulvertaft, 1989). Block faulting and tilting due to extension led to a general deepening of the basin in western and north-western Nuussuaq, and to uplift and rejuvenation in the eastern, bounding gneiss terrain which became a mountainous area with considerable relief (*1. E. Maastrichtian Unconformity*, Appendix 2).

The oldest Paleogene sediments are included in the marine Kangilia Formation (Rosenkrantz, 1970). Prior to deposition of the Kangilia Formation a marine transgression took place. At Ataa the Kangilia Formation is erosively cut by the younger coarse fluvial Quikavsak Member which elsewhere has eroded into the Cretaceous Atane Formation. The Kangilia deposits are well exposed on the north coast and in the central part of Nuussuaq and can be followed to the south across Nuussuaq to northern Disko. They are unconformably overlain by shallow marine sandstones referred to the Agatdal Formation on central and northern Nuussuaq and by the Paleocene Quikavsak Member along the south coast of Nuussuaq (Dam and Sønderholm, 1998). In south-eastern Nuussuaq and eastern Disko the sediments overlying the Quikavsak Member appear to be almost entirely non-marine. The sandstones of the Quikavsak Member were deposited in an incised valley system. The incision of the Quikavsak Member valley system followed a tectonic episode associated with major uplift of the Nuussuaq Basin (*2. E. Paleocene Unconformity,* Appendix 2). It is suggested that this tectonic episode reflects the arrival of the North Atlantic mantle plume (Dam et al., 1998). The valley incision was followed by rapid major subsidence associated with extensive volcanism.

Paleocene pre- to syn-volcanic sediments are exposed in eastern Nuussuaq and northern and eastern Disko. The non-marine sediments on Nuussuaq were described as the Upper Atanikerdluk Formation by Koch (1959), whereas the marine sediments on Nuussuaq are referred to the Kangilia and Agatdal Formations (Rosenkrantz, 1970). Faulting at the Cretaceous-Tertiary boundary, erosional unconformities, coarse channellised conglomerates and sand-dominated units in the Kangilia Formation are reported from Ataata Kuua (Pulvertaft and Chalmers, 1990; Dam and Sønderholm, 1998).

The stratigraphic relation between the oldest volcanic rocks of Vaigat Formation (i.e. Tunoqqu Member) and previously established sediment formations and members are not clear (Pedersen et al., 1996)(Fig.3.1). The marine Kangilia and Agatdal Formations are definitely older. The dominantly non-marine Quikavsak Member is overlain by the Tunoqqu Member but is rather unconstrained in time. The Quikavsak Member is interpreted as a fault-controlled incised valley system filled with fluvial and estuarine deposits. The valleys were eventually drowned during a phase of rapid rise in relative sea level (Dam and Sønderholm, 1998).

In latest Maastrichtian-Early Paleocene time the Nuussuaq Basin was subjected to two, possibly three extensional tectonic episodes, each followed by uplift (*1. E. Maastrichtian Unconformity and 2. E. Paleocene Unconformity*, Appendix 2). Each episode may have lead to rifting and sea-floor spreading (Christiansen et al., 1995). In areas along the south coast more than 1000 m sediments is missing, possible due to uplift and erosion (Dam, Pers.comm, 1998). Fault displacements of several hundred meters have been recorded from each of these episodes, resulting in a pronounced structural relief. The uplift periods were associated with a sudden fall in base-level and incision of two major valley systems on the south-coast of Nuussuaq (Dam and Sønderholm, 1998). Most of the palaeovalleys are associated with and are cross-cutting the faults, suggesting that the faults were controlling not only the establishment but also the trend of the valleys. All the valleys were filled in response to rising base levels, and thus belong to the transgressive systems tract. Filling of the uppermost valley system was characterised by a balance between a rapidly rising base-level, high river discharge and high sedimentation rates (Dam and Sønderholm, 1998). This led to extremely uniform facies successions of the valley fills which constitute the Quikavsak Member. The sea-level rise during this transgressional phase was in the order of 800 m.

The transgressional phase which constituted the Quikavsak Member was followed by extrusion of voluminous of the oldest volcanic rocks, the Vaigat Formation, which formed up to 1000-1500 m thick hyaloclastite deposits in a marine basin. The dramatic sea-level rise and the formation of the volcanic rocks probably had a common cause in a major extensional episode (*Late Rift B (Chron 33-24r),* Appendix 2) leading to crustal thinning and sagging, and to mantle upwelling with subsequent decompressional melting. The extension is related to the onset of sea-floor spreading in the Labrador Sea-Baffin Bay region (Dam et al., 1998).

The overlying Naujât Member (Koch, 1959) consists of dark grey to black shales which were deposited in relatively deep water. The shales overlie an erosion surface (*1. E. Maastrichtian Unconformity and 2. E. Paleocene Unconformity*, Appendix 2) which truncates either the Atane Formation or the Quikavsak Member. The non-marine (lacustrine) origin of the Naujât Member is inferred from the lack of dinoflagellate cysts, the scarcity or absence of pyrite in the sediment and low sulphur values (Piasecki et al., 1992). Recent studies (Boserup and Christiansen, 1998) indicate that the Naujât Member post-dates the Tunoqqu Member and is coeval with the Ordlingassoq Member volcanic rocks (Appendix 2) (Pedersen et al., 1998).

Lacustrine sediments (high TOC, low sulphur, lack of pyrite and absence of dinoflagellates) are found above the Tunoqqu Member and rest on an erosional unconformity only seen in the south-east (Appendix 2). The Naajaat lake and the younger and larger Assoq lake was formed contemporaneous with parts of the Rinks Dal Member of the Maligât Formation and constitutes a major onlapping complex of lakes systems. The best described Naajaat lake was up to 400 m deep and was formed within 0.5-1 million years and covered up to 2500 m^2 (Pedersen et al., 1998). According to Pedersen et al., (1998), four rises in relative lake level were partly due to loading by the volcanic pile. Variations in the rate of subsidence is indicated by marker horizons, the Tunoqqu Member, within the subaerial lava series. The formation of the Naajaat lake was caused by damming (Pedersen et al., 1996). This is further sustained by the a missing link to eustatic changes in sea level; the Naajaat lake phase drowned the Quikavsak Member, and while hyaloclastite breccias of the Ordlingassoq Member were infilled from the west and north-west the black shales of the Naujât Member were deposited in eastern Nuussuaq. The Naujât Member constitutes and upward coarsening sequence which passes up into the Umiussat Member (Pedersen et al., 1998).

The body of water, i.e. the Naajaat lake, within which the Ordlingassoq Member hyaloclastite breccias accumulated was the same as the one in which the sedimentary Naujât Member and Umiussat Member were deposited (Pedersen et al., 1998). The Naajaat lake was deepest close to the volcanic shoreline, the depocentre moved eastwards through time and the area covered by the lake diminished during its late stages. Five rises in relative lake level are recognised ceasing to rise as eruption of the volcanics stopped indicating lake-damming. Rising relative lake level generated accommodation space in fluvial depositional systems where sand-sized sediments was stored.

3.1.1 Itilli Succession

The Itilli succession (Fig.2.1), located in the Itilli valley, is a more than 2500 m thick apron slope succession of which the uppermost 100 m and the lowermost 1500 m is exposed (Dam and Sønderholm, 1994).

The uppermost 100 m of ?Late Maastrichtian - Early Paleocene age (Nøhr-Hansen, 1993) immediately underlie Paleocene hyaloclastites. The age of the lower part of the succession is somewhat uncertain, as the palynomorphs are degraded due to deep burial depth followed by inversion and hydrothermal activity along the Itilli Fault Zone. Nøhr-Hansen (Nøhr-Hansen, 1996) suggest a Campanian - Maastrichtian age. Sediments equivalent to the deeper part of the Atane Formation were penetrated below 960 m in the GRO#3 well and are well exposed on the south-east side of the Itilli valley. These sediments were previously referred to as the Itilli succession (Dam and Sønderholm, 1994). The oldest sediments in this succession are ?pre-Coniacian (Nøhr-Hansen, Pers.comm., 1998) and suggest that the Itilli succession covers most of the Late Cretaceous in age.

The Itilli succession consists of mudstone, thinly interbedded sandstone and mudstone, chaotic beds, amalgamated sandstone, and giant-scale cross-bedded sandstone deposited in a slope apron environment (Dam and Sønderholm, 1994). The amalgamated and giant-scale cross-bedded sandstones were deposited in 1-2 km wide slope channels draining basin-margin source areas. The mudstone and thinly interbedded sandstone and mudstone deposits occur in intervals up to 225 m thick. No systematic vertical variation in sandstone content and bed thickness occur. The chaotic beds are 7-30 m thick and invariably underlie undisturbed channel fill sandstones suggesting that initially channels were excavated largely by retrogressive slumping of unstable slope mudstones.

The turbidite channel sandstone rest on an eroded surface and consists of amalgamated sandstone beds that occur in successions up to 50 m thick. Generally, the turbidite channel deposits show an overall fining-upward trend. The most coarse-grained turbidite sandstones occur at the base of the exposed succession in the Itilli valley (Dam and Sønderholm, 1994).

Sequence stratigraphic concepts have been applied to the Itilli slope succession (Dam and Sønderholm, 1994). The chaotic beds are related to the forced regressive wedge systems tract. The sequence boundary is placed at the erosional unconformity separating the chaotic beds from the overlying channel sandstone turbidites and it represents the lowest point of relative sea-level fall. The channel fill represents the lowstand prograding wedge systems tract and the transgressive systems tract. Poorly developed highstand systems tract deposits include thinly interbedded sandstones and mudstones and are probably also represented in the redeposited material in the chaotic beds (Dam and Sønderholm, 1994).

3.1.2 Age and duration of the Pre-Volcanic Sedimentation

Recent detailed interpretation of the palynological record in GANE#1, GANK#1, GANT#1 (Nøhr-Hansen, 1997a) and in GRO#3 (Nøhr-Hansen, 1997b) has further constrained dating of the pre-volcanic sedimentary succession. GANE#1 and GANK#1 sediments can now be dated as Selandian to ?Early Thanetian, Late Paleocene. GANT#1 is dated as Campanian (Late Cretaceous) to Danian (Early Paleocene) and the Cretaceous/Tertiary boundary is supposed to occur just below 133 m. At Annertuneq on the north coast of Nuussuaq the Cretaceous/Tertiary boundary occur at 452 m.a.s.l. (Nøhr-Hansen and Dam, 1997) (Appendix 1 and 4). These new interpretations has made correlation possible of the Upper Cretaceous deposits from central Nuussuaq to northern Nuussuaq and Svartenhuk Halvø (Nøhr-Hansen, 1997c) and to offshore areas (Nøhr-Hansen, 1998). In the GANW#1 well the dated samples has been redefined to Selandian, Early Paleocene (Nøhr-Hansen, 1997a).(Christiansen et al., 1995)

3.2 Volcanism

The central West Greenland Paleogene volcanic province extends from Disko Island in the south to Svartenhuk Halvø in the north and covers an area of approx. 45.000 km^2 (Fig. 2.1). Flood basalt flows cover a much greater area offshore, extending from 68°N to 73°N (Escher and Pulvertaft, 1995). The total stratigraphic thickness of the exposed Paleogene extrusive sequence is more than 2 km on Nuussuaq, about 3 km on Disko and probably around 5 km on Ubekendt Ejland and Svartenhuk Halvø (Hald and Pedersen, 1975).

The volcanic province on Disko and Nuussuaq are divided into two formations (Fig.3.3 and Appendix 2):

1. the older Vaigat Formation consists mainly of primitive, olivine-rich rocks (Pedersen et al., 1996)
2. the younger Maligât Formation consists mainly of feldspar-phyric plateau basalts (Hald and Pedersen, 1975; Hald, 1977; Larsen and Pedersen, 1992a)

The Vaigat Formation is the lower part of the West Greenland plateau lava succession and consists predominantly of picrites and olivine-phyric basalts (Larsen et al., 1992b; Pedersen et al., 1993). These occur as both subaerial flows and subaqueous volcanic breccias, with interbedded partly marine sediments. There is an abrupt compositional change up through the succession to feldspar-phyric tholeiitic basalts. This boundary defines the base of the Maligât Formation. The upper parts of Maligât Formation were all erupted subaerially and consist of massive basalt flows. Over most of the area the plateau basalts dip 5° in different directions. However, in northwest Disko and northwest Nuussuaq and on Ubekendt Island much steeper dips occur, mainly to the northwest and west.

3.2.1 Vaigat Formation

The early phases of the Paleogene volcanism in the West Greenland Basin are represented by the Vaigat Formation. This formation records a complicated interplay between volcanic pile and sedimentary basin through more than 3 million years e.g. (Piasecki et al., 1992). The lithostratigraphy of the Vaigat Formation on Disko (Pedersen, 1985) and Nuussuaq (Pedersen et al., 1993) is based on a number of lithologically and chemically distinct marker units of contaminated volcanic rocks. On Disko and Nuussuaq an area of more than 10.000 km^2 of the Vaigat Formation is well exposed. The most widespread marker horizon is present over large areas of Nuussuaq and is formalised as the Tunoqqu Member (Pedersen et al., 1996).

Studies have shown that the basin was at least periodically marine; it covered large parts of western and central Nuussuaq and parts of northern Disko. The basin was delimited towards the east and south by large faulted blocks of Cretaceous clastic sediments. Individual foresets can be traced from subaerial lava flows to the bottom of the basin (Pedersen et al., 1993), and the hyaloclastite fans may be compared to Gilbert deltas. The height of the foresets indicate water depths of up to 700 m (Pedersen et al., 1993).

The volcanism of the Vaigat Formation started from eruption centres in north-western and western part of the Nuussuaq Basin. Subaqueous mounds of pillow breccia and hyaloclastite and sequences of thin subaerial lava flows were deposited. The lavas flowed eastwards into a 700-800 m deep water-filled basin, presumably of tectonic origin, where they formed huge eastwards-prograding hyaloclastite fans. With time, the active eruption centres migrated eastwards, and eventually the water-filled basin was filled up (Pedersen et al., 1996). The volcanism occurred in three separate cycles each of which started with olivine-rich primitive magmas and ended with more evolved, often contaminated magmas. These three cycles are represented by three main units (Pedersen, 1985; Chalmers et al., 1999a; Pedersen et al., 1993; Pedersen et al., 1996):

1. **Anaanaa Member**, (informal) comprises the oldest known Paleogene volcanic rocks in West Greenland. It is only known from a limited area in western Nuussuaq (Fig.3.4). The total thickness is more than 1000 m to the west, decreasing ?abruptly to 0 m towards the eastern part of Nuussuaq and Disko area. The rocks comprises picrites, olivine-rich basalts, feldspar-phyric basalts, and siliceous contaminated basalts.
2. **Naujánguit Member,** comprises picrites and olivine-rich basalts, whereas the associated minor members mainly consist of siliceous contaminated basalts and andesites with subordinate feldspar-phyric basalts. During the Naujánguit Member cycle the volcanic rocks prograted considerable towards the east on both Disko and Nuussuaq and filled in the marine basin (Fig.3.4). The total thickness is more than 1000 m to the west, decreasing ?abruptly to 0 m towards the eastern part of Nuussuaq and Disko area. The Tunoqqu Member formed at the end of this volcanic cycle.
3. **Ordlingassoq Member** is the most widespread of the three main units. The rocks comprise almost exclusively picrites and olivine-rich basalts. During this cycle the volcanic migration eastwards continued and large parts of the gneiss terrain were

onlapped by volcanic rocks (Fig.3.4). The total thickness is more than 2000 m over most of the Nuussuaq and Disko area. The previous developed Tunoqqu lave flow plain was flooded by a several hundred meters deep water-filled basin. The nearly total absence of dinoflagellate cysts in sediments within the Ordlingassoq Member volcanics indicates that the water-filled basin during the second stage was almost entirely non-marine (Piasecki et al., 1992). The cycle is therefore probably contemporaneous with parts of the sedimentary Naujât and Umiussat Members in north-eastern Disko area (Pedersen et al., 1996).

In (1996) Pedersen et al. combined volcanology, geochemistry, sedimentology, and multi-model photogrammetry and presented a new geological analysis of the West Greenland Basin within the narrow time window represented by a 50-300 m thick marker horizon, the Tunoqqu Member (Fig.3.1). They demonstrated that this member with its huge conglomerate formed a critical stage of the development during which a large marine embayment was cut off by the advancing volcanic front and subsequently developed into a fresh-water lake (Pedersen et al., 1996).

Pedersen et al., (1996) interpret the Tunoqqu Member conglomerate as being caused by a simple damming effect. The eastward-prograding volcanic rocks gradually obliterated the marine embayment in central Nuussuaq, but north-flowing water courses in the eastern Disko Bugt region would still exist. Because of the damming the water table rose, and the increased gradient between the enclosed basin and the sea to the north generated a outlet torrent between the volcanic front and the gneiss promontory.

Detailed structural analysis by photogrammetry in well-exposed areas has shown that there is a connection between the position of the eruption centers, the configuration of fault blocks, and the location of zones with subtle syn-volcanic movements (Fig.3.4) (Pedersen et al., 1996). Less contaminated lava could have been erupted from fissures outside the centers. All the known eruption sites were situated in tectonically active zones, and it is probable that magmas were channeled towards the surface and developed magma chambers along pre-existing, deep faults (Pedersen et al., 1996).

3.2.2 Maligât Formation

The upper volcanic formation, the Maligât Formation, consists mostly of thick, massive lava flows geochemically different from the lavas of the underlying Vaigat Formation. The Maligât Formation is thickest (up to 2000 m) in central and western Disko where many eruption sites were probably situated (Piasecki et al., 1992; Larsen and Pedersen, 1992a) (Storey et al., 1998). The Maligât Formation was erupted into a existing water-filled basin, which was bounded to the west by the Disko Gneiss Ridge, to the north by the old lava shield of the Vaigat Formation, to the east by a low-lying fluvial plain (Fig.3.3). The extension to the south is uncertain (Piasecki et al., 1992).

On Nuussuaq the Maligât Formation is only known from mountain peaks in excess of 1700 m.a.s.l., and especially on the south coast (Fig.3.3).

On Disko, it has been informally divided into three members (Pedersen, 1975). During the formation of the lower part of the south-east dipping Rinks Dal Member the water-filled basin was filled in from the west and north-west by volcanic products, and by shales and sandstones from the east and south-east. Volcanic and sedimentary rocks are intercalated (Fig.3.1 and Fig.3.2). The Rinks Dal Member consists of up to 1500 m thick subaqueous lavas which often invaded the contemporary sediments to form sills. A following 'pahoehoe unit' of hyaloclastite breccias and thin subaerial pahoehoe lavas made the infilling of the basin nearly complete. The lavas of the following unit, the 'FeTi unit', invaded shale of the Aussivik Member of the Upper Atanikerdluk Formation (Larsen and Pedersen, 1990). The younger lavas, from the upper part of Rinks Dal Member and the Nordfjord and Niaqussat Members, are all subaerial and flowed far to the east; they covered the old fluvial plain and eventually lapped onto the high crystalline basement in eastern Nuussuaq (Larsen and Pedersen, 1992a; Pedersen and Larsen, 1987; Storey et al., 1998).

3.2.3 Age and duration of Volcanic succession

Koch (1959) suggested that parts of the Paleogene non-marine sedimentary succession in the east were contemporaneous with volcanic rocks in the west, and that progradation of volcanic hyaloclastite breccias into a water-covered basin affected the sedimentary facies evolution. Pedersen (1989) likewise suggested that the advancing hyaloclastite fronts caused rapid increase in water depths and changed fluvial plains into deep lakes. Pedersen et al. (1993) presented a photogrammetrically measured 80 km long vertical section along the south coast of Nuussuaq. Recently (Chalmers et al., 1999b), this section has been integrated together with information from wells, seismic and gravity data to a more complete geological profile along the Vaigat fjord area (Fig.3.2):

1. the eastward younging of the volcanic rocks with time,
2. the eastward progradation of hyaloclastite breccia fans into the water-covered basin
3. the variations in water depth with time
4. the tilting towards the east-south-east of both the Vaigat and Maligât Formations

The microfossil assemblages in the intercalated sediments have been used biostratigraphically to estimate the time of onset and the duration of volcanism (Larsen et al., 1992b; Piasecki et al., 1992). Those associated with the oldest known volcanic rocks were thought to belong to nannoplankton zone NP3 (63.8-62.2 Ma). The dinoflagellate assemblage in the Naujánguit Member was considered equivalent to uppermost NP4 and NP5 (~57.5-61.0 Ma) (Piasecki et al., 1992). Higher in the sequence, the dinoflagellate assemblage in the Rinks Dal Member of the Maligât Formation was correlated to NP zones 7-8 (56.2-57.5 Ma) (Piasecki et al., 1992).

Palaeomagnetic investigations of volcanic rocks (lava flows) from lower part of the Vaigat Formation (Riisager and Abrahamsen, 1997) has been carried out at western Nuussuaq and northern Disko. The lava flows were erupted around the polarity change N27-R26. Furthermore, the palaeomagnetic studies provide complete coverage of the Vaigat Formation and Maligât Formation as high as the Rinks Dal Member The measured part of the succession is reversely magnetised with the exception of the lowest part of the Vaigat Formation (= Anaanaa Member) which is normally magnetised. Furthermore, there seems to be a difference of 300 m of the Anaanaa Member between the south coast of Nuussuaq and the north coast of Disko, indicating the presence of a fault along Vaigat. The combination of biostratigraphy and palaeomagnetic information, indicated a minimum duration for the Paleocene main plateau building volcanic phase in West Greenland of ~6 my (Larsen et al., 1992b).

Radiometric age determinations of the Paleocene volcanics was until recently few. A new and more precise picture of the Paleogene volcanic history of West Greenland emerges from a $^{40}Ar/^{39}Ar$ dating study (Storey et al., 1998). Revealed are a series of separate magmatic events ranging in age from Early Paleocene to Late Oligocene. The data significantly revise previous estimates for the duration, and hence eruption rates, of the Paleocene flood basalts of West Greenland and show that they now belong to a group of other short-duration flood basalt events such as the Deccan Traps (Storey et al., 1998; Baksi, 1994). Storey et al. (1998) concluded that the flood basalt volcanism began between 60.9-61.3 Ma

(≈ Chron 27n), which is consistent with the most recent timescale for Paleocene (Berggren et al., 1995). According to Storey et al. (1998) eruption of the Vaigat Formation and the lower and middle part of Maligât Formation occurred in 1 million years or less. The slightly younger age (59.4 ±0.5 Ma) given by samples from the uppermost part of the Maligât Formation, east of the Itilli fault, implies a total duration for the Paleocene volcanism in West Greenland of only 1-2 million years (Storey et al., 1998). Furthermore, Storey et al., (1998) stated that there were two separate occurrences of basaltic volcanism in West Greenland during the Paleogene, distinct in terms of both age and composition. The extrusion of the tholeiitic Paleocene flood (*1. West Greenland Basalts*, Appendix 2) basalts was followed, after a hiatus of ~6 my, by a period of large-scale basaltic volcanic activity of Early Eocene age, with compositions ranging from ferro-tholeiitic through to transitional (*2. West Greenland Basalts*, Appendix 2).

3.3 Post-volcanic igneous activity and sedimentation

In addition to Paleocene volcanics rocks, the West Greenland province comprises younger lavas and intrusive rocks of Eocene age. This second Early Eocene magmatic episode (*2. West Greenland Basalts*, Appendix 2) comprises:

1. N-S and NW-SE dike swarms on Disko
2. a sill and dike system on Nuussuaq
3. a 2000 m thick lava succession, restricted to areas west of the NW-SE trending Itilli fault (i.e. the Kanísut Member of the Maligât Formation).
4. a more than 300 m thick lava succession, restricted to areas west of the NW-SE trending Itilli fault (i.e. the Hareøen Formation).

On Nuussuaq, west of the Itilli fault (Appendix 2), Maligât Formation lavas are overlain by the Nûluk Member, the Ifsorisok Member and the Kanísut Member. The Nûluk Member (not dated) is composed of tholeiitic basalts more that 750 m thick and overlain by a sequence of clastic sediments more than 200 m thick, consisting of debris flows with angular basaltic clasts up to 0.5 m (Hald, 1976). These sediments, the Ifsorisok Member, consist of sandstones, shales, tuffs and coal. Volcanic activity resumed with the eruption of more than 2000 m of basalts and occasional comendite tuffs, the Kanísut Member (Hald, 1976). The basalts are of transitional chemical character and are therefore geochemically distinct from the older tholeiitic lavas of the Maligât Formation. A sample from a comendite tuff gave a plateau age of 52.5 ±0.2 Ma indicating major igneous activity in West Greenland during the Early Eocene.

The volcanics exposed on Hareøen include the youngest lava flows known in the region and new interpretation suggests that the associated lacustrine sediments are distinctly different from those known from Disko and Nuussuaq, and that they may be of Late Miocene age (Hjortkjær, Pers.comm., 1998) (Appendix 2).

It is probable that the Eocene succession also comprises lava on both Ubekendt Ejland and Svartenhuk Halvø, as well as lavas on the continental shelf (Whittaker, 1995).

A generation a N-S to NW-SE trending dykes of Fe-Ti rich tholeiitic basalt composition can be followed throughout the Disko. The dykes post-date all the lavas on Disko. Dykes and sills are also prominent on eastern Nuussuaq along the major boundary faults between the sedimentary basin and the Precambrian gneisses (Fig.3.2) (Pulvertaft, 1989).

A swarm of NNW-trending lamprophyre dykes cuts the youngest volcanic rocks on Ubekendt Ejland. Previous $^{40}Ar/^{39}Ar$ isochron age determination ranges between 30.6 ±5.0 Ma and 39.5 ±9.6 Ma. New $^{40}Ar/^{39}Ar$ ages give a plateau age of 34.1 ±0.2 Ma indicating that the swarm is latest Eocene in age (Storey et al., 1998).

A group of small skerries at Avatarpaat, 2 km offshore from western Disko, consist of alkali basalt and are believed to be the remnant of a volcanic neck. $^{40}Ar/^{39}Ar$ age determination of 27.4 ±0.6 Ma (late Oligocene) implies than the Avatarpaat neck is the youngest dated igneous feature in West Greenland (Storey et al., 1998).

Two noteworthy features of the West Greenland Early Eocene igneous activity (*2. West Greenland Basalts*, Appendix 2) are:

1. the lavas lie close to the Itilli fault, which is a northwards extension of the major transform zone, the Ungava Fracture Zone, which links the Baffin Bay oceanic basin to the Labrador Sea in the south. A transpressional regime existed along this transform during the Late Paleocene to Early Eocene (Chalmers and Laursen-Kirsten-Holt, 1995; Whittaker, 1996) (*Syn-Rift C*, Appendix 2).
2. the present data show an age range for the magmatism of between 54.8 ±0.4 Ma to 52.5 ±0.2 Ma. The oldest coincides with the opening of the North Atlantic during magnetochron 24r and during deposition of NP9 (Soper et al., 1976)

and with the peak in flood basalt activity on the East Greenland margin at around 55-56 Ma (Mathiesen et al., 1995) (*East Greenland Basalts*, Appendix 2)

A possible explanation for the Early Eocene magmatism is that a regional change in plate kinematics at ~55 Ma, due to the opening of the North Atlantic, produced a transtensional regime along the Itilli extension of the Ungava Fault, allowing it to behave essentially like a leaky fault zone (Storey et al., 1998).

3.4 Uplift and erosion

In Early Paleocene, after the Nuussuaq Basin was covered by volcanic rocks, uplift and erosion affected the whole region; parts of the volcanic cover was removed and in various areas the erosion cut deeply into the underlying sediments (Fig. 2.1 and Fig.3.3). Little is however, known on the magnitude and timing of uplift and erosion.

Onshore, evidence of uplift is substantiated by numerous field observations. As mentioned earlier at least two phases of uplift in the Maastrichtian and Paleocene were associated with deep valley incision and subsequent infilling with possible reservoir sandstones (Kristensen and Dam, 1997; Dam et al., 1998). Furthermore, the Late Cretaceous to Early Paleogene deltaic sediments are overlain by a thick succession of Paleocene basalts which consists of hyaloclastite breccias and pillow laves that build up large, delta-like structures up to 700 m thick which wedge or progradate towards the east and south-east (Pedersen et al., 1993; Pedersen et al., 1996). These basaltic lavas were extruded at or very close to base level where they subsequently flowed into a body of water, either marine or a lake, and chilled to form breccias and pillows which tumbled down into the water body. Today the upper surface of these breccias are at an elevation of more than 1000 m (Pedersen et al., 1993), indicating uplift of at least a similar amount. By implication the underlying deltaic sediments have experienced the same degree of uplift. This amount of uplift is supported at position 75 km on the geological profile along the south coast (Pedersen et al., 1993) near Atanikerdluk where an Early Paleocene marine mudstone has been found 1000 m.a.s.l.

A recent study uses zeolite minerals as a help to predict the palaeothickness of the now partly eroded Paleogene flood basalts around the Marraat-1 well. Assuming a constant geothermal gradient of 30°C/km and based on the compiled/composite position of zeolite zone boundaries it can be calculated that the eroded thickness of rocks above the Marraat area equals ~1450 m (Stannius, 1998)(see also Section 3.5).

Interpretation of GRO#3 vitrinite reflectance data, indicates that the thickness of the "missing", presumably mainly volcanic, succession can be estimated to ~1890 m (Bojesen-Koefoed et al., 1997a). This corresponds fairly well to the maximum height of the mountains in the hinterlands (Fig.3.2) and gives important constraints on the magnitude of uplift and erosion of the area.

Offshore, uplift has been identified on seismic data and is associated with the Ungava Fault Zone (Fig.2.1). This major NNE trending zone of strike-slip faulting extends from an area west of the offshore well Ikermiut-1 to the north-western tip of the Nuussuaq where a splay is represented by the Itilli Fault (Fig.2.1). Transpressional movements along this fault system, most probably during the Eocene, has deformed Cretaceous and Lower Paleogene sediments into very large flower structures in the area west of the Ikermiut-1 well (Chalmers et al., 1993). This deformation probably raised overpressured rocks or potential source rocks developed at greater depths to shallower levels in the crust; and may be connected with the offshore mid-Eocene unconformity (*3. mid-Eocene Unconformity*, Appendix 2).

3.5 Other information

Interpretation of zeolite zones is a useful tool to interpret the basin development. Because of the temperature sensitivity the zeolite zones are useful indicators of the thermal and lithological structure of the upper crust (Kristmannsdottir and Tomasson, 1976; Walker, 1960). The zeolite zones may give indication on palaeothickness of the now partly eroded Paleogene volcanics and makes it possible to interpret the geothermal gradient in volcanics at the time when the zeolite zones were established.

A recent zeolite study in the Marraat area concludes that the zeolite zones were established about 1 my after the eruption of the lower Vaigat Formation, the Anaanaa Member (Stannius, 1998). It has furthermore been documented that the zeolite zones are different east and west of the Itilli fault system, there are no indications of different hydrothermal temperatures in the rocks at the time of establishment and that there are no zeolite zones in the Eocene rocks west of Itilli (Stannius, 1998). The zeolite zones are most likely a product of local heating of the rocks, where the local heat source in the area west of Itilli fault zone would produce a higher temperature zone. There is however no evidence of such a local heat source, and other thermal indicators (e.g. maturity indicators, dike frequency etc.)

show no indication of this local source. Stannius (1998) concludes that the zeolite zones around the Itilli fault zone indicates that they were established after the tectonic movement of the rocks on both sides of the Itilli fault zone. Therefore, the zeolitization east and west of the Itilli fault zone must have been more than one event.

It is also possible to predict the palaeotemperature in the rocks when the zeolite zones were established. The presence of chabazite from the top to the bottom of the Marraat-1 core indicates a maximum temperature of 75°C (Stannius, 1998). Fluid inclusions in the zeolites are of poor quality, but the fluid inclusions in calcite are excellent and show the same temperature range as the zeolite zones, homogenisation temperature raging from 80°C to 122°C.

The main factor controlling the zeolite zones is the geothermal gradient present in the area. The geothermal gradient controls the presence of zeolite minerals and position of the zone boundaries. The problem in the Nuussuaq Basin is that no zeolite zone is seen bounded by another zeolite zone neither on the top or on the bottom. Mapping of zeolite zones on Disko, in the Nuussuaq area and on Hareøen indicates that most of the exposed laves experienced regional low-grade metamorphism (< 100°C) in response to geothermal gradients ~30°C/km. In the area west of the Itilli fault zone these lavas were altered at significant higher temperatures (~100°C) and tilted westward after regional metamorphism ((Stannius, 1998) and Stannius, Pers.comm, 1998). Assuming a constant geothermal gradient of 30°C/km and based on the composite position of zeolite zone boundaries it can be calculated that the eroded thickness of rocks above the Marraat area equals ~1450 m (Stannius, 1998).

Hydrocarbons are observed in hyaloclastites and lavas in the lower part of the volcanic succession in the Marraat area. In the Marraat-1 core that hydrocarbons are present as solid bitumen or liquid oil, where the oil belong to the *"Marraat type"* (see Section 4). Oil migration is later than the zeolitization. The solid bitumen is seen as both an early and a late phase in the Marraat-1 core. The liquid is observed to be the latest phase filling the empty or not totally filled vesicles and veins. At least two different oil migrations have occurred separated in time (Stannius, 1998).

4. Exploration potential and thermal maturity

Systematic studies in West Greenland since the early 90'ties (Christiansen, 1993; Christiansen et al., 1992; Christiansen et al., 1994; Christiansen et al., 1995; Christiansen et al., 1996; Christiansen et al., 1997; Christiansen et al., 1999) have given a considerable knowledge on the organic richness and composition of the sediments from the Disko–Nuussuaq–Svartenhuk Halvø region (Fig.2.2). Based on a large number of analytical results that have been partly integrated with sedimentological and biostratigraphical studies from the region several source rock intervals can be predicted.

As part of the present EFP project all available screening source rock data from the region have been presented in the enclosed data report by (Boserup and Christiansen, 1998) (This Volume). The analysed samples have a variety of origins but most of them are from outcrop studies in the 90'ties and drilling in 1992, 1994, 1995 and 1996 (see Table 4.1).

The sediments have been extensively studied by a combination of LECO and Rock Eval pyrolysis (more than 1500 in total) followed by more detailed analysis on a much more limited number of samples (extraction, GC and GCMS, n > 150, and in some cases vitrinite reflectance, n > 150). Most of the analytical data from cores and cuttings have been reported in quite some detail (see Table 4.1) whereas the data from the outcrop studies mainly have been used in published papers. Appendix 4 includes the most relevant analytical data used for basin modelling.

In addition to the studies of the sediments, a considerable knowledge on source rock distribution and geochemistry have been obtained indirectly from detailed studies of oil seeps and oil impregnated cores (Fig.2.2). These oils have mainly been studied by GC and GCMS (more than 150 samples in total). The main conclusions and key examples of data from the seep studies have been published by Christiansen et al. (1996b) and (Bojesen-Koefoed et al., 1997a). Most of the analytical results from the seep studies (analyses prior to the spring of 1997) have been reported by (Bojesen-Koefoed et al., 1997b), whereas the most recent analyses are yet to be reported.

Table 4.1. Origin of samples for analysis of source rocks and oils in West Greenland

<u>Studies and sampling of outcropping sediments</u>

- Field work in 70'ties and 80'es (EJS, JMH, CAC, GKP, CP, HM, TO)
- Field work in 1990 (FGC, MS)
- Field work in 1991 (FGC, GD, DJM, HNH, GKP, MS)
- Field work in 1992 (FGC, GD, HNH, GKP, MS)
- Field work in 1993 (FGC)
- Field work in 1994 (FGC)
- Field work in 1996 (GKP)
- Field work in 1997 (FGC, GD, IN, GKP)
- Field work in 1998 (work still in progress, GD, HNH, GKP, BFH)

<u>Cores and cuttings from penetrated sediments</u>

- Shallow core drilling (400701-400712) by GGU in 1992; data reported by Christiansen et al. (1994)
- GANW#1 by grønArctic in 1994; data reported by Christiansen et al. (1995)
- Falconbridge mineral holes in 1994; some data reported by Dam & Nøhr-Hansen (1995)
- GANE#1, GANT#1 and GANK#1 by grønArctic in 1995; data reported by Christiansen et al. (1996)
- Umiivik-1 by grønArctic for GEUS in 1995; data reported by Christiansen et al. 1997
- GRO#3 by grønArctic in 1996; data reported by Bojesen-Koefoed et al. 1997

<u>Studies and sampling of oil seeps and oil impregnated cores</u>

- Field work in 1992 (FGC)
- Field work in 1993 (FGC, AKP)
- Field work in 1994 (FGC, AKP, LML, JKM, LSS)
- Field work in 1995 (KB, CD)
- Field work in 1996 (FGC, AKP, AB); data reported together with previous results by Bojesen-Koefoed et al. (1997)
- Field work in 1997 (FGC, AKP, AB)
- Field work in 1998 (work still in progress, AB, AKP)
- Marraat-1 core by GGU in 1993; data reported by Christiansen et al. (1994)
- GANW#1 by grønArctic in 1994; data reported by Christiansen et al. (1995)

Initials of collectors: AB: Anders Boesen, KB: Kevin Bate, FGC: Flemming G. Christiansen, CAC: Cathy Croxton, CD: Carsten Dahl, GD: Gregers Dam, LML: Lotte Melchior Larsen, JKM: Jens Konnerup Madsen, DJM: David McIntyre, IN: Inger Nielsen, HNH:Henrik Nøhr-Hansen, AKP: Asger Ken Pedersen, TO: Torben Olsen, GKP: Gunver Krarup Pedersen, CP: Chris Pulvertaft, EJS E.J. Schiener, LSS: Lotte S. Stannius, MS: Martin Sønderholm

4.1 Exploration history and potential source rocks

Evidence of migrated hydrocarbons (thermally altered) was originality reported by Pedersen (1986), but the first fresh oil samples that allowed reliable organic geochemical results were collected in August 1992 along the coast at Marraat on western Nuussuaq (Christiansen, 1993). In 1993 oil impregnation in the volcanics was also confirmed in a thick zone in the Marraat-1 drill hole (Christiansen et al., 1994; Christiansen et al., 1996a). During drilling of GANW#1, GANE#1 and GANK#1 by grønArctic in 1994 and 1995 more oil was discovered, both in cores of volcanic rocks and underlying sediments and at the surface in the vicinity of the drill sites (Christiansen et al., 1995; Christiansen et al., 1996). For the first time more than one oil type was recognised on Nuussuaq (Christiansen et al., 1996b).

In the summer of 1996 the GRO#3 well was drilled on western Nuussuaq as the first deep exploration well in the West Greenland onshore region (Bojesen-Koefoed et al., 1997a). Information from this ~3 km deep well is therefore very import for the assessment of the exploration potential of the Nuussuaq basin and provides the best information so far on the thermal maturity gradient and for prediction of location of oil window and base of the oil preservation zone (see Section 4.2). Previous studies have given some information on maturity gradients, but data have been restricted to samples from outcrop sections less than 500 m in height and with the thickest recorded continuous succession being the GANT#1 core (900 m of core).

Recognition of oil staining and seepage in the volcanic succession overlying the Nuussuaq Basin and new surface shows of oil found during 1996 and 1997 demonstrated that oil impregnation and seepage is much more widespread in West Greenland than previously known (Bojesen-Koefoed et al., 1997a). Evidence of oil at the surface is now known throughout the onshore region from the northern Disko across Nuussuaq, several islands to the north, to the southern part of Svartenhuk Halvø, primarily along the coast of Vaigat and Maligât (Fig.4.1). Furthermore, staining has been found in a 25 km wide zone on the northwestern Disko, from immediately east of the Kuugannguaq valley to Serfarsuit (Fig.4.1). It has not been possible, so far, to recognize seepage or staining on central or southern Disko. Most examples are from volcanic rocks overlying the marine sedimentary successions; however, in 1997 oil-impregnated sandstones were also reported from the mid-Cretaceous non-marine Atane Formation on the north coast of Disko (Christiansen et al., 1999). The two largest near-surface accumulations that contain significant volumes of oil are:

- *Marraat area*: 6x4 km, oil zone several hundred meters thick, porous zones (10-15% porosity) in vesicular lava tops with an average thickness of 15 m, saturation close to 100%. Conservative calculations suggest a cumulative volume of at least 250 mill. barrels, but much more may be found in underlying volcanics and sediments.
- *Sikillingi area*: 5x1 km, oil zone more than 50 m thick, porous zones (15-20% porosity) in hyaloclastites and volcanic conglomerates averaging 10 m in thickness, saturation close to 100%. Conservative calculations suggest a cumulative volume of at least 50 mill. barrels, but much more may be found in underlying volcanics and sediments.

North-west of the Itilli fault, the presence of oil seeps at surface indicate mature source rocks in the area or migration of oil from offshore areas. However, potential source rocks are probably buried to deep to be economic targets at this stage of exploration.

The geographic distribution of the documented oil types seems closely related to the main structures of the basin (Fig.4.1). Oil seepage and staining is mainly observed on outcrops that fulfil the following criteria:

- a stratigraphic position in the lowermost ~1 km of the volcanic Vaigat Formation
- a structural position close to or within regional fracture zones and dyke swarms
- a high concentration of fractures and mineralised veins (especially quartz and fine-grained calcite; less commonly coarse-grained calcite and zeolite minerals)
- a high primary porosity, e.g. vesicular lava flow tops, hyaloclastites or conglomerates
- preferential lithology (especially flinty rocks such as silica-enriched basalts and hyaloclastites, less commonly olivine basalts, rare in picrites).

Organic geochemical results from the oil seeps and oil-stained samples show that degradation is surprisingly low (mainly evaporation of lighter components) and biomarker distributions or specific angiosperm biomarkers suggest the existence of at least five distinct oil types with origins (Bojesen-Koefoed et al., 1997b; Bojesen-Koefoed et al., 1997a):

A. moderately waxy oil containing 28, 30-bisnorhopane, and abundant C27-diasteranes and regular steranes and which originates from Cenomanian-Turonian marine shales (*Itilli oil type*)
B. waxy oil, probably generated from mid-Cretaceous non-marine terrestrially influenced shales and coal of lower part of the Atane Formation (*Kuugannguaq oil type*)
C. waxy oil with characteristic biomarkers which originates from Campanian marine (to deltaic) shales (*Niaqornassuaq oil type*)
D. waxy oil, which based on the presence of abundant anginosperm biological markers, originates from Paleocene marine to deltaic shales (*Marraat oil type*)
E. low wax oil of marine, possible lacustrine shales of the Cretaceous age. Contains a previous unknown series of extended 28-norhopanes, and ring-A methylated steranes (Eqalulik oil type)

These five types have well defined regional distributions and there are many examples of mixing of two or several types. Based on the detailed biomarker composition both the stratigraphic age and depositional environment of the source rocks can be interpreted – and in several cases correlated to analysed sediments from cores.

Generally the oil seeps are not strongly biodegraded. However, a strongly biodegraded oil seep was discovered for the first time in sedimentary outcrops a Asuk during the 1997 field season (Fig.4.1). The oil seep occurs in sandstones of the mid-Cretaceous Atane Formation just underneath the unconformity separating the sandstones from the overlying Paleocene marine mudstones.

Only a few source rock intervals are presently known from wells and outcrops onshore West Greenland and Nuussuaq and there are limited information on their generative potential:

- Upper Paleocene (Selandian) turbidite shelf mudstones from the uppermost 80 m (Unit D, Appendix 2) of sediments in the GRO#3 and GANE#1 wells have TOC-values between 2.4 and 4 wt% and HI-indices between 97 and 217. The mudstones contain abundant higher land plant debris and GCMS-analyses show that the biological marker distribution closely correlates with the Marraat oil type (Bojesen-Koefoed et al., 1999). These mudstones are not known from outcrop.
- During fieldwork in 1997 a lacustrine mudstone within the Quikavsak Member was sample along the south coast of Nuussuaq. This mudstone shows TOC-values between 6.7 and 11 wt% and HI-indices between 144 and 174. At present, it is not

known if the biological marker distribution correlates with any of the known oil types.

- Lower Paleocene (Lower Campanian-Danian) turbidite mudstones from the interval between 400 m and 1170 m in the GRO#3 well have TOC-values between 1.2 and 5.9 wt% and HI-indices between 89 and 139 and (Bojesen-Koefoed et al., 1997a). Although the analysed mudstones from GRO#3 and GANT#1 show a limited hydrocarbon generation potential there are strong similarities in biomarker composition between the Niaqornaarsuk oil type and the Campanian mudstones.
- The biomarker distribution of the known oil types suggests the presence of a Cenomanian-Turonian marine source rock, corresponding to the *Itilli oil type.*
- It is also likely that oils have been generated from coals and shales within the Cretaceous Atane Formation.
- The source rock potential of the Paleogene lacustrine shales found in the southeast part of the Nuussuaq area may locally be high although all known examples are immature. Pedersen et al., (1998) mentioned a moderate to low source rock potential indicated by HI-indices below 80, predominance of kerogen type III and palynofacies dominated by brown and black lignite. However, it is of interest to note that the lacustrine shales constitute a thick succession of organic-rich mudrocks which accumulated rapidly.

It is important to note, that the general richness of the organic material is so high throughout the sedimentary succession that significant amounts of hydrocarbons may have been generated even though the individual samples only have a limited potential for liquid hydrocarbons.

For basin modelling purposes and a regional assessment of the petroleum potential of the region, two of the source rocks seem to be most important; both **A** and **D** are widely distributed and well described from oils (Fig.4.1):

A: *Itilli oil type source rock*: Cenomanian–Turonian marine shales. The oil type is widely distributed in seeps on western Disko, western Nuussuaq, Schades Øer and southern Svartenhuk Halvø. The actual source rock (postmature) is probably present in the Umiivik-1 hole (Dam, 1997) and is also well known from the Kanguk Formation on Ellesmere Island. This type of source rock is expected to be regionally distributed throughout West Greenland.

D: *Marraat oil type source rock*: Paleocene deltaic to marine shales (Unit D, Fig.4.2 and Appendix 2). This oil type is widely distributed on western Nuussuaq, Hareøen and north-western Disko in seeps and also known from the cores of Marraat-1, GANW#1, GANE#1 and GANK#1. The actual source rock (immature or early mature, probably not the most generative facies) has been penetrated in GANE#1 and GRO#3. The source interval has a thickness of ~80 m in GRO#3, typical TOC values of 3–4 wt% and HI-indices around 200. Higher values may occur in local depocenters. This type of source rock is expected to be regionally distributed throughout West Greenland.

By far the most of the analysed shales are dominated by terrestrially derived organic material (i.e. type III kerogen) with only a limited generative potential. It should be noted, however, that many of the shales have HI-indices between 100 and 200, and are likely to be composed of a mixture of organic material without any potential (HI < 50) and a minor fraction of hydrogen-rich material (HI > 400 ?) that may generate liquid hydrocarbons (type II/III kerogen).

A generalised stratigraphic scheme of the Nuussuaq Basin, showing a chronostratigraphic diagram with oil seeps and oil staining, potential source rocks and reservoir rocks is shown in (Appendix 2).

4.2 The GRO#3 well

The recent evaluation of ~3 km deep GRO#3 well with focus on palynostratigraphy (Nøhr-Hansen, 1997b), lithological interpretation and petrophysical evaluating (Kristensen and Dam, 1997). Together with organic geochemistry (Bojesen-Koefoed et al., 1997a) this well provides the best information for basin modelling purposes so far and has added new constrains on facies environment, source rocks, thermal maturity gradient, traps and hydrocarbon potential.

A full suite of petrophysical wireline logs and a vertical seismic program were run in the hole and reported a number of sand intervals containing hydrocarbons and eight zones were tested. Despite some of the drill stem tests showed minor amounts of hydrocarbons the intervals were tight and not able to flow and no commercial rates were obtained. The well was subsequently abandoned.

Figure 4.2 shows a simplified sedimentological and stratigraphic interpretation of GRO#3 with petrophysical logs. The uppermost 312 m of the well penetrates Paleocene hyaloclastites whereas the remaining part is composed of mudstone and sandstones. The overall depositional environment of this clastic system is interpreted as a marine slope with turbidite and debris flow deposits. The succession drilled in the GRO#3 well shows many similarities to the Itilli succession that is exposed ~15 km to the north-west (Dam and Sønderholm, 1994). Diagenesis studies of the succession penetrated by the GANT#1 well on north-western Nuussuaq suggest that the most promising reservoir units should be found in the Paleocene part of the sedimentary sequence (Kierkegaard, 1998).

The stratigraphic ages of the sediments from the base of the volcanics (~300 m) down to 1485 m of the well have been reported as Late Selandian (late Paleocene)–?Coniacian by Nøhr-Hansen (1997b) based on palynological dating. The samples from the deeper part is thermally altered to such a degree that dating is not possible. However, based on comparison of stratigraphic thickness with e.g. the Svartenhuk Halvø area the stratigraphic age at TD in GRO#3 may be Turonian or even older.

The vitrinite reflectance trend recorded in the GRO#3 well is remarkably regular and bears no witness of any kind of anomalies caused by intrusions, hydrothermal activity or changes in maturity gradients across possible unconformities. This undisturbed maturity trend could be the result of a simple subsidence history. Based on the vitrinite reflectance trend the position of the oil window, as defined by thermal maturities in the range from Ro=0.70 % to Ro=1.00 %, can be determined as the interval from approximately 350 m above the present day surface at the drilling site, to approximately 1200 m below the surface. Based on the S1- and S2-trends, it is estimated that the oil window is restricted to the interval from the base of the basalts (~300 m) to ~1500 m. Below ~1500 m, S1 and S2 both decrease rapidly, indicating that generation still took place here during deepest subsidence, however, with a predominance of more gaseous products which have not been retained in the samples to be detected as the S1 parameter. This interpretation is supported by extraction yields, which show a strong decline at depths greater than ~1400 m (Bojesen-Koefoed et al., 1997a).

The base of the oil preservation zone is estimated to ~2200 m (corresponding to a vitrinite reflectance value of approximately 1.9%), at which depth both S1, S2, and extract yields are largely equal to zero. Furthermore, below this depth various biological marker data seem spurious, probably influenced by the presence of caved material and random contamination from unknown sources. This estimated oil preservation limit is in agreement with previous estimates based on shallower boreholes and surface data (Christiansen et al., 1996b).

Based on palynological, sedimentological and petrophysical log data a consistent correlation between the 497 m –565 m section in the GANE#1 well and the 320 m –370 m section in the GRO#3 well can be established (Fig.4.2) (Nøhr-Hansen, 1997b; Kristensen and Dam, 1997). This correlation indicates that GRO#3 is situated at an up-dip position relative to GANE#1 (Kristensen and Dam, 1997). Screening data do not reveal any significant maturity difference between these intervals in GRO#3 and GANE#1. However, biological marker data, principally Ts/(Ts+Tm), Tm/(Tm+17b), and sterane isomerisation ratios clearly show the succession drilled in the GRO#3 well to be slightly more mature than the equivalent succession in GANE#1, despite a greater depth (relative to sea level) in GANE#1 (Bojesen-Koefoed et al., 1997a). This could indicate that the geothermal gradient was slighter higher towards the west (GRO#3 is situated ~4 km west of GANE#1), thereby causing comparable higher thermal maturities in the GRO#3 well (Appendix 4). These observations on the thermal maturity may also have important structural implications, as they may suggest that the tilted fault block structures were formed after the main phase of subsidence and thermal maturation and possibly also petroleum migration. However, the formation of some of these potential traps may be related to transpression in the Eocene or Oligocene (Appendix 2).

With minor variations GRO#3 sediments analysed in the interval 320–510 m, show biological marker distributions closely resembling that of the *Marraat oil type* (Christiansen et al., 1996b; Bojesen-Koefoed et al., 1997a). Thus, all samples represent sedimentary environments receiving large proportions of terrigenous organic matter. Given the variability of the chemical signatures of the rocks analysed in the GRO#3 well, it is indeed conceivable that the *Marraat oil type* was generated from source rocks equivalent to the sediments present in the upper part of the GRO#3 well (Unit D, Appendix 2)(Bojesen-Koefoed et al., 1997a).

Despite the poor data quality in samples from the deeper part of the succession, several parameters point to a comparatively more marine nature of the sediments samples collected in the interval 1500-2300 m (Bojesen-Koefoed et al., 1997a).

Results from the GRO#3 well document and indicate that:

- the most interesting targets for liquid hydrocarbons occur at relatively shallow depths of less than 1.5 km with only limited chances of discoveries below 2.5 km. Significant quantities of gas may occur a greater depths. Furthermore, it is possible that we underestimate the potential due to the high maturity value. This may require restoration of e.g. the TOC values.

- the marine mudstones (Unit D, Appendix 2) in the Nuussuaq Basin are organic-rich although the HI-indices values are low to moderate. Due to the relatively high thermal maturity source rocks cannot be demonstrated in the deeper part of the GRO#3 well
- the source rock for the *Marraat oil type* is in the Paleocene succession with a position between the volcanics and the most interesting reservoir interval, the lateral equivalent of the Quikavsak Member incised valley system.

5. Model concept

The geological evolution (and exploration potential) of the Nuussuaq Basin has been assessed by a stratigraphic analysis of outcrop data and by the use of the Yükler 1D basin model concept (Yükler et al., 1978). The Yükler model is a forward deterministic model which quantifies the geological evolution of a sedimentary basin by calculating compaction, pressure, temperature, thermal maturity and hydrocarbon generation, as a function of time and space.

The model utilises knowledge and data from geological, geophysical, hydrodynamic, geothermal, geochemical and rock mechanics studies in an integrated manner and have been optimised from numerous basin analysis studies undertaken world-wide. The geological framework of the basin is defined by type, age, volumetric and temporal distribution of sediments, structural features, palaeogeography, palaeoclimate, palaeodepositional environments and plate tectonic motions. Thus, the framework of a basin constantly changes as a result of subsidence, changes in water levels, sedimentation, compaction, uplift, erosion, folding and faulting.

Geological information and input data for the model (thickness, age, lithology, porosity, palaeotemperature, heat flow and palaeowater depth) are synthesised into model events (or model layers) in such a way that the model can handle deposition, non-deposition (hiati) and erosion.

Computed values representing present time can be compared with measured values of thickness, porosity, temperature and thermal maturity obtained in the basin, e.g. in wells or at the surface in uplifted terrains. By minimising the error between computed and measured values, the geological model and input parameters are optimised. Thickness is optimised by changing the input porosity of the model layer. This is done automatically by the program although it may be necessary to change the lithological properties (in form of a fixed lithocode for each lithology) to give a better match. Due to the fact that measurements used as control points are averaged values and that the measurements are of varying quality visual optimisation has been used in this study.

Calculation of water flow and sediment compaction are both based on the principle of conservation of mass. The solids volume is determined by subtracting the volume of pores from the bulk volume of the sediments. Hence, the input porosity values are estimated current total average porosity for each model layer, i.e. they include all connected and unconnected pore spaces. The two basic techniques for porosity measurements employ either direct determination methods from cores or other samples, or indirect geophycical methods based on well log data.

In this study the input porosities are mainly based petrophysical estimations. Porosity must be defined not only as a representative average but also so it account for known, frequently occurring processes, e.g. cementation in limestones, and it acts as an indicator of the state of compaction.

The Yükler model calculates optimum porosities during the simulation based on a set of lithologic parameters and on the specific geologic history. Optimisation of porosities is based primarily on comparisons between computed and measured thickness of the model events. Differences of a few percent are not critical as measured bulk porosity values can never be accurate to more than ± 5-10 percent no matter which methods are employed. The default lithotype parameters in the model are based on average trends. Measured porosities e.g. sandstones can vary from approximately 5% to 30% at depths of around 3000 m with an average value of approx. 15%. Therefore, if larger differences occur (>10%), user-defined lithotypes must be applied, in order to take specific local characteristics into account.

The thermal history of each sedimentary unit is determined from an equation which describes the heat movement as a function of heat flow into the basin, surface temperature at time of deposition (sea bottom for marine sediments or surface for non-marine). Heat is transported by conduction and by the fluids moving up through (convection) the sediments as it compacts.

The hydrocarbon generation history is determined from kinetic equations based on the work of Tissot and Espitalié (1975). The original coefficients and pseudo-activation energies used in these equations have later been optimised by Yükler (unpublished data). The amount of generated hydrocarbons is calculated for each model event and presented as normalised values or transformation ratios in gHC per gram of original total organic carbon (TOC). Values are calculated as if the original organic matter type was either 100% of type I, II or III kerogen. An empirical approach divides the hydrocarbon generation into zones each defined as a percentage or degree of alteration.

The concept has been used to model **5** wells and **2** pseudowells (Appendix 3) in the uplifted and exposed parts of the Nuussuaq Basin in order to constrain basin history by optimising the subsidence, uplift and thermal history of the different parts of the basin using sensitive maturity data (Appendix 4). The pseudowells are located in areas with the best data control. Input data for each pseudowell are accumulated from a large area (often > 10 km^2), and therefore not corresponding to a real well.

6. Event definition and modelling strategy

The event definition is based on a modelling relevant subdivision of the stratigraphic succession into a limited number of isochronous geological events, which attempt to represent their corresponding lithostratigraphic entities as closely as possible. Each model layer corresponds to a geological model event and is described in terms of a set of input parameters. However, diachronism is a common characteristic of a number of formations, and these cases are treated as lateral facies and/or event type changes. Furthermore, as the basin modelling is based on a continuous and isochronous forward simulations concept, also the missing parts of the geological record is seriously taken into consideration. For this latter purpose, 'phantom events' are constructed and introduced according to the regional geological understanding of the development and history of the major hiati (e.g. marked non-depositional events, depositional events followed by marked erosional events). The events were all defined with isochronous boundaries, although many of their corresponding lithostratigraphic units are known to be more or less diachronous in nature. Marked diachronism was treated as lateral lithology variation (see below) and/or event type changes. The events are characterised by a positive, zero or negative thickness of homogeneous (i.e. average) lithology corresponding to deposition, non-deposition (hiatus) or erosion, respectively, occurring during a specified time interval. Estimates of the occurrence and extents of erosional and/or non-depositional events are derived initially from regional considerations.

The history of the basin has been divided into a number of model events representing the geological evolution. The aim has been to use subdivisions in excess of 1.0 my., which can clearly be identified on lithology or other significant parameters; lithostratigraphic units, at the formation level, are often the most convenient. Usually the base of a model section is taken at approx. 100 m below the deepest source rock. In this study, the base of the model is established at the first no-flow boundary observed, i.e. the top of what is believed to be the metamorphic basement (Fig.3.2). This is done due to model technical reasons and to ensure the boundary condition of no-flow at the base of the model is strictly obeyed.

The pseudo wells have been constructed from outcrop studies and seismic data and are primarily distributed in areas with good outcrops and many analytical data. To constrain the model a series of calibration data has been used (vitrinite reflectance, isomerisation of steranes and hopanes and apatite fission track length distributions).

Geological information has been compiled from both published and unpublished sources, from field work and analytical studies. The data are combined in the 5 wells and 2 pseudowells located throughout the basin. A total number of 42 model events have been used. All input parameters however, vary laterally across the study area (Appendix 2 and 3). The well-sections were extrapolated down to the basement by the use of seismic data and gravity modelling (Chalmers, 1998; Chalmers et al., 1999b). The total number of events in the geological model, including events of deposition, non-deposition and erosion is chosen in such a way that all major geological changes are described. The known, or inferred, stratigraphic ages have been transferred into absolute ages (M.a.) using the time scale of (Berggren et al., 1995) and a scale convenient for modelling (Appendix 2 and 3). A time-step interval of 250.000-500.000 years has been used. This time-step interval is used to ensure that changes in the magnitude of the variables occur linearly between two consecutive time-steps. Likewise, a vertical grid interval of 25-30 m has been used. This distance represents the grid interval where all parameters and variables are calculated. The time-step interval and the grid interval govern the accuracy of the model.

The geological input parameters for each of the conceptual models used in this study are included in Appendix 5. Furthermore, selected input parameter plots (Palaeosurface temperatures, Heat flow, and Deposition/erosion rates vs. Time) for all the wells and pseudowells are included.

To determine the development of the Nuussuaq Basin, the integration of structural field data with the available photogrammetric and geophysical data have been used (Pedersen et al., 1993). The present-day outcropping volcanics (Fig.2.1 and Fig.3.3) separates major sedimentary outcrop areas showing very different depositional environments. Sedimentological, geochemical and palynostratigraphical analyses of the sediments penetrated in the wells have therefore been essential in the basin modelling study.

The structural and sedimentological evolution of the Nuussuaq Basin initiated with rifting of the Greenland-Canada continent probably as early as 138 Ma, and has mainly been governed by three stages of extension leading to rifting and sea-floor spreading (Christiansen et al., 1995; Chalmers et al., 1999b). Based on knowledge of the timing and regional significance of rift events as described in Section 3 & 4 the following division of the basin development of Nuussuaq Basin is used (Appendix 2, 3 and 5):

1. Unknown Pre-Cretaceous sedimentation [Model Events 1-4]
2. Cretaceous sedimentation [Model Events 5-10]
3. 1: Early Maastrichtian Unconformity [Model Events 11]
4. Late Cretaceous to Early Paleocene sedimentation [Model Events 12-14]
5. 2: Early Paleocene Unconformity [Model Events 15]
6. Early Paleocene sedimentation [Model Events 16-17]
7. Volcanism 1, Vaigat Formation [Model Events 18-20]
8. Volcanism 2, Maligât Formation [Model Events 21-24]
9. Post-Paleocene ?magmatic activity and uplift [Model Events 25-26]
10. 3: ?mid-Eocene Unconformity [Model Events 27]
11. Post mid-Eocene uplift [Model Events 28-42]

The model event 11, which may represent an diachronous unconformity in the Nuussuaq Basin (Appendix 2), is considered to be a larger erosional event in offshore West Greenland, where most of the Late Cretaceous sediments are missing (Nøhr-Hansen, 1998).

This division implies that volcanism post-dates Early Paleocene sedimentation even though the problems around absolute radiometric vs. palynostratigraphic dating has not yet been solved. Furthermore, the event definition is based on the lithological division of the recently drilled GRO#3 well (Unit A-D; (Kristensen and Dam, 1997)).

The lithology is based on published or unpublished sources on depositional facies variation (Table 6.1). The interpretations of lithology are based on in-house descriptions from outcrops and the onshore wells, evaluation of well-logs (Kristensen and Dam, 1997) and interpretations of lateral variation of the depositional facies.

Table 6.1. Description of the lithologies used for basin modelling in the Nuussuaq Basin, West Greenland

LitCode	LITHO NAME	SAND	SHALE	CALC	COAL	DEPOSITIONAL ENVIRONMENT
3.	SANDY SHALE	30	70	0	0	Eocene Sediments
52.	BASALT	10	80	10	0	Vaigat and Maligât Fm.
						-- 54-60 Ma------------------------
4.	SHALE, CLAY, CLAYSTONE	10	80	10	0	Shallow Marine Mudst/Shales
10.	SILTY CLAY	20	80	0	0	
13.	CONGLOMERATIC SAND AND SHALE	75	25	0	0	'B.Dan.Congl.'/ Valley Fill
14.	SAND AND SHALE	50	50	0	0	Turbiditic Succession
15.	COARSE CONGLO. SAND AND SHALE	70	30	0	0	Valley Fill, Quikavsak Mb.
						-- 65 Ma---------------------------
18.	CARBONACEOUS SHALE	10	80	0	10	Marine Shelf Shales (Kangilia Fm.) (Outer Shelf / Slope)
						-- 92 Ma---------------------------
23.	SHALY COALY SANDSTONE	50	20	0	30	Non-Marine Fluviatile Delta OR Shallow-Marine Coaly Sandstone/Mudstone (Atane Fm.) i.e. Source Rock Lithology
						---115 Ma--------------------------
10.	SILTY CLAY	20	80	0	0	Pre-Barremian
						---136 Ma--------------------------
33.	SILTY SHALY SAND	60	40	0	0	'Model-Basement'

The palaeowater depths are based on published or unpublished outcrop-based measurements, seismics (Chalmers et al., 1999b) and on personal communication (Appendix 5). The palaeowater depth values used here has no implications for the results of the modelling of the maturation. However, in detailed assessments of possible migration routes more accurate estimates and 2D modelling may be needed.

The thickness of the model events and the amount of erosion (Appendix 3) are primarily based well data and on interpretation of cross sections displaying both well-sections and seismic surfaces (Fig.3.2). Beside Figure 3.2 the stratigraphic column from the basement to the base of the drilled sections is incorporated in the modelling by using the information from neighbouring well-sections and the interpretation of the general basin history.

It should be noted that both lithology and palaeowater depths are averaged values for each model event. Thus, the assigned lithology in the conceptual model assumes that its constituents are homogeneously distributed both laterally and vertically. Palaeowater depths do not take into account any water depth variations during an event and should, therefore, probably be regarded as maximum values.

The surface palaeotemperature used in the model events is estimated from palaeoclimatic models and palaeolatitude (Scotese et al., 1988; Rowley and Lottes, 1988; Smith et al., 1981) and palaeobathymetry. For the events 1-6 that represent a continental pre- to early-rift phase, a surface temperature of 15°C is used. For the remaining events that mostly represents periods with marine to deltaic sedimentation an average surface temperature of

5-10°C is used. For the Quaternary –5°C is used. Quantitative data on palaeotemperature such as oxygen isotopes, are not available and information on porosity is limited to the petrophysical study by (Kristensen and Dam, 1997). A recent zeolite study argues for the use of a geothermal gradient of *c.* 30°C/km (Stannius, 1998). This is in agreement with the only available temperature data from the West Greenland area offshore data indicating a gradient of 24-28°C/km (Rolle, 1985).

The five oil types described in Section 4 corresponds to possible source rocks deposited during the following model events (see Appendix 2):

A. **Model event 6 or 7** = ***Itilli oil type,*** Cenomanian-Turonian marine shales (LitCode 23, Table 6.1)
B. **Model event 8** = Kuugannguaq oil type, mid-Cretaceous non-marine terrestrially influenced shales and coal of lower part of the Atane Formation
C. **Model event 10** = Niaqornassuaq oil type, Campanian marine (to deltaic) shales
D. **Model event 16** = ***Marraat oil type***, Paleocene marine to deltaic shales
E. **Model event 17** = Eqalulik oil type, marine, possible lacustrine shales of Cretaceous age, but several possibilities

For basin modelling purposes and a regional assessment of the petroleum potential of the region, **A** and **D** source rocks seem to be most important (see Section 4; Fig.4.1).

6.1 Strategy for the modelling of the Nuussuaq Basin

Based on the geochemical results from the GANW#1, GRO#3, GANE#1, GANK#1 and GANT#1 wells, it is now possible to make direct comparison of the maturity variation and gradient and to correlate most of the maturity parameters such as T_{max}, R_o, CPI etc., and various hopane and sterane isomerisation values in both the northern and southern area of Nuussuaq (Appendix 4).

Optimisation of temperature and maturity in basin modelling can be controlled by either changing the absolute heat flow values, the duration of heat flow, the thickness of volcanics rocks or the surface temperature. The variations in heat flow with time are estimated from the general basin history, with higher values in periods of rifting and volcanic activity, and lower (and generally decreasing) values in tectonically stable periods with slow and uniform subsidence. The heat flow values in the Nuussuaq Basin are interpreted to have been evenly distributed during the development of basin with a gradual increase at the onset of the rifting phase (Early Cretaceous) reaching a maximum of 1.1 Heat Flow Units [HFU] during the active rifting phase (Early Cretaceous), which may have lasted until Early Paleocene. The onset and duration of this rifting phase is not clear. During the subsequent post-rift or drifting phase (Cretaceous-Early Paleocene) of relatively uniform subsidence caused by thermal contraction, lower and gradually constant values of 1.0 are used (Appendix 5).

From Appendix 1 and 4 it seems clear that minor differences in maturity of the sediments in the GANW#1, GRO#3, GANE#1 and GANK#1 wells is controlled by depth alone (Christiansen et al., 1996b; Bojesen-Koefoed et al., 1997a). This implies that the now eroded succession of volcanics, that was present before uplift and erosion, had a more or less constant thickness, at least in western part of the Nuussuaq Basin. In contrast GANT#1 well, located in the northern part of Nuussuaq, show considerably higher maturity relative to sea level. Expressed in another way the oil window is located deeper under the volcanics in the northern part of Nuussuaq (Appendix 1), may be due to fewer volcanics in the northern part of Nuussuaq.

The outcrop section at Annertuneq seems to have a slightly higher maturity relative to sea level than the nearby GANT#1 well, a difference corresponding to ≈ 200 m. Whatever the reason is for the maturity variation, it is very clear that the oil window is situated considerably deeper in the GANW#1, GRO#3, GANE#1 and GANK#1 wells than in the Tunorsuaq valley and on the north coast of Nuussuaq (Appendix 1 and 4).

Based on these maturity observations **Model Scenario A** (also called 'Maximum Volcanics' in Appendix 1-10) has been used. As there are no other observation or indication of difference in heat flow between the northern and southern part, the same heat flow history for the whole area, except for the volcanic events around 60-54 M.a. where the heat flow has been increased to 1.40 HFU (Appendix 5a and Section 7.3). The 1.40 HFU peak value is determined from Figure 6.1 by extrapolating the tilted volcanics towards west to a position above the GANW#1, GRO#3, GANE#1 and GANK#1 wells. From seismic information in the Vaigat fjord area, the total Cretaceous succession is interpreted to more than 5 km thick (Fig.3.2), and outcrop information from the same area suggests, by extrapolation (Fig.6.1), that basalts of a maximum thickness of 3-4 km once covered the area, possibly increasing to more than 5 km towards the north (Hald and Pedersen, 1975).

This scenario assumes a more or less constant thickness of the succession of volcanics decreasing to the north and representing the whole Vaigat Formation and the lowermost Maligât Formation, only minor lithological variations and that each volcanic member can be stratigraphically added to a total thickness (Appendix 3a). Furthermore, it is assumed that the depositional rate was relatively constant throughout the Cretaceous and that the Paleogene volcanics were extruded as horizontal flows. This strategy is the same as used for a basin modelling study from East Greenland (Mathiesen et al., 1999) (Mathiesen et al., 1995). In this study, a little higher heat flow peaks of 1.4-1.5 HFU were used; values which in the present study will result in smaller thickness of the volcanic rocks. Thus, the basic concept of this scenario has then been to use this generalised heat flow history in all wells and pseudowells, and to optimise the models by varying the thickness of the volcanic rocks. This results in a variation of thickness of the volcanics from north to south in order to explain the maturity differences (Appendix 3a).

Due to dating of the Paleogene volcanism (Section 3.2.3), the duration of the Vaigat Formation members (Anaanaa Member, Naujánguit Member and Ordlingassoq Member) are taken as 0.5 my, each with a peak heat flow and a subsequent event with rapidly decreasing heat flow. This subdivision more accurately monitor the effect of the volcanic events on the thermal maturity history in the individual wells and pseudowells.
The **Model Scenario B** (also called 'Minimum Volcanics') is based on the assumption that top of the volcanics is just above the present day topography and that the area extent of the volcanic hyaloclastites and lava flows are very limited. It is furthermore assumed that all the volcanics belong to the Anaanaa Member (in the West) and the Naujánguit Member (towards the north-east; Appendix 3b). The model scenario is supported by the use of zeolite minerals as a help to predict the palaeothickness of the now partly eroded Paleogene flood basalts around the Marraat-1 well where it is calculated that the eroded thickness of rocks above the Marraat area equals ~1450 m (Stannius, 1998). Interpretation of GRO#3 vitrinite reflectance data further supports this scenario indicating that the thickness of eroded volcanic succession can be estimated to ~2000 m (see also Section 3.5). Both amount corresponds fairly well to the maximum height of the mountains in the hinterlands around the wells (Fig.3.2). By adding the known volcanic thickness from the GRO#3 well (~300 m, Appendix 1) this gives a maximum volcanic thickness of ~2300 m.

The general assumption from Model Scenario A on thickness of Cretaceous sediments, lithological variation etc. is used. Model Scenario differs in the way the volcanics have emerged. To match the optimisation data, a heat flow history with maximum of 2.0 HFU and slowly decreasing to 1.0 HFU over a period of 20 my is needed (Appendix 5b and Section 7.3). A heat flow value of 2.0 HFU is acceptable if the volcanics have emerged from a magma source close to the Nuussuaq Basin. This is indicated by several eruption sites in or very near the Nuussuaq area as shown in Figure 3.3 (Pedersen et al., 1996; Larsen and Pedersen, 1992a).

7. Optimisation and modelling of maturity

A forward model calculates parameter values in the past as a function of the input parameters. Thus, optimisation is of fundamental importance for calculation of the thermal and hydrocarbon generation history, especially of the parameters which affect the thermal maturity calculations.

Highly sensitive maturity data (vitrinite reflectance, steranes, hopanes and T_{max}) from especially the GRO#3 and GANT#1 wells have been applied to optimise the subsidence, uplift and thermal history (Appendix 4). T_{max} has not been used for optimisation in this study, but has been used to substantiate the results from the vitrinite reflectance optimisation. Fission track analysis and modelling have been included to constrain the modelling (see section 8).

7.1 Optimisation of formation thickness

As the geometrical framework of the geological model must be satisfactorily reproduced during simulation, the first step in the optimising procedure is to ensure that the calculated thicknesses are in accordance with the observed values. In practice, this is done by adjusting the input porosity and re-runing the program. If a reasonable fit can not be obtained, the formation lithology must be changed. In this study a precision of 5 % was used for events thicker than one grid step and a precision of 30 % was used for thicknesses less than one grid step (one grid step = 25-30 m). Results from optimisation of thicknesses are not shown in this report.

7.2 Optimisation of subsurface temperature and thermal history

The important factors influencing the temperature profile and the thermal history are: the surface temperature, the heat flow and the lithology.

Surface temperature or formation temperatures are usually determined on basis of measurements obtained during well logging and well testing. The Yükler program includes heat transport in the formation water as it is forced through the sediments during compaction.

Furthermore, the program calculates the heat capacity and thermal conductivity of the sediments based on the composition of the lithologies, porosities and temperature. Optimisation of temperature profiles are carried out by changing present day heat flow and the average surface temperature. However, if this is not enough to obtain a good match changes in lithologies are necessary.

Due to lack of measured temperature profiles from the Nuussuaq Basin temperature data have not been available in this study and optimisation of surface temperature has not been possible.

Instead, the thermal history is matched against thermal indicators such as vitrinite reflectance, sterane and hopane isomerisation ratios and thermal annealing of fission tracks. The optimisation is carried out by changing the heat flow history until a good match between calculated and measured values of the thermal indicators was obtained. Although estimation of the paloeo heat flow is connected with many uncertainties, an acceptable match between measured and calculated thermal indicators should be obtained.

7.3 Results of maturity optimisation

A number of optimisation runs have been carried out and the most significant input parameters and results are included in Appendix 5 and 6. Appendix 6 includes results after optimisation of all wells and pseudowells based on Model Scenario A ('Maximum Volcanics') App.6a.1 to App. 6a.21 and based on Model Scenario B ('Minimum Volcanics') App.6b.1 to App.6b.21. For assessment of the petroleum potential of the region, the source rocks **A** (model layer 6-7) and **D** (model layer 17-14) are used to illustrate the hydrocarbon generation in the Nuussuaq Basin (Section 4.1).

Beside the two main scenarios (A and B, Section 6.1) other scenarios, to assess the effect on the optimisation by changing the value of different input parameters, were carried out e.g.:

- Thickness of volcanics succession
- Heat flow history
- Variation in erosion amount through time (e.g. decreasing, increasing and linear erosion rates)

All the modelling scenarios and the resulting plots are based on reasonable geological concepts and integrate all available geological information and knowledge. Based on the results of the maturity optimisation the following conclusions may be drawn:

- Most of the optimisations show an acceptable match between both vitrinite reflectance, sterane and hopane isomerisation. In the GRO#3, GANE#1 and GANK#1 wells it has not been possible to match both vitrinite reflectance, sterane and hopane isomerisation for the same scenario (App.6a.3 and App.6b.3). This could be due to use of not fully calibrated kinetic parameters.
- The GANE#1 and GANK#1 wells have too few volcanics to match the optimisation data, if the Model Scenario A and B are used (App.6a.4,App.6a.5 and App.6b.4,App.6b.5). This indicates the need for a more varied volcanic thickness in the southern part of Nuussuaq than used in the Model Scenario A and B (Appendix 3a and 3b).
- Based on the geohistory plots (kerogen type III) e.g. App.6a.12 and App.6b.12, it is clear that the most rapid changes took place during deposition of the volcanic succession due to increased volcanic thickness and heat flow.
- For the source rock **A** (model layer 6-7) both Model Scenario A and B resulted in postmature source rocks (e.g. App.6a.12 and App.6b.12; model layer between green lines).
- For the source rock **D** (model layer 17-14) both Model Scenario A and B resulted in immature to mature source rocks (e.g. App.6a.13 and App.6b.13; model layer between red lines) at ~50 Ma. The GANT#1 well and the Annertuneq pseudowell both have immature source rock, due to colder conditions in the northern part of the Nuussuaq Basin.
- Following extrusion of the volcanic rocks, the basin was mainly uplifted and eroded and the temperature of the sediments decreased gradually. It should be noted that the pattern of hydrocarbon generation zones following unit boundaries during the period of erosion, means that different geological models of erosion generate the same amounts of hydrocarbon. However, small tectonic movements may generate or remove traps or they may change the direction of updip migration of the hydrocarbons generated. Information on the uplift pattern of the region is therefore important for the evaluation of the plays in the area.

8. Fission track modelling

Apatite fission track data have been obtained from 11 samples from different parts of the basin (Table 8.1; for location see Fig.2.2 and Appendix 1 and 3) and apatite fission track analysis (AFTA) and modelling were used as an integrated part of the present project to further constrain the modelling results obtained from maturity data (Section 7). All analyses were carried out by Eurotrack, London, during August 1995 and June 1997 (Eurotrack, 1995; Eurotrack, 1997). Data quality are moderate due to lack of apatite crystals in the samples.

Fission track modelling is based on a mathematical model which calculates the fission track length distribution as a result of the thermal history; this has several advantages compared to other thermal indicators (e.g. vitrinite reflectance and biomarkers); fission tracks may provide us with detailed information on uplift and erosion, and fission tracks do not migrate as in the case of biomarkers.

Table 8.1 Appendix 7 and 8 include details on the analysed samples with stratigraphic ages/Formation, calculated ages and other analytical data important for fission track analysis and modelling.

8.1 Description of method

Apatite fission track thermochronology is an inorganic method for analysing low-temperature thermal histories (e.g. (Naeser, 1979; Green et al., 1989)). Fission tracks are created in minerals by spontaneous fissioning of ^{238}U. The track length is sensitive to temperature and time and therefore hold information on the thermal history of the rock sample (Gleadow et al., 1986).

Fission tracks are lines of crystal defects created by natural fissioning of ^{238}U which is present as a trace element in most minerals. The defects are believed to appear as a result of mutual repulsion of mineral atoms (Coulomb explosion) after they have been ripped of electrons by the passing positively charged fission fragments (Fleischer, 1981).

The tracks may be seen in transmission electron microscope. They have a diameter of 10-30 Å and a initial length of around 16 μm (for apatite). The tracks are made visible in a light microscope by etching. The acid has the highest etching preference in the tracks and in natural fractures. Only tracks with a connection to the surface of the mineral are etched. A track length distribution histogram is constructed for near horizontal tracks. The circumstance that only etched tracks are seen introduces a bias in the histogram relatively to the original unetched tracks. Thus long tracks have a higher change of reaching a connection to the surface than short tracks. Another bias enters when only near horizontal tracks are chosen for the histogram. Statistical calculations have shown that the total biases are limited except for very short tracks (Kunzendorf et al., 1991).

Fission tracks are annealed as a function of temperature and time due to migration of vacancies and interstitials. The tracks are generated trough time and are annealed to different stages. Thus, sample host rocks that have undergone different thermal histories (i.e. different temperature-time paths) have different mean confines track lengths and track length distributions (e.g. (Gleadow et al., 1986)). This arises because

- All tracks have a similar length (≈16 µm) when produced (Gleadow et al., 1986).
- New tracks are progressively added to apatite grains through time
- The ultimate length of a track is controlled largely by the maximum temperature it has experienced (Duddy et al., 1988)

Hence, the distribution of horizontally confined tracks contains a complete record of the temperature below approx. 125°C because each track has experienced a finite (and different) part of the thermal history.

The kinetics of fission track annealing for apatite have been established from a series of laboratory experiments (e.g. (Green et al., 1986; Green et al., 1989; Laslett et al., 1987; Duddy et al., 1988)). The accumulation of fission tracks in a mineral is determined by the temperature-time pathway(s) of the host rock through a particular temperature range, for apatite from 120°C to 60°C. On the high-temperature side, newly formed fission tracks can be (partly) annealed depending on the time available. On the low-temperature side (<60°C), new tracks will be stable (e.g. (Naeser, 1979)). The so-called closure temperature lies within this partial annealing zone and for apatite it generally is taken at 100°C although it depends on the cooling rate and the chemical composition of the apatite (e.g. (Green et al., 1985; Green, 1988)). The geological significance of the apparent fission track ages strongly depends on the shape of the pathway. Only in the cases of a simple cooling history do fission tracks date the last time at which the mineral passed the closure temperature. Any low temperature re-setting, however, would produce a mixed age and the geological meaning of the obtained apparent age is obscured. The quality and distribution of an individual sample's age data are best visualised in a radial plot (Galbraith, 1990), a graphical method for comparing crystals of differing ages and differing precessions.

If cooling is rapid, and no further heating occurs, long tracks will accumulate. The time at which the host rock last cooled below 110 °C can be calculated by counting the number of tracks present, and measuring the amount of uranium. Thus, if cooling is protracted or temperatures again increases, existing tracks are shortened, and the fission track age is reduced in value. So, in order to evaluate the degree of annealing that has taken place, the length of restricted/confined tracks is measured. Due to the range of inherited province ages found in sedimentary apatite, and the variation in annealing properties of individual grains (Green et al., 1989), a significant spread of individual grain ages may be present within the sample.

Studies of thermal annealing of fission tracks in apatite indicate that temperature is more important than time. In basement rocks with a simple linear cooling history, the distribution becomes skewed, with a mean around 12-13µm and a standard deviation between 1.2 to 2.0µm.

Superimposed upon the temperature-time path is the apatite composition, specifically the Cl content, which determines the upper (higher) temperature at which fission tracks are totally annealed. In a sample containing a range of apatite compositions, those grains with least Cl (flour-apatite) will anneal slightly faster and be overprinted at temperatures of c. 100°C at time-scales of 10 My or more; grains with Durango composition (0.4 wt% Cl) will be overprinted at c. 110°C, and grains with several wt% Cl will be overprinted at 125°C.

Providing we have an annealing model, the length distribution histogram can be calculated based on the thermal history of a rock sample. The fission track mathematical model uses the measured length distribution histogram and temperature history derived from basin modelling results and determines a calculated distribution histogram as output; i.e. the fission track modelling plot (e.g. App.8a.1). Thus, the software simulates the formation of tracks in the apatite lattice through time, and their subsequent annealing in response to time and temperature. The resulting track length distribution model can than be compared with the measured distribution histogram and a match between the measured and the calculated histograms indicates that temperature history is possible (e.g. App.8a.1). Other important input parameters are uranium content to determine the age of the fission tracks, and constants to determine the annealing of tracks (Kunzendorf et al., 1991; Jensen et al., 1993).

8.2 Qualitative interpretation of AFTA

Table 8.1 and Appendix 7 lists fission tracks data and analysis results. The qualitative interpretation of age and length data is a combined assessment of the fission track age (FTA), the stratigraphic age (SA), the spread and trends of ages, min. and max. crystal age, mean track length, Std. and track length pattern. If FTA is younger than SA it implies near-total post-depositional annealing, otherwise it implies minor post-depositional annealing and the samples may retain some inherited fission track characteristics.

Notice that the **'Evt'** column corresponds to the model event where the sample was taken (see also Appendix 3). The **'FT.Age'** is the central age (Ma) $\pm 1\sigma$**.** As seen from Table 8.1 the data are of very variable quality. Fission track data are normally only acceptable for fission track modelling when the number of apatite crystals (**'No.Cryst'**) are larger than 25 and the number of measured fission tracks (**'Tracks'**) are larger than 75. About half of the samples yielded good quality apatite fission-track data in terms of a satisfactory number of single-grain age analyses, although the track-length data are very modest for three of these samples (409131a(Itilli), 409131b(Itilli) and (400916(Itilli)). Thus, only three samples have acceptable data background, 439101-653 and 439101-654 from the GANT#1 well and 400914 from the Itilli area (see **'Optim'** column in Table 8.1).

Table 8.1. Data and results from fission tracks analysis used for fission track modelling in the Nuussuaq Basin, West Greenland

<u>Apatite fission track analysis data</u>

AREA	SAMPLE-NO.	Sample Type	Strati.Age	Evt	Loaction	Age	+/- 1σ	Tracks	No.Cryst	MTL	+/- 1σ	STDV
West	400914	Outcrop	?E. Paleocene	17_b	Itilli_1	45	4	**33**	**16**	13,17	0,39	2,20
	400916	Outcrop	?E. Paleocene	17_b	Itilli_1	62	10	*14*	*8*	13,57	0,52	1,88
	409131a	Outcrop	?E. Paleocene	14_b	Itilli_1	36	7	*8*	*4*	15,05	0,82	2,16
	409131b	Outcrop	?E. Paleocene	14_b	Itilli_1	59	14	*10*	*4*	13,37	0,58	1,74
Central	439001-737	Cuttings, 737	Selandian	16m	GANE_1	61	6	13	9	13,27	0,44	1,53
North-Coast	400878	800 m.o.h	? Selandian	16m	GANT_1	295	14	107	22	10,52	0,22	2,21
	439101-653	646 m.o.h	Maastrich.	12^t	GANT_1	149	27	**82**	**28**	10,64	0,26	1,75
	439101-654	571 m.o.h	m.Campanian	10^t	GANT_1	45	26	**76**	**21**	12,40	0,22	2,31
	439101-655	Core, 150,54 m	m.Campanian	10_b	GANT_1	57	23	*12*	13	11,96	0,36	3,24
	400881	Core, 579,19 m	? Selandian	16m	AnnerT_1	327	5	104	24	10,28	0,31	2,67
	400813	Core, 749,93 m	Late Danian	14^t	AnnerT_1	318	11	47	26	10,92	0,58	1,93

<u>Data used for fission track modelling</u>

AREA	SAMPLE-NO.	F.Tr.Density	WELL	Evt	P(X^2)	*U [ppm]*	E_Age	Optim
West	400914	2,330E+05	Itilli_1	17_b	62	10,7	74	**XX**
	400916	3,940E+05	Itilli_1	17_b	3	14,1	74	
	409131a	2,350E+05	Itilli_1	14_b	65	13,7	74	
	409131b	3,360E+05	Itilli_1	14_b	2	13,5	74	
Central	439001-737	6,390E+05	GANE_1	16m	6	22,1	62	X
North-Coast	400878	1,725E+06	GANT_1	16m	75	8,7	62	
	439101-653	1,883E+06	GANT_1	12^t	<1	9,8	74	**XX**
	439101-654	2,282E+06	GANT_1	10^t	0	13,4	83	**XXX**
	439101-655	1,036E+06	GANT_1	10_b	0	13,0	83	X
	400881	4,100E+05	AnnerT_1	16m	0	19,2	62	
	400813	2,830E+05	AnnerT_1	14^t	0	11,8	65	

Based on new palynostratigraphic dating (Nøhr-Hansen, 1997a), the stratigraphic age of samples from the GANE#1 and GANT#1 (Table 8.1 and Appendix 1) are now defined, so information can be gained by comparing the Fission track ages (**'FT.age'**) vs. stratigraphic age. It can be seen that most of the central apatite fission track ages (except samples 400878(GANT#1), 439101-653(GANT#1), 400881(Annertuneq) and 40013(Annertuneq)) are no older than Cretaceous (Table 8.1). The youngest single-grain ages measured in the samples are 20-30 Ma (Eurotrack, 1997). Visual inspection of the radial plots also suggests an age component of ~30 Ma. This age can be interpreted in terms of a *minimum* timing for the last major annealing event experienced by these samples (i.e. when they were hotter than 100-120°C). From the radial plots sample 439101-653(GANT#1) clearly represents a mixed age population and can be expressed in terms of a Paleogene or Neogene component and a Triassic-Permian component (Eurotrack, 1997). Statistical modelling of the single-grain age data in terms of two normally distributed age populations assigns 60% of the data to a population with a mean of 50-60 Ma., and the remaining data to a component of 250-270 Ma. The younger mode is consistent with the other samples which represent a sample from a single population. Thus, the minimum age for total annealing is ~30 Ma based on individual crystal ages, but statistical modelling of the age distribution suggest perhaps 50-60 Ma to be a more reasonable estimate (Eurotrack, 1997).

It should be noted that the samples with relatively few track-length measurements will tend to have mean track-length biased to longer lengths as a consequence of sampling bias. Each of the three reasonably well-defined track-length distributions tend to have a negative skew, with a tail of short tracks (e.g. sample 439101-653(GANT#1) and sample 439101-654(GANT#1), Appendix 7). There is also a hint of bimodality in these distributions. The relationship between the fission-track age and the mean track length is shown in Figure 8.1. As can be seen, the younger ages tend to be associated with the longer track lengths (bearing in mind the bias mentioned above).

This relationship can be interpreted as a single two-stage thermal history, with each sample coming from a different palaeotemperature prior to cooling. This simple scenario is also in accord with the tendency towards bimodality in the track-length distribution. The relationship of long mean track length and young fission track age, indicates the approximate time of cooling from around 120°C to an age around 50-60 Ma. The old ages of 149,295,318 and 327 Ma with shorter mean can be interpreted as samples which experience the least cooling, i.e. was at a lower temperature relative to the other samples. As seen from Table 8.1 by comparing with the model event (**'Evt'** column) this is a reasonable explanation. The actual maximum temperature depends on the duration of the cooling episode and the relative amount of time elapsed since this episode, although 80-90°C is a reasonable estimate. This simplified interpretation is only directly applicable to surface samples with no provenance-related fission tracks (i.e. inherited tracks). Sample 439101-653(GANT#1) probably does not satisfy these criteria.

Thus, samples 400878(GANT#1), 439101-653(GANT#1), 400881(Annertuneq) and 400813(Annertuneq) all have old apatite central ages that imply long term residence at low temperatures (< ≈100°C). However, the mean track length data for many of the samples are substantially reduced (**'MTL'** Table 8.1) and can only be explained by recent residence within the partial annealing zone, otherwise one would expect mean track length values > 14μm. Furthermore, since many of the samples have a Late Cretaceous to Early Tertiary stratigraphic age the annealing must post-date deposition, because if the samples had remained below 60°C the mean track length would have been higher than those measured. This enables a preliminary qualitative classification of the samples into two groups:

1. Samples from north coast of Nuussuaq (GANT#1 and Annertuneq wells and pseudowells), have significantly reduced mean track lengths (≤ 11.5μm) indicating recent residence within the middle part of the partial annealing zone (< ~90°C). Higher temperatures would reduce the large relative errors present in many of the these samples.
2. Samples from western and the central part of Nuussuaq (Itilli and GANE#1 well and pseudowells), have characteristically longer mean track length (> 11.5μm) indicating a protracted cooling history with recent departure from within the lower part of the partial annealing zone (< ~70°C).

The coexistence of old apatite fission track ages (327-149 Ma) and short mean track length values (≤ 11.5μm) indicates one of two possibilities for Group 1:

- The samples have been exposed to high temperatures or have resided in the annealing zone for a long time and have experienced recent cooling
- The samples are currently at annealing temperatures

Since the samples 400878(GANT#1), 400881(Annertuneq) and 400813(Annertuneq) are from outcrop, the latter can here be discounted. Samples 439101-654(GANT#1) and

439101-655(GANT#1) is of Early Paleocene age, indicating that annealing must post-date deposition, because if the sample had remained below 60°C the contribution of newly formed long tracks would lead to higher mean track length values than those measured.

In contrast, Group 2 have slightly longer mean track length values (> 11.5µm) and therefore one can only infer protracted cooling in order to preserve the old ages, with either:

- an earlier departure from within the partial annealing zone (decreasing erosion rate)
- a later departure from lower parts of the partial annealing zone (increasing erosion rate), to enable a greater accumulation of annealed tracks to produce a longer mean track length (i.e. glacial erosion).

On the other hand, the rather symmetric distributions, and the high values of the mean with small standard deviations (**'STDV'**, Table 8.1) indicate a fast passage of the apatites from the unstable track zone, through the partial stable zone to the stable track zone (i.e. rapid cooling). For the cooling history of the 'basement' (model event 1) this would imply a rapid decrease of the temperature to below ~70°C. However, the fission track length parameters and the different fission track ages do not support an undisturbed continuous pre-Cretaceous cooling history of the sample rocks, but rather indicate a period of rapid cooling and uplift after deposition.

8.2.1 Conclusion

11 samples (6 outcrop, 1 cuttings and 3 core) all yielded sufficient apatite for fission track analysis. By combining the analysis results with the qualitative interpretations of the overall data the following scenario is suggested:

- Erosion from a relative old (Precambrian) source region (indicated by the majority of the zircon fission track ages being older than 500 Ma), with a minor contribution from some Upper Cretaceous source (indicated only by two single-grain ages in samples 439101-655(GANT#1) and 1 grain in sample 400914(Itilli) (Eurotrack, 1997).

- Samples experienced maximum palaeotemperature in the Late Cretaceous/Early Paleocene, and the three samples of best quality experienced maximum palaeotemperatures of ~100 to > 110°C.
- Subsequently the samples underwent relatively monotonic cooling to their present-day temperatures, but with increasing erosion rates during the last part of the cooling history (i.e. Quaternary). As the region was affected by Early Paleocene volcanism, then these denudation rates are likely to be maximum. However, it is important to note that not all samples are consistent with very rapid cooling, as might be expected adjacent to a lava flow or shallow dyke/sill.
- The samples must have been buried to a reasonable depth (i.e. 1-3 km) and progressively exhumed during the Paleogene and Neogene.

Furthermore, the length distribution of samples 400881(Annertuneq), 400813(Annertuneq), 400878(GANT#1), 439101-653(GANT#1) and 439101-654(GANT#1) have tracks smaller than 9-10μm (Appendix 7) suggesting an even more complicated history for these areas. The occurrence of small tracks is the result of partial annealing, due to a mild temperature increase, causing a decrease in the length of the accumulated fission tracks. This is in agreement with colder conditions in the northern part of Nuussuaq. The preservation of small tracks indicates that the ambient temperature cannot have been very high and this is supported by the apparent ages not deviating from the overall age range. It should be noted, however, that one would expect younger ages for these samples when the temperature increase takes place at a much younger time-point. The small tracks could be relics of an older history of these samples or it could preclude rapid cooling from maximum palaeotemperature to below ≈60°C and thus favour a temperature history involving protracted cooling for these samples. Nevertheless, the presence of these small tracks indicate that the obtained ages are mixed ages and should be treated with care!

All these confusing and contradicting interpretations illustrates the weakness of using fission track analysis, - if it is not closely combined with and constrained by geological information. Therefore, in order to determine which of these qualitative interpretations and temperature history scenarios are the most likely, fission track modelling are needed (see Section 8.3).

8.3 Fission track modelling

Fission track modelling was used in this study to assess the thermal history and uplift history constrained with available geological data and maturity modelling. The mathematical model used in this study is a in-house computer program developed together with P.K. Jensen (Jensen et al., 1993). The fission track modelling program uses a modified version of the annealing algorithm of Laslett et al. (1987), calibrated from the Durango apatite, equivalent to the most common apatite composition. The model integrates results from the Yükler basin model and combines it with geological information, age of fission track distribution and temperature history for a given sample. Thus, the modelling procedure used here incorporate stratigraphic constrains and modelling results obtained from maturity modelling to further assess the burial and temperature history of the Nuussuaq Basin.

The uncertainties associated with maturity data have a direct impact on determination of the heat flow history. The use of fission track data, as a supplement to the maturity data, demonstrate a need for further adjustment of the thickness of the Volcanic Succession and the Paleogene and Neogene uplift and erosion. In the few cases where optimisation using maturity data and optimisation using fission track data have resulted in conflicting heat flow histories, the model optimised against maturity data has been weighted higher. This decision was made because, in contrast to maturity data, the apatite data are often obtained from single scattered samples that could have been affected by local dykes and convection of hot water.

Furthermore, one must emphasise, that the *best* thermal history obtained by fission track modelling may not necessarily be the *true* one, nor will it necessarily be *unique*, i.e. there may be others thermal histories which can match the observed data equally well, and that the model solutions are relatively insensitive to temperature variations below 50-60°C. The quality of the thermal history is governed by the quality of the original data and thus structure and resolution in a individual thermal history should not be over-interpreted, particularly where relatively few track-length measurements were determined. Only the data from:

- Sample 400914 : Itilli
- Sample 439101-653 : GANT#1
- Sample 439101-654 : GANT#1

are of sufficient quality to permit reliable fission track modelling. Of these 3 samples sample 439101-654(GANT#1) has the most optimal relationship between fission track age (i.e. around deposition of Volcanic rocks) and number of tracks (min. 75 tracks) (Table 8.1). Based on fission tracks modelling, all three samples fit the same thermal history:

- maximum palaeotemperature and maximum burial in Late Cretaceous/Early Paleocene (~70-50 Ma).
- followed by relatively monotonic cooling through the Paleogene and Neogene

Sample 400914(Itilli) appears to have been totally annealed in the Early Paleocene (i.e. max. palaeotemperature > 110°C), while sample 439101-653(GANT#1) experienced a maximum palaeotemperature of ~100°C, and sample 439101-654(GANT#1) was 5-10°C hotter. Samples 439101-653(GANT#1) and 439101-654(GANT#1) both have a distinctive tail of very short tracks (i.e. a strong negative skew to the track-length distribution)(Appendix 7). This suggest a very high degree of annealing, as would be expected at temperatures of 100-110°C.

The fission track modelling strategy was to check the qualitative interpretation (Section 8.2) and to adjust the previously obtained basin model strategies based on maturity data (Model Scenario A and B, Section 6.1). Unfortunately the well with the best maturity data, the GRO#3 well, has not yet been sampled for fission track analysis. Thus the GANT#1 well, which also contains reliable maturity data, and especially the sample (439101-654(GANT#1), was has used to illustrated the different fission track modelling scenarios.

Plots of the results for all the 11 samples are included in Appendix 8 (App.8a.1 to App.8a.11 and App.8b.1 to App.8b.11). The match of both Model Scenario A and B are acceptable. Model Scenario B ('Minimum volcanics') seems to match the fission track distribution a little better than Model Scenario A. From the fission track modelling results it can be concluded that:

- The Itilli samples (400914, 400916, 409131a and b) are not annealed enough, either do to few volcanics or due to local hydrothermal activity along the Itilli fault (App.8a.1 to App.8a.4 and App.8b.1 to App.8b.4).
- The GANE#1 sample (439001-737) show perfect matches (App.8a.5 and App.8b.5).
- The GANT#1 samples (400878, 439101-653, 439101-654 and 439101-655) all match reasonable well. The two uppermost samples (400878 and 439101-653;

App.8a.6 and App.8a.7) are a little too hot, indicating that the Model Scenario A ('Maximum volcanics') have too thick volcanics compared to Model Scenario B. App.8a.8 and App.8b.8 indicate a linear cooling history increasing up to present time; however, all 4 samples indicate very late cooling (i.e. during Quaternary).

- The Annertuneq samples (400881 and 400813) all match reasonable well. Again Model Scenario A ('Maximum volcanics') is a little too hot due to thicker volcanics compared to Model Scenario B (e.g. App.8a.10 vs. App.8b.10).

Appendix 9 is a scenario (GANT_1x1) to illustrate the effect of a post mid-Eocene cooling history (i.e. Post- *3. mid-Eocene Unconformity*, Appendix 2). All erosion of volcanics lie within the last 5-10 my. The maturity data gives a perfect match, but the fission track modelling gives a poor match (App.9.1 vs. App.9.2).

Furthermore, different cooling scenarios were used for sample 439101-654 (GANT#1) to assess the fission track modelling sensitivity and cooling trend. The following cooling scenarios, based partly on the qualitative interpretation and geological knowledge, have been modelled; all with a acceptable match (i.e. a possible solution) (Appendix 10); App.10a.1 is original Model Scenario B ('Minimum volcanics') version of the 439101-654 sample (= App.8b.8):

- Removing the Eocene deposits gives too thin volcanics (App.10a.2)
- Peneplanetion is located in the upper part of annealing zone, but should residence within the middle part of the partial annealing zone (~90-70°C) (App.10a.3)
- Miocene peneplanetion fits the data better than a older peneplanetion (App.10a.4)
- The erosion rate decreases, but calculates too long fission tracks (App.10a.5)
- Example of a optimal cooling history, based on fission track modelling of **one** sample alone (App.10a.6)
- Deposition during Eocene is acceptable within 300-400 m depending on lithology (sediments or volcanics) and heat flow (App.10a.7)

The max. temperature and the timing of heating events (65 Ma. 30 Ma. etc.) are difficult to model due to lack of enough reliable samples.

The modelling scenarios illustrate that it is not yet possible to determine heating events prior to time of maximum temperature but subsequent heating events can only be detected if the temperature has been lower that the maximum temperature. Consequently, it is not possible to determine the temperature history prior to 49 Ma.(≈ oldest Fission Track Age) for the sample 439101-654(GANT#1), and only to some extent the temperature history around deposition of the Volcanic succession (≈ 61½-49 Ma.), from the fission track data alone. Furthermore, it clearly illustrates how difficult it is to determine a specific temperature-time path for a given sample based on fission track alone. One will often end up with more that one solution. Thus, other methods should be used in combination with fission track analysis and modelling and it shows why geological constrain and maturity modelling is necessary.

8.3.1 Conclusion

The fission track modelling results show that a simple straightforward interpretation of apatite dates as reflecting simple post-volcanic uplift and cooling is the most realistic scenario based on the very limited data. Data quality (numbers of crystal ages and track lengths) for the samples is so variable, due to low apatite content, that quantitative modelling is only practical for 3 samples, where one has been chosen for modelling of different scenarios. From fission track modelling the following is concluded:

- Fission track modelling showed that the basic concept, to use the same generalised heat flow history in all wells and pseudowells, could be accepted. Minor adjustments had no influence on the maturation optimisation.
- Of the two Model Scenarios A and B, B gave the overall best match, but A is almost as acceptable.
- Maximum palaeotemperature and maximum burial in Late Cretaceous/Early Paleocene (~70-50 Ma), was followed by relatively monotonic cooling through the Paleogene and Neogene, and with increasing erosion rate (i.e. erosional denudation rate) during especially the last 5-10 my.
- The combination of the 4 samples stratigraphically picked in or collected near the GANT#1 well location illustrates the obvious use of fission track modelling if samples are collected based on geological knowledge.

Younger geological events could have been involved in order to explain the side by side occurrence of apatites of different ages (Appendix 7). The following alternatives should be considered:

- Block faulting with considerable vertical movement (the role of Kuugannguaq and Itilli faults Fig.2.1)

- Thermal activity during the Late Paleogene and Neogene; the possible existence of Eocene deposition (App.10a.7)
- Variation in composition of the apatites, expressed in Cl/(Cl+F) ratios
- Recent U-gain or U-loss of the apatites (not known)

In such a balanced, but also critical system, small variations in the rate of uplift or in the geothermal gradient, operating over longer time, can generate a large variation in fission track dates and distribution. Even small variations in chemical composition of apatites can influence the final results, because of different annealing behaviour of fission tracks under similar temperature-time conditions. It is worth noting that the fission track modelling algorithm used in this study takes, to some degree, the variations in apatite into account. Furthermore, no Cl-rich apatite has been observed (Kierkegaard, Pers.comm., 1997). If the apatites are Cl-rich, then the palaeotemperature estimates would be ~10°C too LOW. If the apatites were pure F-rich apatite, then the palaeotemperature estimates would be ~10°C too HIGH. If the detrial grains are of variable composition, then the shorter track may well be associated with F-rich apatite and the longer tracks with more Cl-rich apatites. In this case, we can assume that the Durango model may give a reasonable approximation to an average composition, although the maximum palaeotemperature estimates may be slightly too high (within 10°C) and the rate of cooling a little to rapid.

9. Discussion

The following main issues from the present modelling study should be discussed:

1. Which model scenario is the most likely in the Nuussuaq Basin: Model Scenario A with a maximum volcanic thickness of 3-4 km or 1000-1500 m more than observed to day or Model Scenario B with minimum volcanic thickness of 2-2.5 km or only a few hundred meters above the maximum height of the mountains in the hinterlands.
2. What erosion or cooling history is the most possible.
3. Existence of Eocene volcanic activity or sedimentation.
4. Exploration potential.
5. The time relation between: Volcanism <-> Erosion <-> Uplift <-> Tilting <-> Faulting.
6. Regional significance.

<u>Add.1:</u> The Model Scenario A and B are both possible according to the modelling results (Section 7 and 8), however Model Scenario B seems to match the data slightly better than Model A. There are many observation which supports both the scenarios:

- **Model Scenario A:** stratigraphic thickness of up to 2 km or more hyaloclastites and continental flood basalts of the Vaigat Formation are found in the Nuussuaq area, 2 km of the overlying Maligât formation are found on Disko just south of Nuussuaq and around 5 km on Ubekendt Ejland and Svartenhuk Halvø north of Nuussuaq (Section 3.2). If the top volcanic surface offshore on Figure 9.2 is extrapolated onshore, and accounting for the displacement along the Itilli, Gassø and Kuugannguaq Fault zones (Fig.3.2), then the top volcanic surface lies ~1500 m above present day maximum height of the mountains.
- **Model Scenario B:** The major extensional episode (*Late Rift B (Chron 33-24r),* Appendix 2) lead to crustal thinning and sagging, and to mantle upwelling with subsequent decompressional melting indicating high heat flow values under the Nuussuaq basin ('Possible large intrusion in basement' in Fig.9.1). Interpretation of zeolite zone boundaries indicates that 1450 m of volcanics are missing above the Marraat area (Section 3.5). Interpretation of GRO#3 vitrinite reflectance data, indicates that the thickness of eroded volcanic succession can be estimated to ~2000 m, which corresponds fairly well to the maximum height of the surrounding mountains.

Assuming the same general heat flow history for all the wells, the combined results from maturity modelling and fission track modelling clearly indicate variation in volcanic thickness. This variation is both between the southern part and the northern part of the Nuussuaq Basin and local variation within the southern part (i.e. the GANE#1 and GANK#1 wells). In general, this means that hydrocarbons in the northern part have experience colder conditions than those in the southern part. This could be explained by thinner volcanics in the northern part of the Nuussuaq area, but could also be explained by:

- Lower heat flow due to a higher frequency of intrusions and/or hydrothermal activity in the southern and especially western part of the Nuussuaq Basin
- Tilting during the volcanic stage, causing the indicated variation in volcanic thickness

It is important that the Model Scenarios A and B should be regarded at a maximum and minimum case and that the results are based on a limited number of optimisation data. Hopefully new data will substantiate which of the model, that is the most likely .

Add.2: The amount of erosion in the wells and pseudowells varies from ~4000 m in west down to ~2400 m in the north according to Model Scenario A and from ~2400 m in west down to ~1200 m in the north according to Model Scenario B. Both scenarios illustrate the need for thinner volcanics in the north, if the heat flow history is the same in the whole area. Furthermore, both scenarios could fit the optimal cooling history, based on fission track modelling of **one** sample alone (App.10a.6). In absence of sufficient good-quality track length data, it is difficult to establish whether cooling from maximum temperature was rapid or protracted even though there is evidence from East Greenland of a rather protracted uplift and cooling history throughout the Paleogene and Neogene (Mathiesen et al., 1999)

In general, the amount of erosion is clearly decreasing from the onshore area towards the offshore area (Fig.9.2), where there is a general increase in thickness of Paleogene sediments towards west. The interval overlying the volcanics show a distinct down lapping and onlapping pattern toward to the onshore part. Thus, the interval interpreted as Upper Eocene seems to be missing further onshore, probably due to uplift onshore during or after the Upper Eocene period (Chalmers, Pers.comm, 1998).

Add.3: A sample from a comendite tuff gave a plateau age of 52.5 ±0.2 Ma which could indicate igneous activity in West Greenland during the Early Eocene. As shown in Section 7 and 8 it is possible to keep a consistent model if Eocene thickness is up to 300 to 400 m or more if a heat flow lower than the 1.2 HFU used. It should be emphasised that this is based on **one** fission track sample only from the northern part of Nuussuaq. It is not possible to determine if it is 300 m volcanic rocks or e.g. 400 m sediments. The three fission track samples 400878(GANT#1), 400813(Annertuneq) and 400881(Annertuneq) all contain qualitative evidence for a Late Eocene reheating at ~30 ±10 Ma.

<u>Add.4:</u> The oil discovered on Nuussuaq is so widespread and includes so many types of oil that more than one effective source rock must occur below the basalts. Occasionally there is evidence of mixing of several of the oil types either during migration or trapping. There is no doubt than the thickness and distribution of the volcanics play a major role on the generation history of these source rocks (Section 7 and 8). According to the basin modelling results the hydrocarbons were generated just after or during deposition of the volcanics at ~50 Ma.

Comparison of the distribution of seeps (Fig.2.1) with the structural map (Fig.9.1) shows that the seeps occur where the depths to basement are large, i.e. in the block-faulted region north of the Disko Gneiss Ridge. If there are hydrocarbons in this area, the fault-blocks could form structural traps (Fig.3.2).

The main potential reservoirs onshore Nuussuaq are all found below the volcanics; the Upper Cretaceous fluvio-deltaic sandstones (Atane Formation), the Paleocene marine canyon sandstones (Quikavsak Member) and Upper Cretaceous–Paleocene Slope channel sandstones (Itilli Succession), as have been documented in the GRO#3, GANE#1 and GANT#1 cores (Section 4). The finding of oil seeps indicate that the hydrocarbons have migrated through the volcanic rocks where they were lost. Offshore similarly generated oil could accumulate in post mid-Eocene reservoirs overlying the volcanics further to the south-west.

Interpretation of the Marraat area indicates that oil migration in this area took place after the growth of zeolite minerals. The solid bitumen is seen as both an early and a late phase in the Marraat-1 core. The liquid is observed to be the latest phase filling the empty or not totally filled vesicles and veins. Thus, at least two different phases of oil migration have occurred separated during the Paleocene (Section 3.5). Up to five different oil types in such a limited area does not indicate long distance migration. Tectonic movements along the transtensional Ungava Fault Complex in Eocene may have controlled the oil generation and later migration or re-migration during downfaulting west of the Itilli fault zone providing room for the Maligât Formation (2*. West Greenland Basalts*, Appendix 2) or along dike intrusions acting as migration paths. The 6 my gab during deposition of the Maligât Formation in and west of the Itilli fault zone could cause local variation in thermal maturity in this area, due to hydrothermal activity.

Other unexplained observations, which has to be considered are:

- Why is oil seeps and shows only found in connection with volcanics of the Vaigat Formation and not in connection with the Maligât Formation.
- Why is the oil not biodegraded if it was generated ~50 Ma.
- In the GRO#3 well, observations on the thermal maturity may have important structural implications, as they may suggest that the tilted fault block structures were formed after the main phase of subsidence and thermal maturation and possibly also petroleum migration.

The problem with timing and duration of the volcanism and the interplay between volcanism and Early Paleocene sedimentation due to disagreement between the biostratigraphic work and $^{40}Ar/^{39}Ar$-geochronology (Section 3.1 and 3.2) will only affect time for generation of hydrocarbons by 5 my and is only of minor importance.

Figure 9.1 divides, based on structural styles, the Nuussuaq area into provinces with different prospectivity. The main prospective area extend from north-western Disko, across central Nuussuaq east of Itilli fault and somewhat further to the north into Uummannaq Fjord (Fig.9.1). This area is characterised by large, rotated fault blocks which could provide structural traps. Furthermore, the Pre-volcanic sedimentation is often more than 5 km thick and the area includes the main surface indication of oil found so far (Fig.2.1). The ages, depositional environment and lateral extent of the potential source rocks are largely unknown. For the source rocks to be mature, they have to be buried at a minimum depth, implying that they will not be mature where depth to basement is low. A arbitrary depth to basement of approximately 1 km has so far been used to divide possible prospective areas from non-prospective areas (Fig.9.1). The prospective area may continue further south on western Disko. Depth to basement is here between 2 and 4 km below sea level and mature source rocks, reservoirs and seals could all be present. The intensity of volcanism may have been too intense as many of the eruption sites are found in or west of this area. On eastern Nuussuaq, eastern Disko and in Disko Bugt, the depth to basements is generally less than 2 km and possible source rocks would not be mature. In Disko Bugt the seismic surveys furthermore suggest that the sediments are probably very uniform in lithology (seismic Facies 2) and it is therefore not likely that reservoirs, source rocks and seals are found together. In a small area under eastern Disko depth to basement is calculated to be more than 3 km (Fig.9.1) and possible source rocks could be mature. However, the seismic interpretation in this area is very uncertain (Chalmers, Pers.comm, 1998). Oil generated here could migrate laterally into traps along the eastern flank of the Disko Gneiss Ridge and under Disko.

Add.5: The Itilli fault zone, with tilting of the basalts northwest of the fault zone, is regarded as a relatively young feature and no other SW-NE orientated faults have been identified in the Nuussuaq Basin east and south-east of the Itilli fault. Observations on the thermal maturity have important structural implications, as they may suggest that the tilted fault block structures were formed after the main phase of subsidence and thermal maturation at 60-50 Ma and possibly also after petroleum migration.

From the 1:100.000 map sheets Qutdligssat and Agatdal (e.g. change from hyaloclastite to subaerial facies) the Vaigat Formation strikes roughly SW-NE across northern Disko and Nuussuaq (Fig.3.3) and dips towards E-SE (Fig.3.2). There is a remarkable parallelism between the height contours in and the direction of the NE-SW striking Itilli fault zone (Fig.3.3). Larsen and Pedersen (1992a) concluded, based on several field observations, that considerable crustal movement took place contemporaneously with the deposition of the volcanic rocks. The movement started no later than the time of beginning of the Ordlingassoq Member and continued until after the deposition of the Niaqussat Member (Appendix 2). Relative subsidence in the south-east and uplift in the northwest is consistently indicated throughout this time. The occurrence of marine elements in the south at a relatively late stage in the basin development suggests that the actual movement was tilting and not differential uplift. The recorded crustal movement could not have been caused by loading by the heavy volcanic rocks because this would produce movements opposite to those observed (Fig.3.2). The crustal movements may have been caused by large-scale plate tectonic processes and reflect lithospheric thinning with subsidence in the south-east in combination with uprise and melting of mantle material at the site of the subsequently formed continental margin in the northwest (Fig.9.1). This indicates that tilting and Early Paleocene volcanism occurred contemporarily. If the Paleogene magmatism occurred from ~61½ Ma. to mid-Eocene, a period of more than 15 my it could indicate that the magmatic evolution of this volcanic margin was initially catastrophic but later reflected a long history of tectonic adjustments and minor volcanic activity.

Add.6: Interestingly, the slowdown to near cessation of seafloor spreading in the Labrador Sea (around mid-Eocene, 46-49 Ma), corresponds with igneous activity along the East Greenland margin between 47-55 Ma (Mathiesen et al., 1995). This igneous activity may be related to the relative eastward motion of the Iceland plume (Dam et al., 1998). The coincidence in timing at ~60 Ma with the volcanic succession, suggests that the location of the hotspot appears to have directly influenced onset of seafloor spreading in the northern Labrador Sea, but also its eventual shutdown at ~50 Ma, as the Iceland plume became progressively more influential in the eastern Atlantic.

<u>Development of the Nuussuaq Basin</u>

There appears to be a 6-8 km deep basin under north-western Disko, western Nuussuaq and Vaigat that extends northwards beyond data coverage (Fig.9.1). It is possible that this deep basin in the northwest is a rift-basin (*Pre- to Syn-Rift A*, model event 1-10; Appendix 2) bounded its east by a fault zone (Gassø fault zone or the Kuugannguaq fault zone)(Fig.3.2). If this is the case, the more extensive shallower basin east of the fault zone that extends over much of eastern Nuussuaq, eastern Disko and Disko Bugt could represent the thermal subsidence phase of this rifting episode, during which the Atane Formation was deposited. These basins were then dissected by a new phase of rifting in the Maastrichtian and Early Paleocene (*Late Rift B*, model event 12-17; Appendix 2)(Dam et al., 1998; Chalmers et al., 1999b) which created the N-S and WNW-ESE trending faults that form the eastern limit of the basin and large, faults blocks, 2 to 20 km wide, which rotated the Facies 1 sediments (i.e. Atane Formation) into the blocks as described by Chalmers et al., (1999b). The rift blocks were then eroded (*2. E. Paleocene Unconformity,* model event 17; Appendix 2). Just after this voluminous Late Paleocene basaltic lavas were extruded and contemporary tilted, due to mantle upwelling increased the maturity of the source rocks (model event 18-23; Appendix 2). These were in turn dissected during the Eocene by faults along the N-S trend and a new NE-SW Itilli trend (model event 24-27; Appendix 2) before the area was further uplifted and eroded (model event 28-42; Appendix 2).

9.1 Tectonic backstripping

To determine the timing and magnitude of erosion in an area like the Nuussuaq Basin, it is necessary to calculate the thickness of the originally deposited sediments and then to determine how and when the sediments were removed by erosion. The key to this problem is the thermal maturity of the remaining sediments. The information on the thermal history of sediments is stored in the thermal indicators. The thermal history of the sediments is evaluated as a consequence of the input data by calculating the corresponding thermal indicator values. Measured and calculated values are thus compared and input parameters are subsequently changed until an acceptable fit is obtained. The first step is to develop a consistent geological scenario for the whole area, which is in accordance with all available geological information. The next step is to adjust the depositional part of the model in such a way that the maximum values for the maturity parameters calculated are in agreement with those measured (see Section 7). It is essential to determine the maximum temperature, because the maturity indicators are much more sensitive to temperature than to time. This also means that thermal indicators such as isomerisation of steranes and vitrinite reflectance give little if any information on the cooling history during erosion and uplift. However, basin modelling applying apatite fission track length distributions offers a unique opportunity to determine the erosion history (see Section 8). The annealing of individual fission tracks can be described by more or less the same chemical reaction theory as the alteration of other thermal indicators (Laslett et al., 1987; Duddy et al., 1988)(see Section 8.1). Individual fission tracks consequently do not hold more information on the erosion than maturity indicators. The fundamental difference is, however, that new fission tracks are constantly generated throughout time, while the organic material which forms the basis for the other thermal indicators was formed at the time of deposition. This means that the youngest fission tracks, which are the longest, only has experienced the latest part of the thermal history, and thus contains information on this part of the geological history.

In Nuussuaq Basin it has been possible to analyse apatites where all tracks older than the time of maximum temperature has been totally annealed (Section 8). In this case all existing fission tracks contain information on the cooling history and thus the erosion history at this particular point in space. Fission track analysis is therefore excellent to constrain the erosion history. As mentioned, the pattern of hydrocarbon generation zones follow the unit boundaries during the period of erosion (Section 7.3 and Appendix 6). This means that different geological models of erosion generates the same amount of hydrocarbons. Furthermore, the timing of this generation is the same. However, even small tectonic movements may generate or remove traps or they may change the direction of updip migration of the hydrocarbons generated. Information on the uplift pattern of the region is therefore important for the evaluation of the plays in the area.

In order to distinguish the tectonic uplift from the total erosion, the individually wells and pseudowells have to be referred to a common reference level. One reference level could be the surface elevation of the wells (Riis and Jensen, 1992). The tectonic uplift is then estimated from a series of sections with projected wells and pseudowells. These sections are then tectonically backstripped to remove the effect of the changing sediment load. For this purpose a simple Airy type isostatic model (Airy, 1855) is chosen, although the dimensions of the present day Nuussuaq Basin may be too small for this assumption. The reason for this is that information on the flexural rigidity of the lithosphere in the region is not available (Chalmers, Pers.comm, 1998).

Furthermore, it is assumed that the Nuussuaq Basin always has been and still is in isostatic equilibrium and that the wells and pseudowells are in isostatic equilibrium if the elevation of the top of the well or pseudowell corresponds to the mean elevation within a radius of 10 km. The remaining and missing section has been included in the compensation and the densities used for the sediments in this compensation have been taken from the basin modelling output. First the profile are isostatically compensated to show the profiles just after the deposition of the Upper Cretaceous to Lower Paleocene sediments. If the sediments during this period were close to sea level the elevation of the Upper Cretaceous surface on the backstripped profiles represents the tectonic uplift.

This strategy could be acceptable for the Nuussuaq Basin, and has been used with success for the Jameson Land Basin (Mathiesen et al., 1999). However, as stated above, the maximum extension of the Nuussuaq Basin, the geological understanding, the two possible model scenarios, the timing and distribution of volcanics and sediments is at present very limited. Due to the complex geology, the lack data and thus a reliable reference level, it is without meaning to try to backstrip 5 wells, where 4 of the wells are located within 20 km.

Hopefully, as the geological understanding increases, backstripping of profiles and compiling of maps with total and tectonic uplift will become more demanding and reasonable.

10. Conclusions

Apatite fission data (AFTA) and Vitrinite Reflectance (VR) can be integrated and modelled together to allow tighter constraints to be placed on the unknown parts of the thermal history of rocks than would be possible by modelling of either one or the other thermal indicator. The integrated modelling of VR and AFTA data has been essential to establish the complete range of maximum temperatures and the timing of uplift of the Nuussuaq Basin, because neither methods gives a complete result by itself. For example, in parts of the basin the maximum palaeotemperature exceeded the range over which fission tracks can record temperatures (20-≈120°C), which is not a limitation for the VR. Fission track record the timing of cooling, whereas VR does not. This more complete description, made possible by the integrated modelling, allows us to compare the timing and magnitude of uplift of the Nuussuaq basin independently with the timing of subsidence and unconformity development.

Basin modelling constrained by maturity data and apatite fission track data has made it possible to outline a consistent erosion and uplift history of the Nuussuaq Basin. The uncertainties associated with maturity data have a direct impact on determination of the heat flow history. In the few cases where optimisation using maturity data and optimisation using fission track data have resulted in conflicting heat flow histories, the model optimised against maturity data has been used. This decision was made because, in contrast to maturity data, the apatite data are often obtained from single scattered samples that could have been affected by local dykes and convection of hot water and because of the moderate quality of the data.

A general model concept and timeframe has been established and has then been used as input for an integrated 1D basin modelling and fission track modelling study and is based on application of all available core- and log-data as well as other information of sedimentological, organic geochemical, biostratigraphical and petrophysical nature. In addition, seismic and interpretation has been used. New interpretation of seismic and stratigraphic data as well as new collected data show the distribution of several km thick pre- and syn-rift sediments of presumed Cretaceous (or older) age. These sediments overlain by are Paleocene post-rift sediments both on- and offshore Nuussuaq. The Cretaceous and the Lower Paleocene deposits are assumed to contain possible source and reservoir rocks, together with structures that can accumulate hydrocarbons.

The integration of basin modelling and apatite fission track analysis and modelling shows that it now is possible to establish a consistent subsidence and uplift and erosion history, which match the optimisation data. The modelling study is based on new maturity data and fission track data.

The main conclusions are:

- It has been documented how important the data background is for constraining and quantifying the geological model concept. The project shows that the understanding of the maturity data has been increased, but that the fission track data are to few to decide which of several possible model concepts is the most likely.
- Two concepts, which should be regarded as a maximum and minimum case are established:
- **Model A:** after extrusion of 3-4 km thick volcanics first as a linear then as an increasing erosion rate up to present removed volcanics and sediments corresponding to 1000-1500 m more than the present height of the mountains. The heat flow peak at 1.4 HFU is limited to short periods around the extrusion of the volcanic rocks.
- **Model B:** after extrusion of 2-2½ km thick volcanics first as a linear then as an increasing erosion rate up to present removed volcanics and sediments corresponding the present height of the mountains. The heat flow peak at 2.0 HFU is limited to short periods around the extrusion of the basalts and then decreases over the next 20 my.
- The amount of erosion in the wells and pseudowells varies from ~4000 m in west down to ~2400 m in the north according to Model A and from ~2400 m in west down to ~1200 m in the north according to Model B.
- Both model concepts are possible based on available data and illustrates the need for thinner volcanics in the north, if the heat flow history is the same in the whole area.
- Furthermore, both scenarios could fit the optimal cooling history, based on fission track modelling of **one** sample from the northern part of Nuussuaq alone. Based on the same fission track sample, fission track modelling supports the existence of up to 300-400 m Eocene deposition of volcanics rocks or sediments.
- Hydrocarbon generation history indicates, as a consequence of the extensive volcanics that the main generation of hydrocarbons took place just after extrusion of the volcanics. In addition generation of hydrocarbons could have been further increased during a Eocene deposition.

Although there is no unique solution for modelling 1D pseudowells, all results presented are in accordance with the suggested geological scenarios. In practice it is easy to change critical, but basically unknown, parameters and re-optimise the models using alternative scenarios.

The present study does not contribute to the discussion of the tectonic or magmatic mechanisms that obviously caused this major regional uplift. However, the quantitative data obtained - especially on the timing of uplift, are very important for comparison with other areas in the development of consistent models. Furthermore quantitative data on magnitude and timing of uplift have strong implications for hydrocarbon exploration, especially when discussing the preservation potential of once trapped hydrocarbons (Skagen, 1992). However, regardless of the results from this modelling study the Nuussuaq Basin still remains underexplored, but very promising, and future studies will without doubt increase the exploration potential.

Acknowledgements

The ‘West Greenland Group’ on GEUS is tanked for useful contributions and critical discussion on several of the topics included in this report. Torben Bidstrup is tanked for useful discussions and Jette Halskov for patience and drafting.

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Whittaker, R.C., Hamann, N.E. and Pulvertaft, T.C.R. (1997): A new frontier province offshore Northwest Greenland; structure, basin development, and petroleum potential of the Melville Bay area. *AAPG Bulletin* **81**, 978-998.

Yükler, M.A., Cornford, C. and Welte, J. (1978): One-dimensional model to simulate geologic, hydrodynamic and thermodynamic development of a sedimentary basin. *Geologische Rundschau* **67**, 960-979.

Figure captions

Fig. 2.1 : Summary map of the geology onshore and offshore showing locations, faults etc. together with the bathymetry offshore. **A**: Agatdalen, **Aaf**: Aaffarsuaq, **Ant:** Annertuneq **As**: Asuk, **Atk**: Ataata Kuua, **Atn**: Atanikerdluk, **DGR:** Disko Gneiss Ridge, **Ga:** Gassø Fault, **Ik**: Ikorfat **It**: Itilli **K**: Kuugannguaq, **M**: Marraat, **NK**: Nuuk Killeq, **Sa**: Saqqaqdalen, **Se**: Serfat, **Uka**: Ukalersalik, **Ung**: Ungava strike-slip fault system. Offshore faults are taken from Skaarup et al., (In Press).

Fig. 2.2 : Map of the northern part of Disko and Nuussuaq showing well locations and the distribution of localities with seepage, staining of oil and where petroliferous odour has been recognised.

Fig. 3.1 : Summary of stratigraphy of the Pre-Volcanic Sedimentation and succession of volcanics on Nuussuaq and north-eastern Disko. Modified from Piasecki et al., (1992); Pedersen et al., (1996) and Pedersen et al., (1998).

Fig. 3.2 : Simplified cross-section along the Vaigat fjord area based on a composite geological profile. Notice the annotated fault displacements. Modified from Chalmers et al., (In Press).

Fig. 3.3 : Geological map of Disko and Nuussuaq showing present-day distribution of the volcanic succession. Contours east of the Disko Gneiss Ridge are heights in meters for the base for the Niaqussat Member, Maligât Formation. Modified from Larsen and Pedersen (1992a).

Fig. 3.4 : Map showing the maximum distribution with maximum thickness annotated for the Vaigat Formation and the Maligât Formation. The volcanics (Maligât Formation) with maximum extent are the youngest and overlie the older volcanics (i.e. Model Scenario A ('Maximum volcanics')).

Fig. 4.1 : Regional map of the Disko-Nuussuaq-Svartenhuk Halvø area showing the distribution of localities with seepage and staining of oil.

Fig. 4.2 : Correlation of the GRO#3 and GANE#1 wells based on wireline log data and core material and used for event splitting. Presence and shows of hydrocarbons is marked with red bars. Log interpretation of the GRO#3 well indicates presence of hydrocarbon within Unit C. Modified from Kristensen and Dam (1997).

Fig. 6.1 : Section from Figure 3.2 with extrapolated total stratigraphic thickness of the volcanic succession before fault displacement. Outcrop information suggests, by ex-

trapolation, that basalts of a maximum thickness of 3-4 km once covered the area. The extrapolation assumes that the volcanics have been extruded on top of each other, at least in the western part of Nuussuaq.

Fig. 8.1 : Relationship between apatite Fission track Age and mean track length. Notice sample 409131a(Itilli); FTA = 36 Ma, which is the minimum age for the last major annealing event.

Fig. 9.1 : Depth to base of the sediments. Modified from gravity ‘a’ model from Chalmers et al., (In Press).

Fig. 9.2 : Simplified cross-section from offshore to onshore along the Vaigat fjord area based on a composite geological profile from Whittaker (1995) and Figure 3.2.

Appendix captions

Appendix 1 : A schematic cross-section through all wells pseudowells and areas with relevant geological information. All information has been compiled using the same depth reference. The composite cross-section includes information on thickness of model events based on Fig.3.2, palynozones, correlation and position of oil window and is based on well data Appendix 4 (above red line in each well) and other compiled knowledge (below red line and above top of well) from the Nuussuaq Basin.

Appendix 2 : Timeframe, stratigraphic framework and tectonic events and other important information combined with a simplified cross-section compiling geological information and stratigraphic relationship for the Nuussuaq Basin and the areas west of Nuussuaq. The schematic NE-SE cross-section runs from offshore areas and Hareøen trough Itilli along the south coast of Nuussuaq to north Disko.

Appendix 3 : Timeframe, event splitting, input thickness and other important basin modelling input data. Position of potential source rocks and fission track samples is also shown. **a)** <Wellname>_1 -concept with maximum amount of volcanics. **b)** <Wellname>_6 -concept with minimum amount of volcanics.

Appendix 4 : Maturity data from all wells used to optimise models combined with palynology. Position of top of oil window is based on maturity raking defined in (Christiansen et al., 1996).

Appendix 5 : Model concept tables and input parameter plots showing surface temperatures, heat flow values and deposition/erosion rates. Abbreviations for the input parameters columns are : **Nb**.: Sedimentary layer or event number; **NAME:** Formation/Event name; **LITHO:** Lithological type of the layer or event [Litho-Code]; **DURA:** Duration of event [My]; **THICK:** Thickness of sedimentary layer or event [m] where nature of the model event is expressed as deposition( ), non-deposition(0.0) and erosion(-); **PORO:** Average total porosity of the sedimentary layer [%]; **WATER:** Average palaeowater depth at the time of the sedimentary event [m]; **SURFTEMP:** Sediment-water interface temperature at the time of the event (palaeodepositional temperature) [°C]; **H-FLOW:** Regional heat flow history [HFU] **D-RATE:** Deposition or Erosion(-) Rate [m/My]; **TIME:** Time at end of model event [M.a.]; **DEPTH:** Present day depths. **a)** <Wellname>_1 -concept with maximum amount of volcanics. **b)** <Wellname>_6 -concept with minimum amount of volcanics.

Appendix 6 : Maturity Modelling; Optimisation and Hydrocarbon Generation Results. Coloured layers on the stratigraphic column on the right side of the optimisation plots mark potential source rock layers. Note that the coloured column the right side of the vitrinite reflectance plot is the widely used maturity zonation. This zonation should only be used as a guide line and should not be confused with the hydrocarbon generation zonation used in the hydrocarbon generation plots. **a)** <Wellname>_1 -concept with maximum amount of volcanics. **b)** <Wellname>_6 -concept with minimum amount of volcanics.

Appendix 7 : Fission Track Analysis Data and Results.

Appendix 8 : Fission Track Modelling; Optimisation and Results. **a)** <Wellname>_1 -concept with maximum amount of volcanics. **b)** <Wellname>_6 -concept with minimum amount of volcanics.

Appendix 9 : Fission Track Modelling; Post mid-Eocene Erosion.

Appendix 10 : Fission Track Modelling; Cooling History Scenarios.

Appendix 11 : Report: Boserup,J and Christiansen,F.G.: (1998): LECO and Rock Eval data from the Nuussuaq Basin, onshore West Greenland.
- Available from: https://doi.org/10.22008/gpub/15375

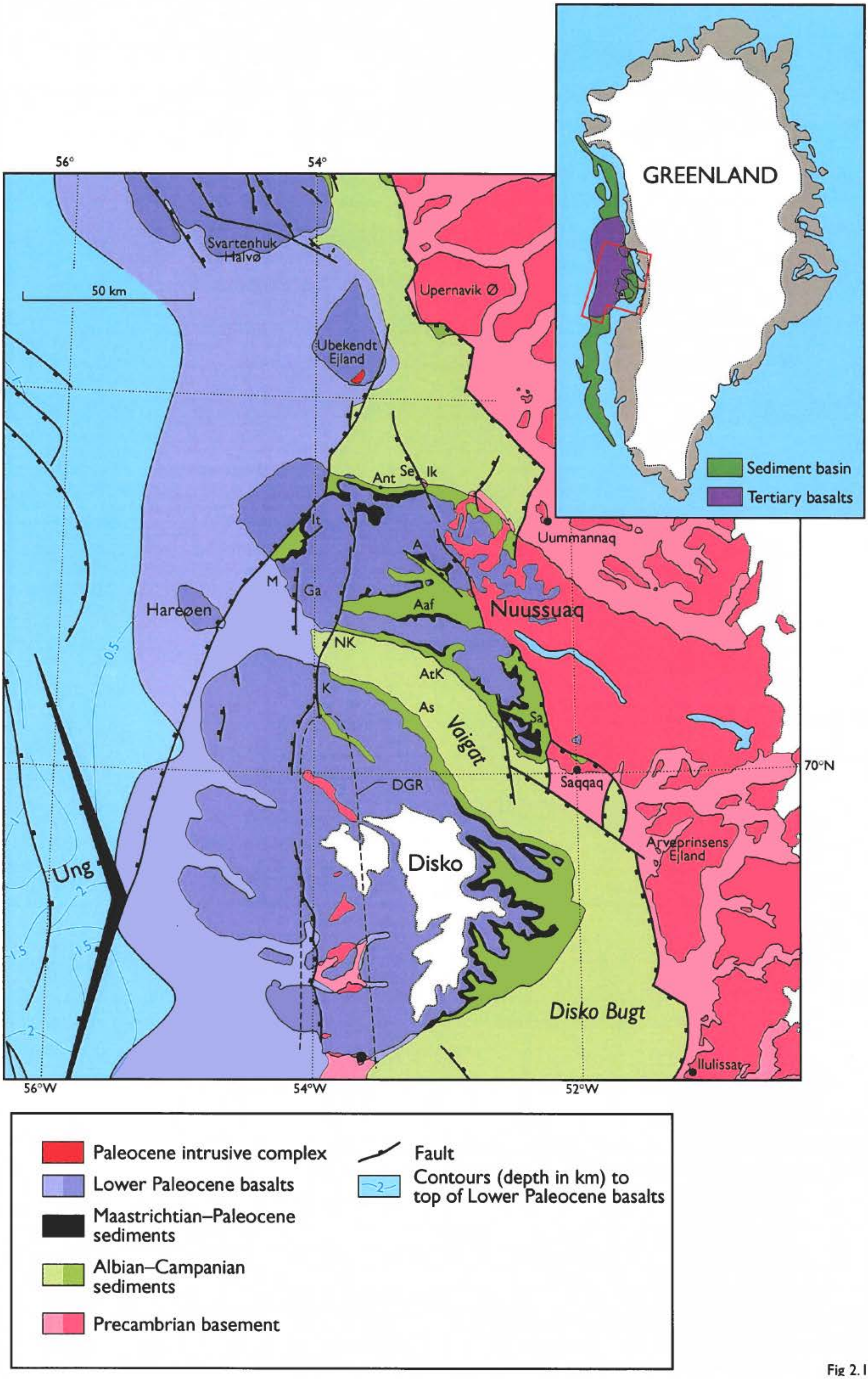

GREENLAND
Sediment basin
Tertiary basalts
56°
54°
Svartenhuk Halvø
50 km
Upernavik Ø
Ubekendt Ejland
71°N
Ant
Se
Ik
It
Uummannaq
A
M
Ga
Hareøen
Aaf
Nuussuaq
NK
0.5
AtK
K
As
Vaigat
Sa
70°N
70°N
DGR
Saqqaq
Arveprinsens Ejland
Ung
Disko
2
1.5
1.5
2
Disko Bugt
Ilulissat
56°W
54°W
52°W
Paleocene intrusive complex
Lower Paleocene basalts
Maastrichtian–Paleocene sediments
Albian–Campanian sediments
Precambrian basement
Fault
Contours (depth in km) to top of Lower Paleocene basalts

Fig 2.1

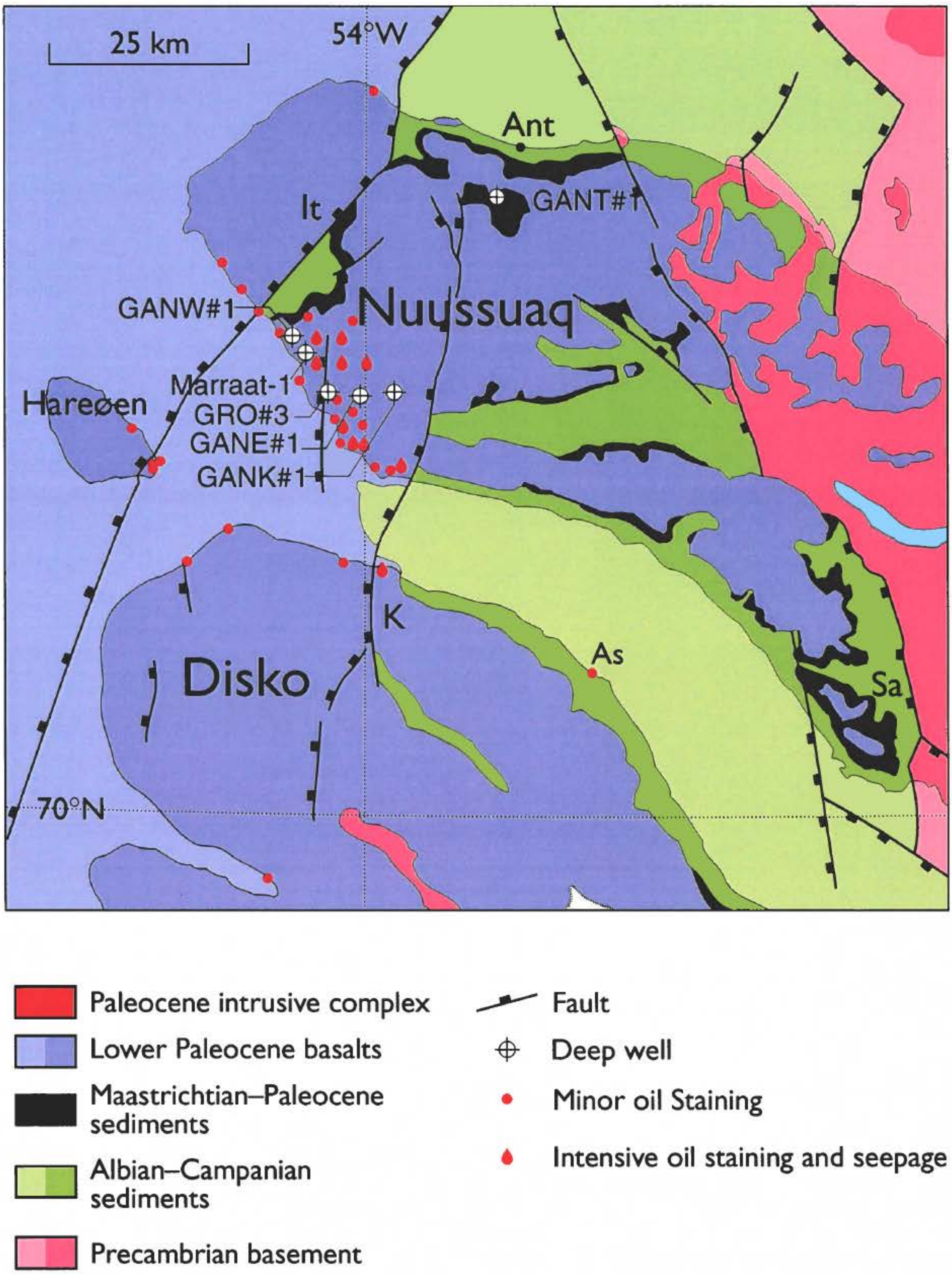
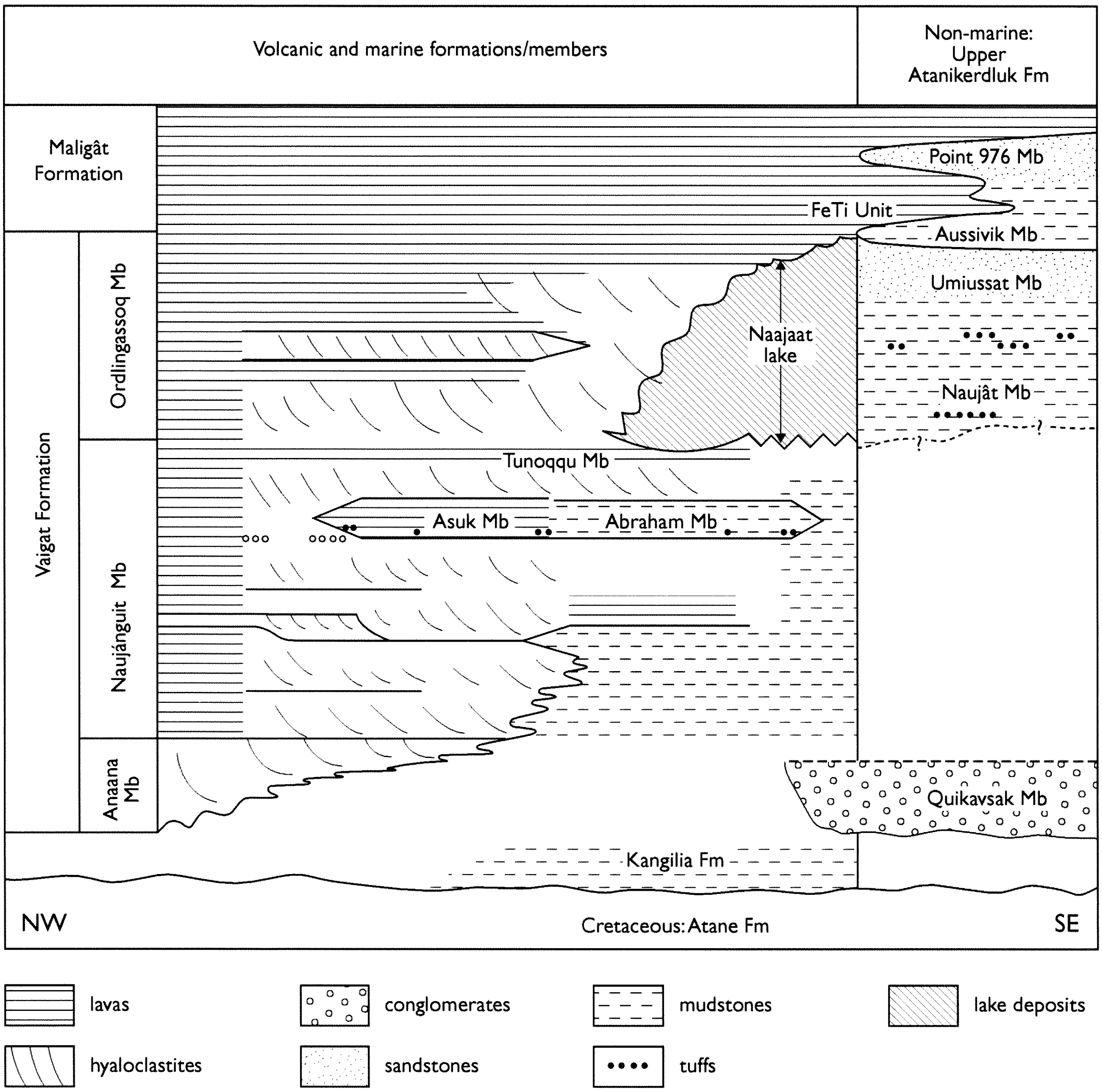

25 km
54°W
Ant
GANT#1
It
Nuussuaq
GANW#1
Marraat-1
Hareøen
GRO#3
GANE#1
GANK#1
K
Disko
As
Sa
70°N
Paleocene intrusive complex
Lower Paleocene basalts
Maastrichtian–Paleocene sediments
Albian–Campanian sediments
Precambrian basement
Fault
Deep well
Minor oil Staining
Intensive oil staining and seepage

Fig 2.2


Volcanic and marine formations/members
Non-marine: Upper Atanikerdluk Fm
Maligât Formation
Vaigat Formation
Ordlingassoq Mb
Naujánguit Mb
Anaana Mb
60.0 Ma
60.5 Ma
61.0 Ma
61.5 Ma
Point 976 Mb
FeTi Unit
Aussivik Mb
Umiussat Mb
Naajaat lake
Naujât Mb
Tunoqqu Mb
Asuk Mb
Abraham Mb
Quikavsak Mb
Kangilia Fm
NW
Cretaceous: Atane Fm
SE
lavas
conglomerates
mudstones
lake deposits
hyaloclastites
sandstones
tuffs

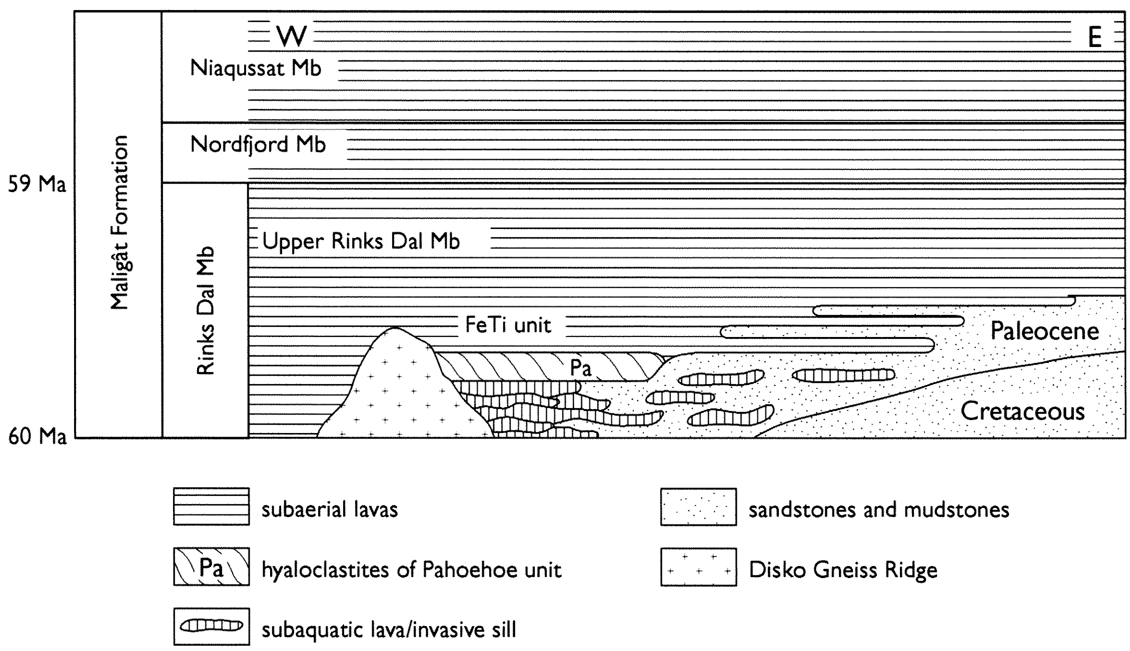

W
E
Niaqussat Mb
Nordfjord Mb
Maligât Formation
Rinks Dal Mb
Upper Rinks Dal Mb
59 Ma
60 Ma
FeTi unit
Pa
Paleocene
Cretaceous
subaerial lavas
sandstones and mudstones
Pa
hyaloclastites of Pahoehoe unit
Disko Gneiss Ridge
subaquatic lava/invasive sill

Fig 3.1

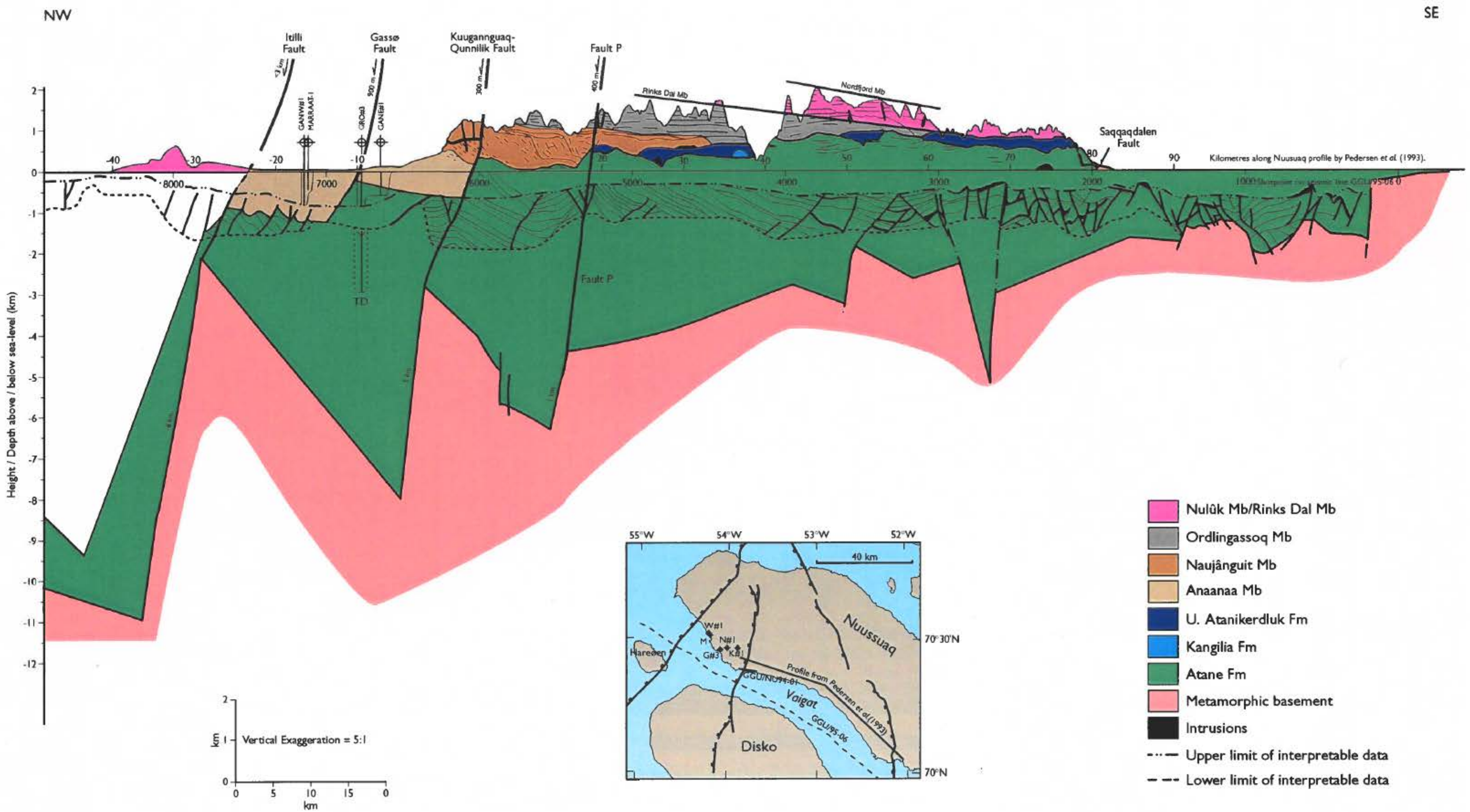

NW
SE
Itilli Fault
Gassø Fault
Kuugannguaq-Qunnilik Fault
Fault P
Rinks Dal Mb
Nordfjord Mb
Saqqaqdalen Fault
Kilometres along Nuusuaq profile by Pedersen et al. (1993).
Height / Depth above / below sea-level (km)
TD
Vertical Exaggeration = 5:1
km
55°W
54°W
53°W
52°W
40 km
Nuussuaq
70°30'N
70°N
Hareøen
Disko
Vaigat
Profile from Pedersen et al.(1993)
GGU/95-06
Nulûk Mb/Rinks Dal Mb
Ordlingassoq Mb
Naujânguit Mb
Anaanaa Mb
U. Atanikerdluk Fm
Kangilia Fm
Atane Fm
Metamorphic basement
Intrusions
Upper limit of interpretable data
Lower limit of interpretable data

Fig 3.2

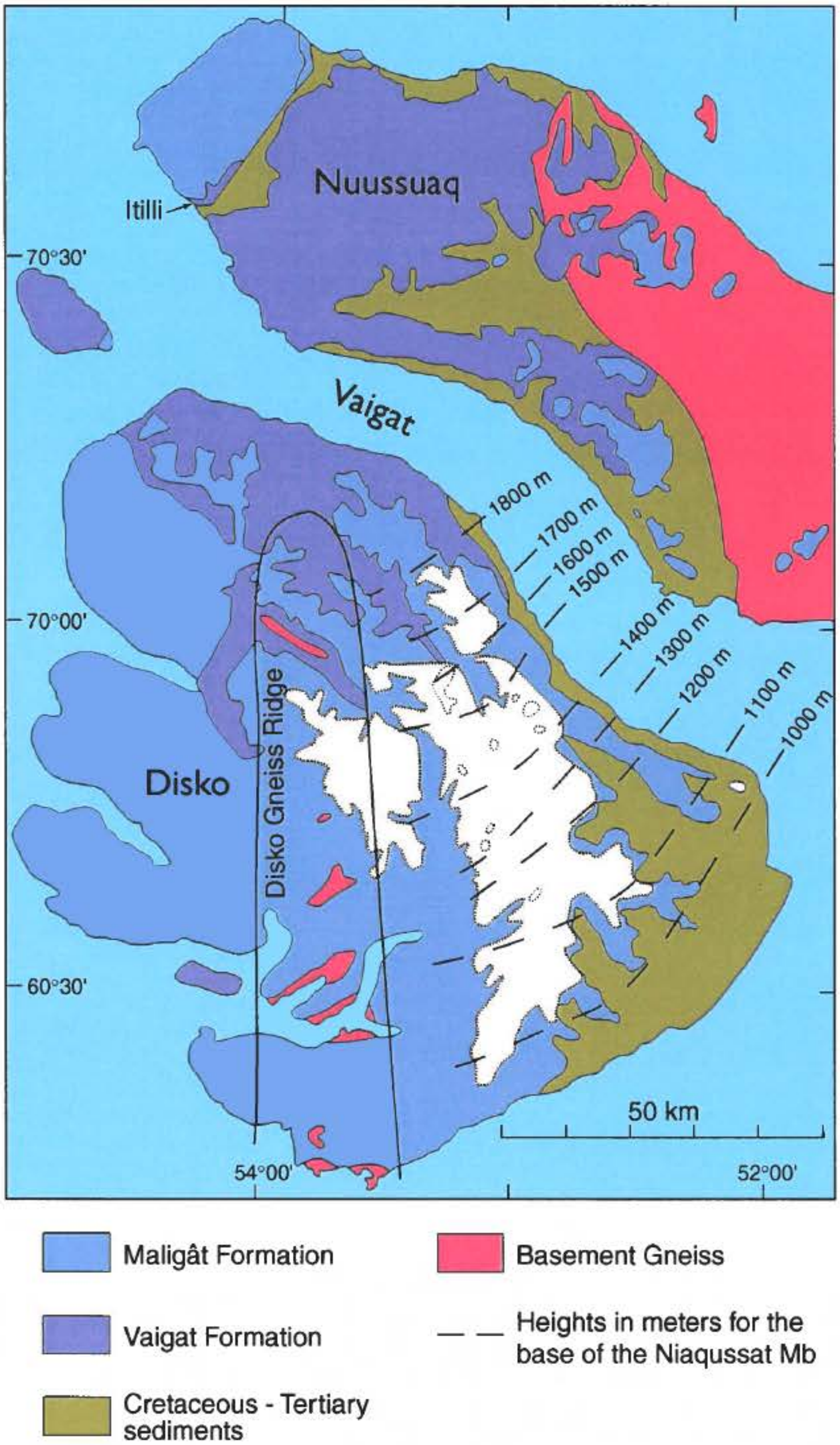
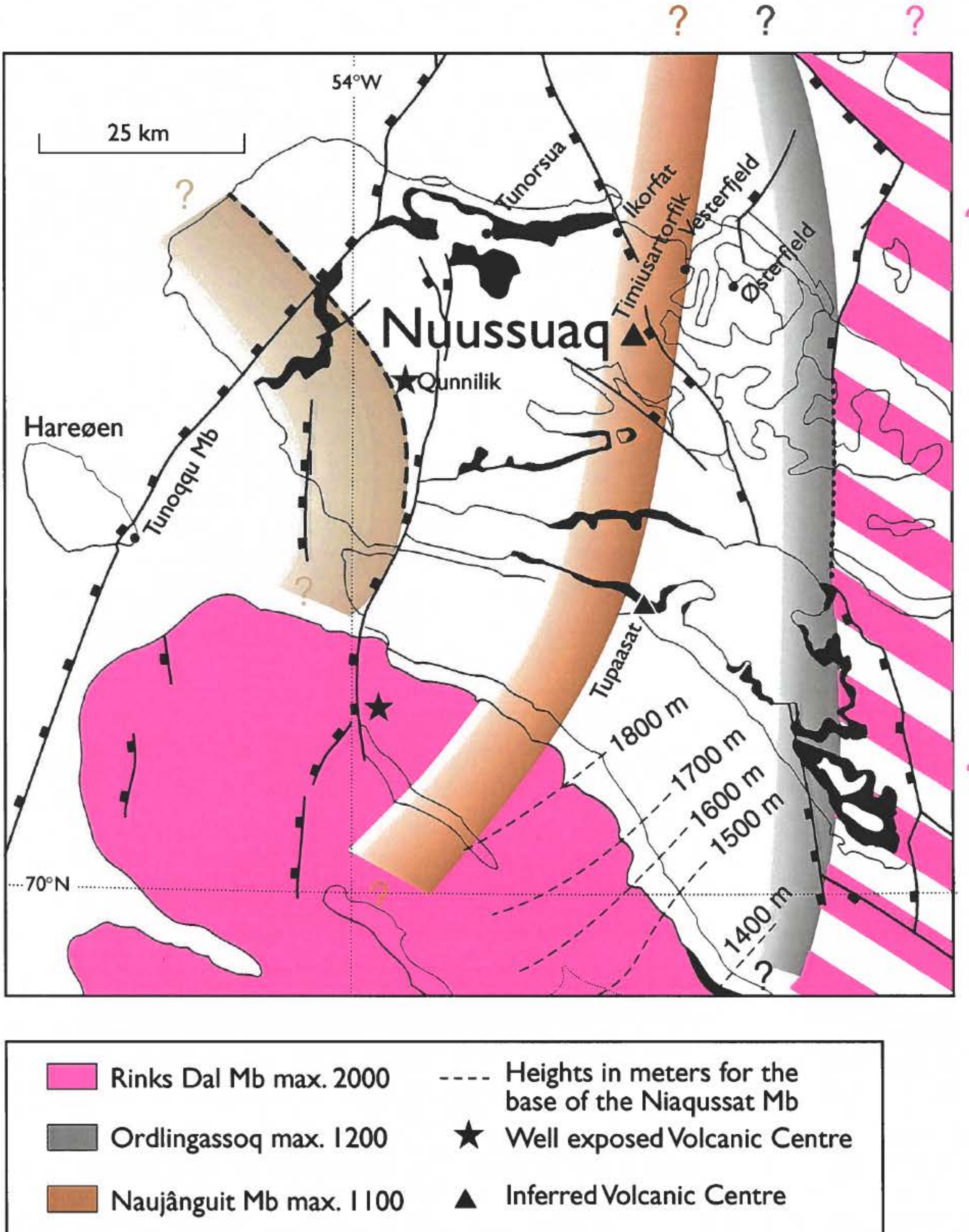
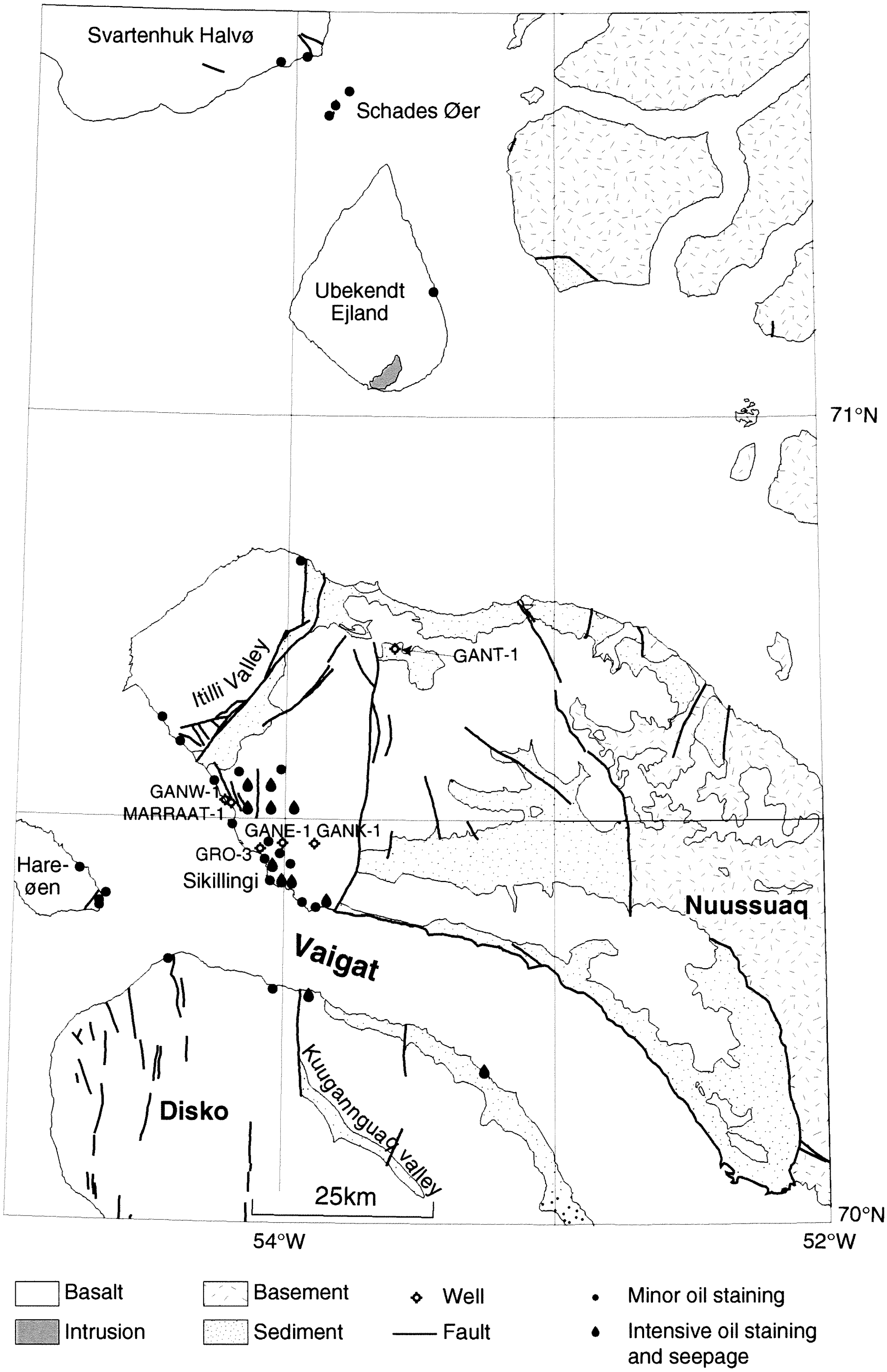

Nuussuaq
Itilli
Vaigat
Disko
Disko Gneiss Ridge
70°30'
70°00'
60°30'
54°00'
52°00'
50 km
1800 m
1700 m
1600 m
1500 m
1400 m
1300 m
1200 m
1100 m
1000 m
Maligât Formation
Vaigat Formation
Cretaceous - Tertiary sediments
Basement Gneiss
Heights in meters for the base of the Niaqussat Mb

Fig 3.3



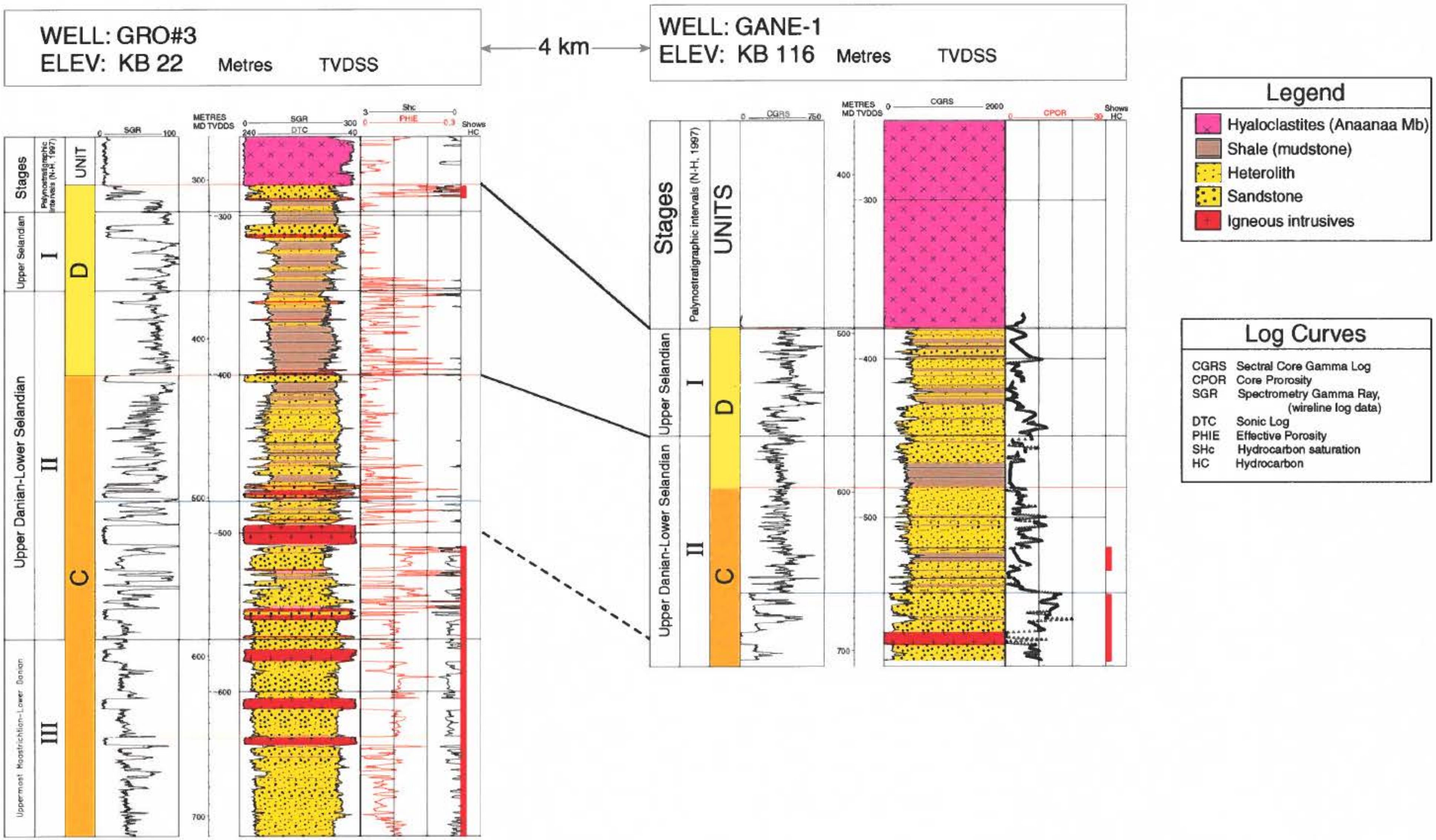
?
?
?
54°W
25 km
?
Tunorsua
Ikorfat
Vesterfjeld
Timiusartorfik
Østerfjeld
?
Nuussuaq
Qunnilik
Hareøen
Tunoqqu Mb
?
Tupaasat
1800 m
1700 m
1600 m
1500 m
?
70°N
?
1400 m
?
Rinks Dal Mb max. 2000
Ordlingassoq max. 1200
Naujânguit Mb max. 1100
Anaanaa Mb max. 1400
Heights in meters for the base of the Niaqussat Mb
Well exposed Volcanic Centre
Inferred Volcanic Centre

Fig 3.4



Svartenhuk Halvø
Schades Øer
Ubekendt
Ejland
71°N
GANT-1
Itilli Valley
GANW-1
MARRAAT-1
GANE-1
GANK-1
GRO-3
Hare-
øen
Sikillingi
Nuussuaq
Vaigat
Disko
Kuugannguaq valley
25km
70°N
54°W
52°W
Basalt
Intrusion
Basement
Sediment
Well
Fault
Minor oil staining
Intensive oil staining
and seepage

Fig 4.1



WELL: GRO#3
ELEV: KB 22 Metres TVDSS
4 km
WELL: GANE-1
ELEV: KB 116 Metres TVDSS
Stages
Palynostratigraphic intervals (N-H. 1997)
UNIT
UNITS
Upper Selandian
Upper Danian-Lower Selandian
Uppermost Maastrichtian-Lower Danian
I
II
III
D
C
SGR
DTC
PHIE
Shc
Shows HC
CGRS
CPOR
METRES MD TVDDS
Legend
Hyaloclastites (Anaanaa Mb)
Shale (mudstone)
Heterolith
Sandstone
Igneous intrusives
Log Curves
CGRS Sectral Core Gamma Log
CPOR Core Prorosity
SGR Spectrometry Gamma Ray, (wireline log data)
DTC Sonic Log
PHIE Effective Porosity
SHc Hydrocarbon saturation
HC Hydrocarbon

Fig 4.2.

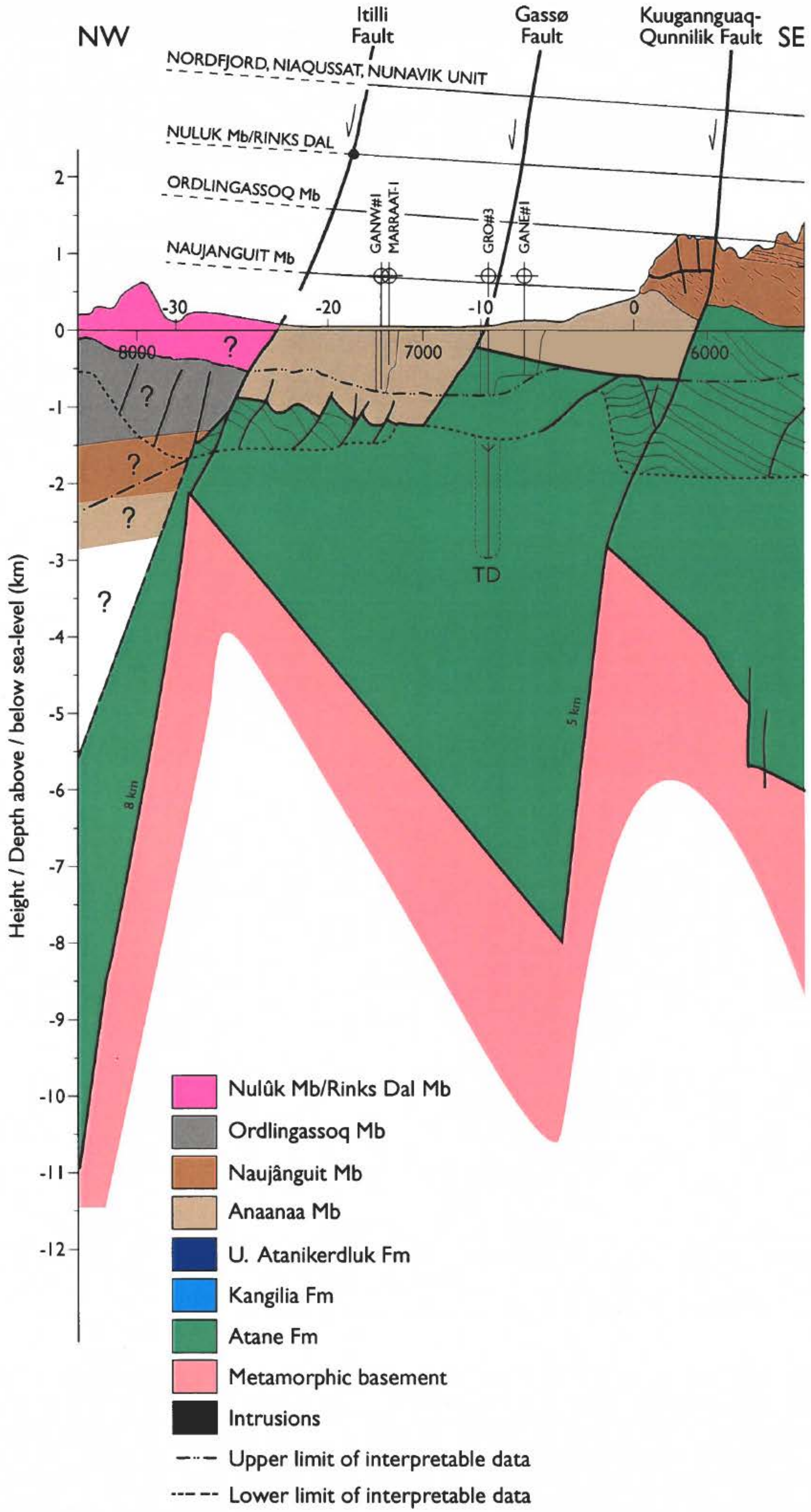

NW
Itilli Fault
Gassø Fault
Kuugannguaq-Qunnilik Fault
SE
NORDFJORD, NIAQUSSAT, NUNAVIK UNIT
NULUK Mb/RINKS DAL
ORDLINGASSOQ Mb
NAUJANGUIT Mb
GANW#1
MARRAAT-1
GRO#3
GANE#1
-30
-20
-10
0
8000
7000
6000
TD
8 km
5 km
Height / Depth above / below sea-level (km)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
Nulûk Mb/Rinks Dal Mb
Ordlingassoq Mb
Naujânguit Mb
Anaanaa Mb
U. Atanikerdluk Fm
Kangilia Fm
Atane Fm
Metamorphic basement
Intrusions
Upper limit of interpretable data
Lower limit of interpretable data

Fig 6.1

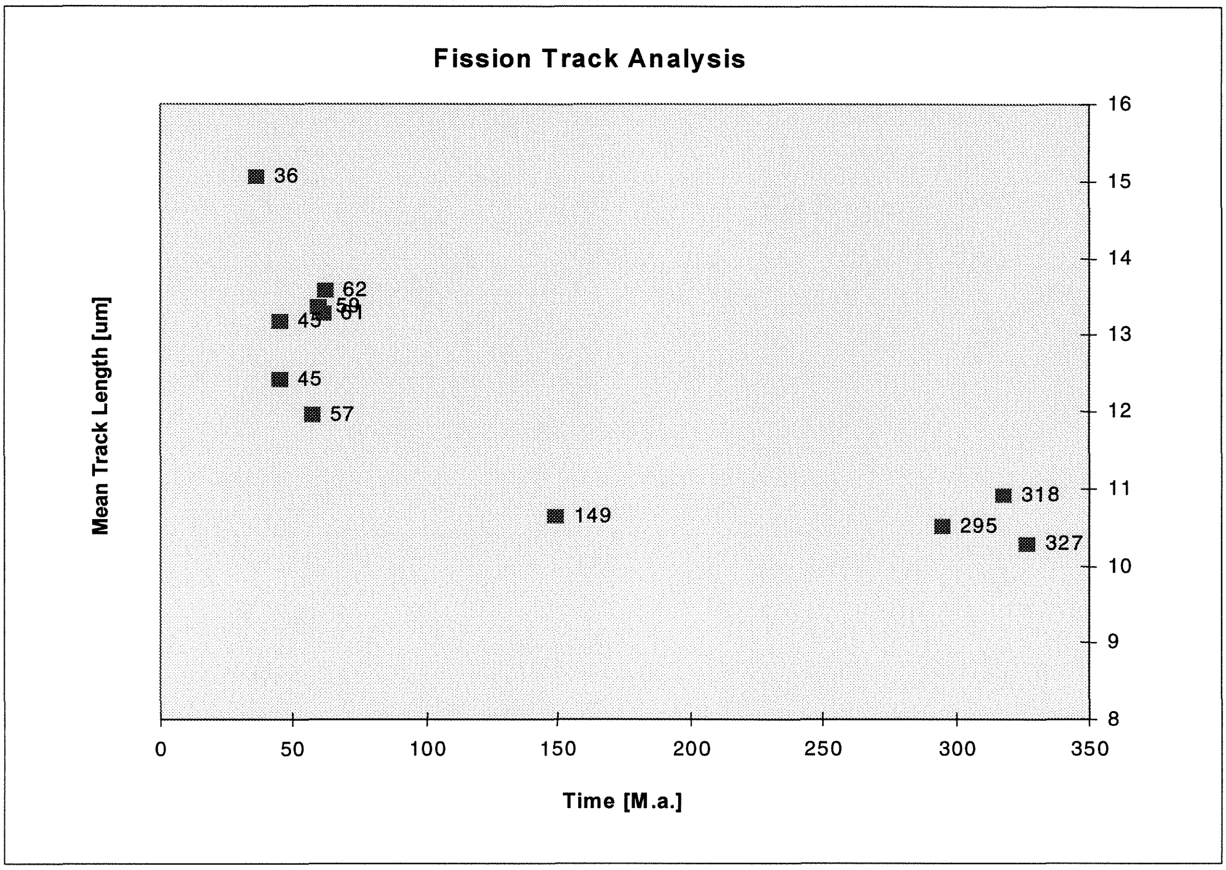

Fission Track Analysis
Mean Track Length [um]
Time [M.a.]
36
62
59
61
45
45
57
149
318
295
327
16
15
14
13
12
11
10
9
8
0
50
100
150
200
250
300
350

Fig 8.1

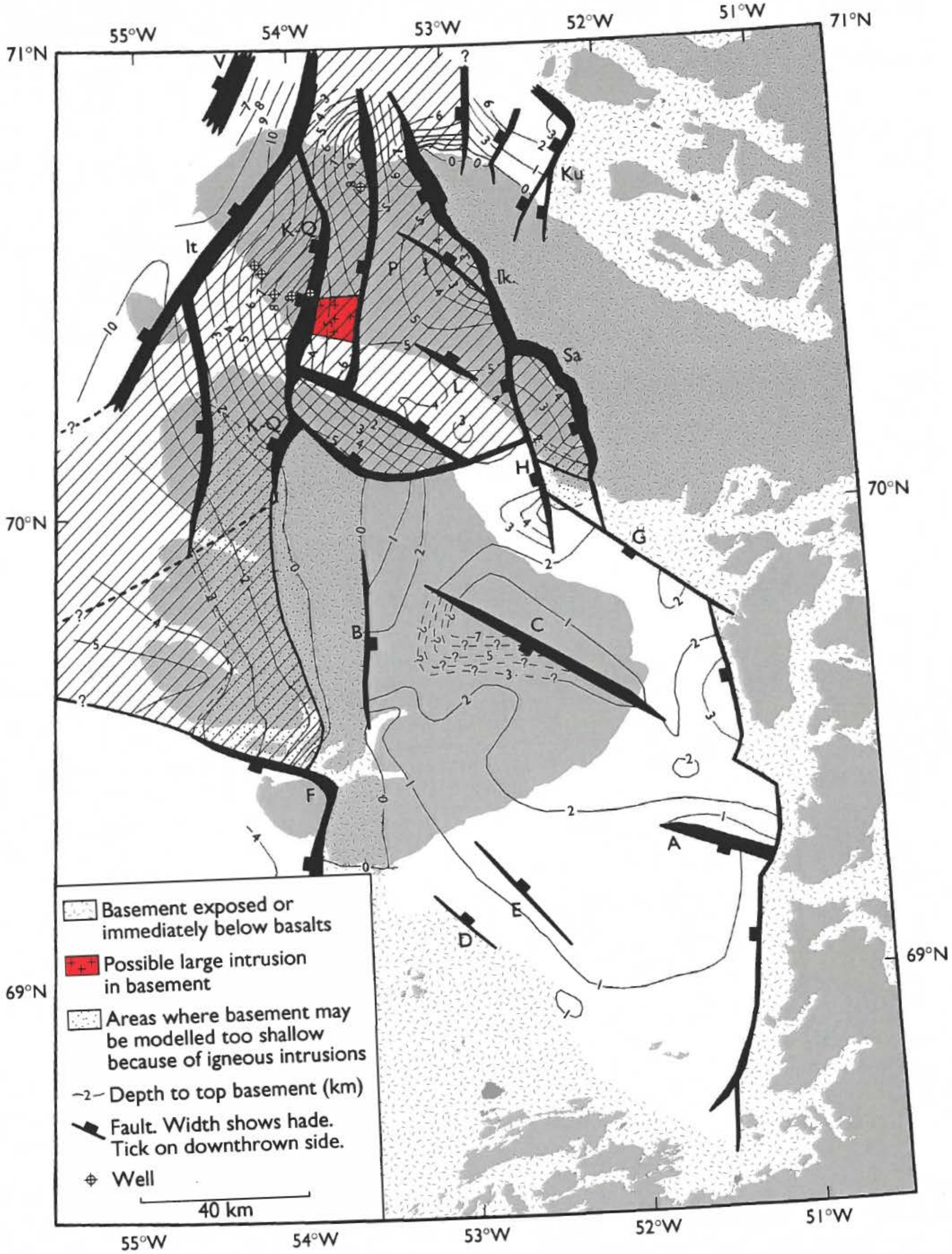

55°W
54°W
53°W
52°W
51°W
71°N
70°N
69°N
V
It
K-Q
P
Ik.
Ku
Sa
L
H
G
B
C
F
A
E
D
Basement exposed or immediately below basalts
Possible large intrusion in basement
Areas where basement may be modelled too shallow because of igneous intrusions
Depth to top basement (km)
Fault. Width shows hade. Tick on downthrown side.
Well
40 km

Fig 9.1

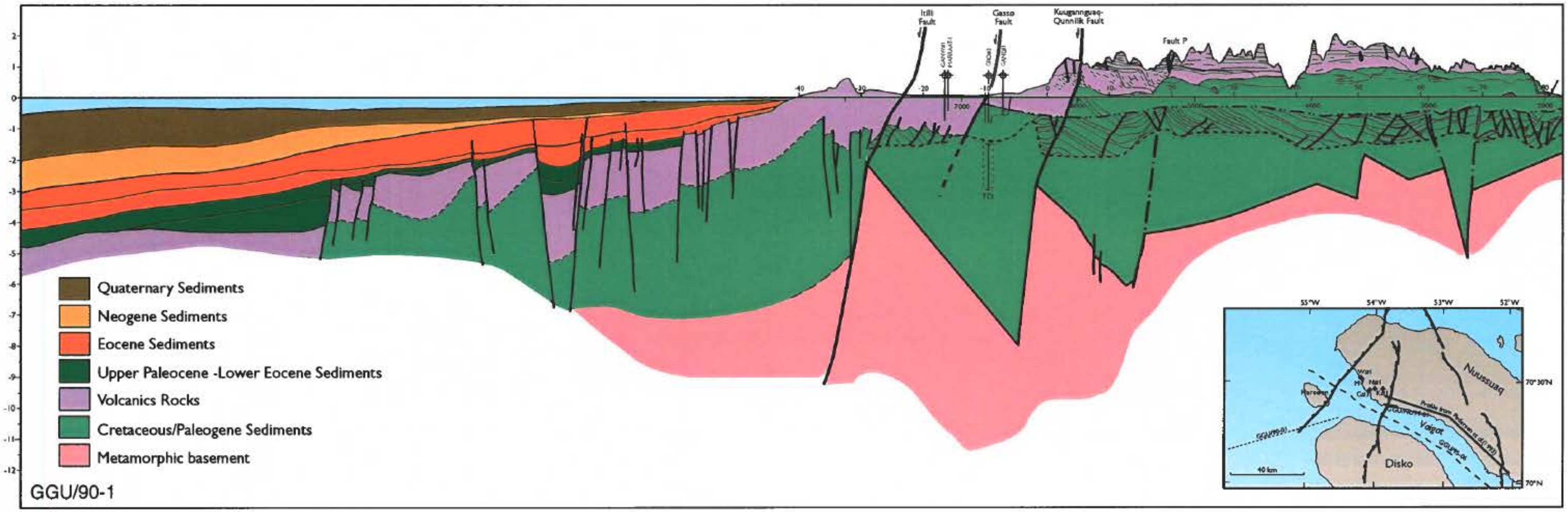
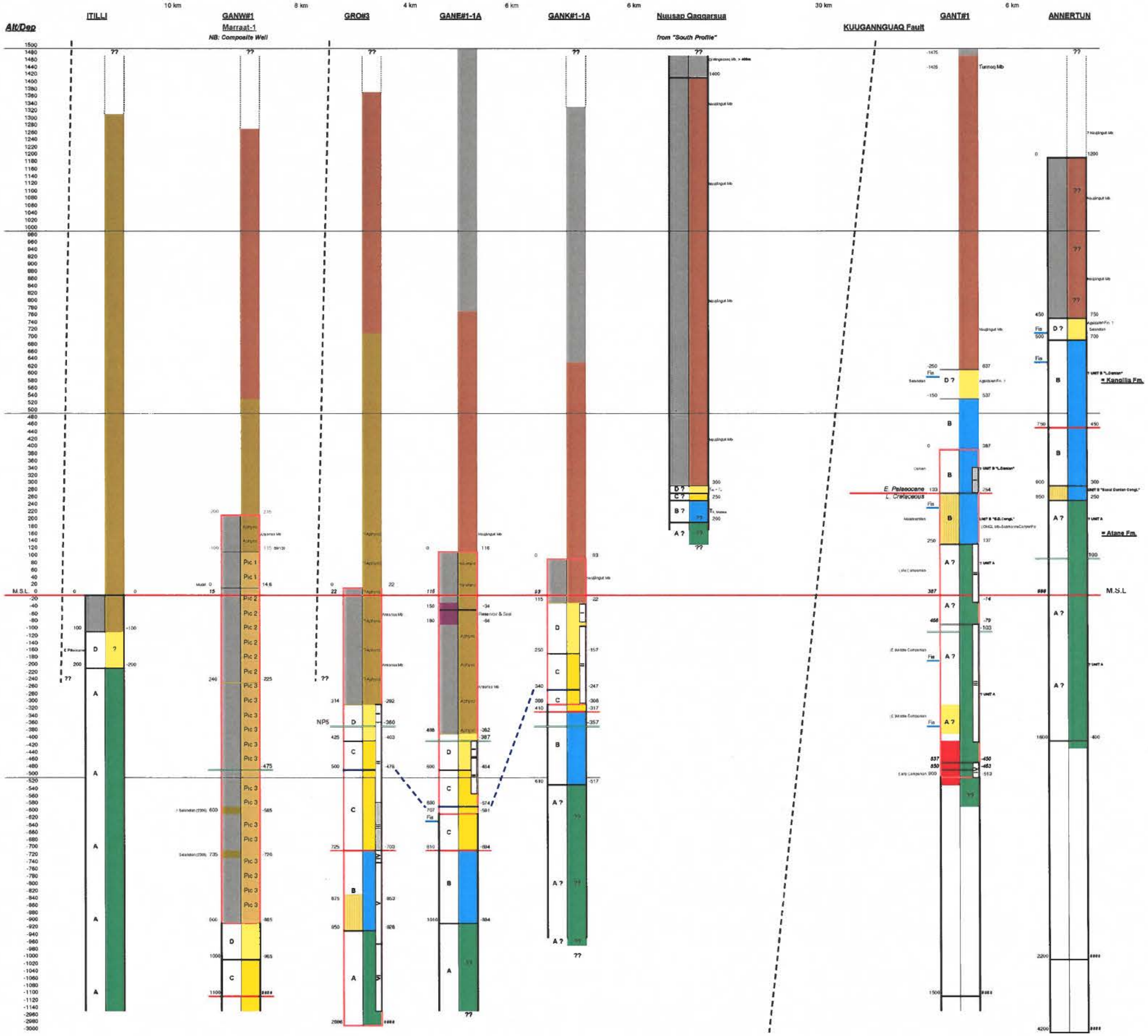

Itilli Fault
Gasso Fault
Kuugannguaq-Qunnilik Fault
Fault P
Quaternary Sediments
Neogene Sediments
Eocene Sediments
Upper Paleocene -Lower Eocene Sediments
Volcanics Rocks
Cretaceous/Paleogene Sediments
Metamorphic basement
GGU/90-1
Nuussuaq
Disko
Vaigat
40 km
55°W
54°W
53°W
52°W
70°30'N
70°N

Fig 9.2

APPENDIX 1

Schematic Cross-section through modelled wells and pseudowells



Legend:

Ordlingassoq Mb.
Naujânguit Mb.
Anaanaa Mb.

UNIT D Unnamed Selandian Sediments (IIUpper + I
Shallow Marine and NON.Marine Sediments
UNIT C Quikavsak Mb. (III + II
NON-Marine Deltaic
UNIT B Kangilia Mb. (Maastr. --> E-Pal. = V + IV
Marine Shelf
UNIT A Unnamed Upper Cretaceous Sediments (=Itilli Succ.;
Slope Turbidites

K-T Boundary (= Event 16)

Oil Window (relative to MSL)
Bleeding Oil !!, - Seal and Reservoir, **UNIT 5/7 in GANE#1**
Dry Gas
Intrusion (Thickness > 5m)

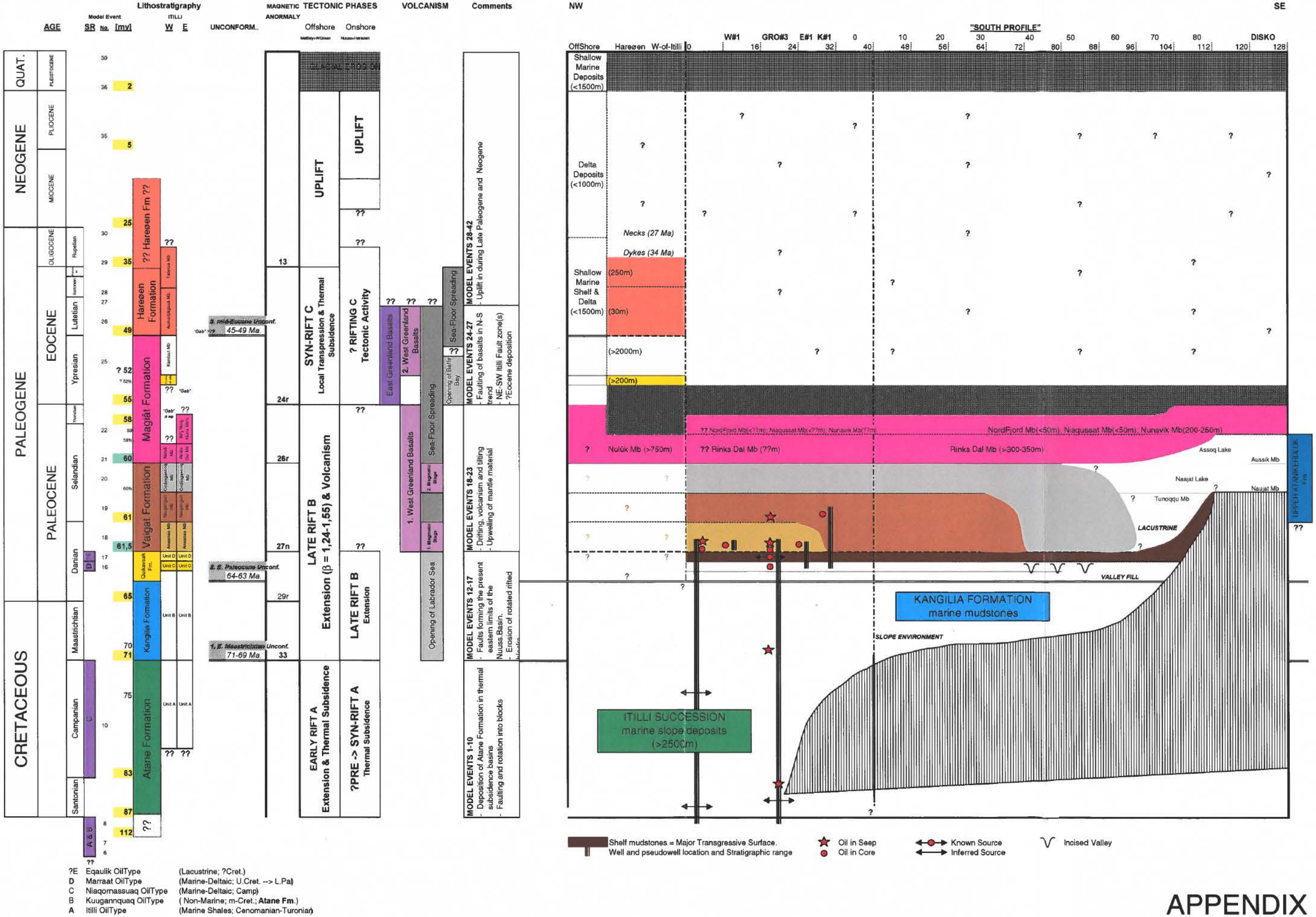
2. E.Paleocene Unconformaty — Base of the Shoreface of the Lower Paleocene AGATDAL Fm.

1. E.Maastricthiam Unconformaty — Base of the Upper Maastrichtian - Basal Paleocene KANGILIA Fm. (= Canyon Conglomerate)

APPENDIX 1

APPENDIX 2

Timeframe and Stratigraphic framework



Lithostratigraphy
MAGNETIC ANORMALY
TECTONIC PHASES
VOLCANISM
Comments
NW
SE
AGE
Model Event
SR No. [mv]
ITILLI
W E
UNCONFORM..
Offshore Onshore
QUAT.
NEOGENE
PALEOGENE
CRETACEOUS
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
Rupelian
Lutetian
Ypresian
Selandian
Danian
Maastrichtian
Campanian
Santonian
?? Hareøen Fm ??
Hareøen Formation
Magiât Formation
Vaigat Formation
Quikavsak Fm.
Kangilia Formation
Atane Formation
3. mid-Eocene Unconf. 45-49 Ma.
2. E. Paleocene Unconf. 64-63 Ma.
1. E. Maastrichtian Unconf. 71-69 Ma.
UPLIFT
SYN-RIFT C
Local Transpression & Thermal Subsidence
? RIFTING C
Tectonic Activity
LATE RIFT B
Extension (β = 1,24-1,55) & Volcanism
LATE RIFT B
Extension
EARLY RIFT A
Extension & Thermal Subsidence
?PRE -> SYN-RIFT A
Thermal Subsidence
East Greenland Basalts
2. West Greenland Basalts
1. West Greenland Basalts
Sea-Floor Spreading
Opening of Baffin Bay
Opening of Labrador Sea
MODEL EVENTS 28-42
- Uplift in during Late Paleogene and Neogene
MODEL EVENTS 24-27
- Faulting of basalts in N-S trend
- NE-SW Itilli Fault zone(s)
- ?Eocene deposition
MODEL EVENTS 18-23
- Drifting, volcanism and tilting
- Upwelling of mantle material
MODEL EVENTS 12-17
- Faults forming the present eastern limits of the Nuuss Basin.
- Erosion of rotated rifted blocks
MODEL EVENTS 1-10
- Deposition of Atane Formation in thermal subsidence basins
- Faulting and rotation into blocks
"SOUTH PROFILE"
OffShore
Hareøen
W-of-Itilli
W#1
GRO#3
E#1
K#1
DISKO
Shallow Marine Deposits (<1500m)
Delta Deposits (<1000m)
Necks (27 Ma)
Dykes (34 Ma)
Shallow Marine Shelf & Delta (<1500m)
(250m)
(30m)
(>2000m)
(>200m)
NordFjord Mb(<50m); Niaqussat Mb(<50m); Nunavik Mb(200-250m)
Nulûk Mb (>750m)
?? Rinks Dal Mb (??m)
Rinks Dal Mb (>300-350m)
Assoq Lake
Aussik Mb
Naajat Lake
Naujat Mb
Tunoqqu Mb
LACUSTRINE
VALLEY FILL
UPPER ATANIKERLUK Fm.
KANGILIA FORMATION
marine mudstones
SLOPE ENVIRONMENT
ITILLI SUCCESSION
marine slope deposits
(>2500m)
Shelf mudstones = Major Transgressive Surface.
Well and pseudowell location and Stratigraphic range
Oil in Seep
Oil in Core
Known Source
Inferred Source
Incised Valley
?E Eqaulik OilType (Lacustrine; ?Cret.)
D Marraat OilType (Marine-Deltaic; U.Cret. --> L.Pal)
C Niaqornassuaq OilType (Marine-Deltaic; Camp)
B Kuugannquaq OilType (Non-Marine; m-Cret.; Atane Fm.)
A Itilli OilType (Marine Shales; Cenomanian-Turonian)

APPENDIX 2

APPENDIX 3

Timeframe, Event splitting, Input thickness and other input modelling data

APPENDIX 3a : <Wellname>_1 -concept with maximum amount of volcanics

APPENDIX 3b : <Wellname>_6 -concept with minimum amount of volcanics

TIME-FRAME and Model Thickness:

Storey et al. 97

Period	Epoch	Stage	AGE	Dura	E.No	Work Name	Model Name		M.P Chr	(REGIONAL) GEOLOGICAL SETTINGs	
PLEISTOCENE			0,5	0,5	42	GLACIAL UPLIFT	GLACIAL UPLIFT				
			1	0,5	41	GLACIAL UPLIFT	GLACIAL UPLIFT				
			1,5	0,5	40	GLACIAL UPLIFT	GLACIAL UPLIFT				
			2	0,5	39	GLACIAL UPLIFT	GLACIAL UPLIFT				
NEOGENE	PLIOCENE		3	1	38	NEOGENE UPLIFT	NEOGENE UPLIFT				
			4	1	37	NEOGENE UPLIFT	NEOGENE UPLIFT				
		ZANCLEAN	5	1	36	NEOGENE UPLIFT	NEOGENE UPLIFT			RENEWED due to Collision of Green-Euro (Trettin, 91)	
	MIOCENE		7,5	2,5	35	NEOGENE UPLIFT	NEOGENE UPLIFT				
			10	2,5	34	NEOGENE UPLIFT	NEOGENE UPLIFT			? Peneplanetion of flanks	
			15	5	33	NEOGENE UPLIFT	NEOGENE UPLIFT			and of Depo.of.Ero.Prod in OFFSHORE areas	
			20	5	32	NEOGENE UPLIFT	NEOGENE UPLIFT			ONSET; Fennoscan(Rohrman,95) and E.Green (Larsen,90)	
		AQQUITANNIAN	25	5	31	HAREØEN Fm.	UPLIFT / Depo ?			**Hareøen**: Sedimenter **303 m.A.s.l. & Dinoflag..!!**	
PALEOGENE	OLIGO CENE		30	5	30	HAREØEN Fm.	UPLIFT / Depo ?				
		RUPELIAN	35	5	29	HAREØEN Fm.	UPLIFT / Depo ?				
	EOCENE		40	5	28	HAREØEN Fm.	UPLIFT / Depo ?			Arrival of PLUME to Norwegian-E.Green region (Lawer..94)	
			45	5	27	HAREØEN Fm.	UPLIFT / Depo ?			**Hareøen**: Sedimenter **130 m.A.s.l.** ?Dinoflag..!!	
		LUTETIAN	49	4	26	HAREØEN Fm.	**OffShore + Hareøen ??**	? P.2 ?	21 (46.3-49)		
			54	5	25	MALIGÂT Fm.	**Ifsorisok Mb / NON-Depo**			Ifso.. : > 200m & Kanisut Mb. etc.	
		YPRESIAN	55	1	24	MALIGÂT Fm.	Volcanism / NON-Depo ?		24r (54-55)	Continental Break-Up (56 Ma) Green-NW.Euro (53-52 ?)	
	LATE PALEOCENE	THANETIAN	58	3	23	MALIGÂT Fm.	Volcanism / NON-Depo ?		25	Nunavik Unit	
			59	1	22	MALIGÂT Fm.	Volcanism / NON-Depo ?		26r (57.9-60.0)	Nordfjord, Niaqussat Mb.'s	
			60	1	21	MALIGÂT Fm.	**Nuluk Mb / Rinks Dal Mb**		26r (57.9-60.0)	**< 1300 m**	
			60,5	0,5	20	VAIGÂT FM	**Ordlingassoq Mb.**	P.1		**< 1200 m** =Naujat Lake =Assoq Lake =Umiussat Mb	
		SELANDIAN	61	0,5	19	VAIGÂT FM	**Naujânguit Mb.**		27n (60.9-61.3)	**< 1100 m** Incl. **Tunoqqu Mb** =Asuk Mb	
	EARLY PALEOCENE		61,5	0,5	18	VAIGÂT FM	**Anaanaa Mb.**		27n (60.9-61.3)	**< 1400 m** Only in Western Part / ChannelSlope in Itilli	
			62	0,5	17	UNIT D	**SS6**		? NP5 ?	Marine slope environ. **=?Agatdalen Fm.**	T_{mu} &
			63	1	16	UNIT C	**Quikavsak Mb.**			Turbidite slope Channel / Canyon Environ. **=CG-2**	T_{sa}
			64	1	15		REG. UNCONFORM.		28n	**2. E.Paleocene Unconform.** SB Val.Inci.; **East** Only	
		DANIAN	65	1	14	KANGILIA Fm.	**Danian-1 / SS5**		29r	UNIT-B3	T_K
CRETACEOUS	LATE		67	2	13	KANGILIA Fm.	**Maastr-2 / SS4**		31n	UNIT-B2 Missing on North Nuussuaq !!	
			69	2	12	KANGILIA Fm.	**Maastr-1 / GC-1**			UNIT-B1 ="Basal Danian Conglomerate"	
		MAASTRICHTIAN	71	2	11		UNC/NON_Depo		33n	**1. E.Maastr. Regional Unconform.**	
		CAMPANIAN	83	12	10	ATANE Fm.	**Campanian / SS3**			UNIT-A	
		SANTONIAN	87	4	9	ATANE Fm.	**Santonian / SS2**			UNIT-A (Chaotic beds)	
		CONIACIAN	89	2	8	ATANE Fm.	**Coniacian / SS1**			UNIT-A	
		TURONIAN	92	3	7	ATANE Fm.	**Turonian / SS1**			UNIT-A = Turbidite Succ. = Slope apron environment	
		CENOMANIAN	96	4	6	ATANE Fm.	**Cenomanian**			UNIT-A	
		ALBIAN	106	10	5	ATANE Fm.	**Albian**			UNIT-A	

Itilli Fault | Kuugannguaq Fault

E.No	ITILLI	MARR/GANW	GRO#3	GANE#1-1A	GANK#1-1A	GANT#1	ANNERTUN
TopKote	½	14,6	17,6	116	93	387	1200
	Constant Erosion Rate, increasing from Pleistocene	Constant Erosion Rate, increasing from Pleistocene	Constant Erosion Rate, increasing from Pleistocene	Constant Erosion Rate, increasing from Pleistocene	Constant Erosion Rate, increasing from Pleistocene	Constant Erosion Rate, increasing from Pleistocene	Constant Erosion Rate, increasing from Pleistocene
42	-700	-200	-350	-150	-150	-150	-150
41	-400	-200	-200	-100	-100	-100	-100
40	-200	-100	-150	-100	-50	-200	-100
39	-75	-75	-50	-100	-50	-100	-100
38	-200	-200	-200	-100	-100	-100	-100
37	-200	-200	-200	-100	-100	-100	-100
36	-200	-200	-200	-150	-100	-100	-100
35	-225	-225	-200	-150	-150	-200	-200
34	-300	-300	-300	-150	-150	-100	-200
33	-300	-300	-300	-300	-300	-200	-200
32	-125	-125	-100	-100	-100	-350	-150
31	-200	-200	-200	-200	-200	-350	-150
30	-200	-200	-200	-200	-200	-250	-150
29	-200	-200	-200	-200	-200	-250	-150
28	-200	-200	-200	-200	-200	-250	-150
27	-4025 -300	-3225 -300	-3350 -300	-2600 -300	-2450 -300	? -3100 -300	-2400 -300
26	0	0	0	0	0	0	0
25	300	300	300	300	300	300	300
24	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0
21	925	925	900	900	900	750	750
20	825	825	800	750	700 (0)	700	700 (0)
19	675 (0)	675 (0)	650 (0)	650 (0)	100 +550	450 +650	450 +650
18	1400 (100)	900+500 (900)	300+700 (300)	500 (500)	0 (100)	0	0 (450)
17	E 50 (150)	100 (1000)	125 (425)	100 (600)	150 (250)	100	0
16	D 0	100 (1100)	300 (725)	F1 200 (800)	150 (410)	F4 150	F1 50 (500)
15	-200	-200	-200	-200	-200	-200 (0)	-200
14	300 (250)	200	200	200	200	300 (100)	F2 450 (750)
13	C 50 (300)	75	75	50	50	0	150
12	100 (400)	150	150 (950)	150 (1000)	150	F1 150 (250)	50 (950)
11	-250	-250	-250	-250	-250	-250	-250
10	B 750 (900)	750	750 (1450)	750	750	F2,3 900 (900)	900 (1200)
9	600 (1500)	1000	1000	1000	1000	1000	1000
8	1000 (2500)	1000	1000 (3000)	1000	1000	1000	1000
7	A 1000	500	500	500	500	500	500
6	?A 500	500	500	500	500	500	500
5	500	500	500	500	500	500	500
			from Well & Fig. 3.2b			from Well & (Pedersen et al.,1996)	
TD in Well	2800	1000	3000	700	400	900	1200
Exhumation ?	-4025	-3225	-3350	-2600	-2450	-3100	-2400
Maligât Fm.	**1225**	**1225**	**1200**	**1200**	**1200**	**1050**	**1050**
Vaigat Fm.	**2900**	**2900**	**2450**	**1900**	**1350**	**1800**	**1800**
UNIT C / D	**50**	**200**	**425**	**300**	**300**	**250**	**50**
Kangilia Fm. / UNIT B	**450**	**425**	**425**	**400**	**400**	**450**	**650**
Atane Fm./ UNIT A	2100	2500	2500	2500	2500	2650	2650
?Atane Fm. + SUM(1-7) =	5500 7600	5500 8000	5500 8000	5500 8000	5500 8000	2000 4650	2000 4650

LEGEND:

GEUS: ModelTime Scale

Fm.Name: ModelEvent Name

E.No.: Event Number

Potential Source Rock EVENTS

Fission Track Sample EVENTS

APPENDIX 3a

TIME-FRAME and Model Thickness:

Storey et al. 97

Period	Epoch	Stage	AGE	Dura	E.No	Work Name	Model Name		M.P Chr	(REGIONAL) GEOLOGICAL SETTINGs	
PLEISTOCENE			0,5	0,5	42	GLACIAL UPLIFT	GLACIAL UPLIFT				
PLEISTOCENE			1	0,5	41	GLACIAL UPLIFT	GLACIAL UPLIFT				
PLEISTOCENE			1,5	0,5	40	GLACIAL UPLIFT	GLACIAL UPLIFT				
PLEISTOCENE			2	0,5	39	GLACIAL UPLIFT	GLACIAL UPLIFT				
NEOGENE	PLIOCENE		3	1	38	NEOGENE UPLIFT	NEOGENE UPLIFT				
NEOGENE	PLIOCENE		4	1	37	NEOGENE UPLIFT	NEOGENE UPLIFT				
NEOGENE	PLIOCENE	ZANCLEAN	5	1	36	NEOGENE UPLIFT	NEOGENE UPLIFT			RENEWED due to Collision of Green-Euro (Trettin, 91)	
NEOGENE	MIOCENE		7,5	2,5	35	NEOGENE UPLIFT	NEOGENE UPLIFT				
NEOGENE	MIOCENE		10	2,5	34	NEOGENE UPLIFT	NEOGENE UPLIFT			? Peneplanetion of flanks	
NEOGENE	MIOCENE		15	5	33	NEOGENE UPLIFT	NEOGENE UPLIFT			and of Depo.of.Ero.Prod in OFFSHORE areas	
NEOGENE	MIOCENE		20	5	32	NEOGENE UPLIFT	NEOGENE UPLIFT			ONSET; Fennoscan(Rohrman,95) and E.Green (Larsen,90)	
NEOGENE	MIOCENE	AQQUITANNIAN	25	5	31	HAREØEN Fm.	UPLIFT / Depo ?			**Hareøen**: Sedimenter **303 m.A.s.l. & Dinoflag..!!**	
PALEOGENE	OLIGOCENE		30	5	30	HAREØEN Fm.	UPLIFT / Depo ?				
PALEOGENE	OLIGOCENE	RUPELIAN	35	5	29	HAREØEN Fm.	UPLIFT / Depo ?				
PALEOGENE	EOCENE		40	5	28	HAREØEN Fm.	UPLIFT / Depo ?			Arrival of PLUME to Norwegian-E.Green region (Lawer..94)	
PALEOGENE	EOCENE		45	5	27	HAREØEN Fm.	UPLIFT / Depo ?			**Hareøen**: Sedimenter **130 m.A.s.l.** ?Dinoflag..!!	
PALEOGENE	EOCENE	LUTETIAN	49	4	26	HAREØEN Fm.	**OffShore + Hareøen ??**	? P.2 ?	21 (46.3-49)		
PALEOGENE	EOCENE		54	5	25	MALIGÂT Fm.	**Ifsorisok Mb / NON-Depo**	? P.2 ?		Ifso.. : > 200m **&** Kanisut Mb. etc.	
PALEOGENE	EOCENE	YPRESIAN	55	1	24	MALIGÂT Fm.	Volcanism / NON-Depo ?	? P.2 ?	24r (54-55)	Continental Break-Up (56 Ma) Green-NW.Euro (53-52 ?)	
PALEOGENE	LATE PALEOCENE	THANETIAN	58	3	23	MALIGÂT Fm.	Volcanism / NON-Depo ?		25	Nunavik Unit	
PALEOGENE	LATE PALEOCENE		59	1	22	MALIGÂT Fm.	Volcanism / NON-Depo ?		26r (57.9-60.0)	Nordfjord, Niaqussat Mb.'s	
PALEOGENE	LATE PALEOCENE		60	1	21	MALIGÂT Fm.	**Nuluk Mb / Rinks Dal Mb**	P.1	26r (57.9-60.0)	**< 1300 m**	
PALEOGENE	LATE PALEOCENE		60,5	0,5	20	VAIGAT FM	**Ordlingassoq Mb.**	P.1		**< 1200 m** =Naujat Lake =Assoq Lake =Umiussat Mb	
PALEOGENE	LATE PALEOCENE	SELANDIAN	61	0,5	19	VAIGAT FM	**Naujânguit Mb.**	P.1	27n (60.9-61.3)	**< 1100 m** Incl. **Tunoqqu Mb** =Asuk Mb	
PALEOGENE	EARLY PALEOCENE		61,5	0,5	18	VAIGAT FM	**Anaanaa Mb.**	P.1	27n (60.9-61.3)	**< 1400 m** Only in Western Part / ChannelSlope in Itilli	
PALEOGENE	EARLY PALEOCENE		62	0,5	17	UNIT D	**SS6**		? NP5 ?	Marine slope environ. **=?Agatdalen Fm.**	T_{mu} &
PALEOGENE	EARLY PALEOCENE		63	1	16	UNIT C	**Quikavsak Mb.**			Turbidite slope Channel / Canyon Environ. **=CG-2**	T_{sa}
PALEOGENE	EARLY PALEOCENE		64	1	15		REG. UNCONFORM.		28n	**2. E.Paleocene Unconform.** SB Val.Inci.; **East** Only	
PALEOGENE	EARLY PALEOCENE	DANIAN	65	1	14	KANGILIA Fm.	**Danian-1 / SS5**		29r	UNIT-B3	T_K
CRETACEOUS	LATE		67	2	13	KANGILIA Fm.	**Maastr-2 / SS4**		31n	UNIT-B2 Missing on North Nuussuaq !!	T_K
CRETACEOUS	LATE		69	2	12	KANGILIA Fm.	**Maastr-1 / GC-1**			UNIT-B1 ="Basal Danian Conglomerate"	T_K
CRETACEOUS	LATE	MAASTRICHTIAN	71	2	11		UNC/NON_Depo		33n	**1. E.Maastr. Regional Unconform.**	
CRETACEOUS	LATE	CAMPANIAN	83	12	10	ATANE Fm.	**Campanian / SS3**			UNIT-A	
CRETACEOUS	LATE	SANTONIAN	87	4	9	ATANE Fm.	**Santonian / SS2**			UNIT-A (Chaotic beds)	
CRETACEOUS	LATE	CONIACIAN	89	2	8	ATANE Fm.	**Coniacian / SS1**			UNIT-A	
CRETACEOUS	LATE	TURONIAN	92	3	7	ATANE Fm.	**Turonian / SS1**			UNIT-A = Turbidite Succ. = Slope apron environment	
CRETACEOUS	LATE	CENOMANIAN	96	4	6	ATANE Fm.	**Cenomanian**			UNIT-A	
CRETACEOUS	LATE	ALBIAN	106	10	5	ATANE Fm.	**Albian**			UNIT-A	

TopKote

Itilli Fault — *Kuugannguaq Fault* ?

E.No	Source	½ ITILLI		14,6 MARR/GANW		17,6 GRO#3		116 GANE#1-1A		93 GANK#1-1A		387 GANT#1		1200 ANNERTUN	
42		-700		-200		-350		-150		-100		-150		-150	
41		-400		-200		-200		-100		-50		-100		-100	
40		-200		-100		-150		-100		-50		-350		-100	
39		-75		-75		-50		-100		-50		-250		-100	
38		-200		-200		-200		-100		-100		-300		-100	
37		-200		-200		-200		-100		-100		-200		-100	
36		-200		-200		-200		-50		-100		-50		-150	
35		-125		-125		-150		-100		-100		-100		-150	
34		-100		-100		-150		-100		-100		-100		-150	
33		-200		-200		-100		-100		-100		-150		-150	
32		0		0		0		0		0		-200		0	
31		0		0		0		0		0		0		0	
30		0		0		0		0		0		0		0	
29		0		0		0		0		0		0		0	
28		0		0		0		0		0		0		0	
27		-2400 0		-1600 0		-1750 0		-1000 0		-850 0		-1950 0		-1250 0	
26		0		0		0		0		0		0		0	
25		300		300		300		300		300		300		300	
24		0		0		0		0		0		0		0	
23		0		0		0		0		0		0		0	
22		0		0		0		0		0		0		0	
21		0		0		0		0		0		0		0	
20		425		425		400		350		300	0	600		600	0
19		675	0	675	0	650	0	650	0	100 +550		450 +650		450 +650	
18		1400	100	900+500	900	300+700	300	500	500	0	100	0		0	450
17	E	50	150	100	1000	125	425	100	600	150	250	100		0	
16	D	0		100	1100	300	725	F1 200	800	150	410	F4 150		F1 50	500
15		-200		-200		-200		-200		-200		-200	0	-200	
14		300	250	200		200		200		200		300	100	F2 450	750
13	C	50	300	75		75		50		50		0		150	
12		100	400	150		150	950	150	1000	150		F1 150	250	50	950
11		-250		-250		-250		-250		-250		-250		-250	
10	B	750	900	750		750	1450	750		750		F2,3 900	900	900	1200
9		600	1500	1000		1000		1000		1000		1000		1000	
8		1000	2500	1000		1000	3000	1000		1000		1000		1000	
7	A	1000		500		500		500		500		500		500	
6	?A	500		500		500		500		500		500		500	
5		500		500		500		500		500		500		500	

Increasing Erosion Rate from Miocene

from Well & Fig. 3.2b (GRO#3)

from Well & (Pedersen et al.,1996) (GANT#1)

	ITILLI		MARR/GANW		GRO#3		GANE#1-1A		GANK#1-1A		GANT#1		ANNERTUN
TD in Well	2800		1000		3000		700		400		900		1200
Exhumation ?	-2400		-1600		-1750		-1000		-850		-1950		-1250
Maligât Fm.	**300**		**300**		**300**		**300**		**300**		**300**		**300**
Vaigat Fm.	**2500**		**2500**		**2050**		**1500**		**950**		**1700**		**1700**
UNIT C / D	**50**		**200**		**425**		**300**		**300**		**250**		**50**
Kangilia Fm. / UNIT B	**450**		**425**		**425**		**400**		**400**		**450**		**650**
Atane Fm./ UNIT A	2100		2500		2500		2500		2500		2650		2650
?Atane Fm. + SUM(1-7) =	7600	5500	8000	5500	8000	5500	8000	5500	8000	2000	4650	2000	4650

LEGEND:

GEUS: ModelTime Scale

Fm.Name: ModelEvent Name

E.No.: Event Number

Potential Source Rock EVENTS

Fission Track Sample EVENTS

APPENDIX 3b

APPENDIX 4

Maturity Data from all wells used to optimized models

WELL: GANW#1

TopKote: 14,6 m.A.S.L.

Altitude	Depth	TMax(°C)	Ro(%)	H32 22B/ 22B+22R	S29 20B/ 20B+20R
	0,0				
	-391,7			0,60	0,44
	-404,7				
	-489,9				
	-487,6	445			
	-488,3	446			
-476,7	-491,3				
	-492,6				
	-524,8	437			
	-527,2	440			
	-529,0	437	0,62	0,61	n.a.
	-530,0	443			
	-530,9	443			
	-531,0	449			
	-531,7	455			
	-532,4	530			
	-532,9	527			
	-536,3				
	-544,4	458			
	-545,7	449			
	-546,9	448			
	-547,5	446			
	-547,6	444	0,93	0,62	(0,51)
	-548,0	464			
	-548,8	442	0,74	0,62	(0,51)
	-549,4	442			
	-550,0	444			
	-550,3	441	0,73	0,59	(0,52)
	-560,7	442			
	-561,8	444			
	-561,9	444			
	-562,6	442			
	-563,1	442			
	-564,0	443			
	-564,8	440			
	-566,7	442			
	-556,2	442			

U.Sediment; L.Sediment Selandian

WELL: GRO#3

TopKote: 17,6 m.A.S.L.

Altitude	Depth	TMax(°C)	Ro(%)	H32 22B/ 22B+22R	S29 20B/ 20B+20R
	0,0				
	-314,0				
	-320,0	452		0,59	n.a.*
	-350,0	431		0,58	n.a.*
	-340,0	437			
	-360,0	433			
	-360,0	432		0,60	n.a.*
	-370,0	439	0,77		
-362,4	-380,0	437		0,61	n.a.*
	-390,0	437		0,59	n.a.*
	-400,0	437		0,61	n.a.
	-410,0	439		0,60	n.a.*
	-420,0	437		0,59	n.a.*
	-430,0	437		0,58	n.a.
	-440,0	438		0,62	n.a.*
	-460,0	439			
	-510,0	442	0,72		
	-590,0				
	730,0				
	760,0				
	980,0				
	-990,0	442		0,65	0,48
	-1110,0	450	0,98		
	-1150,0	450	1,01	0,60	0,50
	-1160,0	452			
	-1160,0	454			
	-1170,0	451		0,60	0,50
	-1170,0	456			
	-1180,0	452		0,64	0,47
	-1180,0	457			
	-1190,0	456			
	-1200,0	457			
	-1200,0	459			
	-1210,0	457			
	-1210,0	459			
	-1220,0	457			
	-1230,0	456		0,61	0,46
	-1230,0	459			
	-1240,0	461			
	-1250,0	473	1,32		
	-1250,0	461			
	-1260,0	465			
	-1280,0	469			
	-1290,0	469			
	-1300,0	468	1,23		
	-1310,0	458			
	-1320,0	459			
	-1350,0	459			
	-1360,0	469			
	-1370,0	463			
	-1390,0	465			
	-1390,0	466	1,23		
	-1400,0	467			
	-1410,0	465			
	-1420,0	465			
	-1430,0	469			
	-1440,0	461		0,64	n.d.
	-1450,0	469			
	-1460,0	470			
	-1470,0	470			
	-1485,0	475		n.d.	n.d.
	-1525,0	472			
	-1535,0	477			
	-1545,0	477	1,42		
	-1560,0	481			
	-1570,0	487			
	-1585,0	490			
	-1650,0	485			
	-1680,0	486			
	-1725,0	501	1,61		
	-1730,0	484			
	-1770,0	499			
	-1780,0	493			
	-1790,0	499			
	-1800,0	521			
	-1810,0	530			
	-1820,0	528			
	-1830,0	524		0,58	n.d.
	-1840,0	530			
	-1855,0	527			
	-1890,0	528			
	-1935,0	529			
	-1950,0	529			
	-1970,0	538			
	-1985,0	535			
	-2000,0	539			
	-2050,0	534			
	-2060,0	537			
	-2145,0	544		0,60	(0,42)
	-2185,0	556			
	-2190,0	560			
	-2200,0	563			
	-2215,0	560			
	-2240,0	555			
	-2255,0	558			
	-2270,0	560			
	-2285,0	560			
	-2300,0	559		0,61	(0,44)
	-2335,0	557			
	-2350,0	554			
	-2360,0	565			
	-2385,0		2,25		
	-2375,0	557			
	-2395,0	559			
	-2435,0		2,29		
	-2450,0	563			
	-2470,0	568			
	-2490,0	564			
	-2510,0	564		n.d.	n.d.
	-2530,0	566			
	-2550,0	568			
	-2565,0	570			
	-2580,0	572			
	-2590,0	573			
	-2605,0	573			
	-2630,0				
	-2700,0	570			
	-2710,0	574			
	-2720,0	572			
	-2730,0	572			
	-2740,0	573			
	-2750,0	571			
	-2760,0	571			
	-2820,0	571			
	-2875,0	577		n.d.	n.d.
	-2910,0	576			
	-2930,0	571			
	-2960,0	573			
	-2990,0	560			

Interval I - Late Danian - Selandian; Interval II - Late Danian - Early Selandian; Interval VI - ?Early to Late Campanian; Interval VII - ?Coniacian - ?Early Campanian; Interval - Tyre Coniacian/Santonian

WELL: GANE#1-#1A

TopKote: 116 m.A.S.L.

Altitude	Depth	TMax(°C)	Ro(%)	H32 22B/ 22B+22R	S29 20B/ 20B+20R
	-6,8			0,58	0,37
	-6,6				
	-47,1			0,60	0,39
	-147,8			0,62	0,39
	-147,8				
	-152,9			0,62	0,40
	-152,9				
	-158,2			0,61	0,42
	-158,2				
	-241,0			0,58	0,38
	-241,0				
	-267,8			0,58	0,40
	-267,8				
	-497,7	430			
	-498,5	437			
	-501,8	439			
-387,0	-503,0			0,60	0,36
	-503,9	439	0,70		
	-504,0	439			
	-506,3	439			
	-507,9	441			
	-510,0	432			
	-510,3	438	0,66	0,58	0,52
	-513,0	438			
	-515,5	438			
	-518,0	442			
	-520,0	432			
	-522,0	434			
	-526,4	432	0,69	0,60	n.a.
	-526,7	433			
	-530,0	432			
	-532,0	435			
	-533,9	435			
	-534,5	433	0,70	0,59	0,60
	-536,5	435			
	-536,7	430			
	-537,3	436			
	-540,0	430			
	-541,9	432			
	-542,0	432			
	-543,7	438			
	-553,3	430			
	-564,4	436			
	-564,7	437	0,75	0,60	0,49
	-565,3	438			
	-566,8	437			
	-567,8	430			
	-568,2	429			
	-570,2	437			
	-578,4	433			
	-581,5	532*			
	-582,0	440			
	-583,0	439			
	-584,0	439			
	-584,4	433			
	-586,5	439			
	-586,5	438			
	-587,1	440			
	-588,1	441			
	-588,6	440			
	-589,0	442			
	-589,0	439			
	-591,0	443			
	-591,1	439			
	-591,8	444			
	-592,1	441			
	-593,0	439			
	-593,7	441			
	-594,7	434			
	-596,2	437			
	-597,2	439			
	-597,4	436			
	-599,1	440			
	-600,0	439	0,67	0,61	0,42
	-604,9	442			
	-607,1	438			
	-608,9				
	-615,0	436	0,68	0,62	0,31
	-627,1	434			
	-633,4	432			
	-633,7	434			
	-636,4	431	0,58	0,57	n.a.
	-636,8	433			
	-636,5	439			
	-637,6	438			
	-638,1			0,61	n.a.
	-638,5			0,60	n.a.
	-640,0	436			
	-640,3			0,61	n.a.
	-641,4	436	0,60	0,60	0,34
	-642,0	437			
	-643,5	439			
	-644,6	433			
	-645,8	438			
	-649,4	436	0,71	0,60	0,30
	-649,8	432			
	-651,8	437			
	-663,5	457*			
	-669,8	n.d.*			
	-678,7	485*			
	-679,8				
	-680,2	512*			
	surf			0,59	0,36
	surf			0,58	0,36

Interval I - Selandian

Interval II - Selandian

Early part of Oil Window (T_{Max}: 432 - 443°C)
Varierer omkring EO / MainOil (T_{Max}: 440; %R_o: 0.7)

WELL: GANK#1-#1A

TopKote: 93 m.A.S.L.

Altitude	Depth	TMax(°C)	Ro(%)	H32 22B/ 22B+22R	S29 20B/ 20B+20R
	-88,4			0,59	0,39
	-115,0				
	-120,9	422			
	-130,7	421			
	-138,2	426			
	-144,1	434			
	-151,5	434	0,58	0,44	n.a.
	-157,0	431			
	-158,6			0,43	n.a.
	-163,1	435			
	-164,2			0,48	0,38
	-167,6	429			
	-174,7	434			
	-180,8	430			
	-188,9	433	0,57	0,45	n.a.
	-198,7	435			
	-229,4	432		0,43	0,17
	-240,3	432			
	-252,3	436			
	-259,3	428		0,60	n.a.
	-270,2			0,39	0,33
	-281,6	428			
	-310,2	439		0,49	n.a.
	-318,8	440			
	-326,9	521*			
	-331,4			0,60	n.a.
	-362,1	435	0,56	0,63	n.a.
	-369,8	440			
	-365,9	434	0,62	0,57	n.a.
	-371,8	436			
	-379,5	438	0,62	0,59	n.a.
	-387,0	431			
	-389,5	434			
	-392,8	434			
	-395,8	431	0,56	0,58	n.a.
	-396,5	438			
-357	-450				

Interval I - Selandian

Interval II - Selandian

Early part of Oil Window (T_{Max}: 421 - 440°C)

WELL: GANT#1

TopKote: 387 m.A.S.L.

Altitude	Depth	TMax(°C)	Ro(%)	H32 22B/ 22B+22R	S29 20B/ 20B+20R
	-58,2	437			
	-68,1	436	0,63	0,55	0,27
	-76,3	438			
	-88,0	431			
	-97,2	431	0,66	0,56	0,31
	-121,9	437			
	-133,2				
	-254,7	434			
	-267,3	443	0,67	0,59	0,36
	-277,2	437			
	-288,7	434			
	-295,1	437			
	-310,0	437			
	-322,2	443	0,64	0,59	0,40
	-331,5	437			
	-340,0	440			
	-354,5	438			
	-374,9	438	0,64	0,59	0,46
	-386,2	435			
	-401,1	431			
	-416,9	437			
	-466,2	437			
	-476,0	437	0,71	0,62	0,51
-103,1	-490,1	437			
	-506,8	440			
	-519,1	442	0,78	0,61	0,42
	-536,7	439			
	-551,2	440			
	-567,5	449			
	-589,4	442	0,71	0,65	0,48
	-593,9	446			
	-606,9	438			
	-608,0	444		0,64	0,50
	-610,8			0,63	0,50
	-645,9	441	0,74	0,61	0,51
	-671,2	443			
	-691,8	441	0,74	0,61	0,51
	-706,8	443	0,79	0,62	0,55
	-794,0	444	0,76	0,61	0,54
	-797,1	448	0,86	0,63	0,48
	-813,1	467			
	-836,7	449	0,93	0,64	0,49
	-850,3	448			
	-859,2	460			
	-869,5	449		0,61	0,51
	-879,5	462			
	-894,5	464	0,96	0,63	n.a.

Interval I - Danian; Interval II - Late Campanian; Interval III - Early to Middle Campanian; Interval IV - Early Camp.

Early part of Oil Window (T_{Max}: 431 - 444°C)

PEAK Generation at Base (TMax: 448 - 467°C)

Maastrichtian MAX. (254.7-133.2 = 150 m)
Campanian MAX. (900-254.7 = 650 m)

Fiss 4: 200 m A.PROFILE !! 400979
Fiss 1: 150,54 m B.S.L.
Fiss 2: 579,19 m B.S.L.
Fiss 3: 749,93 m B.S.L.

WELL: Annertuneq

TopKote: 1200 m.A.S.L.

Altitude	Depth	TMax(°C)	Ro(%)	H32 22B/ 22B+22R	S29 20B/ 20B+20R
	0,0				
695	-505,0	424		0,29	0,12
659	-541,0	417		0,17	n.a.
638	-562,0	422		0,21	0,07
570	-630,0	420		0,18	0,02
470	-730,0	427		0,26	0,09
605	595,0				
400	-800,0	424		0,31	n.a.
319	-881,0	431		0,38	0,11
218	-982,0	431		0,59	0,21
112	-1088,0	440		0,57	0,27
100	-1100,0	443		0,58	0,28
98	-1102,0	441		0,61	0,34
76	-1124,0	440		0,58	0,29
36	-1165,0	441		0,60	0,41
-7	-1207,0	456		0,61	0,41
-38	-1238,0	444		0,61	0,41
-64	-1264,0	445		0,62	0,40

Fiss 1: 725 m A.S.L. 400601
Fiss 2: 646 m A.S.L. 400612

LEGEND:

Top of Oil Window, based VitRef (= 0.70 %Ro)

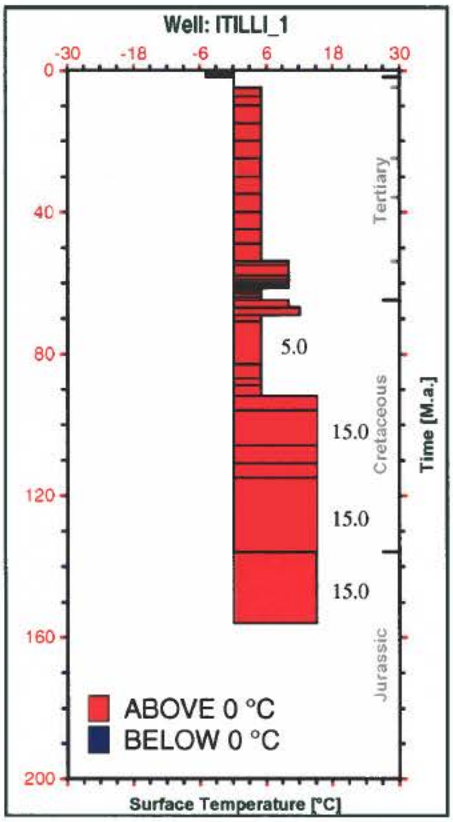
APPENDIX 4

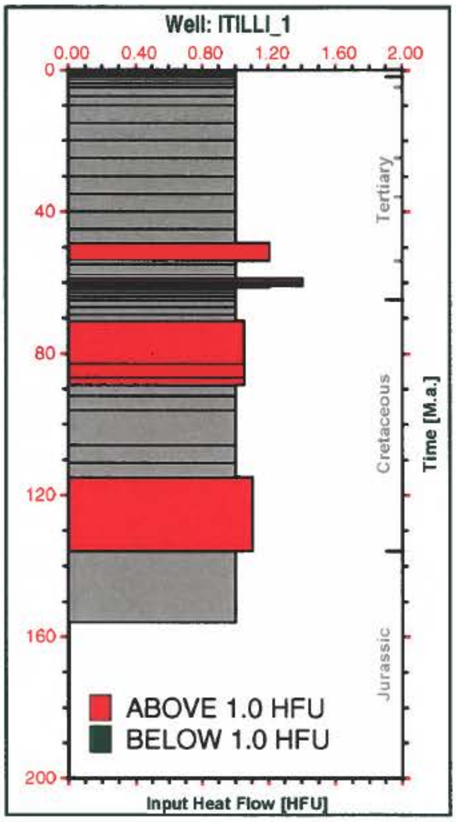
APPENDIX 5

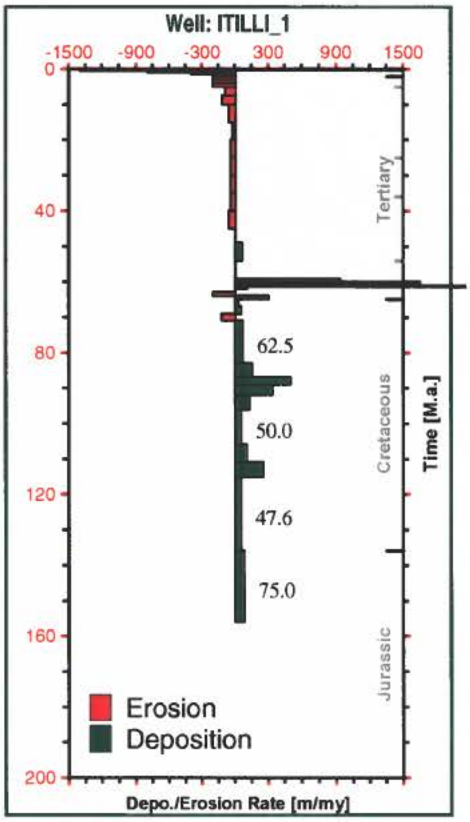
Model Concept Table and Input Parameter Plots

APPENDIX 5a : <Wellname>_1 -concept with maximum amount of volcanics

APPENDIX 5b : <Wellname>_6 -concept with minimum amount of volcanics





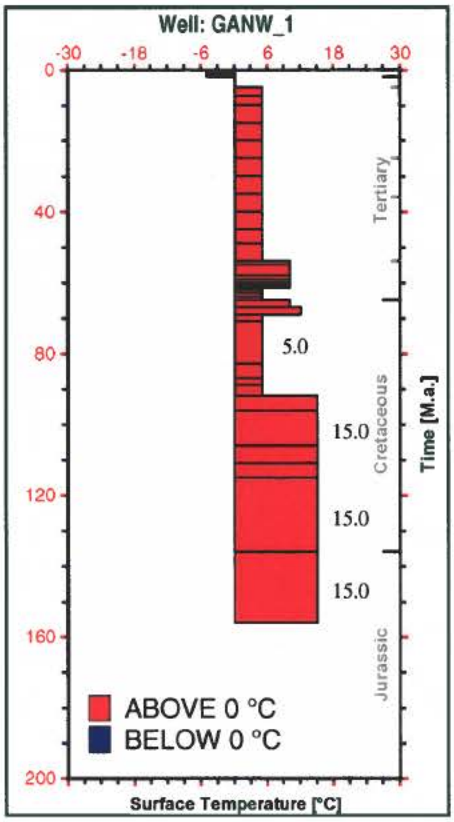


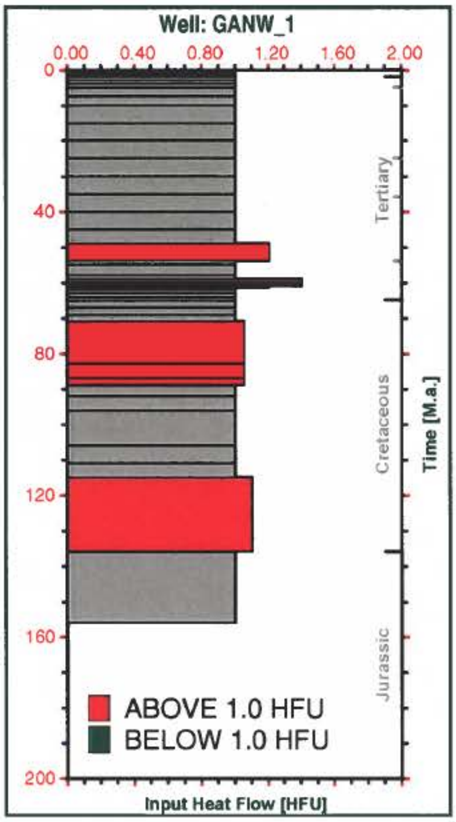
H:\NUUSSUAQ\ITILLI_1.PRN

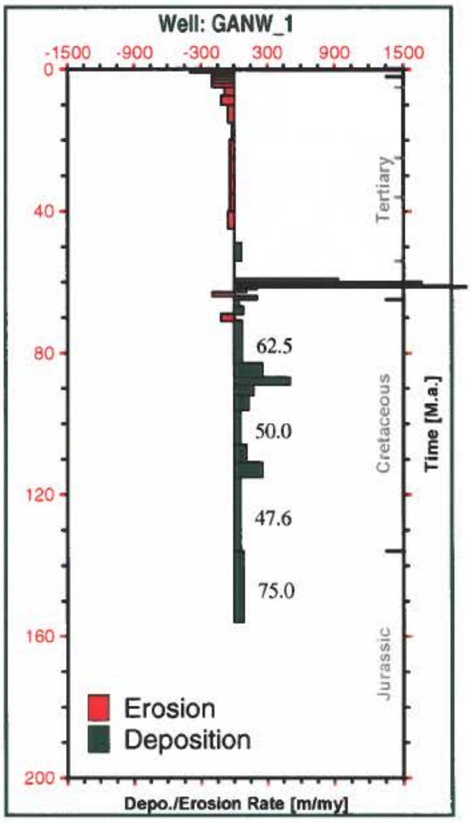
WELLNAME: ITILLI_1. UNITS: Meters/øC .PRN UPDATE: Torsdag 24 Sep 1998 - 18:38:27.91

NB-EVENTS: 42 TIMESTEP: 500000.00 DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-700.00	26.00	0.00	-5.00	1.00	-1400.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-400.00	26.00	0.00	-5.00	1.00	-800.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-75.00	26.00	0.00	-5.00	1.00	-150.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-225.00	25.70	0.00	5.00	1.00	-90.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-300.00	26.00	0.00	5.00	1.00	-120.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-125.00	25.70	0.00	5.00	1.00	-25.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-200.00	28.20	0.00	5.00	1.00	-40.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-200.00	28.20	0.00	5.00	1.00	-40.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	925.00	27.70	100.00	10.00	1.40	925.00	60.00	-------
20	Ordlingassoq M	52	0.50	825.00	27.70	250.00	10.00	1.40	1650.00	60.50	-------
19	Nauj nguit Mb	52	0.50	675.00	12.40	500.00	10.00	1.40	1350.00	61.00	-------
18	Anaanaa Mb	52	0.50	1400.00	7.50	500.00	10.00	1.20	2800.00	61.50	100.00
17	UNIT-D /SS6	10	0.50	50.00	20.40	50.00	5.00	1.00	100.00	62.00	150.00
16	UNIT-C /Quikav	10	1.00	0.00	18.20	100.00	5.00	1.00	0.00	63.00	-------
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	300.00	28.80	150.00	5.00	1.00	300.00	65.00	250.00
13	Maastr-2 SS4	13	2.00	50.00	14.20	20.00	10.00	1.00	25.00	67.00	300.00
12	Maastr-1 GC-1	14	2.00	100.00	17.10	150.00	12.00	1.00	50.00	69.00	400.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	20.60	100.00	5.00	1.05	62.50	83.00	900.00
9	Santonian SS2	18	4.00	600.00	18.80	150.00	5.00	1.05	150.00	87.00	1500.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	2500.00
7	Turonian SS1	18	3.00	1000.00	17.00	200.00	5.00	1.00	333.33	92.00	3500.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4000.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	4500.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5000.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6000.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7000.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	8500.00





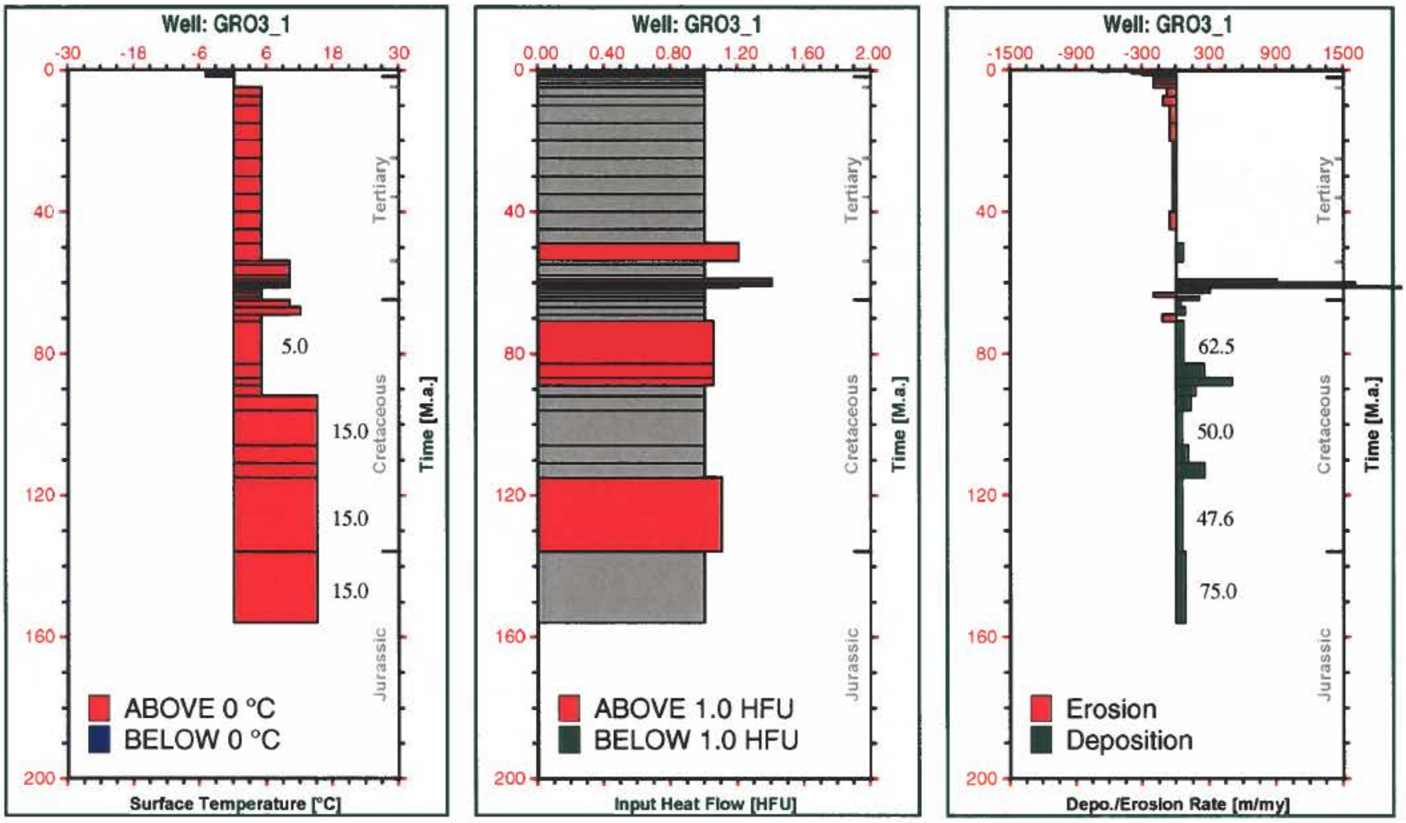


H:\NUUSSUAQ\GANW_1.PRN

WELLNAME: GANW_1.   UNITS: Meters/øC   .PRN UPDATE: Torsdag 24 Sep 1998 - 20:00:33.08

NB-EVENTS: 42   TIMESTEP: 500000.00   DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-75.00	26.00	0.00	-5.00	1.00	-150.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-225.00	25.70	0.00	5.00	1.00	-90.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-300.00	26.00	0.00	5.00	1.00	-120.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-125.00	25.70	0.00	5.00	1.00	-25.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-200.00	28.20	0.00	5.00	1.00	-40.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-200.00	28.20	0.00	5.00	1.00	-40.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	925.00	27.70	100.00	10.00	1.40	925.00	60.00	-------
20	Ordlingassoq M	52	0.50	825.00	27.70	250.00	10.00	1.40	1650.00	60.50	-------
19	Nauj nguit Mb	52	0.50	675.00	12.40	500.00	10.00	1.40	1350.00	61.00	-------
18	Anaanaa Mb	52	0.50	1400.00	7.50	500.00	10.00	1.20	2800.00	61.50	900.00
17	UNIT-D /SS6	10	0.50	100.00	18.40	50.00	5.00	1.00	200.00	62.00	1000.00
16	UNIT-C /Quikav	10	1.00	100.00	18.20	100.00	5.00	1.00	100.00	63.00	1100.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	75.00	14.20	20.00	10.00	1.00	37.50	67.00	1175.00
12	Maastr-1 GC-1	14	2.00	150.00	17.10	150.00	12.00	1.00	75.00	69.00	1325.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1825.00
9	Santonian SS2	18	4.00	1000.00	17.90	150.00	5.00	1.05	250.00	87.00	2825.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	3825.00
7	Turonian SS1	18	3.00	500.00	17.00	200.00	5.00	1.00	166.67	92.00	4325.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4825.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	5325.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5825.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6825.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7825.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	9325.00

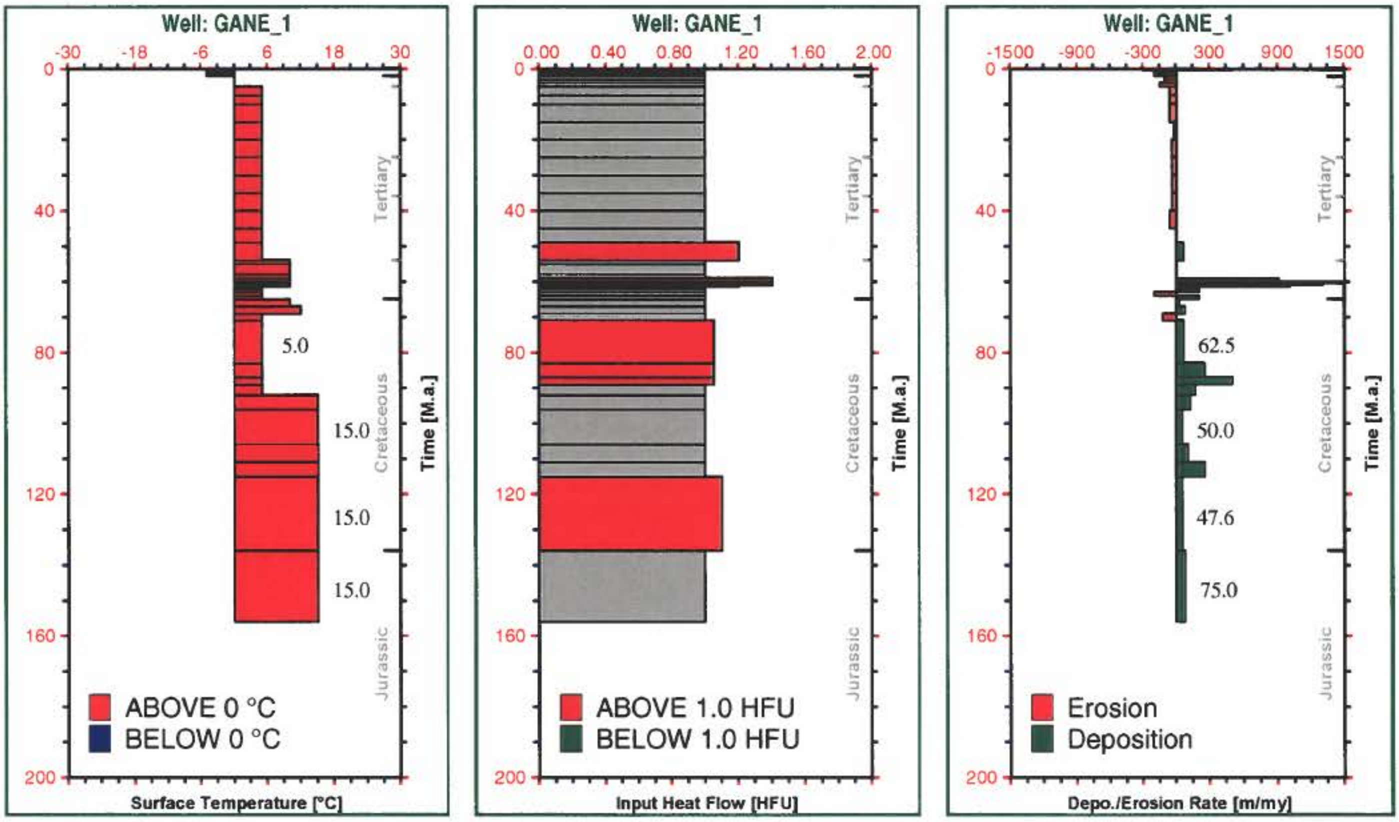


H:\NUUSSUAQ\GRO3_1.PRN

WELLNAME: GRO3_1. UNITS: Meters/øC .PRN UPDATE: Torsdag 24 Sep 1998 - 18:48:29.23

NB-EVENTS: 42 TIMESTEP: 500000.00 DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-350.00	26.00	0.00	-5.00	1.00	-700.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-200.00	25.70	0.00	5.00	1.00	-80.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-300.00	26.00	0.00	5.00	1.00	-120.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-150.00	28.20	0.00	5.00	1.00	-30.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-150.00	28.20	0.00	5.00	1.00	-30.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	900.00	27.70	100.00	10.00	1.40	900.00	60.00	-------
20	Ordlingassoq M	52	0.50	800.00	27.70	250.00	10.00	1.40	1600.00	60.50	-------
19	Nauj nguit Mb	52	0.50	650.00	12.40	500.00	10.00	1.40	1300.00	61.00	-------
18	Anaanaa Mb	52	0.50	1000.00	7.50	500.00	10.00	1.20	2000.00	61.50	300.00
17	UNIT-D /SS6	10	0.50	125.00	20.40	50.00	5.00	1.00	250.00	62.00	425.00
16	UNIT-C /Quikav	10	1.00	300.00	18.20	100.00	5.00	1.00	300.00	63.00	725.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	75.00	14.20	20.00	10.00	1.00	37.50	67.00	800.00
12	Maastr-1 GC-1	14	2.00	150.00	17.10	150.00	12.00	1.00	75.00	69.00	950.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1450.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2450.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	3450.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	3950.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4450.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	4950.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5450.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6450.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7450.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	8950.00



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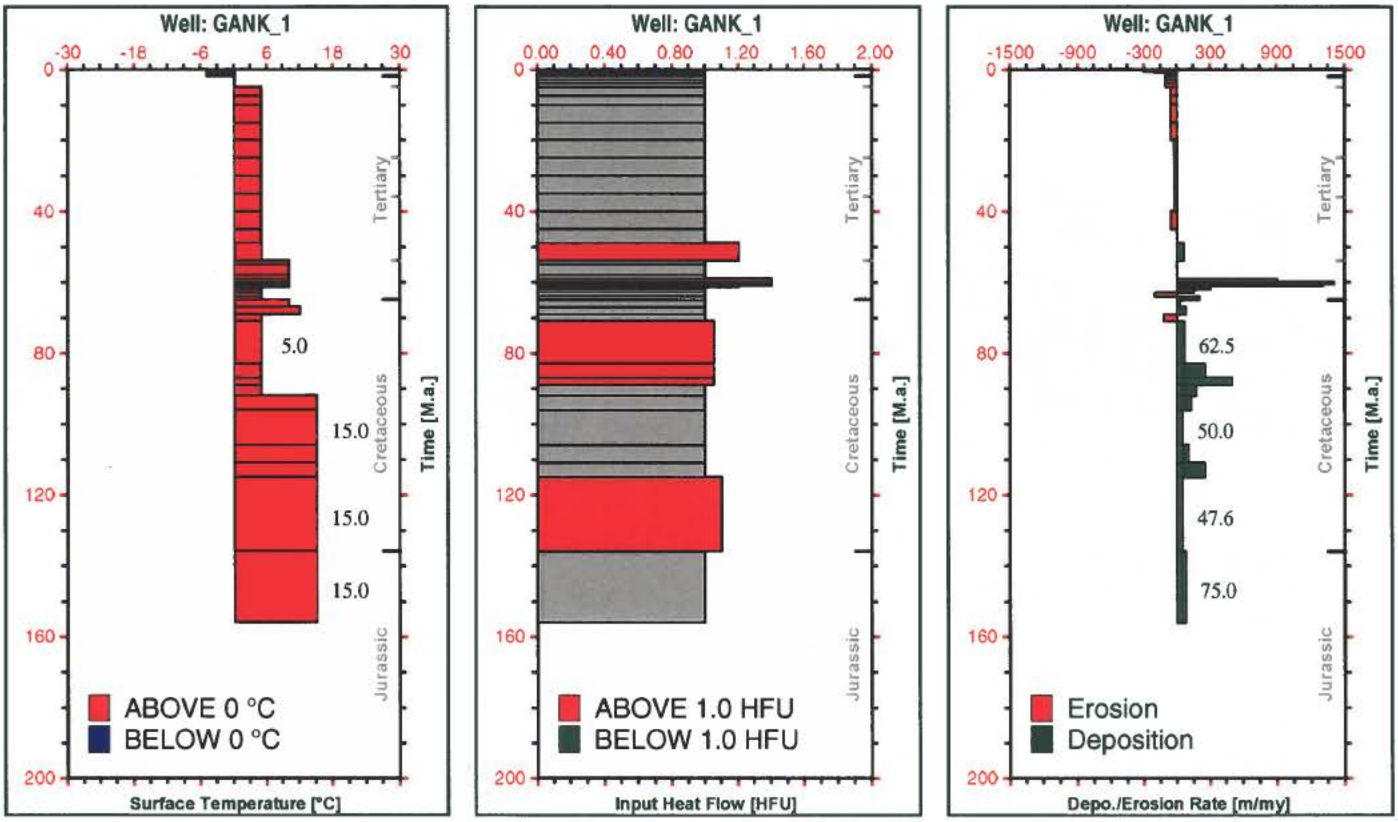
WELLNAME: GANE_1.　　UNITS: Meters/øC　　.PRN UPDATE: Torsdag 24 Sep 1998 - 18:51:22.96

NB-EVENTS: 42　　TIMESTEP: 500000.00　　DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-150.00	26.00	0.00	0.00	1.00	-150.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-150.00	25.70	0.00	5.00	1.00	-60.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-150.00	26.00	0.00	5.00	1.00	-60.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-100.00	25.70	0.00	5.00	1.00	-20.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-200.00	28.20	0.00	5.00	1.00	-40.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-200.00	28.20	0.00	5.00	1.00	-40.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	900.00	27.70	100.00	10.00	1.40	900.00	60.00	-------
20	Ordlingassoq M	52	0.50	750.00	27.70	250.00	10.00	1.40	1500.00	60.50	-------
19	Nauj nguit Mb	52	0.50	650.00	12.40	500.00	10.00	1.40	1300.00	61.00	-------
18	Anaanaa Mb	52	0.50	500.00	7.50	500.00	10.00	1.20	1000.00	61.50	500.00
17	UNIT-D /SS6	10	0.50	100.00	20.40	50.00	5.00	1.00	200.00	62.00	600.00
16	UNIT-C /Quikav	10	1.00	200.00	18.20	100.00	5.00	1.00	200.00	63.00	800.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	50.00	14.20	20.00	10.00	1.00	25.00	67.00	850.00
12	Maastr-1 GC-1	14	2.00	150.00	17.10	150.00	12.00	1.00	75.00	69.00	1000.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1500.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2500.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	3500.00
7	Turonian SS1	18	3.00	500.00	17.00	200.00	5.00	1.00	166.67	92.00	4000.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4500.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	5000.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5500.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6500.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7500.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	9000.00

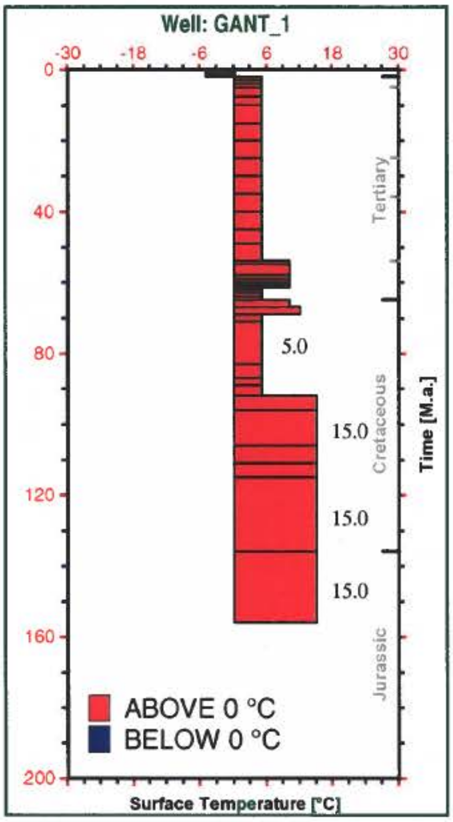


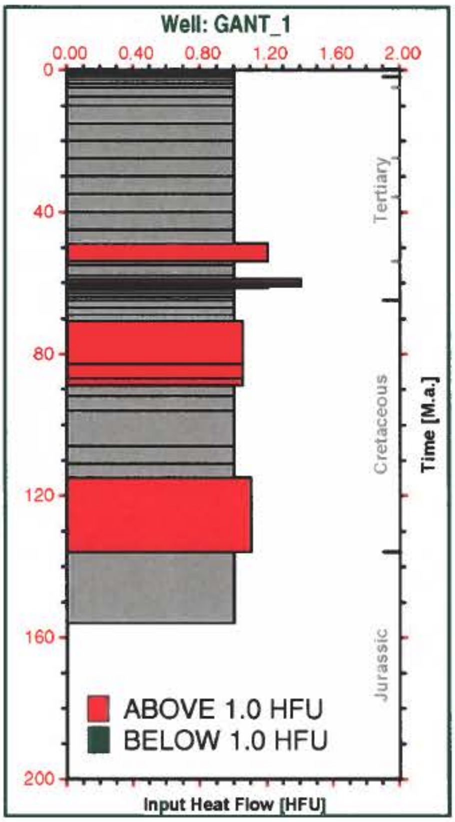
H:\NUUSSUAQ\GANK_1.PRN

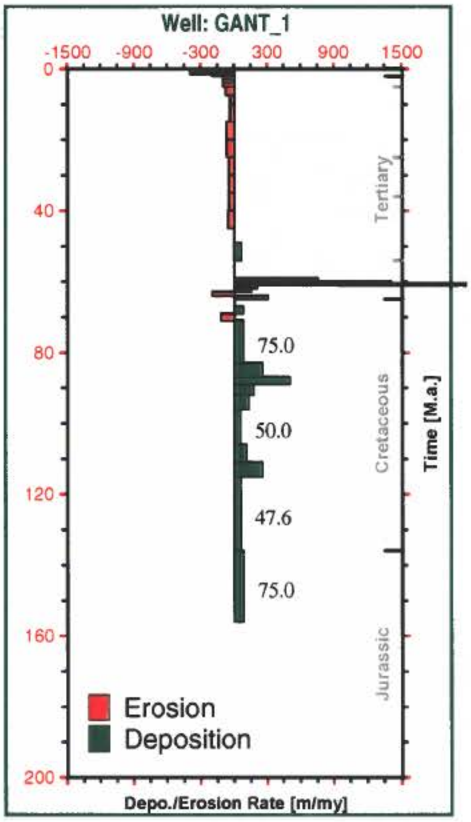
WELLNAME: GANK_1. UNITS: Meters/øC .PRN UPDATE: Torsdag 24 Sep 1998 - 20:08:39.39

NB-EVENTS: 42 TIMESTEP: 500000.00 DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-150.00	25.70	0.00	5.00	1.00	-60.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-150.00	26.00	0.00	5.00	1.00	-60.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-300.00	25.70	0.00	5.00	1.00	-60.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-150.00	28.20	0.00	5.00	1.00	-30.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-150.00	28.20	0.00	5.00	1.00	-30.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	900.00	27.70	100.00	10.00	1.40	900.00	60.00	-------
20	Ordlingassoq M	52	0.50	700.00	27.70	250.00	10.00	1.40	1400.00	60.50	-------
19	Nauj nguit Mb	52	0.50	650.00	12.40	500.00	10.00	1.40	1300.00	61.00	100.00
18	Anaanaa Mb	52	0.50	0.00	7.50	500.00	10.00	1.20	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	150.00	21.40	50.00	5.00	1.00	300.00	62.00	250.00
16	UNIT-C /Quikav	10	1.00	150.00	20.10	100.00	5.00	1.00	150.00	63.00	400.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	50.00	14.20	20.00	10.00	1.00	25.00	67.00	450.00
12	Maastr-1 GC-1	14	2.00	150.00	18.90	150.00	12.00	1.00	75.00	69.00	600.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1100.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2100.00
8	Coniacian SS1	18	2.00	1000.00	19.40	175.00	5.00	1.05	500.00	89.00	3100.00
7	Turonian SS1	18	3.00	500.00	17.00	200.00	5.00	1.00	166.67	92.00	3600.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4100.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	4600.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5100.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6100.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7100.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	8600.00





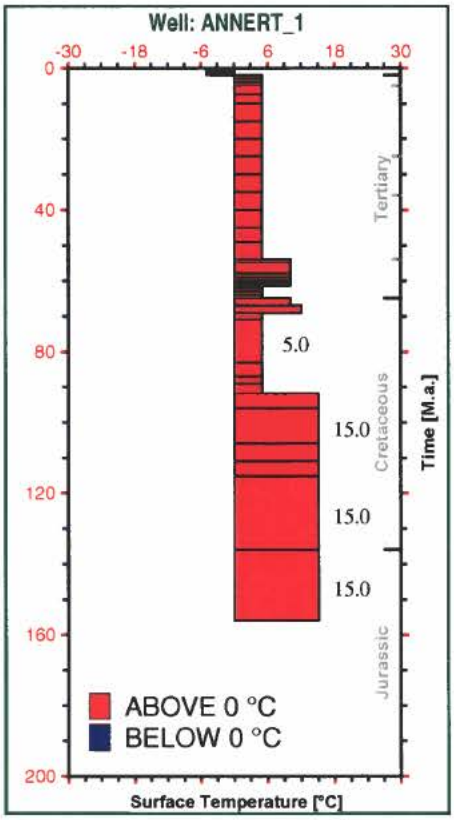


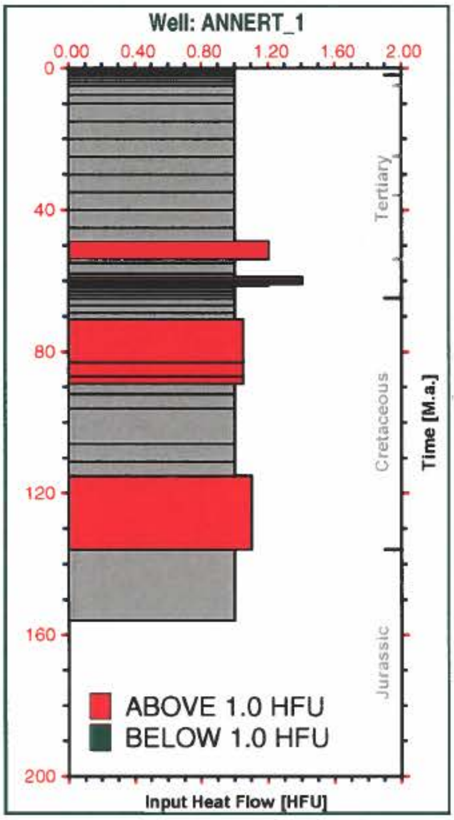
H:\NUUSSUAQ\GANT_1.PRN

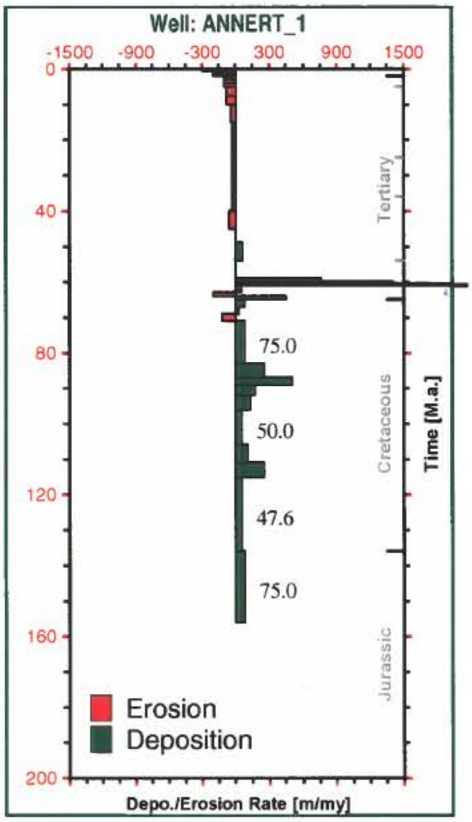
WELLNAME: GANT_1.   UNITS: Meters/øC   .PRN UPDATE: Torsdag 24 Sep 1998 - 20:11:28.67

NB-EVENTS: 42   TIMESTEP: 500000.00   DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-200.00	26.00	0.00	5.00	1.00	-80.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-350.00	25.70	0.00	5.00	1.00	-70.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-350.00	25.70	0.00	5.00	1.00	-70.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-250.00	25.70	0.00	5.00	1.00	-50.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-250.00	28.20	0.00	5.00	1.00	-50.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-250.00	28.20	0.00	5.00	1.00	-50.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	750.00	27.70	100.00	10.00	1.40	750.00	60.00	-------
20	Ordlingassoq M	52	0.50	700.00	27.70	250.00	10.00	1.40	1400.00	60.50	-------
19	Nauj nguit Mb	52	0.50	1100.00	12.40	500.00	10.00	1.40	2200.00	61.00	-------
18	Anaanaa Mb	52	0.50	0.00	7.80	500.00	10.00	1.20	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	100.00	20.40	50.00	5.00	1.00	200.00	62.00	-------
16	UNIT-C /Quikav	10	1.00	150.00	18.20	100.00	5.00	1.00	150.00	63.00	-------
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	300.00	28.80	150.00	5.00	1.00	300.00	65.00	100.00
13	Maastr-2 SS4	13	2.00	0.00	14.20	20.00	10.00	1.00	0.00	67.00	-------
12	Maastr-1 GC-1	14	2.00	150.00	18.90	150.00	12.00	1.00	75.00	69.00	250.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	900.00	20.60	100.00	5.00	1.05	75.00	83.00	900.00
9	Santonian SS2	18	4.00	1000.00	18.70	150.00	5.00	1.05	250.00	87.00	1900.00
8	Coniacian SS1	18	2.00	1000.00	19.30	175.00	5.00	1.05	500.00	89.00	2900.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	3400.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	3900.00
5	Albian	23	10.00	500.00	13.00	5.00	15.00	1.00	50.00	106.00	4400.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	4900.00
3	Barremian	23	4.00	1000.00	12.30	5.00	15.00	1.00	250.00	115.00	5900.00
2	Pre-Barremian	10	21.00	1000.00	16.10	100.00	15.00	1.10	47.62	136.00	6900.00
1	Basement	33	20.00	1500.00	13.80	100.00	15.00	1.00	75.00	156.00	8400.00





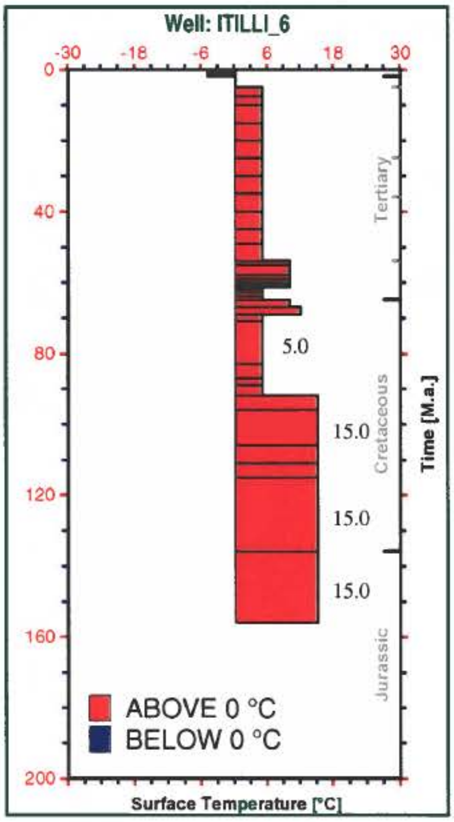


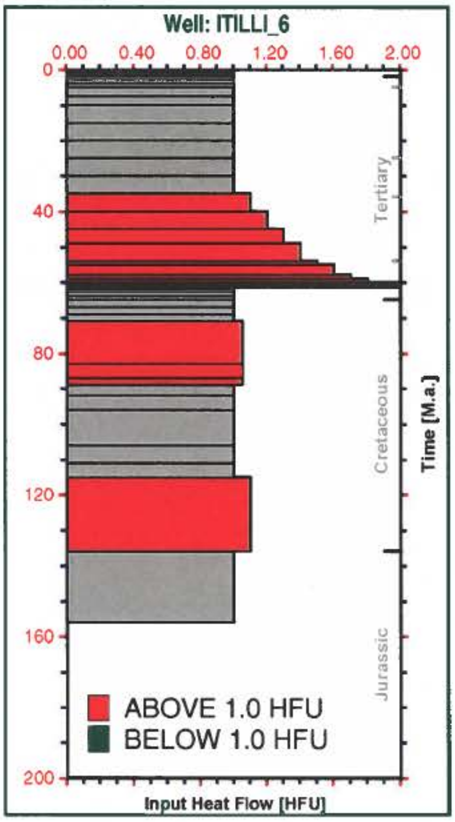
H:\NUUSSUAQ\ANNERT_1.PRN

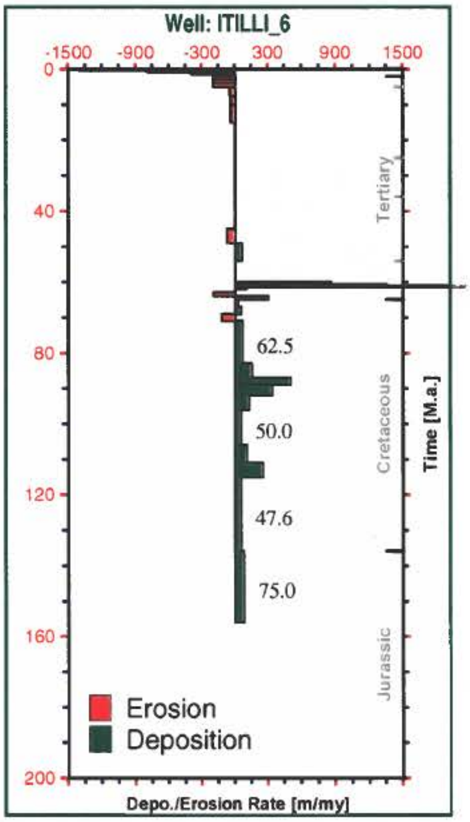
WELLNAME: ANNERT_1. UNITS: Meters/øC .PRN UPDATE: Torsdag 24 Sep 1998 - 20:14:22.56

NB-EVENTS: 42 TIMESTEP: 500000.00 DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-200.00	26.00	0.00	5.00	1.00	-80.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-200.00	26.00	0.00	5.00	1.00	-80.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	-150.00	28.20	0.00	5.00	1.00	-30.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	-150.00	28.20	0.00	5.00	1.00	-30.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	-300.00	28.20	0.00	5.00	1.00	-60.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.20	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.00	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.00	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	750.00	27.70	100.00	10.00	1.40	750.00	60.00	-------
20	Ordlingassoq M	52	0.50	700.00	27.70	250.00	10.00	1.40	1400.00	60.50	-------
19	Nauj nguit Mb	52	0.50	1100.00	11.80	500.00	10.00	1.40	2200.00	61.00	450.00
18	Anaanaa Mb	52	0.50	0.00	7.80	500.00	10.00	1.20	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	0.00	20.40	50.00	5.00	1.00	0.00	62.00	-------
16	UNIT-C /Quikav	10	1.00	50.00	20.90	100.00	5.00	1.00	50.00	63.00	500.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	450.00	28.80	150.00	5.00	1.00	450.00	65.00	750.00
13	Maastr-2 SS4	13	2.00	150.00	14.20	20.00	10.00	1.00	75.00	67.00	900.00
12	Maastr-1 GC-1	14	2.00	50.00	18.90	150.00	12.00	1.00	25.00	69.00	950.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	900.00	20.60	100.00	5.00	1.05	75.00	83.00	1600.00
9	Santonian SS2	18	4.00	1000.00	18.70	150.00	5.00	1.05	250.00	87.00	2600.00
8	Coniacian SS1	18	2.00	1000.00	19.30	175.00	5.00	1.05	500.00	89.00	3600.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	4100.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4600.00
5	Albian	23	10.00	500.00	13.00	5.00	15.00	1.00	50.00	106.00	5100.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5600.00
3	Barremian	23	4.00	1000.00	12.30	5.00	15.00	1.00	250.00	115.00	6600.00
2	Pre-Barremian	10	21.00	1000.00	16.10	100.00	15.00	1.10	47.62	136.00	7600.00
1	Basement	33	20.00	1500.00	13.80	100.00	15.00	1.00	75.00	156.00	9100.00





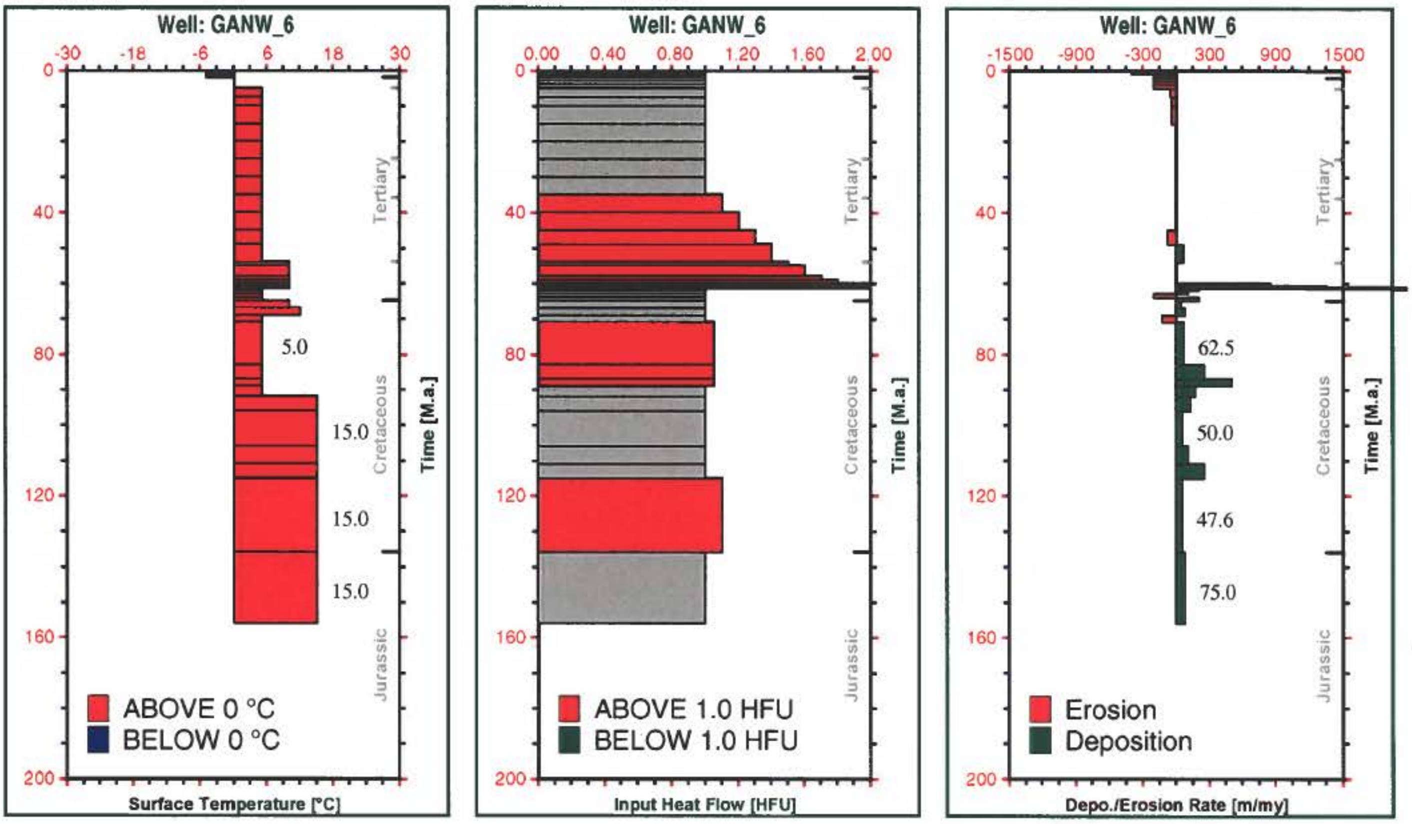


H:\NUUSSUAQ\ITILLI_6.PRN

WELLNAME: ITILLI_6.   UNITS: Meters/øC   .PRN UPDATE: Fredag 25 Sep 1998 - 11:10:46.27

NB-EVENTS: 42   TIMESTEP: 500000.00   DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-700.00	26.00	0.00	-5.00	1.00	-1400.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-400.00	26.00	0.00	-5.00	1.00	-800.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-75.00	26.00	0.00	-5.00	1.00	-150.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-125.00	25.70	0.00	5.00	1.00	-50.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	425.00	27.70	250.00	10.00	2.00	850.00	60.50	-------
19	Nauj nguit Mb	52	0.50	675.00	12.40	500.00	10.00	2.00	1350.00	61.00	-------
18	Anaanaa Mb	52	0.50	1400.00	7.50	500.00	10.00	2.00	2800.00	61.50	100.00
17	UNIT-D /SS6	10	0.50	50.00	23.50	50.00	5.00	1.00	100.00	62.00	150.00
16	UNIT-C /Quikav	10	1.00	0.00	18.20	100.00	5.00	1.00	0.00	63.00	-------
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	300.00	28.80	150.00	5.00	1.00	300.00	65.00	250.00
13	Maastr-2 SS4	13	2.00	50.00	14.20	20.00	10.00	1.00	25.00	67.00	300.00
12	Maastr-1 GC-1	14	2.00	100.00	17.10	150.00	12.00	1.00	50.00	69.00	400.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	900.00
9	Santonian SS2	18	4.00	600.00	18.80	150.00	5.00	1.05	150.00	87.00	1500.00
8	Coniacian SS1	18	2.00	1000.00	19.40	175.00	5.00	1.05	500.00	89.00	2500.00
7	Turonian SS1	18	3.00	1000.00	17.00	200.00	5.00	1.00	333.33	92.00	3500.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4000.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	4500.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5000.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6000.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7000.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	8500.00

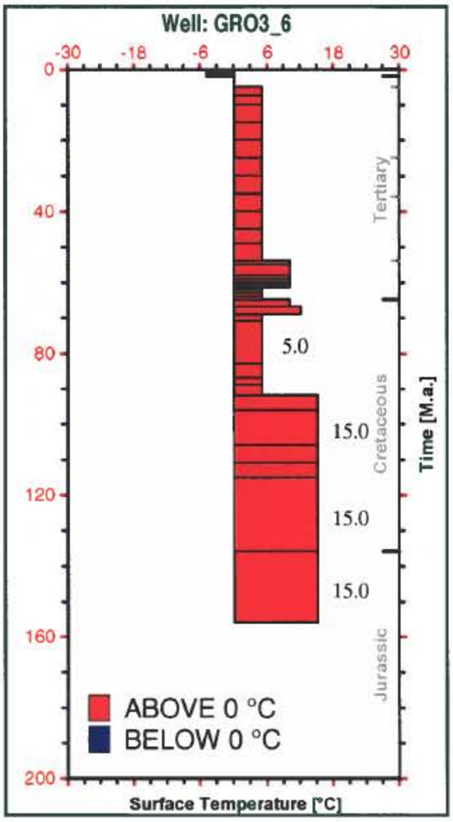


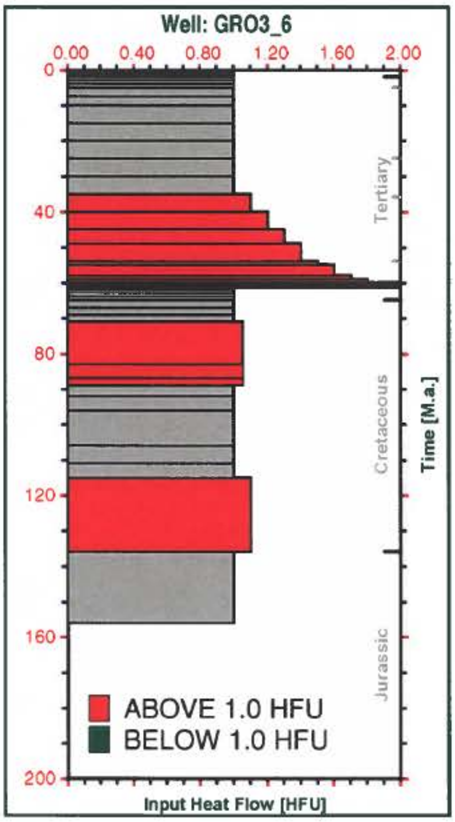
H:\NUUSSUAQ\GANW_6.PRN

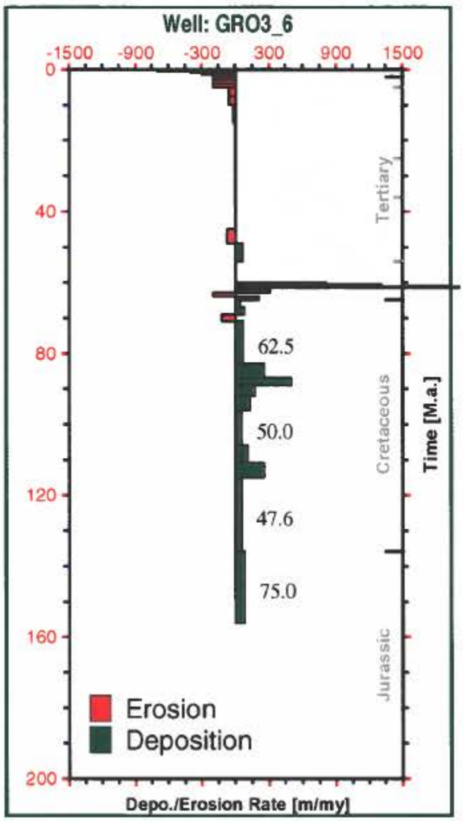
WELLNAME: GANW_6.   UNITS: Meters/øC   .PRN UPDATE: Fredag 25 Sep 1998 - 11:13:23.90

NB-EVENTS: 42   TIMESTEP: 500000.00   DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-75.00	26.00	0.00	-5.00	1.00	-150.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-125.00	25.70	0.00	5.00	1.00	-50.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	425.00	27.70	250.00	10.00	2.00	850.00	60.50	-------
19	Nauj nguit Mb	52	0.50	675.00	12.40	500.00	10.00	2.00	1350.00	61.00	-------
18	Anaanaa Mb	52	0.50	1400.00	7.50	500.00	10.00	2.00	2800.00	61.50	900.00
17	UNIT-D /SS6	10	0.50	100.00	20.40	50.00	5.00	1.00	200.00	62.00	1000.00
16	UNIT-C /Quikav	10	1.00	100.00	18.20	100.00	5.00	1.00	100.00	63.00	1100.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	75.00	14.20	20.00	10.00	1.00	37.50	67.00	1175.00
12	Maastr-1 GC-1	14	2.00	150.00	17.10	150.00	12.00	1.00	75.00	69.00	1325.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1825.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2825.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	3825.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	4325.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4825.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	5325.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5825.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6825.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7825.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	9325.00





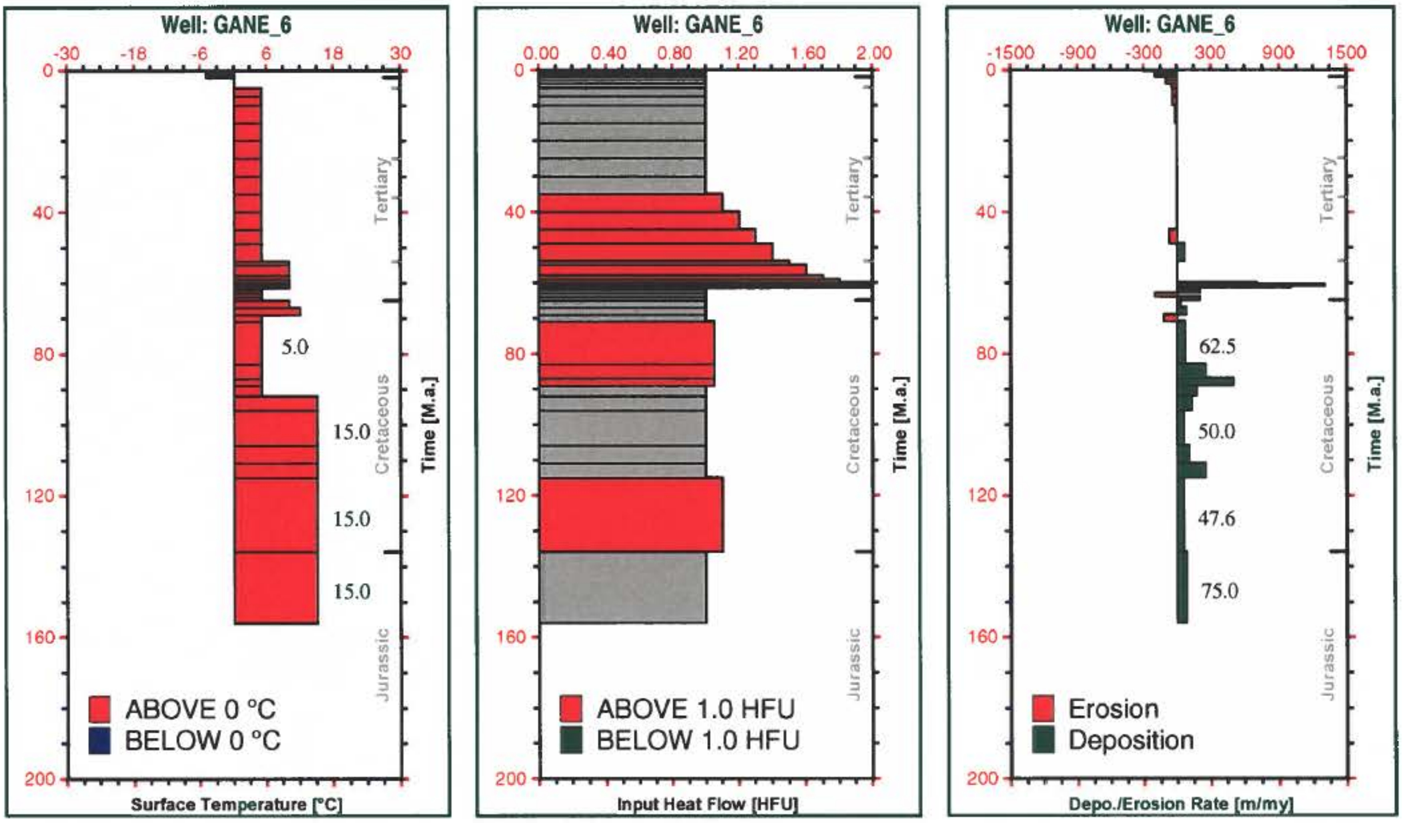


H:\NUUSSUAQ\GRO3_6.PRN

WELLNAME: GRO3_6.   UNITS: Meters/øC   .PRN UPDATE: Fredag 25 Sep 1998 - 11:16:05.00

NB-EVENTS: 42   TIMESTEP: 500000.00   DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-350.00	26.00	0.00	-5.00	1.00	-700.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-200.00	26.00	0.00	-5.00	1.00	-400.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-200.00	26.00	0.00	0.00	1.00	-200.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-150.00	25.70	0.00	5.00	1.00	-60.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-150.00	26.00	0.00	5.00	1.00	-60.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-100.00	25.70	0.00	5.00	1.00	-20.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	400.00	27.70	250.00	10.00	2.00	800.00	60.50	-------
19	Nauj nguit Mb	52	0.50	650.00	12.40	500.00	10.00	2.00	1300.00	61.00	-------
18	Anaanaa Mb	52	0.50	1000.00	7.50	500.00	10.00	2.00	2000.00	61.50	300.00
17	UNIT-D /SS6	10	0.50	125.00	22.40	50.00	5.00	1.00	250.00	62.00	425.00
16	UNIT-C /Quikav	10	1.00	300.00	19.10	100.00	5.00	1.00	300.00	63.00	725.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	75.00	14.20	20.00	10.00	1.00	37.50	67.00	800.00
12	Maastr-1 GC-1	14	2.00	150.00	18.00	150.00	12.00	1.00	75.00	69.00	950.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1450.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2450.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	3450.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	3950.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4450.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	4950.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5450.00
3	Barremian	23	4.00	1000.00	.11.70	5.00	15.00	1.00	250.00	115.00	6450.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7450.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	8950.00

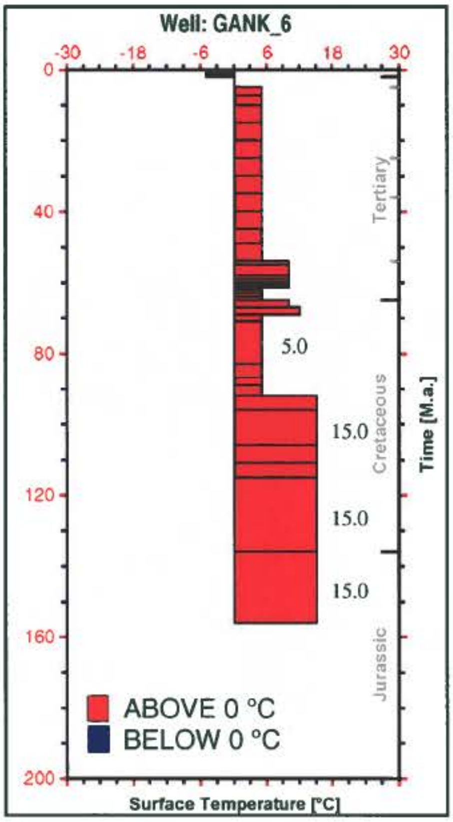


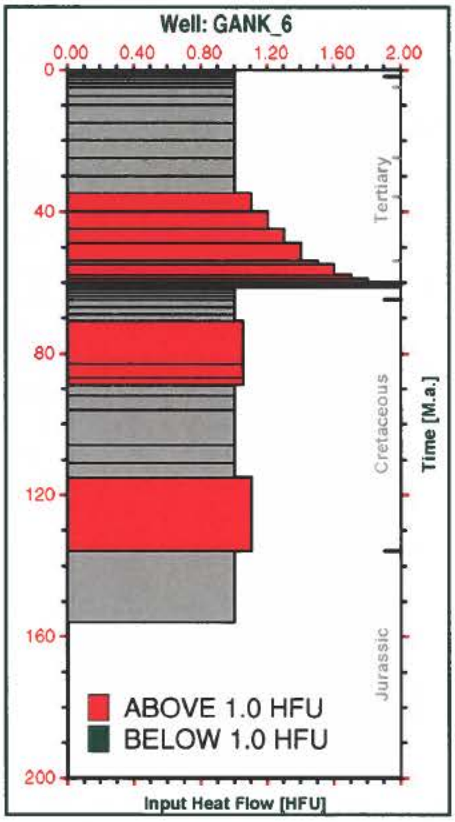
H:\NUUSSUAQ\GANE_6.PRN

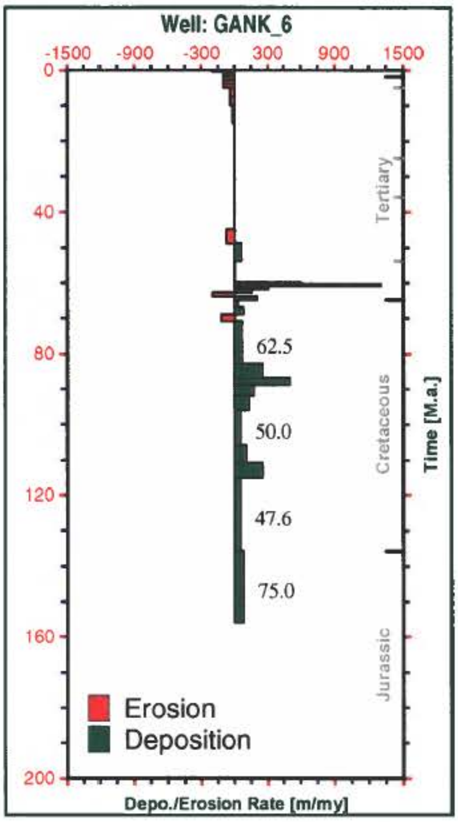
WELLNAME: GANE_6. UNITS: Meters/øC .PRN UPDATE: Fredag 25 Sep 1998 - 11:18:45.38

NB-EVENTS: 42 TIMESTEP: 500000.00 DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-50.00	26.00	0.00	0.00	1.00	-50.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-100.00	25.70	0.00	5.00	1.00	-40.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-100.00	25.70	0.00	5.00	1.00	-20.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	350.00	27.70	250.00	10.00	2.00	700.00	60.50	-------
19	Nauj nguit Mb	52	0.50	650.00	12.40	500.00	10.00	2.00	1300.00	61.00	-------
18	Anaanaa Mb	52	0.50	500.00	7.50	500.00	10.00	2.00	1000.00	61.50	500.00
17	UNIT-D /SS6	10	0.50	100.00	21.30	50.00	5.00	1.00	200.00	62.00	600.00
16	UNIT-C /Quikav	10	1.00	200.00	20.10	100.00	5.00	1.00	200.00	63.00	800.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	50.00	14.20	20.00	10.00	1.00	25.00	67.00	850.00
12	Maastr-1 GC-1	14	2.00	150.00	18.90	150.00	12.00	1.00	75.00	69.00	1000.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	21.70	100.00	5.00	1.05	62.50	83.00	1500.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2500.00
8	Coniacian SS1	18	2.00	1000.00	18.50	175.00	5.00	1.05	500.00	89.00	3500.00
7	Turonian SS1	18	3.00	500.00	17.00	200.00	5.00	1.00	166.67	92.00	4000.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4500.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	5000.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5500.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6500.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7500.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	9000.00





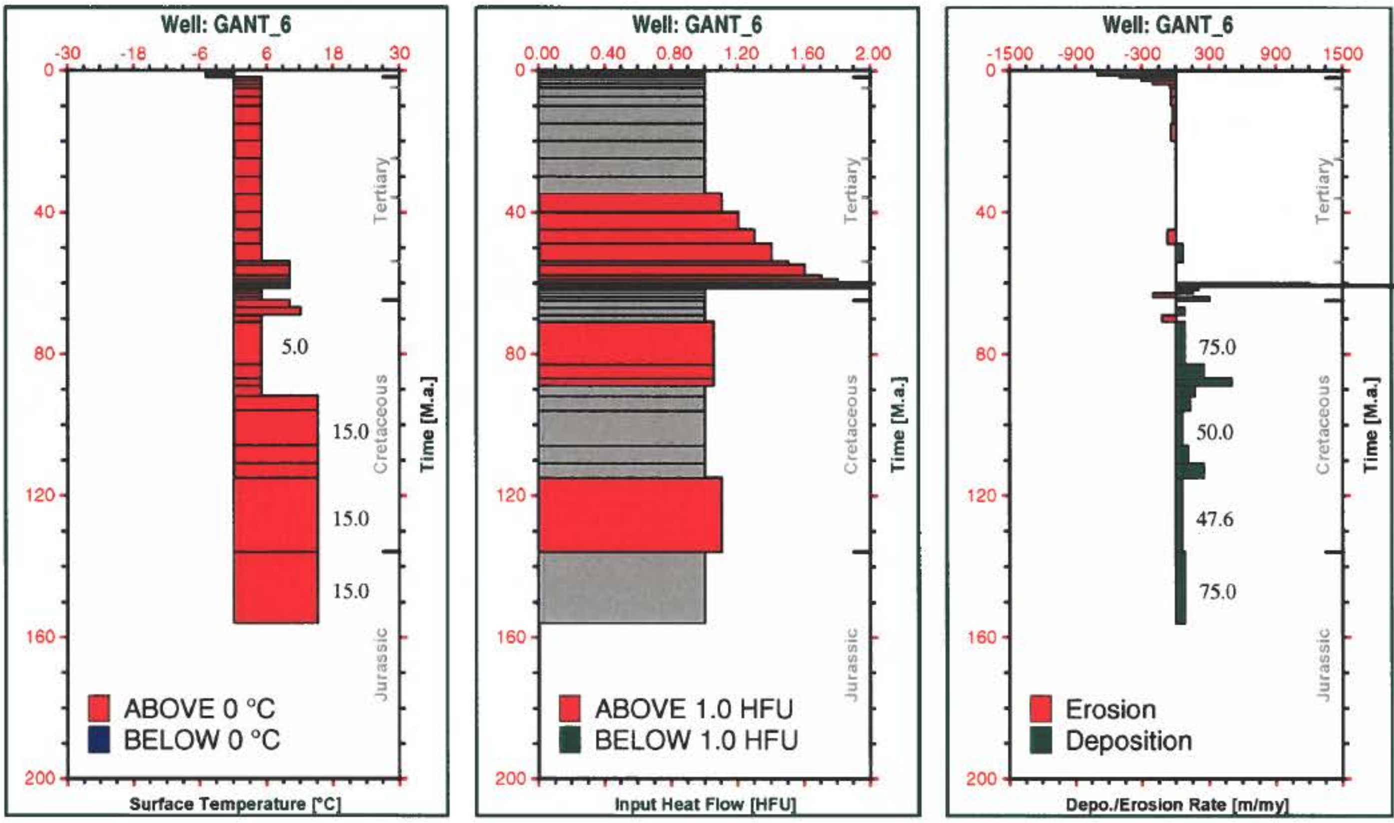


H:\NUUSSUAQ\GANK_6.PRN

WELLNAME: GANK_6.　　UNITS: Meters/øC　　.PRN UPDATE: Fredag 25 Sep 1998 - 11:21:31.81

NB-EVENTS: 42　　TIMESTEP: 500000.00　　DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-50.00	26.00	0.00	-5.00	1.00	-100.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-100.00	26.00	0.00	0.00	1.00	-100.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-100.00	25.70	0.00	5.00	1.00	-40.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-100.00	25.70	0.00	5.00	1.00	-20.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	300.00	27.70	250.00	10.00	2.00	600.00	60.50	-------
19	Nauj nguit Mb	52	0.50	650.00	12.40	500.00	10.00	2.00	1300.00	61.00	100.00
18	Anaanaa Mb	52	0.50	0.00	7.50	500.00	10.00	2.00	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	150.00	27.20	50.00	5.00	1.00	300.00	62.00	250.00
16	UNIT-C /Quikav	10	1.00	150.00	24.50	100.00	5.00	1.00	150.00	63.00	400.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	200.00	28.80	150.00	5.00	1.00	200.00	65.00	-------
13	Maastr-2 SS4	13	2.00	50.00	14.20	20.00	10.00	1.00	25.00	67.00	450.00
12	Maastr-1 GC-1	14	2.00	150.00	21.80	150.00	12.00	1.00	75.00	69.00	600.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	750.00	22.80	100.00	5.00	1.05	62.50	83.00	1100.00
9	Santonian SS2	18	4.00	1000.00	18.80	150.00	5.00	1.05	250.00	87.00	2100.00
8	Coniacian SS1	18	2.00	1000.00	19.40	175.00	5.00	1.05	500.00	89.00	3100.00
7	Turonian SS1	18	3.00	500.00	17.00	200.00	5.00	1.00	166.67	92.00	3600.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4100.00
5	Albian	23	10.00	500.00	12.40	5.00	15.00	1.00	50.00	106.00	4600.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5100.00
3	Barremian	23	4.00	1000.00	11.70	5.00	15.00	1.00	250.00	115.00	6100.00
2	Pre-Barremian	10	21.00	1000.00	15.30	100.00	15.00	1.10	47.62	136.00	7100.00
1	Basement	33	20.00	1500.00	13.10	100.00	15.00	1.00	75.00	156.00	8600.00

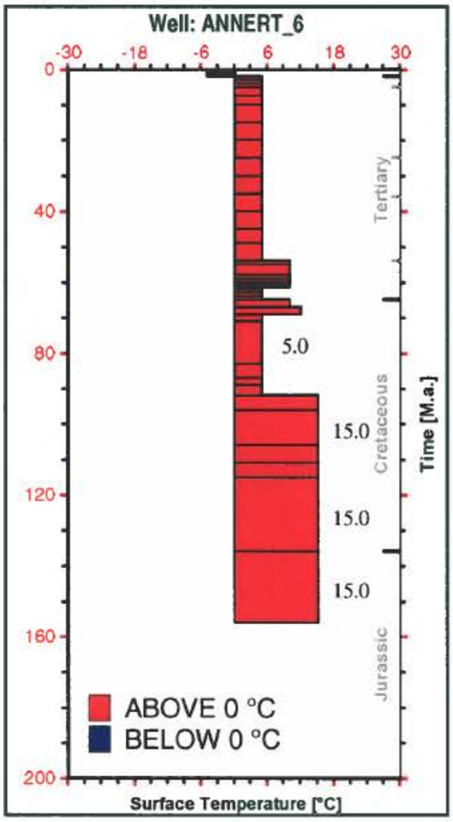


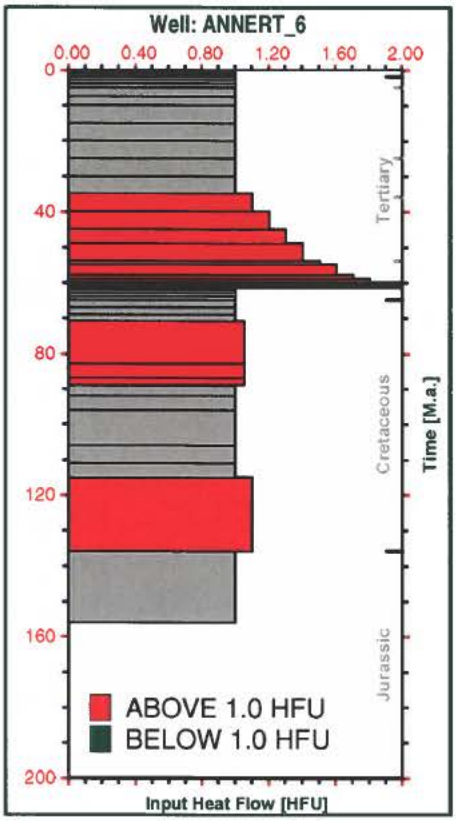
H:\NUUSSUAQ\GANT_6.PRN

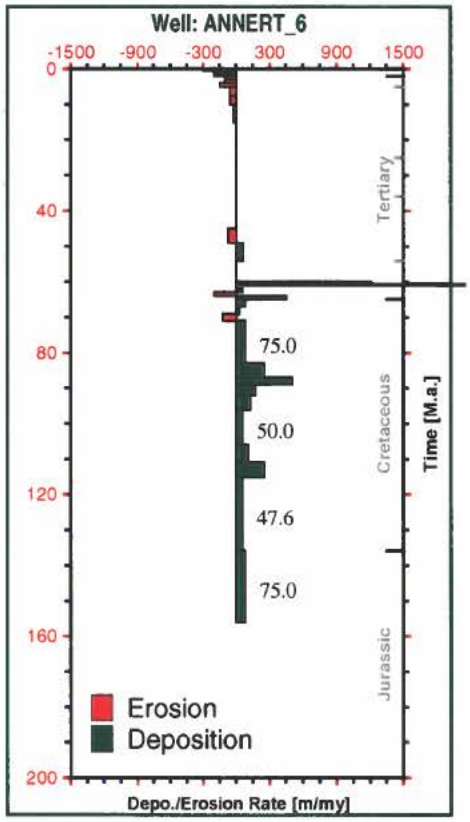
WELLNAME: GANT_6.   UNITS: Meters/øC   .PRN UPDATE: Fredag 25 Sep 1998 - 11:26:36.15

NB-EVENTS: 42   TIMESTEP: 500000.00   DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-350.00	26.00	0.00	-5.00	1.00	-700.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-250.00	26.00	0.00	-5.00	1.00	-500.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-300.00	25.70	0.00	5.00	1.00	-300.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-200.00	25.70	0.00	5.00	1.00	-200.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-50.00	25.70	0.00	5.00	1.00	-50.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-100.00	26.00	0.00	5.00	1.00	-40.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	15.00	-------
32	Neogene UPLIFT	1	5.00	-200.00	25.70	0.00	5.00	1.00	-40.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	600.00	27.70	250.00	10.00	2.00	1200.00	60.50	-------
19	Nauj nguit Mb	52	0.50	1100.00	12.40	500.00	10.00	2.00	2200.00	61.00	-------
18	Anaanaa Mb	52	0.50	0.00	7.80	500.00	10.00	2.00	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	100.00	20.40	50.00	5.00	1.00	200.00	62.00	-------
16	UNIT-C /Quikav	10	1.00	150.00	18.20	100.00	5.00	1.00	150.00	63.00	-------
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	300.00	28.80	150.00	5.00	1.00	300.00	65.00	100.00
13	Maastr-2 SS4	13	2.00	0.00	14.20	20.00	10.00	1.00	0.00	67.00	-------
12	Maastr-1 GC-1	14	2.00	150.00	18.90	150.00	12.00	1.00	75.00	69.00	250.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	900.00	21.60	100.00	5.00	1.05	75.00	83.00	900.00
9	Santonian SS2	18	4.00	1000.00	19.60	150.00	5.00	1.05	250.00	87.00	1900.00
8	Coniacian SS1	18	2.00	1000.00	20.30	175.00	5.00	1.05	500.00	89.00	2900.00
7	Turonian SS1	18	3.00	500.00	18.80	200.00	5.00	1.00	166.67	92.00	3400.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	3900.00
5	Albian	23	10.00	500.00	13.00	5.00	15.00	1.00	50.00	106.00	4400.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	4900.00
3	Barremian	23	4.00	1000.00	12.30	5.00	15.00	1.00	250.00	115.00	5900.00
2	Pre-Barremian	10	21.00	1000.00	16.10	100.00	15.00	1.10	47.62	136.00	6900.00
1	Basement	33	20.00	1500.00	13.80	100.00	15.00	1.00	75.00	156.00	8400.00







H:\NUUSSUAQ\ANNERT_6.PRN

WELLNAME: ANNERT_6. UNITS: Meters/øC .PRN UPDATE: Fredag 25 Sep 1998 - 11:30:48.31

NB-EVENTS: 42 TIMESTEP: 250000.00 DEPTHSTEP: 25.00

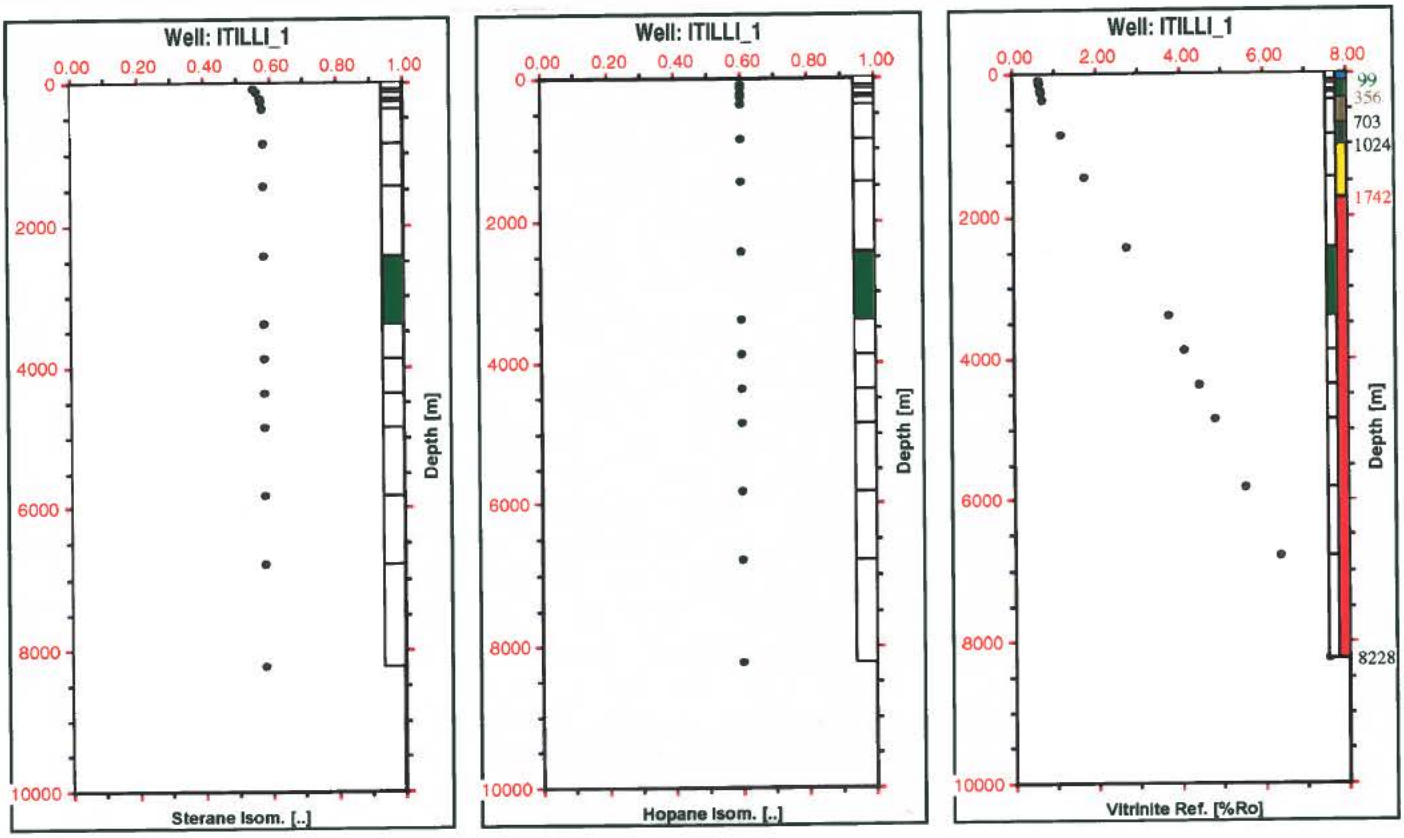
Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-100.00	25.70	0.00	5.00	1.00	-100.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-150.00	25.70	0.00	5.00	1.00	-150.00	5.00	-------
35	Neogene UPLIFT	1	2.50	-150.00	26.00	0.00	5.00	1.00	-60.00	7.50	-------
34	Neogene UPLIFT	1	2.50	-150.00	26.00	0.00	5.00	1.00	-60.00	10.00	-------
33	Neogene UPLIFT	1	5.00	-150.00	25.70	0.00	5.00	1.00	-30.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.10	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.20	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	-300.00	28.20	0.00	5.00	1.30	-75.00	49.00	-------
25	Volca./Ifsoris	3	5.00	300.00	28.20	0.00	5.00	1.40	60.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.50	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.60	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.70	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	0.00	27.70	100.00	10.00	1.80	0.00	60.00	-------
20	Ordlingassoq M	52	0.50	600.00	27.70	250.00	10.00	2.00	1200.00	60.50	-------
19	Nauj nguit Mb	52	0.50	1100.00	11.80	500.00	10.00	2.00	2200.00	61.00	450.00
18	Anaanaa Mb	52	0.50	0.00	7.80	500.00	10.00	2.00	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	0.00	20.40	50.00	5.00	1.00	0.00	62.00	-------
16	UNIT-C /Quikav	10	1.00	50.00	20.90	100.00	5.00	1.00	50.00	63.00	500.00
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	450.00	28.80	150.00	5.00	1.00	450.00	65.00	750.00
13	Maastr-2 SS4	13	2.00	150.00	14.20	20.00	10.00	1.00	75.00	67.00	900.00
12	Maastr-1 GC-1	14	2.00	50.00	18.90	150.00	12.00	1.00	25.00	69.00	950.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	900.00	20.60	100.00	5.00	1.05	75.00	83.00	1600.00
9	Santonian SS2	18	4.00	1000.00	18.70	150.00	5.00	1.05	250.00	87.00	2600.00
8	Coniacian SS1	18	2.00	1000.00	19.30	175.00	5.00	1.05	500.00	89.00	3600.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	4100.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	4600.00
5	Albian	23	10.00	500.00	13.00	5.00	15.00	1.00	50.00	106.00	5100.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	5600.00
3	Barremian	23	4.00	1000.00	12.30	5.00	15.00	1.00	250.00	115.00	6600.00
2	Pre-Barremian	10	21.00	1000.00	16.10	100.00	15.00	1.10	47.62	136.00	7600.00
1	Basement	33	20.00	1500.00	13.80	100.00	15.00	1.00	75.00	156.00	9100.00

APPENDIX 6

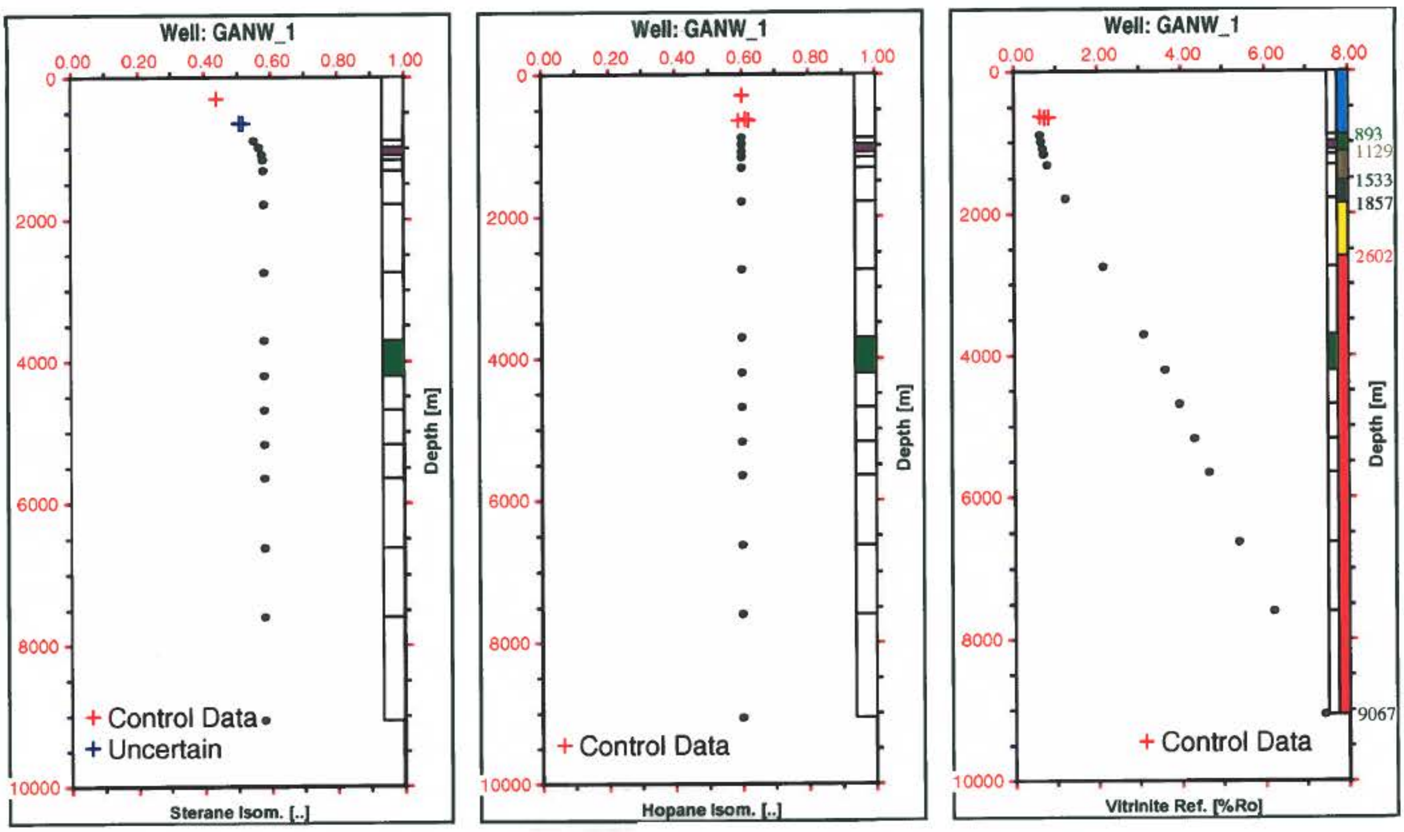
Maturity Modelling; Optimisation and Hydrocarbon Generation Results

APPENDIX 6a : <Wellname>_1 -concept with maximum amount of volcanics

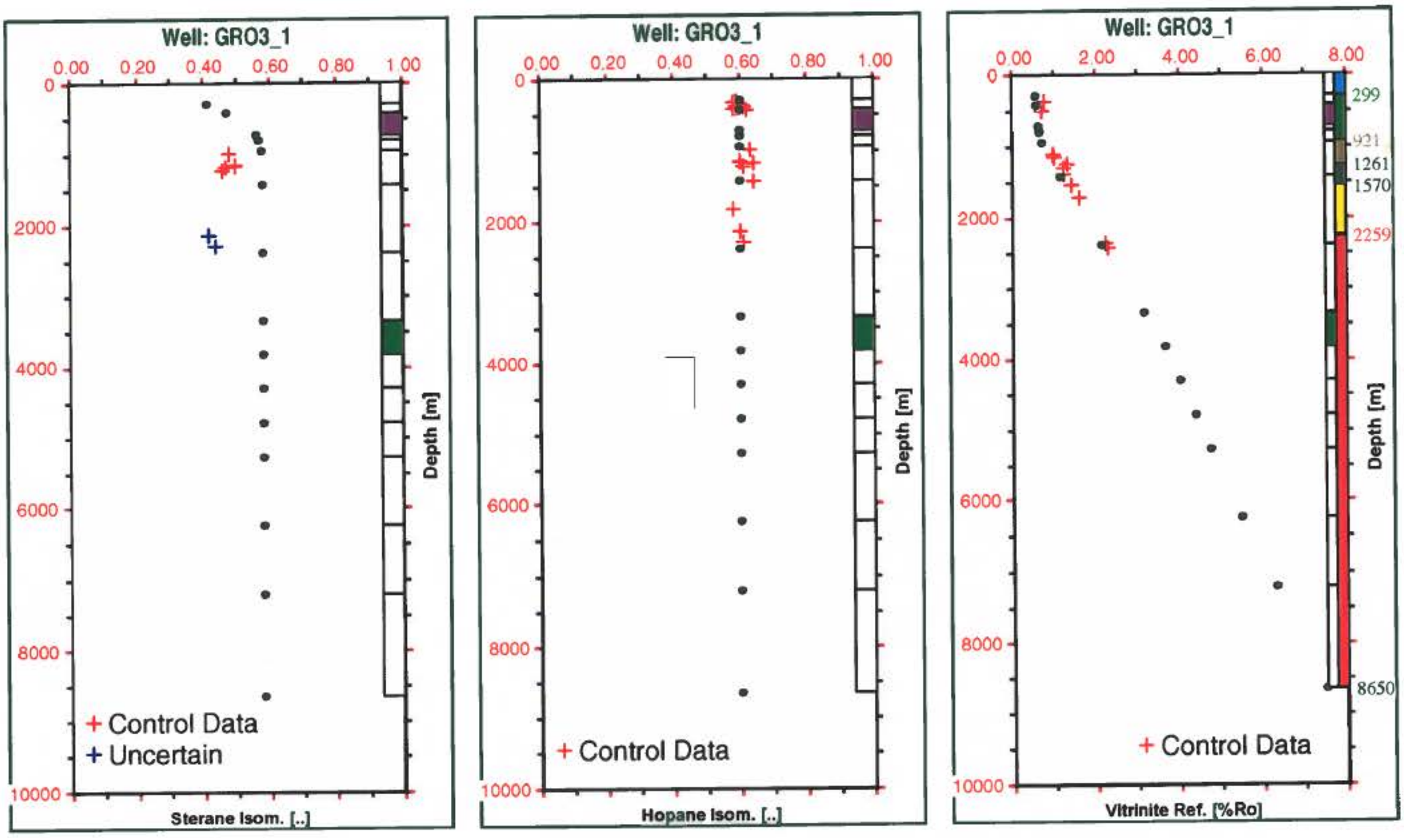
APPENDIX 6b : <Wellname>_6 -concept with minimum amount of volcanics



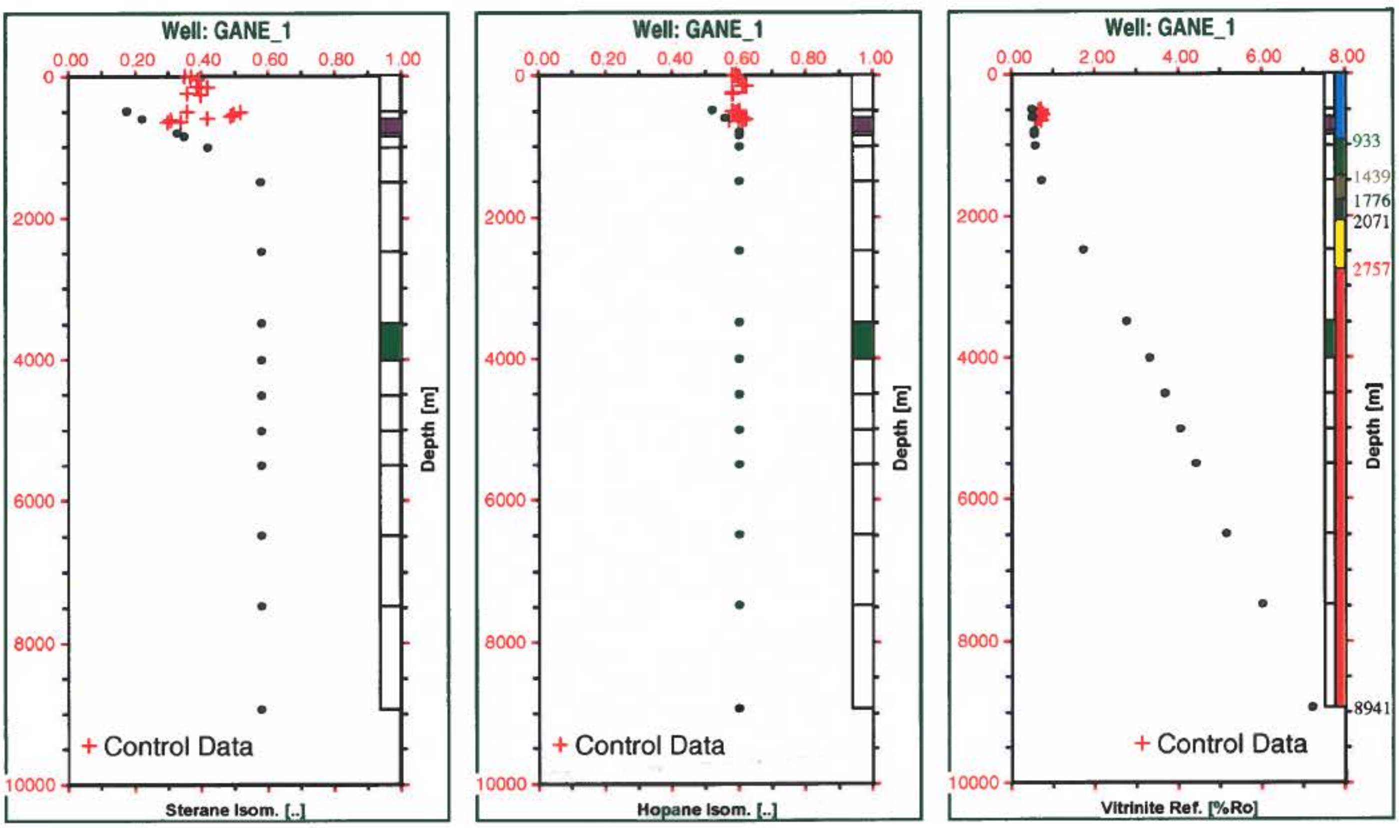
APP. 6a.1 Optimisation of the Itilli pseudowell, western Nuussuaq. **Model Concept:** Maximum volcanics.



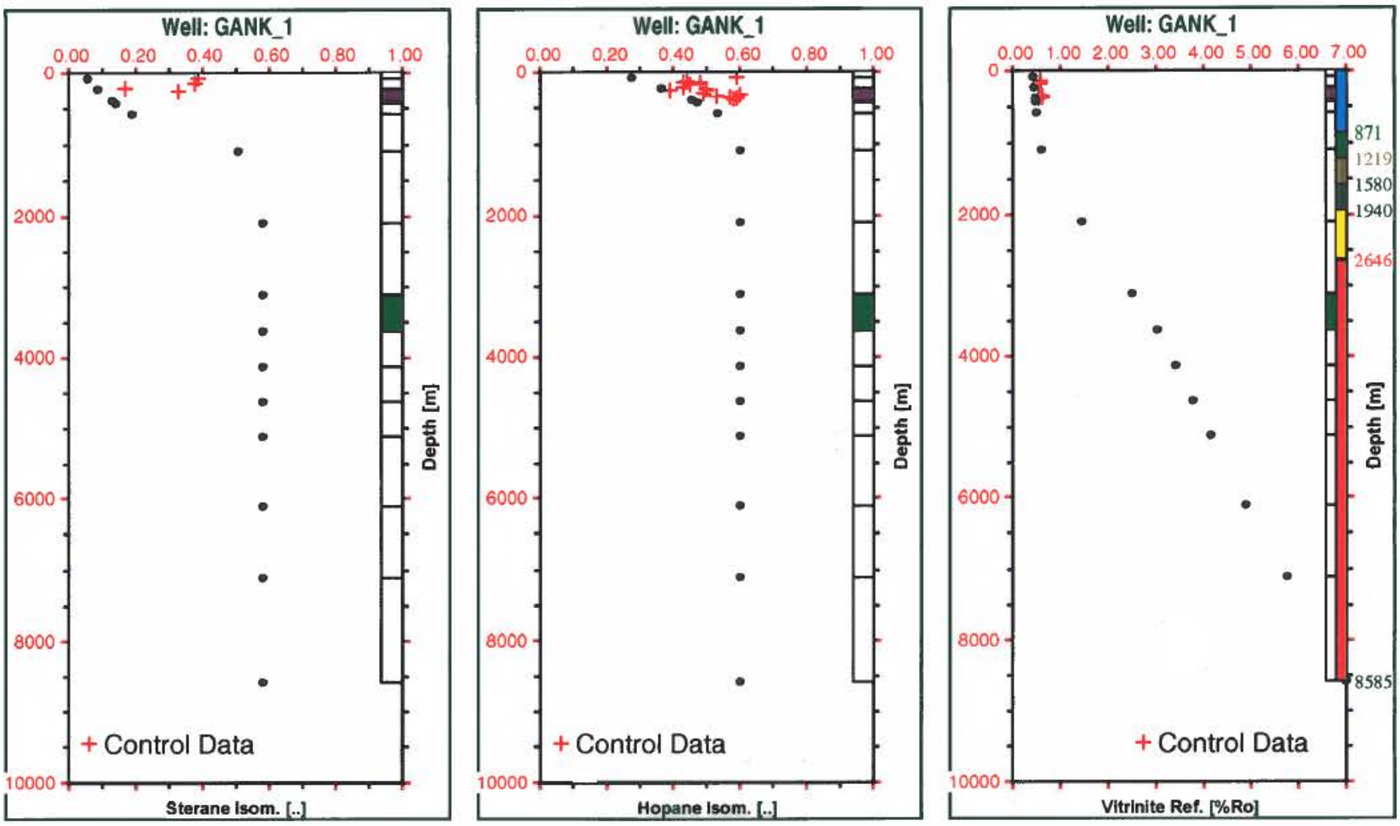
APP. 6a.2 Optimisation of the GANW#1 well, central Nuussuaq. **Model Concept:** Maximum volcanics.



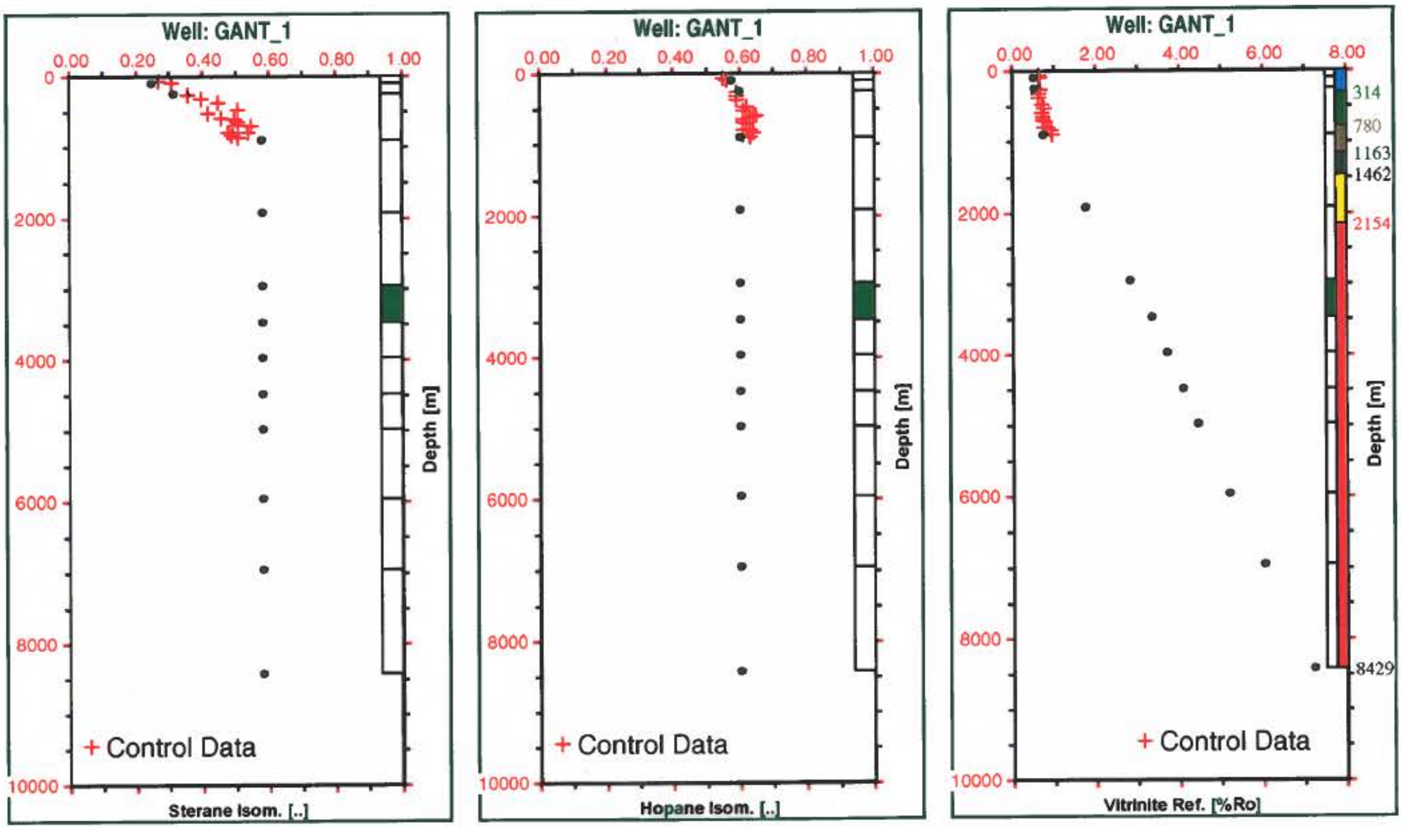
APP. 6a.3 Optimisation of the GRO#3 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.



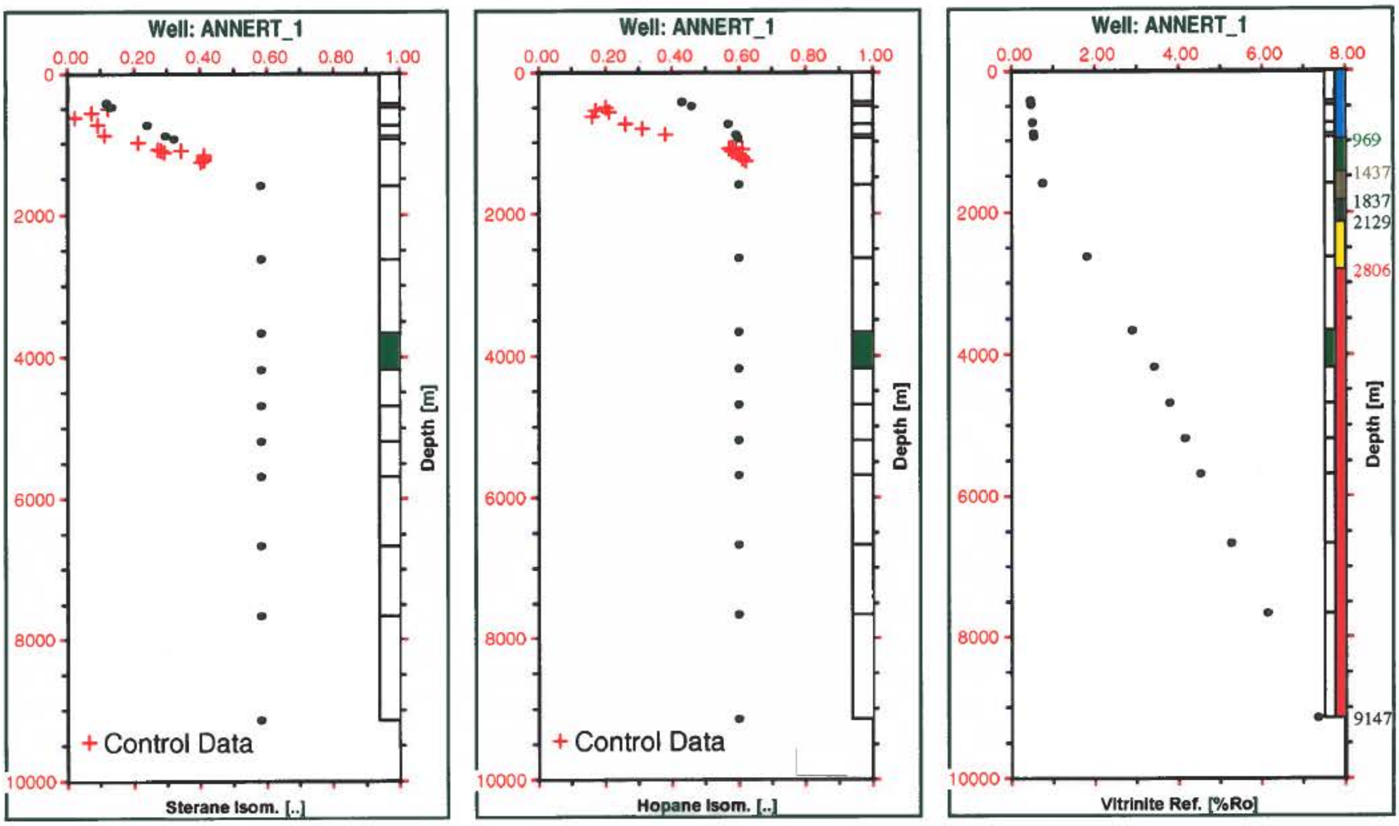
APP. 6a.4 Optimisation of the GANE#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.



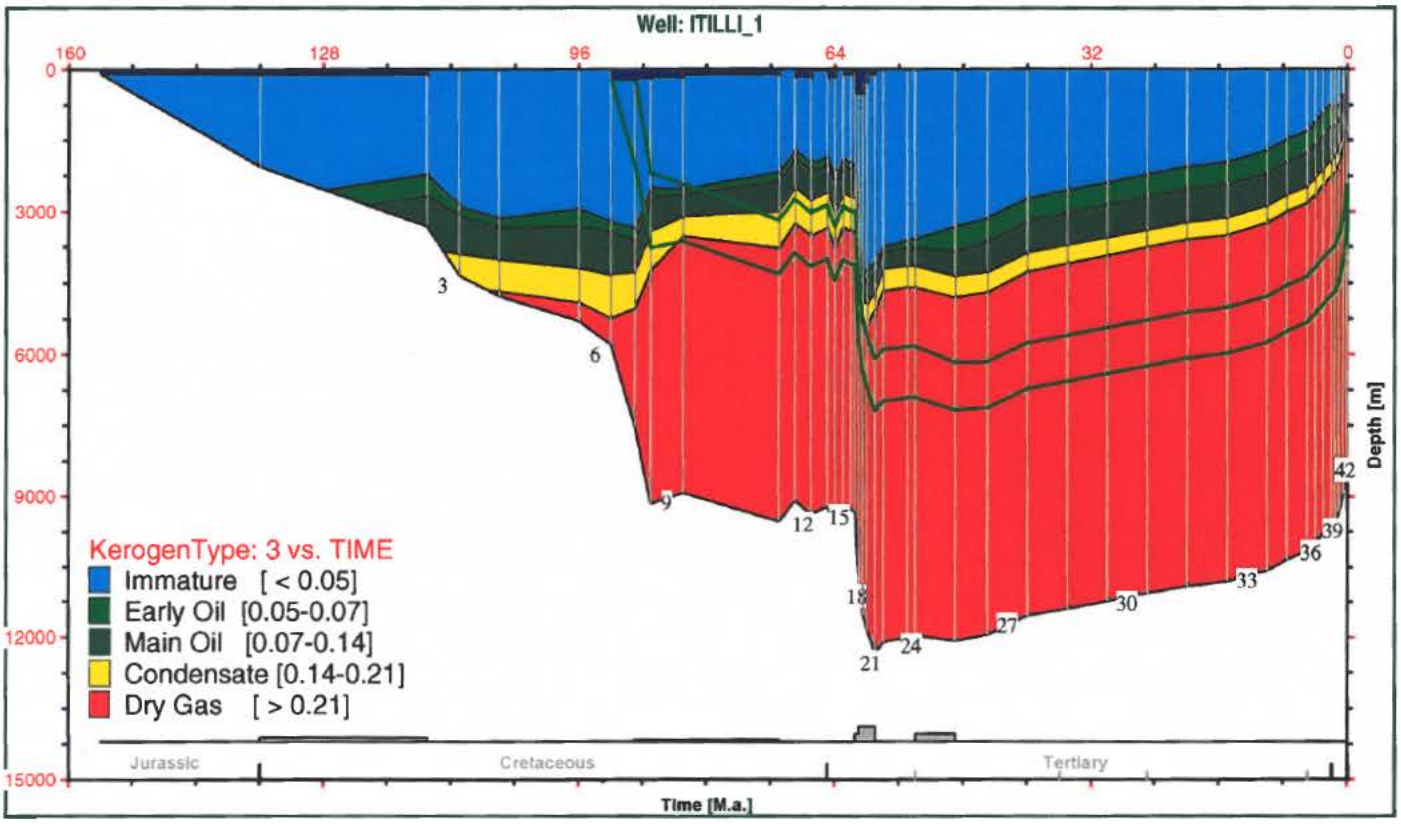
APP. 6a.5 Optimisation of the GANK#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.



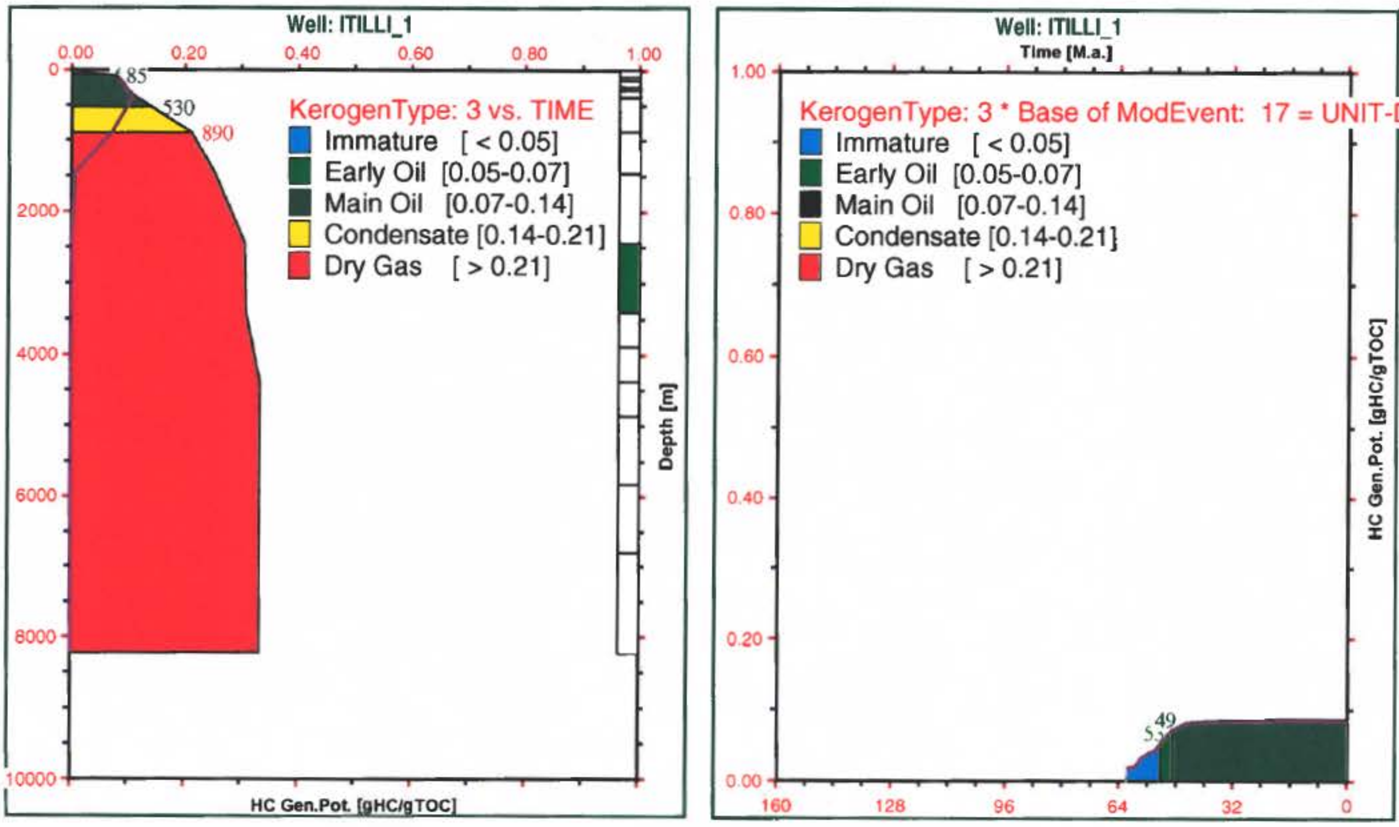
APP. 6a.6 Optimisation of the GANT#1 well, northern Nuussuaq. **Model Concept:** Maximum volcanics.



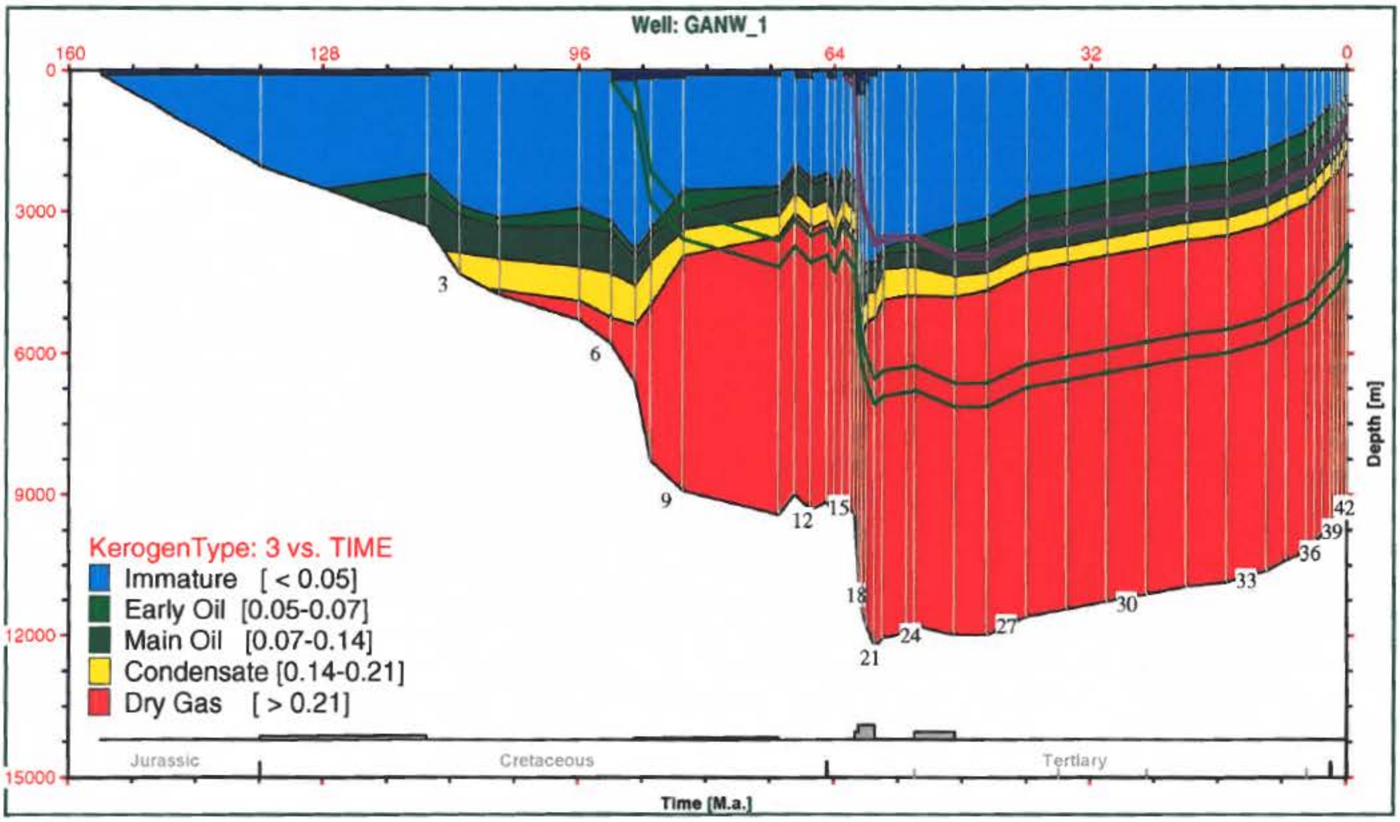
APP. 6a.7 Optimisation of the Annertuneq pseudowell, northern Nuussuaq. **Model Concept:** Maximum volcanics.



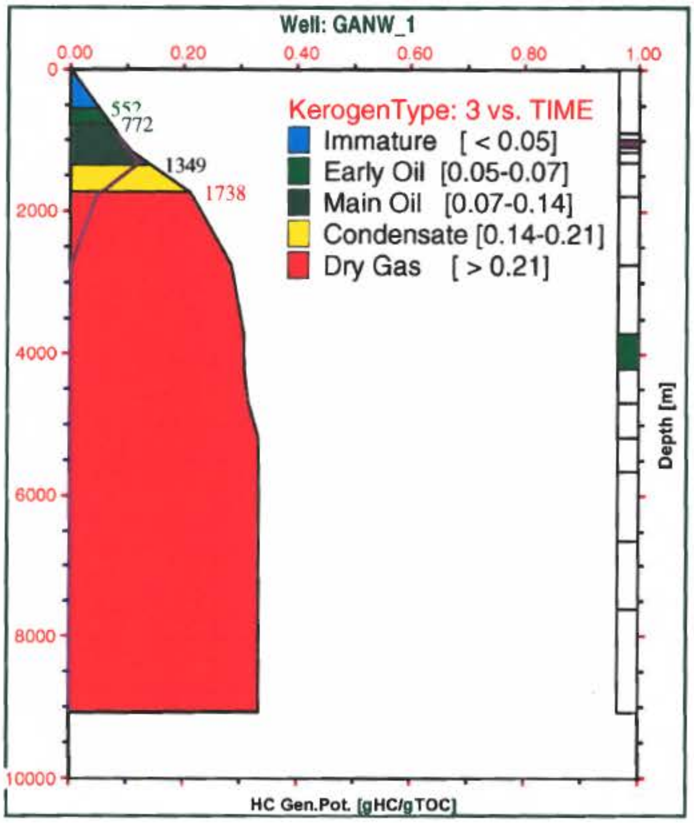
APP. 6a.8 Geohistory for the Itilli pseudowell, western Nuussuaq. **Model Concept:** Maximum volcanics.

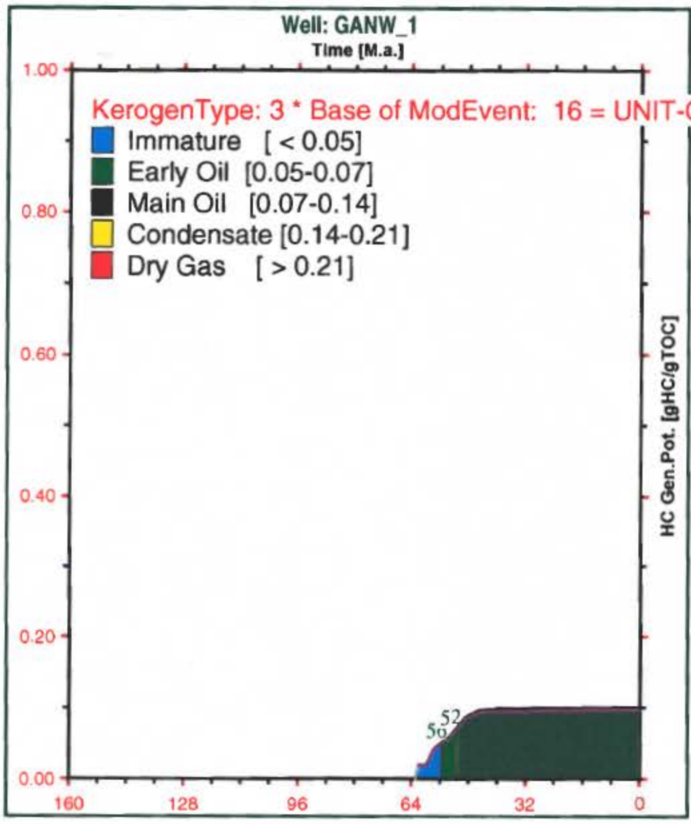


APP. 6a.9 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the Itilli pseudowell, western Nuussuaq. **Model Concept:** Maximum volcanics.

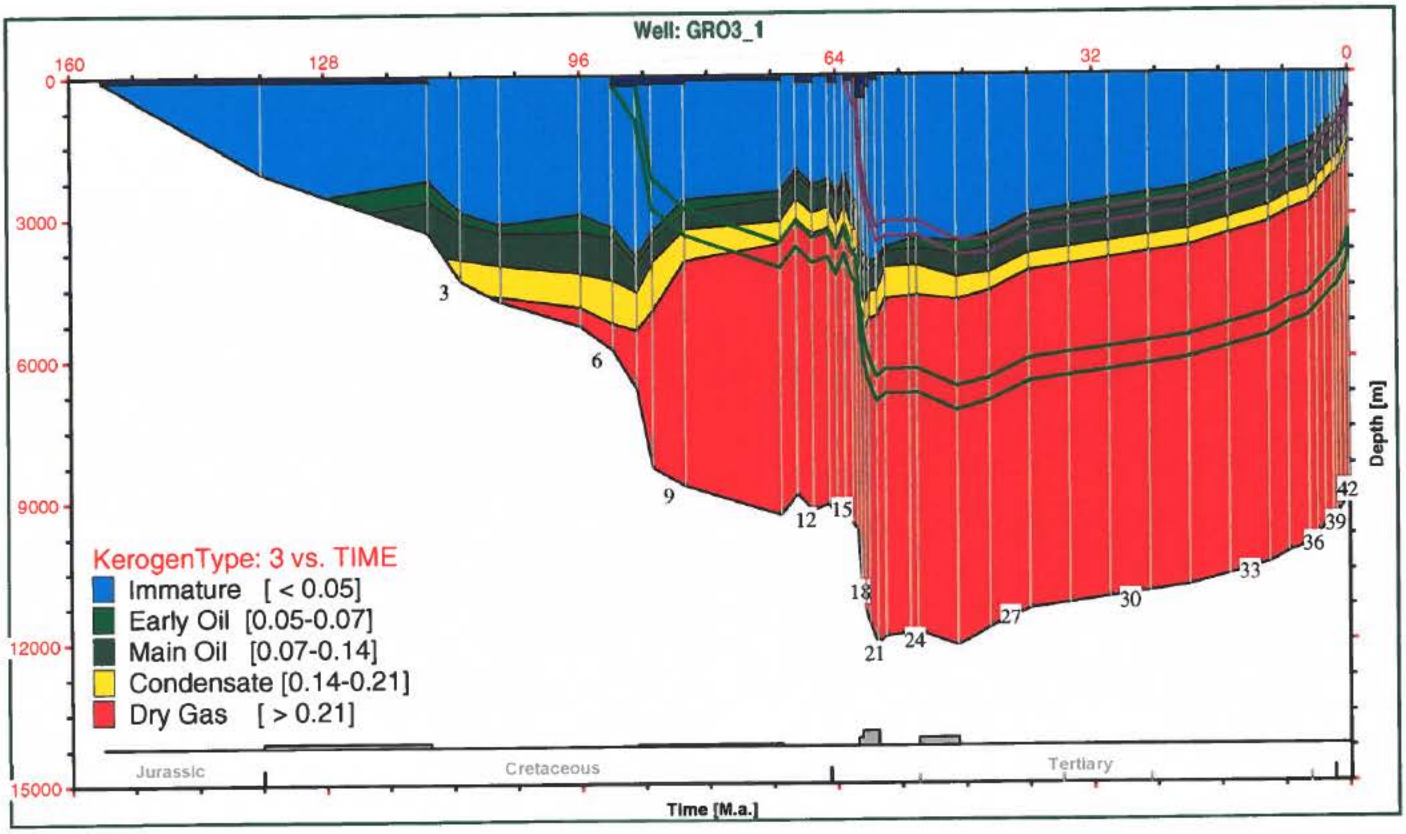


APP. 6a.10 Geohistory for the GANW#1 **well**, **southern** Nuussuaq. **Model Concept:** Maximum volcanics.

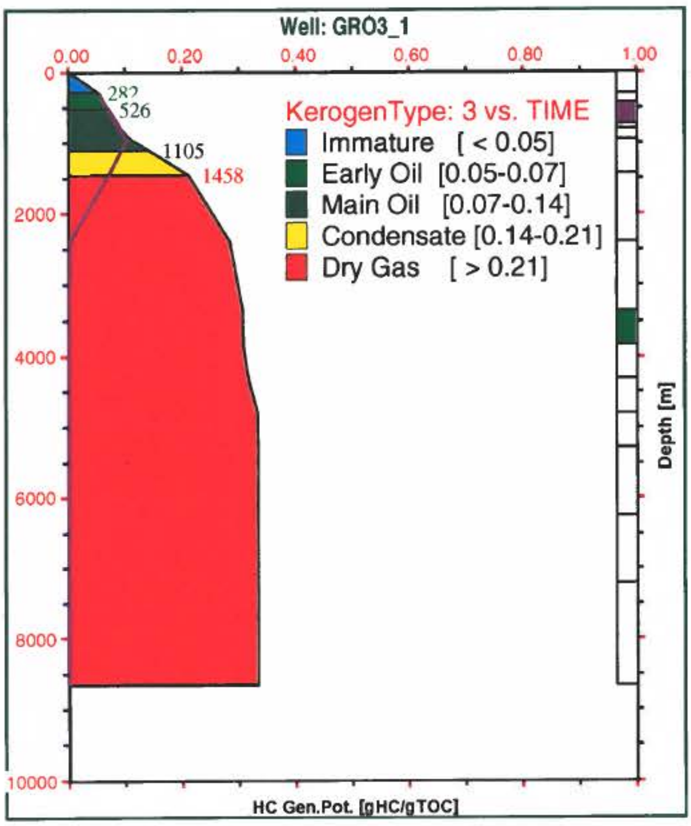


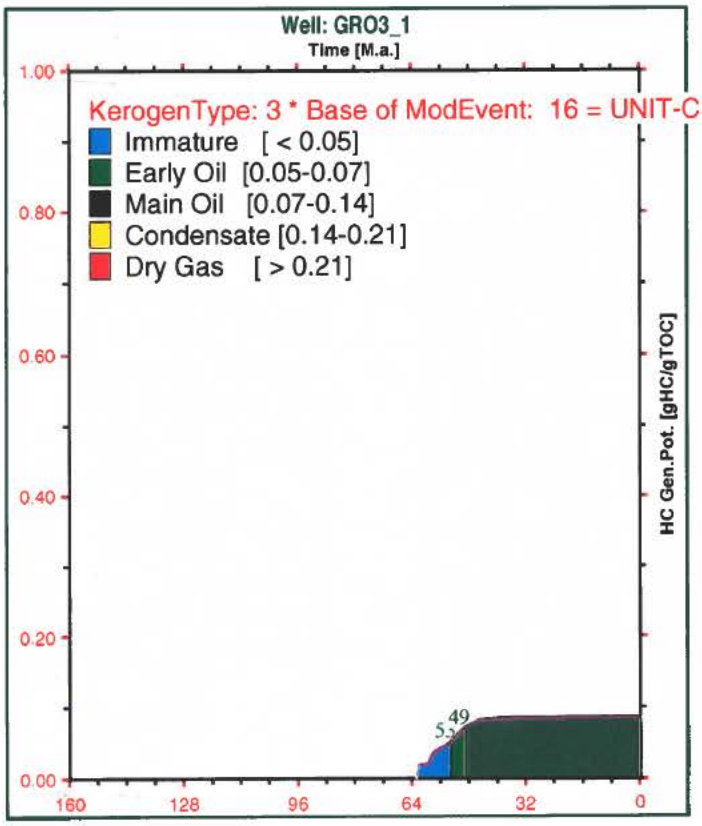


APP. 6a.11 Hydrocarbon generation vs. Depth (**right**) **and Time** (left) for potential source rock for the GANW#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

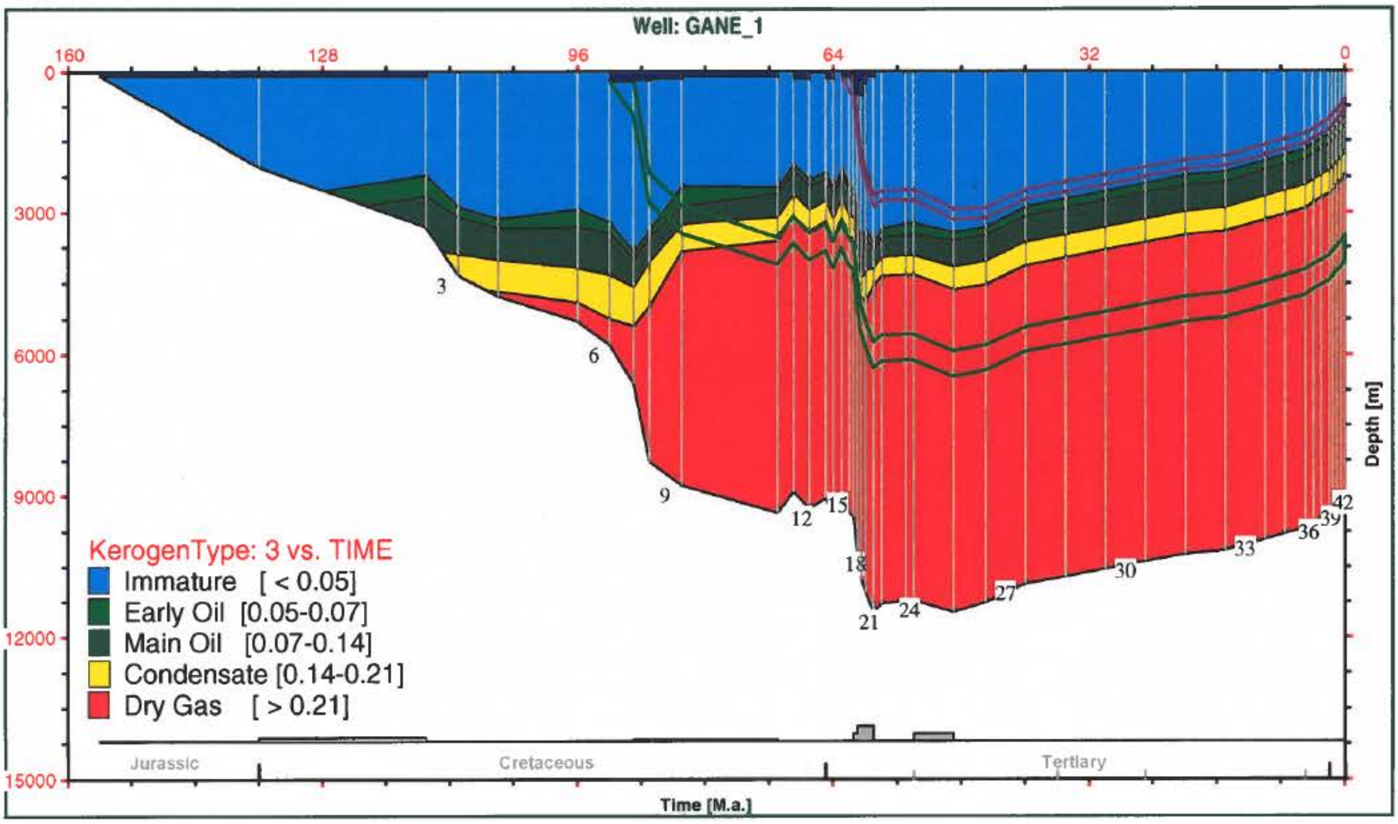


APP. 6a.12 Geohistory for the GRO#3 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

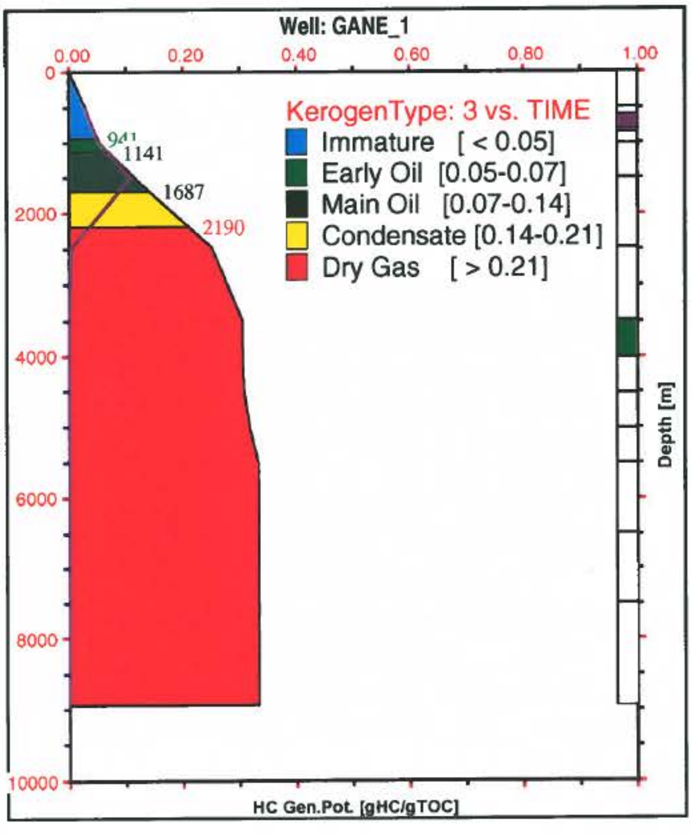


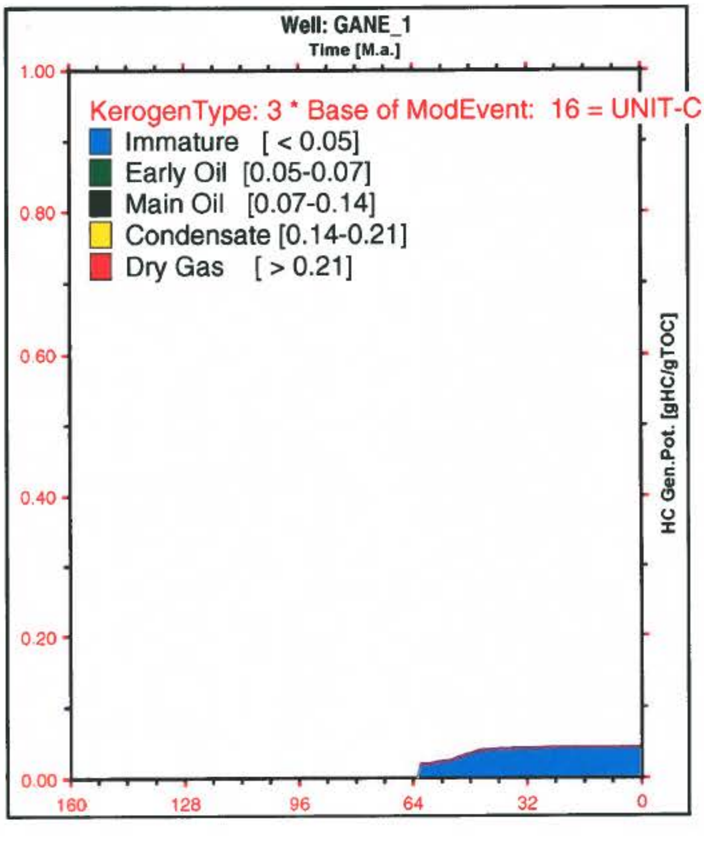


APP. 6a.13 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GRO#3 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

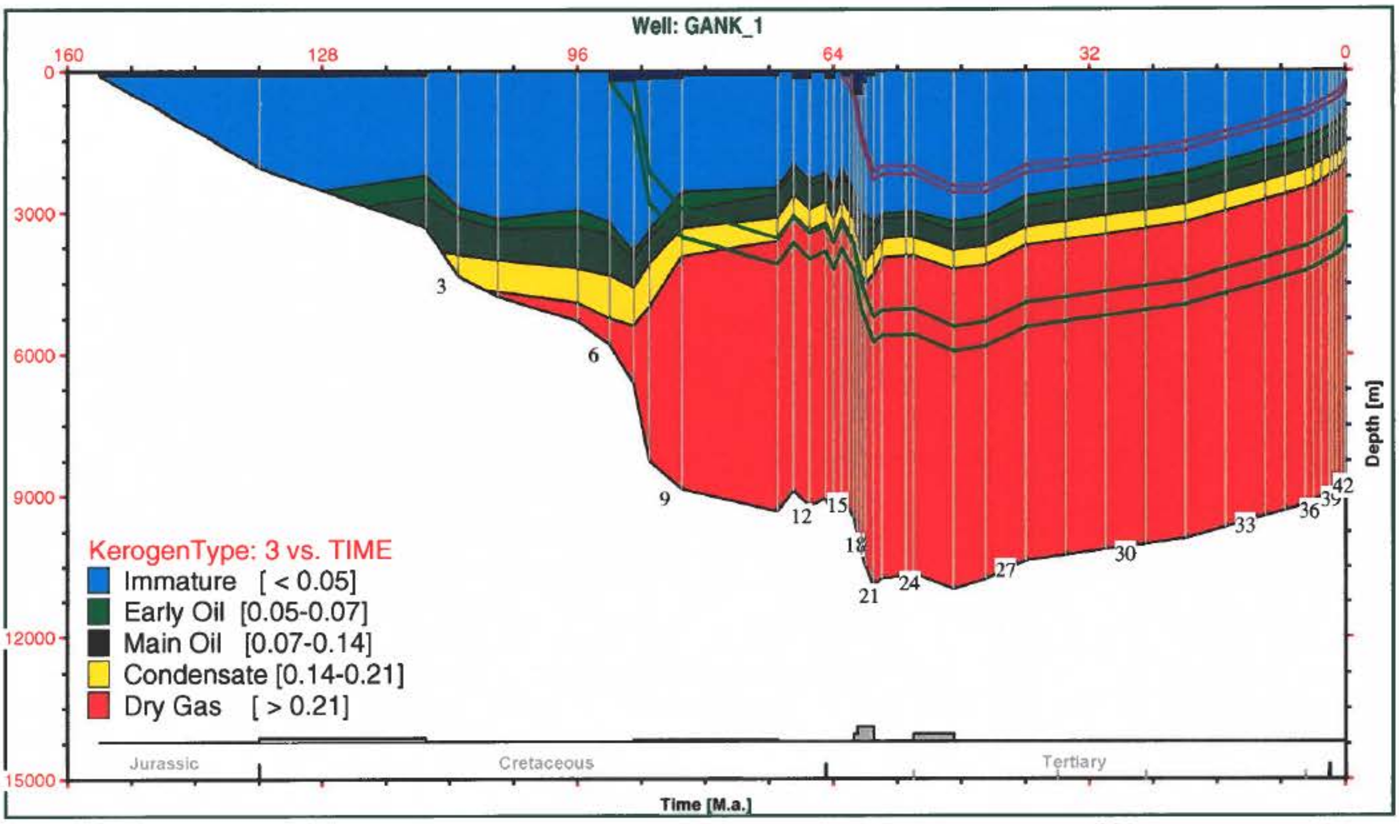


APP. 6a.14 Geohistory for the GANE#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

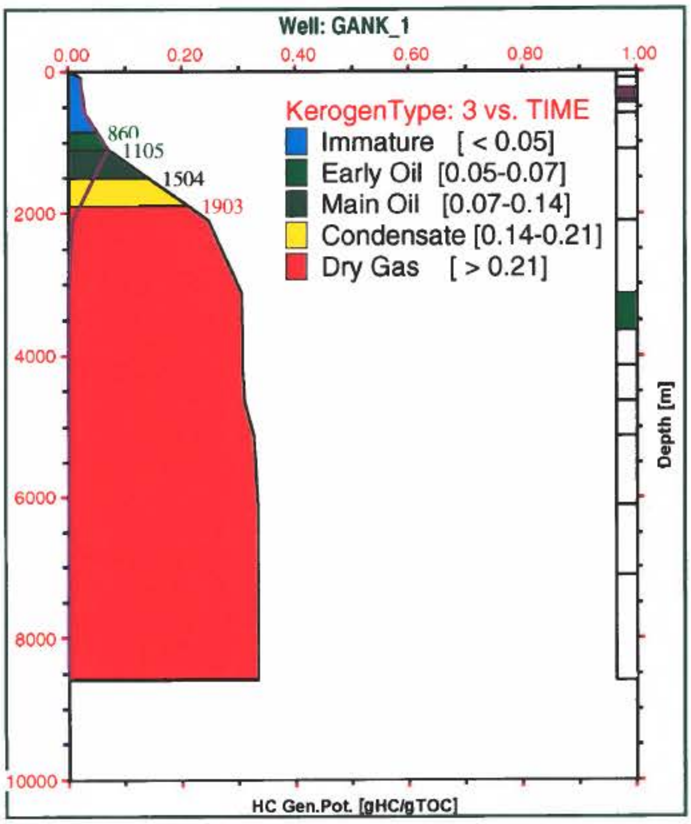


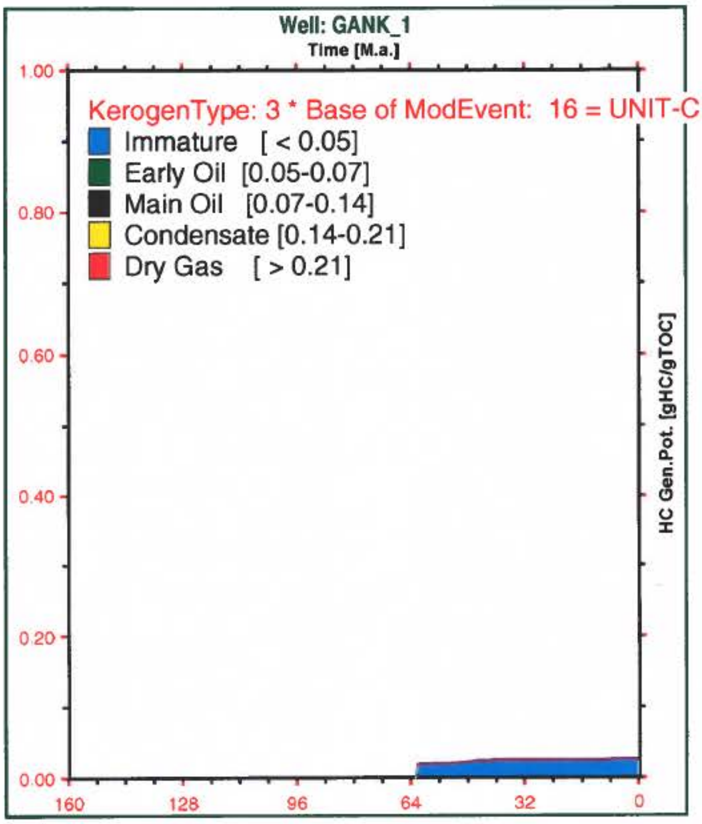


APP. 6a.15 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANE#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

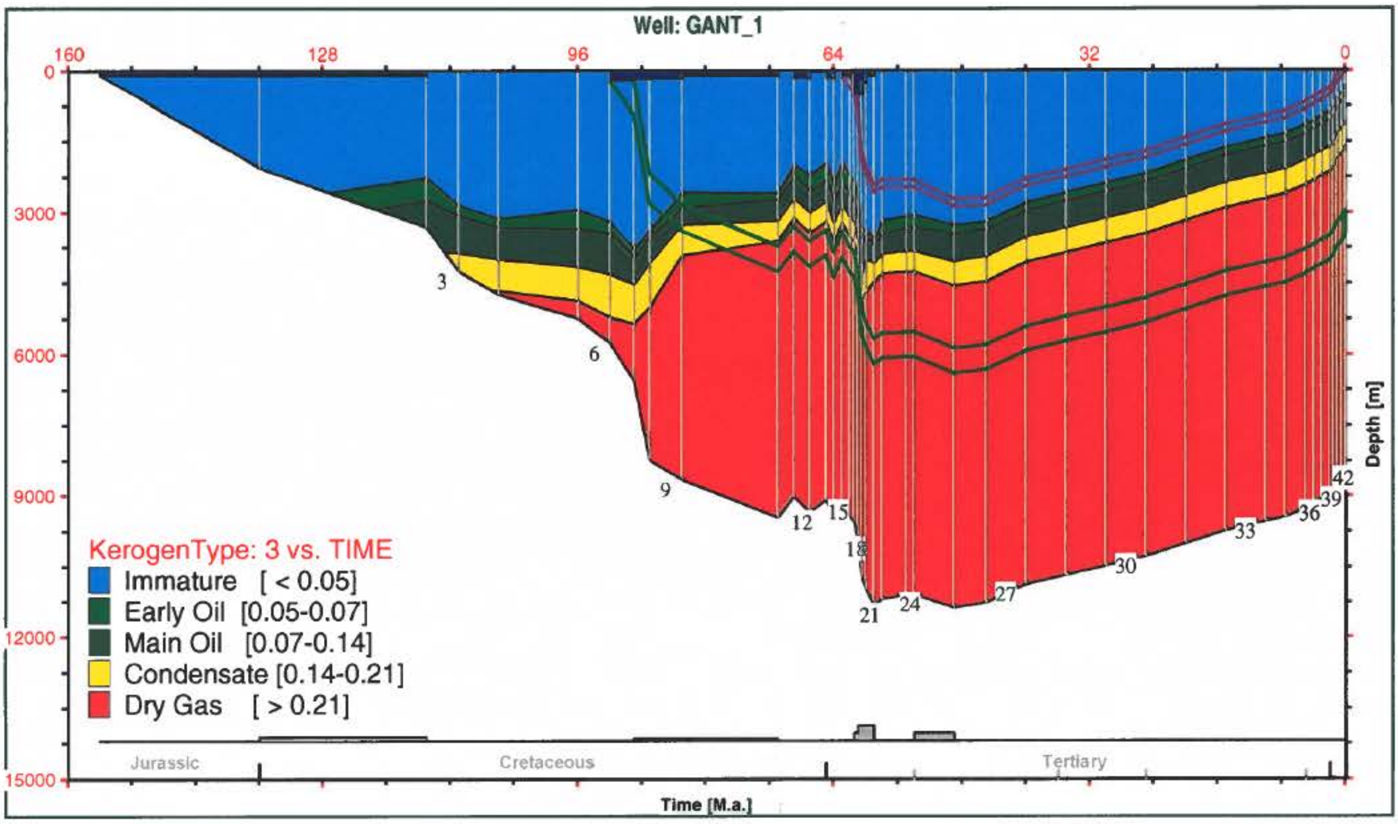


APP. 6a.16 Geohistory for the GANK#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

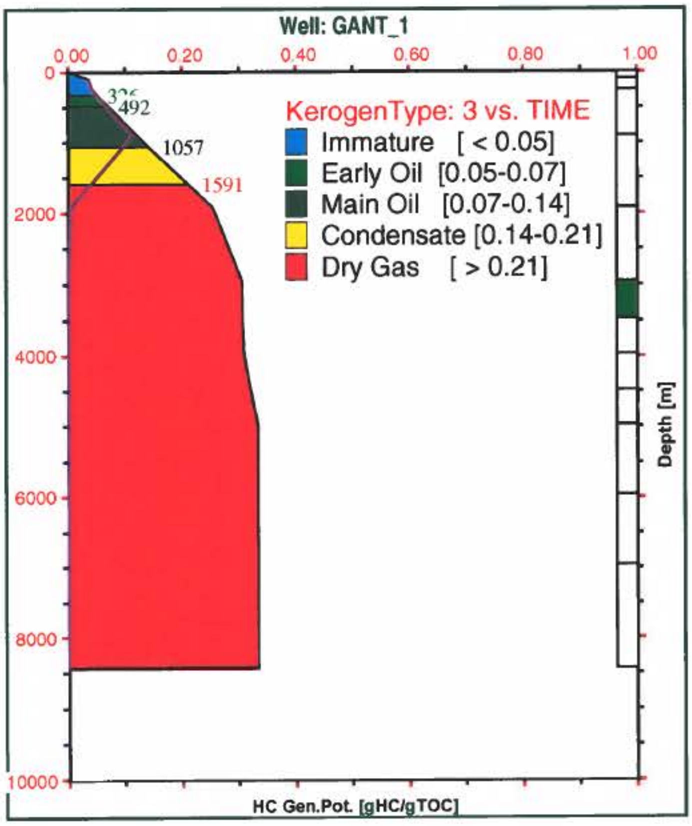


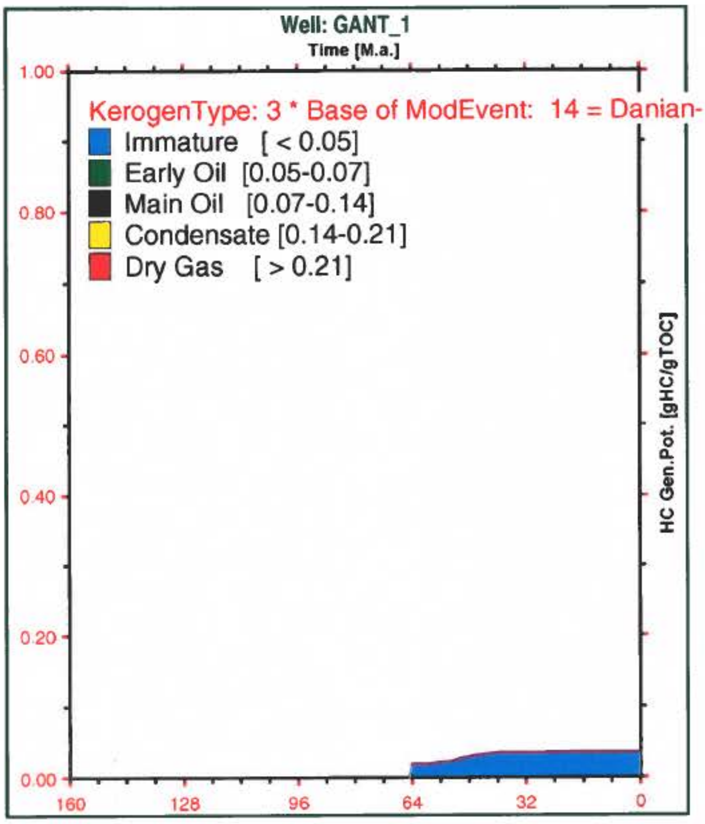


APP. 6a.17 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANK#1 well, southern Nuussuaq. **Model Concept:** Maximum volcanics.

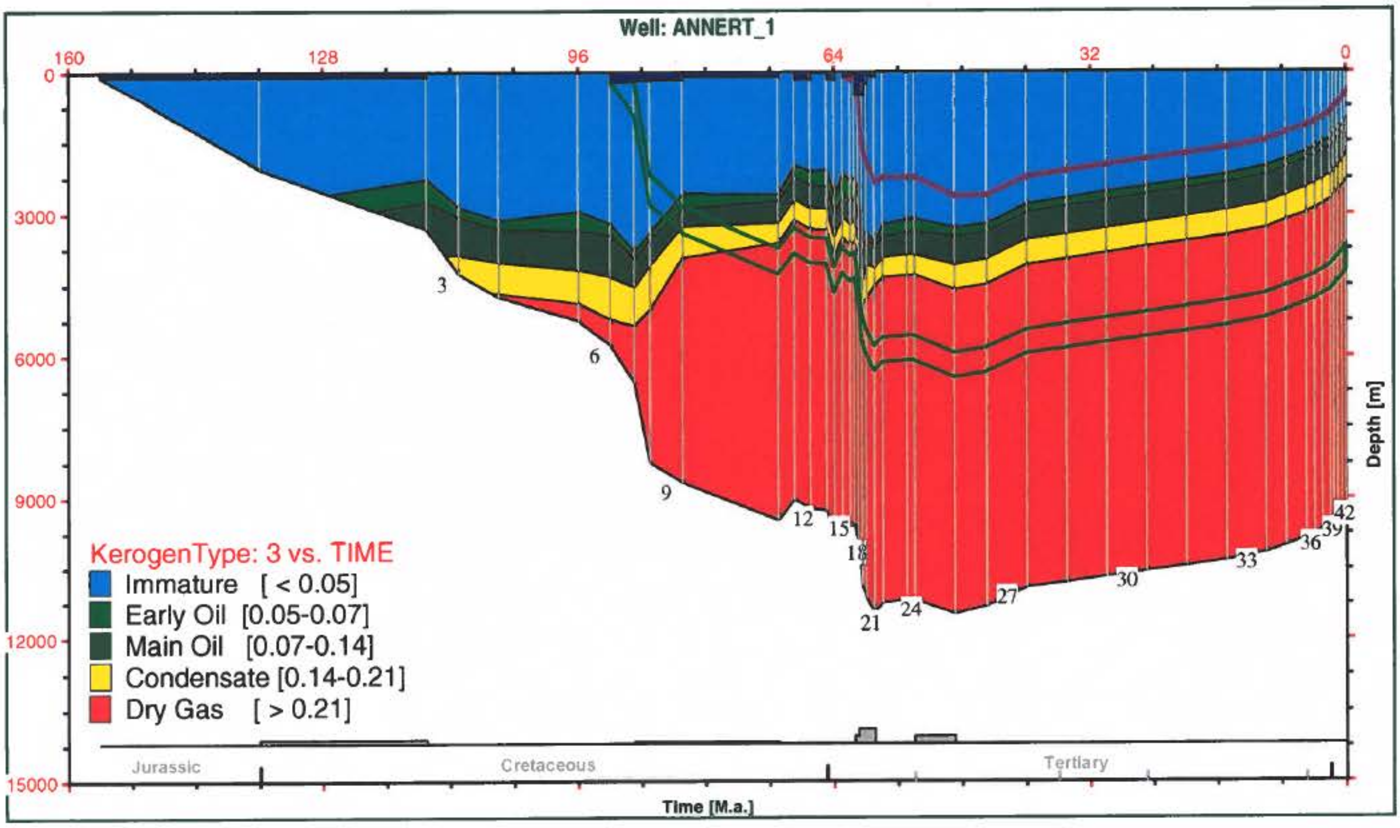


APP. 6a.18 Geohistory for the GANT#1 well, northern Nuussuaq. **Model Concept:** Maximum volcanics.

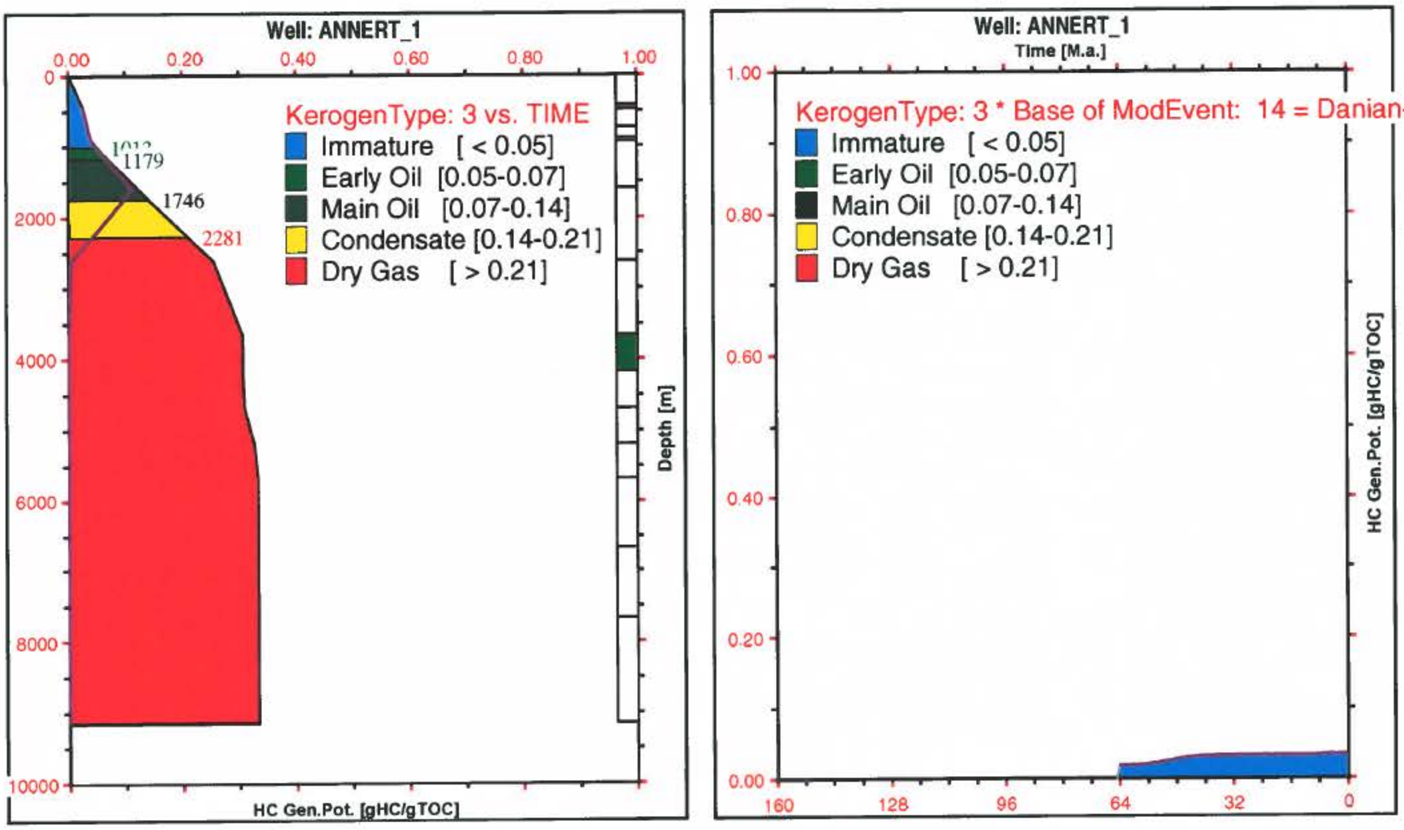




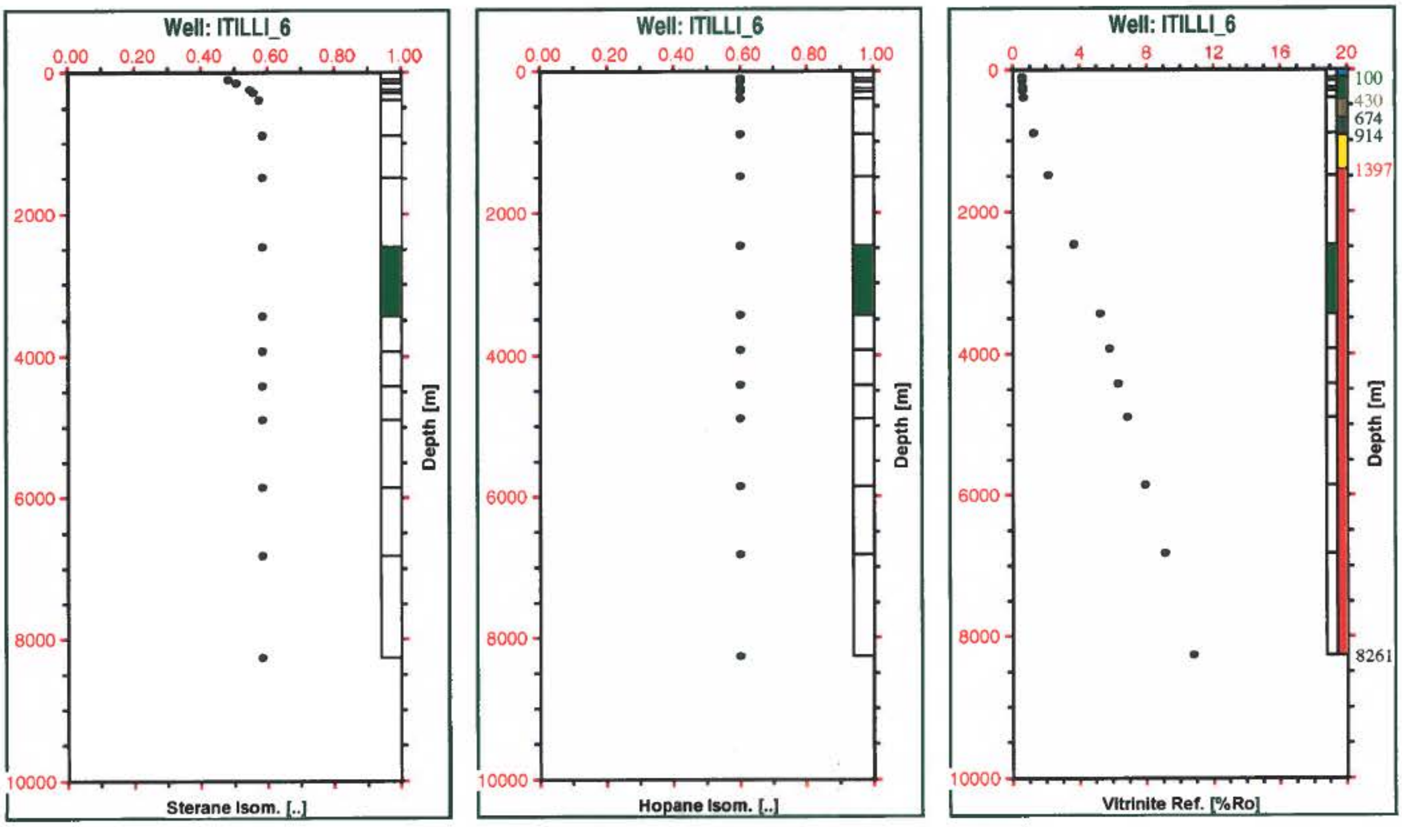
APP. 6a.19 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANT#1 well, northern Nuussuaq. **Model Concept:** Maximum volcanics.



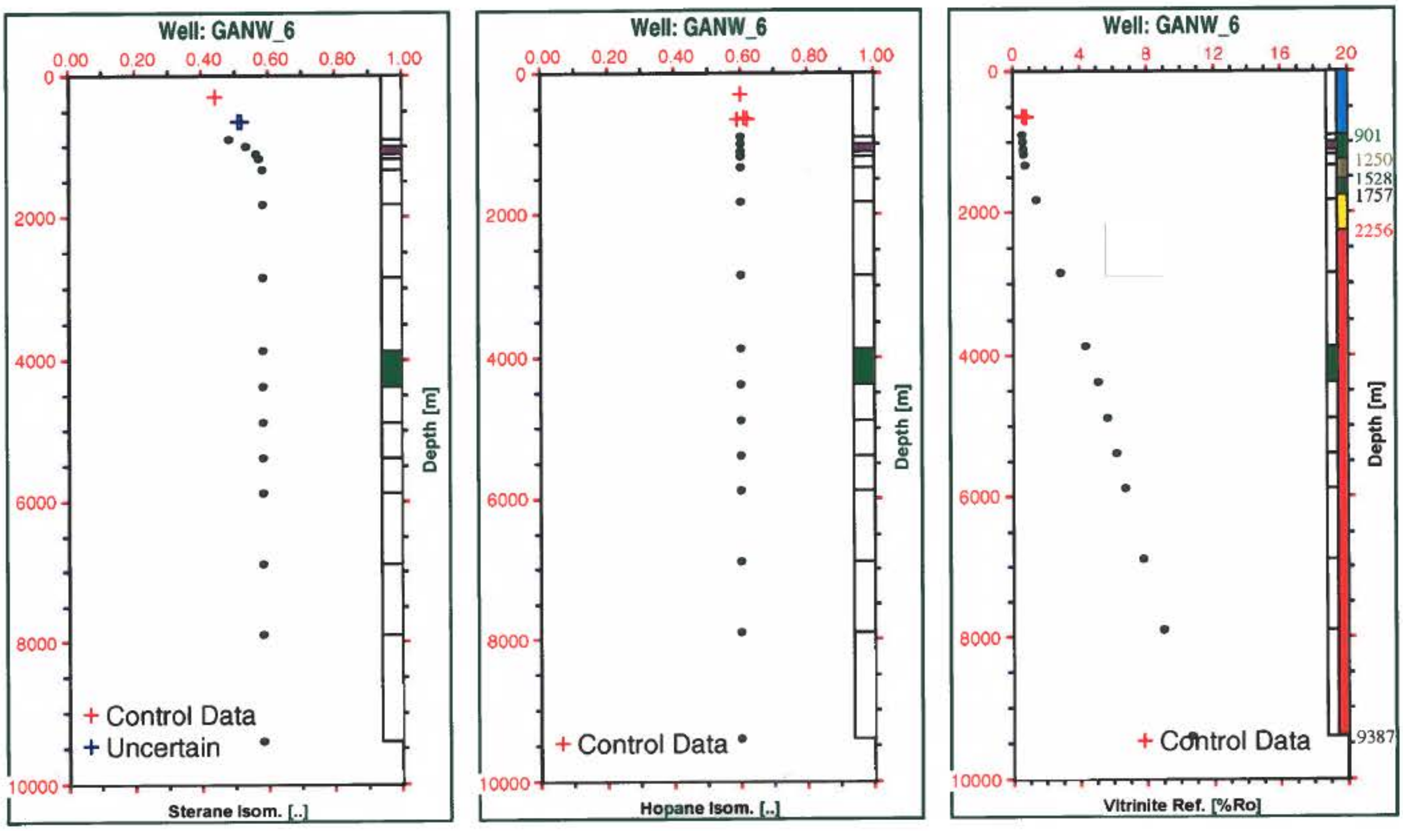
APP. 6a.20 Geohistory for the Annertuneq pseudowell, northern Nuussuaq. **Model Concept:** Maximum volcanics.



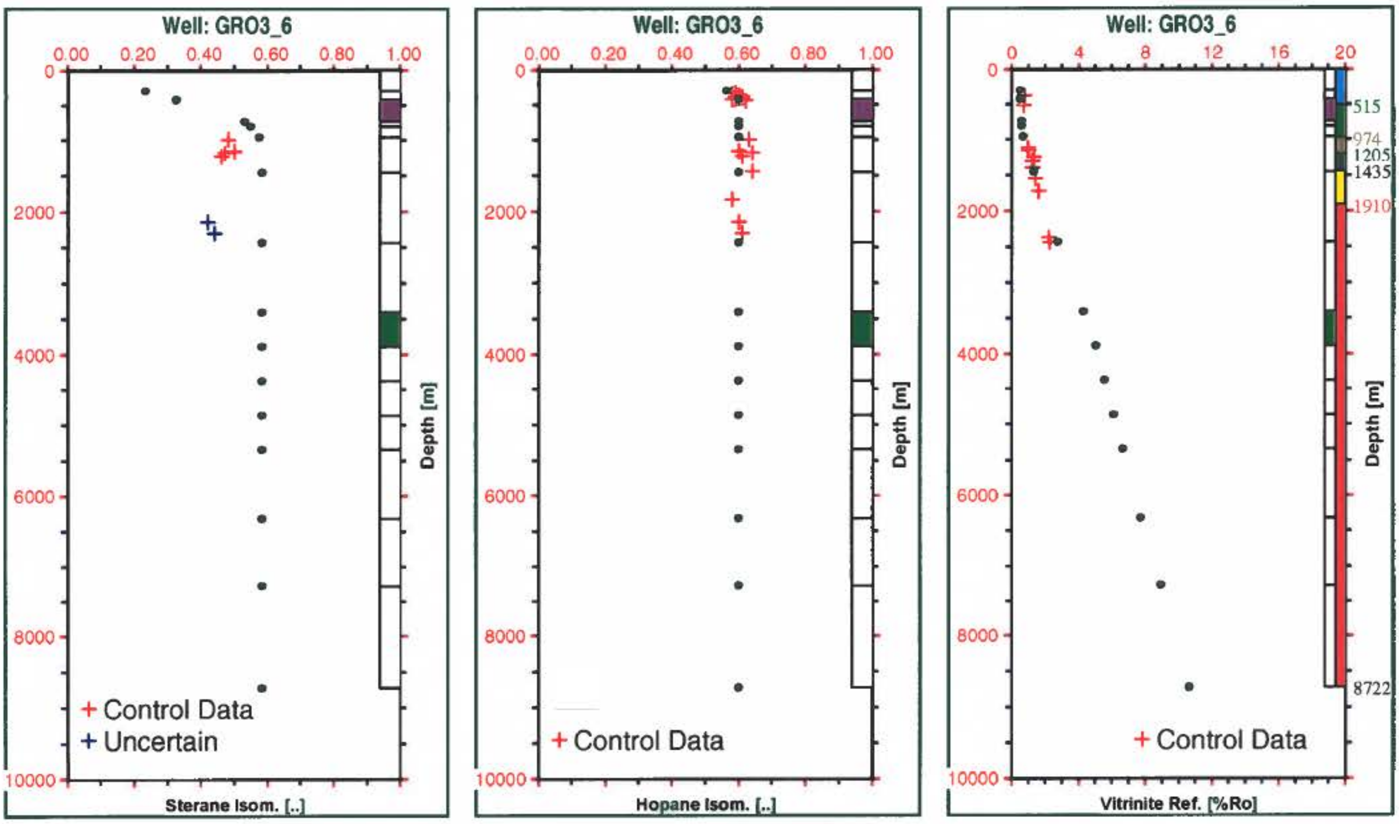
APP. 6a.21 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the Annertuneq pseudowell, northern Nuussuaq. **Model Concept:** Maximum volcanics.



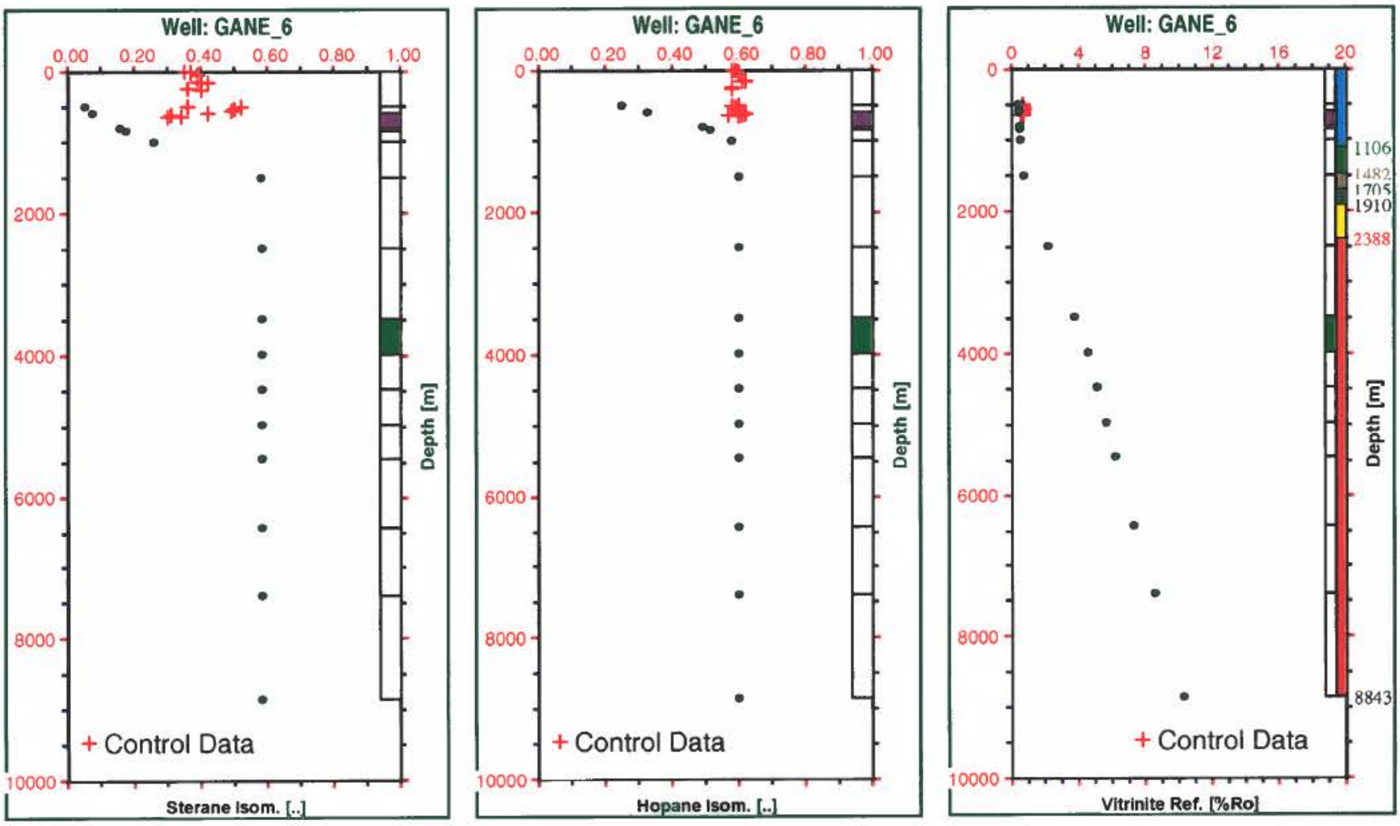
APP. 6b.1 Optimisation of the Itilli pseudowell, western Nuussuaq. **Model Concept:** Minimum volcanics.



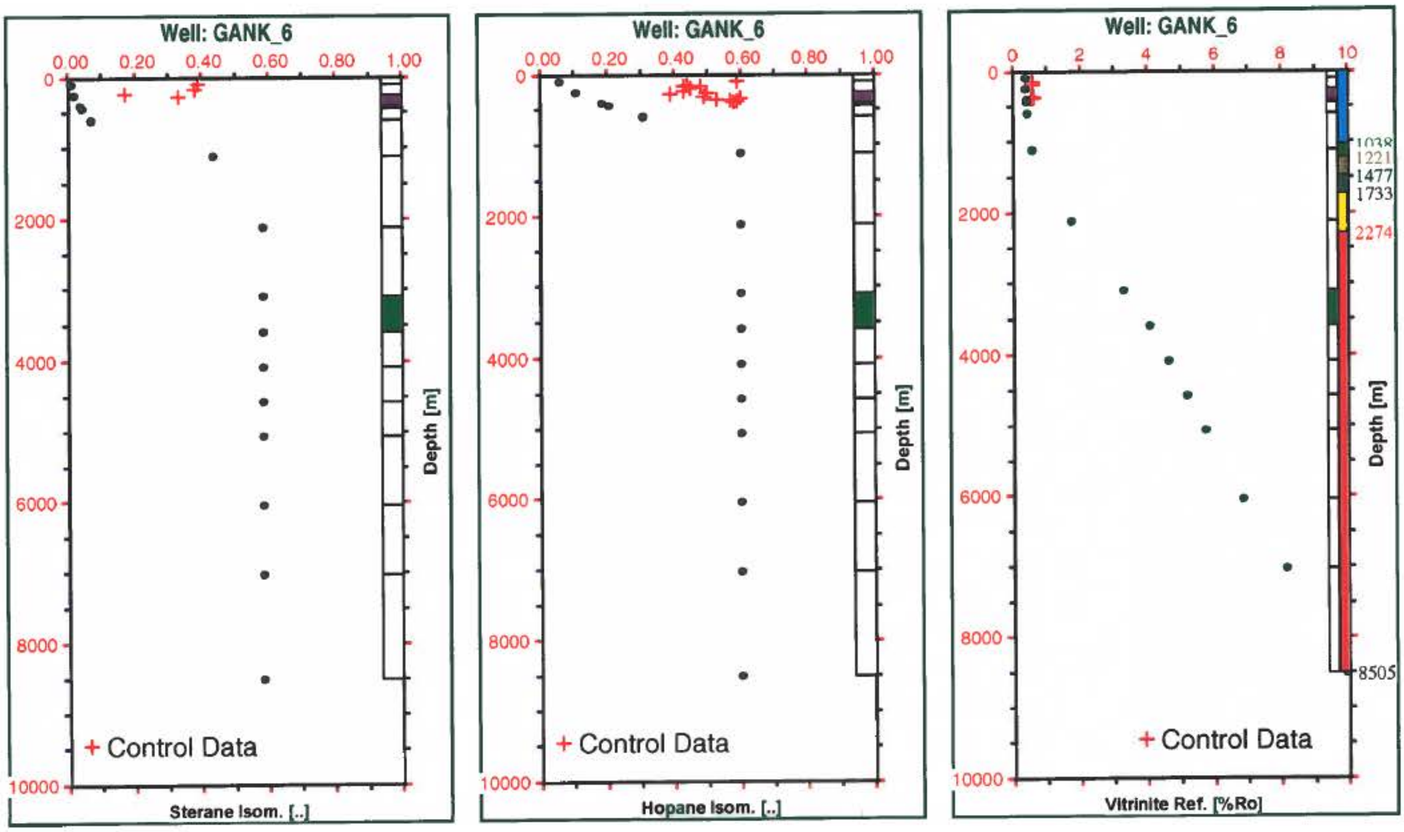
APP. 6b.2 Optimisation of the GANW#1 well, central Nuussuaq. **Model Concept:** Minimum volcanics.



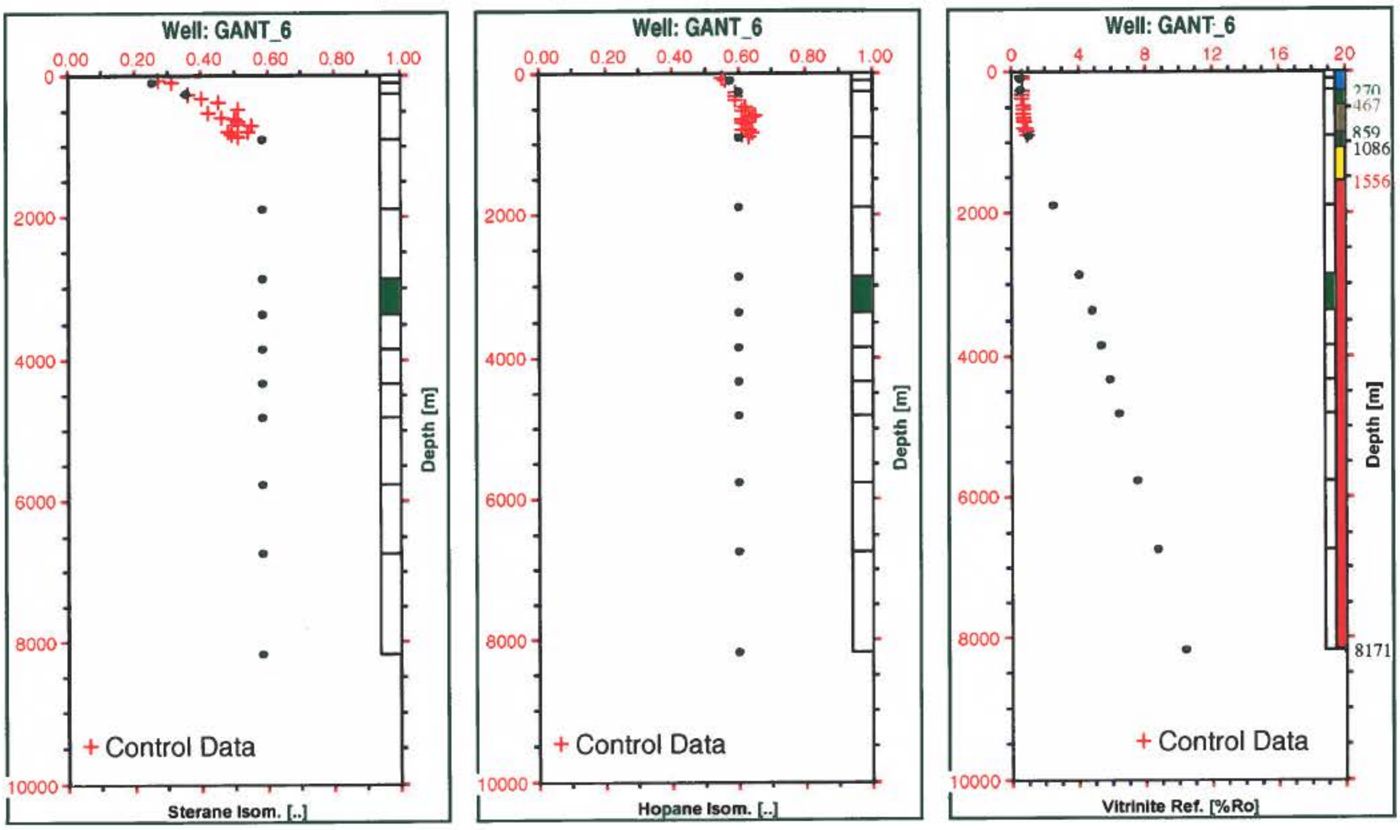
APP. 6b.3 Optimisation of the GRO#3 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.



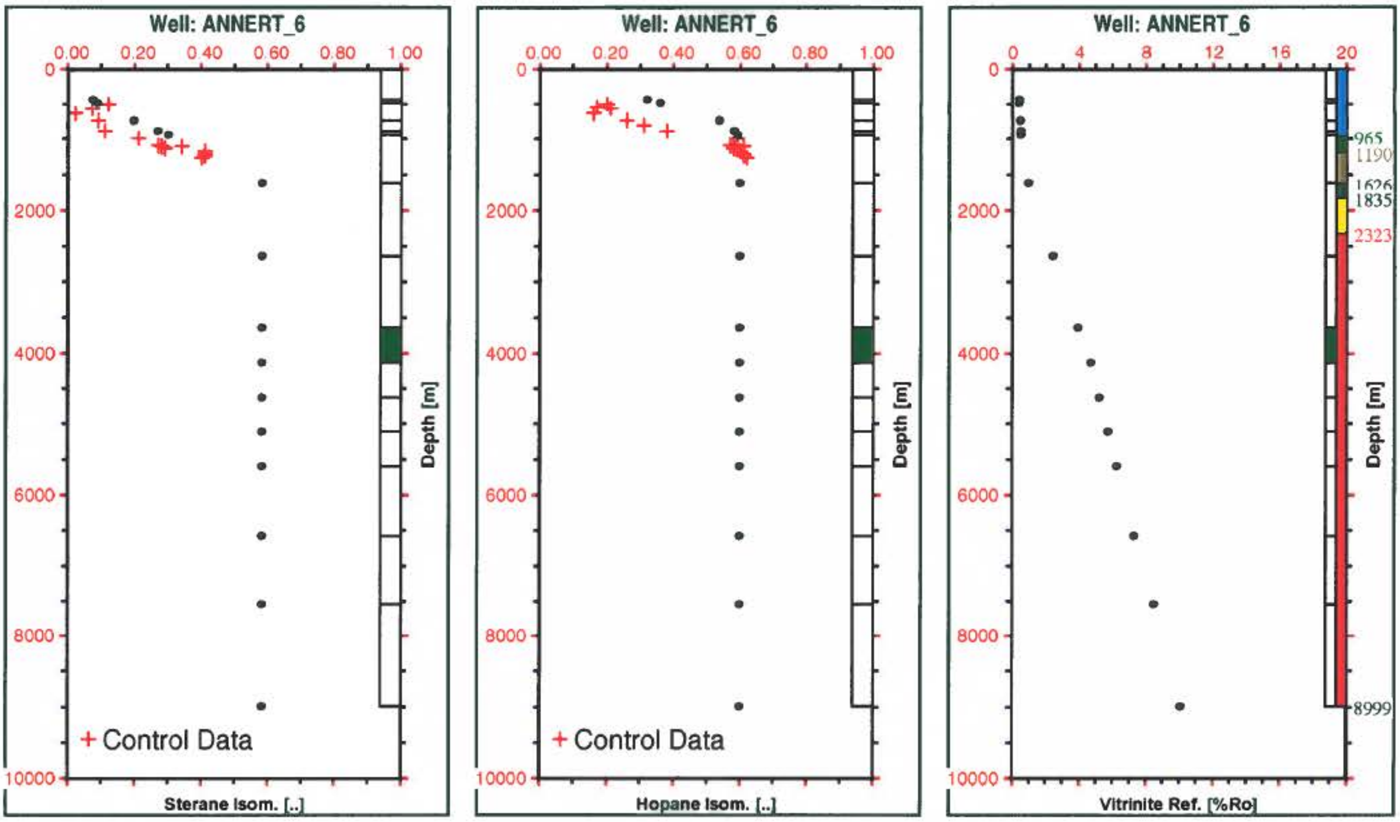
APP. 6b.4 Optimisation of the GANE#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.



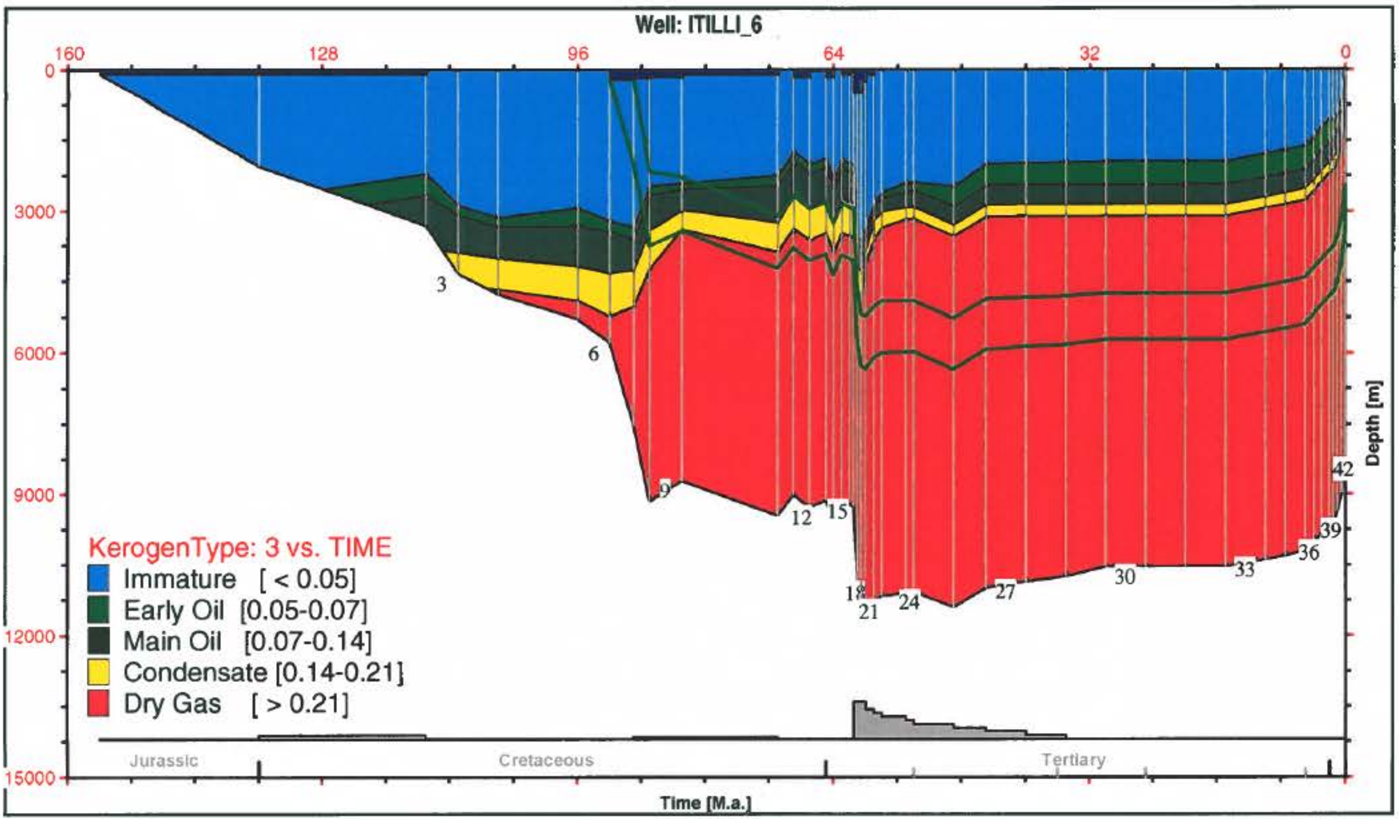
APP. 6b.5 Optimisation of the GANK#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.



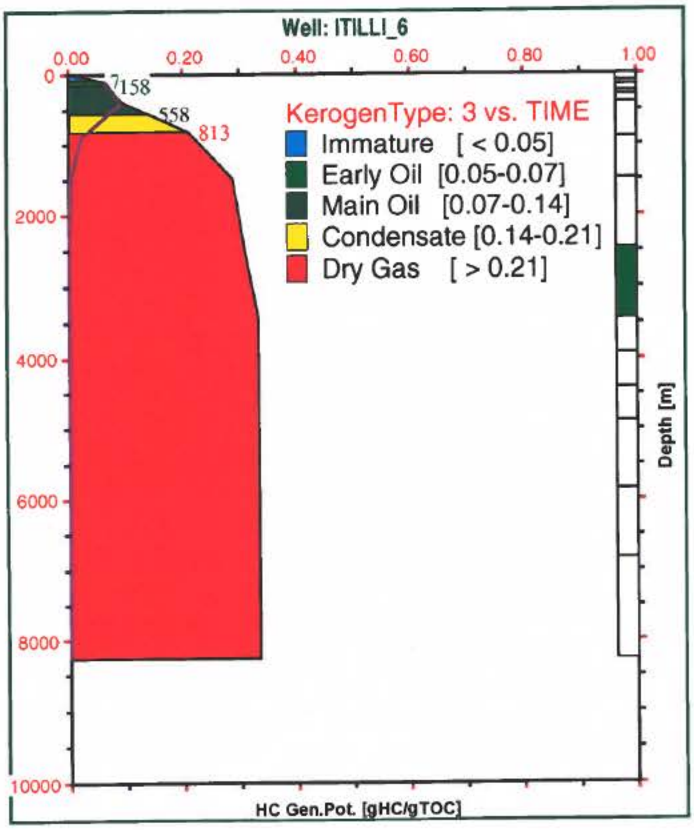
APP. 6b.6 Optimisation of the GANT#1 well, northern Nuussuaq. **Model Concept:** Minimum volcanics.

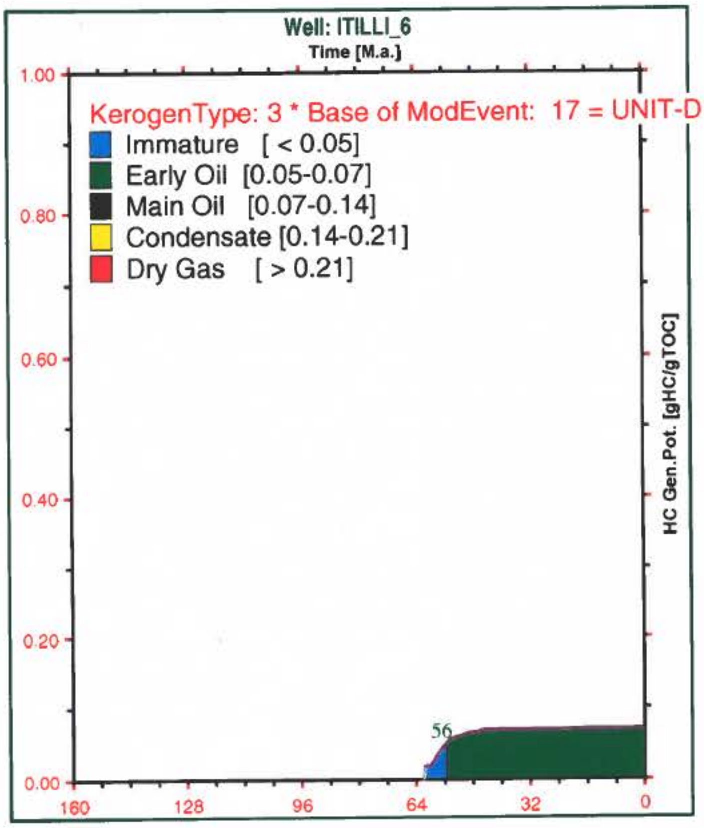


APP. 6b.7 Optimisation of the Annertuneq pseudowell, northern Nuussuaq. **Model Concept:** Minimum volcanics.

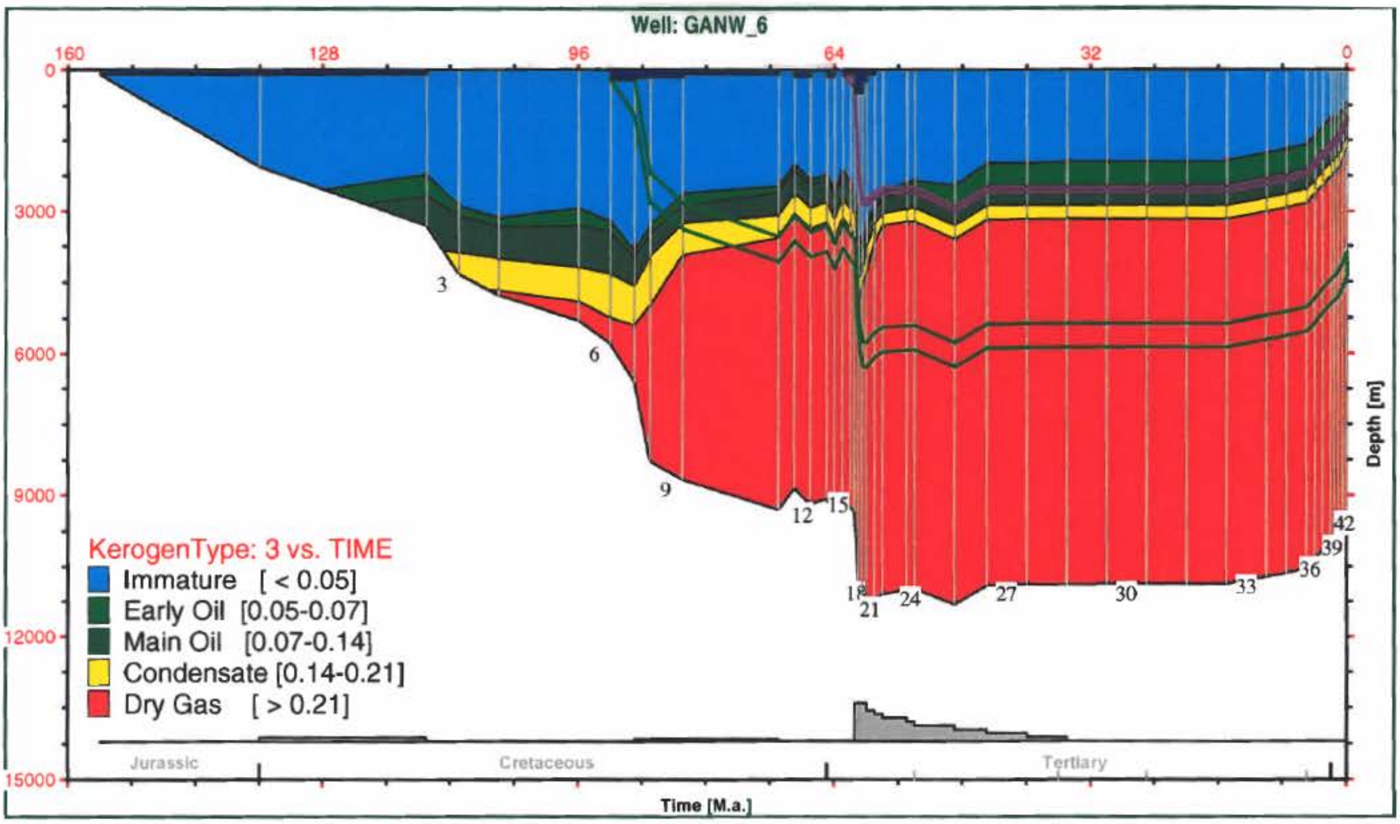


APP. 6b.8 Geohistory for the Itilli pseudowell, western Nuussuaq. **Model Concept:** Minimum volcanics.

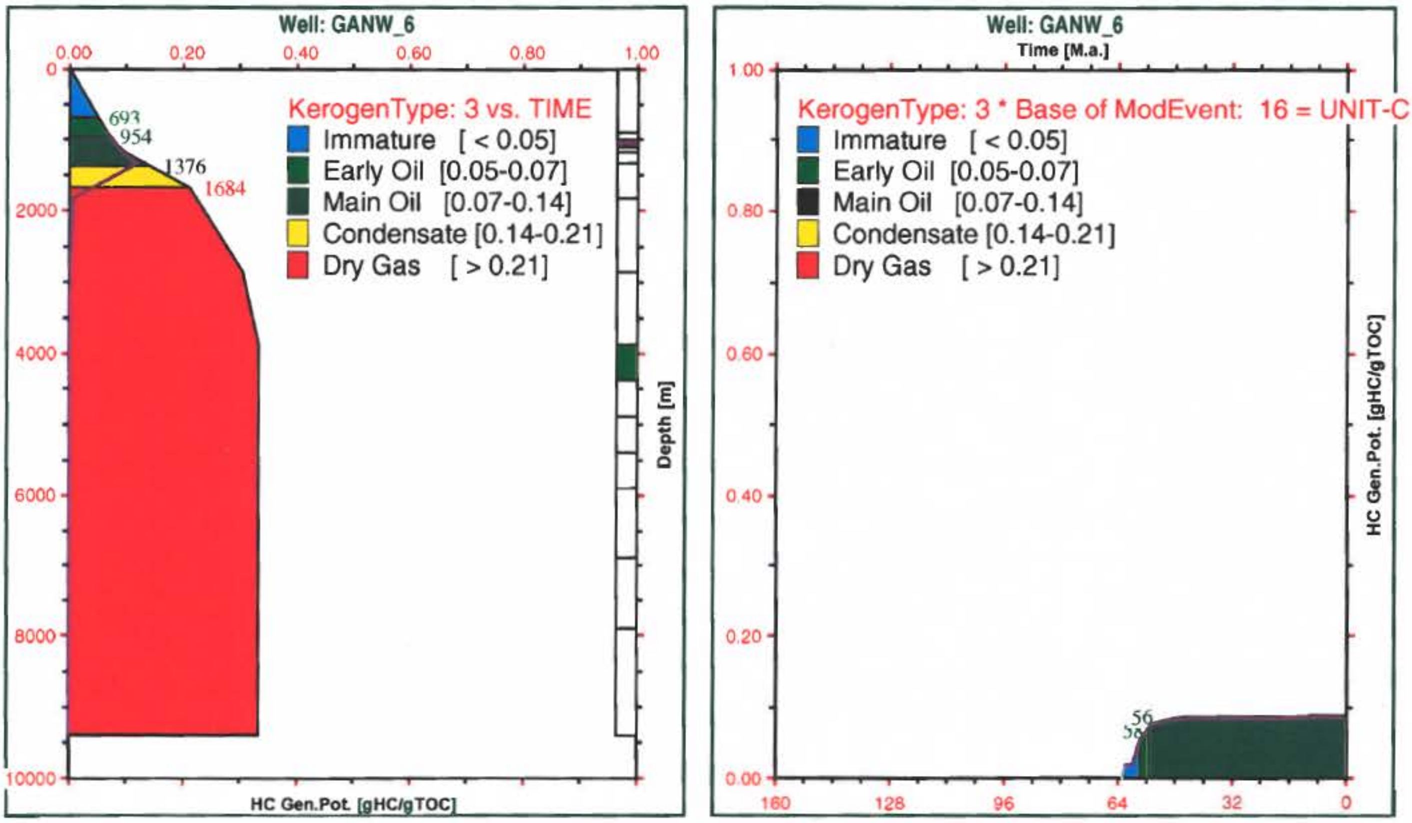




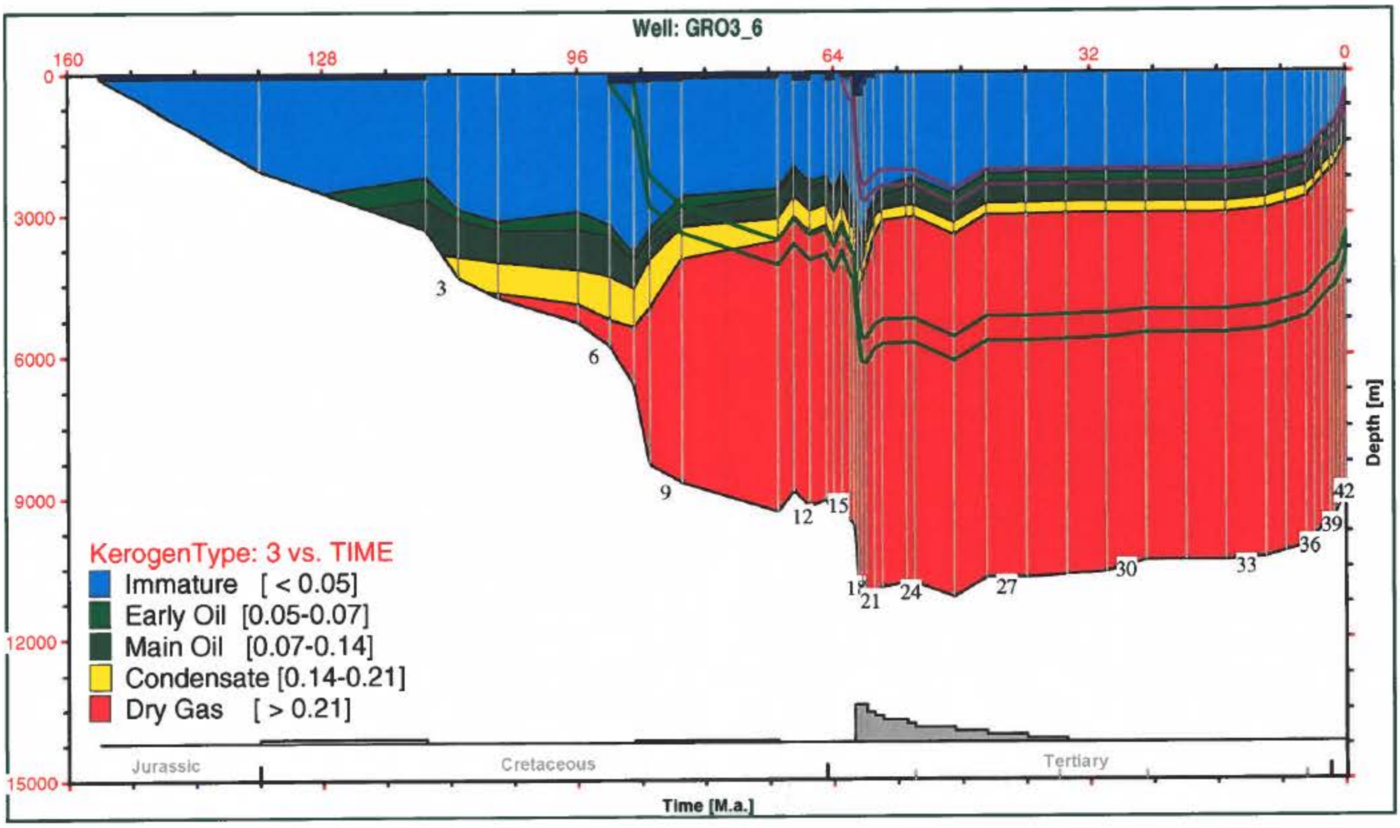
APP. 6b.9 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the Itilli pseudowell, western Nuussuaq. **Model Concept:** Minimum volcanics.



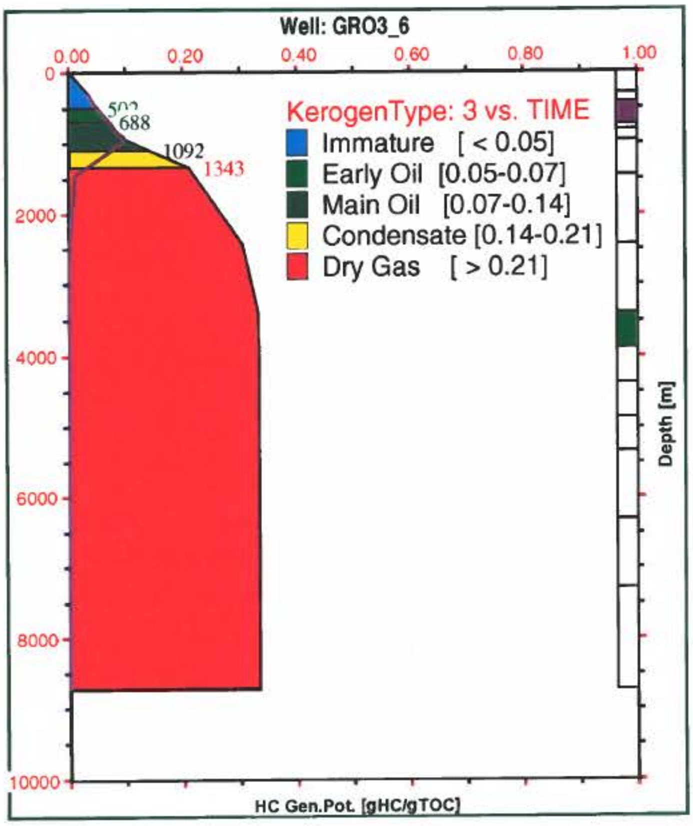
APP. 6b.10 Geohistory for the GANW#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.

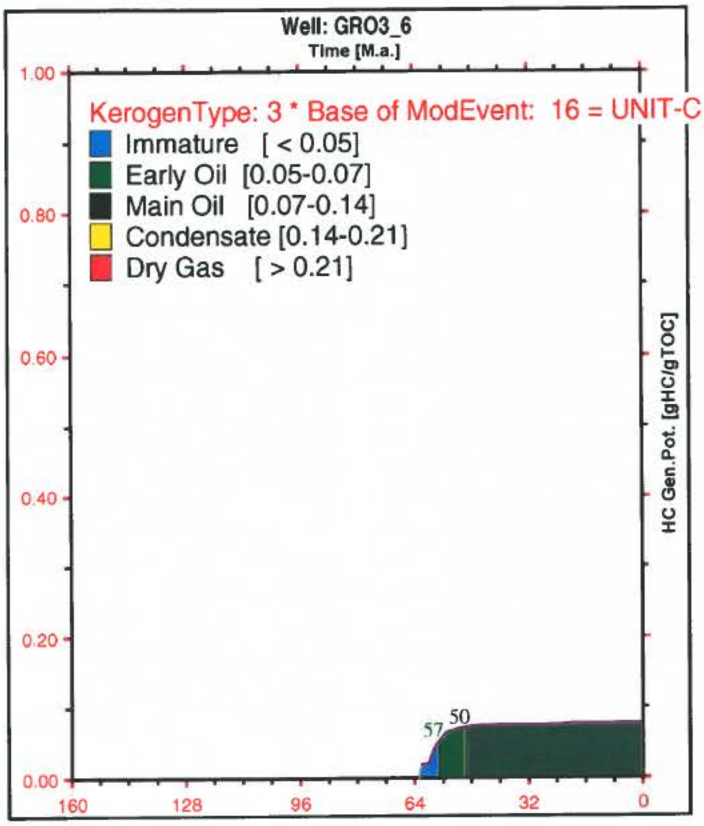


APP. 6b.11 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANW#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.

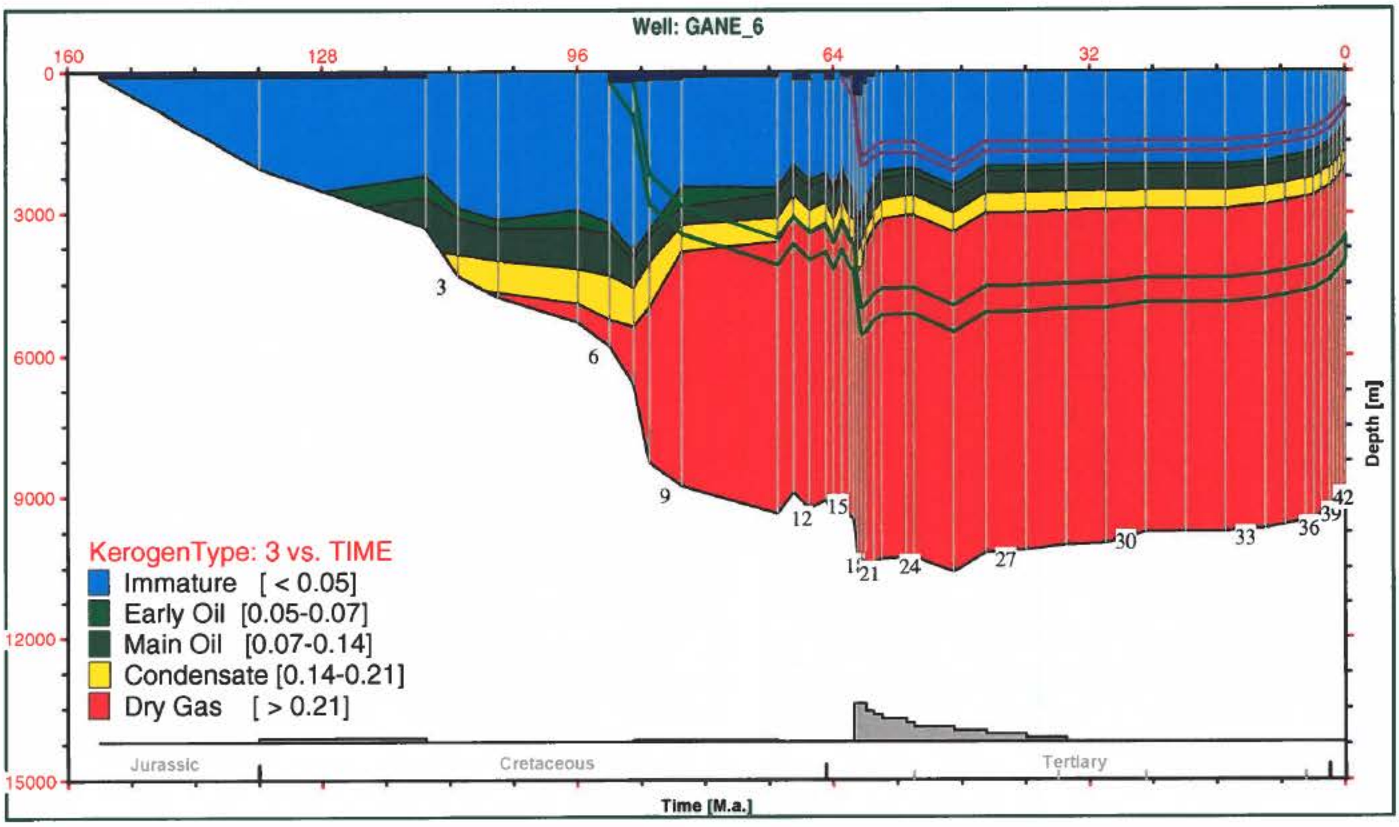


APP. 6b.12 Geohistory for the GRO#3 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.

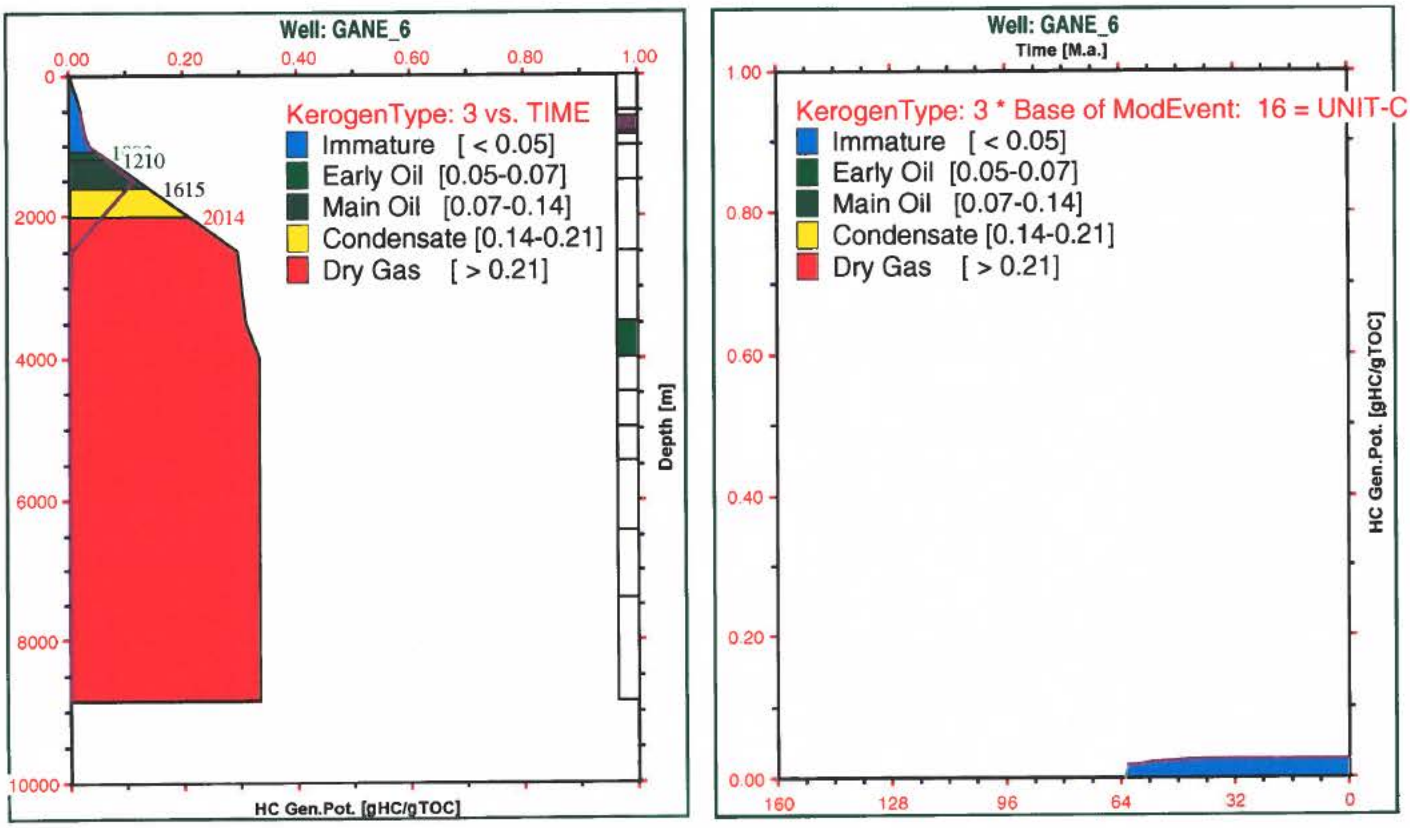




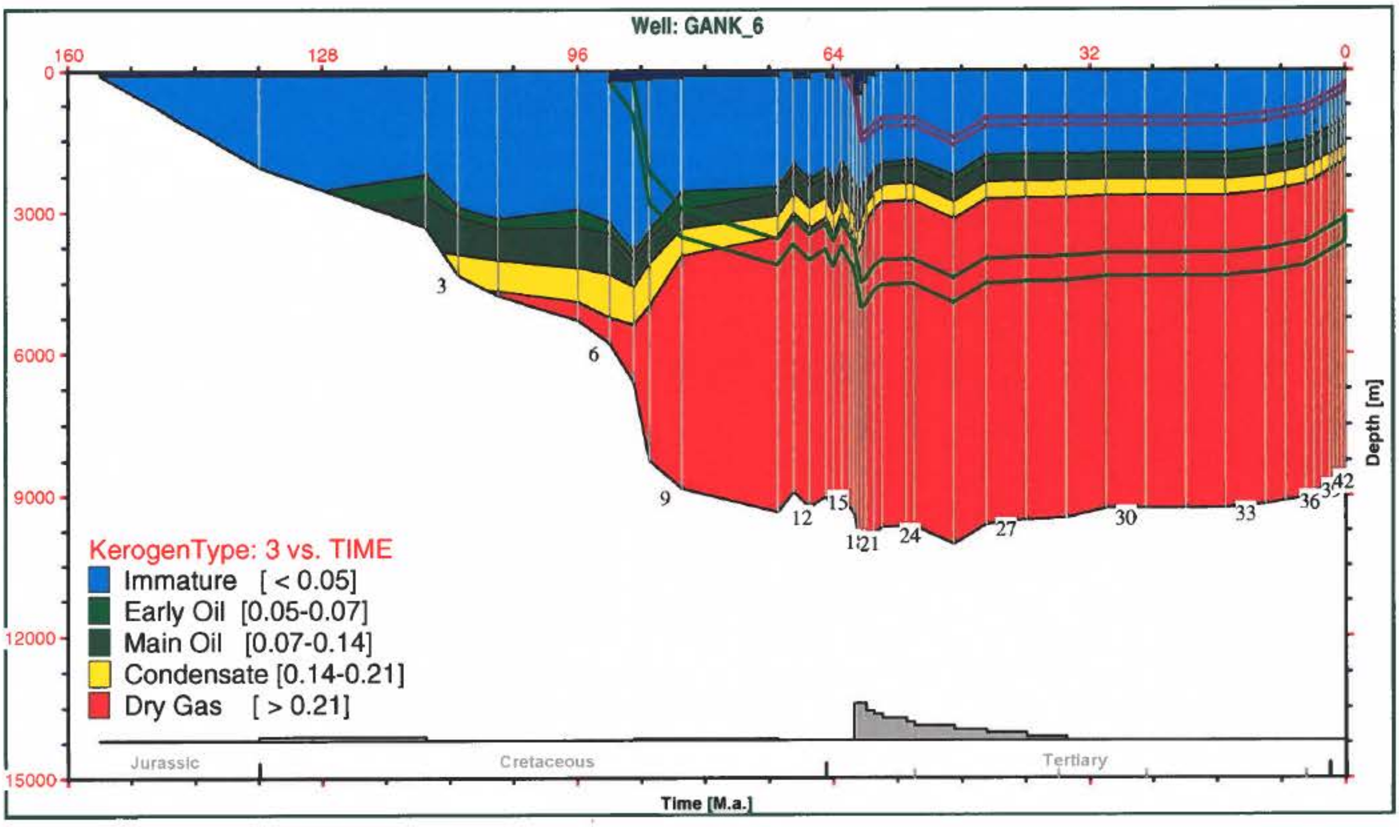
APP. 6b.13 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GRO#3 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.



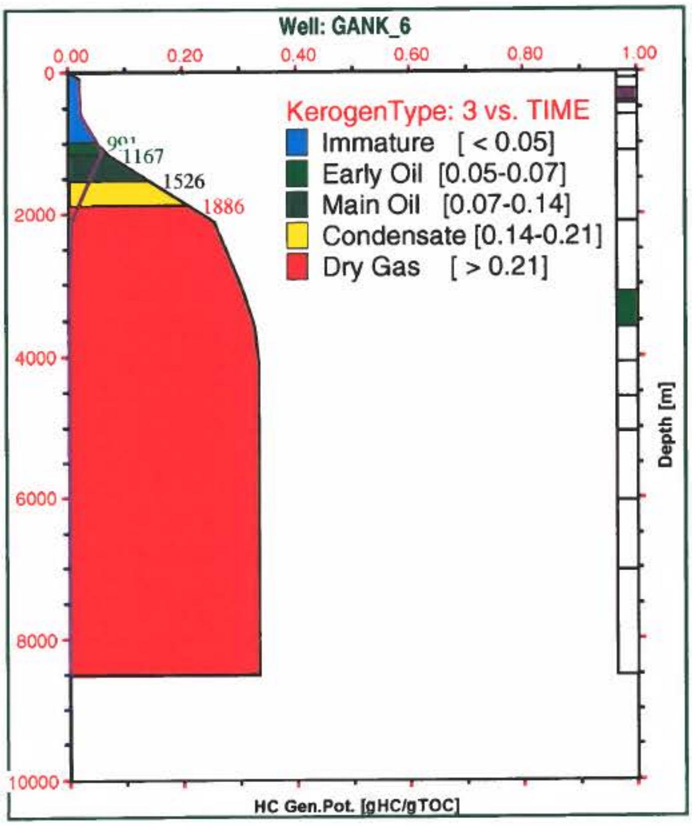
APP. 6b.14 Geohistory for the GANE#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.

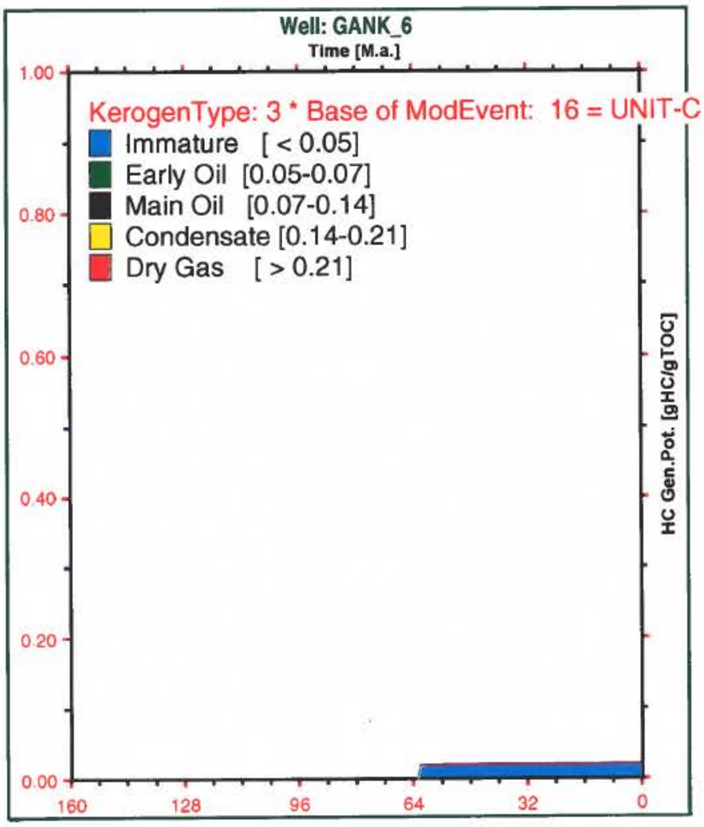


APP. 6b.15 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANE#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.

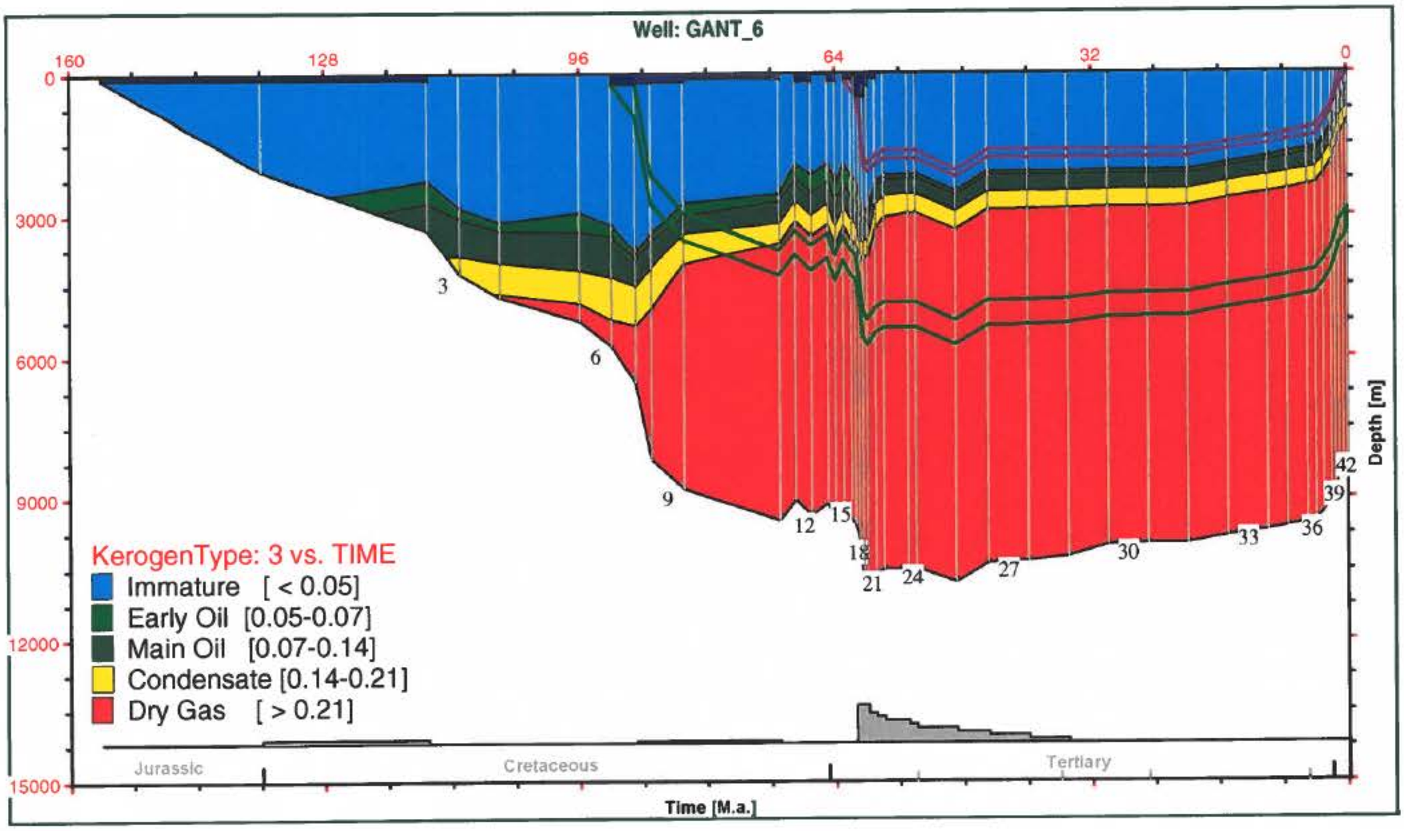


APP. 6b.16 Geohistory for the GANK#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.

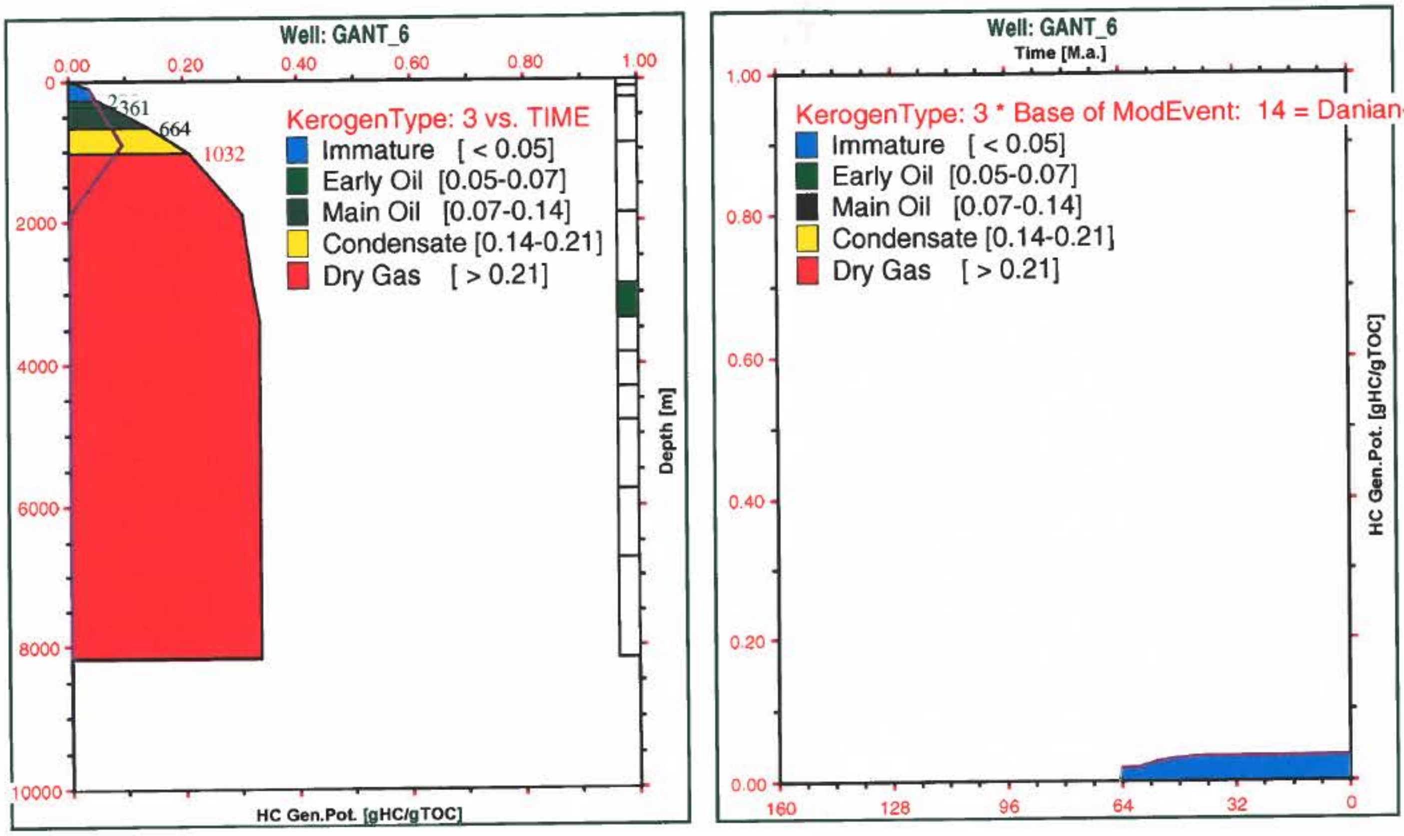




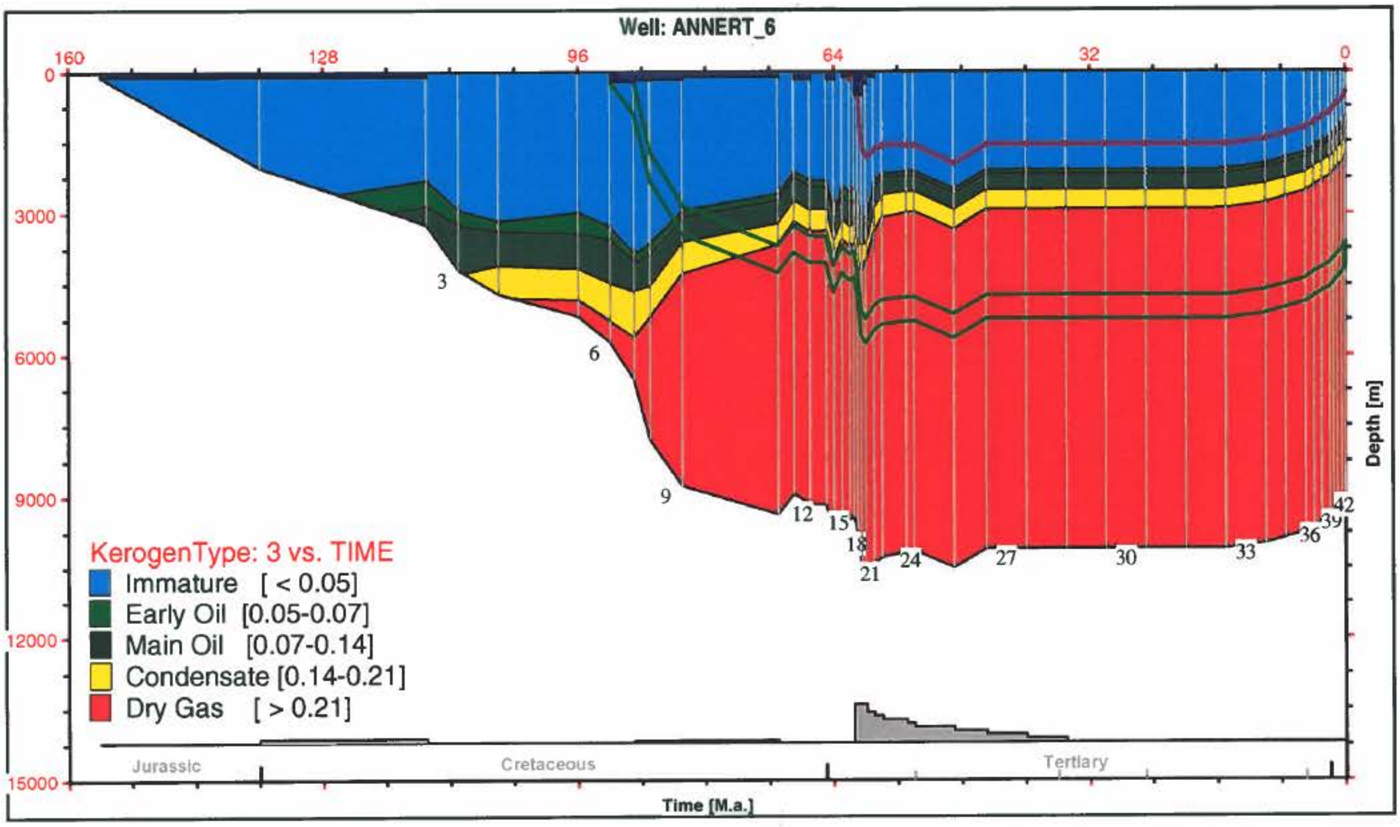
APP. 6b.17 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANK#1 well, southern Nuussuaq. **Model Concept:** Minimum volcanics.



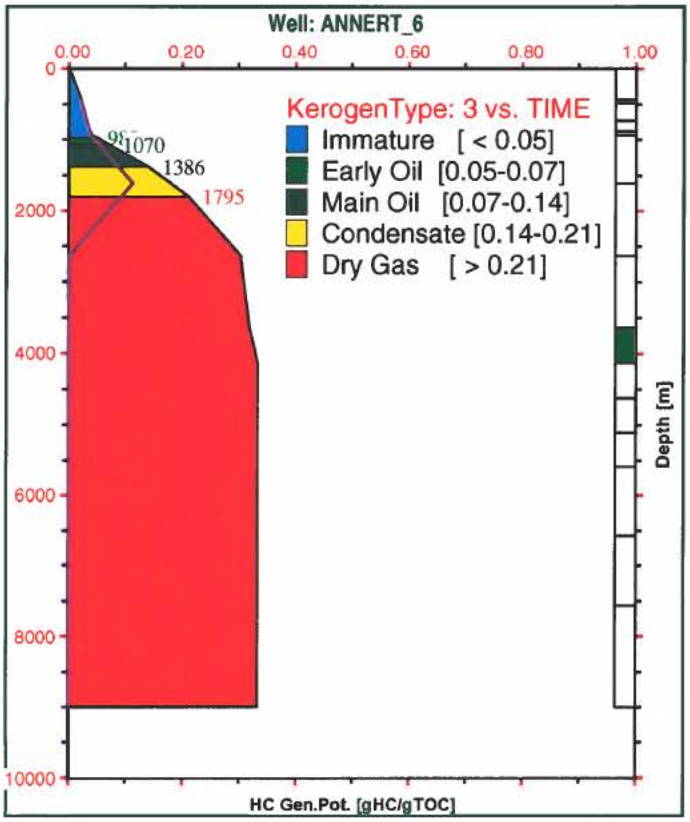
APP. 6b.18 Geohistory for the GANT#1 well, northern Nuussuaq. **Model Concept:** Minimum volcanics.

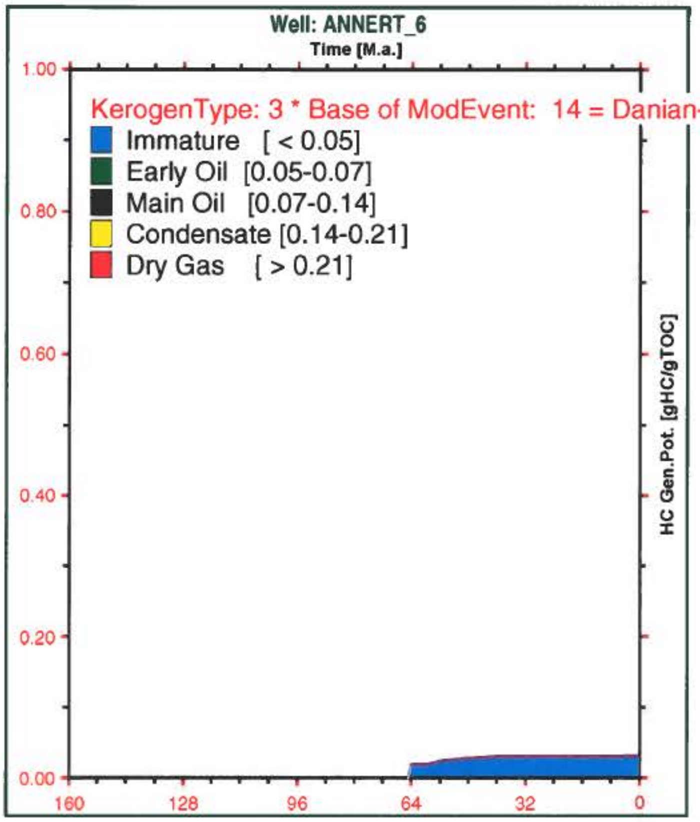


APP. 6b.19 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the GANT#1 well, northern Nuussuaq. **Model Concept:** Minimum volcanics.



APP. 6b.20 Geohistory for the Annertuneq pseudowell, northern Nuussuaq. **Model Concept:** Minimum volcanics.





APP. 6b.21 Hydrocarbon generation vs. Depth (right) and Time (left) for potential source rock for the Annertuneq pseudowell, northern Nuussuaq. **Model Concept:** Minimum volcanics.

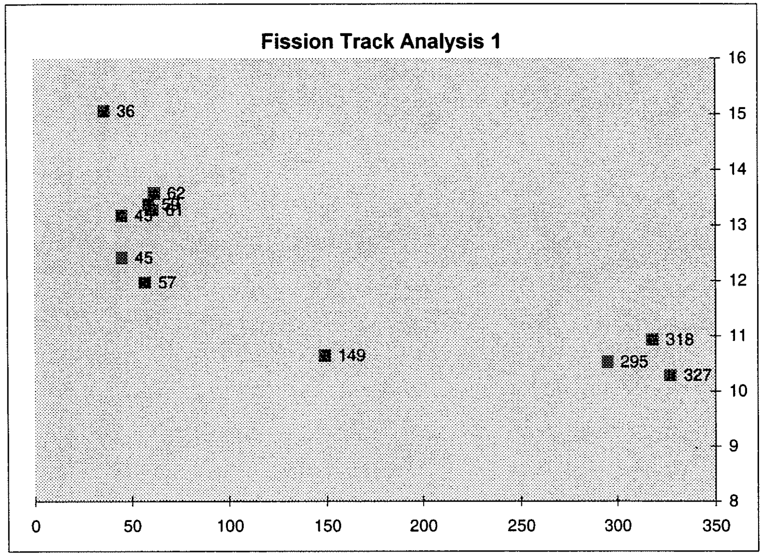
APPENDIX 7

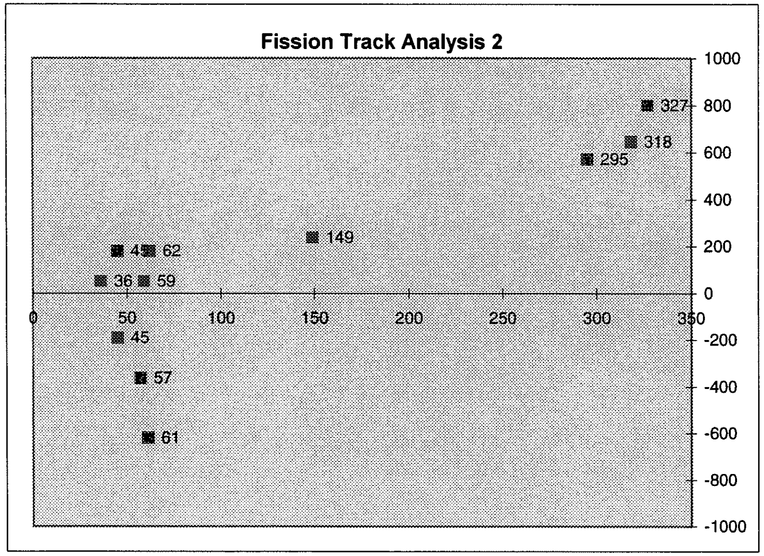
Fission Track Analysis Data and Results

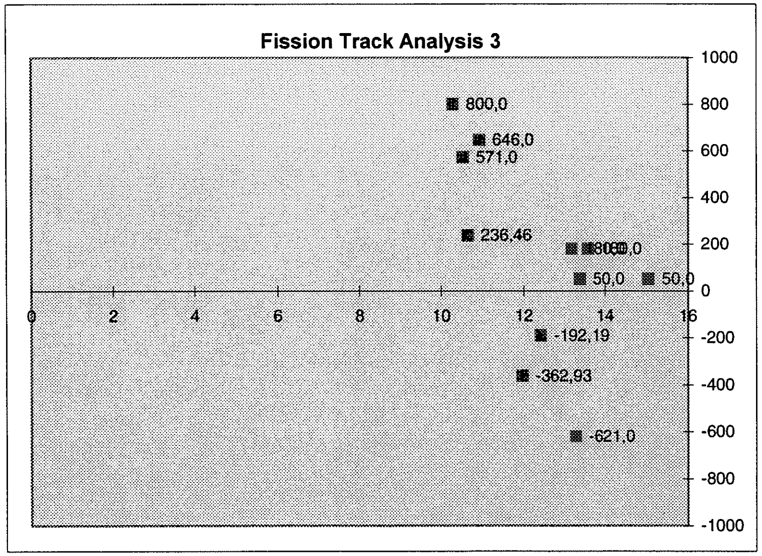
Fission Track Data

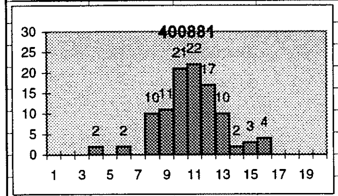
ID	Sample No.	Sample Type	Alti./Depth	Evnt_No	Sample location	Central Age	1Delta	2Delta	No.Crystals	No. Tr.	M. Length	1Delta	Stand.Div.	F.Tr. Density	P(X^2)	U [ppm]	COMMENTS
Nuuss	400914	Outcrop	180,0	17,bot	Itilli	45	4		16	33	13,17	0,39	2,20	2,330E+05	62	10,7	Near Base Volcanics
Nuuss	400916	Outcrop	180,0	17,bot	Itilli	62	10		8	14	13,57	0,52	1,88	3,940E+05	3	14,1	Near Base Volcanics
Nuuss	409131-a	Outcrop	50,0	14,bot	Itilli	36	7		4	8	15,05	0,82	2,16	2,350E+05	65	13,7	150 m below Volcanics
Nuuss	409131-b	Outcrop	50,0	14,bot	Itilli	59	14		4	10	13,37	0,58	1,74	3,360E+05	2	13,5	150 m below Volcanics
Nuuss	439001-737	Cuttings, 737	-621,0	16.mid	GanE#1	61	6		9	13	13,27	0,44	1,53	6,390E+05	6	22,1	Near TD
Nuuss	400881	800 m.o.h	800,0	16	AnnerTun	327	14		24	104	10,28	0,22	2,21	1,725E+06	75	8,7	200 m above TopKote; Quality: Good ?
Nuuss	400813	646 m.o.h	646,0	12,bot	AnnerTun	318	27		16	47	10,92	0,26	1,75	1,883E+06	<1	9,8	150.54 m below TopKote; Quality: Goo
Nuuss	400878	571 m.o.h	571,0	10,top	GanT#1	295	26		22	107	10,52	0,22	2,31	2,282E+06	0	13,4	579.19 m below TopKote; Quality: Goo
Nuuss	439101-653	Core, 150,54	236,46	10,bot	GanT#1	149	23		28	82	10,64	0,36	3,24	1,036E+06	0	13,0	749.93 m below TopKote; Quality: Goo
Nuuss	439101-654	Core, 579,19	-192,19	16	GanT#1	45	5		21	76	12,41	0,31	2,67	4,100E+05	0	19,2	800 a m.A.s.l. = Agatdalen Fm.
Nuuss	439101-655	Core, 749,93	-362,93	14,top	GanT#1	57	11		13	12	11,96	0,58	1,93	2,830E+05	0	11,8	646 a m.A.s.l. = 'Danian'

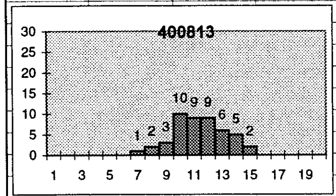
Qaulitative Plots

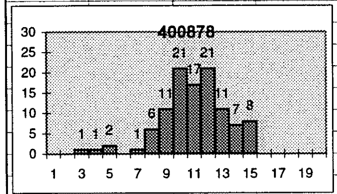


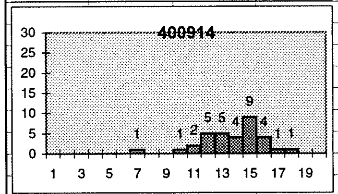


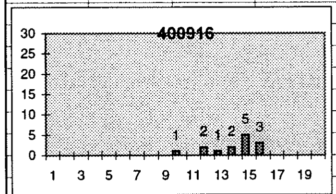


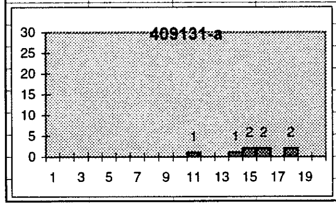












ID	Sample No.	Alti./Depth	Central Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	SUM
Nuuss	**400881**	**800**	**327**				**2**		**2**		**10**	**11**	**21**	**22**	**17**	**10**	**2**	**3**	**4**					**104**
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	400881	800	327																					
Nuuss	**400813**	**646**	**318**							**1**	**2**	**3**	**10**	**9**	**9**	**6**	**5**	**2**						**47**
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	400813	646	318																					
Nuuss	**400878**	**571**	**295**			**1**	**1**	**2**		**1**	**6**	**11**	**21**	**17**	**21**	**11**	**7**	**8**						**107**
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	400878	571	295																					
Nuuss	**400914**	**180**	**45**							**1**			**1**	**2**	**5**	**5**	**4**	**9**	**4**	**1**	**1**			**33**
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	400914	180	45																					
Nuuss	**400916**	**180**	**62**										**1**		**2**	**1**	**2**	**5**	**3**					**14**
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	400916	180	62																					
Nuuss	**409131-a**	**50**	**36**											**1**			**1**	**2**	**2**		**2**			**8**
Nuuss	409131-a	50	36																					
Nuuss	409131-a	50	36																					
Nuuss	409131-a	50	36																					
Nuuss	409131-a	50	36																					
Nuuss	409131-a	50	36																					
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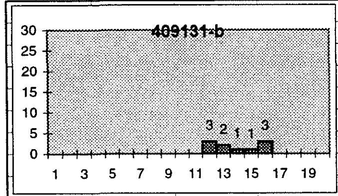
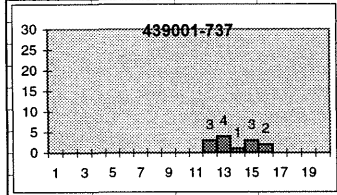
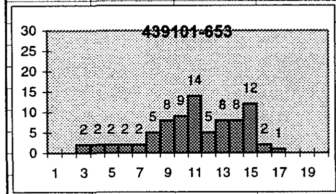
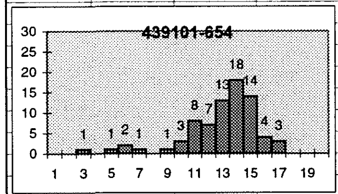
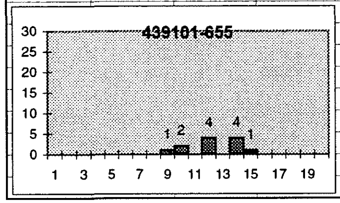
Nuuss	409131-a	50	36																					











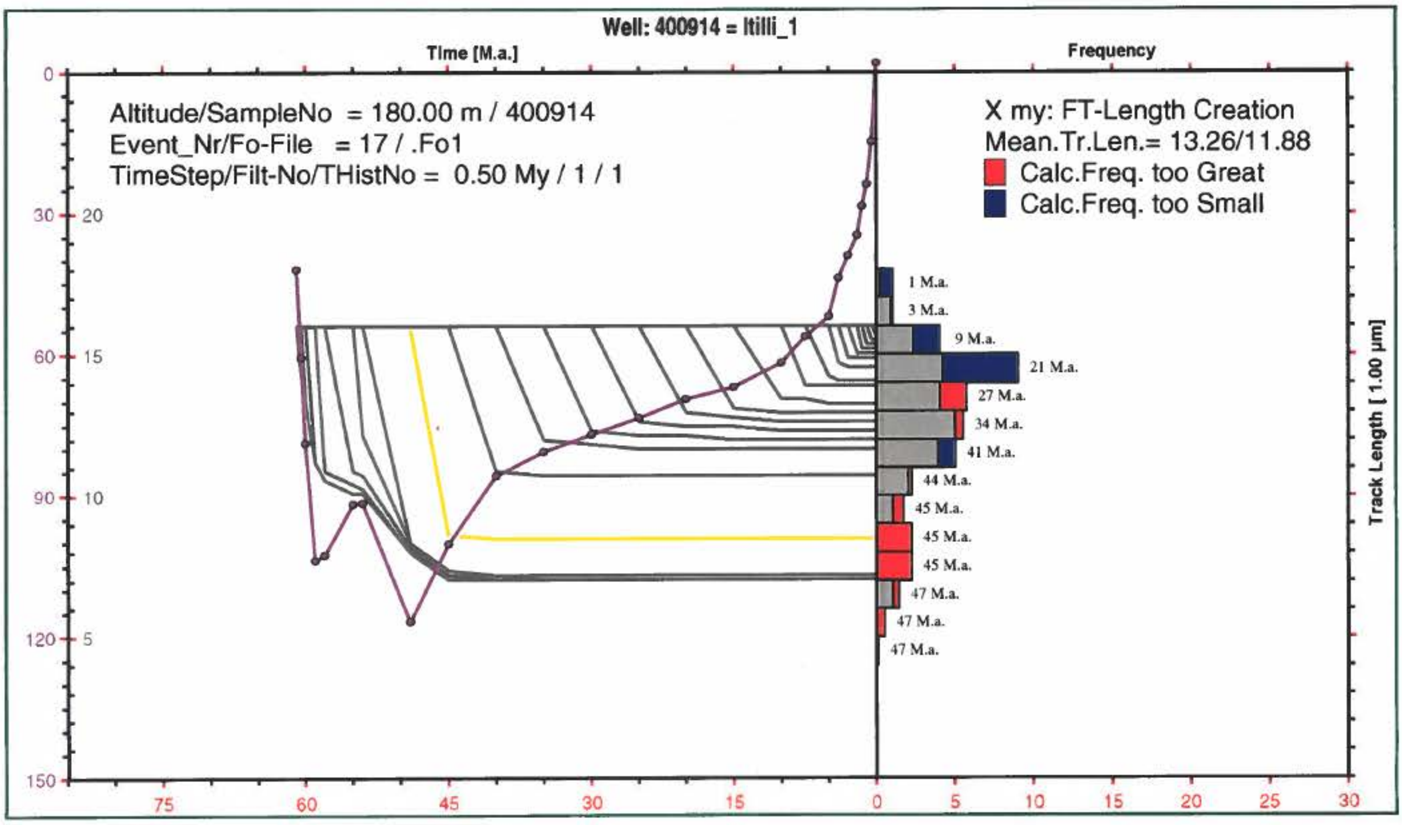
Nuuss	**409131-b**	**50**	**59**											**3**	**2**	**1**	**1**	**3**					**10**
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	409131-b	50	59																				
Nuuss	**439001-737**	**-621**	**61**											**3**	**4**	**1**	**3**	**2**					**13**
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	439001-737	-621	61																				
Nuuss	**439101-653**	**236,46**	**149**		**2**	**2**	**2**	**2**	**2**	**5**	**8**	**9**	**14**	**5**	**8**	**8**	**12**	**2**	**1**				**82**
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	439101-653	236,46	149																				
Nuuss	**439101-654**	**-192,19**	**45**		**1**		**1**	**2**	**1**		**1**	**3**	**8**	**7**	**13**	**18**	**14**	**4**	**3**				**76**
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	439101-654	-192,19	45																				
Nuuss	**439101-655**	**-362,93**	**57**								**1**	**2**		**4**		**4**	**1**						**12**
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				
Nuuss	439101-655	-362,93	57																				

APPENDIX 8

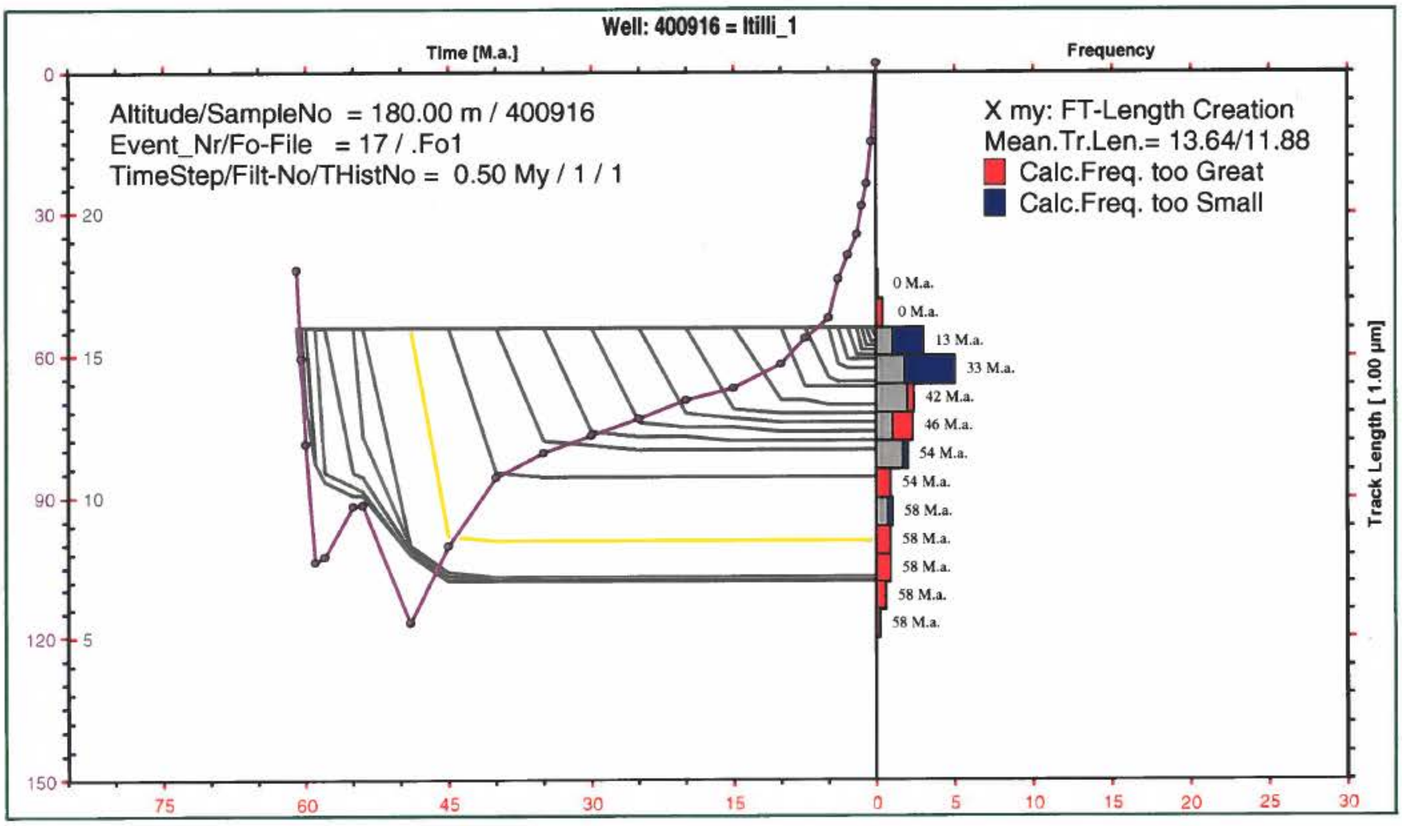
Fission Track Modelling; Optimisation and Results

APPENDIX 8a : <Wellname>_1 -concept with maximum amount of volcanics

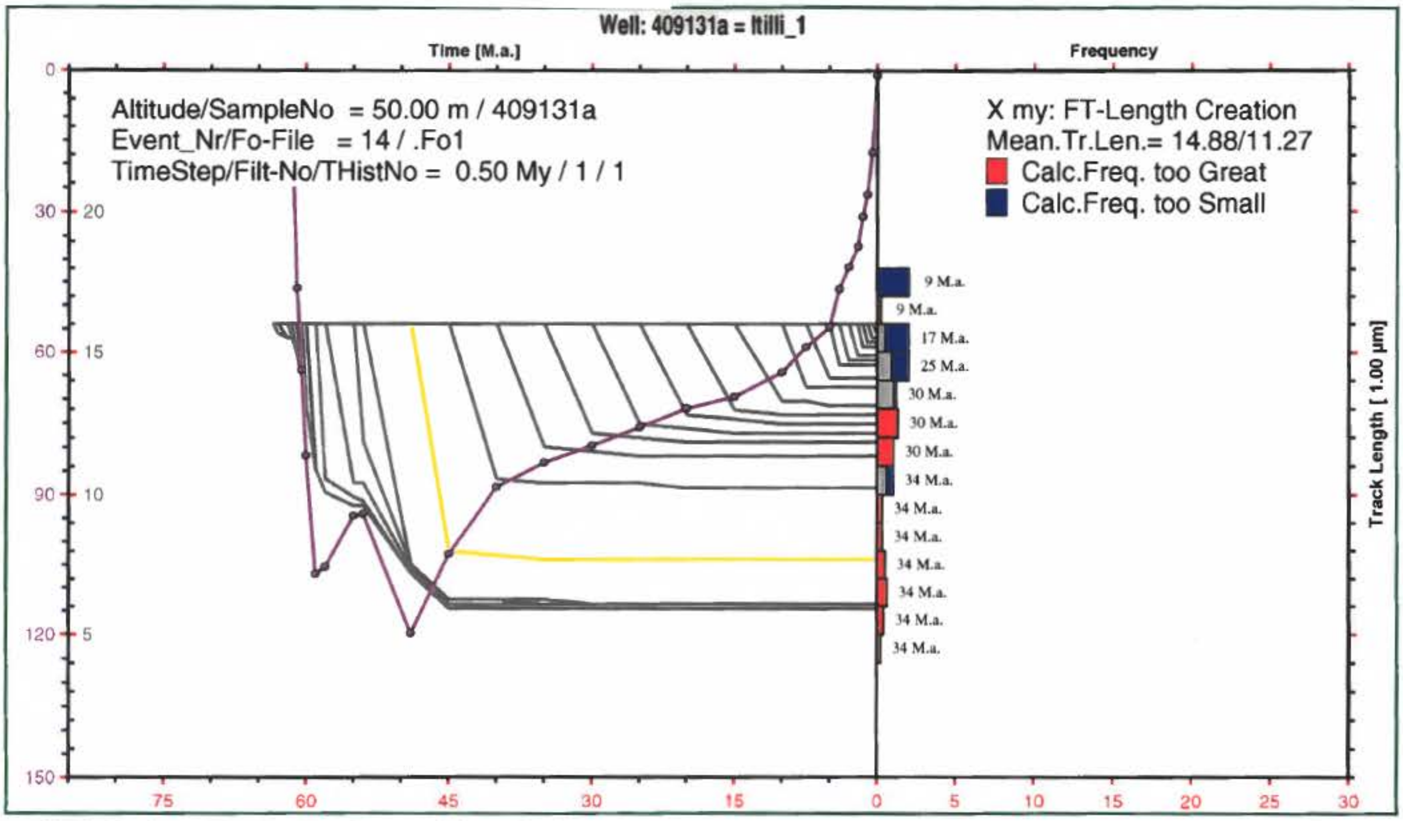
APPENDIX 8b : <Wellname>_6 -concept with minimum amount of volcanics



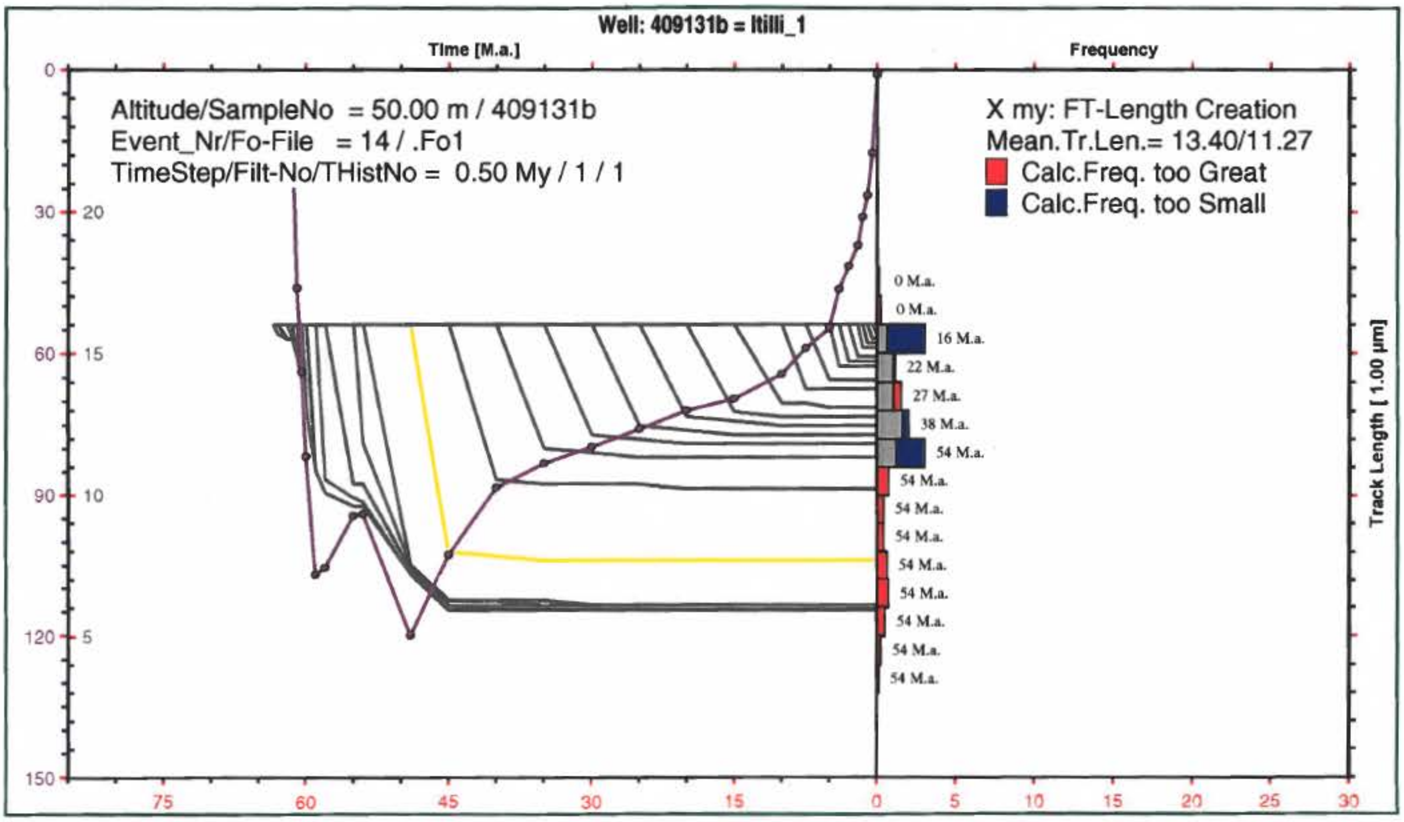
APP. 8a.1 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 400914; Model Event: 17; ?E Paleocene; FTA: 45 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



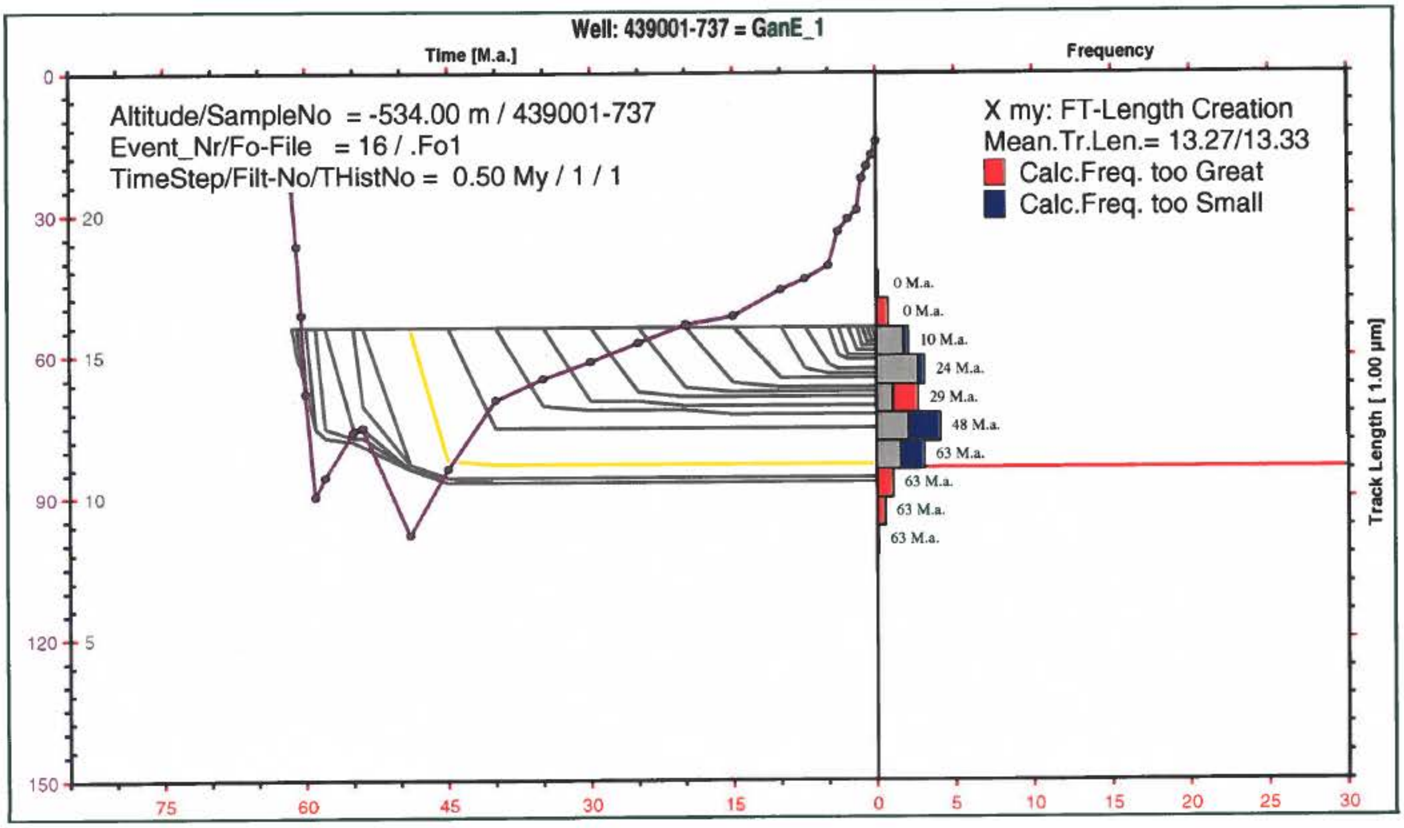
APP. 8a.2 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 400916; Model Event: 17; ?E Paleocene; FTA: 62 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



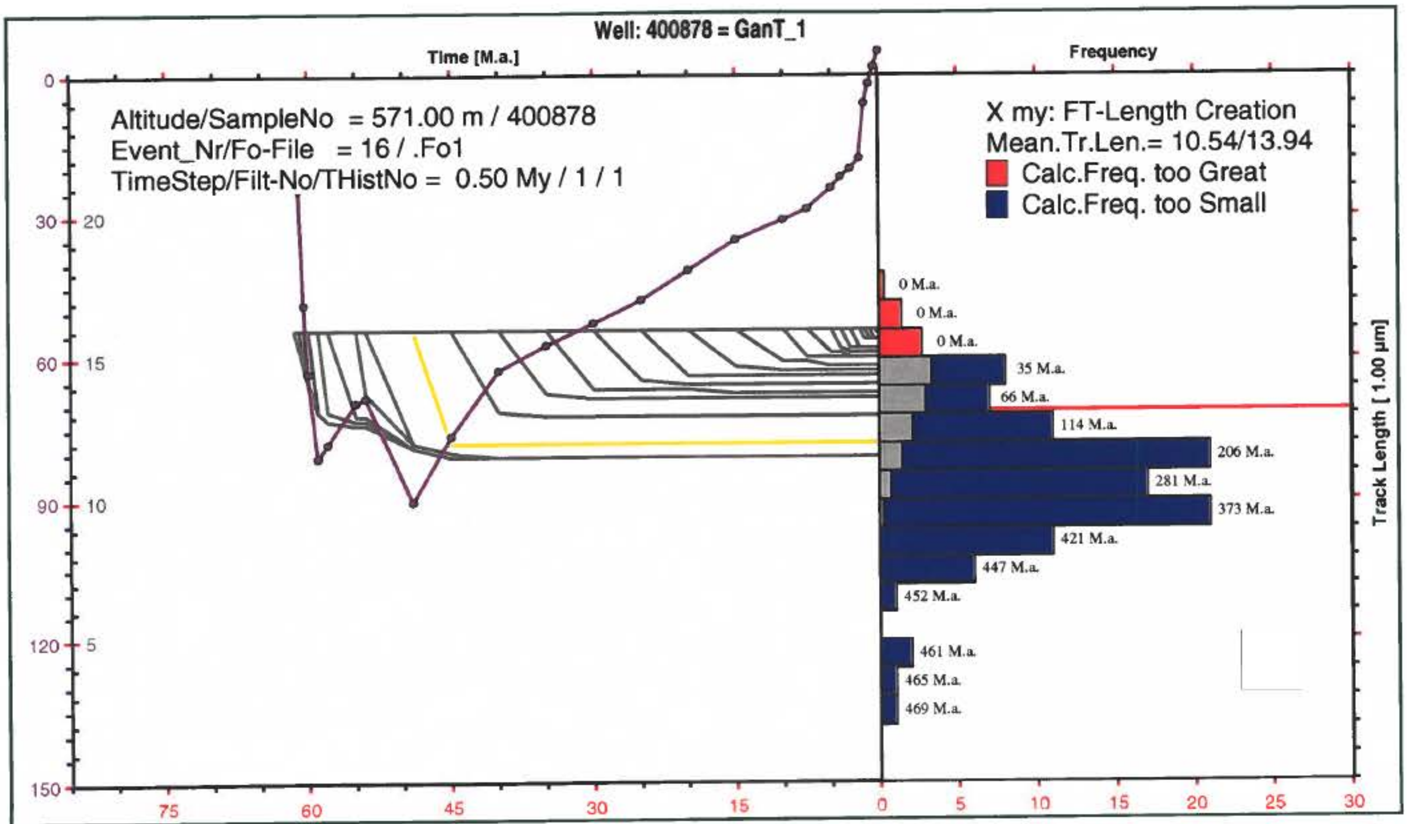
APP. 8a.3 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 409131a; Model Event: 14; ?E Paleocene; FTA: 36 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



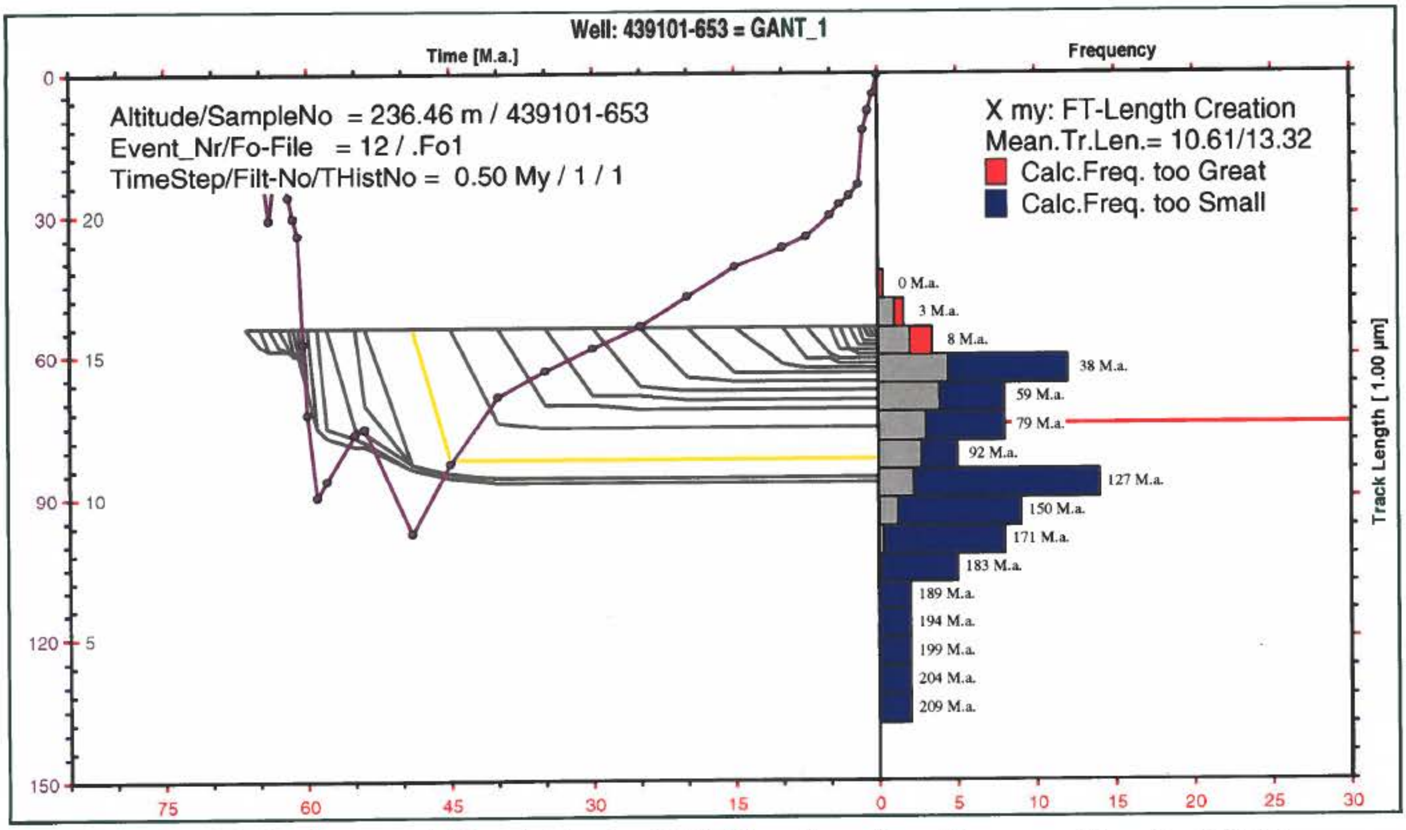
APP. 8a.4 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 409131b Model Event: 14; ?E Paleocene; FTA: 59 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



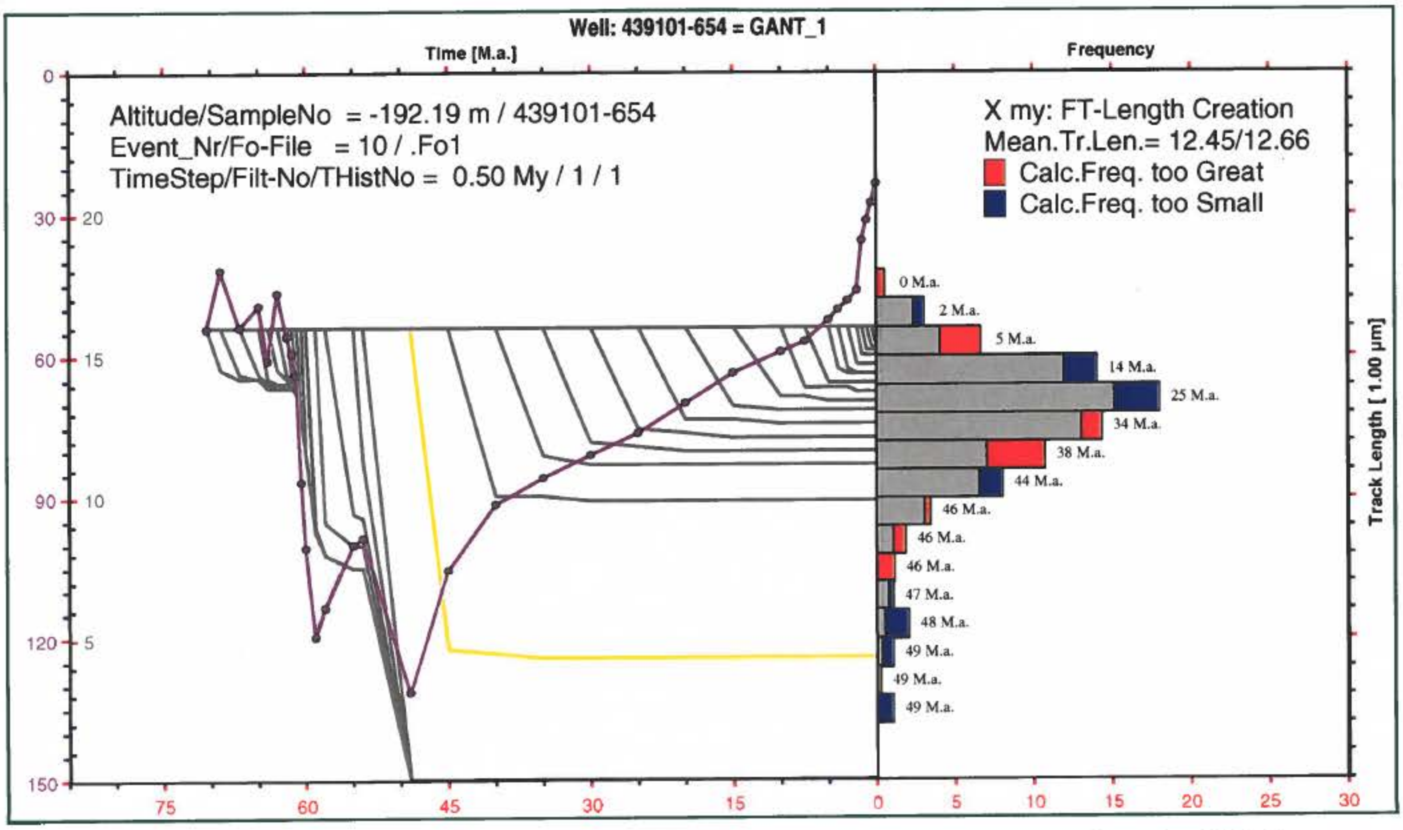
APP. 8a.5 Fission track modelling plot for the GANE#1 well, central Nuussuaq. Sample: 439001-737; Model Event: 16; Selandian; FTA: 61 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



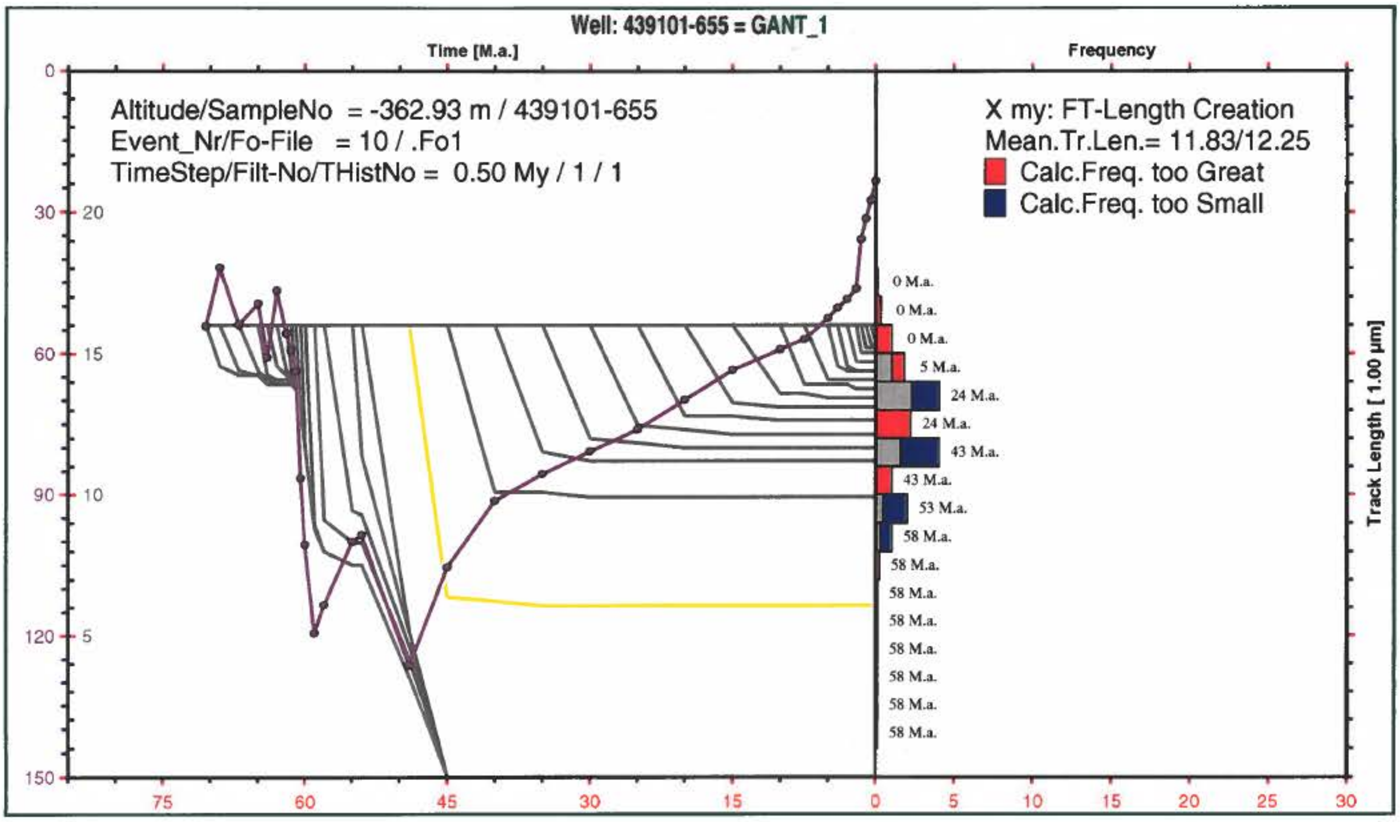
APP. 8a.6 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 400878; Model Event: 16; ? Selandian; FTA: 295 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



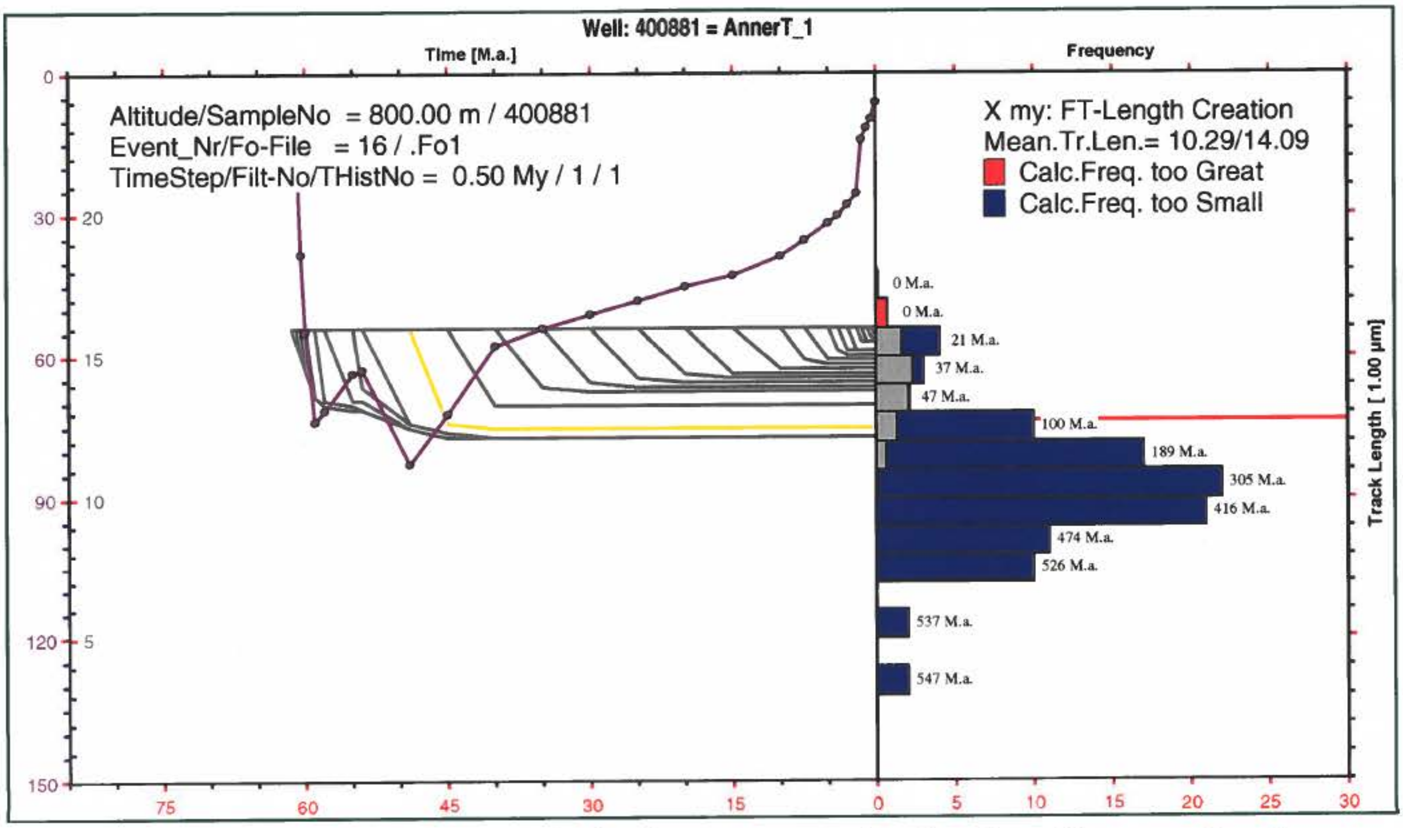
APP. 8a.7 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-653; Model Event: 12; Maastrichtian; FTA: 149 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



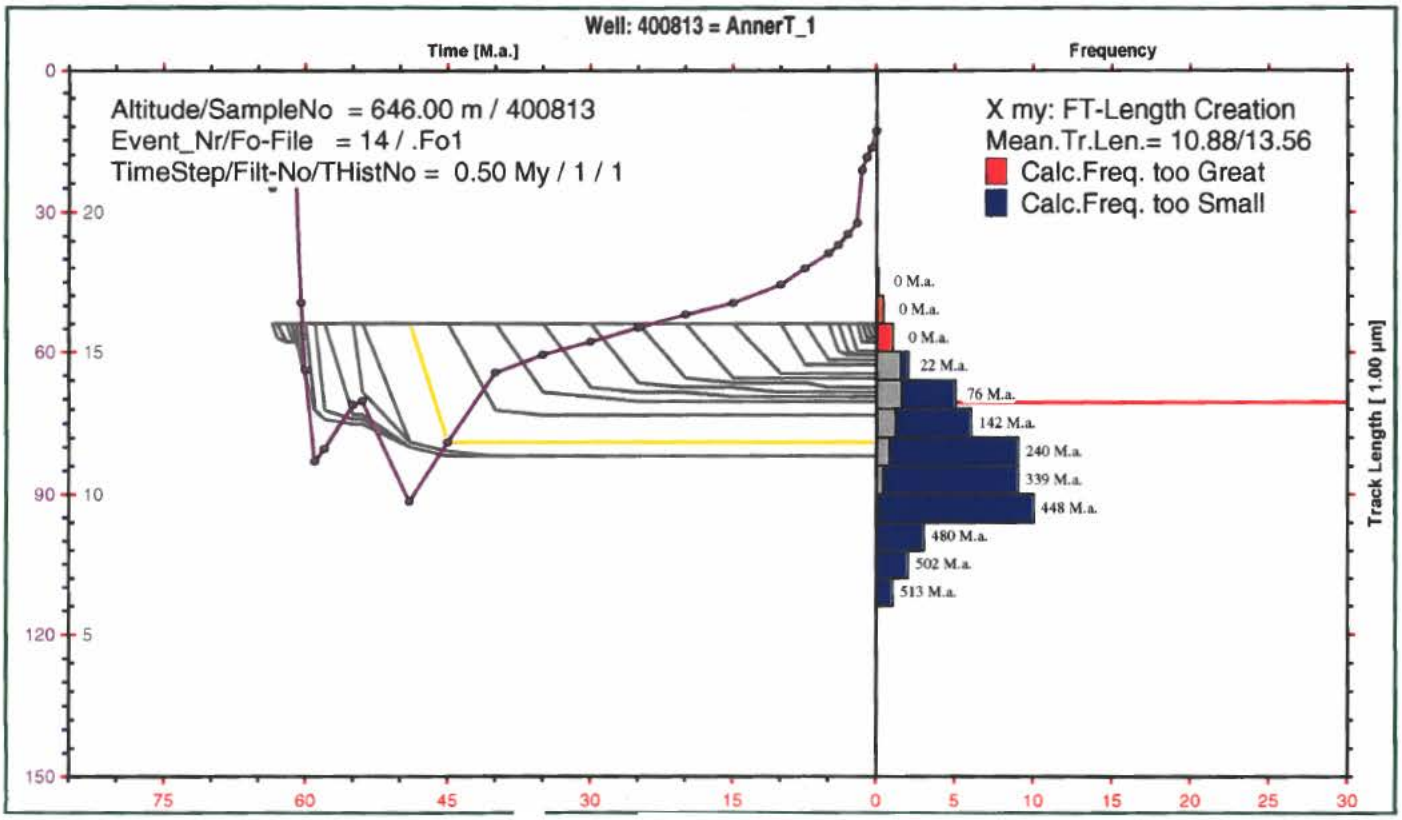
APP. 8a.8 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



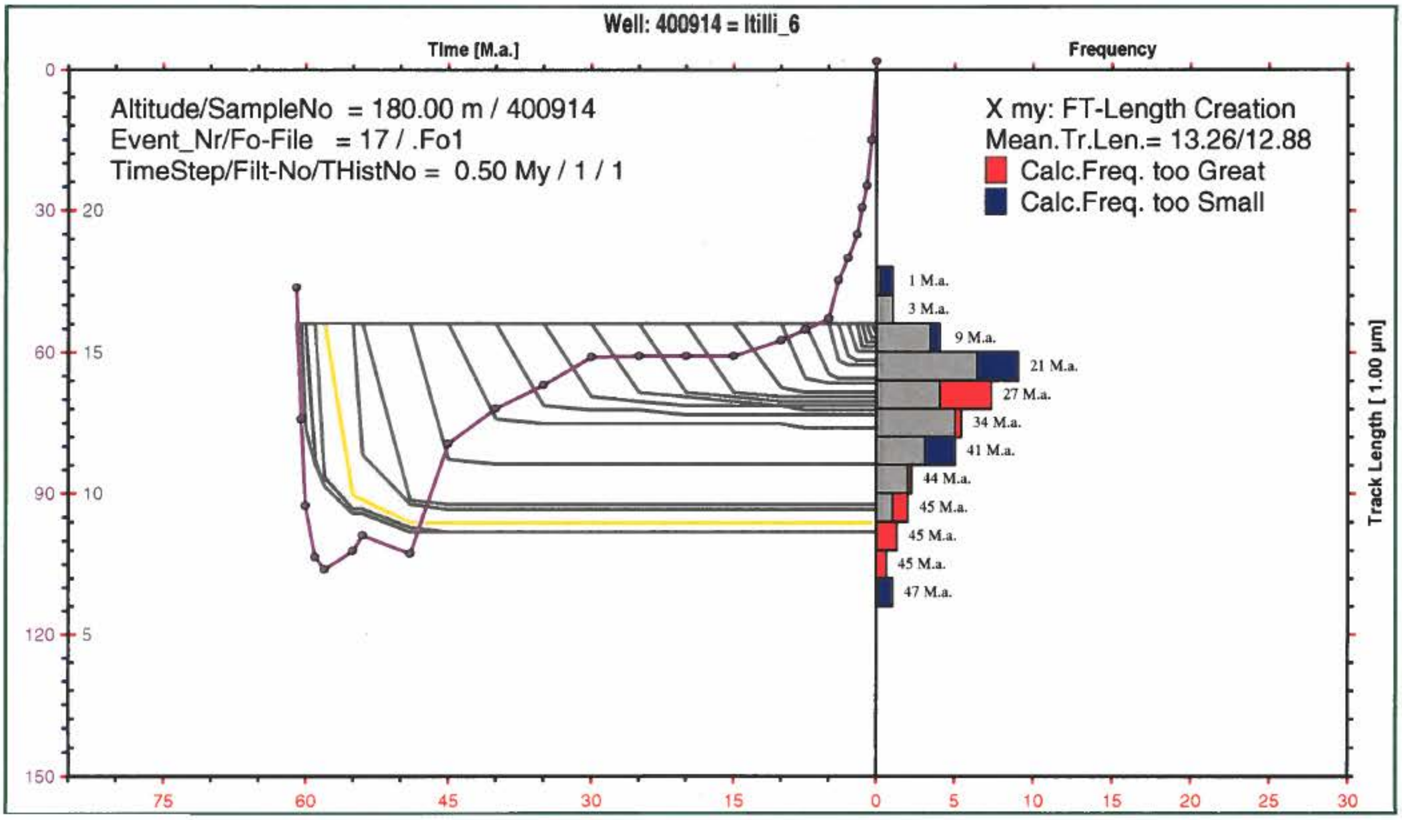
APP. 8a.9 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-655; Model Event: 10; m. Campanian; FTA: 57 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



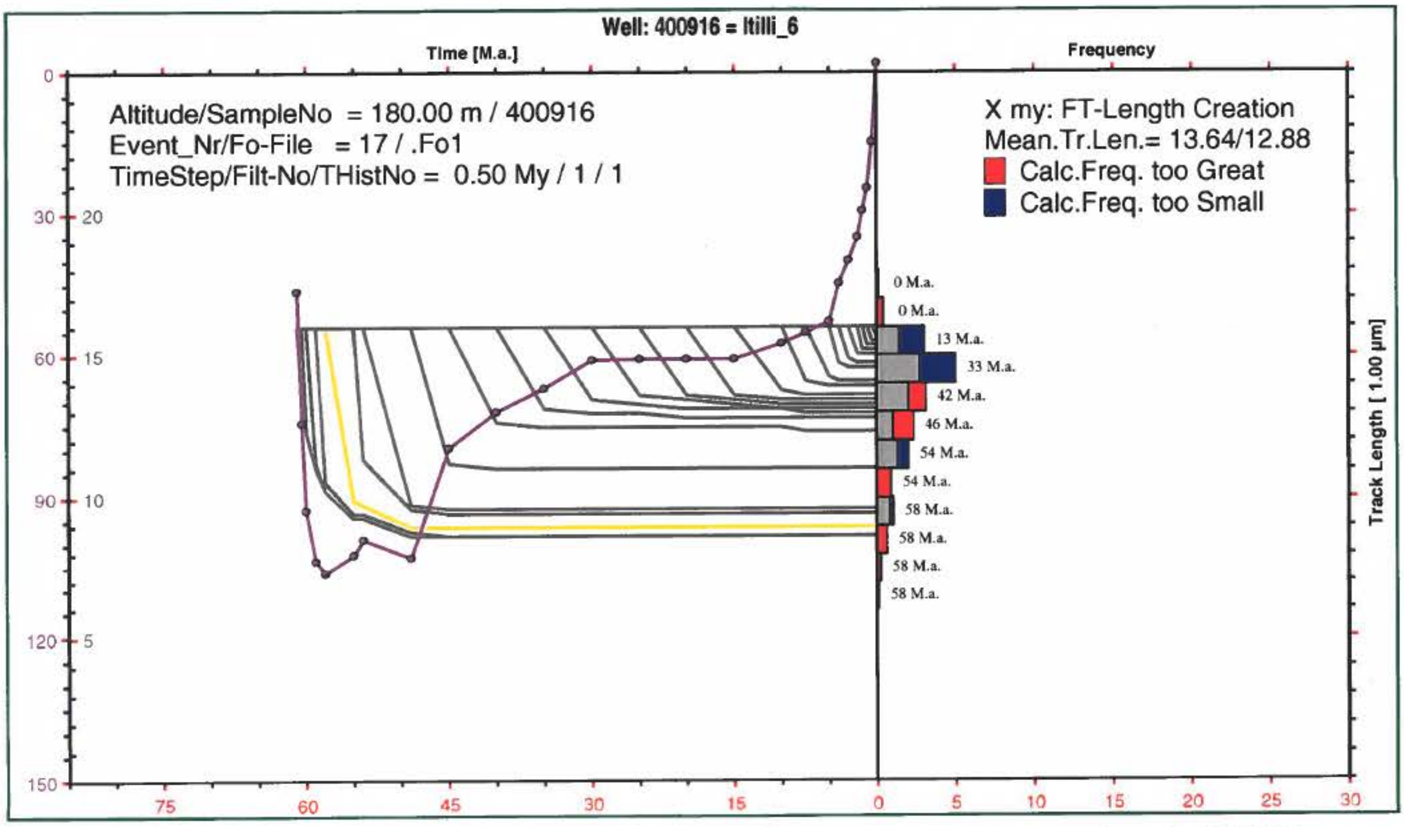
APP. 8a.10 Fission track modelling plot for the Annertuneq pseudowell, northern Nuussuaq. Sample: 400881; Model Event: 16; ? Selandian; FTA: 327 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



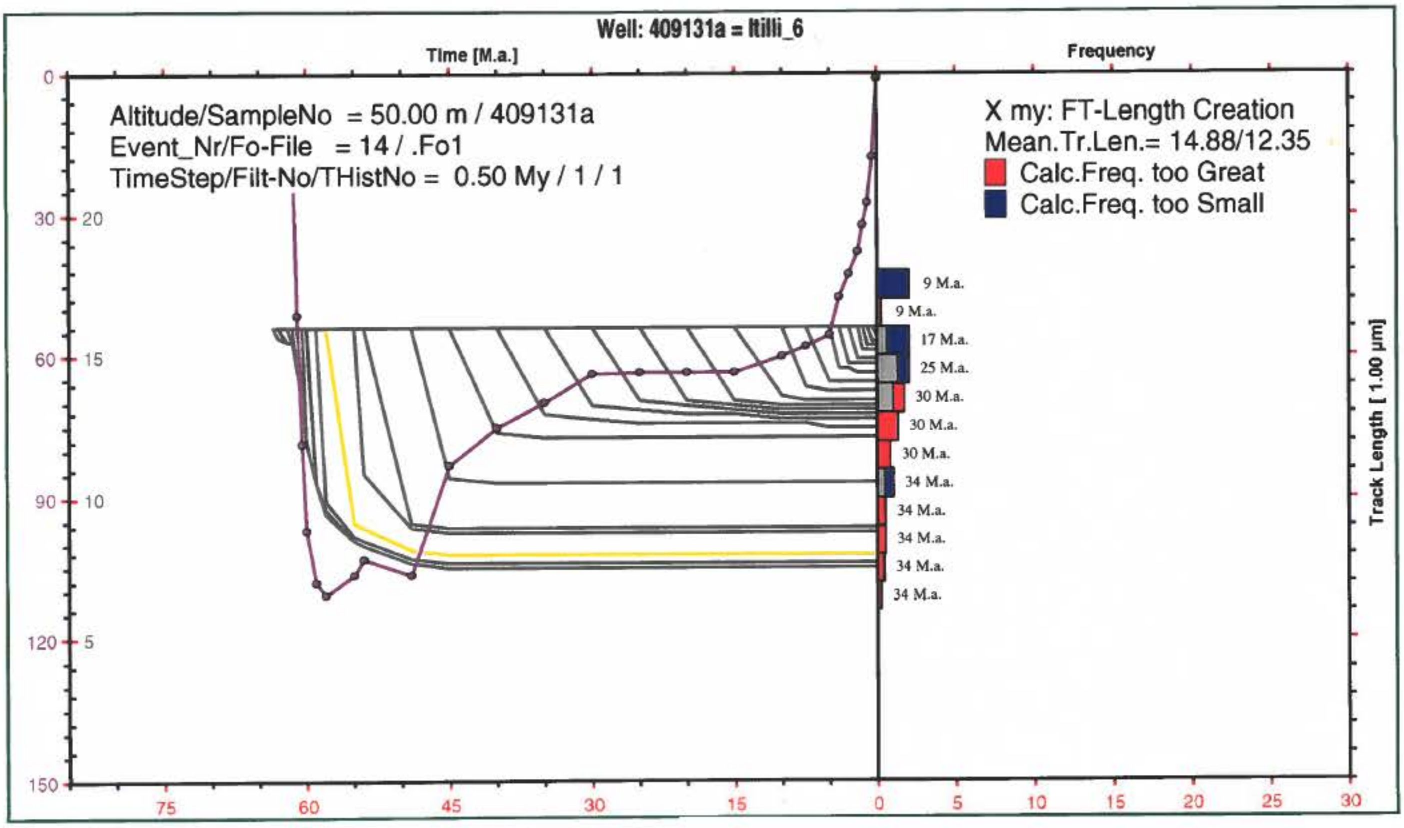
APP. 8a.11 Fission track modelling plot for the Annertuneq pseudowell, northern Nuussuaq. Sample: 400813; Model Event: 14; Late Danian; FTA: 318 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Maximum volcanics.



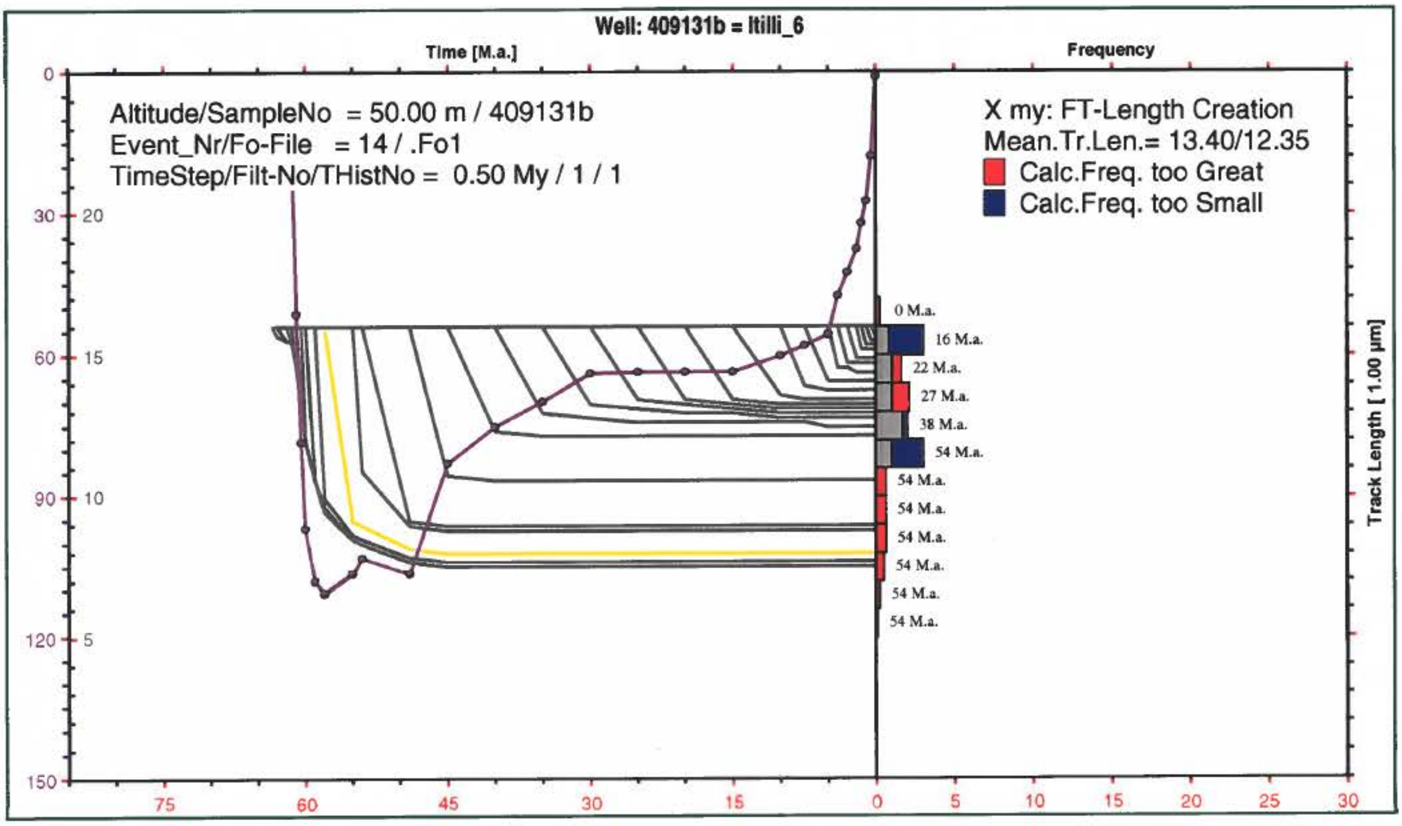
APP. 8b.1 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 400914; Model Event: 17; ?E Paleocene; FTA: 45 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



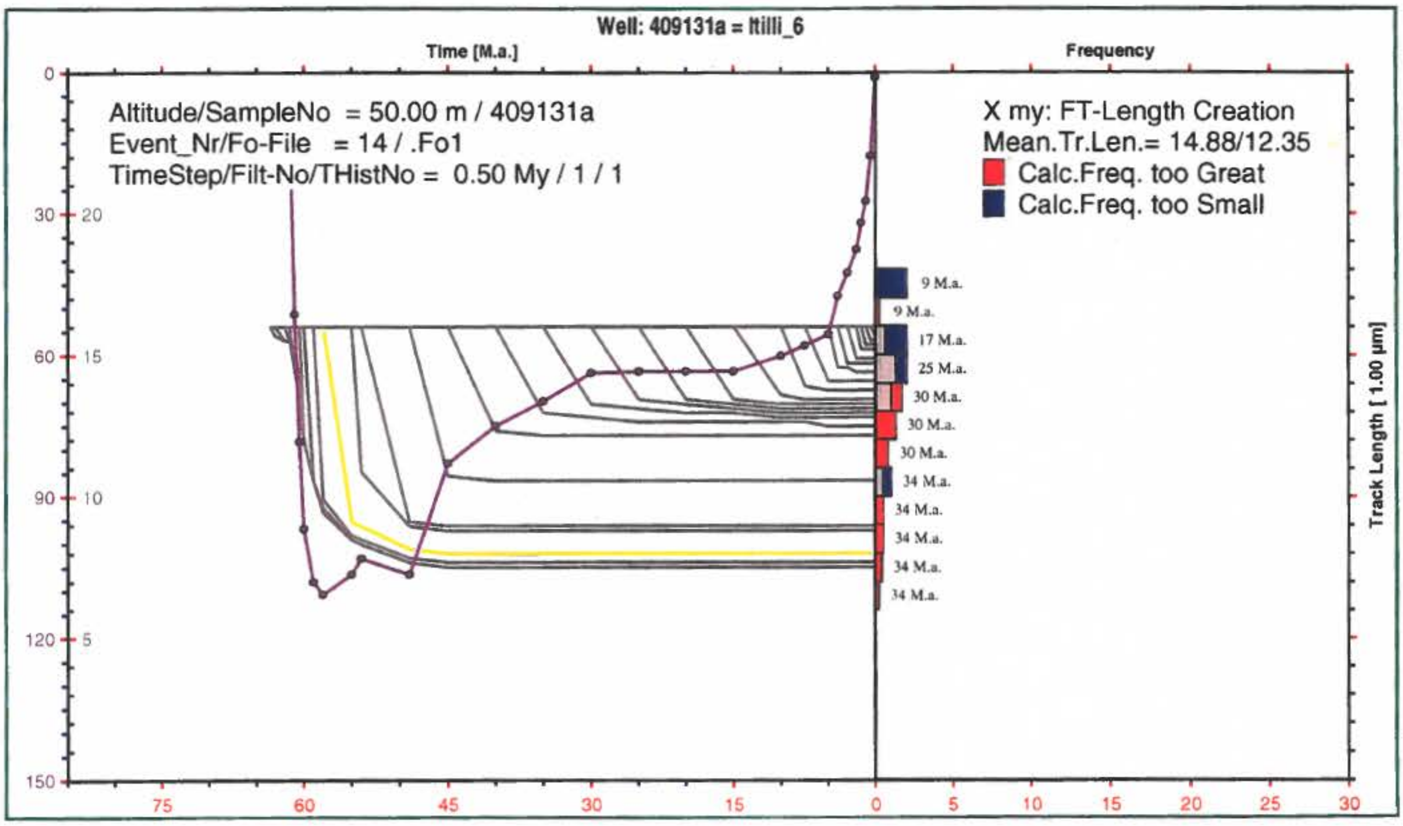
APP. 8b.2 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 400916; Model Event: 17; ?E Paleocene; FTA: 62 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



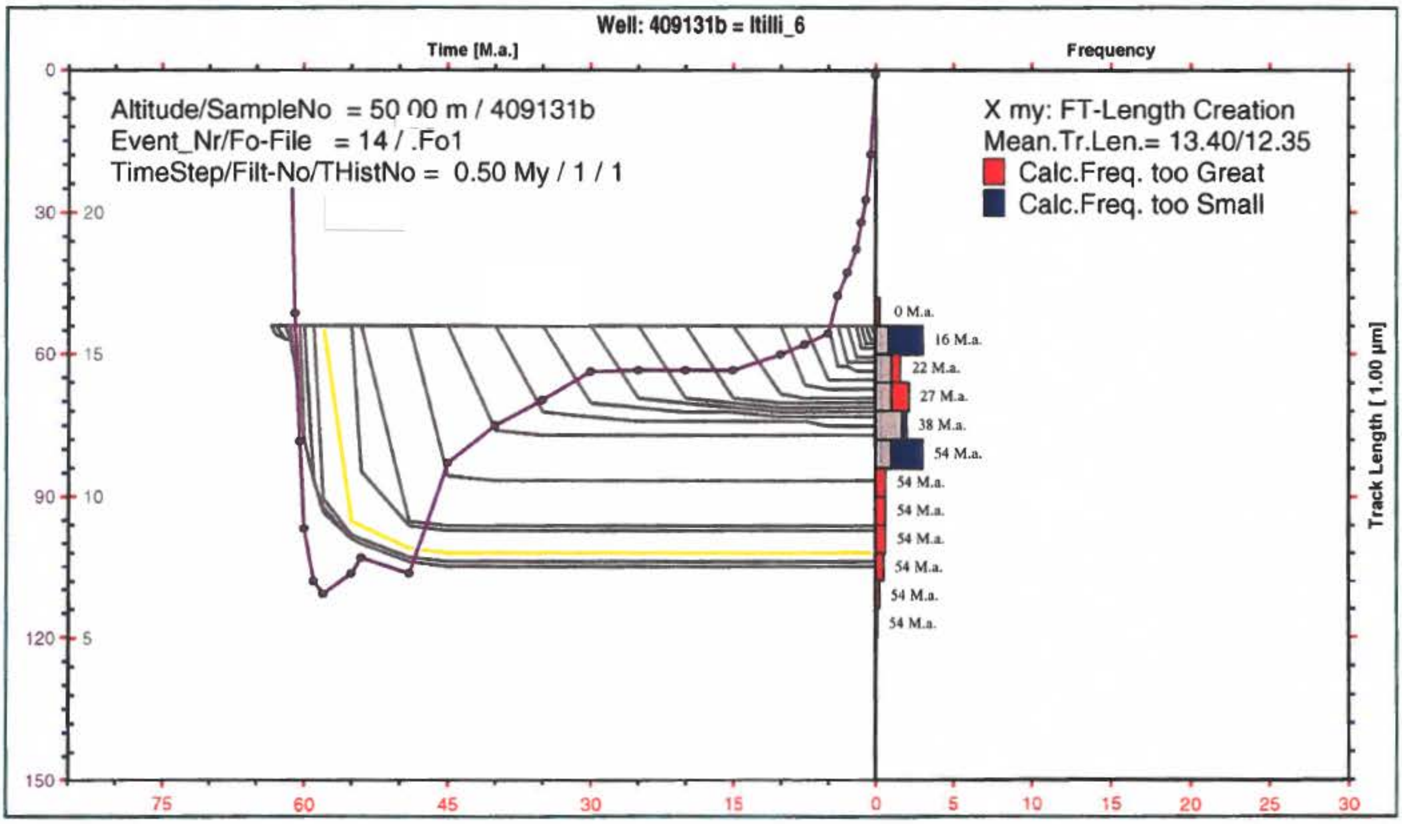
APP. 8b.3 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 409131a; Model Event: 14; ?E Paleocene; FTA: 36 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



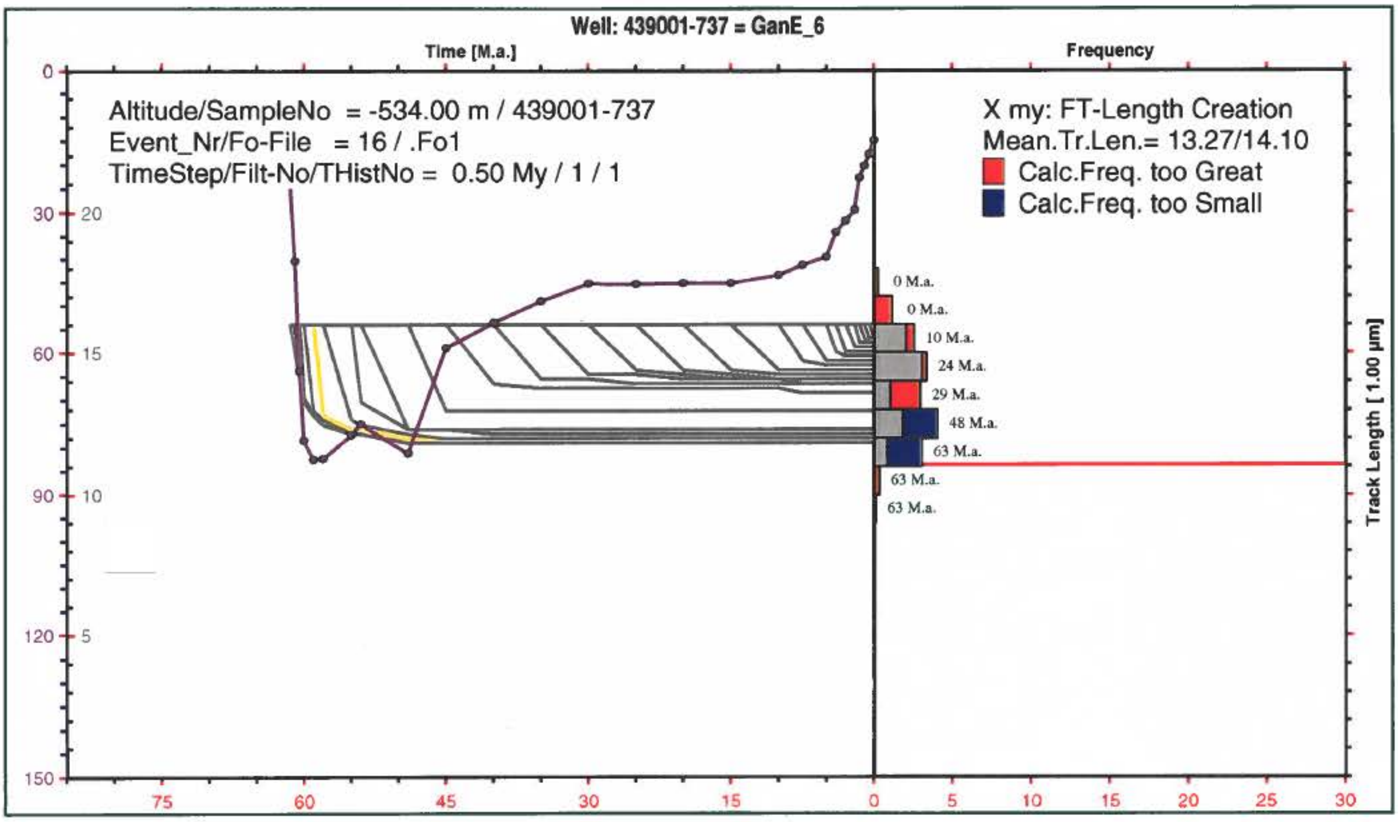
APP. 8b.4 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 409131b Model Event: 14; ?E Paleocene; FTA: 59 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



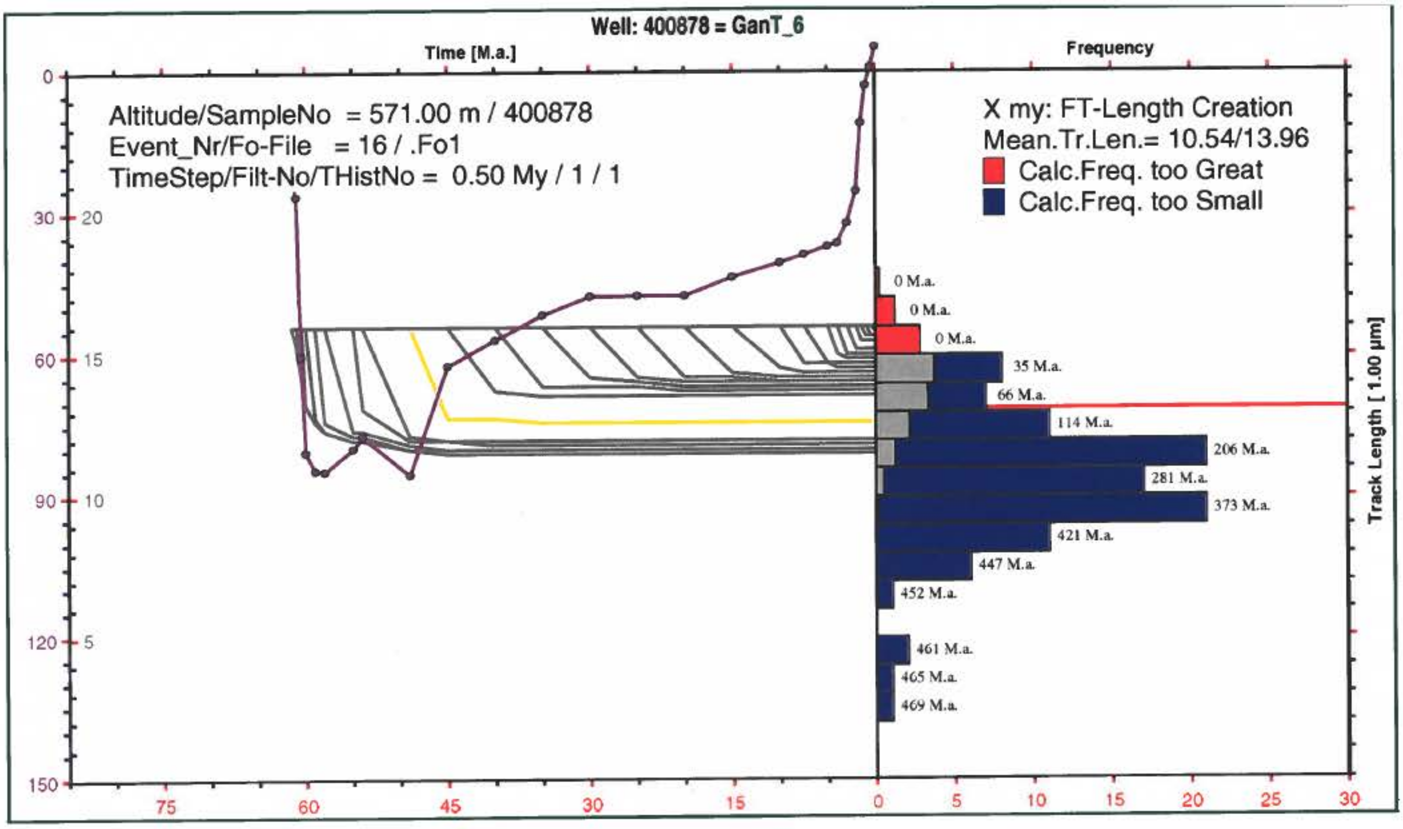
APP. 8b.3 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 409131a; Model Event: 14; ?E Paleocene; FTA: 36 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



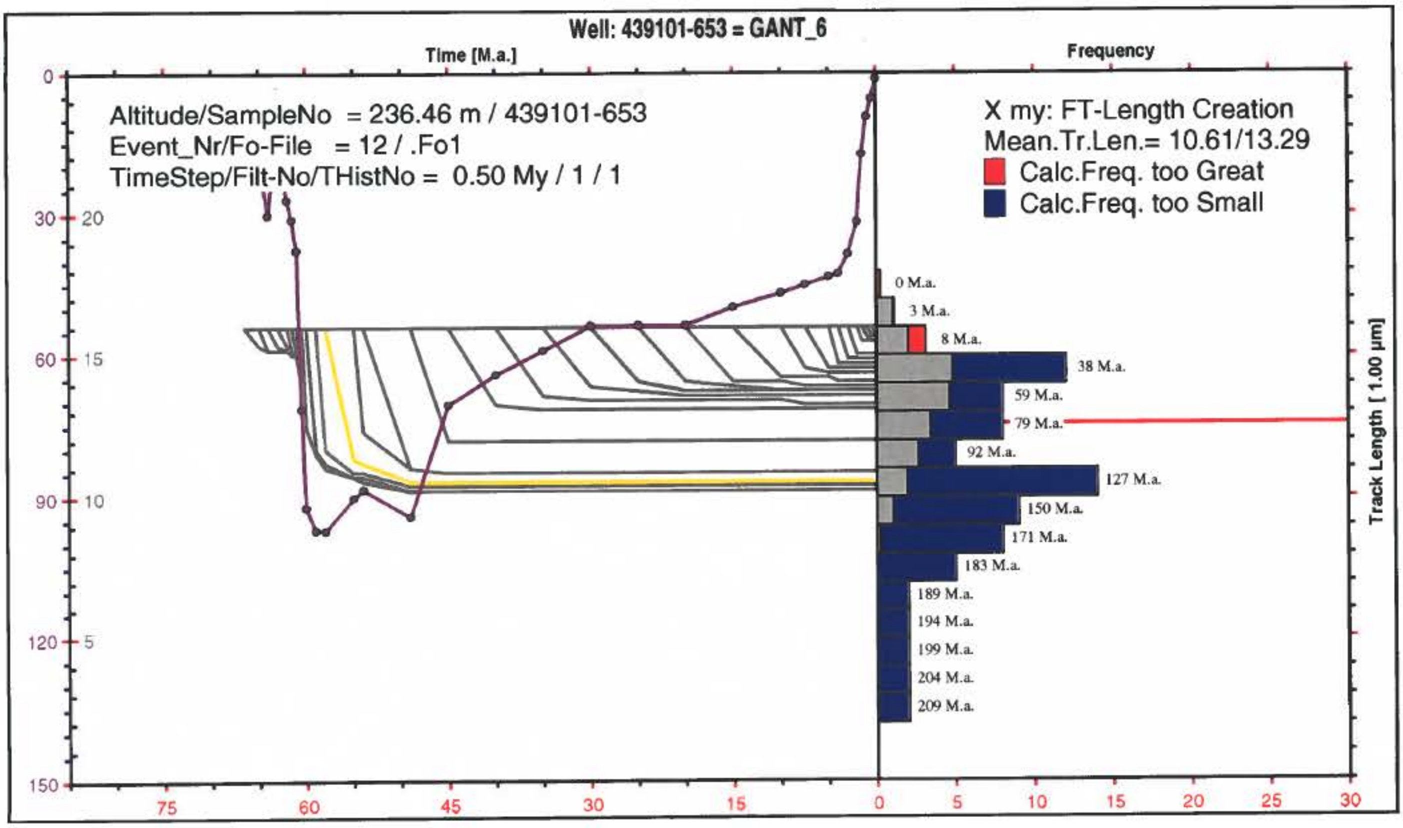
APP. 8b.4 Fission track modelling plot for the Itilli pseudowell, western Nuussuaq. Sample: 409131b Model Event: 14; ?E Paleocene; FTA: 59 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



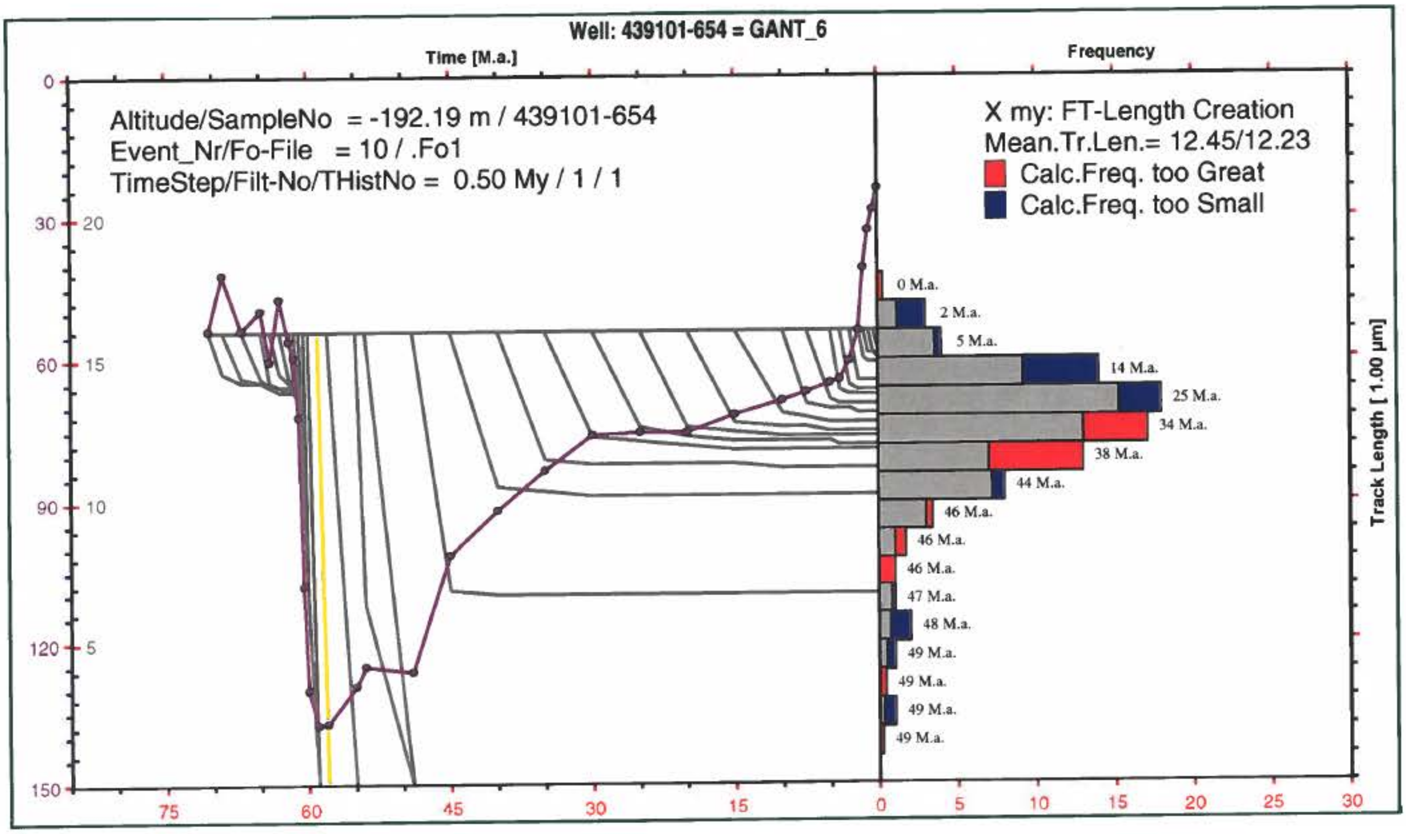
APP. 8b.5 Fission track modelling plot for the GANE#1 well, central Nuussuaq. Sample: 439001-737; Model Event: 16; Selandian; FTA: 61 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



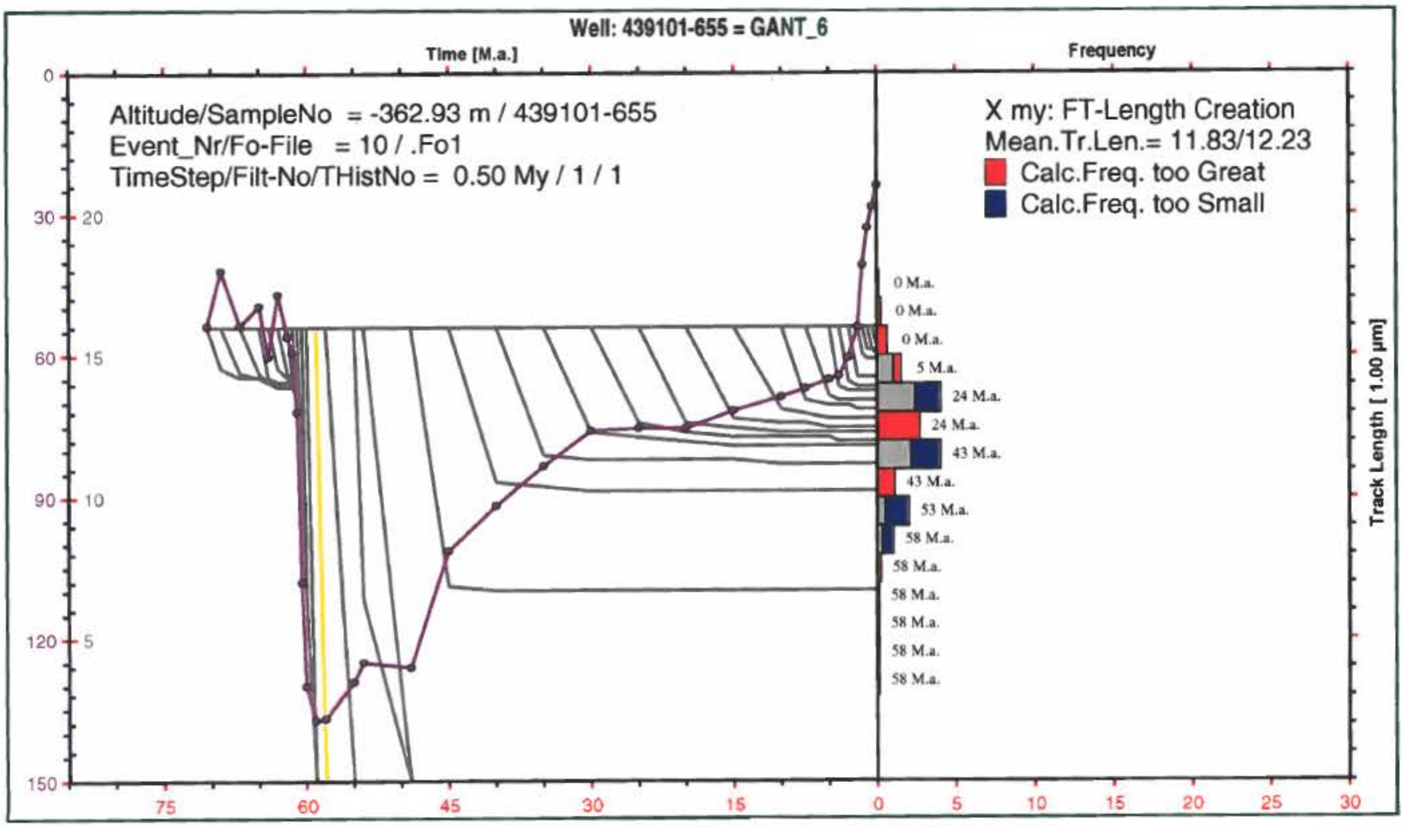
APP. 8b.6 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 400878; Model Event: 16; ? Selandian; FTA: 295 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



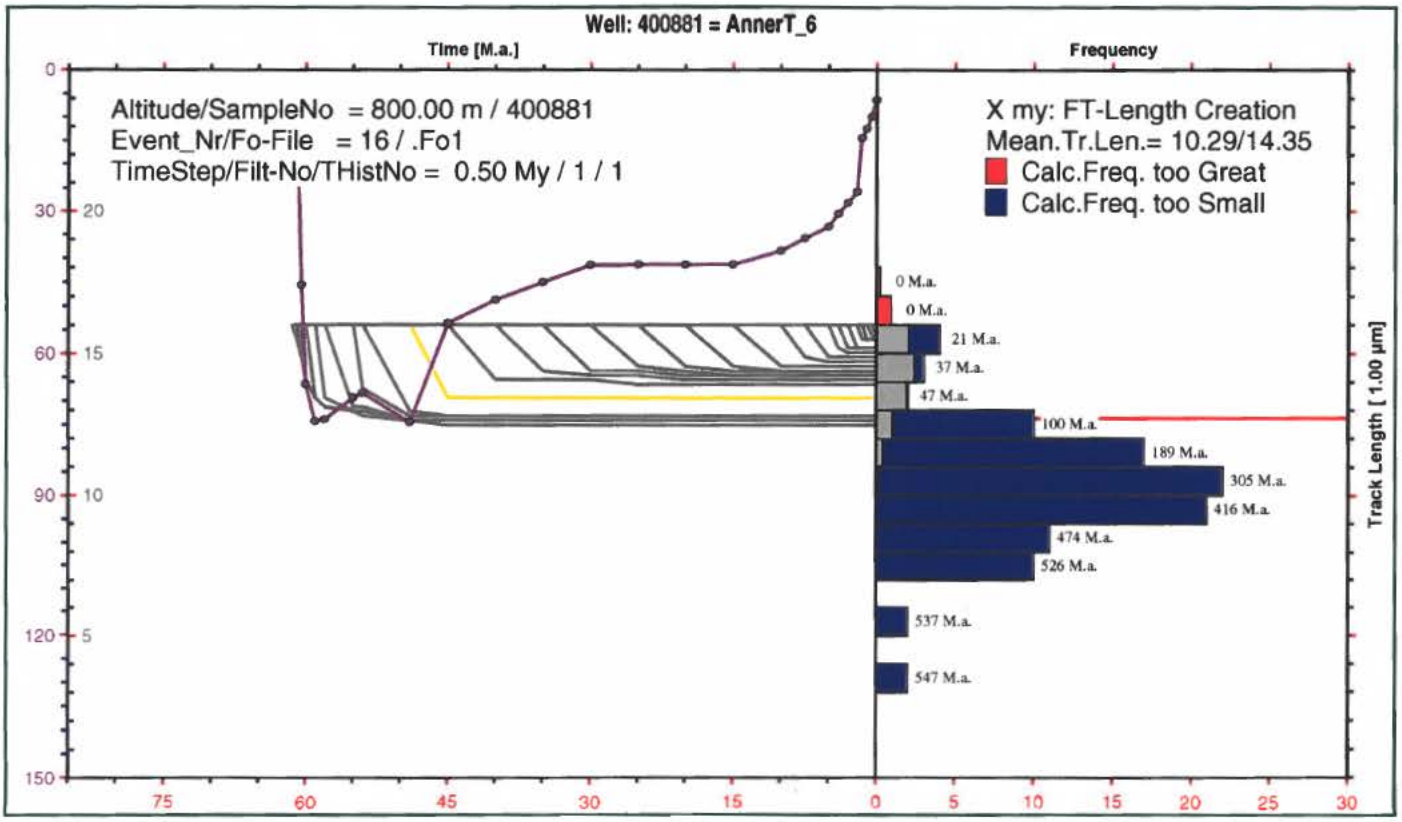
APP. 8b.7 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-653; Model Event: 12; Maastrichtian; FTA: 149 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



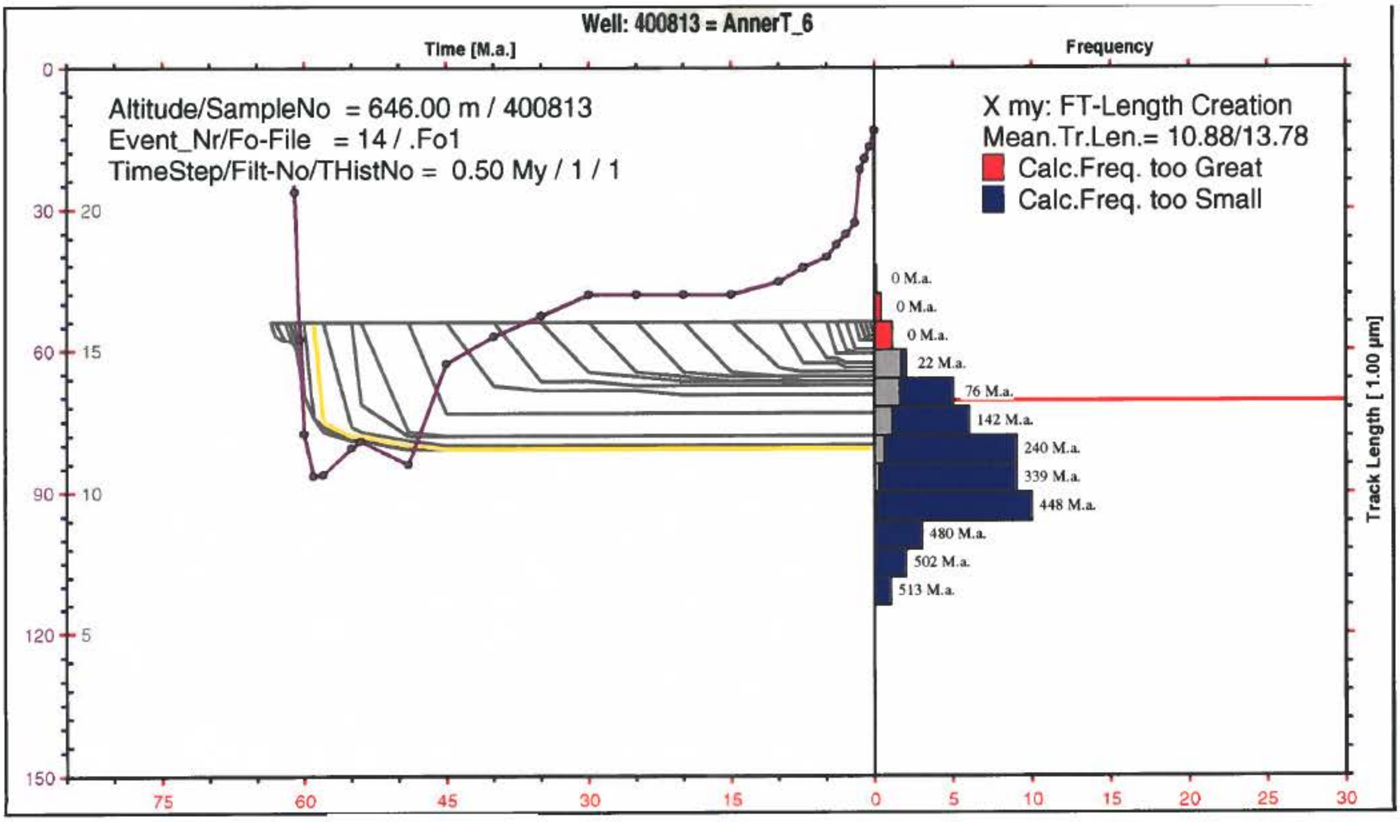
APP. 8b.8 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



APP. 8b.9 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-655; Model Event: 10; m. Campanian; FTA: 57 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.



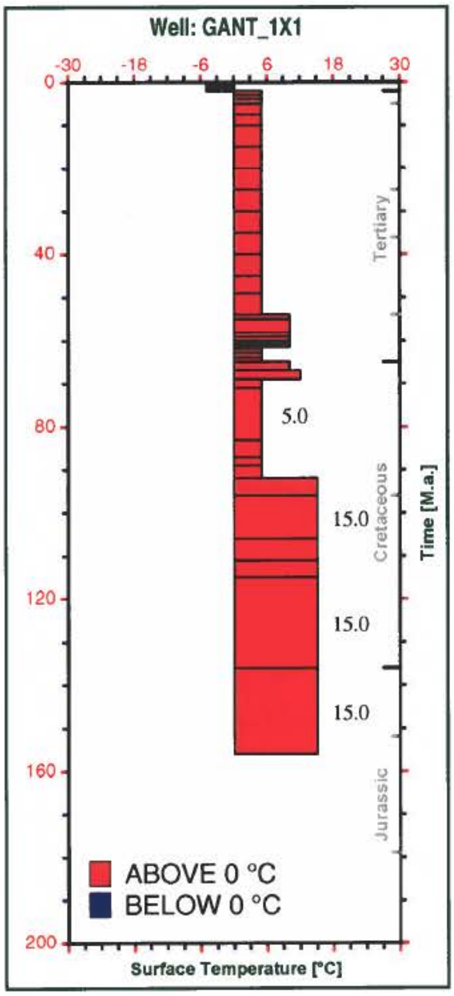
APP. 8b.10 Fission track modelling plot for the Annertuneq pseudowell, northern Nuussuaq. Sample: 400881; Model Event: 16; ? Selandian; FTA: 327 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.

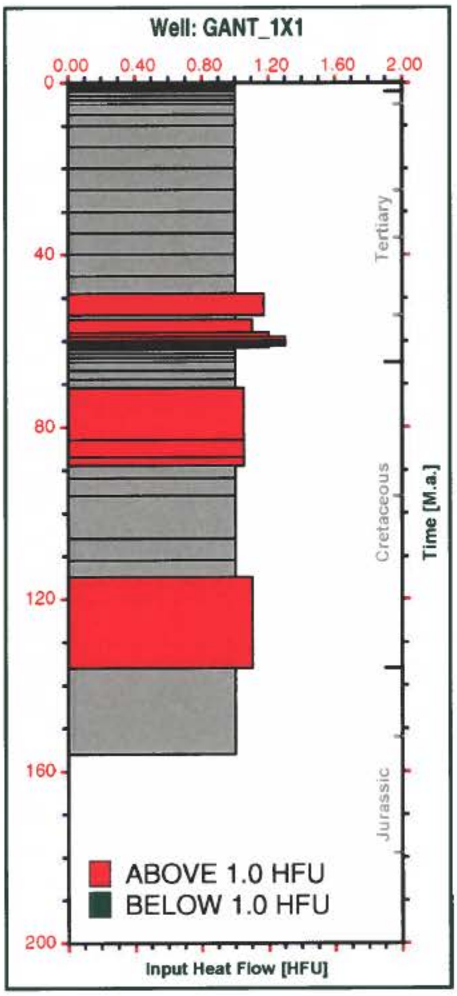


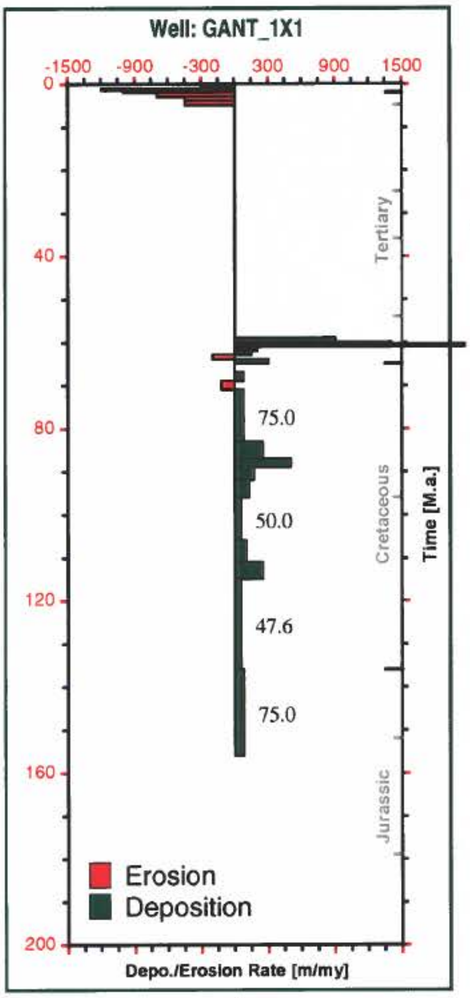
APP. 8b.11 Fission track modelling plot for the Annertuneq pseudowell, northern Nuussuaq. Sample: 400813; Model Event: 14; Late Danian; FTA: 318 Ma. **Left:** Plot showing annealing of fission tracks as a function of time (lower X-axe) and temperature (outer Y-axe). **Right:** Modelled track length distribution histogram superimposed on measured track length distribution. **Model Concept:** Minimum volcanics.

APPENDIX 9

Fission Track Modelling; Post mid-Eocene Erosion





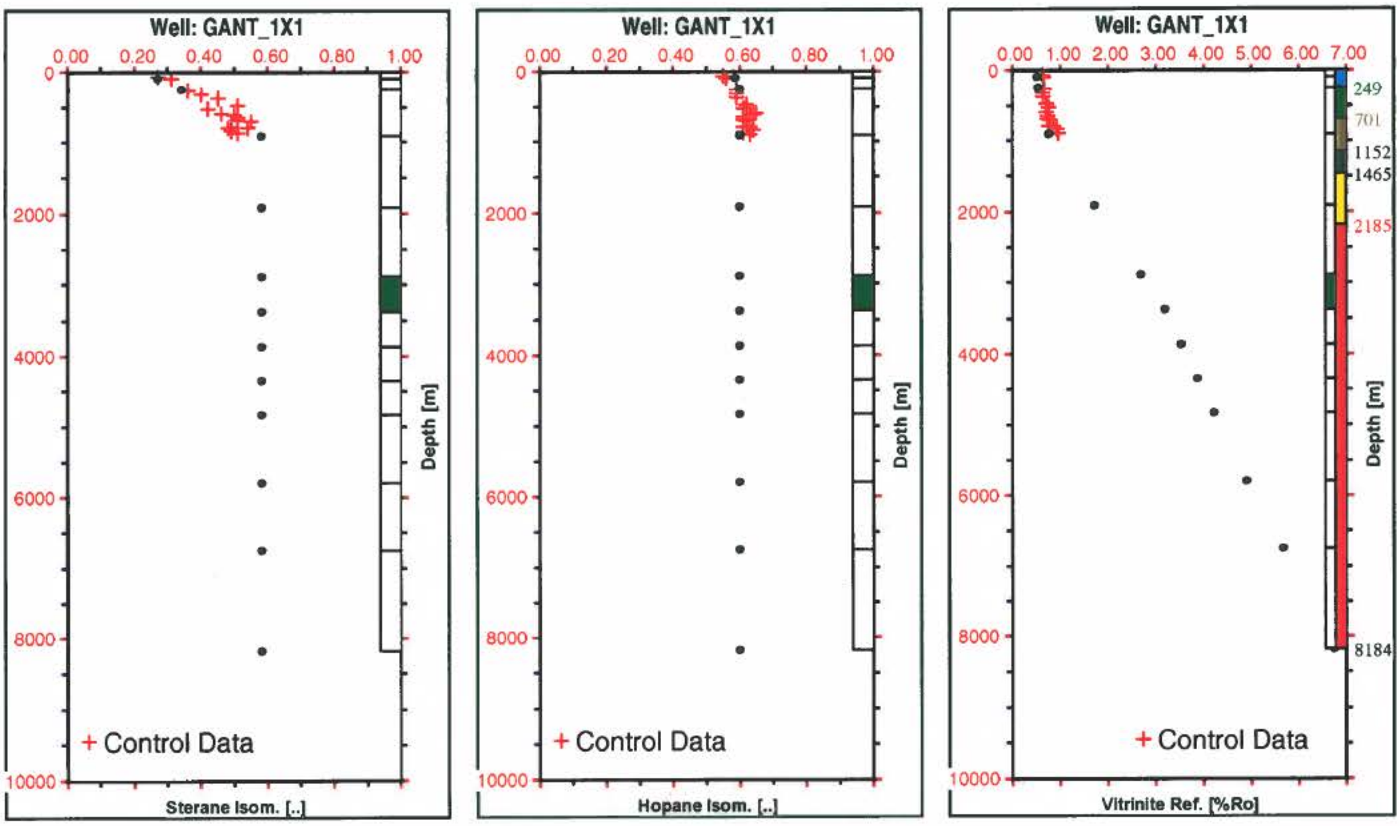


H:\NUUSSUAQ\GANT_1X1.PRN

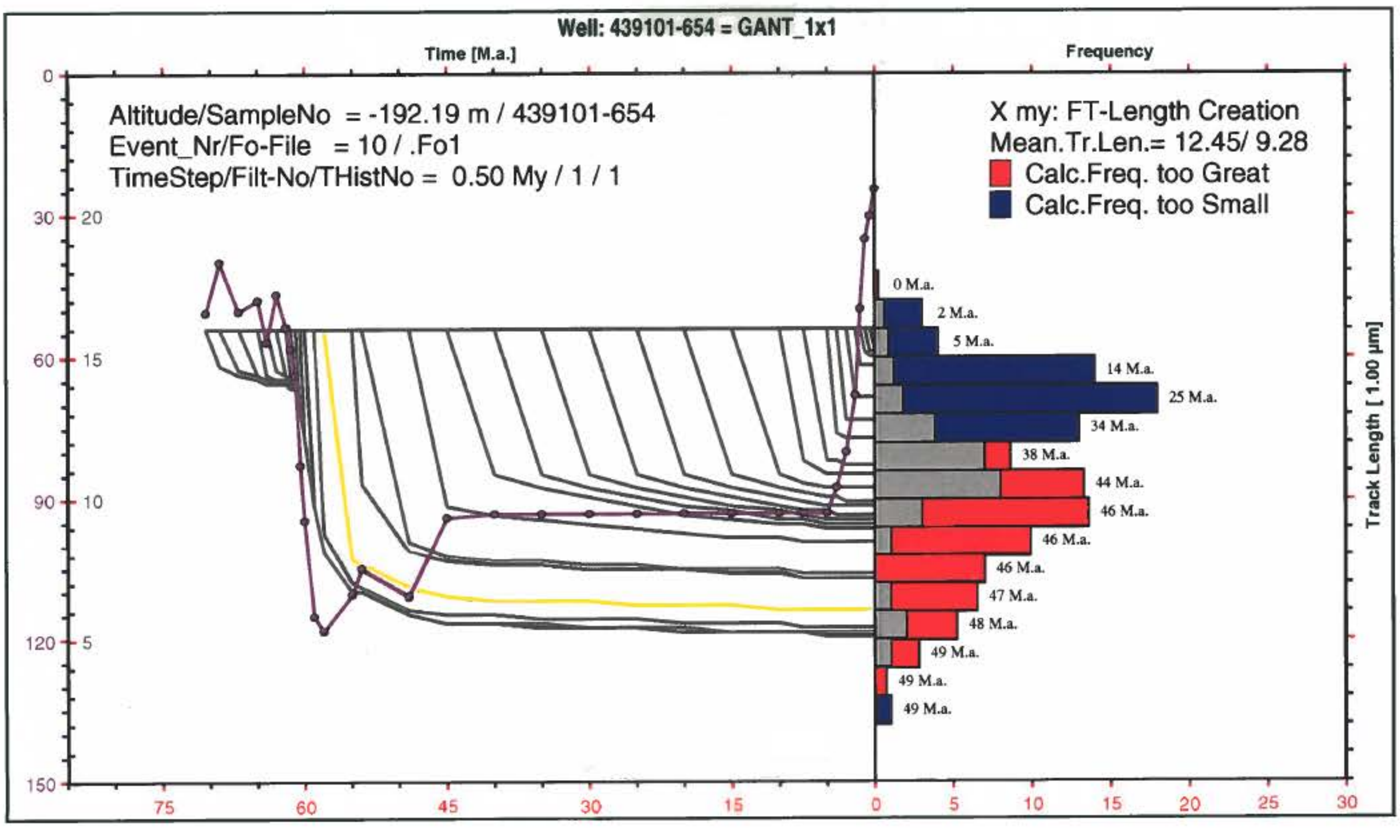
WELLNAME: GANT_1X1. UNITS: Meters/øC .PRN UPDATE: S›ndag 20 Sep 1998 - 10:12:45.80

NB-EVENTS: 42 TIMESTEP: 250000.00 DEPTHSTEP: 25.00

Nb.	NAME	LITHO	DURA	THICK	PORO	WATER	SURFTEMP	H-FLOW	D-RATE	TIME	DEPTH
42	Glacial UPLIFT	1	0.50	-150.00	26.00	0.00	-5.00	1.00	-300.00	0.50	-------
41	Glacial UPLIFT	1	0.50	-100.00	26.00	0.00	-5.00	1.00	-200.00	1.00	-------
40	Glacial UPLIFT	1	0.50	-600.00	26.00	0.00	-5.00	1.00	-1200.00	1.50	-------
39	Glacial UPLIFT	1	0.50	-500.00	26.00	0.00	-5.00	1.00	-1000.00	2.00	-------
38	Neogene UPLIFT	1	1.00	-700.00	25.70	0.00	5.00	1.00	-700.00	3.00	-------
37	Neogene UPLIFT	1	1.00	-450.00	25.70	0.00	5.00	1.00	-450.00	4.00	-------
36	Neogene UPLIFT	1	1.00	-450.00	25.70	0.00	5.00	1.00	-450.00	5.00	-------
35	Neogene UPLIFT	1	2.50	0.00	26.00	0.00	5.00	1.00	0.00	7.50	-------
34	Neogene UPLIFT	1	2.50	0.00	26.00	0.00	5.00	1.00	0.00	10.00	-------
33	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	15.00	-------
32	Neogene UPLIFT	1	5.00	0.00	25.70	0.00	5.00	1.00	0.00	20.00	-------
31	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	25.00	-------
30	UPLIFT /DEPO	52	5.00	0.00	25.70	0.00	5.00	1.00	0.00	30.00	-------
29	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	35.00	-------
28	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	40.00	-------
27	UPLIFT /DEPO	52	5.00	0.00	28.20	0.00	5.00	1.00	0.00	45.00	-------
26	Hareoeen Fm	3	4.00	0.00	28.20	0.00	5.00	1.00	0.00	49.00	-------
25	Volca./Ifsoris	3	5.00	0.00	28.20	0.00	5.00	1.17	0.00	54.00	-------
24	Volca./NON.Dep	52	1.00	0.00	10.30	0.00	10.00	1.00	0.00	55.00	-------
23	Volca./NON.Dep	52	3.00	0.00	10.30	0.00	10.00	1.10	0.00	58.00	-------
22	Volca./NON.Dep	52	1.00	0.00	27.70	0.00	10.00	1.20	0.00	59.00	-------
21	Nuluk / Rinks	52	1.00	900.00	27.70	0.00	10.00	1.30	900.00	60.00	-------
20	Ordlingassoq M	52	0.50	700.00	27.70	250.00	10.00	1.30	1400.00	60.50	-------
19	Nauj nguit Mb	52	0.50	1100.00	12.40	500.00	10.00	1.30	2200.00	61.00	-------
18	Anaanaa Mb	52	0.50	0.00	7.80	500.00	10.00	1.20	0.00	61.50	-------
17	UNIT-D /SS6	10	0.50	100.00	20.40	50.00	5.00	1.00	200.00	62.00	-------
16	UNIT-C /Quikav	10	1.00	150.00	18.20	100.00	5.00	1.00	150.00	63.00	-------
15	2.UC-E.Paleoce	1	1.00	-200.00	20.10	0.00	5.00	1.00	-200.00	64.00	-------
14	Danian-1 SS5	10	1.00	300.00	28.80	150.00	5.00	1.00	300.00	65.00	100.00
13	Maastr-2 SS4	13	2.00	0.00	14.20	20.00	10.00	1.00	0.00	67.00	-------
12	Maastr-1 GC-1	14	2.00	150.00	18.90	150.00	12.00	1.00	75.00	69.00	250.00
11	1.UC-E.Maastri	1	2.00	-250.00	28.00	0.00	5.00	1.00	-125.00	71.00	-------
10	Campanian SS3	18	12.00	900.00	20.60	100.00	5.00	1.05	75.00	83.00	900.00
9	Santonian SS2	18	4.00	1000.00	18.70	150.00	5.00	1.05	250.00	87.00	1900.00
8	Coniacian SS1	18	2.00	1000.00	19.30	175.00	5.00	1.05	500.00	89.00	2900.00
7	Turonian SS1	18	3.00	500.00	17.90	200.00	5.00	1.00	166.67	92.00	3400.00
6	Cenomanian	23	4.00	500.00	13.10	5.00	15.00	1.00	125.00	96.00	3900.00
5	Albian	23	10.00	500.00	13.00	5.00	15.00	1.00	50.00	106.00	4400.00
4	Aptian	23	5.00	500.00	13.20	5.00	15.00	1.00	100.00	111.00	4900.00
3	Barremian	23	4.00	1000.00	12.30	5.00	15.00	1.00	250.00	115.00	5900.00
2	Pre-Barremian	10	21.00	1000.00	16.10	100.00	15.00	1.10	47.62	136.00	6900.00
1	Basement	33	20.00	1500.00	13.80	100.00	15.00	1.00	75.00	156.00	8400.00



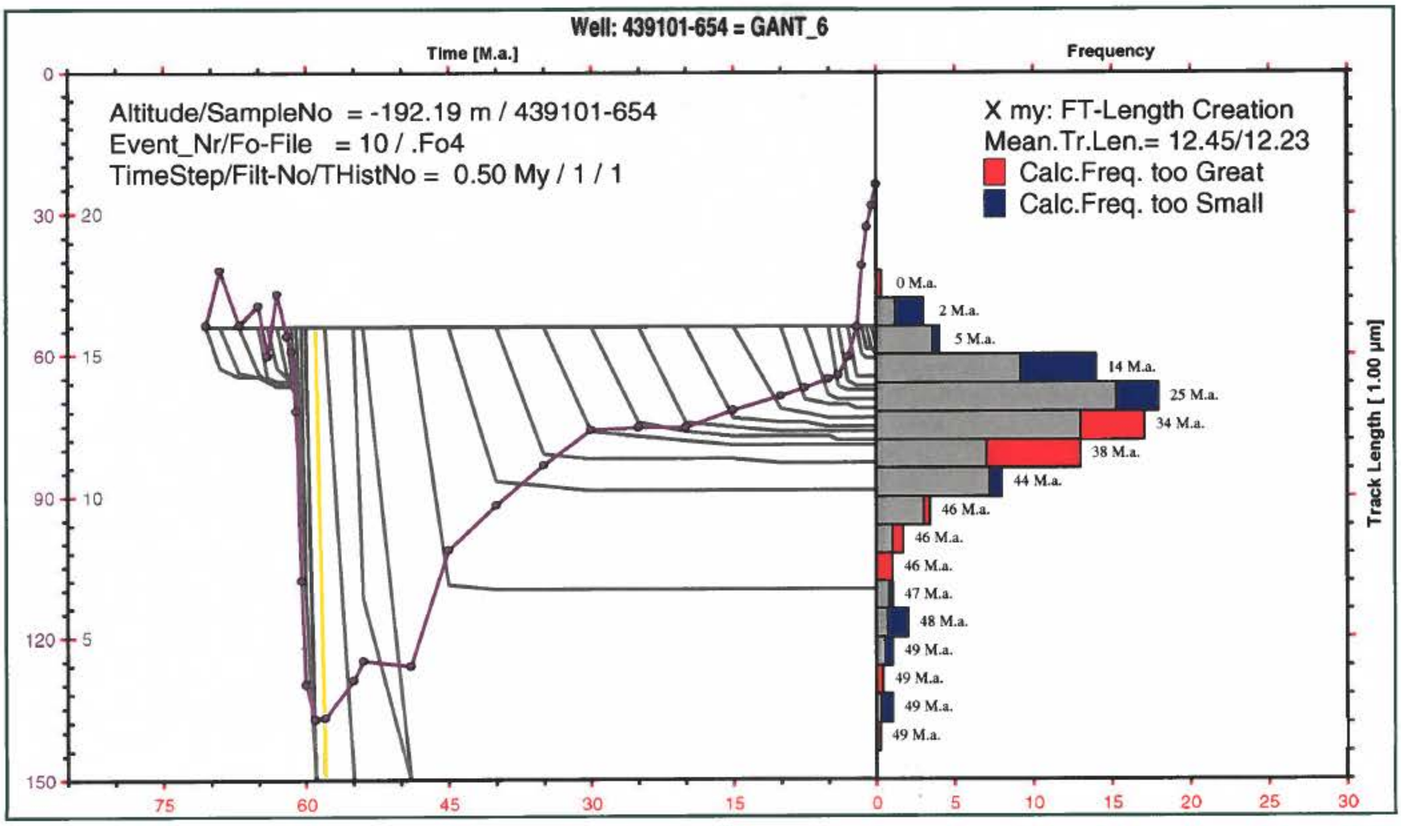
APP. 9.1 Optimisation of the GANT#1 well, northern Nuussuaq. **Model Concept:** Post mid-Eocene erosion.



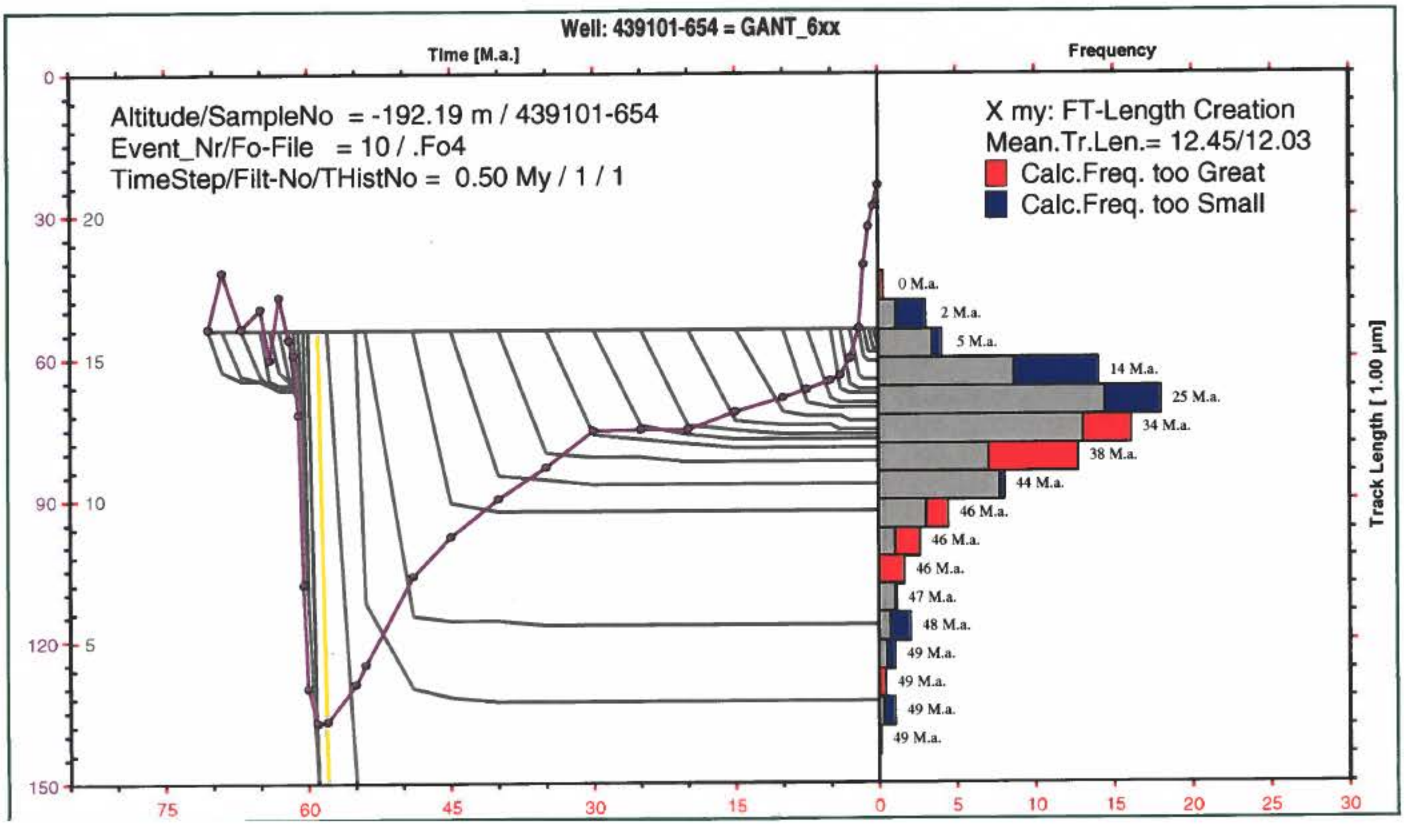
APP. 9.2 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** Post mid-Eocene erosion..

APPENDIX 10

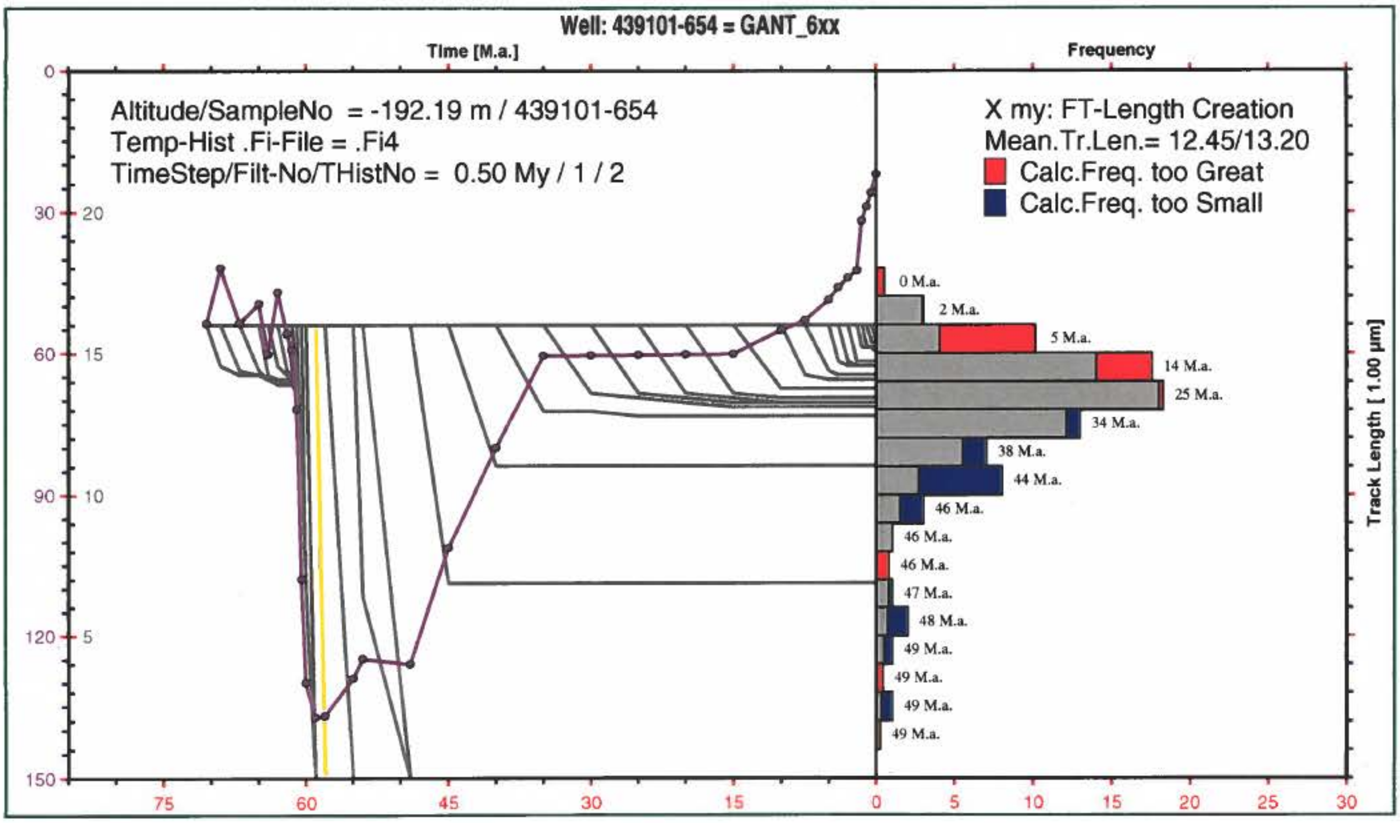
Fission Track Modelling; Cooling History Scenarios



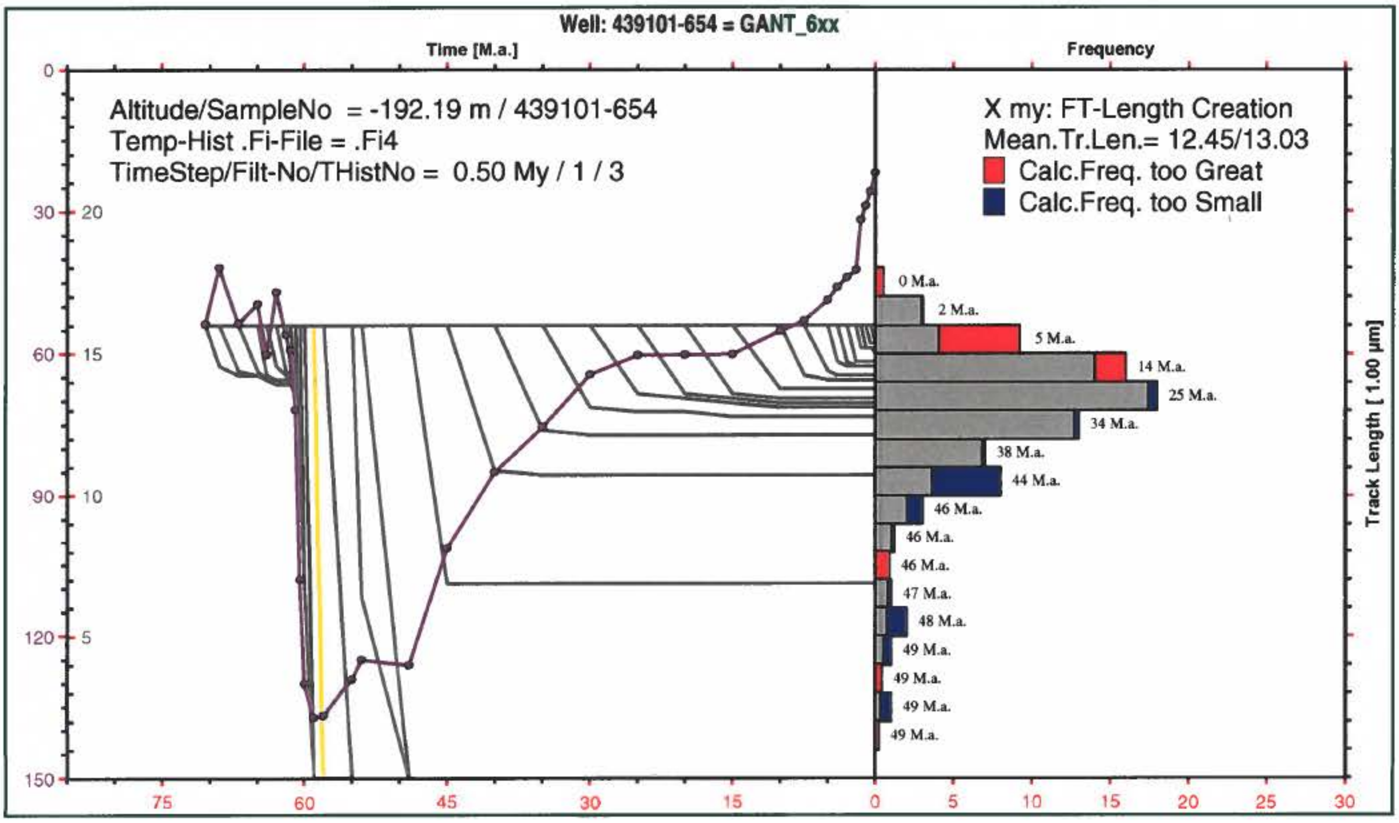
APP. 10a.1 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** Minimum volcanics incl. ±300 m Eocene volcanics.



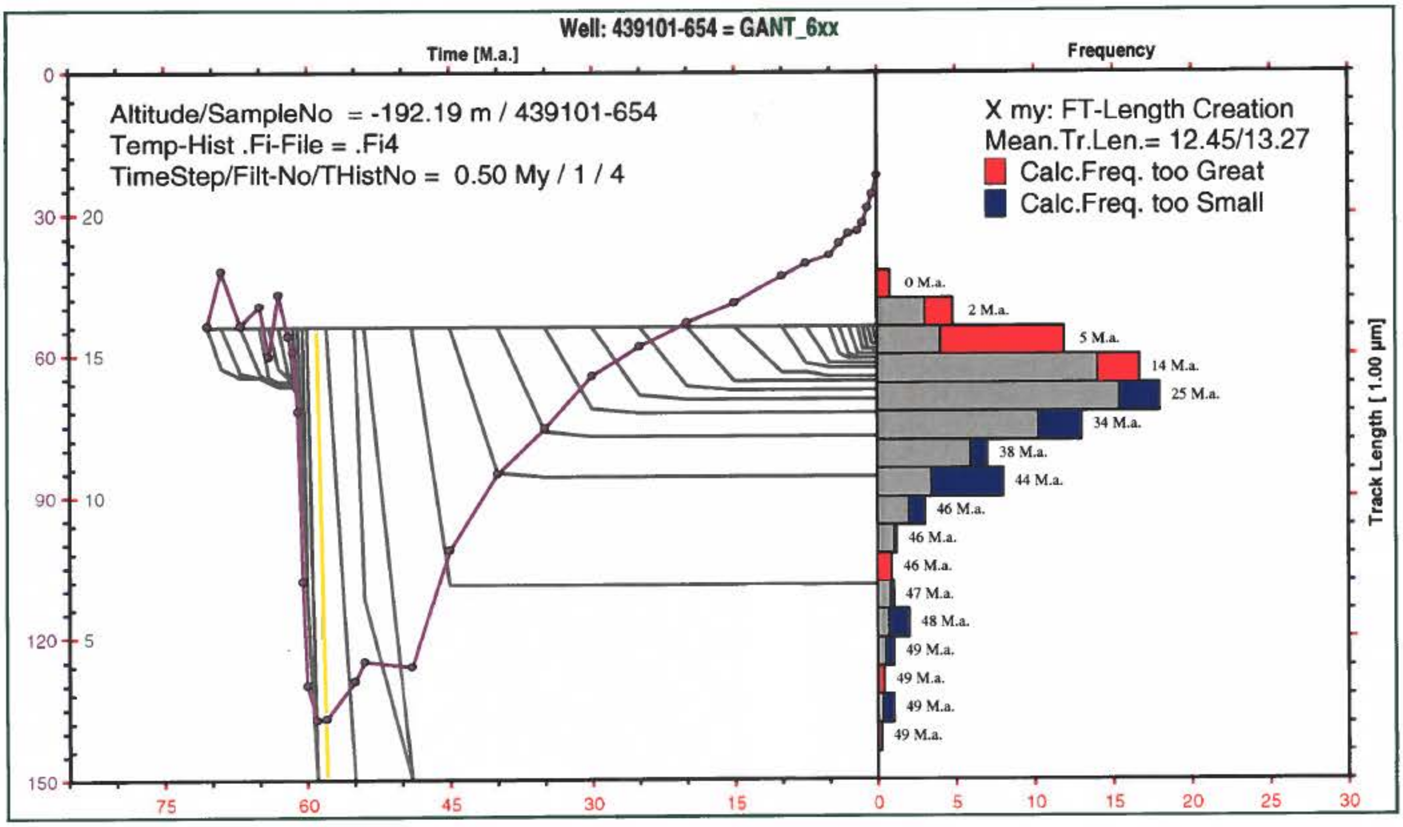
APP. 10a.2 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** 0 m Eocene volcanics.



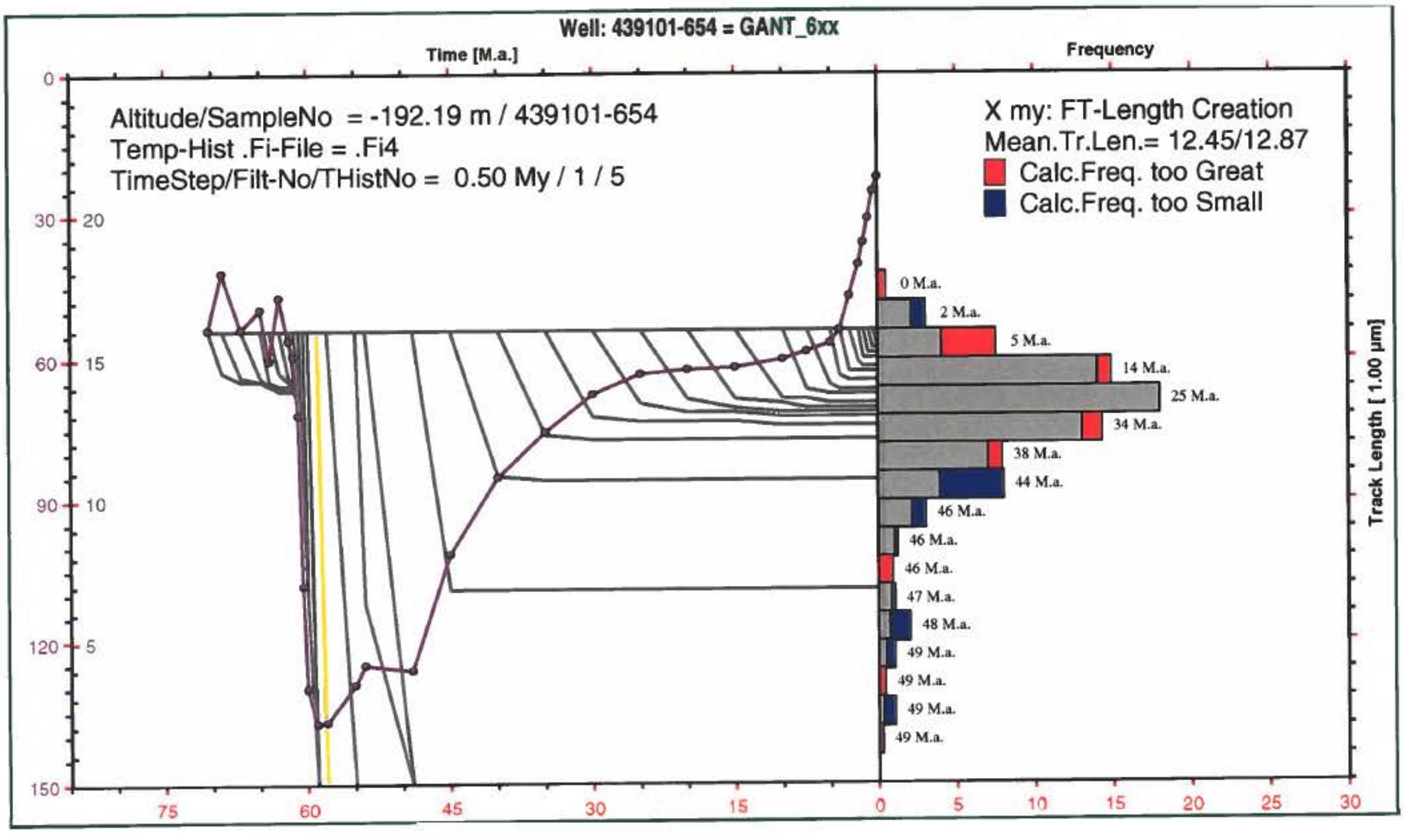
APP. 10a.3 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** ±300 m Eocene volcanics and Oligocene and Miocene peneplanisation.



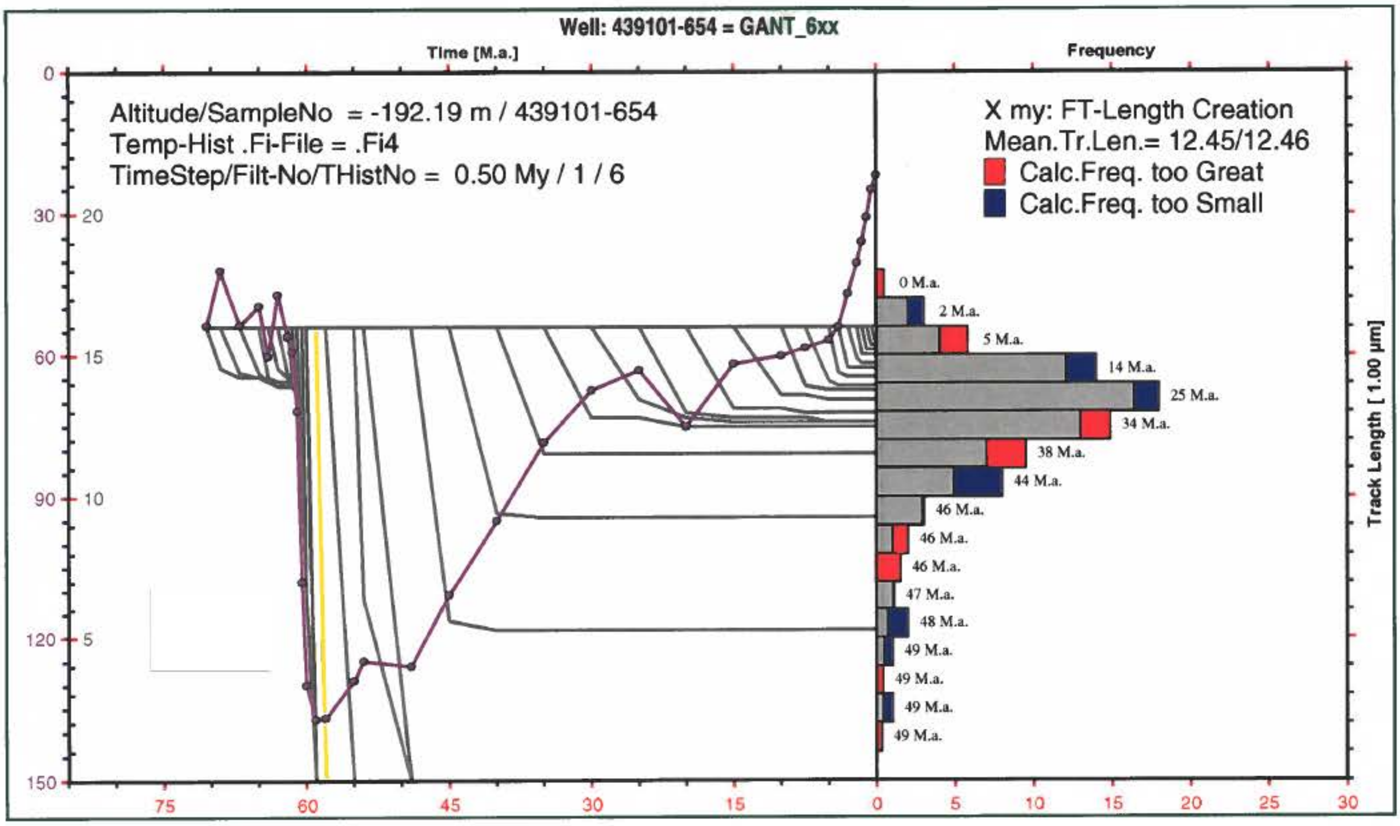
APP. 10a.4 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** ±300 m Eocene volcanics and Miocene peneplanisation.



APP. 10a.5 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** ±300 m Eocene volcanics and decreasing erosion rate from Eocene to Present.



APP. 10a.6 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** ±300 m Eocene volcanics and optimal cooling history.



APP. 10a.7 Fission track modelling plot for the GANT#1 well, northern Nuussuaq. Sample: 439101-654; Model Event: 10; m. Campanian; FTA: 45 Ma. **Model Concept:** ±300 m Eocene volcanics and Early Miocene deposition.

APPENDIX 11

Boserup,J and Christiansen,F.G.: (1998):

LECO and Rock Eval data from the Nuussuaq Basin,

onshore West Greenland.

Danmarks og Grønlands Geologiske Undersøgelse Rapport

1998/89

https://doi.org/10.22008/gpub/15375