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Report file no.

13993

# KANGAMIUT-1

# Interpretation of the basal section of well Kangamiut-1, offshore southern West Greenland

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GEUS

Copenhagen

07-07-1997

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/76

# Interpretation of the basal section of well Kangâmiut - 1, offshore southern West Greenland

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# Abstract

The well Kangâmiut-1 is the only well that was drilled offshore West Greenland during the 1970s that has intersected a possible reservoir below a seal and in which the presence of hydrocarbons has been recorded. Measures to control overpressured formations may have lead to the excessive invasion of the reservoir by drilling fluids which may be all that was recovered during a Drill Stem Test. There are different interpretations of the reservoir section of the well which have important implications as to the prospectivity of both the Kangâmiut Ridge and the West Greenland Basin. The interpretation presented here suggests that the reservoir section consists of a syn-tectonic fan, comprising boulder size clasts of altered and kaolinitic basement which experienced probable minimal transport, deposited on the western flank of the Kangâmiut Ridge. This interpretation along with a re-evaluation of the drilling and testing results suggests that the prospectivity of the Kangâmiut Ridge was not successfully evaluated by the well.

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# Introduction

The period 1970 to 1978 saw an active search for hydrocarbons on the continental shelf of southern West Greenland. Between 1970 and 1975 the shelf between 62°N and 70°N was surveyed by a regional grid of multichannel seismic data, and more detailed surveys were performed following the awarding of concessions in 1975. The Kangâmiut-1 well (Manderscheid, 1980) is one of five wells drilled offshore southern West Greenland in the period 1976 to 1977, all of which were dry (Chalmers & Pulvertaft, 1993). The Kangâmiut-1 well was the only well of the five in which a possible reservoir was encountered below a seal (Chalmers & Pulvertaft, 1993). However there are different interpretations of this section and of the results of a Drill Stem Test performed in it. These interpretations have important consequences for the prospectivity of the entire offshore southern West Greenland Basin.

The Kangâmiut-1 well was drilled in 1976 at 66° 09′ 01" N, 56° 11′ 24" W, 145 km SSW of Sisimiut (Fig. 1) in a water depth of 179 m. Drilling was carried out by the dynamically positioned drill ship *Pelican*. The operator of the licence was Total Grønland Olie A/S (Total) and other participants in the licence were Gulf Oil Canada-Greenland A/S (Gulf Oil Company), Elf Aquitaine Denmark A/S and Greenland Petroleum Consortium (-Grepco). The well was drilled to test possible Lower Tertiary sandstones within closure on the western flank of the Kangâmiut Ridge. The well was drilled to a total depth of 3874 mbkb (meters below kelly bushing) and was abandoned as a dry well. The lithostratigraphy of the sediments intersected in this and other wells drilled in the region in 1976-77 has been summarised by Rolle (1985).

A summary of several different interpretations of the basal section of the Kangâmiut-1 well and a new interpretation based on the drilling results, petrophysical logs and samples acquired in the well is presented. All depths quoted refer to depths in metres below kelly bushing unless otherwise stated.

# Previous interpretations

A number of different interpretations of the basal 182 m of the Kangâmiut-1 well have been presented in the literature (Manderscheid 1980; Rolle 1985) (Fig. 2) and in reports from the operator, partners and contractors which are now open-file. Some of these interpretations were summarised by Chalmers (1992).

## Geoservices

The initial wellsite interpretation of the lithology intersected during drilling of the well was made by the contract mudlogging company, Geoservices (Fig. 3). They interpreted the lithology to a depth of 3674 m as consisting of light-brown, soft claystone becoming darker with increasing depth. Throughout this section traces of dead oil were seen in the cutting samples (on examination in the ultra-violet light cabinet).

At a depth of 3674 m a medium to coarse-grained sandstone was intersected with an associated increase in drilling rate (drilling break). This sandstone bed was interpreted to be 5 m thick. The section from 3679 m to 3777 m was interpreted to consist of poorly-sorted, angular, feldspathic sandstone with abundant potassic feldspars and chlorite interbedded with dark pyritic mudstone. The drilling rate curve is highly variable over this interval reflecting the different interbedded lithologies. In the depth interval 3777 m to 3803 m Geoservices recorded a very hard, light-green, quartz-feldspathic rock with black ferro-magnesian minerals and veins of calcite and quartz.

Between 3803 m and 3848 m Geoservices (1976) recorded a feldspathic quartzite with intercalations of white soft clay and sand, which they interpreted as possibly heavily altered basement. The drilling rate over this interval was again highly variable. Basement was interpreted to be intersected at a depth of 3848 m where it consists of a dark-green, fine-grained rock with metamorphic lineations. Geoservices interpreted this to represent an amphibolite. The well was terminated in this rock type at a depth of 3874 m.

## Reports from Total Grønland Olie A/S

After completion of drilling, Sommer (1976; *In*: Chalmers, 1992) produced a preliminary interpretation based on the petrological and petrophysical characteristics of the rock types intersected in the well (Fig. 2). He interpreted the section from 3673 m to 3682 m as very coarse, monogenetic conglomerate with clasts of gneissic basement interlayered with black organic marine shales. This overlies pyritic and organic-rich mudstone between 3682 m to 3692 m. The interval 3692 m to 3840 m was interpreted by Sommer (1976) as heavily kaolonitised gneissose basement. A chloritised metadolerite dyke is interpreted to be present between 3840 m to 3874 m.

However, Bousquet *et al.*, (1977) reported on the biostratigraphy and petrology of the rocks intersected in the well based on a microscopic and X-ray diffraction study of cuttings, sidewall cores and conventional cores, which changed the Sommer (1976) interpretation to a small degree. Bousquet *et al.* (1977) stated that the interval 3692 m to 3704 m consists of very altered basement or a basement wash. Weathered gneissic basement was interpreted to be present below this over the interval 3704 m to 3845 m. Below this an an amphibolite dyke is present between 3845 m to 3874 m.

In a seperate study for Total Grønland Olie A/S, Sørensen (1977) interpreted the section fom 3674 m to 3700 m as kaolinitic clay or kaolinitic gneiss containing fragments of fresh gneiss and dyke, along with fragments of sedimentary rock. Sørensen (1977) attributed the presence of these sedimentary fragments to the *forcing* (my italics) of the fragments into the samples during drilling/sampling. From 3700 m to 3849 m a kaolinitic quartzo-feldspathic rock is present which Sørensen (1977) suggested is a correlative of the tonalitic, orthopyroxene-bearing gneiss exposed onshore West Greenland. The chloritised metadolerite dyke in the interval 3849 m to 3874 m, is suggested to be comparable to the onshore Kangâmiut dykes.

The interpretation presented by Total was summarised by Manderscheid (1980, fig. 2). This states that the interval 3668 m to 3700 m consists of a very coarse grained conglomerate with clasts of gneissic basement, metadolerite and black organic shale. This lies on kaolinitic quartzo-feldspathic gneiss over the interval 3700 m to 3849 m, which has been intruded by a chloritised metadolerite dyke between 3849 m and 3874 m (TD).

## Report from Gulf Oil

An anonymous geologist employed by Gulf Oil (Gulf Oil Company, 1977; *In*: Chalmers, 1992), interpreted the basal section to consist of a succession of arkosic sandstones and conglomerates with interbeds of clay over the interval 3674 m to 3846 m (Fig. 2). This interpretation was based on the variable response of both the gamma ray and sonic logs and the highly variable penetration rate. A good correlation was made between "quartz rich sands" and drilling breaks and porous zones as indicated by the sonic log. This interpretation is similar to that produced by Geoservices (1976).

The Gulf Oil Company (1977) report interpreted the section from 3674 m to 3727 m to consist of coarse to medium grained feldspathic sandstones with occasional claystone interbeds. The sands from this interval are predominantly quartz with abundant euhedral quartz overgrowths and white secondary clays suggesting a porous open framework. No samples are available from 3702 m to 3711 m due to the irregular circulation of drilling mud to stabilise the hole following the recording of the uncontrolled influx of formation fluids.

The interval from 3727.5 m to 3790 m is interpreted as predominantly a tight, coarse, conglomeratic arkose rich in fragments of gneiss. Sandy clays occur in a zone from 3760 m to 3765 m. Drilling breaks were recorded upon intersection of a series of thick, quartz-rich, feldspathic sandstones between 3790 m and 3837 m. Two quartz-rich sandstones at 3825 m to 3830 m and 3832 m to 3837 m are seperated by a tight, coarse grained, igneous conglomerate. The sonic log suggests that these quartz rich beds are porous and the drilling rate log shows drilling breaks that correspond exactly to these porous zones. An increase in methane to a peak of 4.8% gas recorded on the gas chromatograph, occurs within the lower porous zone. A gneissic igneous conglomerate occurs over the depths 3837 m to 3846 m, with the top of basement intepreted at a depth of 3846 m and continuing to total depth at 3784 m.

Gulf Oil Company (1977) suggested that the high percentage of quartz (90%) could not arise solely from the alteration of gneiss. Numerous quartz grains with euhedral pyramidal overgrowths were identified, which probably developed in a porous, open framework allowing overgrowths to grow freely. The form of quartz crystals in altered gneiss would not be of this type. Another similar quartz-rich zone occurs between 3810 m and 3817 m where the sonic log indicates some porosity (Fig. 4).

The thin sections made from sidewall cores show a wide degree of alteration with no set pattern with depth. This variability was interpreted as indicating a tectonic wedge in which weathered besement materials had been stripped off at various stages of decomposition and redeposited. Gulf Oil Company (1977) interpreted an arkosic sand wedge thickness of 172 m, with a total sand thickness of 97 m. The total porous section with porosity greater than 10% was estimated to be 53 m. Gulf Oil Company (1977) judged these sands to have prospective potential which was not fully evaluated by the well.

## Rolle (1985)

Rolle (1985) interpreted claystones between 2625 m and 3674 m, which he referred to as the Ikermiut Formation. In well Ikermiut-1, which is the type section, the Ikermiut Formation (1534 m to 3619 m) is Campanian to Middle Eocene in age, whereas in Kangâmiut-1 this same formation is Paleocene in age (Croxton, 1981).

Coarse grained, kaolinitic arkosic sandstones consisting of fragments of granite, interbedded with bluish black to dark grey carbonaceous shale were interpreted over the section from 3674 m to 3700 m (Fig. 2), containing a Campanian dinoflagellate assemblage. Rolle (1985) termed this unit the Narssarmiut Formation and suggested that it could be a clastic wedge within the Ikermiut Formation and that it could be analagous to the Freydis Member of the Labrador shelf which McWhae *et al.* (1980) suggested is a proximal clastic wedge within the Upper Cretaceous Markland Formation. Downdip of the Kangâmiut Ridge the lower part of the Ikermiut Formation may be represented by Upper Cretaceous mudstones. The base of the Narssamiut Formation was placed at a depth of 3700 m on the basis of the petrophysical logs, below which kaolinised basement was interpreted. This is intruded by a chloritised metadolerite dyke between the 3849 m and total depth at 3874 m.

# Interpretation techniques

Analysis of the subsurface facies intersected in well Kangâmiut-1 has been made by the integration of numerous data types. The following petrophysical logs were used: Gamma Ray (GR), Spontaneous Potential (SP), Microspherically Focused (RMSFL) and Shallow (RLLS) and Deep Resisitvity (RLLD), Compensated Formation Density (FDC), Compensated Neutron Log (CNL), Sonic and the Dipmeter (HDT). All were acquired by Schlumberger Logging Services. Geological logs used include the mud log (Geoservices, 1976) and the composite log produced by Bousquet *et al.*, (1977). Formerly internal reports of the various companies, which are now open file at GEUS, were used including the Well History Report (Manderscheid & Quin 1977), a memorandum on drilling problems (Dubroca, 1977), Biostratigraphy and Petrology Report (Bousquet *et al.*, 1977), Sommer (1976 *In*: Chalmers, 1992), Sørensen (1977) and an anonymous internal report from Gulf Oil Company (1977; *In*: Chalmers, 1992).

The techniques of subsurface facies analysis involve an integration of seismic data, all available well data such as petrophysical logs, cuttings and (when available) cores (Selley, 1976). The gamma ray, resistivity, density and sonic logs were compiled as digital files and a hardcopy plot produced which was used as a working copy for interpretation. Lithological interpretation was added based on cuttings collected during the drilling of the well and any surviving sidewall and conventional cores. Once the lithology was established, the logs were examined for characteristics which may or may not have geological significance, such as the identification of baselines, trends, abrupt breaks and log shapes. Having established the lithology and the electrofacies, further environmental data was added such as dipmeter and biostratigraphic information. The intent was finally to reconstruct the depositional environments and mechanism of formation of rock units based upon inferences from the available data. This work was carried out at the same time as a re-interpretation of the palynology of the well by Nøhr-Hansen (pers. comm).

The gamma ray log provides information concerning formation radioactivity (Rider, 1986). This is largely due to the uranium, thorium and potassium content of clay minerals. Since clay content normally increases with decreasing grain size, the gamma ray log generally indicates vertical grain size changes. However, the gamma ray log may react to any other radioactive grains within a rock. The density log is a continuous record of the formation bulk density, which is a function of the density of the minerals forming the rock matrix and the volume of free fluids which it encloses. Therefore by implication the method is an indication of the porosity of a rock type. The sonic log measures the interval transit time of sound through a rock and is dependent upon lithology and rock texture. Thus, the sonic log is a further porosity measuring tool. The resisitivity log measures the resistance to the passage of an electric current through a formation. Conductivity logs measure a formations conductivity but this is generally converted directly to resistivity. Most rock materials are essentially insulators while the enclosed fluids are conductors, the exception being hydrocarbons which are infinitely resistive. This makes the principal use of the resistivity measurement the identification of hydrocarbons, but it can contribute information on lithology. Of greatest value in lithology and environmental interpretation are however the gamma, density and sonic logs.

The most direct evidence for the subsurface geology is provided by cores and sidewall cores recovered from the well. A sidewall core is obtained by lowering a sidewall 'gun' into the hole on the end of the logging cable; it consists of a series of hollow cylindrical 'bullets' 1.8 cm in diameter and 2.0 - 3.0 cm long. The tool is lowered to total depth and depth-calibrated using a gamma ray tool, and it is then pulled up the hole. The sampling points are decided in advance and are based on the inspection of logs already run in the hole. The tool is stopped exactly at the depth chosen and a 'bullet' is fired explosively into the sidewall (Rider, 1986). A small core of rock is then retrieved from this bullet, from which thin sections can then be made. Because of the sampling method the recovered core is often shattered.

The degree to which sidewall cores are representative of the lithology as a whole is debatable, especially since the cores are fired into the sidewall rather than mechanically cored into it. This technique can verify the petrology of the rock sampled directly by the sidewall core bullet, but if that core was taken from a large clast within a formation comprised of large cobbles or boulders, the results may give a false impression of the gross composition of the formation. Where such a situation is suspected the sidewall cores must be interpreted in association with other subsurface formation evaluation indicators such as drill cuttings and petrophysical logs.

The engineering parameters recorded at the wellsite (Geoservices, 1976) also provided valuable information relating to the drilling of the well (Fig. 3). The rate of penetration log is a particularly useful lithology indicator, with drilling breaks (increase in drilling rate) generally suggesting the intersection of sandstone beds. The mud log also records gas levels in the well and the presence or absence of hydrocarbon shows.

# Summary of operations during the drilling of the basal section of the well

A summary of drilling operations is of assistance in the understanding of the geology of the basal section of the well, from which the new interpretation presented in this paper was developed. The relevant interval was reported in a number of sections based on the lithological and drilling characteristics described in daily and weekly reports (Total, 1976) and from the mud log (Geoservices, 1977). Throughout this description the density of the drilling fluid relates to the weight of the fluid per unit volume and is quoted in both kilograms per litre and pounds per US gallon (ppg), with the weight of the fluid controlled by various additives.

## Depth interval 3200 m to 3673 m

Drilling progressed through a predominantly mudstone section to a depth of 3673 m (Fig. 4). The mudstone is organic rich, and dark-grey to black in colour. This suggests that the environment of deposition was deep-marine, which conjecture is supported by high gamma values and consistently slow sonic velocities averaging 110 microseconds/ft. In the interval 3200 m to 3250 m a decrease in the gauge of the hole prevented efficient retrieval of the drill-string and a total of 40 tons of overpull was required to free the pipe. This decrease in gauge of the hole was attributed to the formation being overpressured causing the sidewall of the hole to encroach into the well bore (Bate, 1995). From 3200 m to 3673 m the drilling rate steadily decreased from 10 min/m to 15 min/m and gas levels averaged 1.0 % over this interval. The gas consisted mostly of methane but there were traces of C2 (ethane), C3 (propane) and C4 (butane). This section is the lowermost 473 m of Rolle's (1985) Ikermiut Formation which has been dated as Paleocene in age in Kangâmiut-1 (Croxton, 1981) and as Late Paleocene to Early Eocene by Nøhr-Hansen (pers. comm).

## Depth interval 3673 m to 3706 m

At a depth of 3673 m the drilling rate increased from 14 min/m to 6 min/m (a drilling break) and was maintained to a depth of 3679 m. The lithology of the formation over which the drilling break occurred consists of medium to coarse-grained, sub-angular to rounded feldspathic sandstone intercalated with thin black shale (Geoservices, 1976). Below a depth of 3679 m the drilling rate returned to 18 min/m through a mudstone section with background gas levels of 0.3% to 0.6% with a mud specific gravity of 1.38 kg/1 (11.5 ppg) rising to a specific gravity of 1.44 kg/1(12.0 ppg).

At a depth of 3695 m the drill string was retrieved from the well to replace the drill bit which had become dulled. Upon resumption of drilling a drilling rate of 18 min/m was established. A further drilling break was recorded at 3700 m when the drilling rate increased to 3 min/m which was maintained until a depth of 3704 m within an arkosic sandstone. Over the interval 3705 m to 3706 m the drilling rate slowed to 10 – 11 min/m.

At a depth of 3706 m (July 14th 1976) a flow-check was performed to investigate if mud was flowing back into the mud pits due to excessive pressure in the formation rather than because of mechanical pumping. A mud gain of 1 $m^3$ was recorded and the well was then closed-in, i.e. the pipe-rams were closed around the drill pipe to prevent uncontrolled flow of the influx up the annulus. Circulation was resumed and the formation fluids circulated through the choke manifold. Gas levels of 9 % total gas were recorded (C1 7%, C2 0.23 %, C3 0.12 %, C4 0.03%) confirming that a gas kick had been taken (Geoservices mud log, 1976; Manderscheid & Quin, 1977). This gas was burned-off using the drilling derrick gas flare. The presence of gas constituents up to C4 suggests that the gas is moderately wet which could indicate that the hydrocarbon in the sandstone is condensate or possibly oil.

To control the increased formation pressure the specific gravity of the drilling mud was raised from 1.42 kg/1(11.8 ppg) to 1.68 kg/1(14.0 ppg) and circulated repeatedly at the 9 5/8" casing shoe to condition the mud. During this circulation the mud was degassed via the degasser and the resulting gas was flared-off. This resulting increase in the weight of the drilling mud caused a degradation in the other mud characteristics, such as viscosity and gel strength, and a total of nine hours was needed to condition the drilling mud (weekly wellsite report, 1976).

The hole was re-opened and another flow check performed which proved negative. The string was then lowered to a depth of 3689 m. During this circulation the drill string became stuck and circulation was lost. The pipe was eventually freed with 60 tons of overpull. Another flow-check showed that the well was again flowing and the well was closed in. Circulation was resumed throught the choke manifold. On re-opening of the well the string was pulled to the shoe and attention paid to filling the drill pipe with mud to prevent swabbing as each section of drill pipe was retrieved.

The string was lowered into the well and the hole reamed repeatedly to bottom to bring it into gauge. Reaming was very difficult over the interval 2990 m to 3185m with the bit eventually balling. A new bit was attached to the string and reaming resumed. Over the interval 3616 m to 3633 m the string became repeatedly stuck. The returning drilling mud indicated that *gas was flowing into the well* from the interval 3673 m to 3704 m, requiring degassing of the mud.

## Depth interval 3706 m to 3767 m

Finally on the 24th July, nine days after recording the initial kick, new formation was drilled with an average penetration rate of 12 min/m slowing to 20 min/m. The daily wellsite reports describe the formation as consisting of quartzo-feldspathic sandstones with fragments of translucent and white quartz, feldspar and chlorite which are angular and poorly sorted (Fig. 4). Over the interval 3706 m to 3725 m the sandstones were porous and gas-charged but become less porous with depth, and were intercalated with black shale (weekly wellsite report, 1976). The Geoservices mud log (1976) makes reference to pale yellow fluorescence within drill cuttings which may indicate the presence of liquid hydrocarbons, with a gravity possibly between 25 and 35 API (North, 1985).

Hole conditions were reported to be very difficult especially in the overlying shale interval, with caving and narrowing of the hole. Schlumberger logs were acquired over this depth interval, during which a second kick was taken and a 7 $m^3$ gain in the mud pits recorded. The daily wellsite reports attribute this second influx to gas entering the well from the same interval from where the first kick was taken, i.e. 3673 m to 3704 m. The Schlumberger tool was retrieved from the well and a kill mud with a specific gravity of

1.85 kg/1 (15.4 ppg) circulated to stabilise the well. During this conditioning the mud was degassed continually.

## Depth interval 3767 m to 3777 m

After stabilisation of the hole, drilling recommenced using a mud specfic gravity of 1.72 kg/1 (14.3 ppg). Drilling continued to a depth of 3777 m through similar lithologies to those decribed above, at which point further logging was successfully completed. The results of the seismic calibration velocity survey (CVL log), performed during the Schlumberger logging appeared to indicate a strong reflector at a depth of between 3807 m to 3827 m which was interpreted to represent basement (weekly wellsite report, 1976).

## Depth interval 3777 m to 3874 m (TD)

Drilling resumed with the mud weight maintained at 1.72 kg/1 (14.3 ppg) and continued through a tightly cemented feldspathic sandstone section (Fig. 4) with a drilling rate of between 30 and 40 min/m (daily wellsite report, 1976; Geoservices mud log, 1976). Drilling breaks at 3825 m from 22 min/m to 2.5 min/m and again at 3832 m from 18 min/m to 4 min/m correspond to two zones with slower sonic values. These suggest the presence of two porous units. An increase in the percentage of methane in the drilling mud to 4.8 % was also recorded opposite the lower zone.

At a depth of 3840 m the rate of penetration decreased from an average of 15 min/m to 40 min/m which was maintained until total depth with the recorded lithology consisting of dark green heavily altered amphibolite (Geoservices mud log, 1976). Drilling continued to a depth of 3870 m at which point Core No. 2 was cut over the depth interval 3870 m to 3874 m with 100 % recovery. The recovered core consists of a hard, dark-green, fine-grained rock rich in ferro-magnesian minerals and chlorite with scattered small garnet crystals. It has been interpreted as an intrusion that has been metamorphosed to amphibolite facies (Geoservices mud log, 1976), which was confirmed by Sørensen (1977). At this point it was decided to terminate the well and a final TD logging of the open hole section was performed.

## Drill Stem Test and Results

As a result of the influx of hydrocarbons into the well whilst drilling through the sandstone section 3674 m to 3706 m, it was decided to perform a Drill Stem Test over this interval. The interpretation that hydrocarbons are present in that interval is supported by a degree of cross-over of the FDC-CNL logs at a depth of 3677 m and again at 3693 m (Fig. 4). The 7" liner was run and set at a depth of 3855.5 m and subsequently perforated over the intervals 3674 m to 3682 m and 3686 m to 3705 m. Pressure readings recorded an initial formation pressure of 500 kg/cm$^2$ (7610 psi) which was maintained for 1 hour 25 minutes on a 1/8" choke with a flow rate of 7.5 m$^3$/h, after which pressure declined and within 45 minutes the well had ceased flowing. The testing string was then pressured to 2000 psi and bled-off with no results. This was repeated with a build-up to 3000 psi. The result was again negative. Following a one and a half hour build-up, reverse circulation recovered a total of 29 m$^3$ of fluid. Chemical analysis of the fluid suggests that it had characteristics similar to that of the drilling mud. The testing string was recovered and the well was abandoned.

# Discussion

The interpretation of the genesis of the rock types intersected over the basal interval of well Kangâmiut-1 has direct and important implications for the prospectivity of the Kangâmiut Ridge and the offshore West Greenland area in general. The following discussion compares two different interpretations. One is that the interval from 3700 m to 3849 m consists of in situ kaolinitic basement. The other interpretation suggests that the same interval is a fan whose material was derived from similar kaolinitic basement.

The identification of primary tonalitic/granitoid gneiss basement as opposed to rapidly deposited sediments derived from the same gneiss has been a common problem in the oil industry. Pettijohn (1949) summarised the problem thus: In some cases the granitic residuum is so little reworked and so little decomposed that upon cementation it looks very much like the granite itself. It is then termed a ' recomposed granite ' (or quartz porphyry). Such rocks may be readily mis-identified. This is of serious consequence when an oil well is concerned, because the drilling may be terminated upon the supposition that the crystalline basement has been reached, whereas all that was encountered was a tongue of granite wash."

The published interpretations (Manderscheid, 1980; Rolle 1985) (Fig. 2) state that the section from 3700 m to 3849 m consists of kaolinitic tonalitic orthopyroxene-bearing gneiss intruded by a chloritised metadolerite dyke between 3849 m to 3874 m (TD). This interpretation was made chiefly by the analysis of thin sections produced from sidewall cores recovered from the well (Sommer, 1976; Sørensen, 1977) and was influenced by comparison with the nearest onshore exposure of basement which comprises tonalitic orthopyroxene gneiss intruded by Kangâmiut dykes.

In an attempt to corroborate the thin section study of Sørensen (1977), additional thin sections have been made from sidewall cores recovered from the well. It has not been possible to locate the thin sections of the sidewall cores described by Sørensen and it has only been possible to prepare three further thin sections from the remains of the sidewall cores stored at GEUS (T. C. R. Pulvertaft, pers. comm., 1996). These are from depths of 3738 m, 3765 m and 3790 m (Appendix I). These new thin sections unquestionably represent highly altered basement rocks.

The material that is left from the remaining 12 sidewall cores taken between 3700 m and 3835 m consists of small fragments, loose sand and clay powder. Angular quartz grains are invariably present; in two samples (3712 m and 3714.5 m) there are occasional prismatic quartz crystals showing pyramid faces. In a few samples altered plagioclase could be recognised. A rusty brown $Fe^{3+}$ mineral is present in several samples. Occasional grains of iron oxide and one pyrite grain was also observed.

It is possible that the sidewall cores could have been recovered from a large cobble or boulder of heavily altered basement deposited in close proximity to an active fault scarp in the form of a talus deposit or submarine fan. The impression given by the material from the 12 cores of which no thin section could be made is indecisive. All the material could be from strongly weathered basement, or it could conceivably be from a sludge that has slipped off a steep slope of weathered basement. In the latter case the material certainly has not been transported more than a few tens of metres, as there has not been any marked increase in the relative amount of quartz as a result of winnowing of clay minerals, nor has there been any abrasion of quartz grains. The first sample with fresh plagioclase was recovered from a depth of 3843 m; the rock is a typical tonalite. Several of the cuttings from the same sample are however strongly weathered (T. C. R. Pulvertaft, pers. comm., 1996). In fact no further sources of demonstrable evidence to support the interpretation that the interval from 3700 m to 3849 m consists of in situ altered basement are available other than what is provided by the thin sections recovered from sidewall cores. Clearly however, these samples are the most direct evidence available to the nature of the subsurface encountered by the borehole.

Unfortunately the presence of kaolinite on its own is not diagnostic for a particular interpretation of the subsurface. Kaolinite ($Al_2\,Si_2\,O_5\,(OH)_4$) is the most common of the Kaolin family of minerals and can form as a result of hydrothermal, residual, and sedimentary processes (Murray, 1988). The transformation of radioactive alkali feldspar (K, Na [Al $Si_3\,O_8$] ) (Deer, Howie & Zussman, 1966) into kaolinite occurs by the leaching of potassium, sodium and silica (Murray, 1988) resulting in a preferential concentration of non-radioactive materials. This situation would have the effect of producing a lower response on the gamma ray log which may give a misleading impression of a sandy lithology.

The hydrothermal and residual clays are classed as primary kaolins and are formed by the alteration of crystalline rocks such as granites. The alteration can result from surface weathering (high rainfall and poor drainage in a temperate to tropical climate), from groundwater movement below the surface, or by hydrothermal action under generally acidic conditions. The sedimentary kaolins are mostly the result of the erosion, transportion and deposition of kaolin formed elsewhere, but some have been formed from arkosic sediments that were altered after deposition, primarily by groundwater. However, there are far more primary kaolins in the world than secondary kaolins because special geologic conditions are necessary for the deposition and preservation of the sedimentary kaolins.

Kaolinitised zones can achieve substantial thicknesses. For example, the weathering of granites in the Kalovy Vary area of Czechoslovakia has produced a kaolin layer up to 50 m thick (Kuzvart, 1969). Even greater thicknesses have been recorded in the Snowy Mountains of Australia where Ollier (1969) states that 'completely weathered rock has been found at depths of 900 ft (274 m) below an undulating ground surface.' Thus it cannot be discounted that the 149 m of kaolinitisation attained in the Kangâmiut-1 well, from 3700 m to 3849 m, was produced by a progressive process of kaolinitisation of basement gneiss. However, the highly variable drilling rate and log response through this interval tends to suggest a heterogeneous nature to the rocks possibly reflecting differing cementation and porosity characteristics.

Interpretation of regional seismic data offshore southern West Greenland suggests that the faulting that controlled the development of the Kangâmiut Ridge occurred in two phases; the first in the Aptian /Albian and the second in the Paleocene (Chalmers *et al.*, 1993). By implication, the timing of exposure and kaolinisation of the basement rock may have taken place synchronous with this faulting. The palaeo-latitude of Greenland during the Upper Cretaceous was approximately 50° N (Smith *et al.*, 1981) with indicators for the prevailing climatic conditions provided by the coal bearing nonmarine sediments of the Atane Formation, onshore the Nuussuaq peninsula West Greenland (Pedersen & Pulvertaft, 1992). Ammonites and bivalves present within the Atane Formation have been dated as Albian to Campanian in age (Birkelund, 1965; Olsen & Pedersen, 1991). Lower Cretaceous weathering is evidenced on the north coast of Nuussuaq at Kûk where the effect of Cretaceous weathering has produced kaolinitic gneissose basement to a depth of 35 m below the sub-Cretaceous surface (Pulvertaft, 1979). One of the conclusions of Pulvertaft's (1979) study was that 'the point at which residual sediment gives way to the first transported sediment is impossible to fix.' Thus it may be reasonable to assume that during much of the Cretaceous and Paleocene conditions suitable for the deep weathering of basement rocks prevailed.

The drilling rate curve displayed on the mud log (1976) (Fig. 3) is highly variable over the interval 3670 m to 3840 m with no consistent trend. Rapid increases in drilling rate (drilling breaks) are evident at numerous depths within this interval. The drilling breaks at 3674 m and 3700 m occurred within lithologies consisting of medium to coarse grained sandstones with abundant feldspars and metamorphic grains (Geoservices, 1976). Accessory minerals include mica and glauconite, the presence of the latter indicating deposition in a marine environment and possibly with a low degree of winnowing (Selley, 1976). The gamma log response at these depths (Fig. 4) corroborates the intersection of sandstone beds.

The gamma log (Fig.4) suggests that the interval between 3672 m and 3704 m consists of a series of sandstone beds whereas the sonic log records a decrease to between 160 microseconds/ft and 110 microseconds/ft, possibly indicating a very poorly cemented sandstone or the presence of mudstone. The mud log (Geoservices, 1976) also reports a mudstone section between 3679 m and 3692 m. Gastropods, echinoderm spicules, sharks teeth and lignite were also recorded over this interval (Bousquet *et al.*, 1977). Rolle (1985) interpreted the section from 3674 m to 3700 m to consist of coarse grained and gravelly, poorly-sorted, very kaolinitic arkose with interbeds of carbonaceous shale, which he termed the Narssarmiut Formation, resting on altered basement at a depth of 3700 m. This interpretation would mean that the influx of formation fluids at a depth of 3706 m originated from within altered basement. Similarly the drilling break at a depth of 3700 m would be where basement would be first encountered

A degree of cross-over of the FDC - CNL logs at a depth of 3693 m to 3694 m may indicate the presence of hydrocarbons. The sonic log also suggests increased porosity and possibly the presence of gas over this same depth interval. The weekly wellsite report (1976) states that the influx of hydrocarbons occured at a depth of 3706 m; however neither the nuclear or resistivity logs appear to indicate hydrocarbons at this depth.

The drilling rate over the interval 3706 m to 3778 m was extremely variable with numerous short-lived drilling breaks reflecting a heterogeneous lithology. The mud log (Geoservices, 1976) (Fig. 3) describes this interval as consisting of interbeds of quartzo-feldspathic sandstone and dark-grey, silty-shale, both of which have abundant silicious fractures. Both the sonic log and gamma ray response (Fig. 4) over this interval are variable suggesting that, if the lithology is indeed sandstone, then it is moderately to well-cemented. The mud log (Geoservices, 1976) also recorded traces of pale yellow fluorescence within drill cuttings from this interval. The velocity survey acquired at a depth of 3777 m showed a strong reflector which was interpreted at the wellsite (weekly wellsite report, 1976) as representing basement at a depth between 3807 m to 3827 m. This may also lend support to the assertion that the well had yet to reach basement and that the rock types in this interval are sedimentary.

The slow drilling rate of about 40 min/m from 3778 m appears to reflect a more uniform lithology which the mud log (Fig. 3) (Geoservices, 1976) describes as a very hard, quartzo-feldspathic rock. The potassium and plagioclase feldspars are highly altered. From 3803 m soft white clay (kaolinite?) is present (weekly wellsite report, 1976). Both the gamma and sonic logs are inconclusive and appear to reflect minor variations in the chemistry and petrology of the rock.

The drilling breaks at 3825 m and again at 3832 m (Fig. 4) are coincident with two zones of apparently increased porosity as demonstrated by the sonic log, and 4.8% methane and traces of ethane and propane were recorded from the lowermost porous zone. Gulf Oil Company (1977) identified euhedral quartz overgrowths in thin sections made from sidewall cores recovered from these zones, which was attributed to growth within an open porous network which allowed crystal terminations to develop. An independent analysis of the palynology of the well by Imperial Oil (Gulf Oil Co., 1977) has identified pollen and spores of Paleocene age within this interval.

Below a depth of 3846 m, a change in the character of the gamma and sonic logs is evident. The interval transit time decreases to a constant value of 50 microsec/ft from a highly variable transit time ranging between 50 to 110 microsec/ft above 3846 m. The gamma log is also highly variable above a depth of 3846 m. The mud log (Fig. 3) records that a dark-green basic rock was intersected at a depth of 3848 m. It was at this depth that basement was intersected. The rock recovered from the core that was cut between 3870 m and 3874 m confirmed this rock type as consisting of an amphibolite intrusion.

# Geological model for the basal section of Kangâmiut-1

An alternative interpretation basal section in well Kangâmiut-1 to that produced by Sommer (1976 *In*: Chalmers, 1992), Sørensen (1977), Manderscheid (1980) and Rolle (1985) and more in agreement with the wellsite interpretation produced by Geoservices (1976) and by the Gulf Oil Company (1977 *In*: Chalmers, 1992) (Fig. 2), is suggested by an integrated interpretation of modern seismic data, the petrophysical logs and engineering data recorded during drilling of the well. This interpretation (Figs 2 and 4) suggests that the interval from 3672 m to circa 3840 m is a coarse clastic fan consisting of large cobbles and boulders of kaolinitic basement deposited on the flank of the Kangâmiut Ridge, with in-situ unaltered basement being intersected at a depth of 3840 m.

The variable drilling curve suggests the intersection of a heterogeneous succession of rocks, which is here attributed to a sedimentary origin. Such a situation would be expected when drilling through a talus-type fan consisting of large boulders. The rate of penetration would be slow when drilling through the boulders but would increase rapidly when drilling through the interclast cement or boulders of less hard lithology. The drilling breaks at 3674 m, 3700 m, 3825 m and 3832 m corroborate this. The identification of euhedral quartz overgrowths within thin sections made from samples recovered from these intervals suggests a sedimentary origin for this rock type. This is supported by the variable gamma ray log response and the zones of varying porosity as indicated by the sonic log. Direct evidence for the presence of hydrocarbons within this interval can be provided by the recorded influx of wet gas at a depth of 3706 m, the identification of fluorescence in samples over the depth rage 3720 m to 3750 m and the recording of a total of 4.8% gas comprising $C_1$, $C_2$ and $C_3$ at a depth of 3832 m. Such indications of hydrocarbons are most readily attributed to their presence within a sedimentary rock as opposed to the invasion of the hydrocarbons into a kaolinitic gneiss.

The recent interpretation of thin sections made from sidewall cores recovered from the well (T. C. R. Pulvertaft, 1996 pers. comm), may indicate that the sidewall cores were taken from boulders of altered basement deposited in a kaolinitic sludge that had slipped off a steep slope of weathered basement, such as a fault scarp. The degree of transportation of these boulders is inferred to be low due to the lack of an increase in the relative amount of quartz grains as would be expected due to the winnowing of clay minerals during transport, and due to the absence of marked abrasion of the quatrz grains.

It is suggested that the well drilled through a syn-tectonic fan consisting of large boulders of kaolinitic basement before intersecting unaltered amphibolite basement at a depth of 3840 m. The well was terminated in this rock type at a depth of 3874 m (Fig. 4). The model proposes that a granitic basement ridge experienced kaolinisation at some point updip of the well position, within a humid, temperate to sub-tropical climate, during the mid-Cretaceous to Early Paleocene. Erosion of this rock type produced numerous large boulders of kaolinitic basement and a kaolinite-rich sandy clay slurry which was redeposited a few tens of metres from the fault scarp. This deposition probably occurred in a marine environment as evidenced by the presence of glauconite and mica in drilling cutting samples (Geoservices, 1976). During the Paleocene this fan was transgressed and sealed by a thick succession of mudstones

Interpretation of recent seismic data lends support to the model that the interval between 3700 m and circa 3840 m is of sedimentary origin. A seismic line, orientated east-west positioned 40 m from the well, provides further evidence that this 146 m interval represents syn-tectonic fan deposited on the western flank of the Kangâmiut Ridge (Figs. 5 & 6). The fan is interpreted to extend over a range of 100 shot points which represents a lateral extent of 2.5 km. The present dip of the base of the fan is estimated at 1° which is a sufficient angle to allow for the accumulation of boulders and cobbles in close proximity of a fault scarp. The strong reflector above the fan may represent the contact of the base of the overlying mudstone section with the sands and cobbles of the fan. Unfortunately only a single line of recent vintage processed seismic data is available within the vicinity of the Kangâmiut-1 well, which limits the validity of the seismic interpretation. However, new seismic data with a closer line spacing were acquired in 1995 covering the entire length of the Kangâmiut Ridge and interpretation of the finally processed data may provide further evidence to support the presence of fans flanking the Kangâmiut Ridge.

An analogous fan may be present at Fortune Bay onshore southern west Disko island approximately 350 km to the north of Kangâmiut-1 (Møller-Nielsen, 1985). Precambrian gneissic basement is exposed at the surface with weathering exploiting joints in the gneiss resulting in the preferential kaolinisation of the gneiss along these joints. These blocks have subsequently fallen approximately 15 m down slope to come to rest at the foot of the cliff. The resultant scree-type fan consisting of boulders of kaolinitised gneiss has a lateral extent of approximately 10 m.

Much larger scale examples of a fan system are the large Jurassic and Cretaceous fans deposited adjacent to rotated fault blocks in the Wollaston Forland area of northern East Greenland (Surlyk, 1978). Substantial oil and gas production from submarine fans deposited adjacent to active fault scarps is well documented in theViking Graben of the North Sea. In a number of locations the Upper Jurassic Brae Formation has been deposited as high density debris flows on the flanks of the western margin of the Viking Graben, often in close association with the prolific source rock of the Kimmeridge Clay Formation. Examples include the Brae Oilfield (Turner *et al.*, 1987), and the Thelma, Toni and Tiffany oil fields (Cherry, 1993).

# Summary and conclusions

1. Sommer (1976) and Sørensen (1976) interpreted the basal section of Kangâmiut-1 as consisting of heavily altered basement. They based this interpretation on the analysis of thin sections made from sidewall cores taken from the well and comparison to onshore exposures of basement.Sørensen (1977) appears to disagree with the interpretationprovided by the contracted mudlogging company (Geoservices, 1976) at the wellsite who interpreted arkosic sandstones to a depth of 3848 m.

2. Interpretation of the drilling data, well logs and modern seismic data has led to a revised interpretation that this interval consists of a Paleocene talus fan deposited on the hanging wall of a faulted basement high. The talus fan consists of large blocks of kaolinitic tonaltic basement that experienced minimal transport before deposition.

3. These conglomerates and sandstones contain the only recorded presence of hydrocarbons offshore West Greenland. The Drill Stem Test performed over the upper sandstone unit in the interval 3674 m to 3705 m probably failed to test any formation fluids and in fact probably recovered only drilling mud. It is likely that the great length of time during the operations required to stabilise the hole (high mud weight, repeated circulation and reaming) following the repeated influx of formation fluids from this interval, resulted in drilling mud invading the formation. It is not unlikely that it was these fluids that were recovered during the Drill Stem Test.

4. The implication of this inconclusive Drill Stem test is that the prospectivity of the Kangâmiut Ridge was not adequately tested by the well. Thus some of the existing literature unjustifiably downgrades the prospectivity of the Kangâmiut Ridge and by implication the whole of the southern West Greenland Basin.

*Acknowledgements*. I would like to thank Richard Whittaker for initiating this project. Chris Pulvertaft is thanked for describing and interpreting thin sections from the basal section of the well. Jan Escher is thanked for help in translating sections of the original Total Oil reports. Jim Chalmers made valuable suggestions to the text. Finally GEUS drafting staff are thanked for preparation of figures.

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# Appendix I

## Description of thin samples from recently made sidewall cores

Depth 3738 m (sidewall core # 15)
This is an altered relatively mafic granitoid with about 15% quartz. This quartz occurs as irregulary-shaped, almost amoeboid grains up to 2 mm in size. Single grains consist of up to about five optic units, and show undulate extinction but no severe strain. Relics of plagioclase can be recognised by their lamellar twinning. K-feldspar seems also to have been present. Chlorite is abundant both as dispersed fine material and as 'books' up to 1 mm across.The chlorite appears to have replaced both mafic minerals and to some extent plagioclase. A little dirty brown biotite is present; this may be primary, as are also the few grains of opaque oxide. Apatite in rounded grains up to 0.3 mm in size is relatively abundant. Apart from chlorite, a clay mineral (?kaolinite), sericite and calcite are the main secondary minerals. A fracture crossing the rock is filled by chlorite.

Depth 3765 m (sidewall core # 9)
The sample from 3765 m is extremely altered, so that nothing can be said about the nature of the original rock. In notable contrast to almost all other remnants of sidewall cores, only very little quartz is present in the thin section; this occurs a grains less than 0.5 mm in size. A little apatite is present as grains less than 0.2 mm in size and there are a few grains of very dark brown, almost opaque material with a suggestion of cleavage. Otherwise the rock consists of clay material and calcite. The calcite occurs as blebs of very fine material in a mesh of clay, and in thin veins.

Depth 3790 m (sidewall core # 8)
The deepest sample that could be sectioned consists of an altered granitoid. The surviving primary minerals are quartz, opaque oxide, biotite and a little apatite. The quartz forms irregularly shaped grains up to 2.5 mm in size. The largest grains consist of up to 8 optic units. A few grains show slightly strained undulate extinction. Some grains have 'dusty' cores which cross boundaries between optic units. It has not been possible with a standard microscope to resolve the extremely fine-grained material that is reponsible for the dustiness. The biotite is red-brown, up to 0.3 mm, and associated with opaque oxide grains, sometimes occurring as lamellar intergrowths with oxides. The secondary material is mainly calcite and almost isotropic clay aggregate. Occasionally it is possible to discern relics of plagioclase with lamellar twinning, in spite of virtually total replacement by secondary minerals.

The material that is left from the remaining twelve sidewall cores taken between 3700 m and 3835 m consists of small fragments, loose sand and clay powder. Angular quartz grains are invariably present; in two samples (3712 m and 3714.5 m) there are occasional fragments of prismatic quartz crystals showing pyramid faces. Altered plagioclase could be recognised in a few samples. A rusty brown $Fe^{3+}$ mineral is present in several samples. Occasional grains of Fe oxide and one pyrite grain were also observed.

The impression given by the material from the twelve cores of which no thin section could be made is indecisive. All the material could be from strongly weathered basement, or it could conceivably be from a sludge that has slipped off a steep slope of weathered basement. In the latter case the material has certainly not been transported more than a few tens of metres, as there has not been any marked increase in the relative amount of quartz as a result of winnowing of clay minerals, nor has there been any abrasion of the quartz grains.

The first cutting with fresh plagioclase was recovered from a depth of 3843 m; the rock is a typical tonalite. Several of the cuttings from the same sample are however strongly weathered.

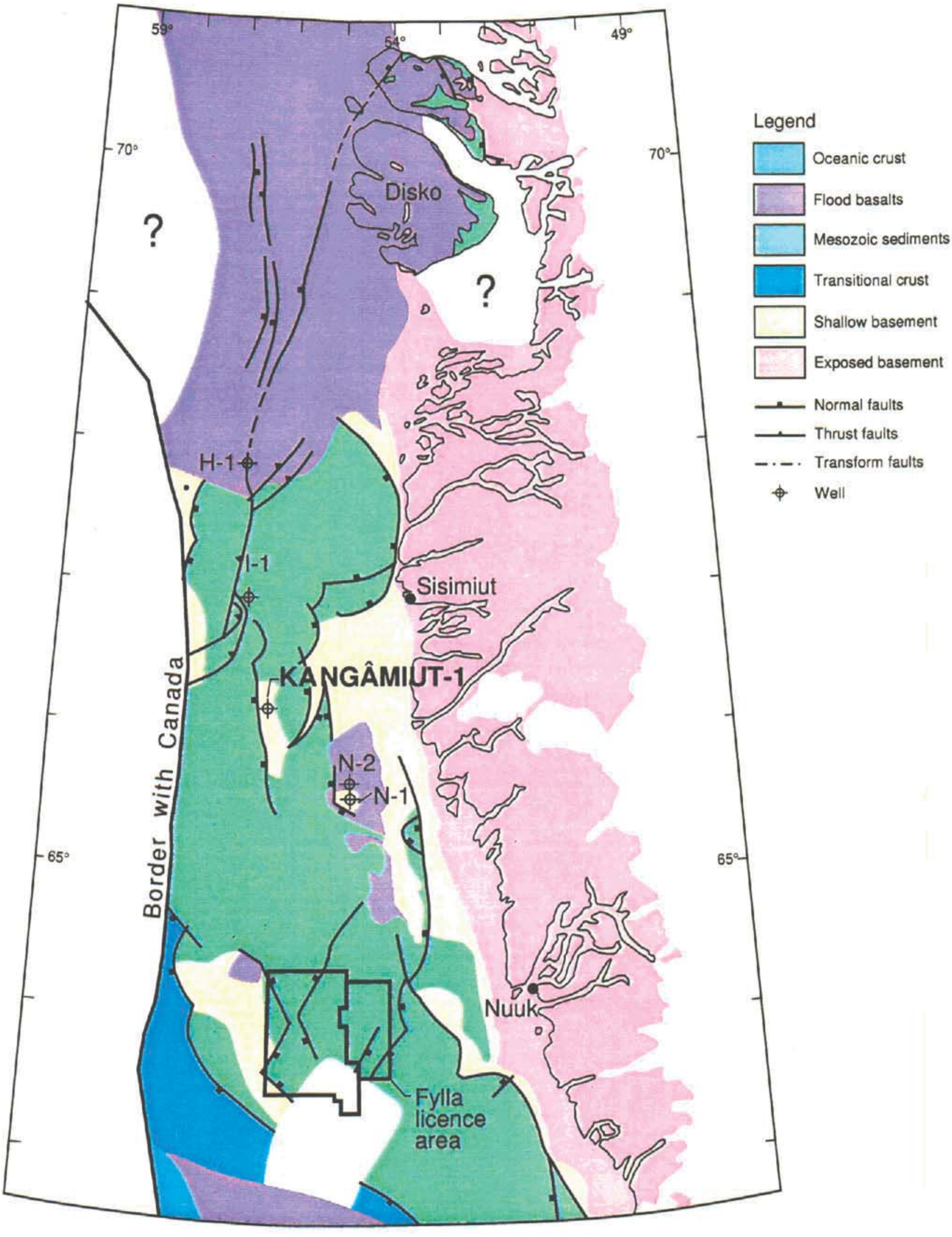



Fig. 1: Location of the Kangâmiut-1 well in the southern West Greenland Basin.
H-1: Hellefisk -1, I-1: Ikermiut-1, N-1, N-2: Nukik-1 and 2.

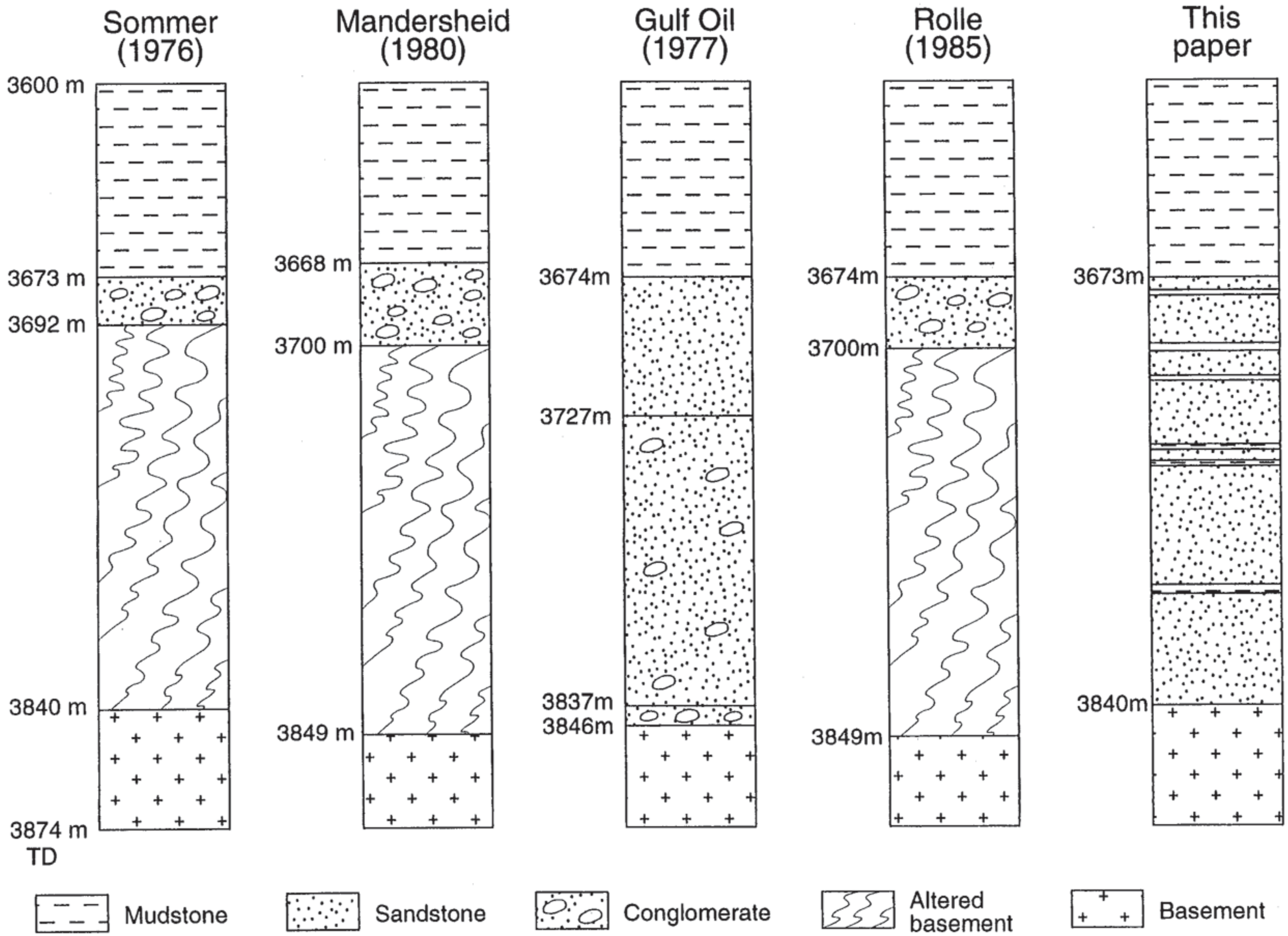
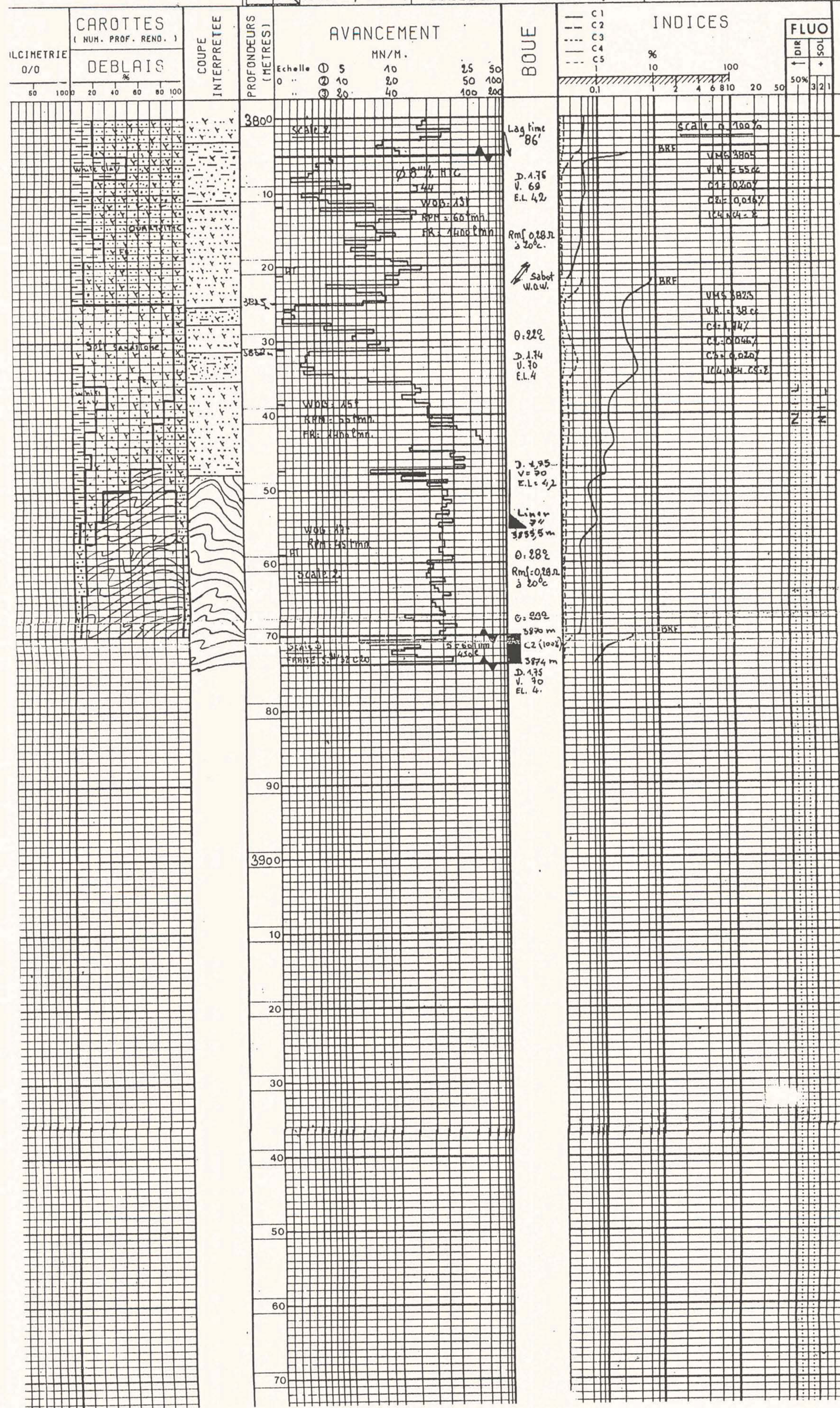



Fig. 2. Comparison of the various interpretations of the basal 274 m of well Kangâmiut-1

Fig. 3. Mud log from the Kangamiut-1 well from the depth interval 3600 to 3874 m (Geoservisces, 1976)

| ]TAL<br>-IALE L 00181<br>SUBSURFACE<br>LOG DE CHANTIER AU 1/500 | COORDONNEES | TUBAGES | FORAGE KANGAMIUT | FEUILLE N° 20 |
|---|---|---|---|---|
| | X = 66°08'59"8N | ø 30" SABOT A 212,80 m | PERMIS 34 AREA | DE 3600 m |
| | Y = 56°11'27"2W | ø 18"5/8 SABOT A 482,40 m | PAYS GREENLAND | A 3800 m |
| | Zf = 179,70 m | ø 13"3/8 SABOT A 1389,75 m | APPAREIL PELICAN | |
| | Zt Zab ± 12,30 m | ø 9"5/8 SABOT A 2935,20 m | | |
| | | ø Liner 7" SABOT A 3855,5 m | | |




## DESCRIPTION OBSERVATIONS

Presence of scarce green and black ferro-magnesians (oxyde and chlorites?), alterated.
Many veins of {calcite / quartz}
Feldspathic quartzite slightly metamorphised.

— 3803 —

- Feldspathic quartzite (A/A).
- With intercallations of white soft CLAY and SAND: medium to coarse, milky or translucide, subangular, with white alterated feldspars.

Probably alterated basement

S.P.E (T.D = 3805 m).
- FDC - CNL - GR (3779 - 2930 m).

— 3848 m —

Basement:

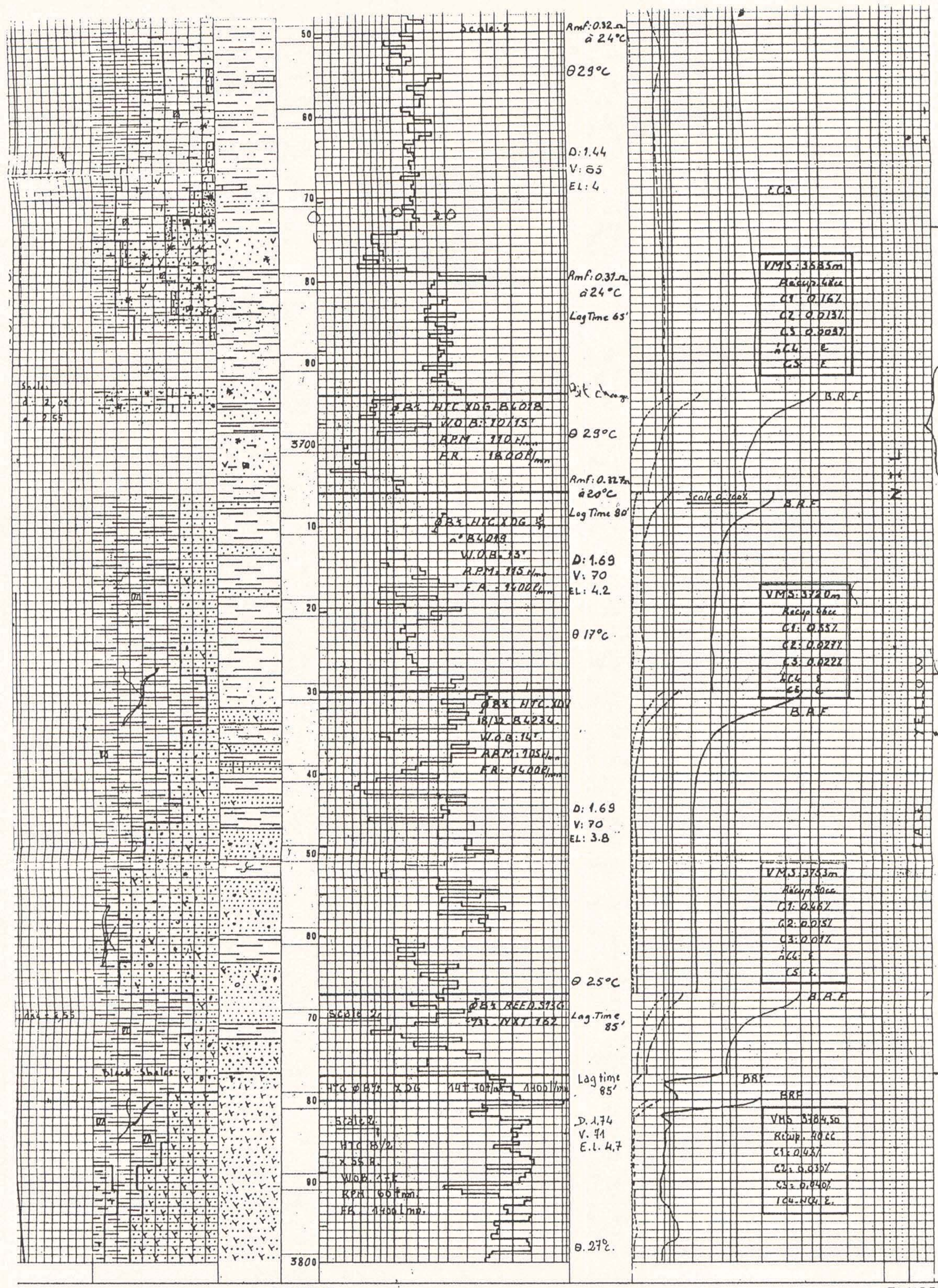
- Dark green basic rock, compact, fine grained, with mainly FELDSPARS and FERRO-MAGNESIANS (Amphiboles alterated in Chlorites, oxydes), and some micro-grains of quartz. slightly calcitic.
- Presence of metamorphic features (beginning of lineation)
- This rock, very alterated, and fractured (cf. CORE2), may be an AMPHIBOLITE.

S.P.E.
- BHC-GR (RUN4)
- HDT (RUN2)
- SWC (RUN 3)

T.D. = 3874 m

GGU BILAG
011826
JR.NR. 411-1

VMS - Vacuum Mud Still.




- 3674 m
- Sandstone, medium to coarse, with white and greenish grains of quartz.
Presence of Feldspars and metamorphic rocks fragments.
The grains are subangular and sometimes more rounded.

N.B. Kick of Gaz around 3700m with C1: 8.6; C2: 0.23; C3: 0.12; iC4: 0.02; nC4: 0.05; C5: ε — % V.M.S. during circulation in reaming

- Dark grey Shale, sometimes slightly silty or sandy.
Traces of pyrite and glauconite

— 3728 m —

- Sandstone, quartzitic, feldspathic, with translucide and white quartz
- Quartzitic Fragments (with quartz, potassic feldspare, and chlorite) are altérated and abundant.
The grains are angular and poorly sorted.

- Interbedded Shale, pyritic (A/A)
- Abundant siliceous and fractures sometimes, opened, with automorphic quartz.
- Traces of calcite.
These veins are visible in Shale, and probably in quartzite.

S.P.E: BHC-GR (RUN 3) 3759m - 2930

— 3777m —

S.P.E: DLL-NSFL (RUN 2) 3765 - 2930

Light to greenish quartzo-fedspathic rock, very hard, with a quartzitic structure (the Grains of translucide quartz are sometimes engrained or broken, and have a rolling extinction)
The Feldspars (Potassic and Plagioclases) are alterated.

## LEGEND

SILT · SAND, SANDSTONE · ARGILLACEOUS SANDSTONE · ARKOSIC SANDSTONE · CONGLOMERATE · BRECCIA
CLAY, SHALE · SANDY/SILTY SHALE · CALCAREOUS SHALE · LIMESTONE · COQUINA · CHALKY LIMESTONE
REEF LIMESTONE · DOLOMITE · DOLOMITIC LIMESTONE · MARL · DOLOMITIC MARL · ANHYDRITE
GYPSUM · ROCK SALT · COAL, LIGNITE · VOLCANICS · INTRUSIVE ROCKS · METAMORPHIC ROCKS
GLAUCONITE · PYRITE · MICA · FERRUGINOUS · FOSSIL · CALCITE
BITUMEN TAR · OIL · CONDENSATE · GAS · FLOOD WATER · LOSS · GAIN · DIRECTIONAL SURVEY

## FLUORESCENCES

IN COLUMN DIRECT FLUORESCENCE
THE LINE INDICATES THE PERCENTAGE OF FLUORESCENT SAMPLES
WEAK FLUORESCENCE
MEDIUM
STRONG

IN COLUMN FLUORESCENCE WITH SOLVENT
+ = WEAK
++ = MEDIUM
+++ = STRONG

## OBSERVATIONS

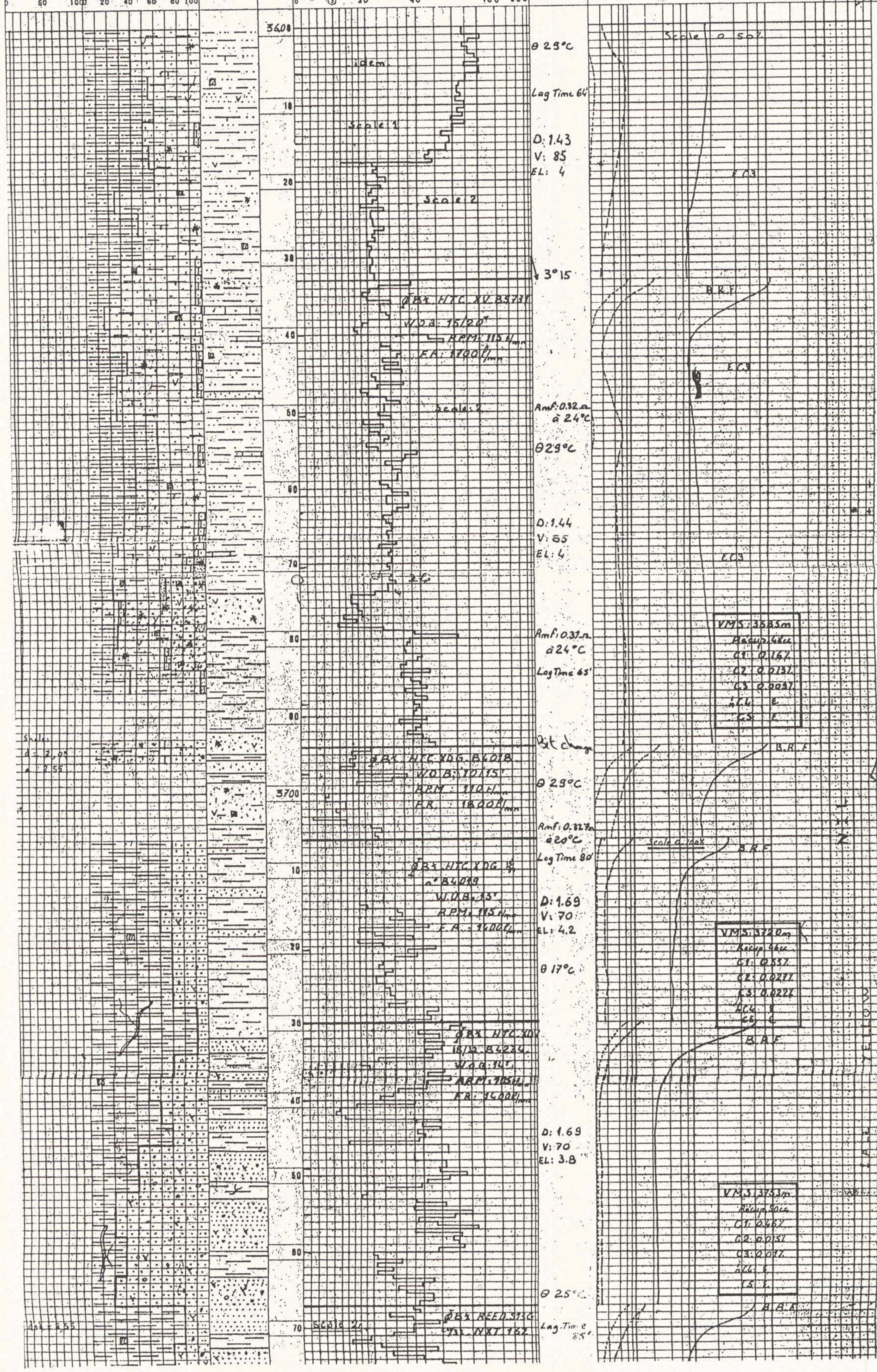
SHEET N° 19

WELL KANGAMIUT

RESIDENT GEOLOGIST
STORZ - HARRY - CALTERO

| | | | | |
|---|---|---|---|---|
| OTAL L 00181<br>SUBSIDIARY<br>SUBSURFACE<br>MASTER LOG 1/500<br>200 METRES PER SHEET | COORDINATES<br>X = 66° 08' 59" 8 N<br>Y = 56° 11' 27" 2 W<br>Zs Zt − 179,7 m<br>Zt Zrb + 12,3 m | CASINGS<br>30" SHOE AT 212,8 m<br>18" 5/8 SHOE AT 489,4 m<br>13" 3/8 SHOE AT 1389,75 m<br>9" 5/8 SHOE AT 2335,2 m<br>SHOE AT | WELL KANGAMIUT<br>CONCESSION 34 AREA<br>COUNTRY GREENLAND<br>RIG PELICAN | SHEET N° 19<br>FROM 3600 m<br>TO 3800 m |

CALCIMETRY 0/0 | CORES (NUMBERS-DEPTHS-RECOVERIES) / SAMPLES % | LITHOLOGY | INTERPRETATION | DEPTHS (METRES) | DRILLING RATE MN/M. | MUD | SHOWS | FLUO | DESCRIPTION OBSERVATIONS | FORMATIONS





OGU BLAS
011825
JR. NR. 411-1


VMS = Vaccum Mud Still

— 3674 m

- Sandstone, medium to coarse, with white and greenish grain of quartz.
Presence of Feldspars and metamorphic rocks fragments.
The grains are subangular and sometimes more rounded.

N.B. Kick of Gaz around 3700 m
with C1: 1.6, C2: 0.23, C3: 0.12, iC4: 0.02, nC4: 0.05, C5: ε — % V.M.S. during circulation in reaming

- Dark grey Shale, sometimes slightly silty or sandy.
Traces of pyrite and glauconite.

— 3728 m —

- Sandstone, quartzitic, feldspathic with translucide and white quartz
- Quartzitic Fragments (with quartz, potassia feldspars, and chlorite) are alterated and abundant.
The grains are angular and poorly sorted.

- Interbedded Shale, pyrite [illegible]
- Abundant siliceous and [illegible] tures sometimes opened with automorphic quartz.
Traces of calcite.
These veins are [illegible] Shale and probably [illegible]

S.P.E.I. BHC-GR (RUN B) 3753m - 2930

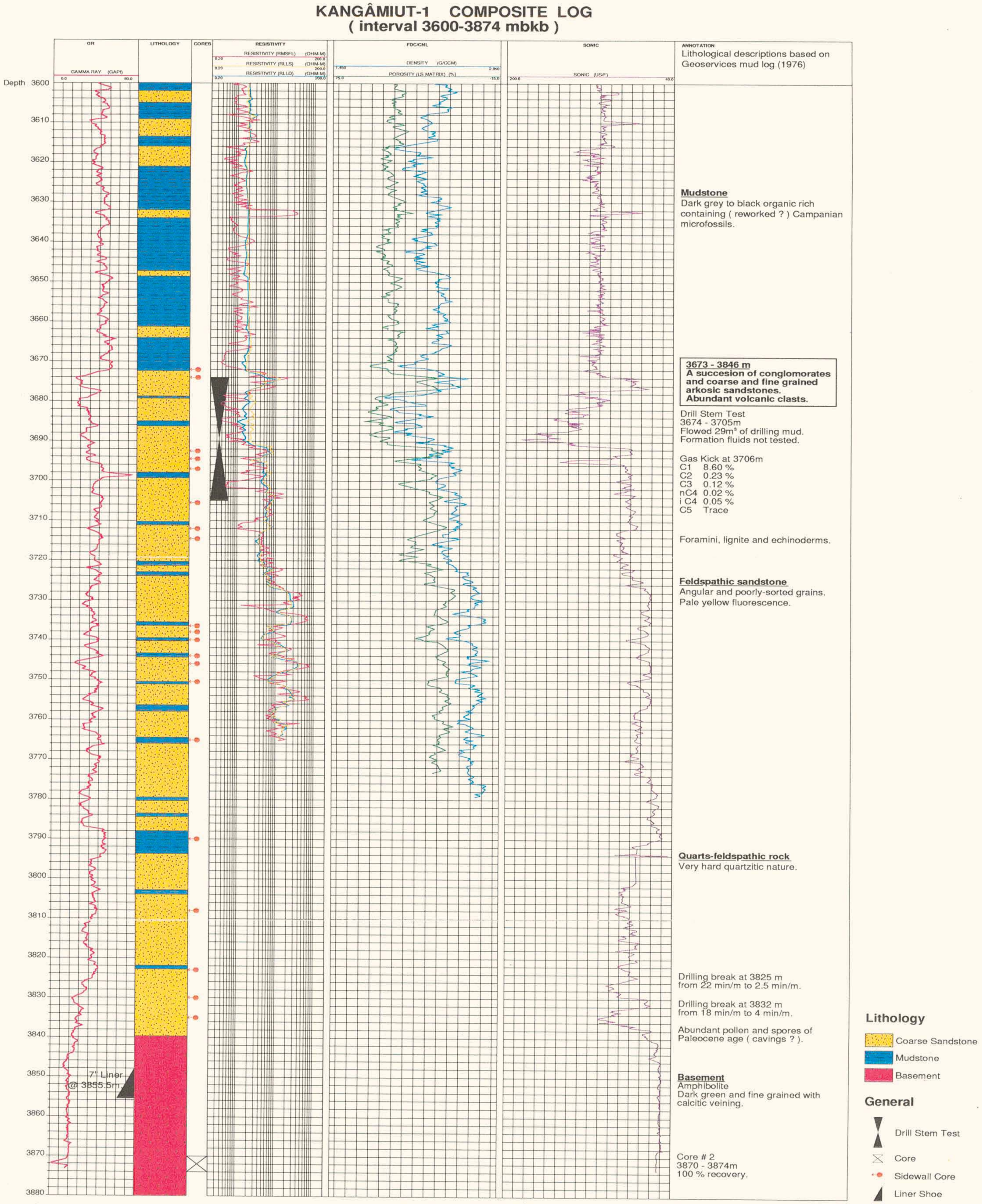



Fig. 4: Interpretation of the basal 274 metres of well Kangâmiut-1.

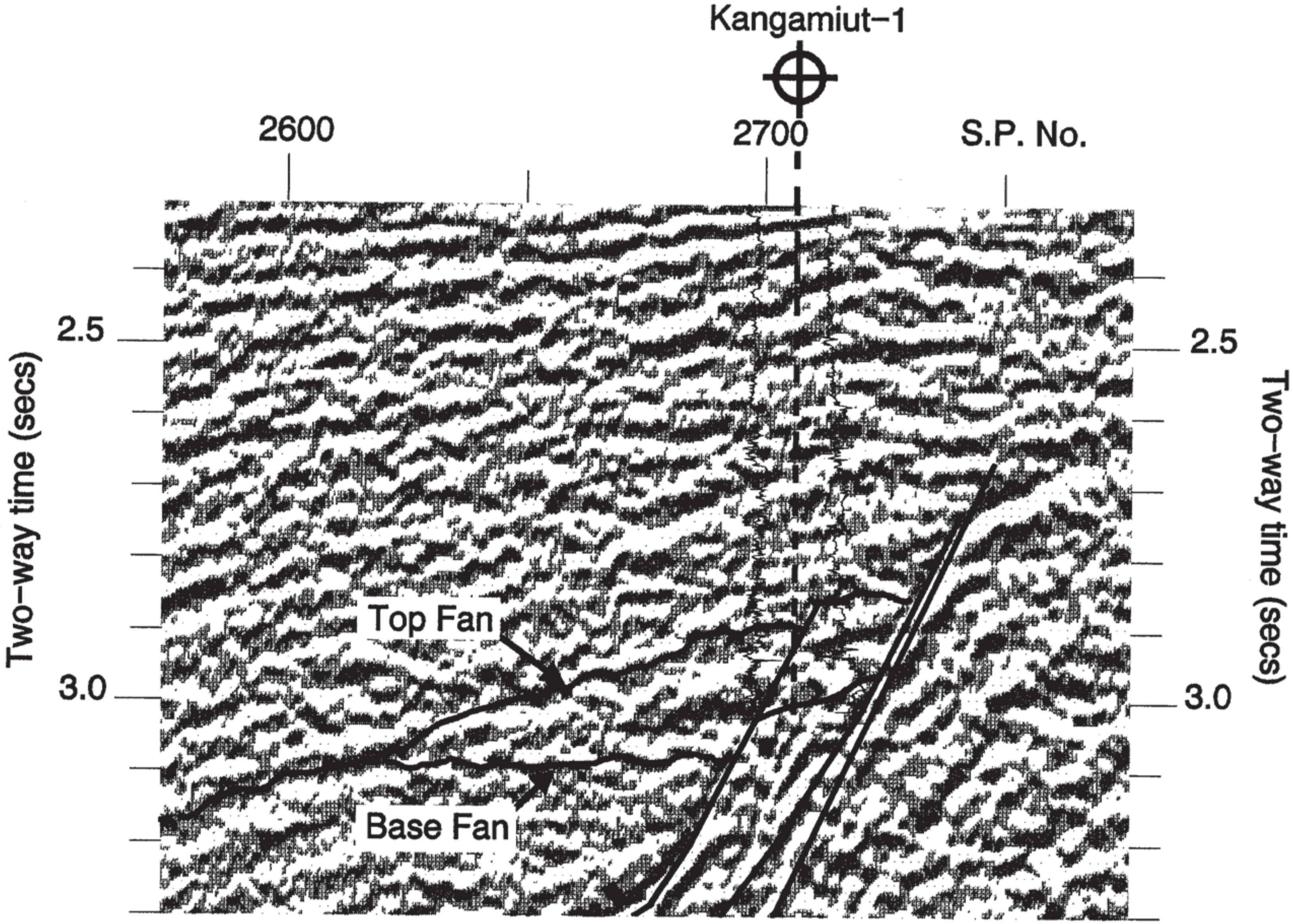



Fig. 5. Part of seismic line GGU/90-7 interpreted to show the fan penetrated by well Kangamiut-1. The logs shown are gamma ray (left) and sonic (right)

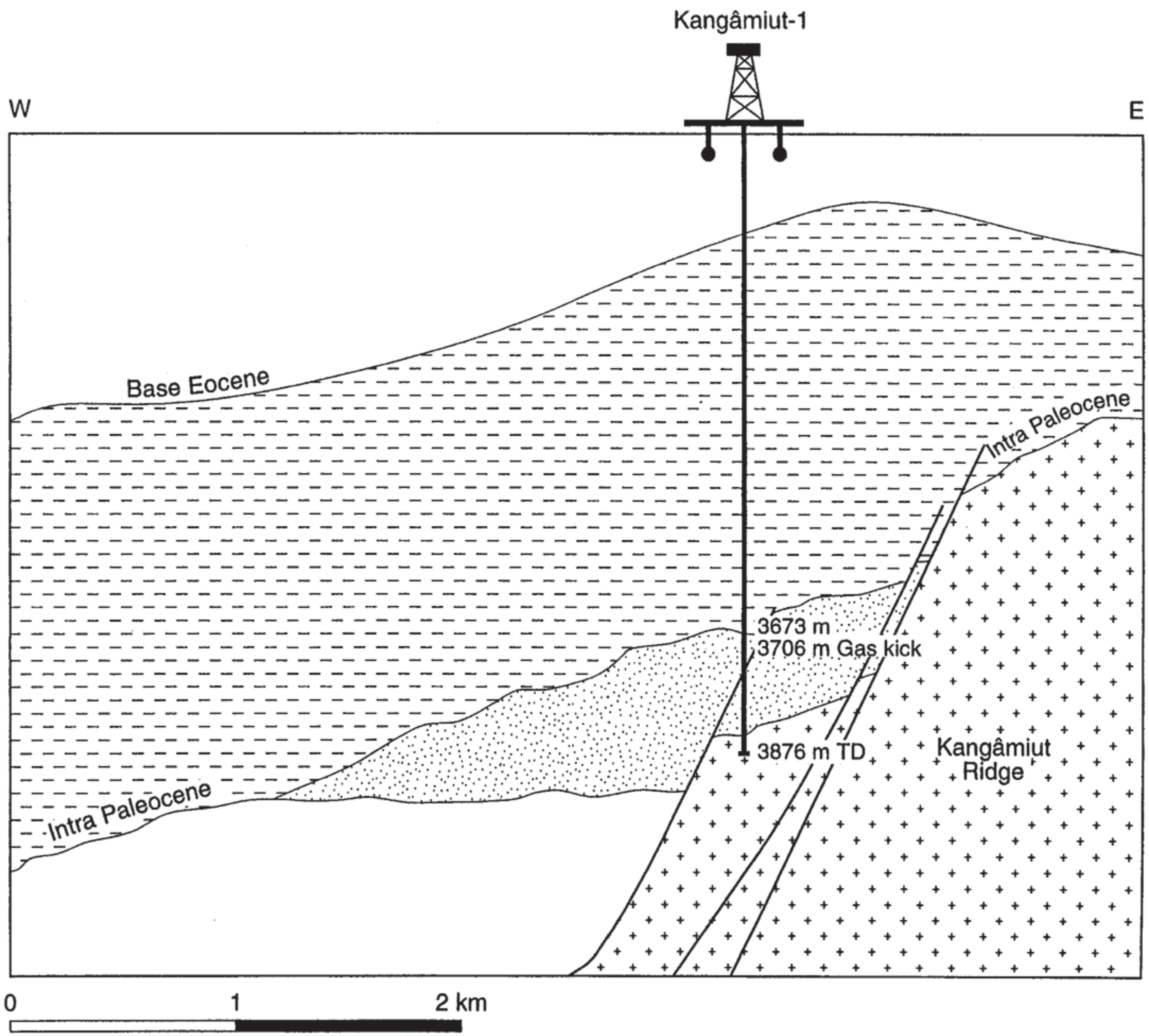



Fig. 6. Schematic representation of the interpreted fan in the basal section of Kangâmiut-1