The nature of the basal section in the Kangâmiut-1 well, offshore West Greenland

James A. Chalmers

Open File Series 92/9

December 1992

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

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The nature of the basal section in the Kangâmiut–1 well, offshore West Greenland

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Abstract

Interpretation of the deepest section of the Kangâmiut–1 well, offshore southern West Greenland, is of importance for its evidence about both the tectonic development and petroleum prospectivity of the area. Previously confidential oil company documents in GGUs' archives are now open for access. Two of these documents contain formerly unpublished interpretations which suggest either that the interval previously interpreted as basement "wash" over weathered basement may be a fanglomerate over weathered basement or that it and the section previously interpreted as weathered basement may in fact be a fanglomerate.

Introduction

The Kangâmiut–1 well was drilled as an oil exploration well offshore southern West Greenland in 1976 at 66°09'01"N, 56°11'24"W. The well was drilled by a group of concessionaires who held licence no. 34 and the operator was Total Grønland Olie A/S. Other partners in the concession were Gulf-Oil Canada-Greenland A/S, Aquitaine Denmark A/S and Greenland Petroleum Consortium (Grepco) K/S.

The interpretation of the basal section of the Kangâmiut–1 well that is normally cited was given by Manderscheid (1980) and Rolle (1985). Both of these authors interpret basement from 3700 m to TD at 3874 m. Rolle (1985) describes this as being overlain by 26 m of sediments containing coarse arkose interbedded with carbonaceous shales which he named the Narssarmiut Formation. Manderscheid (1980) describes the section from 3688–3700 m as "Conglomerate, very coarse, debris composed of gneissic basement, metadolerite and black organic shale". This coarse clastic section is in turn overlain by the mudstones of Rolle's (1985) Ikermiut Formation. Rolle (1985) dates the Narssarmiut Formation as Campanian on the basis of dinoflagellates, but Manderscheid (1980) includes the section from 3688–3700 m (KB) in the lowest part of a section he dates as "Lower Eocene shale and Paleocene (2625–3700 m)". Rolle (1985) also notes the presence of "a reworked Carboniferous assemblage" in the interval 3674 to 3700 m.

Chalmers & Pulvertaft (in press) showed that Kangâmiut–1 was the only well offshore West Greenland which had penetrated a possible hydrocarbon reservoir underlying a seal. They accepted Rolle's (1985) and Manderscheid's (1980) lithostratigraphy. However, Chalmers & Pulvertaft (in press) showed on a seismic section that Kangâmiut–1 had been drilled into a small fault block (rider) on the west flank of the Kangâmiut Ridge, and that a major fault exists up-dip of the well. The lack of hydrocarbons in the well could be explained by the seal being breached by this fault.

Chalmers & Pulvertaft (in press) also accepted Rolle's (1985) interpretation of the depositional environment of the Narssarmiut Formation, which is ..."During the Late Cretaceous most of the *(southern West Greenland)* region was transgressed, with the possible exception of the most positive areas, and the interbedded granite wash and black shale of the Narssarmiut Formation were deposited followed by regional sedimentation of the dark organic-rich shale of the Ikermiut Formation. There is no evidence of major differential movements at this time, but they are likely to have started towards the end of the Cretaceous."

There are two documents within GGU's archives that are relevant to the interpretation of the basal part of the Kangâmiut–1 well. Both documents were written during the 1970s, and are internal company reports. They were originally confidential, but are now held on open file in GGU. Both reports offer alternative interpretations of the basal section of Kangâmiut–1 from that presented by Rolle (1985).

The first report, dated 13 September 1976, is in the form of an internal memorandum within the oil company C.F.P (Compagnie Française des Pétroles (Total)) from F. Sommer in the laboratory in Bordeaux to M. Manderscheid. The original is in French, but a translation into English is offered here. This report describes the same lithostratigraphy as Manderscheid (1980) and Rolle (1985), but in the attached figure, Sommer interprets the Narssarmiut Formation as a syn-tectonic fanglomerate.

The second report is undated but was received by GGU archives early in April 1977. It is an anonymous internal report from the Gulf oil company who were one of Total's partners in the licence group that drilled Kangâmiut–1. This report suggests a very different lithostratigraphic interpretation of the basal section from those by Total, Manderscheid (1980) and Rolle (1985); that the arkosic fanglomerate section in Kangâmiut–1 stretches as far down as 3846 m (KB). The report and attached figure also mentions that hydrocarbon gases up to C_5 were encountered in porous zones in what has normally been interpreted as basement, but that water saturations are impossible to calculate in these zones since no resistivity log was run over this part of the hole. A DST was performed in the uppermost porous zone, and this flowed only water, but the lower porous zones interpreted by Gulf, and from which gas was measured in the drilling mud, were never tested. The Gulf report also quotes another report from Imperial Oil which dates the sediments at 3840 m as "Middle to Late Paleocene". This suggests that the palynomorphs used by Rolle (1985) to date the 3674 m to 3700 m interval as Campanian may be reworked. It is also possible, however, that the Middle to Late Paleocene palynomorphs at 3840 m may have been collected from cavings from higher in the hole.

The implications of the interpretations presented here are that the section below 3674 m in the Kangâmiut–1 well may be a fanglomerate deposited during an episode of fault activity in the Paleocene. Chalmers (in press) has used seismic stratigraphy to identify a Paleocene tectonic episode farther southeast and suggested that the western flank of the

Kangâmiut Ridge could also have been affected by fault movement at this time, and in particular that the fault east of the Kangâmiut–1 well could have been active during the Paleocene. This tectonic episode could also be the same as one known from onshore West Greenland (Rosenkrantz & Pulvertaft, 1969; Pulvertaft & Chalmers, 1990; Christiansen *et al.*, 1992), onshore Baffin Island (Burden & Langille, 1990) and from the Bylot Island area (Miall *et al.*, 1980). This episode of tectonism may also be related to the onset of sea-floor spreading in the Labrador Sea, which is now believed to have commenced during the Paleocene (Chalmers, 1991; Chalmers *et al.*, in press).

In view of the importance of the lowermost section of the Kangâmiut–1 well in the interpretation of the history and petroleum prospectivity of the West Greenland Basin, it is felt necessary to make these interpretations available to a wider audience than they hitherto have been.

The original reports are reproduced with the spelling and grammar of their authors. Additions by Chalmers are given in parentheses and italics. The attached figures were not in a suitable form for reproduction and they have been redrawn but retain the original content.

Acknowledgments

I wish to thank Jan Escher for help with the French translation and Chris Pulvertaft for general comments.

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Memorandum

Expediteur: F. Sommer (TEP/DE/LAB.)
s/c. Monsieur Rouge
Destinateur: M. Manderscheid (Total Groenland)
cc. M. Jacque (TEP/DE/BBF)
M. Bousquet (TEP/DE/LAB)
Bordeaux, le 13 Septembre 1976

PETROGRAPHIE DU FOND DU PUITS DE KANGAMIUT

LE SOCLE : 3692 m - 3873 m.

Le socle se subdivise en deux ensembles :

a - **de 3692 m à 3840 m** : c'est une série gneissique dont une constante est la richesse en apatite et la quasi absence de micas. Cet ensemble est différement altéré sans doute selon des directions d'anciennes zones de fracture et de diaclases. Ainsi, certains niveaux sont altérés principalement en kaolinite, donnant un aspect d'argile blanche gréseuse (type clab no. 1). Cette altération a respecté intégralement l'architecture de la roche; par conséquent, aucun phénomène sédimentaire n'est entré en jeu. L'altération s'est faite in situ.

D'autres zones sont entièrement illitisées, selon les mêmes principes. On note alors une forte augmentation du gamma ray. Dans d'autres niveaux encore prédomine la chlorite.

Toutes ces zones altérées sont characterisées par un sonic relativement lent. Les niveaux où les feldspaths sont plus frais ont un sonic plus rapid : ex. clabs 16 - 15 - 13 - 12.

D'autres niveaux se distinguent dans cet ensemble gneissique ; ce sont les zones mylonitisées comme celle où est prélevé le clab 9 ou celle située entre 3810 m et 3835 m ; les fractures remplies de calcite s'observent à différentes échelles de grandeur, certaines recoupant les cristaux, d'autres beaucoup plus grandes pouvant atteindre un centimètre de diamètre.

b - **de 3840 m à 3873 m** : nous sommes en présence d'une unité métamorphique différente : au matériel quartzo-feldspathique s'ajoute des minéraux tels que grenats et amphiboles. Cette série paraît relativement plus saine (moins altérée) et plus compacte.

En conclusion, le socle rencontré paraît provenir du métamorphisme d'une série sédimentaire, marneuse à la base (donnant des charnockites et éventuellement des amphibolites), plus gréseuse vers le haut (donnant le gneiss). Cette série métamorphisée a été ensuite tectonisée par une phase ancienne. L'exposition de ce socle aux agents atmosphériques a favorisé l'installation d'un réseau de diaclase, et la décompression de la roche, l'infiltration des eaux méteoriques donnant une altération du type kaolinitique. L'illitisation est sans doute très récente et correspond à l'envahissement de ce socle fracturé, altéré et légèrement poreux, par les eaux connées, salées, expulsées des sédiments marins en contrebas.

LES PREMIERS SEDIMENTS

De 3673 m à 3692 m se trouve une série pour laquelle on ne dispose que de rares renseignements et de mauvaise qualité de surcroît.

Les clabs en effet sont composés d'un agglomérat de cuttings provenant de niveaux très divers sus-jacents ou sous-jacents. Le premier clab (en descendant) qui semble avoir pénétré la roche en place semble être le clab 25 (voir description des clabs).

Les cuttings montrent l'apparition des premiers morceaux de socle vers 3668 m. Il s'agit de morceaux de formes quelconques (cuttings) ressemblant en tout point au socle gneissique sous-jacent avec le même degré d'alteration. Cette apparition précoce peut être due à un mauvais calcul du temps de remontée des cuttings, si on les rapports au niveau situé à 3675 m. Vers 3675 m, et jusque vers 3680 m, ces morceaux de socles prédominent dans les cuttings.

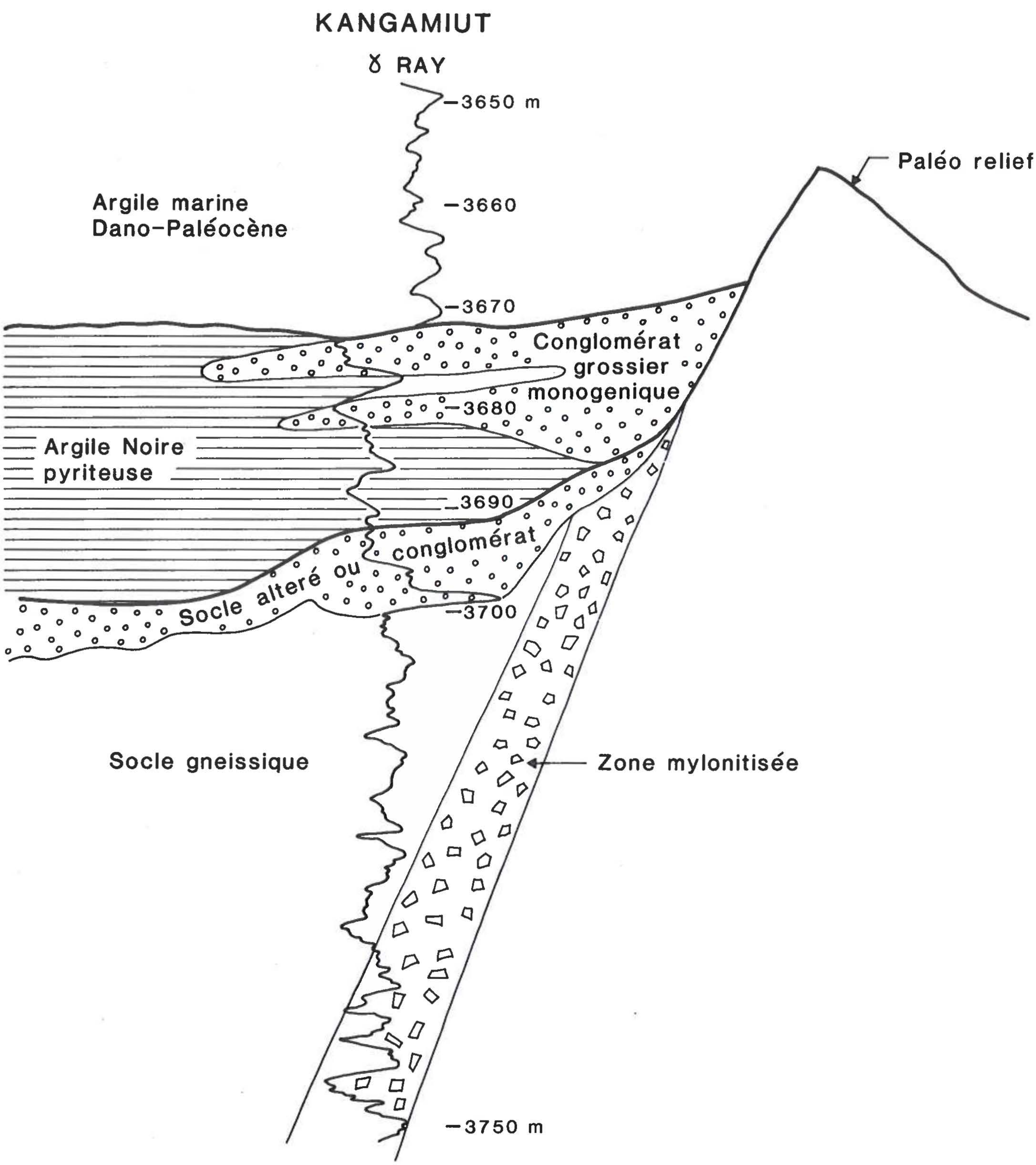
Vers 3684 m et jusque vers 3690 m, les débris de socles diminuent et à côté des retombées de gros débris d'argile brune très finement silteuse des séries feuilletées supérieures, apparaissent des débris d'argile silreuses à finement gréseuses gris-noirâtres, pyriteux, très riches en matières organiques noires. Ces débris enfin disparaissent vers 3690 m et vers 3699 m, les débris de socle gneissique sont à niveau largement prédominants.

En conséquence, la succession lithologique de cet intervalle pourrait être la suivante :

3700 - 3690 m : socle gneissique très altéré; éventuellement arène en boule pour expliquer le cavage.

3690 - 3682 m : argile silteuse à finement gréseuse, pyriteuse, très riche en matière organique.

3682 - 3673 m : passées de conglomérats monogéniques à débris de socle gneissique séparées par un niveau argileux. Le fait de n'avoir jamais trouvé dans les échantillons de grains de quartz isolé ou de feldspath isolé, ou de petits grains de socle roulés nous fait penser à des conglomerats à éléments relativement grossiers.


KANGAMIUT
γ RAY
−3650 m
−3660
−3670
−3680
−3690
−3700
−3750 m
Paléo relief
Argile marine
Dano-Paléocène
Conglomérat
grossier
monogenique
Argile Noire
pyriteuse
Socle alteré ou conglomérat
Socle gneissique
Zone mylonitisée

Informal translation into English of the memorandum by F. Sommer (Total/C.F.P. Laboratories, Bordeaux) and addressed to G. Manderscheid (Total Greenland). The memorandum is dated 13 September 1976.

PETROGRAPHY OF THE BASAL SECTION OF THE KANGÂMIUT-1 WELL

THE BASEMENT : 3692 m - 3873 m

The basement can be subdivided into two units :

a - from 3692 m to 3840 m : This is a gneiss series all of which is rich in apatite and from which micas are nearly absent. This unit is differentially altered undoubtedly along the ancient fracture and joint zones. Thus, particular levels are altered mainly to kaolinite, which gives an appearance of sandy, white mudstone (type side-wall core no. 1). This alteration has completely followed the structure of the rock; there is thus no sedimentary phenomenon acting here. The alteration has happened in situ.

Other zones are entirely illitised due to the same causes. In these, a large rise in the gamma log is noted. At other levels, chlorite predominates.

All the altered zones are characterised by a relatively slow sonic *(log)*. Where feldspars are fresher, the sonic *(log)* is faster, e.g. side-wall cores 16 - 15 - 13 - 12.

Other levels can be distinguished in this gneissic section. These are the mylonitised zones, where side-wall core 9 was collected, or the zone situated between 3810 m (KB) and 3835 m (KB). Fractures filled with calcite are observed at different scales, some cutting through crystals and others as much as a centimetre across.

b - from 3840 m to 3873 m : this is quite a different metamorphic unit; of quartzo-feldspathic material enriched by minerals such as garnet and hornblende. This series appears relatively fresh (less altered) and more compact.

In conclusion, the basement appears to consist of a metamorphosed sedimentary series, marly at the bottom (revealed by charnockites and perhaps by amphibolites), sandier towards the top (shown by the gneiss). This metamorphic series has been tectonised in situ during an ancient event. The exposure of this basement to atmospheric action has encouraged the appearance of a joint system and the decompression of the rock, the infiltration of meteoric water has resulted in kaolinite alteration. The illitisation is undoubtedly very recent and corresponds to the invasion of the fractured, altered and somewhat porous basement by salty connate water expelled from deeper-lying marine sediments.

THE FIRST SEDIMENTS

From 3673 m to 3692 m (KB) is found a series about which only rare indications of extremely poor quality can be found.

The side-wall cores are composed of an agglomerate of cuttings of very diverse origin derived from both above and below. The first side-wall core (from the top) which appears to have penetrated "rock-in-place" appears to be no. 25.

The cuttings show the appearance of the first basement fragments around 3668 m (KB). They consist of fragments which entirely resemble the various forms of underlying gneissic basement with the same degree of alteration. This early appearance is perhaps due to a poor estimate of the time necessary to circulate the cuttings *(up to surface)* from the 3675 m (KB) level. From 3675 and down to 3680 m (KB) the cuttings consist predominantly of basement fragments.

From 3684 m and down to 3690 m (KB) the amount of basement debris decreases and apart from caved debris of very fine, silty brown mudstone from the upper slaty series, *(there is also)* the appearance of mudstone debris *(which is)* silty to fine grey-black sandy, pyritic, and very rich in black organic material. This debris finally disappears between 3690 m and 3699 m (KB), *(where)* the gneissic basement debris once again predominates.

Consequently, the lithological succession of this interval could be as follows :

3700 m - 3690 m (KB) : very altered gneissic basement; possibly exfoliation explains the caving.

3690 m - 3682 m (KB) : mudstone, silty to fine sandy, pyritic, very rich in organic matter.

3682 m - 3673 m (KB) : sections of monogenetic *(oligomict?)* conglomerate *(consisting)* of gneissic basement debris separated by a mudstone interval. The fact of never having found in the samples any trace of isolated quartz grains or feldspar grains or small rounded grains of basement makes us think that the conglomerates are relatively coarse.

Interpretation of the Basal Section
Kangâmiut No. 1 Well
(Anonymous internal report from the Gulf oil company)

INTRODUCTION

The accompanying stratigraphic column with gamma-sonic log illustrates the differences between the Gulf and Total interpretations of the basal section in the Kangâmiut well. Gulf's interpretation places 564 feet (172 M) of strata in the basal sedimentary section and Total interprets 79 feet (24M) of sediment above a thick (502 feet or 153 M) altered basement. The identification of true granitic basement when it is overlain by arkosic sediments is an old recurring problem in the oil industry. Pettijohn's comments regarding a similar but slightly different problem to ours seems appropriate:

> "In some cases the granitic residuum is so little reworked and so little decomposed that upon cementation it looks very much like granite itself. It is then termed a "recomposed granite". Such rocks may be readily misidentified. This is a 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"."
> Pettijohn, Sedimentary Rocks; Page 259.

We regard the interval from 3692 to 3845 M to be sedimentary and not insitu *(sic)* altered basement and will present our reasons for this interpretation.

Arkoses and granite "washes" genetically fall into two types,
(1) residual or basal arkoses which are thin and small in areal extent and
(2) tectonic arkoses which are thick and more extensive.

Thick tectonic arkoses are rapidly accumulated wedge shaped deposits associated with strongly uplifted granitic massifs. The Kangâmiut well is located on the western flank of a high relief

Precambrian gneissic basement fault block which is the ideal environment in which one would expect to find a thick wedge of basement derived clastics. The central Precambrian gneissic basement core of the Kangâmiut structure had a relief of at least 5,000 feet (1524 M) above the surrounding area. On high relief structures, erosion often interrupts the process of weathering. Weathered and variably altered material becomes stripped off periodically to become deposited and interbedded with coarser slightly to non-altered products and the fault controlled canyons and stream channels contribute coarse fresh materials. This results in a variable sedimentary wedge of extremely altered to fresh gneissic rock occurring in beds of no set order and with all degrees of intermixing. Quartz rich sands and clay beds, products of extreme weathering can occur with coarse conglomeratic little altered igneous material. The single most important result of this granite weathering process is the enrichment of the newly deposited sedimentary wedge in quartz. There is very minor transport of materials a few miles or less and consequently, quartz grains are generally angular. Bedding in the wedge deposit is high angle generally, probably greater than 30 degrees.

A residual or basal arkose differs from a tectonic arkose in that it exhibits extreme weathering at the surface which gradually diminishes with depth to the fresh unaltered basement.

The above paragraphs briefly outline some of the basic characteristics of tectonic arkose wedge deposits which are important to interpretation.

DETAILED INTERPRETATION OF THE BASAL SECTION (3674-3845 M)

The Kangâmiut well has an extremely variable sequence of quartz rich sand, felspathic *(sic)* sands, arkose, clay and coarse conglomeratic variably altered gneissic materials 564 feet (172 M) thick which has many of the attributes of a tectonic arkose wedge deposit. The variability of the section is apparent by the response of the gamma and sonic log curves, by the variable penetration rate during drilling and the bore hole cuttings which are all indicative of lithologic changes that can be attributed to bedding. There is good correlation of quartz rich sands in samples with the drilling breaks and the porosity indicated by the sonic log which cannot be a mere coincidence.

In detail the section from the base upwards consists of a gneissic igneous conglomeratic basal bed 3846 to 3837 M lying on the dark green amphibolite dike. The basal sequence grades upwards to a thick quartz rich, clayey and variably feldspathic sandstone sequence (3837-3790 M) with porous zones and scattered conglomerate beds. Two quartz rich sandstones 3832 to 3837 M and 3825 to 3830 M are separated by a tight coarse grained igneous rich conglomeratic bed. The sonic log indicates these quartz rich sands to be porous and the drilling mud-log shows a drilling break that exactly corresponds to the porous zones indicated on the sonic log. In addition, there is an increase in methane gas and other hydrocarbon C_2 and C_3 in the mud as the two zones are penetrated reaching a peak of 4.8% methane opposite the lowest porous zone. The vacuum mud sample at 3823 M, prior to penetrating the zones, had a methane reading of 1.74%. The water saturation cannot be calculated because a resistivity log was not run over this part of the hole. The high quartz content of the porous sands indicates that enrichment has occurred by weathering and decomposition of igneous material. The percentage of quartz is so high (up to 90%) that it could not possibly be solely from the in situ altered gneiss. Many of the quartz grains have clear euhedral pyramidal crystal overgrowths which probably developed in a porous open framework which allowed crystal terminations to form. The quartz from in situ altered gneissic rocks would not be of this type.

Another similar quartz-rich zone occurs between 3810 and 3817 M. The sands are variably clayey with some porosity indicated on the sonic curve and this zone has a drilling break associated with it. Other clayey sands occur upwards to 3790 M. At 3800 M a dolomitic sandy zone is present.

The interval from 3790 to 3727.5 M is predominantly coarse conglomeratic arkose rich in gneissic rock fragments variably altered and non-porous with the exception of a sand and clay interval from 3760 to 4775 which has indications of porosity.

Samples in the basal part of this interval are extremely poor. Clayey sand and a dolomitic zone occur from 3760 to 3765M.

The remaining section from 3727 to the top of the basal sand and arkose wedge or base of the overlying dark grey to black shales is medium to coarse sands variably feldspathic. Samples are poor mainly dark grey to black shales with scattered quartz grains where the hole is washed out from 3678 to 3696 M. No samples are available from 3702 to 3711 because of the gas kick and irregular circulation. The sands of this interval are predominantly quartz and an abundant number of the grains have euhedral quartz overgrowths and white secondary clay adhering to them suggesting a porous open framework. This interval is enriched in quartz over what would be expected from the drilling up of in situ quartz feldspar gneiss. Porous sand estimates are optimistic over the washed out interval where the logs are unreliable.

PALYNOLOGY

Palynology studies carried out by Imperial Oil indicate an increase of pollen and spores in the basal sand and arkosic section. Imperial regards the basal section as sedimentary and dates the sediments at 3840 M as Middle to Late Paleocene.

SIDEWALL CORE THIN SECTIONS

The coarse feldspars and gneissic rock fragments present in three main zones (coloured orange) *(reference not understood)* and in other scattered thinner zones probably occur as pebbles and perhaps boulders. Actual size of pebbles contributing the coarse feldspar rich arkosic material cannot be determined from cuttings. A great deal of emphasis has been placed on thin sections made from sidewall cores in the interpretation of in situ altered gneissic basement. Many of the sidewall cores were taken opposite sections of the hole where samples indicate coarse gneissic and feldspar fragments. These cores could be sampling pebbles or boulders. Some of the thin sections can be interpreted to be sedimentary with large fragments of altered gneiss in a clayey sandy matrix. (See attached memo with photographs by M. Lerand.)

The thin sections show a wide degree of alteration with no set pattern with depth. A normal weathering profile from extremely altered to fresh material is not present. The depth and degree of alteration of some of the thin section *(sic)* is as follows:

3744 M	Little alteration
3765 M	Completely altered
3790 M	Completely altered
3830 M	Fresh unaltered
3835 M	Completely altered

The variability in alteration suggests a tectonic arkosic wedge in which weathered basement materials are stripped off at various stages of decomposition and redeposited.

CONCLUSIONS

The interpretation of the basal section in the Kangâmiut well has an important bearing on our exploration of the Greenland concessions. We have presented the reasons for interpreting the section from 3692 M to 3845 M as sedimentary rather than in place altered gneissic basement. The gross sand and arkose wedge thickness is 564 feet (172 M). The total "sand" including sand, arkose, and coarse conglomeratic gneissic rock fragments is 318 feet (97 M) of which the total porous section with greater than 10% porosity is optimistically placed at 174 feet (53 M). These porous sands are prospective potential reservoir beds which have not been evaluated on the "K" structure.

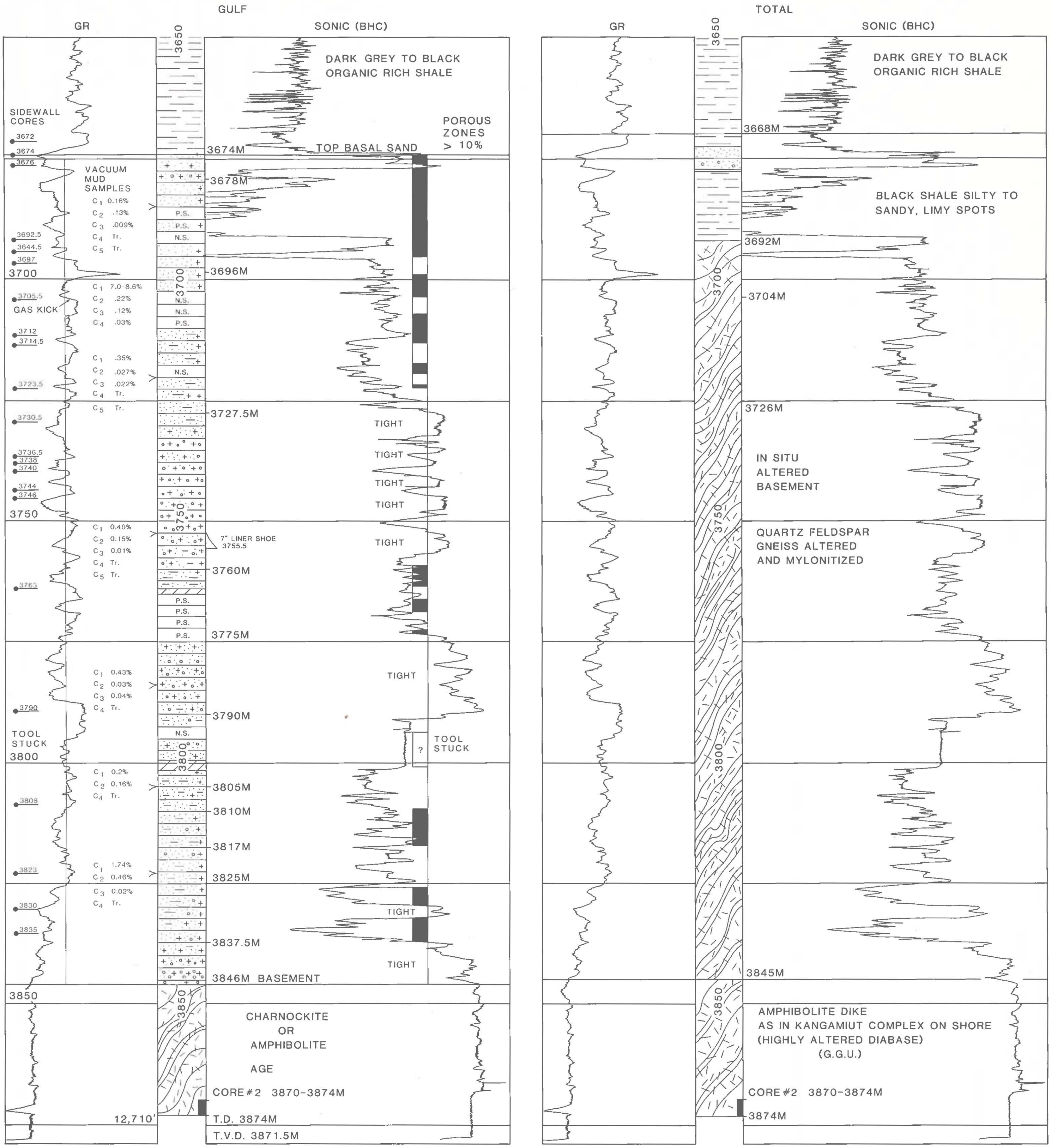
Although arkoses tend to be not highly regarded as reservoirs because of associated clays, quartz sands do occur in this environment and a number of major oil and gas accumulations have been found. The Amal-Nafoora-Augita Field in the Sirte Basin, Libya, has recoverable reserves of 5.2 billion barrels. The Panhandle Field, Texas, has recoverable reserves of 1.65 billion barrels of oil and 30 TCF of gas.

Figure:

Stratigraphic Column Interpretation of Basal Section

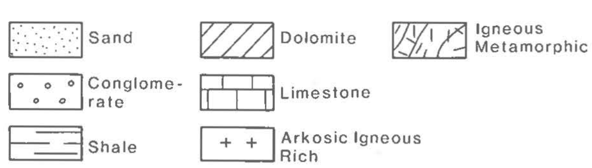
KANGAMIUT NO. 1

INTERPRETATIONS OF BASAL SECTION



BASAL SAND (GULF)

GROSS THICKNESS	564'	(172 M)
TOTAL SAND	318'	(97 M)
POROUS SAND >10%	174'	(53 M)



BASAL SAND (TOTAL)

GROSS THICKNESS	79'	(24 M)
TOTAL SAND	16'	(5 M)
ALTERED BASEMENT	502'	(153 M)

Addendum:

Sediment-Basement Contact in Kangâmiut No. 1 Well, with photographs of thin sections.

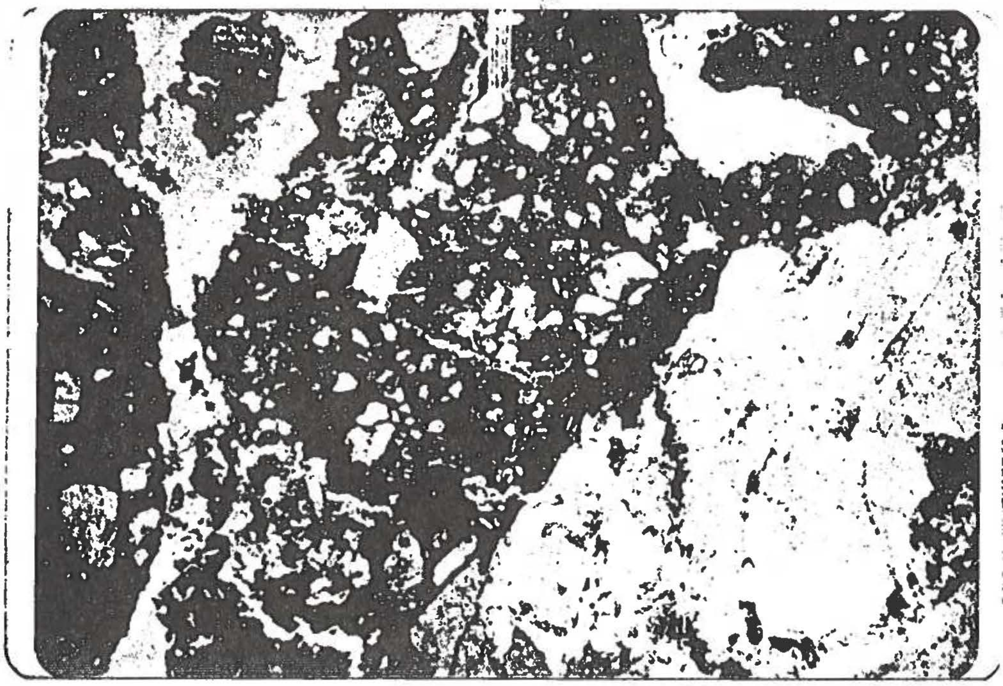
SEDIMENT-BASEMENT CONTACT IN THE WEST GREENLAND KANGAMIUT NO. 1 WELL AS INTERPRETED FROM THIN SECTIONS

Thin sections prepared by Total from cores recovered from the West Greenland Kangâmiut No. 1 well have been briefly examined with a view to identifying a change in lithology which might be interpreted as representing the contact between overlying sedimentary rock and underlying basement rock.

A major change in lithology occurs between depths of 3830m and 3870m (Figs. 1, 2). Thin sections from 3870m and deeper are all characterized by the presence of very thin veinlets filled or lined with chlorite. The best rock is highly altered and the crystalline texture indicates it belongs to a metamorphic or igneous basement complex. The thin section from 3830m in contrast, appears to possess a clastic texture and lacks chlorite veinlets as do all thin sections above 3870m. The slide contains areas of dark silty and sandy clay that is tentatively interpreted as the matrix of a very coarse grained, very poorly sorted, possibly conglomeratic sediment. The coarser components are somewhat similar to parts of the underlying basement rock. It could be argued that the rock at 3830m is not sedimentary and that the sand, silt and clay size material originated in a shear zone and is really a cataclastic. Alternatively, the inferred sedimentary material could have filtered down into fissures in weathered basement. In the absence of other supportive data, the more optimistic interpretation of a sedimentary origin of the rock at 3830m is preferred.

A thin section from 3835m was not readily identifiable as to texture and origin, but it lacks chlorite veinlets and may be of sedimentary origin. At 3790m a thin section contains what appears to be an elongate, rounded zircon grain which would suggest a sedimentary origin. Slides from 3692.5m and 3697m consist of silty claystone bearing some resemblance to the finer material at 3830m.

It is concluded that the major change in lithology between depths of 3830m and 3870m probably represents sedimentary rock above and crystalline basement rock below a contact that lies somewhere in the 40m interval between. The interpreted sedimentary section appears to be composed of siliceous very coarse grained, possibly conglomeratic, detritus derived by erosion from a source similar to the underlying basement rock.



3830 m

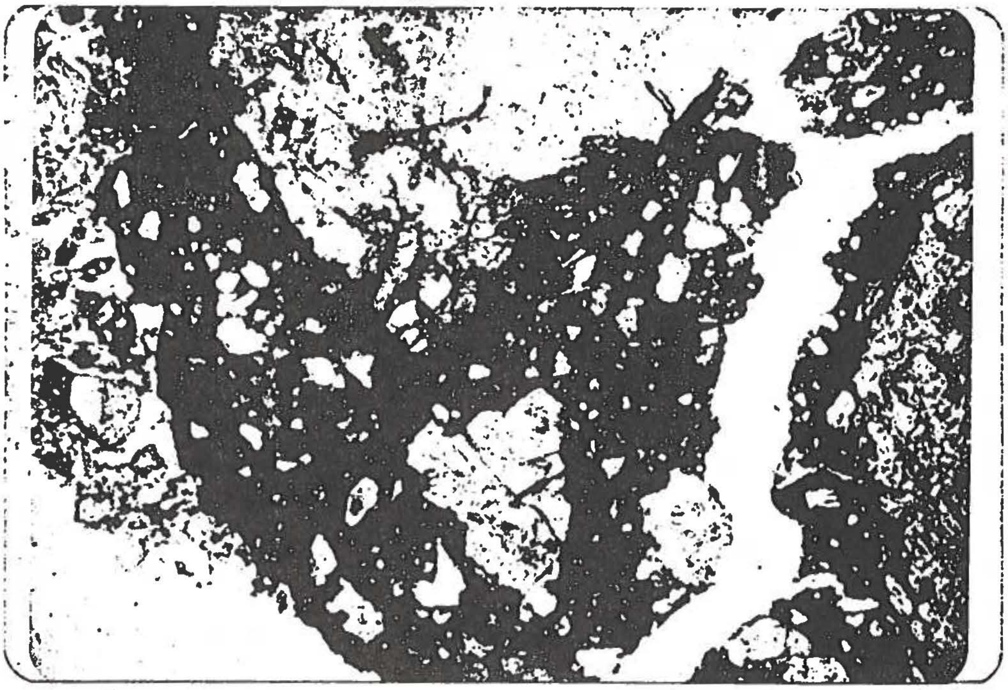
SEDIMENT

BASEMENT

3870 m

Mag. approx. X10

FIGURE 1



3830 m

SEDIMENT

BASEMENT

3870 m

Mag. approx. X10

FIGURE 2

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