The Facies of the Ivishak Formation from conventional core descriptions, electric logs, and petrographic thin sections as determined by U. S. Minerals Management Service from the following exploratory-well cored intervals:

Amoco Production No Name Island No. 1 (13,896' – 13,866'),
Amerada Hess Corp Northstar No. 1 (11,217'-10,999'),
Sohio Alaska Petroleum Reindeer Island Strat Test No. 1 (12,350' – 12,085'),
Shell Western E & P Inc. Seal Island BF-47 No. 1 {Seal Island A-1} (13,080'-12,674'),
Shell Western E & P Inc. Seal Island BF-57-1 {Seal Island A-3} (14,741'-14,475'),
Shell Western E & P Inc. OCS Y-0181-1 {Seal Island A-2} (12,872'-12,301),
Exxon Company USA OCS Y-0280-1 {Antares No. 1} (8,388'-8,110'),
Exxon Company USA OCS Y-0280-2 {Antares No. 2} (11,450'-11,050'),
Sohio Alaska Pet. Co. OCS Y-0334-1 {Mukluk No. 1} (8,145'-7,401'),
Tenneco OCS Y-0338-1 {Phoenix No. 1} (8,543'-8,040'),
Shell Oil Company OCS Y-370-1 {Sandpiper No. 1} (12,118-11,804'), and
Amoco OCS Y-0371 {Sandpiper No. 2} (14,484'-14,381').

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THE FACIES OF THE IVISHAK FORMATION FROM CONVENTIAL CORE DESCRIPTIONS, ELECTRIC LOGS AND THIN SECTION PETROGRAPHY

Facies and Depositional Environments

Continuous cores throughout portions of the Ivishak Formation from seven federal and five State of Alaska exploratory wells in the Beaufort Sea between 153 and 148 degrees west longitude form the basis for this study. These wells and their cored intervals are listed below in table 1. These wells are located on a regional map of the Beaufort Sea in figure 1.

WELL NAME AND OCS #	CORED INTERVAL (MD)	FORMATIONS ENCOUNTERED	IVISHAK STRATIGRAPH IC ZONES
REINDEER ISLAND	12,350-12,085	KAVIK, IVISH AK	1,2,3
NO NAME ISLAND	13,896-13,866	IVISHAK	1
NORTHSTAR, BF46#1	11,217-10,999	IVISHAK, SHUBLIK	3
SEAL ISLAND BF-47#1	13,080-12674	IVISHAK	1,2,3
SEAL ISLAND BF-57 #1	14,741-14,475	IVISHAK	3
SEAL ISLAND OCS#-0180			
SEAL ISLAND OCS#-0181	12,872-12,468 12,468-12,301	IVISHAK, SHUBLIK	1,2,3
MUKLUK, OCS#-0334	8145-7401	LISBURNE, ECHOOKA KAVIK IVISHAK	1,2,4
PHOENIX OCS# 0338	8543-8040	IVISHAK SHUBLIK	1,2,4
ANTARES OCS# 0280 #1	8388-8110	IVISHAK	1,2,4

ANTARES OCS# 0280 #2	11,450-11,050	IVISHAK	1,2,4
SANDPIPER OCS# 370 #1	12,118-11,804	IVISHAK	1,2,3
SANDPIPER OCS# 0371 #2	14,484-14,381	IVISHAK	1,2,3

Table 1- A listing of State of Alaska and Federal OCS exploration wells in this study, and the zones penetrated from conventional coring

Ten lithofacies for modern and ancient braided stream environments were established by Miall in 1977. These lithofacies were modified by Atkinson, Trumbly and Kremer, 1988 to incorporate the lithofacies found in the Prudhoe Bay Field of the North Slope of Alaska (Table 1). These individual facies were then grouped into a vertical sequence of facies associations (I-XII) which defined specific depositional subenvironments (table 2). These subenvironments were packaged into distinct broad depositional systems of zones 1-4. These depositional systems include from the base of the Ivishak to the top: constructive deltaic-marine sands and shales of zone 1; Braidplain-advance, lower to middle aggrading, stacked and fining upwards channel sandstones of zone 2P; upper braidplain, alluvial fan dominated conglomerates and conglomeritic sandstones of zone 3: fluvial retreat middle to predominately lower braidplain fining upwards channel sequences of zone 2R, and shallow marine and shoreline transgressive sandstones of zone 4 (figure.).

The depositional history of the Ivishak Formation was controlled by localized tectonic events which had a controlling affect on the deposition of the various depositional zones and facies associations. This, in turn, had a direct affect on the reservoir quality of the originally laid-down sandstones.

Thus, general subsidence which took place during the progradation of the very fine to medium grained sandstones of zone 1, was abruptly accelerated, and followed by a major drop in base level, which led directly widespread deposition of medium to coarse grained aggrading fluvial sandstones. These sandstones of Zone 2p display the best reservoir characteristics, having the highest porosities and permeabilities, and very high lateral and vertical connectivity. The highest reservoir connectivity probably occurs within the alluvial fan conglomerates at the top of zone 3. These deposits mark the cessation of tectonic uplift. The culmination of tectonic uplift brought about a relative rise in sea level, and widespread deposition of floodplain deposits.

ZONE 1

Zone 1 is a regressive sequence of delta front, interbedded sandstones, siltstones and mudstones found at the base of the Ivishak Formation. Zone 1 as described by Atkinson and others (1988), consists of a coarsening and cleaning upwards succession of interbedded sandstones and shales ranging in thickness between 80 and 150 feet. The base of Zone 1 is conformably transitional with the underlying interbedded prodelta and marine sandstones and shales of the Kavik Formation, except where it is truncated by an unconformity with the pre-Mississippian argillite basement. The top of Zone 1 consists of non-marine, lacustrine delta-fill deposits of red siltstones and mudstones. Internally, zone 1 consists of three facies, X, IX, and VIII, associated with lower and subaqueous delta-plain environments. The lower delta-plain environment resides within the portion of river-marine interaction extending from the shoreline to the landward extent of tidal influence.

Subenvironments within the delta front include interbedded sandstones, siltstones and shales of the distal bar (facies X), distributary mouth bar (facies IX), channel (facies VIII), subaqueous levee, marsh, and interdistributary bay deposits (facies VII).

The entire section of zone 1 strata was cored only in the Mukluk exploratory well. Other wells in the study area core only portions of zone 1 strata. The facies of Zone 1 were determined from the combination of electric log character, bedding characteristics and lithologies from conventional cores, and petrographic examination of thin sections. Core chips from each facies of Zone 1 were thin sectioned to determine the framework minerology, cement types, degree of sorting, and diagenesis.

The thickness of zone 1 ranges between 80 and 160 feet. The thickest section of zone 1 strata occurs within the Mukluk exploratory well, where it is transitional into the Kavik Shale. The conventional cores from zone 1 consists of massive to thin bedded sandstones. Internally, the bedding changes from interlaminated mudstone, siltstones and sandstones that display cross-ripple laminations at the base of zone 1 to massive (Sm), parallel laminated (Sl), and crossbedded sandstones (Sx) at the top of zone 1. Ripple laminations are more common in the fluvial-marine transitional interval between the Kavik Shale and the Ivishak Formation. The more massive and crossbedded sands are more common in the upper fluvial dominated interval of zone 1.

Petrographcally, zone 1 coarsens upward from a very well sorted, silty, very fine-grained, quartz-rich, sandstone of facies X, to a moderately well sorted fine to medium-grained, clean, quartz, chert sandstone of facies VIII.

The Antares OCS-Y-0280 #1 exploratory well was drilled about 40 miles west,northwest of the Mukluk exploratory well. Here the base of the Ivishak Formation rests unconformably upon the Pre-Mississippian argillite basement, and may be conformable with the overlying early Triassic Shublik Formation. Continuous conventional cores were examined from the argillite basement to the Shublik Formation with the exception of a small interval at the top of zone 1, facies association VIII, which was sampled from sidewall cores.

Examination of whole core, thin sections from sidewall cores, and electric logs showed that zone 1 consists of facies IX and VIII. The lower-most facies X appears to be missing from zone 1, as evident from the unconformity that resides as a rubble zone at the base of zone 1. The whole core shows that facies IX lies unconformably upon the argillite basement and consists of interlaminated (Sl) dark and light grey sandstones (figure.). Thin sections from the core show a very fine to fine grained well sorted sandstone (figure). The top of facies IX is massive (Sm), and is light grey in color, except for thin interbeds of the underlying facies (Sl). The upper most facies of zone 1, facies VIII was sidewall cored. Thin sections from this interval show a poor to moderately sorted fine to medium grained sandstone.

Framework Mineralogy

The framework minerology of zone 1 is predominately made up of monocrystalline quartz which ranges between (30-50%), polycrystalline quartz in percentages of less than 5%, chert which ranges between 5 and 20% and sedimentary rock fragments between 2 and 18% (fig.). There is a gradual increase in the percentage of chert, polycrystalline quartz and sedimentary rock fragments from the base to the top of zone 1. (fig.334fmz1.lin; phxmin). The ratio of the percentage of quartz/chert decreases from a high of 10/1 at the bottom of zone 1 to a low of 3/1 at the top of the zone. The mean grain size for quartz changes from very fine to fine at the base of zone 1 to fine to medium and sometimes to coarse at the top of zone 1.

Cements and Matrix

In the Mukluk explorartory well, the interstices between the framework grains are partially filled with undifferentiated clay, clay rip-up clasts, authigenic kaolinite, quartz overgrowths, and primary ankerite and secondary siderite cements. The change in the percentages of these interstice-filling materials are found in figure . Undifferentied clay consists of a combination of clay, crushed chert, quartz and sometimes recrystallized cement. There is a significant decrease in the percentage of undifferentiated clay and siderite cement from the marine section of the Kavik Formation to the top of zone 1 of the Ivishak Formation. In zone 1 of the Antares well, ankerite is clearly the primary cement and siderite the secondary cement, partially replacing ankerite.

In the Antares #1 well, the dark grey, very fine grained sandstones of facies IX contains an abundance of matrix material that fills the interstices between the grains. The matrix material consists of crushed and degraded chert, quartz and clay. Ankerite and siderite cements are found within the groundmass. Ankerite is white and turbid and is the primary cement. Siderite is dark brown and is found replacing ankerite. The coarser laminations of fine grained sandstones contain reddish brown clay clasts that contain silt and very fine grained quartz and chert.

These data is reflected in the higher porosities and permeabilites found at the top of zone 1. Average core porosities range from a low of 11% to a high of 23%. Permeabilities measured from core in the Mukluk well range from a low of 0.18md in facies X to over 373md in facies VIII.

Facies X

Core Description

In the lower-most facies association X in the Mukluk well, a 40 foot thickening-upward sequence of interbedded sandstones and shales is transitional with the underlying Kavik Formation. The cored interval consists of medium to dark grey-brown, silty, very fine grained quartz-rich sandstones. The dominant facies are Sm, Sl, MSl, and Ml (table 3). Less important facies include MSr, MSd, and Sx. Current ripple cross-laminations are common in the transitional zone between the top of the marine Kavik Shale and the bottom of facies association X. These facies are much less important towards the top of facies association X where the depositional facies of Sm and Sl predominates. Carbonized plant debris are concentrated along thin laminae in facies Sl and MSl. The fine grained siltstones and mudstones (Ml and MSl) are located at the base of the thickening-upwards sequence.

In the Phoenix exploratory well, facies X was not cored although electric log characteric in that interval suggests this sandstone unit is present. Thirty miles to the west, in the Antares well, facies X is missing as facies IX lies unconformably upon the argillite basement.

A thin section cut from sandstone in the Mukluk exploratory well at

7953' is very well sorted, very fine grained and consists of 53% quartz, 23% clay, 3% shale fragments, 2% chert, and 10% siderite\ankerite cement. The sphericity of the quartz grains ranges between subangular to subrounded prior to the initiation of quartz overgrowths.

Diagenesis

Quartz grains display evidence of of pressure solution and subsequent corrosive dissolution. Pressure solution is evident from observing euhedral surfaces along grain boundaries and interlocking grains. The quartz grain boundaries have been partially replaced by ankerite cement and later dissolved by corrosive fluids. This process has been partially inhibited by the abundance of fine-grained material which had blocked the pathways of fluid migration. The chert grains are difficult to examine because they have been partially dissolved and replaced by clay and secondary ankerite cement. The abundant ductile shale fragments and undifferentiated clay are wrapped around detrital grains where they fill pore space and block pore throats.

The reservoir potential of facies X is poor, with average core derived porosities of 10% and permeabilities 0.32md in the Mukluk well. These low values are the result of the fine grained size, abundant interstial clay, quartz overgrowths and the addition of ankerite cement which has further reduced the porosity and permeability in facies association X.

Facies association X was deposited as Delta Front silts and sands. The depositional facies found within facies association X is represented by a set of thickening-upward shale to sandstone sequences that are more shaly at the base where they were dominated by the influence of the marine environment of the Kavik Shale as evident in depositional facies Ml and MSr. In comparsion, the top of facies X had a more predominate fluvial influence. These facies are represented by Sm and Sl.

Facies IX

Facies IX consists of massive to parallel laminated sandstones of depositional facies Sm and Sl (Tables 2 and 3). Some of these sequences contain coarse grained mudstone lag deposits at their base. The sandstones consist of thin, thickening upward sequences of very fine to fine grained quartz-rich sediments. Facies association IX is distinquished from facies association X by the absence of shale\siltstone beds of Ml, MSl, and the abundance of carbonaceous debris.

Within the Antares exploration well, dark grey, well sorted, very fine grained matrix-rich sandstones are interlaminated with light grey, well sorted fine grained matrix poor sandstones (Sl) at the base of the sequence whereas massive well sorted sandstones with scattered coarse clasts of triplitic chert are found at the top of the facies (Sm).

A thin section cut from core chips at 7887' in the Mukluk well consists of very fine to fine grained, well sorted, quartz-rich sandstone. The framework mineralogy consists of 51% quartz and 14% chert. The remainder of the sample consist of 29% light to dark brownish material, 3% carbonized plant material, 3% clay, and 2% ankerite cement. Quartz is predominately monocrystalline. The carbonacous debris is carbonized plant material and is typically found in very thin continuous to discontinuous laminae interlaminated with the sandstone of facies Sl (fig.).

The sample at 7887' has a core porosity of 11.6% and permeability of.31 millidarcies. This sample has a petrographic porosity of less than 10%. Porosities and permeabilities are very low because of the abundance of ductile matrix material (brownish material and clay), secondary cements and recrystallization and interpenetration of quartz grains. Quartz shows extensive evidence of dissolution and recrystallization as evident by the presence of quartz overgrowths, sutured contacts, and euhedral faces. Most chert has been partially dissolved and replaced by clay and secondary ankerite cement. Facies IX sediments is interpreted as being deposited as distal fan-delta sands of the lower delta plain environment.

Facies VIII

Facies VIII consists of predominately massive sandstone (Sm) to parallel laminated sandstone beds (Sl), with lesser amounts of cross-bedding, and very minor amounts of ripple and convolute beds. The sandstone beds are typically massive, although fining upward sequences of crossbedded sandstones are typically found towards the top of zone 1. The crossbedded sandstones typically have basal erosional surfaces defined by disrupted carbonaceous material from the underlying beds.

These beds are made up of moderately well sorted, fine to medium grained sandstones with occasional thin laminae of carbonaceous material. In the Mukluk well, the sandstones are made up of predominately quartz with significant amounts of chert and sedimentary rock fragments. Over 10% of the chert is tripolitic. An example of a facies VIII sandstone from the Mukluk well is shown in figure .

The thin section cut at 7846 of the Mukluk well is a very well sorted, fine to medium grained quartz-rich sandstone. The framework mineralogy consists of 53% quartz, 4% chert, 29% carbonaceous material, 2.8% sedimentary fragments, 2.3% quartz overgrowths, 9.1% ankerite cement, and 18.2% porosity. Core permeability is 60md.

In the Phoenix well, facies VIII consists of interbedded very fine to medium grained sandstone, and thin laminae of carbonized plant material and siltstones. The coarse-grained beds show erosional bases with lag deposits and crossbedded sandstones. The lag deposits consist of shale rip-up clasts and carbonized plant debris. The finer-grained beds are red in color and appear to have been oxidized. These sandstones and siltstones are overlain by reddish siltstones and mudstones of facies VII.

The thin section cut from core at 8543 feet of the Phoenix well consists of a well sorted, very fine to fine grained, silty sandstone interlaminated with dolomitic siltstone and carbonaceous plant material. This sample consists of over 45% monocrystalline quartz and less than 10% chert clasts. The sandstone shows good porosity and permeability, except for the those very thin zones adjacent to the dolomitic siltstone. In those areas the pores have been filled by dolomite or ankerite cement. Intergranular porosity is about 15%, whereas microporosity may add an additional 10% to the rock.

In the Sandpiper #1 well, OCS-Y-0370, facies association VIII consists of fine to medium grained, massive to crossbedded sandstones organized in fining upwards sequences, with basal lag deposits of carbonaceous material. A sample cut from a conventional at 12,047 feet consists of 46% monocrystalline quartz, 4.4% polycrystalline quartz, 16% chert, of which 14% are triplotic, and 1.6% rock fragments. Porosity and permeability reducing elements include carbonaceous material 4.0%, clay, 6.5%, siderite\ankerite cement 2.4% and quartz overgrowths which consist of 10% of the sample. This sample has a core porosity of 16.5% and a core permeability of 65 millidarcies. The good permeabilities are caused by the coarser grain sizes and abundance of secondary porosity formed by the dissolution of chert.

Diagenesis and Reservoir Potential

There is a significant increase in porosity and permeability in the strata of facies VIII as compared to either facies IX or X in the Mukluk well. The increased porosities and permeabilities in facies VIII are due to the extensive development of secondary porosity from the dissolution of carbonate cements and the dissolution of chert grains. Secondary porosity from aggressive, corrosive fluids was more pervasive because of the increased intial permeabilities established by coarser grain sizes, and lesser amounts of matrix material and cements in the pore spaces.

Petrographic examination of numerous thin sections from facies X through VIII has recognized numerous examples of secondary porosity which have significantly enhanced the porosity and permeability of facies VIII. The petrographic evidence includes: corroded grains, partial dissolution of chert grains, oversized pore spaces, floating grains, and inhomogeneity of packing. A thin section cut from a depth of 7845 feet in the Mukluk well shows oversized pore spaces and inhomogeneity of packing formed by the dissolution of chert grains (light green) (fig.).

Authigenic carbonates are generally corrosive with respect to stable silicate sandstones, and will therefore, on dissolution, leave behind a record of their former presence (Burley and Kantorowicz, 1986). The surfaces of quartz grains display pitted, etched, embayments and depressions, while chert grains display phases of partial to complete dissolution. The pervasive dissolution of the silicate framework (quartz and chert) was caused by corrosion during ankerite or dolomite cement precipitation and later dissolution by chemically, highly aggressive fluids. Pits are the smallest corrosive feature observed, being between 1 and 2 microns in diameter, and having involved only a limited removal of quartz. Embayments are larger coelesced pits, penetrating through overgrowths into the detrital grain and reaching diameters of 20 microns. Depressions are enlarged embayments, and have completely removed the overgrowth surfaces.

A prior authigenic event produced the euhedral surfaces found on most of the quartz grains. These surfaces have been penetrated and corroded by ankerite and dolomite cements forming the pitting and etching so pervasive on all the quartz surfaces. Embayments in the quartz grains have formed where the cements have been carried away in solution by aggressive fluids.

Chert grains display different stages of dissolution. The predominate type of chert grain is tripolitic, that is with the petrograhic microscope, the blue-epoxy impregnating dye can easily be seen through the grain. Some of the chert grains show a honeycombed texture (intragranular microporosity) whereas other chert grains display moldic porosity (intragranular macroporosity). Moldic porosity is evident because of the clay rims (brownish material) that has kept the original shape of the grain intact. The final stage was the creation of intergranular, interconnected pore spaces which occurred with the complete dissolution of the chert grain and the opening of pore throats between grains (fig. schematic diagram). This stage was most prevalent in facies association VIII because of the coarser grain sizes and the tendency for facies association VIII to contain tthe least amount of cement and matrix reducing elements.

<u>Flow Chart Illustrating the Schematic Diagenetic Pathways in Zone I, Facies VIII, of the Ivishak Formation, Beaufort Sea, Alaska þ</u>

þþþþþþþþþþþþþþþþþþþþþþþþþþ
þ BRACKISH OR MARINE þ
þ PORE WATERS þ

Extensive Non-Ferroan
Calcite

Burial

Partial Filling Of Intergranular
Pore Spaces (quartz authigenesis)

INTRODUCTION OF FORMATION WATERS

Ankerite and Dolomite
Cements

Introduction of Aggressive Solutions,
Generation of Secondary Porosity

Dissolution of
Chert and Cements

Hydrocarbon Flush

→ **POROUS SANDSTONE**

Facies VII

Zone 1 is separated from the overlying Zone 2 by the floodplain/lake deposits of facies VII. This facies is laterally extensive offshore and within the Prudhoe Bay Field to the south (fig.). In the Prudhoe Bay field, facies VII forms an intra-reservoir seal over a very large area. Continuous conventional coring in the Mukluk and Phoenix wells show these lithologies to consist of predominately mudstones and argillaceous siltstones, with thin, interbedded very fine (vfU) to medium (mL) grained sandstones. The mudstones are massive, as bedding has been completely obliterated by intense burrowing. The mudstones display a mottled red texture, from the pedogenic formation of soils. The siltstones are interlaminated with very fine grained sandstones. Some siltstone\sandstone units display disrupted bedding from burrowing organism, while other units include worm burrows, carbonate concretions, climbing ripples and gas-escape features. The thin sandstone units which may be as coarse as medium grained, are generally less than one foot in thickness and may display crossbedding.

Three thin-sections from the Mukluk well were examined for minerological constituents and diagenesis under the petrographic microscope. These thin-sections cut at the top of facies VII at depths of 7817'to 7810. The mineralogical framework of these sandstones ranged in composition from 34%-39% monocrystalline quartz, 4-5% poloycrystalline quartz, 13-18% sedimentary rock fragments, and 10-12% chert. Porosity reducing elements are highly variable within intervals of less than two feet. These elements range from 6-25% siderite and 11-13% clay. These sandstones range from being moderately to very well-sorted.

This interval consists of distinct zones of both tightly compacted and porous, sandstones. The differentiation into compacted, cemented and porous zones may occur within a two foot interval, and apparently developed independently of depositional facies, grain size and texture. Porosity values range from a low of 1% in a very fine grained argillaceous sandstone to over 12% in a fine to medium-grained thinly bedded sandstone units. The majority of the porosity is intergranular in nature. In the Phoenix well, facies VII has an average porosity of 7.8% and a average permeability of 1.28md.

These sandstones have gone through four phases of diagenesis. These diagenetic phases include: pressure solution and the recrystallization of quartz which resulted in the formation of quartz overgrowths; the precipitation of siderite and dolomite cements with the selective replacement of framework grains (chert, sedimentary rock fragments, and quartz); dissolution of cements with resulting etching and notching of grain boundaries, and development of secondary porosity, with subsequent partial infilling of kaolinite. The kaolinite was formed by the degradation of ductile shale fragments, chert and sedimentary rock fragments.

In a thin section of a core chip cut at 8500 feet of the Phoenix well, facies VII strata consists of interlamininated mudstone and siltstone. The thin laminations within the siltstone have been disturbed by extensive burrowing, while patches of siderite-ankerite cement are scattered throughout. These samples can be up to 6' in thickness, and may act as local vertical seals to hydrocarbon and fluid migration. Another example of lithologies within this interval, is a very fine to fine grained argillaceous sandstone, at 7816' of the Mukluk well. This sample has very low porosities and permeabilities because of the abundance of siderite cement and fine grained ductile fragments which have impeded the transport of corrosive fluids. In this sample, siderite cement, post-date the main phase of quartz authigenesis, occludes porosity and permeability, and replaces detrital grains and quartz overgrowths. The framework minerals display a high degree of pitting, etching and notching from siderite replacement. A similar example of this is also found within a very well sorted, silty, very fine grained sandstone at a depth of 8536' of the Phoenix well. In contrast, a fine to medium grained sandstone at 7812' of the Mukluk well has a porosity of 18.5% porosity and a permeability of 54md. Within facies VII, these sands are very thin being less than two feet in thickness. The sample at 7812' exhibits isolated patches of siderite cement, and many of the quartz grains still retain their euhedral faces with little evidence of siderite replacement and pitting.

The very high percentage of fine-grained sediments and the high degree of bioturbation suggests that these sediments were deposited within a very low energy environment. Facies VII would have been deposited in the floodplain adjacent to an active stream. The mudstones and siltstones display a color mottling attributed to soil formation. These ancient soils display patches that are reddish-brown in color and are found throughout facies VII. The color mottling is due to repeated emergence on the floodplain. The paleosols show their maturity by the presence of intense red colors found throught facies VII. The laterally extensive nature of these floodplain deposits may be accounted for by the liklihood that the streams could have become more fixed in their position so longer periods of time were available for deposition on the floodplain or that a brief period of subsidence occurred prior to the next pulse of uplift in overlying Zone 2. The presence of interbedded sandstones within the siltstones and mudstones suggest periodic influxes of coarser grained sediments from overbank flooding on adjacent rivers.

Zone 2

Zone 2 strata is the main reservoir facies for the Prudhoe bay Oil Field to the south. The subaerially braided and meandering stream, fluvial deposits of zone 2 are dominant in the northwestern portion of the study area between the Antares and Phoenix wells, but grade eastward into coarser grained, upper braidplain sandstones, and conglomeritic sandstones found in the Sandpiper, Northstar, Seal Island, and Reindeer Island wells to the east (fig.).

This eastward change in grain size and depaoitional environment illustrated in the change in gamma-ray log character.
The gamma-ray log character is more serrated in the western-most Antares well,becoming blocky towards the northeast, in the direction of the Sandpiper well. The top of zone 2P is defined by

the overlying blocky gamma-ray and good separation between the sonic and density curves characterized by the strata in zone 3.

The Phoenix, Mukluk and Antares wells display the greatest thickness in zone 2 strata. These rock units belong to facies III, IV and V of the subaerial, fluvial dominated coastal plain. Zone 2 consists of an upward coarsening progradational cycle, and an overlying upward fining transgressional cycle. The progradational cycle is capped by the conglomeritic beds of zone 3. The transgressional cycle begins just above zone 3 strata. The progradational cycle thins to the west from the Reindeer Island well to the Antares well.

The Antares well is the western-most well in the study area. Zone 2 was most affected by the marine transgressive event that put a close to fluvial cycle of deposition within the Ivishak Formation. The fluvial dominated strata of zone 2 consists of a very thin coarsening upwards sequence, (progradational cycle) followed by a much thicker fining upwards sequence (transgressive cycle) (fig . strat column).

The base of zone 2 in the Antares well consists of a thin coarsening-upwards sequence of poorly sorted, silty sandstones that grades upwards to a coarse grained sandstone, and then into a massive conglomerate (core photo #6). These proximal sandstones and conglomerate beds were deposited in a braided stream environment. The mostly massive beds contain poorly sorted chert-quartz rich sandstones whose maximum grain size may be over 3.00mm. The upward increase in grain size, massive beds and poorly sorted nature of the strata indicates deposition in a very high energy flow regime.

Zone 2 of the Phoenix well is subdivided into distinct facies that are differentiated by their internal stratification, grain size, sorting, mineralogical makeup, and electric log character. In the Phoenix well, these facies consist of stacked fining upwards sequences of predominately sandstones of facies IV which display numerous cut and fill structures, and conglomeritic beds of facies III which are massive in appearance. These braided stream deposits are separated by thin abandoned channel and floodplain deposits of facies VI.

The log character of zone 2 is much different than in zone 1. In Zone 1 the gamma-ray curve has a serrated to smooth funnel shape, whereas the gamma-ray curve in zone 2 has a characteristic shape like a serrated cylinder (fig. log reg.). The gamma-ray curve takes on a more cylinder-like, and is less serrated profile in the exploration wells to the northeast, because those wells are more proximal to the source terrane and therefore consist of coarser grained clastic sediments. Likewise, there is a greater separation between the sonic and density curves in zone 2 than in zone 1 of the Phoenix well.

Point count data extracted from petrographic thin sections in the Mukluk exploratory well reveal some major mineralogical distinctions between zones 1 and 2 of the Ivishak Formation. The framework mineralogy for zone 1 is predominately made up monocrystalline quartz (30-55%), and lesser amounts of sedimentary rock fragments and chert (fig.334fmz1.lin). In comparison, sedimentary rock fragments and specifically chert are the predominate framework constituents along with quartz in zone 2. There is an overall decrease in the precentage of undifferentiated clay and siderite cement within zone 2 as compared to zone 1 in the Mukluk exploratory well.

The mean and maximum grain sizes for chert and quartz were measured using a micrometer stage on the petrographic microscope. Twenty five grain size counts were measured for both quartz and chert

Six thin sections, cut from conventional cores were examined to determine the minerology and diagenesis attributed to the braided stream deposits of facies III and IV. Pieces of core were thin sectioned from separate intervals of a series of fining upward sequences to try to determine the change in grain size, sorting, and percentage of matrix material. These samples are typically moderately to very well sorted, range in grain size between fine and coarse grain; display a predominate unimodal grain distribution, although they can be bimodal at the base of channel and in the conglomerates of facies II and III, and may contain clasts that reach a maximum grain size of over 5.00 mm. (pebble-cobble).

Facies IV

Facies IV is the predominate sedimentary facies described within zone 2 of the Phoenix well. The internal stratification of facies IV consists mostly of thin fining upward sequences that are 1 to 3 foot in thickness (fig. 1PHXST). These fining upward sequences typically but not always, consist of erosional bases that contain lag deposits of extraformational granule to pebble-size clasts of chert and mudstone intraclasts. These basal units are massive to horizontally stratified. The basal units are overlain by planar-x-stratified and trough x-stratified bedding, that are overlain by parallel stratified beds of fine sand silt, and capped by a very thin bed of grey shale (fig.1PHXST).

In facies IV, the largest clasts are typically found as basal lag deposits, but may also be found scattered throughout parts of the coarser grained fraction of the bar sequence. These predominately pebble-size clasts are made up of chert and mudstone intraclasts. The coarsest fraction of chert within facies IV falls between 1 and 2 millimeters, whereas facies III contains chert clasts over 5mm (fig. 3 PHXGS). Chert and quartz make up over 50%

of the samples in zone 2. Facies III has a larger ratio of chert to monocrystalline quartz and a greater percentage of polycrystalline quartz than facies IV (fig. 2PHXMIN).

Many of the these upward fining sequences are stacked with very little evidence of any fine grained overbank deposits. The reason for these stacked channel deposits may have been due to the fact that the alluvial valleys were young, steep and highly constrained. This may have caused the younger fluvial channels to erode its predecessor, removing any fine grained deposits left over from the older channels (fig. narrow disconnected alluvial valleys). In contrast, the fluvial retreat facies of zone 2R consists of abundant fine grained overbank deposits, and more abundant fines mixed in with the coarse fraction. These deposits more closely resemble meandering streams, deposited toward the end of Ivishak non-marine deposition, on a low-lying alluvial plain.

A thin section sampled from 8,484 feet of the Phoenix well, near the base of a channel sequence consists of moderately sorted subangular to subrounded chert and subangular mudstone clasts that are granule in size. These granule-size clasts are found swimming in fine to coarse grained subangular to subrounded chert, quartz and mudstone clasts. This grain-size distribution is slightly bimodal. There is over 45% chert and 22% quartz. Chert occurs in porous and non porous forms with one-third of the chert displaying microporosity. One-third of the quartz is in a polycrystalline form. The average grain size of chert is 1.14mm as compared to .344 mm for quartz. The maximum grain size for quartz is .727mm as compared with 2.18mm for chert. There is less than 5% porosity reducing and permeability restricting elements such as cements, matrix, and clays. Core porosity is 24.7% and core permeability is 3117md, making this an excellent reservoir rock.

A thin section cut at 8448 feet of the Phoenix well was cut from the middle of some tabular x-stratified beds in the middle of a fining upwards sequence. This sample consists of moderately to well sorted, fine to medium grained subangular to subrounded quartz (31.2%), chert (26%) and mudstone clasts, with coarse to very coarse subangular to subrounded clasts of chert that are aligned parallel to bedding. The mean grain size for chert is .618mm whereas the mean grain size for quartz is .270mm. The maximum grain size for quartz is .57mm whereas the maximum grain size for chert is 1.42mm. Approxiamately 10% of the quartz is polycrystalline, and 15% of the chert displays microporosity. This sample contains less than 15% matrix material made up of cement, clay, and organic matter. The core porosity and permeability is 23.2% and 399md respectively.

These units represent an upward decrease in flow regime from the high velocity currents found at the basal section to the low velocity currents at the top. The silts and clays were deposited from suspension by slowly moving or stagnant waters on irregular surfaces inherited from earlier stronger currents. These layers of fine silt and clay furnish the mud intraclasts incorporated in the overlying lag deposits.

Facies II

Facies II consists of planar to massive beds of conglomerate and conglomeritic sandstone. Pebbles and granule-size clasts of chert and lithic fragments make up between 5 and 50% of the rock. Matrix is predomiately fine to coarse grained, poor to moderately sorted consisting mostly of quartz and lithic rock fragments. This facies has a bimodal grain distribution. The maximum clast size of chert being three times the mean (fig.3PHXGS). In some sections there appears to be a sharp increase from facies IV in the percentage and maximum clast size of chert and polycrystalline quartz

Dark red shales, thin red siltstones, and very fine grained sandstones separate facies IV from facies III in zone 2. Dark red floodplain shales are common within zone 2 in the Phoenix and Mukluk wells. Some of these shale units are correlatable in the wells to the east? These beds form intra-reservoir vertical seals to the south in the Prudhoe Bay field.

A thin section cut from core at 8377' of the Phoenix well shows two distinct, thin sedimentary laminae. One lamainae, consists of approximately 32% monocrystalline quartz, 20% chert and 5.4% sedimentary rock fragments. This laminae consists of moderately to well sorted fine to coarse grained chert, quartz and sedimentary rock fragments with scattered clasts of very coarse grained to granule-size, subrounded chert clasts. It has very good porosities and permeabilites because most of the interstices are free of cement and matrix material. The other thin laminae within this same thin section contains poorly sorted very fine to granule size chert quartz and shale clasts in a matrix of silty-argillaceous material. The porosity and permeabilities found within this laminae are very poor because of the abundance of fine grained matrix material and cement.

The log character reflects these distinct changes in sedimentary texture. The gamma-ray curve has a slightly serrated, blocky character. The blockiness is due to the coarse grained, matrix-free sediments, whereas the slight serrated character of the gamma-ray is due to the thin laminae of matrix and cement-rich interstices. In general there is good separation between the sonic and density logs.

Reservoir Quality

Porosity and permeability of Zone 2, appears to be related to depositional environment (figs. 4,5, and 6). The sedimentary units with the highest porosities and permeabilities are found within the braided stream deposits of facies III and IV, (fig. 4), and splay sand deposits within the floodplain (fig. 5) Within facies IV, the higher porosity rocks are located in the portions of the braided channels deposited within the highest flow regime. These higher flow regimes are located in the lag deposits at the base of the braided bar sequence. These samples are moderately to well sorted contain fine to coarse grained sediments, and very little matrix material (cements, clay, and shale fragments) filling pore spaces or blocking pore throats.

For example, a thin section cut from the base of a two-foot bed of the Phoenix well at 8484 feet shows a moderately sorted, fine to coarse grained sandstone with granule-size clasts of chert and mudstone. The predominate framework mineral is chert, making up over 45% of this sample. A porosity of 24.7% and a permeability of 3117 millidarcies (md) makes this basal deposit an excellent reservoir rock.

In contrast, the very well sorted, very fine to fine grained argillaceous sandstones are located in the upper part of the braided bar sequence. These sandstones have very poor porosities and permeabilities as they may act more like seals rather than reservoirs. These samples are poor reservoir rock because they were deposited in low-flow regime at the upper part of a braided bar sequence where decreased current velocities have allowed very fine grained suspended material to be incorporated in with the coarser grained framework minerals. The affect of matrix on porosity and permeability is clearly shown in figure 6 where grain density is highest in those depositional facies associated with floodplain and abandoned channel deposits, and lowest in the cleaner braided stream deposits. A thin section cut from the top of an abandoned channel facies at 8454 feet of the Phoenix well displays a high percentage of ductile grains (clay clasts) that have been squeezed and deformed within the interstices significantly lowering porosity and permeability. These rocks may also contain a high percentage of carbonate cement.

There appears to be a distinct electric log character for facies III, IV and VI of zone 2. The gamma-ray curve zone 2 is blocky due to the overall coarse grained nature of these sediments and serrated due to the thin shale drapes, floodplain deposits and scattered mudstone intraclasts. There is little separation between the velocity and density curves in the shale sequences of facies VI and VII. Sonic\density curve separation increases from the predominately sandstones of lower facies IV to the conglomeritic sandstones of facies III (fig.).

The diagenetic reactions are the direct result of the original depositional environment. For example, although good reservoir rocks occur throughout this interval, the best reservoir rock are found in the basal channel deposits where permeabilities make reach over 3 darcies. These deposits contain very little cement as complete flushing of the system by corrosive fluids had dissolved the cements.

Diagenetic reactions include the early mobilization of unstable silica in chert. The solubility of quartz is only 5ppm at 25 degrees centigrade (Siever et al, 1965) and 100ppm at 150 degrees centigrade (Morey et al, 1962). Silica is therefore not very mobile in the subsurface. Precipitation of early quartz cements depends on the availability of less stable silicate minerals of amorphous silica which is significantly more soluble (150ppm at 25 degrees centigrade). Sandstones containing biogenic silica will develop early quartz cements when these phases, often at temperatures of 50-70 degrees centigrade (Keene, 1975). As the silica concentration in the pore water decreases with time as the result of the preciptation of silicate cements, chalcedonic and quartz fringing cements give rise to quartz overgrowths. These quartz overgrowths formed euhedral faces around many of the quartz clasts while blocking pore throats.

Carbonate and iron carbonate cements in the forms of calcite, dolomite, ankerite and siderite partially replace the quartz overgrowths, chert and quartz clasts. Secondary porosity was caused by the flushing of the system by pore waters enriched in organic acids such as carboxylic and phenolic acids derived from the maturation of petroleum. These fluids dissolved the carbonate cements leaving the etched and embayed remains of the framework grains, and greatly increasing the porosity and permeability of the rock.

The graphs of point-counted data of the framework mineralogy, matrix-cements, and grain size distribution shows a significant change from zone 1 to zone 2 of the Ivishak Formation in the Phoenix and Mukluk exploratory wells (figs. 334fmz2.lin, 334cmsz2.lin, 334gsdz2.lin). In figure 338fmz2.lin, monocrystalline quartz is shown to be the dominant framework mineral with a range in sandstones of between 30 and 50%. Chert and sedimentary rock frgaments range between 5 and 20% and display an increase from the bottom to the top of zone 1. In contrast, chert and sedimentary rock fragments are the predominate framework mineral in zone 2 with a range between 20 and 50%. The percentages of carbonate cements and undifferentiated clays are typically very low within zone 2 as compared withthe greater abundance of these porosity reducing elements within zone 1.

The grain size distribution curves for zone 2 shows mean grain size for quartz to be between fine and medium grained, whereas the coarsest clasts of quartz can be in the very coarse grained size. In comparison, the mean grain size for chert ranges between medium and coarse grained, whereas the coarsest clasts of chert can be as large as pebbles. The greatest abundance of granule to pebble-size chert clasts appear towards the top of zone 2.

Zone 2 is a regressive, fluvial sequence of braided stream deposits, deposited within the more distal coastal plain environment of facies V at the base to the more proximal coastal plain environment of facies IV and III at the top of zone 2 (fig.).

Facies V consists of thin (< 3') weakly-developed, fining-upward sequences of fine to medium grained sandstones. The fining-upward sequences are most often capped by thin beds of interlaminated mudstone and siltstone. Where the shale-cap is missing and the fining upward sequences are stacked, the base of the channel sequence can consist of very coarse rip-up clasts of mudstone.

ZONE 4

Zone 4 is a transgressive marine sandstone, equivalent to the Eileen member of the Ivishak Formation, found in the Eileen State exploratory wells onshore. Offshore, zone 4 strata is found in the Mukluk and Antares #1 exploratory wells where it unconformably overlies fluvial sandstones of zone 2. Zone 4 reaches a maximum thickness of approximately 70 feet in the Antares well, and thins to less than 50 feet, 30 miles to the northeast, in the Mukluk well. Zone 4 records the backstepping of depositional environments which took place following the rapid cessation of fluvial coastal plain progradation within zone 2.

The unconformity between the Eileen Sand, and the underlying fluvial sandstones of zone 2 lies at approxiamately 8175' of the Antares 1 exploratory well. The unconformity is represented by a lag deposit of mixed white and grey chert pebbles, reworked from zone 2, and the change between the massive and crossbedded sandstones of zone 2, and the hummocky, rippled, lenticular, silty sandstones of zone 4 (CORE PHOTO #16). The upper boundary of zone 4, between the Eileen Sand and the Shublik Formation is more suspect, as thin sections suggest a transitional mineralogical sequence into the more calcareous, argillaceous sandstones of the Shublik Formation. Other geological evidence from conventional core, suggests a major depositional break at the top of the Eileen Sand. This depositional break is located at rubble zone within the core. There, highly mottled, bioturbated sandstones below the rubble zone, zone 4 lithologies, are replaced by thinly laminated calcareous sandstones above it of the Shublik Formation (core photo #24).

In the Antares well, zone 4 has been subdivided into three facies associations, XI, XII, and XIII. These facies associations were differentiated by their sedimentary structures, and vertical facies relationships identified in conventional core, detrital and authigenic mineralogy, mean and maximum grain distribution, degree of sorting as identified in thin sections, and electric log character (table 3).

The combination of sedimentary structures and authigenic mineralogy suggests that these sediments were deposited within a shallow marine environment. Hummocky, rippled lenticular, fine grained sandstones that contain pyrite nodules and glauconite of facies association XI at the base of zone 4, changes upperwards into facies association XIII where the core is highly mottled and burrowed, and shows signs of pedogenic soil formation.

The following graphs and illustrations contain data that define the major characteristics of zone 4.The percentage of detrital monocrystalline quartz and clay increase sharply across the boundary whereas the percentage of chert and polycrystalline quartz decreases (fig. new280min). In addition, there is a recognizable difference between the types of authigenic and matrix derived minerals found in zone 4 as compared with zone 2. The dominant cement in zone 2 is ankerite whereas zone 4 contains calcite in trace amounts, not shown, iron calcite, and iron dolomite. Authigenic minerals solely found within zone 4 strata include glauconite and pyrite (new280cem).

The mean and maximum grain sizes, and degree of sorting, changes dramatically upwards across the unconformity between zones 2 and 4. The poor to moderately well sorted, fine to coarse grained sandstones of zone 2 are replaced by well to very well sorted, very fine, silty sandstones of zone 4 (figures n2801gs, thin sections of zone 2, 8184 or 8193, and of zone 4, 8161, and 8121).

Analysis of the above described geologic factors suggests that the rate of sea level rise was greater than the supply of sediment from the source terrane to the north. The rise in sea-level after zone 2 deposition resulted in the transgression of the marine environment onto the lower coastal fluvial plain. The lower portion of the coastal plain was eroded, as shallow marine silty sandstones were deposited on top of fluvial sandstones. The fine grain sizes, good sorting, and presence of hummocky structures suggests that the sediments were deposited where gentle wave action sorted the fine grained sediments. The pyrite nodulars in the lowest most facies probably formed just below the sediment water interface in reducing conditions.

Reservoir potential of the transgressive sandstones in the Antares well is very poor. Zone 4 strata has the poorest reservoir characteristics of all the zones studied in wells offshore. Figure

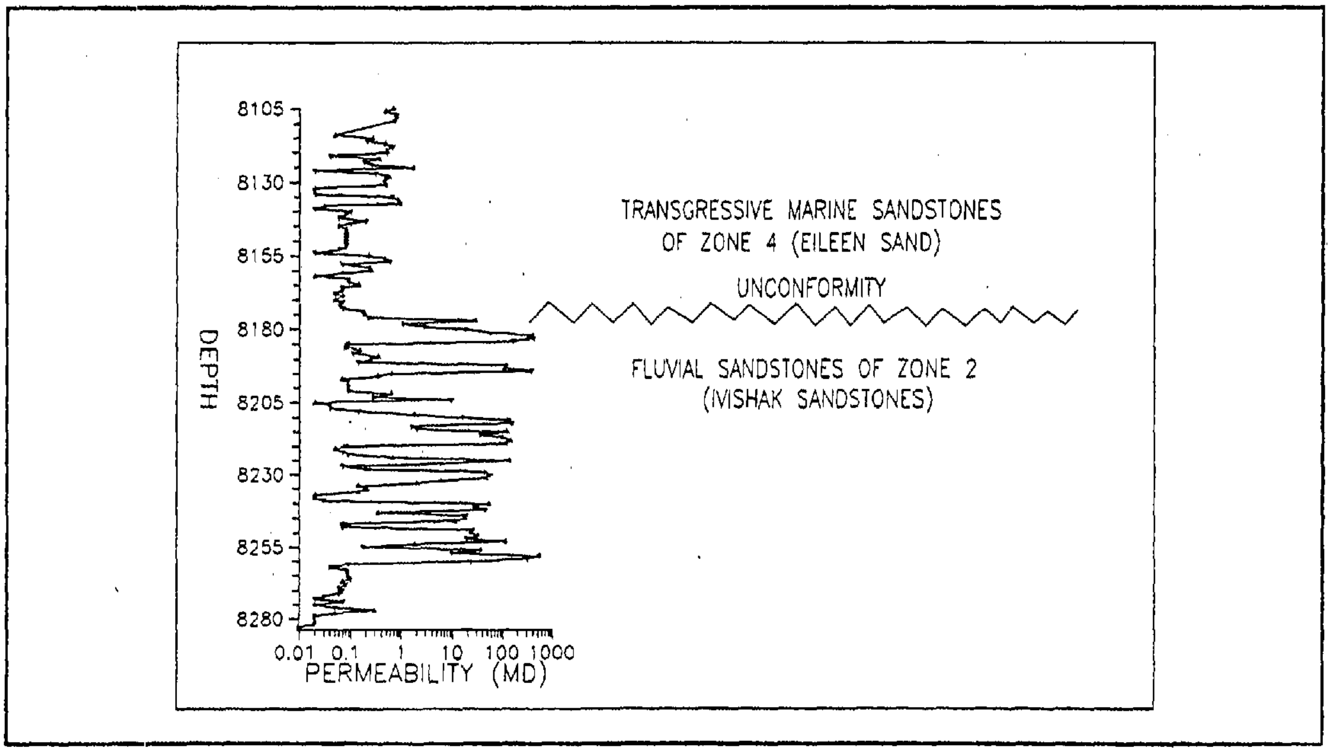

Figure 1. The change in permabilities and reservoir quality between the fluvial, progradational sandstones of zone 2, and the transgressive marine sandstones of zone 4 in OCS-Y-0280 no. 1 (Antares), Beaufort Sea, Alaska.

(280perm.plt) illustrates the sharp decrease in conventional core permeabilities across the unconformity between zones 2 and 4. The poor permeabilities are caused by deposition in a low energy marine

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environment where: predominate detrital grain size was very fine to fine grained; detrital clay was abundant, and where subsequent biogenic reworking and burial diagenesis was extensive.

Reduction in the porosity and permeability of the strata continued following deposition within the shallow marine environment. The organic-rich carbonaceous clays and fine grained sandstones were reworked by near surface burrowing organisms. These burrowing organisms disrupted the original sedimentary fabric of the strata significantly reducing the continuity in pore space within the original rock fabric. Pyrite nodules, iron dolomite, and calcite precipitated within the organic-rich clays. Later burial and compaction squeezed the abundant clay between the detrital grains cutting off most of the remaining pore throats. This was followed by the recrystallization of quartz along detrital grain boundaries. The depositional and diagenetic characteristics of zone 4 suggests that these strata probably acted more like a seal than a reservoir for petroleum within this portion of the Beaufort.

These sections at depths of 8161 and 8120 were looked at in detail at MMS. Four other sections were looked at at Exxon exploration in Houston, Texas. These sections were at the depths of 8174, near the top of the unconformity between zone 2 and zone 4 strata, at 8133 and 8125 feet within facies XII, and at 8108 feet within facies XIII. These sections were only briefly looked at.

The section near the unconformity at 8174 feet, consisted of poorly sorted, very fine to medium grained sandstone. The sandstone contained abundant churned and contorted layers of clay from bioturbation. There was abundant pyrite and scattered traces of glauconite.

SAMPLES IN THIS (WATKINS) BOX

LISTING OF THIN SECTION COLLECTION

Sohio (BP) Mukluk 1 (Y-0334 #1)	Box 1	7,375-7,587	Core Chips, Blue Impreg.
	Box 2	7,612-7,816	Core Chips, Blue Impreg
	Box 3	7,841-9,271	Core Chips, Blue Impreg
	2 box duplicate set	8,180-9,330	Cuttings, No Impregnation
	1 partial box	7,386-8,248	Core Chips, Blue Impreg
Tenneco Phoenix 1 (Y-0338 #1)	Box 2	7,904-8,081	Core Chips, Blue Impreg
	Partial Box 1	8,120-8,513	Core Chips, Blue Impreg
Exxon Antares 1 (Y-0280 #1)			
	Partial Box 3	8,120-8,219	Core Chips, Blue Impreg
	Partial Box 2	8,231-8,377	Core Chips, Blue Impreg
Exxon Antares 2 (Y-0280 #2)			
	Partial Box 3	11,384-11,448	Core Chips, Blue Impreg
Shell Sandpiper 1 (Y-0370 #1)			
	Partial Box 1	11,805-12,087	Core Chips, Blue Impreg
	Partial Box 3	11987	Core Chip, Blue Impreg
	Partial Box 1	12,037-12,112	Core Chips, Blue Impreg
Amoco Sandpiper 2 (Y-0371 #1)			
	Partial Box 2	14,424-14,456 -14,438 -14,456 ok	Sidewall Cores, Blue Impreg. believe not sidewall cores but taken from actual cores!
Shell Seal Island 1 (Y-0181 #1)			
	Partial Box 1	12,468-12,783	Core Chips, Blue Impreg
	Partial Box 1	10,396-10,426	Core Chips, Blue Impreg
	Partial Box 2	10,436-10,501	Core Chips, Blue Impreg
		12,303-12,463	Core Chips, Blue Impreg
	Partial Box 1	12,719-12,866	Core Chips, Blue Impreg
Shell Seal Island 4 (Y-0180 #1)			
	Partial Box 1	15,161-15,186	Core Chips, Blue Impreg
Northstar 3 (State Well)	Partial Box 2	9,438-9,550	Sidewall Cores, Blue Impreg

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Ivishak Study
Horowitz, 1993

Minerals Management Service
Alaska OCS Region
949 E. 36th Ave., Rm. 603
Anchorage, AK 99508-4302

DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATIONS AND (DOMINANT FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	WELL LOG RESPONSE	PERMEABILITY PROFILE
CONSTRUCTIVE DELTAIC MARINE DEPOSITS	VIII. DISTAL COASTAL PLAIN	(sidewall cores only)	Poor to moderately sorted fine to medium grained sandstone which contain increasing amounts of chert and reddish brown clay clasts. The chert is predominately nonporous.	The gamma-ray curve is represented by serrated cylinder. There is very good separation between the density and the velocity curves. GR=28-40 DT=74-80 RHOB=2.32-2.48	Permeability is higher in those samples that are free of interstial matrix of clay, and silt-size detrital fragments.
	IX. CHANNEL MOUTH BAR, DELTA FRONT (Sl, Sm)	Interlaminated light and and dark grey, very fine to fine grained sandstone changing upwards to a light grey massive fine grained sandstone	Interlaminated, well sorted, fine grained sandstones with abundant dark brown clay clasts and moderately to well sorted very fine to fine grained sandstones with an abundance of interstial matrix of clay, silt size chert and quartz. Ankerite and later siderite cements replace the boundaries of detrital grains. Pyrite is found at the top of this facies unit.	The gamma-ray curve is reprsented by a stacked bell-shaped curve. There is good separation between the density and the velocity curves. Gr=30-60 DT=73-76 RHOB=2.39-2.48	Porosity and permeability is good, although it decreases upwards with a decrease in sorting and an increase in interstial matrix.
	X. DISTAL FAN DELTA	(eroded section)			

TABLE 1. The descriptions of conventional, sidewall cores and petrographic thin sections for the development of permeability profiles within zone 1 of the Antares OCS-Y-280 #1 exploratory well.

Ivishak Study
Horowitz 1993

Minerals Management Service
Alaska OCS Region
949 E. 36th Ave., Rm. 603
Anchorage, AK

DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (DOMINANT FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	WELL LOG RESPONSE	PERMEABILITY PROFILE
	V. DISTAL COASTAL PLAIN (Sx)	Poorly developed fining upwards sequences of medium grained sand with crossbedding and abundant clay rip-up clasts at the base. The top of this sequence are reworked chert pebble deposits found just below an unconformity separating the the overlying transgressive shelf deposits of zone 4. (see photo #16, core interval 1701-1710)	Moderately to well sorted very fine to fine grained sandstones which contain an abundance of detrital clay and corrosive authigenic ankerite cement. (see graphs 280min and 280cm). The coarser grained sandstones contain signficantly less cement and clay clasts (see graph 280gs).	The gamma-ray curve consists of serrated (FUS) sequences. GR-50-85 There is fair to good separation between the sonic and density curves RHOB=2.38-2.70 DT=88-70	The range in porosity is between 12.3 and 19.3%, and the range in permeability is between 18 and 411md. The most permeable sandstones are coarser grained sandstones that contain less cement and fewer clasts of clay.
FLUVIAL DOMINATED COASTAL PLAIN DEPOSITS	V. MIDDLE TO DISTAL COASTAL PLAIN (GSx, Sx, Sl) BRAIDED TO MEANDERING STREAM	Stacked, fining upwards sequences of medium grained sandstones with scattered granule-size clasts of chert and clay.	At the base of each sequence, there are moderately to well sorted fine to medium grained sandstones with scattered granule-size clasts of chert. The interstices contain little matrix and only small patches of ankerite cement. The upper part of these (FUS) contain poorly sorted very fine to medium grained sandstones with an abundance of interstial matrix material of very fine grained quartz, chert and clay.	Permeabilities range between 10 and 150mD. Permeabilities reduced by the combination of poor sorting, abundant fine grain detrital clasts, ankerite cement and quartz overgrowths that fill interstial pore space and block pore throats.	
	IV. UPPER TO MIDDLE COASTAL PLAIN (Sx, Sl, Sm) BRAIDED STREAM TO LOW SINUOISTY MEADERING STREAMS	Poorly developed fining upwards sequences of medium grained sandstones that contain granule-size clasts of chert and long wispy clay clasts that parallel the crossbeds. These (FUS) are capped by very thin beds of hematitic siltstone. (see core photo #11)	Moderately sorted fine to medium grained sandstones with detrital chert, quartz, sedimentary rock fragments and scattered patches of ankerite cement. Ankerite cement replaces detrital grains. Trace of triplitic chert.		Permeability reduced by extensive development of quartz overgrowths, ankerite cements and poor sorting.
	II. UPPER TO MIDDLE COASTAL PLAIN (GSm, GSx, GSl, Sx)	10-60% granule to pebble size chert, polycrystalline quartz and mudstone intraclasts. 40-90% fine to coarse grained interstial detrital fragments. Weakly developed FUS, capped by 3" grey shale. Numerous erosional surfaces and abrupt grain size changes. Vertical facies trend is GSm, GSx, GSl, Sx, Sl.	Moderate to poorly sorted fine to coarse grained chert and quartz that contain granule to pebble size angular to subrounded extraclasts of chert and polycrystalline quartz. Interstices contain scattered patches of ankerite cement.	Good permeabilities ranging between 10 and 300mD. Secondary porosity formed from the dissolution of micrporous chert.	

	I. UPPER COASTAL PLAIN/TOP OF ACTIVE FAN DEPOSITION (GSm) DEBRIS FLOWS AND LONGITUDINAL BARS	*50-70% very poorly sorted pebble to cobble size angular to subrounded black grey and white chert and 30-50% fine to coarse grained chert and quartz. Hematite is scattered throughout unit (see core photo #6). No vertical facies trend. This unit is sandwiched between floodplain deposits of facies association VII.*	*Very poorly sorted, strongly bimodal detrital clasts of predominately chert, monocrystalline and polycrystalline quartz. Cementing agent is ankerite found within interstices. Matrix material consists of fine to coarse grained chert and quartz. Some matrix material consists of abundant interstial clay. Hematite coats many of the clasts in some sections.*	*Gamma-ray curve is blocky. There is good separation between the sonic and density curves. DT=65-70 RHOB=2.50-2.62*	*The permeabilities range between .09 and 546md. The variability is caused by the amount and type of matrix material, and interstial cement.*
	V. BRAID DEBRIS FLOWED STREAM DEPOSITS (Sm)	*Coarsening upwards sequence of massive fine grained silty sandstones to coarse grained sandstones (6" thick).*	*Poorly sorted silty sandstones with an abundant matrix of very fine grained chert, quartz and clay. The upper part of the sequence consists of poor to moderately sorted (weakly bimodal) fine to coarse grained matrix rich sandstones. The detrital mineralogy consists of chert and quartz. Siderite? is the predominate cementing agent.*		*The very low permeabilities (.01-.09) are caused by the fine grained size, poor sorting and abundant interstial matrix.*

TABLE 2. The fluvial advance and retreat phases of deposition for zone 2 of the Antares OCS Y-0280 #1 exploratory well.

Horowitz, 1993.

DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (DOMINANT FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	PERMEABILITY PROFILE
TRANSGRESSIVE SHALLOW MARINE AND REWORKED COASTAL DEPOSITS OF ZONE 4	XIII. INTERTIDAL-SHALLOW MARINE (MSm, MSb)	Highly mottled fine grained silty, calcareous sandstones. This core displays a very high degree of paleosol color mottling, and rootlet traces, (possible evidence for pedogenic soil formation). Burrowing structures also appear common (core photos 22-23).	Well sorted very fine to fine grained quartz-rich sandstone which contain detrital quartz (40%) and chert (10%), abundant disturbed layers of interstial brown clay, calcite, iron calcite, collophane?, and glauconite (8108).	Poor permeabilities (avg .50md) because of fine grain size and abundant interstial clay and calcite cements.
	XII. SHALLOW OPEN MARINE (MSr, Sd)	Hummucky lenticular bedding of continuous to discontinuous ripple mudstone/sandstone. These very fine to fine grained silty, calcareous sandstones lack the pyrite nodules found in the underlying unit (core photos 19-21).	very well sorted, very fine to fine grained quartz-chert-rich sandstones. The interstices are filled with a matrix of very fine grained chert quartz and clay along with calcite, iron calcite, and iron dolomite (8120').	Poor permeabilities because of the fine grained detritals and abundant interstial matrix.
	XII. SHALLOW RESTRICTED MARINE DEPOSITS. (MSr,MSd,MSb)	Hummucky, lenticular beds of continuous to discontinuous sand ripples that have been post-depositionally contorted, and contain abundant pyrite nodules, up to 3" in diameter. These very fine to fine grained silty shallow marine sandstones unconformably overlie fluvial sandstones of zone 2. These sandstones contain glauconite, carbonaceous matter, pyrite and are slightly calcareous. (core photos 16-19).	Very well to well sorted fine grained sandstones that contain abundant interstial clay, rhombs of pyrite, iron dolomite, calcite, zoned iron calcite, and glauconite. The nodulars consist of clay, glauconite, pyrite cubes and scattered quartz grains. Burrowing is common and has created an inhomogeniety of packing of quartz grains (8161').	Very poor permeabilities because detrital fraction is fine grained, abundant interstial clay, porosity disruption due to burrowing and the abundance of carbonate and other interstial cements.
	XI. REWORKED TRANSGRESSIVE COASTAL DEPOSITS. Sl, Sm, Sx, GSm	Medium grained sandstones and sandy conglomerates. The sandy conglomerates contain up to 70% granule to pebble-size well rounded chert clasts. Thin <1.0' coarsening upwards sequence.		Permeabilities are as high as 30mD. These basal sandstones and conglomerates contain the highest permeabilities within zone 4.

TABLE 3. The description of conventional core and petrographic thin sections for the characterization of depositional environment and permeability profiles for the transgressive marine sandstones of zone 4 for the Antares OCS-Y-280 #1 exploratory well.

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DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (DOMINANT FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	PERMEABILITY PROFILE
CONSTRUCTIVE DELTAIC MARINE DEPOSITS	VIII. DISTRIBUTARY CHANNEL SANDSTONES (Sx, Sm, Sl, Sd)	Interlaminated fine grained sandstones, light brown siltstones, and very thin laminae of carbonized plant material, grading upwards to thinly laminated siltstones and very fine grained silty sandstones.	Well sorted to very well sorted quartz-rich sandstones which contain monocrystalline and polycrystalline quartz, porous and nonporous cherts, and ankerite cement.	Good secondary porosity in coarser grained sandstones because of the dissolution of tripolitic chert. Permeability decreases adjacent to siltstones due to the precipitation of ankerite cement.
	IX. CHANNEL MOUTH BAR, DELTA FRONT SANDS	NOT CORED (SEE DETAILED SECTION FROM ADJACENT MUKLUK WELL		
	X. DISTAL FAN DELTA	NOT CORED		

TABLE 1. The description of conventional core and petrographic thin sections for the characterization of permeability profiles and depositional environments for zone 1 of the Phoenix OCS Y-0338#1 exploratory well.

DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (VERTICAL FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	PERMEABILITY PROFILE
ALLUVIAL FAN PROGRADATION FROM THE UPPER DISTAL COASTAL PLAIN ENVIRONMENTS TO THE TOP OF THE MAIN ACTIVE FAN	I. UPPER COASTAL PLAIN /TOP OF ALLUVIAL FAN. (Gm, GSm) DEBRIS FLOW DEPOSITS, LONGITUDINAL BARS	Conglomerate, clast supported pebbles up to 2" in diameter, are principly white, grey, and black chert. Less dominant pebble-size clast include polycrystalline quartz and mudstone rip-up clasts. Fine to medium grained detrital clasts make up interstitial area.	Very poorly sorted, strongly bimodal sandy conglomerate. Chert clasts are oftentimes zoned and contain abundant sponge spicules (pict) and other chert clasts contain large fine to coarsely crystalline quartz veins. The interstitial area contains fine to medium grained chert, quartz and mudstone rip-up clasts.	Overall high permeabilities, although the poor sorting and relatively fine grained detrital constituents of interstitial area has reduced the permeabilities within this sample of the Mukluk well. Enhanced microporosity occurs within the larger detrital clasts of this facies.
	II. MID COASTAL PLAIN/ ALLUVIAL FAN DEPOSITS (GSm, GSx) LONGITUDINAL BARS TO LINGUOID BARS AND MINOR CHANNEL FILLS:	No discernable fining upwards sequences. 40-60% fine to coarse grained sandstone and 10-40% granule to cobble size white grey and black chert clasts	Two distinct units, a poorly sorted matrix-rich conglomeritic sandstone and a moderately sorted fine to granule sized matrix-free sandstone. The matrix rich unit is bimodal,very poorly sorted, fine to pebble size clasts with abundant silty and clayey interstitial matrix. The matrix free unit fine to coarse grained with scattered extraformational clasts of chert. Scattered patches of ankerite cement appear within the interstices.	Overall very high permeabilities ranging from 1300-200mD. Lower permeabilities occur within the matrix-rich conglomeritic sandstones.
	III. LOWER MID TO UPPER DISTAL COASTAL PLAIN DEPOSITS (GSm, GSx, Sx, Sl) LINGUOID TO TRANSVERSE BARS.	Weakly developed fining upwards sequences (1-2'). 70-90% fine to coarse grained sandstones; 10-30% very coarse to pebble size extraformational chert clasts found at base of channel sequence and scattered throughout section.	Poorly sorted granule to pebble size chert and polycrystalline quartz floating in a matrix of fine to very coarse chert and minor quartz. Calcite cements occur in scattered isolated patches.	Very high permeabilities ranging between 3180 and 350mD. Primary porosity is dominate because of the predominance of smooth, non-replacive grain surfaces. Secondary porosity associated with grain-corrosion-dissolution also occurred as evident from oversized pore spaces and inhomogeneity of packing, but is of secondary importance here. Microporous chert and macroporous chert from the dissolution of dolomitic rhombs are also present.
	IV. UPPER TO MIDDLE DISTAL COASTAL PLAIN DEPOSITS (GSm, Sm, Sl, Sx, MSl, MSr) BRAIDED,MEANDERING STREAM, POINT BARS DEPOSITS	Well developed fining upwards sequence. Lag deposits of either extraformational chert and\or intraformational siltstone rip-up clasts (GSm). 80-90% fine to coarse grained sandstone (Sx, Sl) and very thin siltstone cap MSl,MSr.	Moderately sorted, mostly fine to coarse grained; abundant chert of porous and nonporous varieties; high percentage of polycrystalline quartz; ankerite is the primary cement with some secondary limonite replacement.	Permeabilities range between 3500 and 200mD. Individual channel sequence display an upward decrease in permeabilities. Grain-dissolution secondary porosity is evident from oversized pore spaces, large interchannel pores, deeply etched and embayed detrital grains. Good percentage of microporosity from abundant tripolitic chert, and macroporosity in coarser deposits from the dissolution of dolomite rhombs in chert.

	VI. CHANNEL ABANDONMENT DEPOSITS *MSl, MSr*	*Interlaminated light grey siltstone and shale and minor amounts of very fine grained sandstone. Forms very thin capping unit over individual channel sands. Can contain color mottling and rootlet traces.*		*These beds have very low permeabilities and where thick enough may act as localized seals between individual channel sands.*
	VII.FLOODPLAIN DEPOSITS, FAN ABANDONMENT DEPOSITS *Md, MSr*	*Interlaminated siltstone/mudstone (80%) and very fine grained sandstones (splay sands). Deep red color and rootlet traces from pedogenic soil formation and structurally mottled. These zones are typically thicker than the abandoned fan\channel deposits and oftentimes separates zone 1 from zone 2 strata.*		*These floodplain deposits are very fine grained and highly indurated by concretionary siderite, and thus have acted as regional sealing units for the migration of petroleum. An exception to this are thin discontinuous splay sands that show significantly higher porosities and permeabilities. This facies may extend across the Beaufort as a regional seal between the Antares and the Sandpiper wells (see x-section). (Grapher figures from Phoenix well).*

TABLE 2. The alluvial fan advance phase of deposition for zones 2 (and 3?) in the Mukluk and Phoenix exploratory wells, Beaufort Sea, Alaska.

THE DESCRIPTION OF CONVENTIONAL CORE AND PETROGRAPHIC THIN SECTIONS FOR THE CHARACTERIZATION OF DEPOSITIONAL ENVIRONMENT AND PERMEABILITY PROFILES FOR THE TRANSGRESSIVE MARINE SANDSTONES OF ZONE 4 IN THE OCS Y-0338 (PHOENIX) EXPLORATORY WELL.

DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (DOMINANT FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	PERMEABILITY PROFILE
TRANSGRESSIVE SHALLOW MARINE AND REWORKED COASTAL DEPOSITS OF ZONE 4	XII. SHALLOW MARINE AND REWORKED SHALLOW MARINE STORM DEPOSITS (GSm, Sb) Sm	Very thin beds of very fine grained to fine grained sandstones/silty (1.0- 5.0' thick) and very thin beds of thickly laminated beds of coarse grained sandstones and granule/pebble matrix supported conglomerates (2.0"to 1.0'thick). Fine grained sandstones are highly mottled displaying highly disrupted bedding (Sb), whereas the conglomerates are mostly massive (GSm). These beds do not display any vertical facies trend except that the fine grained mottled sandstone predominate at the top of this sequence.	Moderately well sorted very fine to medium grained sandstone. Although relatively clean, the interstial areas contain a greater abundance of detrital clay than in facies association XI. Phosphatic material coats many of the detrital clasts of chert and quartz. Detrital clasts are partially replaced by phosphatic material.	Overall good, but variable according to grain size.Higher porosities and permeabilities with the thin interbedded conglomerates and coarse grained sandstones (up to 4000mD). Poorer reservior sandstones are found within the fine grained highly mottled sandstones (<50mD) Primary pores blocked by greater abundance of detrital clays and authigenic phosphatic material. Secondary porosity is evident from the residual rinds of phosphatic material.
	XI. REWORKED SHORELINE COASTAL DEPOSITS Sl, Sx, GSx, GSm, MS	Very thin interbedded fine to coarse grained sandstones and conglomeritic sandstones. Coarsening upwards sequence of displaying a vertical facies trend of Sx, GSx, GSm of <3.0 foot thick. Some CUS are capped by thin beds of interlaminated siltstone, mudstone and very fine grained sandstone (Phoenix well, 0338, 8142').	8140'- (facies unit Sx) Moderately well to well sorted fine to mostly medium grained sandstones with scattered pebble-size mudstone rip-up clasts. Interstices are relatively free of cements and a only contain small amounts detrital clay. (Finer grained deposits contain greater amounts of clay). Late stage dolomite rhombs are scattered thoughout, but concentrated within the mudstone intraclasts. 8123'- (facies unit Sl) Late stage pyrite or hydrocarbon emplacement totally fills pore spaces and has highly etched and fractured the detrital grains. 8120' (facies unit Sl) Finer grained sandstones have a much greater abundance of detrital clay and late stage cements.	Overall high, Porosity range between 11 and 22%. Permeability range between 25 and 1400mD. Depositional environment primary control on reservoir quality; secondary porosity development is very evident by the dissolution of unstable tripolitic chert. Lower reservoir permeabilities within the finer grained sandstones that contain more abundant detrital clay and late stage cements.

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DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (DOMINANT FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	RESERVOIR CHARACTERIZATION FROM PETROGRAPHIC EXAMINATION
CONSTRUCTIVE DELTAIC-MARINE DEPOSITS	VIII. DISTRIBUTARY CHANNEL/SANDSTONE FACIES (Sx,Sm)	Fine to coarse grained, massive to crossbedded sandstones, organized in FUS of 4-10' thick beds. Channel deposits contain basal lag deposits of clay rip-up clasts. Vertical facies trend is Sl,Sm,Sx. Beds grade from more massive beds at the bottom to crossbedded sandstones at the top. The upper-most x bedded sandstones are defined by abundant reworked carbonaceous matter.	Moderately well sorted fine to coarse grained quartz, tripolitic, chert-rich sandstones. Secondary dissolution of chert is very evident in this sample (12,047). The tripolitic chert where still remaining displays replacement by kaolinite and late stage siderite cements.	Initial permeabilites were probably good because of the high mean grain sizes (abundant medium to coarse grained sand, see figure), and the lesser amounts of interstial cements and clays. The secondary dissolution of chert greatly enhanced the permeabilities within this facies. The abundance of tripoltic chert also adds to a significant increase in intergranular and intragranular microporosity (picture 12047). Permeabilties are highest at the base of the channel sequences and decrease upwards.
	IX. CHANNEL MOUTH BAR, DELTA FRONT SANDS OR DELTA PLAIN (Sl,Sm)	Massive sandstone beds with very thin laminae of carbonaceous material. Beds are from 2-12' thick. Carbonaceous laminae, clay-rip-up clasts and erosional surfaces are common.	Poor to moderately sorted very fine to medium grained quartz, chert sandstone with an interstial matrix of very fine grained fragments of quartz, chert and clay, and carbonaceous matter. Interstitial cements include ankerite and siderite. Siderite rhombs are zoned with an inner dark core of iron-poor calcite and an outer lighter colored, iron-rich core.	Fair porosities and permeabilities. The abundance of clay, carbonaceous material, and the extensive recrystallization of quartz has significantly reduced the permeabilities in many of these sands. No wholesale dissolution of tripolitic chert (picture at 12,077).
	X. DISTAL FAN DELTA (Sl,Ml)	Coarsening upwards sequence of very thin beds of silty carbonaceous mudstone grading up into very fine to fine grained sandstones. carbonaceous debris.	Very well to well sorted, very fine to fine grained quartz, tripolitic chert rich sandstones. The interstices contain partially dissolved tripolitic chert, siderite-ankerite cements and dark brown carbonaceous material.	Primary porosities and permeabilities were low because of the abundance of carbonaceous debris and quartz overgrowths, and the lowest mean grain size of the three facies. The secondary dissolution of tripolitic chert increased the porosity and permeability. The replacement of chert by kaolinite and secondary siderite cement lower the final porosities and permeabilities (picture 12,089).

TABLE 1. THE DESCRIPTIONS OF CONVENTIONAL CORES AND PETROGRAPHIC THIN SECTIONS FOR THE DETERMINATION OF PERMEABILITY PROFILES AND DEPOSITIONAL ENVIRONMENTS WITHIN ZONE 1 OF OCS Y-0370 #1 (SANDPIPER) EXPLORATORY WELL.

DEPOSITIONAL ENVIRONMENT	FACIES ASSOCIATION AND (VERTICAL FACIES TYPES)	CORE CHARACTERISTICS	THIN SECTION DESCRIPTION	PERMEABILITY PROFILE
BRAIDPLAIN PROGRADATION AND RETREAT PHASES FROM THE MID-BRAIDPLAIN TO THE UPPER PARTS OF THE MAIN ACTIVE FAN AND THEN BACK TO THE LOWER BRAIDPLAIN	V. MIDDLE TO DISTAL BRAIDPLAIN (Gm, GSx, Sx, Sm)	80-90% fine to coarse grained sandstones and conglomeritic lag deposits organized in stacked, multistoried fining upwards sequences with erosional bases. The basal lags at the bottom of the FUS have a maximum diameter of 3cm.	Poorly sorted fine to coarse grained quartz-chert sandstone with scattered granule to pebbles size chert clasts (GSm). Chert clasts are angular to subrounded. Micro-fining upwards sequences. High percentage of Kaolinite. Pyrite is found within the interstices and within the pebble size tripolitic clasts.	Permeability range between 13 and 52 mD. The coarse grained clasts of the basal lag contain the highest permeabilities which may be over 170 mD, although the poor sorting and abundance of authigenic kaolinite degraded the permeability within some of these rocks.
	V. DISTAL BRAIDPLAIN (GSm, Sl, Ml,Md)	Sharp decrease in size and percentage of chert pebbles from II and III, and a large increase in sand content. 80-90% fine to coarse grained sandstones, and less than 10% gravel. Organized in stacked fining upwards sequences and laminated and crossbedded sandstones. The fining upwards sequences contain erosional bases and a fine grained pebble, sand lag (GSm), gradually grading upwards to a laminated sandstone and then to a very thin shale cap (photo).	Mostly fine to coarse grained sandstones with scattered granule to pebble size chert and poly-crystalline quartz.	Variable, but mostly moderate permeabilities ranging from 5.0 to 170mD, but mostly lower than 50mD. Porosities range between 12 and 18%. The lower permeabilities are due to the finer grain sizes and abundant interstitial siderite cement and authigenic kaolinite. The better sorted coarser grained samples contained very good permeabilities and very little interstitial authigenic material (see photo).
	II. UPPER TO MIDDLE BRAIDPLAIN. Gm, Gm_1, Gms, Sm, M	Gravel content between 30 and 50%. Organized in stacked, multistoried well-developed fining-upward channel sequences that contain erosional bases of poorly sorted conglomerate to well sorted fine grained conglomerate, to matrix supported conglomerates, to floating pebbles and well sorted sandstones. Some of these channel sequences are capped by a thin shale drape. Vertical facies trend is Gm-Gm_1-Gms-Sm-M.	The conglomerates consisted of poorly sorted chert pebble clasts and subordinate polycrystalline quartz. Over 95% of the pebbles are chert. The chert is mostly subrounded whereas the polycrystalline chert can be subangular. A majority of the chert pebbles are tripolitic. Matrix material includes poor to moderately well sorted fine to coarse grained chert and quartz. These clasts are angular to subrounded in appearance. Interstitial material includes secondary authigenic kaolinite and siderite.	Permeabilities are extremely variable although most permeabilities are lower than 80mD (see graph). Permeabilites vary according to the sorting, grain size and amount and type of interstitial kaolinite and siderite cements. Quartz overgrowths also reduce permeability. Some secondary dissolution of chert grains has occurred but it is not widespread.

	I.MIDDLE TO UPPER BRAIDPLAIN *Gm,Gms*	*Gravel content >70%. Max. clast size over 4"in diameter. Massive chert pebble (90%) and polycrystalline quartz pebbles conglomerate.* *Predominately grain supported facies of Gm. No vertical facies trends except for some reversely graded beds.*	*Over 60% of the gravel consists of poorly sorted tripolitic and nontripolitic, subrounded chert pebbles. The polycrystalline quartz are subangular to subrounded, very coarse to granule in size.The matrix consists of angular to subrounded fine to very coarse grained mono and polycrystalline quartz and tripolitic and non tripolitic chert. Some of the finer grained matrix are replaced by siderite cement and authigenic kaolinite.*	*Permeabilities average about 25 Md, although certain zones may be as high as 200mD. The grain supported conglomerates have higher prmeabilities than the matrix supported conglomerates. Permeabilties can vary over a very short interval. Internally, permeability varies according to the amount of poorly sorted fine grained matrix, the abundance of siderite and kaolinite cements. The abundant tripolitic chert significantly reduces the effective porosity in the rock. Secondary dissolution of grains occurs within the coarsest fraction of the conglomerates.*
	II. MIDDLE TO UPPER BRAIDPLAIN. *Gm, Gm,, Gms, Sm*	*Gravel content >50%, maximum clast size over 2" in diameter. Organized within upward fining sequences from 4" to 4' thick.* *Typically these units are pebble supported at the base (Gm), grading up to matrix supported (Gms), to floating pebbles and capped by well sorted sandstones (Sm).* *Sequences generally thicken and coarsen upwards towards facies association I.*	*Chert Pebbles of tripolitic and nontripolitic chert and a matrix of fine grained quartz and medium to granule size clast of chert which contain interstitial clay, siderite cement and kaolinite. Chert makes up over 90 % of the pebble size clasts with lesser amounts of polycrystalline quartz. The pebble size clasts are mostly subrounded whereas the finer grained matrix clasts contain abundant subangular grains.*	*The highest porosities and permeabilites are found within those rocks that contain the coarsest matrix material. The lowest values are found in those rocks that are most poorly sorted, the finest matrix and the greatest amount of siderite and kaolinite. The facies with the highest permeabilities are found within the well sorted conglomerates of facies unit Gm, just above the channel lag deposits of Gm, and the well sorted coarse grained sandstones of facies unit Sm that cap the channel deposits.*

TABLE 2. The alluvial fan advance and retreat phases of deposition for zones 2 and 3 in the Sandpiper OCS Y-0370#1 exploratory well, Beaufort Sea, Alaska.