ACCURATE RESERVOIR EVALUATION
QUALITY CORE SAMPLES - A GOOD STARTING POINT

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Abstract In order to accurately evaluate a reservoir, detailed descriptions and petrophysical measurements must be taken from core samples. Historically, the success of a coring operation was measured as a ratio of core recovered to core cut. Increased communication among geologists, coring companies and core analysis laboratories has seen more emphasis placed on the physical quality of the core samples. This is particularly relevant when soft, unconsolidated formations are to be cored. Specialised coring equipment such as Full Closure and Rubber Sleeve systems do exist to cut and recover extremely unconsolidated formations. However, this equipment has limitations and, to date, has not found an application in the UK North Sea area. This paper describes the developments to existing procedures and equipment to ensure maximum recovery of the highest quality core from unconsolidated, North Sea reservoirs.

INTRODUCTION

Core samples are one of the primary methods used to evaluate a reservoir. Obtaining high quality core samples is absolutely crucial to enable a complete and accurate analysis of the cored rock. Standard coring techniques, at their current stage of development, are usually adequate to obtain the necessary quality of core samples for analysis. However, where a well's objective is in an unconsolidated formation, for example Eocene, particular attention must be paid to the coring of that formation. The successful coring and recovery of unconsolidated formation requires special equipment and techniques, as well as skill and expertise on the part of the coring engineer. The objective with any coring operation is to fill the corebarrel and recover 100% of the core cut. With the techniques now in operation, overall core recovery exceeding 95% has been achieved. This figure is obtained from the evaluation of over 5,000 feet of core from Paleocene and Eocene formations over a two year period. (See Appendix 1)

With recovery problems overcome, more emphasis is being placed on the physical quality of the core being recovered. In order to improve this quality, the main objectives of the coring operation are:

1. To reduce fluid invasion of the core to an absolute minimum.
2. To maintain mechanical integrity and grain structure of the core.
3. To preserve fine sedimentary structures and major bed boundaries, preventing natural fractures from opening and reorienting.

Achieving these objectives will enable the geologist to extrapolate more accurate data from the core samples presented to him, which will lead to more accurate reservoir evaluation.

DRILLING FLUID INVASION

The invasion of drilling fluid into the core is undesirable as this reduces the volume of uncontaminated rock for evaluating and may, in certain circumstances, preclude the measurement of certain parameters. In the coring of unconsolidated formation, this problem cannot be completely erradicated, but certain equipment and procedures will help reduce fluid invasion to a minimum:

Equipment

Core is very vulnerable to fluid invasion during the time it is exposed to the flow of the drilling mud, i.e. from the time the corehead cuts the rock until it enters the inner barrel, hence the faster the core is cut, the less time it is exposed to the drilling fluid. The use of light set Polycrystalline Diamond Compact (P.D.C.) type coreheads ensures the core is cut as fast as possible. These coreheads should be used with "Pilot" type lower shoes which help protect the exposed core from the drilling fluid. (See Figure 1)

The use of a face discharge corehead diverts about 60% of the mud flow away from the core, thus further reducing fluid invasion. (See Figure 2)

The use of a corehead and lower shoe featuring the internal lip system increases to about 95% the flow diverted

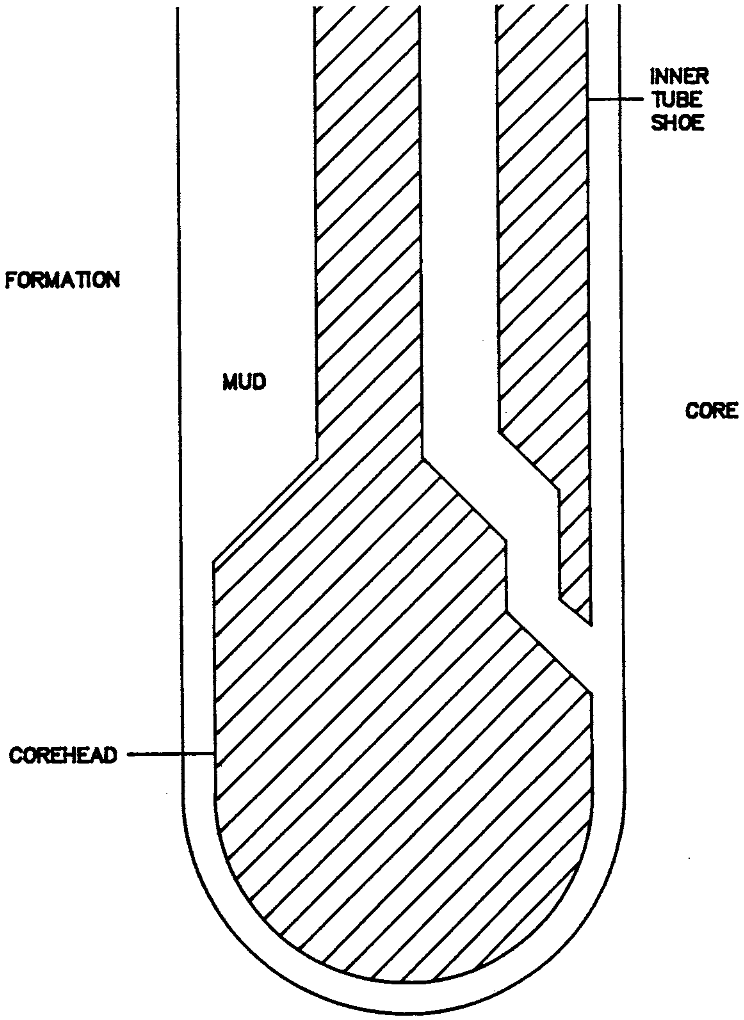

FIGURE 1 Conventional corehead with pilot type lower shoe.

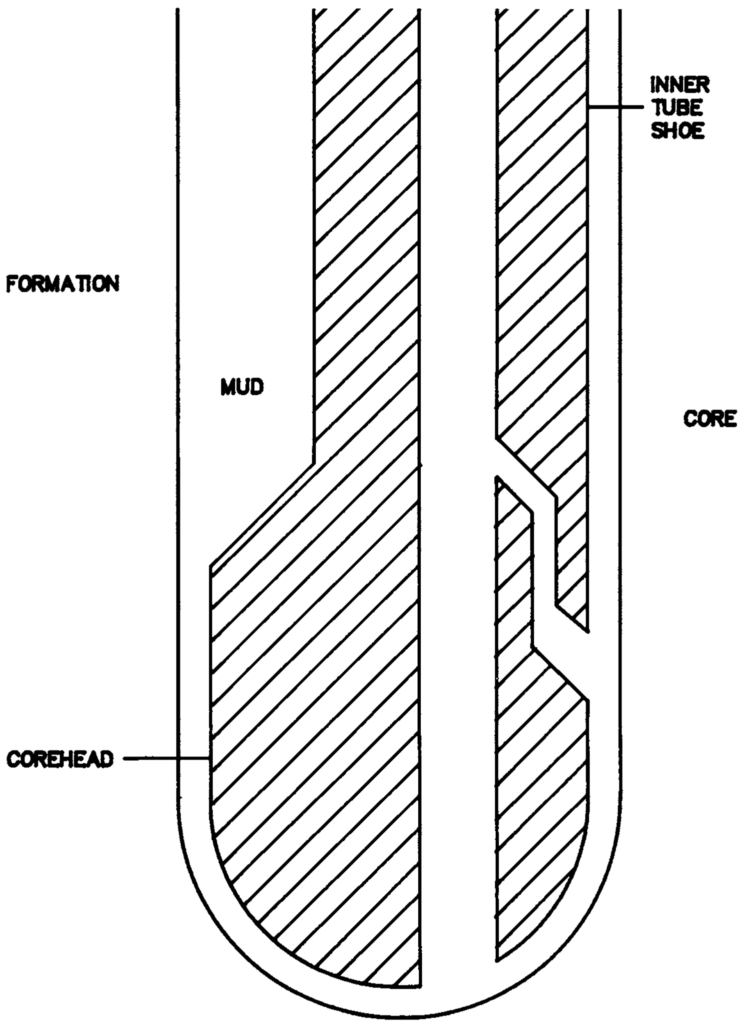

FIGURE 2 Face discharge corehead with pilot type lower shoe.

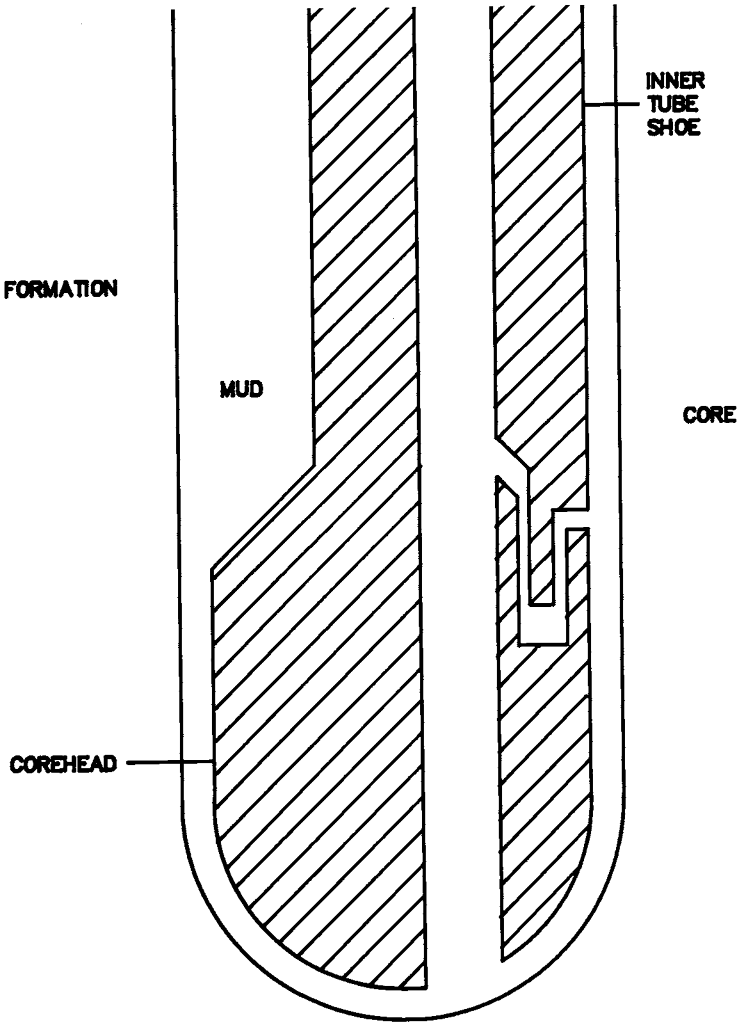

FIGURE 3 Face discharge corehead with internal lip system lower shoe.

away from the newly cut core, thus reducing fluid invasion yet further. (See Figure 3)

Procedures

The greater the difference between the hydrostatic pressure of the drilling fluid and the formation pressure, the greater the extent of the mud invasion of the formation. Drilling mud weight should therefore be kept as close as possible to formation pressure, while still conforming to drilling safety regulations.

The drilling fluid flowrate and pressure drop through the corehead will also have a significant effect on the amount of fluid invasion of the core. A drastic reduction in the flowrate used will therefore reduce the amount of fluid invasion of the core.

Given that some fluid invasion will occur, the use of a tracer in the mud will help to determine the extent of this invasion.

MECHANICAL INTEGRITY OF THE CORE DURING CORING

Depending upon the compressive strength of the formation, there will be a limit to the length of core that can be cut before the core starts to break down. If this core breakdown occurs, there is a strong possibility of losing core and reducing the usefulness of the core sample that is recovered.

Formation breakdown can also occur through "washing" of the core by the drilling fluid. This will either wash the core away completely or reduce the diameter of the core such that it cannot be held by the core catcher.

Again, equipment and procedures have been developed that reduce to an absolute minimum the damage done to the core as it is cut:

Equipment

The point at which the formation begins to break down due to the weight of the column of core will be affected by the frictional resistance encountered by the core as it moves along the inner barrel. Of all the types of inner barrel material available, the lowest friction between core and inner barrel is obtained from fibretube that is made entirely from fibreglass, with no steel connections. The use of all fibreglass fibretube, therefore, allows the maximum length of core to be cut before breakdown occurs.

The extent of core damage due to "washing" by the drilling fluid will be directly proportional to the amount of fluid that comes into contact with the core as it is being cut. The use of the previously mentioned coreheads (face discharge and face discharge with internal lip) will reduce the amount of fluid in contact with the core and hence reduce the possibility of damaging the core in this way.

Procedures

The breakdown of the core during coring may not always be apparent from the information available on surface (torque, standpipe pressure, rate of penetration etc.). This being the case, it is advisable to restrict the length of corebarrel run. The corebarrel length should be 30 feet or, at most, 60 feet. This will limit the length of core attempted in one run and prevent potential lost core due to formation breakdown.

In general, the coring parameters (flowrate, rotary speed and weight on bit) should be reduced. This is done to reduce disturbance of the core to a minimum. At the same time, the previously stated objective of cutting the core as quickly as possible should be borne in mind.

Specifically, the flowrate should be reduced to lessen the chance of damaging the core by washing. Flow rates used would be in the order of 300% less than those used in conventional coring.

Once the core has been cut, care must be taken while tripping out of the hole in order not to mechanically disturb the structure of the core. Slips should be set gently in order to prevent shock waves travelling down the length of the drillpipe to the corebarrel. The core must be surfaced slowly, particularly during the last part of the trip when rapid expansion of gas can cause dilation of the core.

SURFACE HANDLING

Once the corebarrel reaches surface, great care must be taken not to disturb the core. A complete handling package has been designed to minimise core disturbance during recovery and shipment.

The fibretube inner barrels containing core must be laid out in 30 feet sections. Therefore, if a core longer than 30 feet is cut, the inner barrels must be separated on the rig floor. In the recent past, this was done by unscrewing the threaded connection in order to part the inner barrel.

By observation of core in analysis laboratories it has been noted that, in a great many cases, core in close proximity to the connection has been disturbed and re-oriented. This has been due to the rotation of one inner barrel section against the other. In order to overcome this problem, a small air-driven saw is used to cut round the fibretube, thus eliminating the need to rotate it.

To retain the core inside the fibretube while it is laid down, a Shear Plate Boot is used (See Figure 4). This fits around the fibretube at the point at which it is to be parted. The tube is then cut using the saw. Once it is cut, the fibretube is lifted slightly, exposing the core. The shear plate is then pushed through the core, securing it inside the fibretube.

Due to the flexible nature of the core-filled inner barrel, precautions must be taken to ensure that the core is not disrupted in the latter stages of the handling operation. If the inner barrel is laid down onto the catwalk without support, the flexing would disturb the core, opening fractures on one side and crushing the core on the other. A cradle has been designed (See figure 5) to support the inner barrel during the lay-down operation. With the inner barrel hanging vertically in the derrick, the cradle is lifted to the drill floor using a tugger line and is lined up alongside it. The inner barrel is secured to the cradle using fibre strops which are tightened using a ratchet mechanism. The cradle is now lowered down the 'V' door onto the catwalk. On the end of the cradle, wheels on a wide axle prevent the cradle from overturning. The cradle has rollers along its length which allow the inner barrel to be rolled off and into the saw. This eliminates the need to lift the inner barrel out of the cradle for cutting up.

The saw used for cutting the core is housed in a box with holes at either end for entry and exit of the core (See Figure 6). A large diamond-tipped blade rotating at high speed cuts all the way through the core in one movement. This means that the inner barrel does not have to be rotated for cutting.

As each section of core is cut, it is set on a rack which allows all drilling fluid to drain from the annulus between the core and fibretube.

The core must now be protected in a stable environment, ready for shipment ashore. Worthington et al. (1987) suggest that the best method of doing this is by plastic resin injection. The resin is formed by the mixing of two liquid components. The two liquids are injected into the annulus through the single nozzle of a gun, completely

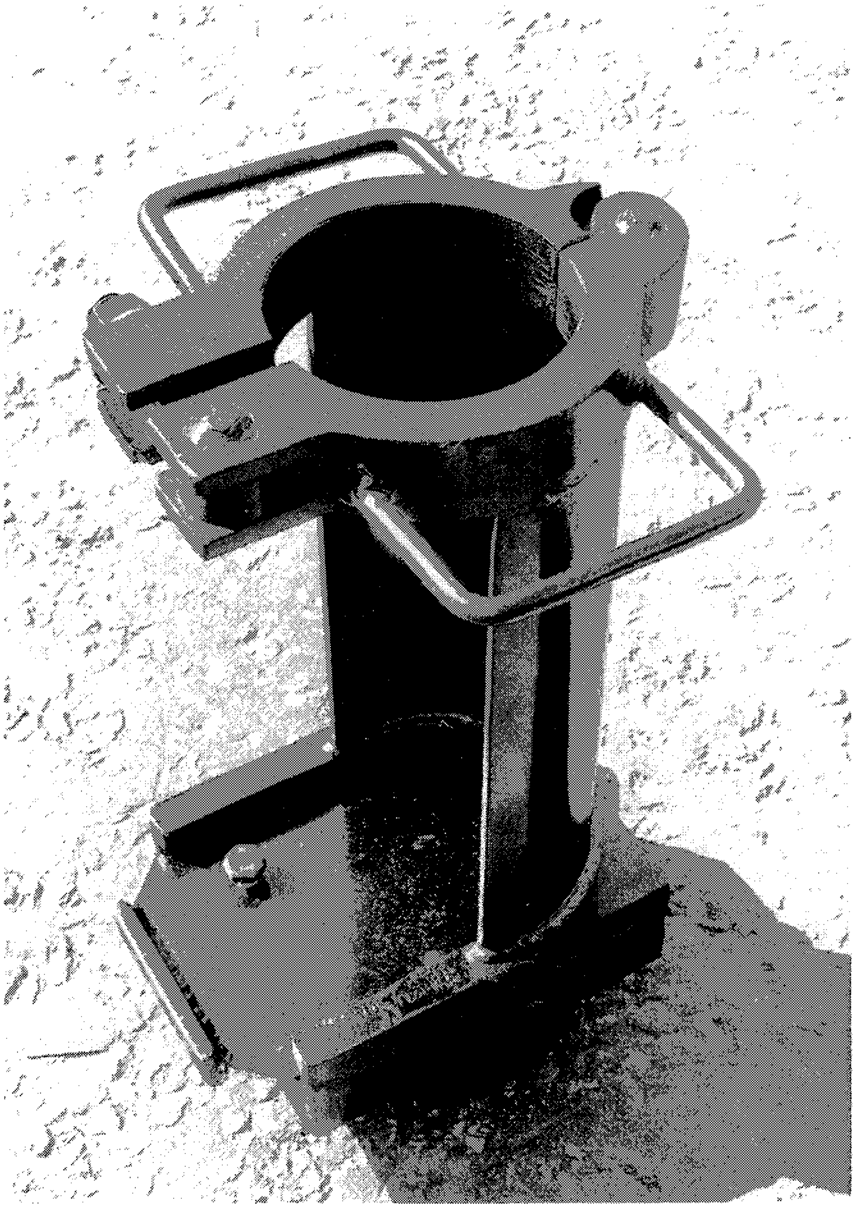

FIGURE 4 Shear plate boot.

FIGURE 5 Fibretube handling cradle.

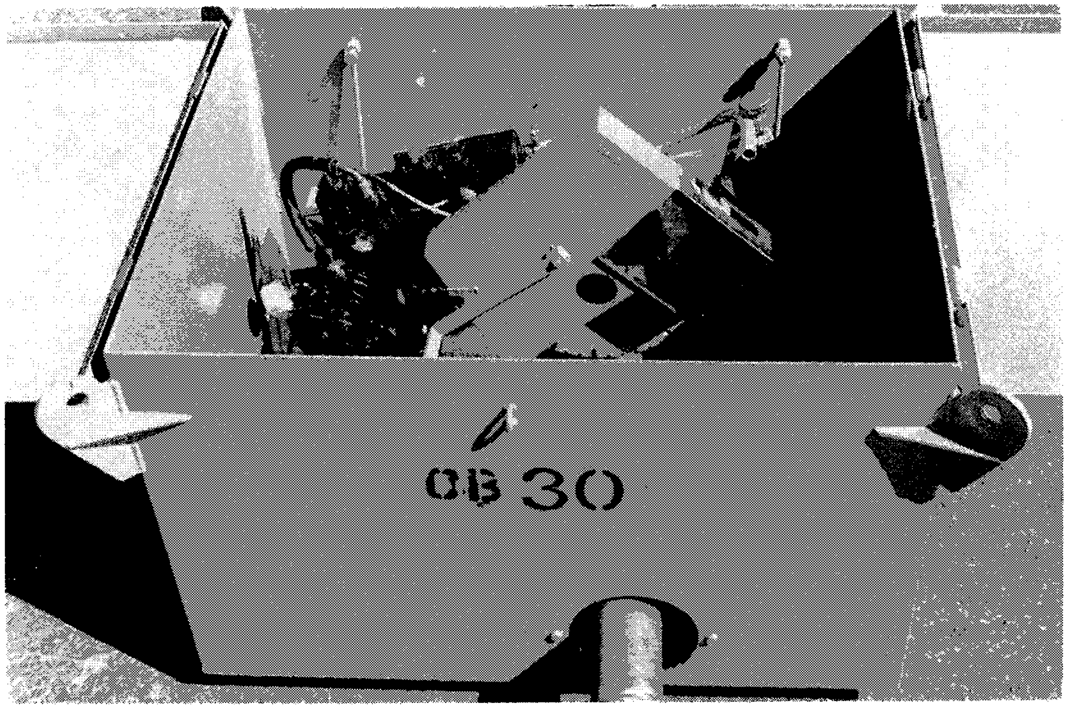

FIGURE 6 Boxed saw unit.

encapsulating the unconsolidated core. The resin sets in approximately 2 minutes and is rigid and non-porous when set.

After the resin sets, the fibretube sections are loaded into a walk-in refrigerated container where temperatures are maintained at a constant 5 degrees C. The fibretubes are solidly packed rendering them incapable of movement. The core is now in a fully protective environment, ready for shipment ashore.

CONCLUSION

Traditionally, coring companies have measured the success rate of their work as a ratio of core recovered to core cut. Only through communication with operators' geology departments and core analysis companies, has extra emphasis been placed on maintaining the best possible physical properties of the core.

This paper has described the development of procedures and equipment that have enabled unconsolidated core to be cut, recovered and preserved in a condition that realistically reflects the properties of the formation cored. This includes:

1. Selection of the correct mud weight to minimise fluid invasion.
2. Use of a light set P.D.C. corehead to maximise rate of penetration.
3. Selection of a corehead and lower shoe combination that suits the application.
4. Use of fibretube inner barrels made entirely from fibreglass to minimise frictional resistance to entry of the core.
5. Coring with greatly reduced parameters, particularly flowrate, to minimise damage to the core and fluid invasion.
6. Running of shorter corebarrel lengths, 30 feet or 60 feet, to prevent formation breakdown due to core column weight.
7. Tripping out of hole carefully to avoid disruption of the core.
8. Use of the complete surface handling package to ensure minimum disturbance to the core.
9. Resination of the core to preserve it for shipment and future analysis.

The success of this approach is demonstrated by the results achieved. This success and the successful coring of other difficult formations can best be maintained and improved by close contact and cooperation among the coring company, analysis company and operator.

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THE BRITISH RUBBER MANUFACTURERS' ASSOCIATION LTD, Polyurethane Elastomers - An Introduction to a Range of Versatile Materials.

WORTHINGTON, A.E., GIDMAN, J., and NEWMAN, G.H. (1987) Reservoir Petrophysics of Poorly Consoildated Rocks, I. Well-Site Procedures and Laboratory Methods, Paper Number 8704, Society of Core Analysts.

APPENDIX 1

Unconsolidated Coring Reports: 1988 - 1989

CORE NO.	FTG	% REC	ROP	C'HEAD	FORMATION
Kerr McGee - 9/18b-20					
					EOCENE
1	59	97	28	CDX	CLY/ST
2	58	100	44	CD504	SAND/CLAY
3	60	100	60	CD504	SAND/CLAY
4	58	100	58	CD504	SAND/CLAY
5	60	100	40	CD504	SAND/CLAY
6	59	95	39	CD504	SAND/CLAY
7	60	88	30	CD504	SAND/CLAY
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	414	97	39.8		
	===	===	====		
Kerr McGee - Well 9/18b-19					
					EOCENE
1	49.5	94	41	CD504	SAND ST
2	58	100	31	CD504	SAND ST
3	60	100	50	CD504	SAND ST
4	58	100	46	CD504	SAND ST
5	59	100	59	CD504	SAND ST
6	60	100	60	CD504	SAND ST
7	58	93	53	CDX	SAND ST
8	58	100	39	CDX	SAND ST
9	58	95	32	CDX	SAND ST
10	58	100	41	CD504	SAND ST
11	58	100	58	CD504	SAND ST
12	58	100	58	CD504	SAND ST
13	88	100	25	CD504	SAND ST
14	89	100	40	CD504	SAND ST
15	88	97	40	CD504	SAND ST
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	957.5	99	41		
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CORE NO.	FTG	% REC	ROP	C'HEAD	FORMATION
Kerr McGee - Well 9/18b-17					
					EOCENE
1	58	90	58	CD504	CLAY/SAND
2	58	100+	33	CD504	CLAY/SAND
3	58	95	38	CD504	SAND
	---	---	--		
	174	97	41		
	===	===	==		
Kerr McGee - Well 9/18b-14					
					EOCENE
1	58	100	58	CD504	SAND
2	60	100	80	CD504	SAND
3	58	92	58	CD504	SAND
4	55	95	61	CD504	SAND
5	60	100	38	CD504	SAND
6	59	100	79	CD504	SAND
7	57	95	82	CD504	SAND
	---	-----	--		
	407	97.6	60		
	===	=====	==		
Kerr McGee - Well 9/18b-11					
					EOCENE
1	39	98	15	CD202	SAND/CLAY
2	61	100	27	CD504	SAND/CLAY
3	61	94	24	CD504	SAND/CLAY
4	46	99	16	CD504	SAND/CLAY
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	207	97.5	20		
	===	=====	==		

CORE NO.	FTG	% REC	ROP	C'HEAD	FORMATION
Kerr McGee - Well 9/18b-10					
					EOCENE
1	61	100	29	CD504	TIGHT
2	61	99	31	CD504	TIGHT
3	44	91	30	CD504	TIGHT
4	24	96	30	CD504	TIGHT
5	61	100	32	CD504	TIGHT
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	251	98	30.5		
	===	===	====		
Conoco - 9/18a-18					
					EOCENE
1	58	65.5	45	CD504	TIGHT
2	36	28	90	CD504	TIGHT
3	60	90	60	CD504	TIGHT
4	56	107	45	CD504	TIGHT
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	210	77	53		
	===	=====	==		
Conoco - 9/18a-15					
					EOCENE
1	40	95	20	CD504	SAND
2	61	97	28	CD504	SAND
3	60	83	28	CD504	SAND
4	50	121	26	CD504	SAND
5	31	83	28	CD504	SAND
6	61	100	10	CD504	SAND
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	303	97	20		
	===	===	==		

CORE NO.	FTG	% REC	ROP	C'HEAD	FORMATION
Ranger - 4/26-2					
					EOCENE
1	61	100	32	CD504	CLAY/SAND
2	61	100	32	CD504	CLAY/SAND
3	60	100	35	CD504	CLAY/SAND
	182	100	33		
B.P. - 9/23b-14					
					EOCENE
1	18.5	100	9.7	CD504	MUD-ST
2	18.5	100	15.4	CD504	MUD-ST
3	18.5	100	12.3	CD504	MUD-ST
4	13	100	13	CD504	MUD-ST
5	18.5	75	12.3	CD504	MUD-ST
7	18.5	100	8	CD504	S/ST
8	18.5	100	8	CD504	S/ST
9	18.5	100	7.4	CD504	S/ST
10	17.5	100	4	CD504	S/ST
11	18.5	100	4.6	CD504	MUD/ST
	179.5	96	7.8		
B.P. - 9/23b-13					
					EOCENE
1	18	100	13.5	CD504	S/ST
2	19	100	10.8	CD504	S/ST
3	18.5	100	12.3	CD504	S/ST
4	18.5	100	9.3	CD504	S/ST
5	18.5	96	9.3	CD504	S/ST-SHALE
6	18.5	99	10.6	CD504	SHALE
	111	99.2	10.7		

CORE NO.	FTG	% REC	ROP	C'HEAD	FORMATION
B.P. - 9/23b-11					
					PALEOCENE
1	61	100	24	CD504	S/ST
2	32	100	36	CD504	S/ST
3	60	100	32	CD504	S/ST
4	61	100	29	CD504	S/ST
5	36	94	12	CD504	SST/CLYST
6	43	84	5.4	CD504	CLAY/ST
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	293	97	16		
	===	===	====		
B.P. - 9/23b-10					
1	30	96	60	CD504	SAND/SHALE
2	60	99	40	CD504	SAND/SHALE
3	37	100	25	CD504	SAND/SHALE
4	62	92	31	CD504	SAND/SHALE
5	40	88	20	CD504	SAND/SHALE
6	30	95	20	CD504	SAND/SHALE
7	43	100	29	CD504	SAND/SHALE
8	28	100	28	CD504	SAND/SHALE
9	36	93	24	CD504	SAND/SHALE
10	31	100	62	CD504	SAND/SHALE
11	31	100	31	CD504	SAND/SHALE
12	31	82	31	CD504	SAND/SHALE
13	45	98	30	CD504	SAND/SHALE
14	61	95	41	CD504	SAND/SHALE
15	61	97	31	CD504	SAND/SHALE
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	626	95.7	30.5		
	===	=====	====		
B.P. - 9/23b-9					
					EOCENE
1	31	100	21	CD504	SAND

CORE NO.	FTG	% REC	ROP	C'HEAD	FORMATION
B.P. - 9/23b-8					
					EOCENE
1	61	100	43	CD504	SAND/CLAY
2	59	85	28	CD504	SAND/CLAY
3	60	40	28	CD504	CLAYSTONE
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	180	75	32		
	===	===	==		