Summary of

Equipment Modifications and

Discussion of Drilling Results

CPOG Strathmore EV 7-12-25-25 W4

Canadian Pacific
OIL & GAS LIMITED

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I. INTRODUCTION

The concept of continuous slim hole coring for evaluation of sedimentary rocks which could contain oil or gas is not new. It had been attempted in Eastern Canada and the North West Territories but had enjoyed only limited success prior to 1967 when Canadian Pacific Oil & Gas Limited became seriously interested in the application.

Canadian Pacific Oil & Gas felt that the problems which had been experienced up to that time were not the result of any basic flaws in the concept but due to improper technique and a general lack of experience in adapting the coring rigs to a soft-rock environment in a safe and efficient manner.

Since CPOG held the petroleum and natural gas rights on several million acres of very remote and completely untested land in the North West Territories we felt that any means of exploration which held the promise of reducing initial drilling expenditures by a factor of two or possibly more must be investigated more thoroughly. For these reasons CPOG took the necessary steps to drill a small diameter, completely diamond cored hole close to Calgary for observation and experimentation in techniques, drilling equipment, auxilliary services and safety problems as they pertained to continuous, slim hole diamond coring under soft rock conditions. By drilling an experimental hole we hoped to answer two main questions:

1) Could a hole be drilled in this manner to a reasonable depth safely and economically in soft rock?
2) Could the necessary information be obtained in the small hole through core examination, electric logging and drill stem testing to properly evaluate the sediments that were penetrated?

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This report summarizes the original drilling equipment and the subsequent modifications to adapt it to the sedimentary rock environment and discusses the results of the drilling of the first hole CPOG Strathmore EV 7-12-25-25 W4.

2. ORIGINAL EQUIPMENT

The original rig shipped from Kirkland Lake, Ontario to Strathmore, Alberta, was a large (by mining standards) surface drill type 'BBS4' manufactured by Boyle Brothers and modified by Heath & Sherwood Drilling Co., for use in Heath & Sherwood's hard rock coring operations in Eastern Canada.

Following is a general rig inventory in point form:

Derrick - 87' Conventional type with 6' substructure.
Approximately 50 ton rating

Draw-works & Rotary Equipment - Boyle Brothers BBS4. Drilling machine rated at 48,000 lbs. with two lines.

Power Supply - 1 - 140 HP GMC Diesel.

Mud Pumps - 1 - Wheatley 1824 $2\frac{1}{2}$" to 4" x 6" 50 GPM
1 - Bean Royal 25 GPM for standby
Both pumps diesel powered.

Light Plant - 15 KW Diesel powered
5 KW Standby
3 KW Standby

Drill String - Long year $3\frac{1}{2}$" O.D. "H.Q." drill rods and 10' core barrels to 5,000' maximum depth.
- Long year 2 3/4" O.D. "NQ" drill rods and 10' core barrels to 8,000' maximum depth.

Wireline Hoist - Independently powered wireline hoist with 1/8" diameter cable for core barrel retrieval.

Miscellaneous Equipment - Light, high-speed swivel.
- 'Acid Test' equipment for deviation surveys.
- wireline stripper.
- fishing equipment including taps, overshots, mills and jars.
- International '500' crawler tractor with blade, winch and gin poles.

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The above inventory represents the rig and most of the associated equipment as it would be used on a core hole in a hard rock environment.

On a hard rock mining evaluation hole there would be no need for pressure control equipment, mud tanks or any of the safety equipment and precautions used as standard oil field practice. The substructure would not be required. The derrick and all other equipment would be handled in pieces suited to one or two men or the International '500' crawler tractor. Personnel accomodation on site, if required, would be in a tent camp which would be very light and portable. The conventional third-party services as required in the oil business (drilling mud, cementing, logging, drill-stem testing, fishing consultants, etc.) would not be required except for the occasional use of drilling mud and the occasional cement job which would all be handled by the contractor's crew using their own equipment.

3. INITIAL MODIFICATIONS

In order to utilize the rig for hydrocarbon exploration in Alberta there were several additions necessary to comply with the safety provisions of the Alberta Drilling Regulations and the Workman's Compensation Board Regulations.

There were also some modifications in both equipment and techniques required to adapt the system to a soft-rock environment.

a) The safety equipment additions were as follows:

- Blow Out Prevention Equipment
  - 6" - 900 series Shaffer LWS Double Gated Preventor
  - 6" - 900 series Regan 'Torus' (Hydril type)
  - Hydraulic Accumulator and remote station
  - Kelly cock
  - Shaffer Inside BOP
- Automatic Engine shut-offs
- Explosion-proof wiring
- Derrick escape buggy
- Remote-fired rig floor heating
- Scott Air Packs

The LWS Shaffer blow out preventers were not chosen with portability and lightweight in mind. They were used because the final blow out preventer stack design had not been decided upon and we did not want to delay the drilling program. The Regan 'Torus' was chosen for its portability and it was intended for use in the final design but it was found that the rubber packer element would not stand up under the invert mud system. Supply and maintenance problems also appeared regarding the Shaffer equipment and a set of Guiberson Preventers was installed. These also proved unreliable and finally a conventional Hydril Preventer was installed and the drilling completed with that unit in place. The final Blowout Preventer Stack is discussed in section four.

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The remote fired heating system was a forced-air furnace with an insulated duct from the furnace house to the rig. It was adequate for the job but it was expected that the rig insulation would have to be much better in the colder weather which would be encountered in the North.

b) The Operational Equipment additions were as follows:

- 600' Longyear 4 1/2" O.D. 'HQ Casing' for drilling surface hole and subsequent cementing in place for surface casing
- 2 compartment mud tank 100 bbl. capacity
- Single cone desilter
- Small shale shaker for surface hole
- Totco deviation survey
- Hydraulic slips
- Power tongs

The 'HQ Casing' was used to drill the surface hole to determine its effectiveness as a drilling string. The surface hole was completed without too much difficulty and the HQ casing was cemented in place as surface casing. Subsequent leaks and problems with this surface casing indicated that the HQ casing was not rugged enough to withstand drilling stresses and still be used as casing. The holes drilled in the North West Territories used conventional casing for surface string - the first hole used 4 1/2" O.D., 9.5 lb. J-55 grade and the second hole used 5" O.D., 11.5 lb. J-55 grade, both sizes obtained commercially.

The two compartment mud tank used on the Strathmore hole was too heavy and bulky to use on the Northern holes. It was used because the final mud tank design was not completed and we did not want to delay the program. Using this two compartment tank did indicate that more than two compartments are desireable and this was taken into consideration in the final mud tank design.

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The single cone desilter was designed to allow 100% of the circulating volume to pass through the cone during each circulation period. With the low circulating volumes used the single cone was adequate and the desilting action was satisfactory.

The shale shaker was required during the drilling of the surface hole but it was not necessary for the cored portion of the hole. While hole was being made by coring the drilled solids were of a size and volume which could be handled by the desilter and even though the shale shaker was in operation throughout the hole it served no useful purpose during the coring period.

A Totco deviation survey assembly was added to decrease the survey time compared to the 'acid test' method. The survey time was cut in half as a result and the rental costs of the Totco instrument were justified.

The hydraulic slips and power tongs were added to decrease tripping time and to ensure a proper and consistent make-up torque on the drill rods. Prior to these additions the accepted practice was to make up the drill rod connections with two pipe wrenches and allow the connections to be tightened in the hole by the torque developed during drilling. As might be suspected this method was slow and unreliable at best and could have caused joint failures resulting in fishing jobs at worst.

The power tongs provided the necessary control over the make-up torque and also made for a safer and more efficient operation during tripping.

The rig crew were housed in a nearby town and transportation was by conventional means.

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The third party services of cementing, mud supply and maintenance, electric logging, drill stem testing, pressure testing, fuel supplies and water supplies were all supplied by conventional oil field methods. Service company personnel supplied and serviced the rig from their respective bases nearest the rig site.

4. SUBSEQUENT MODIFICATIONS

The rig and modifications as described in the previous section represent the equipment as it was used to drill CPOG Strathmore EV 7-12-25-25 W4.

As mentioned previously, the blowout preventer stack, the mud tanks and most of the third party services were not yet adapted to the concept of the highly portable coring rig.

In addition, several changes became apparent which would improve the safety and the general efficiency of future operations.

Early in our evaluations we realized that, in order to maintain the exceptional degree of portability inherent in the original rig, we would have to impose a size and weight limitation on all pieces of equipment added for oil field exploration drilling. With careful planning and desing it was possible to keep additional equipment such as blowout preventers, high pressure pumping equipment, electric logging tools and equipment, drill stem testing tools, crew accomodation etc., to a size and weight compatible with transportation in the de Havilland Single Otter DHC-3 aircraft. These limits apply to any one piece and are a maximum weight of 2,000 lbs., a maximum length of 14 feet and maximum dimensions of 3' 8" x 3' 6" to allow loading through the aircraft's side-loading door.

As a result of the drilling at Strathmore and keeping in mind the portability and the advantages in being able to use the Single Otter Aircraft for 100% of the rig transportation, the decision was made to take the rig into the North West Territories for a drilling program on completely untested CPOG acreage.

Additions and modifications made previous to the Northern drilling can be summarized as follows:

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Blowout Prevention Equipment changed to:

- 1 - 6" 900 Series Shaffer LWP Double Gate Preventer
- 1 - 6" 900 Series Shaffer LWP Single Gate Preventer
- 1 - 6" 900 Series Shaffer Type 51 Stripper Head with 4" flanged outlet.
- 1 - 6" 900 Series space-saver spool with 2" 900 Series flanged outlets.
- Portable accumulater, emergency shut off remote station assembly and rig floor control station.
- Guiberson lubricator and stuffing box assembly for inner core barrel wireline retrieval under pressure.

Drilling String increased to include:

- approximately 800 feet of 4 1/2" O.D. conventional drill pipe c/w collars for drilling surface hole.
- 30 feet (3-10' lengths) of 3 1/2" O.D. drill collar stock to serve as a kelly while drilling with HQ rods.
- 30 feet (3-10' lengths) of 2 3/4" O.D. drill collar stock to serve as a kelly while drilling with NQ rods.

Downhole coring equipment:

- increased core barrel lengths from 10 feet to 20 feet.
- adapted NQ inner barrels for use inside the HQ outer barrels for increased clearance.
- adapted BQ inner barrels for use inside the NQ outer barrels.

Surface equipment added:

- bolted, steel, nine compartment, 100 barrel capacity mud tank.
- 'Lightening' mud and chemicals mixer.
- Halliburton centrifugal cement mixer.
- High pressure independently powered cementing pump and lines for emergency killing procedures.
- Bigger wireline hoist with 1/4" cable.

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- Small steam boiler for additional heat and general utility use around rig.
- Portable, knock-down camp with kitchen, wash house and sleeping quarters for Company and Contractor personnel.

5. DISCUSSION OF DRILLING RESULTS

The results of our drilling at Strathmore figured strongly in the decision to attempt a drilling program on our Northern acreage.

The following observations were made during and at the conclusion of Strathmore EV 7-12.

1. It is technically feasible to drill a slim hole (3 25/32" diameter) in a sand-shale lithological sequence with wire-line diamond coring equipment provided a packed hole is maintained for drill rod support and provided no serious lost circulation problems are encountered.

2. With the equipment used on this project the maximum probable penetration rate was approximately 325 feet per 24 hour day. Because of limitations in pressure control equipment, pumping equipment, drill rod capacity and a general lack of expertise a maximum permissible depth was estimated to be approximately 8,000 feet. The probable average penetration rate expected from surface to a depth of 8,000 feet including all day work activities but not including rigging up was approximately 80 feet per 24 hour day.

3. The HQ and NQ Longyear drill rods are barely adequate for drilling below approximately 6,000 feet. The internal-external -flush threaded connections are inherently weaker than the body of the pipe itself and are therefore a weak point in the system. At depths below 5,000 to 6,000 feet the variations in torque, tensile stresses and bit weight (which often vary according to a sine function plus assorted harmonics and are referred to collectively as 'vibration') start to exceed the design limits of the Longyear joint and drill rod troubles result. The hydraulic pressure seal is also very susceptible to damage so that, unless the drilling crews are extremely careful, the seal will be damaged and the effective hydraulic pressure rating drops to

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about 1,000 psi. This eliminates drill stem testing below approximately 2,000 feet unless a chamber recovery tool is used. A chamber recovery tool is somewhat unsatisfactory because the recovery probably would be mostly mud filtrate. This is because the mud systems possible in a small annulus cannot have good mud-cake building characteristics so filtrate invasion of permeable zones continues relatively unchecked as long as the hole is open and full of mud. This drawback could be overcome partially by testing immediately after penetrating a promising zone but the results of the test would still be ambiguous and it is not always possible to program testing in such a way.

4. An inverted oil emulsion mud system is ideal for maintaining a gauge hole in sands and shales. Although no other mud systems were tried in sand or shales it was concluded that, while there might be a less expensive system no other mud could be expected to provide any better hole conditions. The lack of an effective filter cake and the resulting lack of invasion control appears to be inherent in the small annulus approach to drilling and requires further investigation.

5. Three characteristics basic to the diamond coring system are of considerable help to the mud in maintaining hole erosion to a minimum. The external flush joints on the drill rods keep annular turbulence at the minimum level possible, the large size of the core relative to the hole size keeps the volume of cuttings low which decreases the abrasiveness of the mud in the annulus, and the diamond bit rotating at high speed and low weight produces extremely fine cuttings which would be considerably less abrasive in the annulus than the coarser cuttings produced with a conventional rock bit.

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6. The additional equipment required to adapt the mining rig to hydrocarbon exploration will not seriously affect the logistic superiority which the rig has over conventional oil field equipment.

7. The information available from core examination and electric logging compares favourably with the information to be obtained with a conventional oil field rig.

8. Control of lost circulation is not possible by the conventional method of putting lost circulation materials into the mud system and resuming drilling. When drilling with a small annulus lost circulation zones must be handled as follows:

   1. Stop drilling.
   2. Treat lost circulation zone with cement, sawdust or chemicals until circulation is regained.
   3. Clean out hole and resume drilling with low solids mud system.

   This is unsatisfactory at best and wells with thick lost circulation zones would probably have to be abandoned.

9. High pressure zones, which make it necessary to use a weighted mud for control must be controlled by adding chemicals which will go into solution as they increase the mud weight. Ordinary NaCl is adequate for weights up to 11 lb. per gal. but above that weight more expensive salts must be used. This approach is acceptable from the technical point of view but the cost could become a significant factor expecially if the higher mud weights create any lost circulation problems.

10. According to costs published in Canadian Government Reports for conventional drilling in the Canadian North as compared to estimates prepared for a completely air transported and supported slim hole diamond coring rig considering such things as volume and tonnage of equipment to be moved and expected penetration rates, the cost of a slim hole drilled to 8,000 feet would be about half the cost of the same hole drilled

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with conventional equipment. This estimate assumes an equal risk factor (or contingency allowance) for both types of drilling. Since we can be reasonably certain that the slim hole technique should be assigned a higher risk factor the net effect is an increase in the cost of a slim hole relative to a hole drilled with conventional equipment. Therefore, when risk is considered, the estimated cost of slim hole diamond coring is something over half the expected cost of conventional drilling in remote areas.

Realistic drilling costs whether actual or estimated are difficult to determine in the North because of the wide variations which can be caused by factors which are beyond anyone's control - for example, unusually severe weather conditions or an isolated high pressure zone or other unknown problems encountered in unknown lithologies. For these reasons the above comparison must be used with caution.

II. The basic concept of slim hole coring in sedimentary rocks is still considered to be valid but investigations and improvements are required in the following areas:

1) Drill rod design for deeper holes.
2) Small diamond bit design for soft rocks.
3) Cheaper mud systems.
4) Lost circulation control methods.
5) Portable living facilities.