DEVELOPMENT OF CORING AND ELECTRONIC DATA LOGGING SYSTEMS ENHANCE DATA QUALITY AND QUANTITY FACILITATING IMPROVED ORIENTED CORE ANALYSIS

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Abstract Historically, the unreliability and inaccuracy of results has inhibited the frequency of oriented coring. The advent of a new core orientation system has increased mechanical reliability and enhanced the quality of data. The system affords positive placement of the survey tool which is in turn protected from mechanical and hydraulic disturbances. Core spiralling is also reduced, enhancing the quantity and quality of data. Introduction of programmable Electronic Survey Logging Tools has had very significant impact on the quality and quantity of directional data during oriented coring operations. Ruggedness, associated with solid state technology, has increased reliability to acceptable levels (>90%), whilst the ability to record directional data during coring minimises drilling risks and reduces damage to cores. Repeatability and accuracy of data is verifiable when tandem instruments are used and, by reducing instrument alignment errors to around +/- 1 degree, high quality data for analyses of formation directional trends is provided. Scrutiny of the raw data output from the probe can reveal much about conditions during coring and vibrations, torque and penetration rates can be inferred. Large memory and programmable sample rates can track even the most severely spiralling scribe line leading to successful analysis where previous technology has failed. The accuracy and density of data provided by these systems allows detailed geological analysis (paleocurrent trends, fracture determination) of cored material to be carried out with minimal error margins. The introduction of computer aided goniometers has further reduced error margins in the reorientation of planar features in cores to < +/-2 degrees. This has resulted in overall error margins, from downhole survey to reorientation of planar features, to be reduced to < +/-8 degrees.

INTRODUCTION

Cores can provide valuable information on the properties of hydrocarbon bearing formations. Analysis of cored formation provides data which offers the potential for: (a)enhancement of exploratory information; (b)optimisation of future exploration work in a locality, and of reservoir models for the primary and enhanced recovery potential of producing fields. Thus the results of analysis of cores can play a major role in the evaluation of field economics and can also affect decisions relating to well spacing, geometry, location and numbers.

The addition of a directional reference to such cores can significantly increase the value of the core for reservoir evaluation. Directionally (oriented) referenced core enables much more complete and complex analysis, including the determination of dip and strike of inclined strata or fractures and directional permeabilities.

The taking of oriented cores has long been considered desirable by geologists, geophysicists and reservoir engineers. In practice, however, efforts in obtaining high quality, accurately oriented cores have been fraught with misfortune.

The aim of this present paper is to illustrate the advances which have taken place over the past few years, in terms of technology of the coring, surveying and analysis processes.

ORIENTED CORING

Oriented coring refers to the combination of cutting a core which is marked with a narrow groove along its length and providing directional survey data referenced to this groove.

As the core is cut, it is pushed through a shoe (located behind the corehead) which has three projections (scribe knives) pointing inwards. As the core moves through this shoe, the scribe knives make grooves on the surface of the core. By orienting a survey instrument to one of these knives, known as the primary knife, the direction of the groove made by the primary knife can be determined, the direction being referenced to true north, or magnetic north or highside (either gravity or magnetic).

Ideally, the column of core recovered will have scribe lines along its entire length, directionally referenced, from which the rock's original orientation can be established.

PROBLEMS ASSOCIATED WITH CONVENTIONAL ORIENTED CORING

Historically, the standard methods used for the directional survey aspect of oriented coring have been magnetic multishot survey systems. These systems are based upon a camera which takes photographs on a continuous strip of film of a compass. These photo-mechanical systems, having many moving parts, were neither designed nor suited for use during coring operations. The tool was located directly above the corebarrel, inside a non-magnetic drill collar and was subject to mechanical and hydraulic vibrations.

Instrument failures were frequent - failure rates exceeding 50% were common (Brindley 1988). The operation of these photo-mechanical systems demanded that coring and circulation had to be stopped at intervals for 3-5 minutes to enable still photographs of the compass face to be taken.

The interruption of circulation and coring has several potential side effects undesirable from both the drillers' and geologists' points of view:-

Getting Stuck in Hole

There is a very real risk of differential sticking while the pumps are switched off and the drill string is motionless.

Destruction of Cores

The effect of stopping-starting, for survey shots on the core itself, is deleterious. The incidence of spiralling scribe lines is increased, the core frequently becomes severely fractured or worse, rubbilised. The survey data obtained then becomes increasingly valueless.

Loss of Rig Time

The requirement to stop for 5 minutes at a time is costly in terms of rig time. Several hours of rig time could be consumed if the oriented coring operation has to be carried out over several hundred feet.

The combined influence of lost rig time and the danger of becoming stuck in the hole has usually determined that the frequency of survey shots is kept as low as is possible. The normal frequency has been one survey every 5 - 6 feet cored. This will result in only 6 or 7 data points per 30 feet of core. In certain cases where the scribe lines have spiralled round the core, the data frequency may be simply insufficient, making interpretation of the directional data impossible.

Poor reliability, the danger of becoming stuck in hole and the impoverished nature of data in terms of quality and quantity and at high cost, have determined that oriented coring has been considered an unsatisfactory, high risk activity. It is hardly surprising, therefore, that drilling departments tend to frown at the mere mention of oriented coring and often refuse to carry out this type of work.

ORIENTED CORING MADE POSSIBLE

The development of a radically different core barrel assembly and an electronic survey tool for orientation logging have solved many of the problems seen in the past, associated with the taking of oriented cores.

Oriented Coring System

A new type of core barrel, termed the Corienting barrel, has been developed to address particular problems associated with conventional oriented coring (Diamant Boart Stratabit 1989). These problems were primarily mechanical damage to the survey instrument and spiralling scribe lines caused by torque transmitted via the survey tool to the inner barrel.

Briefly, the Corienting barrel offers a safety zone to the survey tool by positioning it inside a non-magnetic section of inner barrel. The tool is positively placed within this zone providing protection from mechanical and hydraulic disturbances which has been a major source of unreliability. The survey tool is, therefore, no longer in contact with the drill string thus eliminating the transmission of rotary torque to the scribing mechanism.

A secondary advantage to the system is the ability to flush the inner barrel clean prior to coring which, in turn, avoids the problems which can be associated with downhole fill. Figure 1 contrasts the old and new core orientation systems showing the different locations of the survey tool.

Electronic Data Logging System

The system has been described by an earlier Author (Brindley 1988). For the purposes of this paper it will be called the Electronic Multishot (EM).

Briefly, the tool is a battery powered, solid state, electronic device using advanced triaxial accelerometers and magnetometers. Memory capacity is for 2000 individual orientation records, with programmable variable shot interval and start delay. The device evolved from an MWD

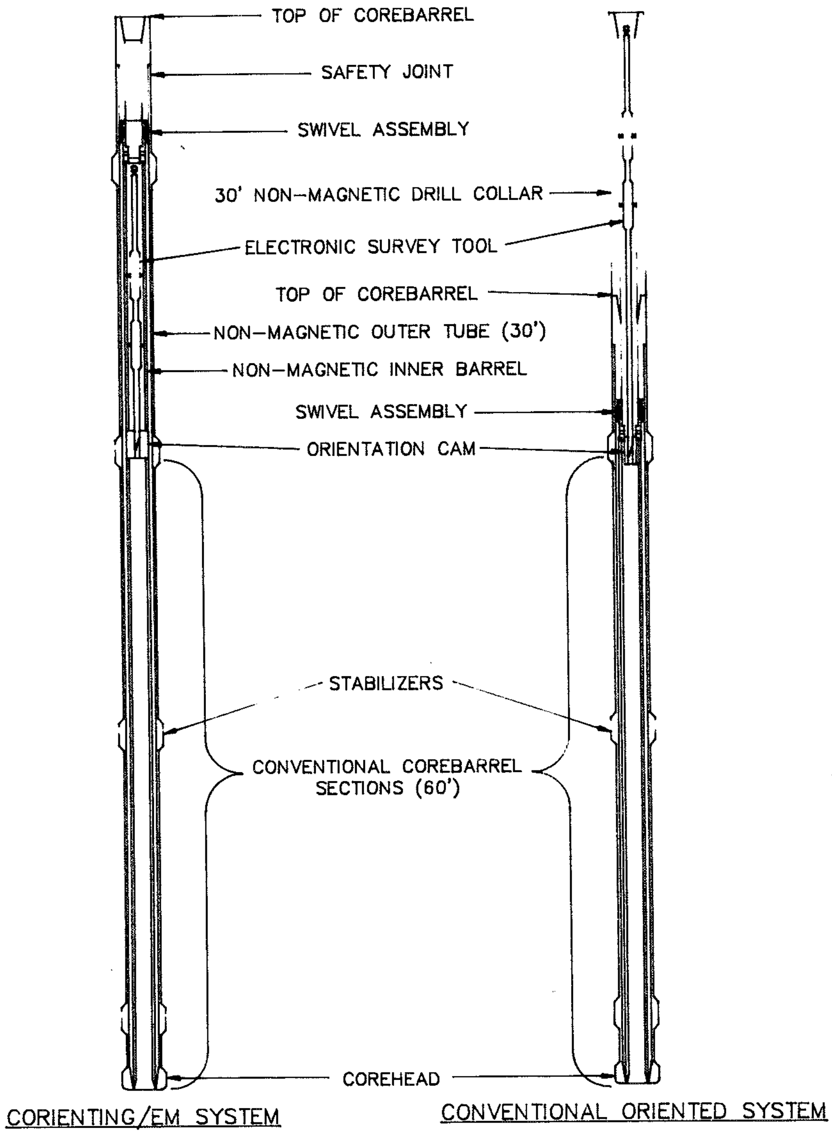

FIGURE 1 Comparison between Corienting/EM system and conventional oriented system

system giving dual advantages of ruggedness and durability during coring and the ability to measure drill-tool orientations whilst drilling and circulating. This has eliminated the need to cease rotating the drillstring and turning the pumps off to take orientation records.

As a direct result of improved ruggedness, reliability has greatly increased. Brindley (1988) reports the rate of success in obtaining full sets of core orientation data using the EM tool has increased to over 90%, compared to a mere 50% for the conventional photo-mechanical based system. Moreover, approximately 95% of these successful EM runs contained additional information from a tandem instrument allowing verification of data. Tandem data sets were rare in the old camera based tools.

Success in providing orientation data is not a complete measure of the success of the core orientation project. Figure 2 shows comparison in the usability of the orientation data in core analysis between conventional oriented coring systems (using photo-mechanical survey tools) and the Corienting system (using EM survey tools). The term "insufficient data" refers to the quantity of data which has no value for oriented core analysis due to lack of survey data, spiralling scribe lines or damaged core.

In the conventional system good analyses results were obtained only 28% of the time. Performance for the Corienting/EM systems is in stark contrast. Of the data provided 60%-70% (on average) is useful - a major improvement.

The elimination of the need to cease drilling and circulating to obtain orientation records is perhaps the single most important advance, and removes most of the objections that drilling departments can have to core orientation projects. Risks of differential sticking, rubbilisation and core fracturing are much reduced. In comparison to conventional oriented coring, substantial rig-time savings are available. Figure 3 illustrates this point. Comparison is made between conventional oriented coring using photo-mechanical survey tools and Corienting combined with EM tools. Assuming the R.O.P. is 20 feet/hour for both cases then rig-time saved is approximately 1 hour per 60 feet of core cut.

The EM tool sample rate is normally programmed (as a function of R.O.P.) to take around 6 shots per foot (compared to a single shot every 5 feet in the photo-mechanical tools). This high density data is clearly advantageous in tracking severely spiralling cores and additionally may frequently allow accurate correlation of breaks in the core to depths during analysis.

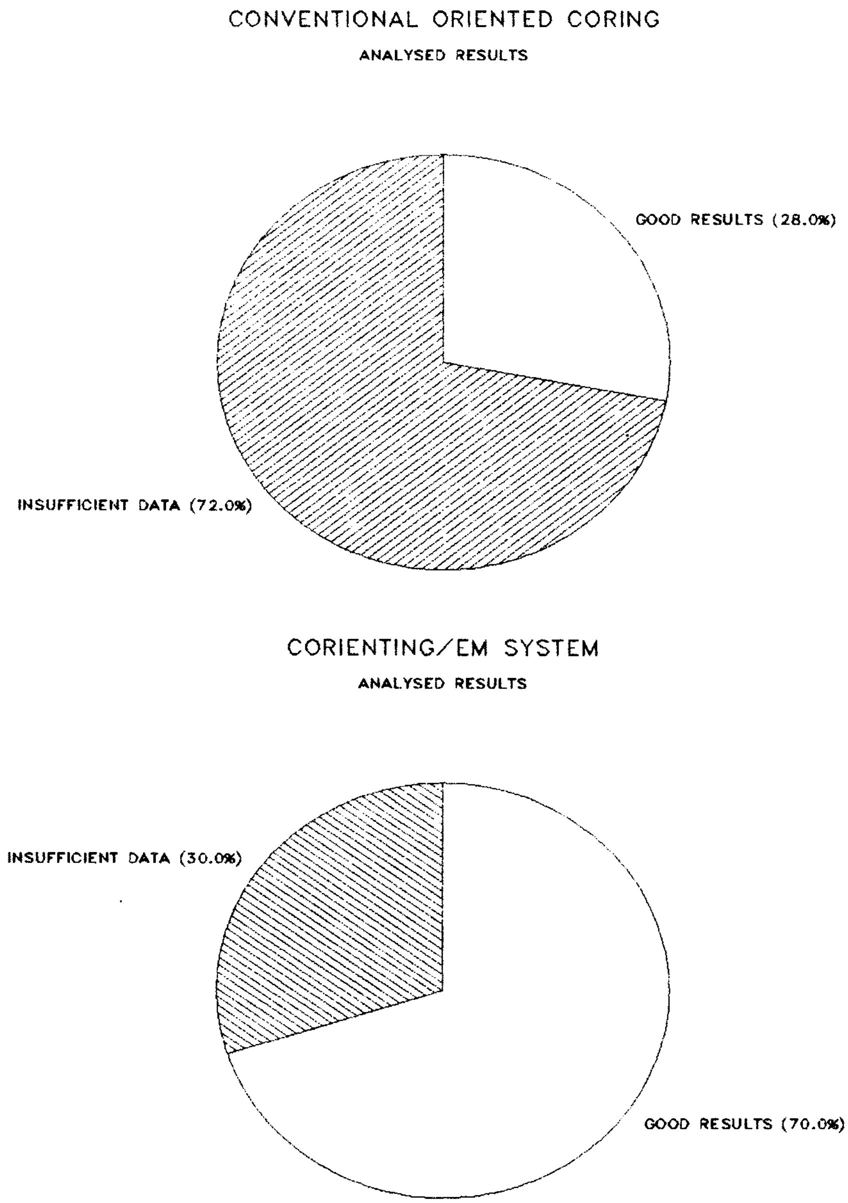

FIGURE 2 Quantity of usable data per foot of core recovered. Conventional oriented coring and Corienting/EM system.

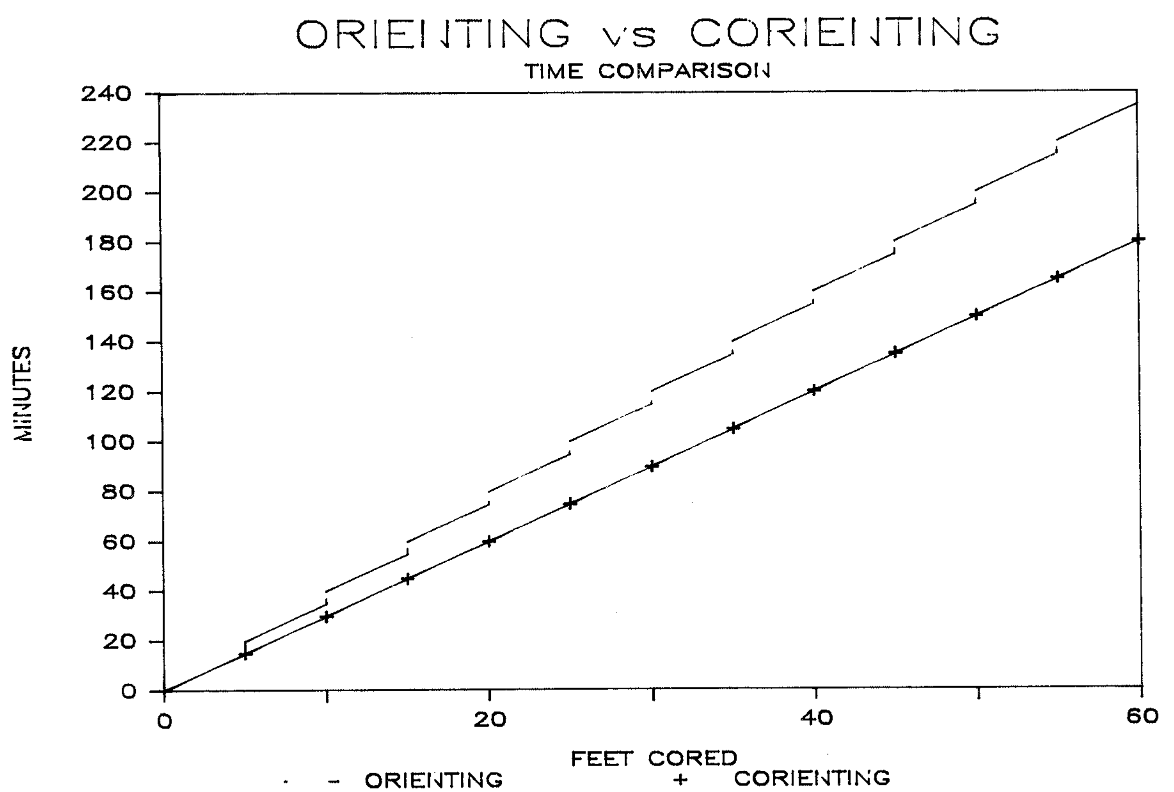

FIGURE 3 Time/feet cored comparison for conventional and Corienting/EM system.

SYSTEM ACCURACIES

Recent reviews (prior to the introduction of the Corienting/EM system) on methods of core orientation by Davison and Hazeldine (1984) and Nelson et al. (1987), concluded that the most accurate method of obtaining orientation data from conventional cores was by orienting the cores downhole using scribe knives and downhole (photo-mechanical) survey equipment. Indeed, in many circumstances it was the only viable method of obtaining reliable directional data. Error margins discussed in the review by Davison & Hazeldine (1984) varied dramatically; +/- 10 degrees for oriented core barrels (using older photo-mechanical equipment) to +/- 20 degrees for palaeomagnetics, +/- 30 degrees for dipmeter, and +/- 45 degrees for borehole deviation survey. In our opinion the error margin quoted for the conventional orienting method is optimistic and is thought to be more realistically in the region of 11.5-17.5 degrees, as in Table 1.

TABLE 1 Error Margins for Conventional Oriented Coring

	Pessimistic	Optimistic
Barrel Alignment	+/- 10 deg.	+/- 5 deg.
Photo-mechanical Survey Tool	+/- 5 deg.	+/- 5 deg.
Survey Tool Alignment	+/- 2.5 deg.	+/- 1.5 deg.
TOTAL	+/- 17.5 deg.	+/- 11.5 deg.

Error margins in the Corienting/EM system have been determined as shown in Table 2.

TABLE 2 Error Margins for the Corienting/EM Systems

	Pessimistic	Optimistic
Barrel Alignment	+/- 7 deg.	+/- 4 deg.
Survey Tool	+/- 2.5 deg.	+/- 1.5 deg.
Survey Tool Alignment	+/- 2.5 deg.	+/- 1.0 deg.
TOTAL	+/- 12 deg.	+/- 6.5 deg.

Nelson et al. (1987) suggests that the most significant errors can result from a lack of multishot data over the cored interval and also by survey point and depth uncertainty. Prior to the introduction of the Corienting/EM system, downhole survey data points were commonly spread out due to the high costs and inconvenience incurred by having to stop the coring process in order to allow the photo-mechanical equipment to operate in a vibration free environment. The EM, however, records azimuth information whilst coring is still proceeding, allowing the process to be both cheaper and more accurate at the same time. The density of data recorded by the EM allows accurate verification of scribe line spiralling which, together with very careful examination and fitting together of the core and comparison of surface measured core gamma to downhole gamma logs, can significantly reduce uncertainties due to depth mismatches. As the EM data can be stored on floppy disc in ASCII format any depth shot-point mismatches can easily be shifted by using readily accessible software.

Goniometry

The parallel introduction of computer aided goniometers (CAG) has significantly improved the accuracy of measuring planar and linear features from oriented cores. Error margins for older mechanical goniometers are estimated at +/- 6.25 degrees (best case) (Nelson et al 1987), while manufacturers of CAG's claim an error margin of +/- 1-2 degrees. Several other major advantages of computer aided goniometers include:

1.Direct digital data input eliminates manual data entry errors.
2.Speed of measuring features.
3.Coded data description entry allows vastly improved data handling of large data base.
4.Automatic well deviation correction.
5.Portability; CAGs are light and can be carried to the core location thereby reducing unnecessary core handling.

The planar or linear features are rapidly measured using electronic 3-space digitisers. Measuring a planar or linear structure involves tracing the feature around the core surface with a stylus arm, and recording discrete points by depressing a toggle switch on the stylus. The position of the stylus and rollers are automatically measured and entered into the computer. The digitized data is automatically entered into data files. Coded descriptions used to describe each measured feature can be used to review the data at any stage of the study. The interactive menu driven software allows selection of plot types for any given feature or depth interval. These include stereographic projections of poles to planes, contoured pole plots, rose diagrams - dip azimuth or strike, histograms, and tadpole plots versus depth.

CONCLUSIONS

Recent technological advances in the coring, survey and analysis processes have resolved many of the problems previously associated with oriented coring:

1.The combination of the electronic multishot together with the Corienting barrel has significantly increased the quantity and quality of data over conventional oriented coring.
2.Developments have made it possible to obtain directional data from downhole oriented cores to an achievable accuracy of less than +/- 8 degrees.
3.The high risk of becoming stuck in the hole and damaging the core while stopping to take directional surveys has been eliminated.
4.The ability to orient the core in one continuous operation has resulted in the saving of valuable rig time.
5.The quality, quantity and accuracy of the data afford improved reservoir description in terms of depositional trends and fracture patterns. Directional permeability can be established and more accurate, three-dimensional reservoir models developed.

6.The introduction of computer aided goniometers has significantly improved the accuracy of measuring planar and linear features.

By combining the developments of the three processes, oriented cores may now be taken on a routine basis with a high degree of success, low risk and reduced time-cost.

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