How to evaluate orientation data, quality control

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Core orientation data are crucial in many types of geologic or reservoir engineering studies.

Given the lengthy list of potential problems, however, how much faith should one put in the results?

In areas where many cores have been oriented from one or more wells, results from a new well can be compared with previous orientation data. Rose diagrams of fracture directions, sediment transport directions or directional permeabilities are particularly useful for this purpose.

Dip and strike of bedding planes can be compared to the well’s dipmeter log. These comparisons are usually done long after the core has been cut and it may prove impossible to trace and rectify suspected errors.

The problem is much the same for the first cores in an area where no prior data base is available.

What techniques are available to improve one’s confidence in orientation results even in areas where no comparison with surrounding wells is possible? As is often the case in oil and gas operations, development of quality control standards offers the best opportunity of ensuring consistency and quality of results. Orientation service companies have their own quality controls but it is both possible and desirable for an operator to improve and check those standards.

Multishot quality control. A suggested list of quality controls for multishot orientation is shown in Table 3.

The quality control steps prior to going in the hole require the close cooperation of operator, coring service and orienting service personnel.

The distance between survey points should be determined such that it does not jeopardize the drilling operation. Survey spacing should not exceed 5 ft if orientation quality is to be maintained.

Downhole, the suggested procedures improve the possibility of having “tie-in” points between the reference groove on the core and the multishot orientation data. After retrieval of the core, a check of the punch marks will reveal if any tightening or loosening has occurred. Even very small punch mark offsets must be noted and measured in order to evaluate orientation results properly.

Careful assembly and marking of the core upon recovery is critical to multishot orienting as much as it is to paleomagnetic orienting. The same procedures are used in either case.

The core should be carefully assembled into continuous intervals, which are defined as a length of core where each piece can be accurately fitted to the next. Continuous intervals are bounded by breaks such as rubble zones, spin off points, the tops and
TABLE 3

QUALITY CONTROL CHECKLIST

MULTISHOT TECHNIQUE

Prior to going in hole:
1. Determine the number of feet between surveys.
2. Specify tandem cameras.
3. Double check instrument make up.
4. Be sure tool is aligned on the principal scribe knife.
5. Double check lug/reference groove offset.
6. Use chisel or punch to set "matched" marks across each threaded joint.

While in the hole:
1. Take a survey 0.5-1.0 ft below top of cored interval.
2. Take a survey immediately above any connection point.
3. Take a survey 0.5-1.0 ft below any connection point.
4. Take a survey at the base of the core, prior to breaking off to trip out.

When the orientation tool and core barrel are retrieved:
1. Mark punch marks at all joints and remeasure amount of offset.
2. Carefully fit core together, mark straight line(s) (MOL) parallel to the axis of core.
3. Correlate core to Geolograph depths noting particularly indication of the top and bottom of the run and any connection points. Mark correlated depths on core.
4. Note breaks in core continuity caused by rubble zones, spin offs, connections. Record tops and bottoms of continuous intervals.
5. Measure angular offset between lines parallel to core axis (MOL) and reference groove at one to two foot intervals.
6. Ask for separate interpretation sheets for the primary and backup cameras. If possible, have them read independently by different orienting engineers.

In the office:
1. Plot out multishot data and MOL/reference groove measurements from the core and overlay.
2. Be sure multishot orientation data are accurately transcribed on any inhouse records and heading of MOL is accurately determined.

PALEOMAGNETIC TECHNIQUE

Prior to going in hole:
No special procedures required. Scribe shoe is recommended but not mandatory.

While in the hole:
No special procedures required.

When the orientation tool and core barrel are retrieved:
1. Carefully fit core together, mark line(s) (MOL) parallel to the axis of core.
2. Note breaks in core continuity caused by rubble zones, spin offs, connections. Record tops and bottoms of continuous intervals.

In the office:
Be sure paleomagnetic orientation data are accurately transcribed on any inhouse records and heading of MOL is accurately determined.

TABLE 4

STRENGTHS AND WEAKNESSES

<table>
<thead>
<tr>
<th>Application/value</th>
<th>Multishot</th>
<th>Paleomagnetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviated hole</td>
<td>F-P</td>
<td>G-F*</td>
</tr>
<tr>
<td>High angle deviated hole</td>
<td>F-P</td>
<td>G-F*</td>
</tr>
<tr>
<td>High latitude drilling site</td>
<td>F-P</td>
<td>F-P</td>
</tr>
<tr>
<td>High temperature hole</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Core grazed</td>
<td>G</td>
<td>F-P</td>
</tr>
<tr>
<td>Rubble zones</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Limited core continuity</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Partial core recovery</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Unconsolidated sediments</td>
<td>G</td>
<td>G</td>
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<td>E</td>
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<td>Core samples required no</td>
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<tr>
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<td>Resolving anomalous points</td>
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<td>P</td>
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<td>Real time data</td>
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<td>P</td>
</tr>
<tr>
<td>Onsite personnel</td>
<td>yes no</td>
<td>yes no</td>
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<td>Equipment failure</td>
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<td>yes no</td>
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<tr>
<td>Risk to hole</td>
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<td>yes no</td>
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<tr>
<td>Rig time</td>
<td>yes no</td>
<td>E = excellent</td>
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<tr>
<td></td>
<td></td>
<td>G = good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F = fair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P = poor</td>
</tr>
</tbody>
</table>

* May be poor to north
† If not disturbed

Almost all of the problems associated with multishot drilling can be avoided by careful attention to detail in the field and in the office. The use of the overlay technique is particularly important in this regard. The overlay technique is used to evaluate the magnitude of depth correlation errors and several types of multishot problems which are not constant over the length of the run. It cannot, however, detect error where every survey point is off by a constant amount, whether 1° or 180°. Thus, the emphasized importance of quality control, double checking equipment and measurements before and after running in the hole.

Transcription of records in a remote office offers some of the same opportunities for introducing errors as at the wellsite. Quality control must include sufficient checks to minimize this po-
Overlays reveal problems

**Tightening**

The two plots show the same general form but the multishot plot is increasingly diverging clockwise. Barrel and tool points were continuing to tighten during the cutting of the entire interval. The compass lug is displaced clockwise of its starting position relative to the reference groove.

**Depth correlation**

Points “a” and “b” on the core plot match closely with their counterpart points “a’” and “b’” on the multishot plot, indicating that a better match probably could be achieved by shifting core depths downward.

**Anomalous data point**

Plots overlay reasonably well except at point “c” where the multishot data points are well away from the core plot. Source of the problem can sometimes be traced from detailed analysis of drilling records.

**Low survey density**

The interval between multishot survey points is too large. Interpolation between those points does not reflect accurately the actual deviations of the reference groove occurring on the core.

Potential in circumstances that may be far removed in both time and location from the original cutting of the core.

**Paleomagnetic quality control.** While paleomagnetic orientation requires no downhole blind procedures, the accuracy of the technique can still be affected by human factors similar to those encountered when using multishot. The procedures for marking and core handling are the same, and avoiding errors at this stage greatly increases accuracy. Paleomagnetic orientation tends to benefit from the fact that sampling and measurements are carried out under less adverse conditions. Equipment calibration and redundant measurement procedures reduce the chances for error.

Given that sources of human error are minimized, paleomagnetic orientation accuracy is largely dependent on the magnetization of the rock itself.

The natural remanent magnetization of the rock consists of the composite (vector sum) of magnetizations that may be acquired through sedimentary, thermal, or chemical means.

Distinct paleomagnetic directions are recorded by many discrete grains, thus the measured vector is an average of these many individual directions. If the individual grain directions are very uniform, the grouping of the plug sample directions from a continuous interval of core will be good, and orientation accuracy will be enhanced (Fig. 9).

If the alignment of the many individual grains is highly variable, then accuracy will be diminished. In practice there are several magnetic components, commonly having different directions, contained in any one sample. These additional components are secondary magnetizations that have been recorded in the rock by chemical or thermal events generally occurring long after deposition.

The different components can be separated in the laboratory using a variety of progressive demagnetization techniques. Different magnetizations are destroyed at somewhat different rates, usually obeying the “last in, first out” principle. Therefore, individual magnetizations are more precisely calculated from the vector subtracted over several demagnetization steps.

The subtracted vectors generally show much tighter groupings than do the directly observed resultant vectors.

Paleomagnetic measurements are amenable to sophisticated vector analysis techniques which enhance the orientation accuracy. These vector analysis techniques also provide sta-
Stereonet plot

The cost of either orientation technique can show tremendous variation from job to job as a result of these factors. Although a direct cost comparison is difficult, an analysis of the service company costs of 10 representative wells showed that the average service cost for the multishot was approximately $20/ft of core oriented less than for paleomagnetic orientation.

The costs for multishot orientation ranged from $50 to approximately $200/ft of oriented core for state-side wellsites. Paleomagnetic orientation costs range from $60 to approximately $190/ft oriented.

A truer comparison of orientation costs must factor in the tangible cost of rig time associated with running a downhole survey. A minimum of 1-3 hr rig time is needed for a typical multishot survey.

If intangible costs (due to problems such as jammed core or stuck pipe) are incurred as a result of the orientation survey, these costs must also be considered. Average costs for the two techniques are comparable when tangible rig costs are included. Undiscovered errors in data reported further increase the cost per foot of core accurately oriented.

Results and value. The paleomagnetic plug sampling technique and the multishot camera technique are the main alternative procedures currently available for orienting cores.

In most ways the paleomagnetic technique is simpler than the multishot technique since fewer people and less rig equipment and time are involved. For these reasons the potential for uncorrectable error in orientation is also reduced. Paleomagnetic orientation is more difficult if several components of magnetization are present in each plug sample. This difficulty can be resolved with proper interpretation techniques. Paleomagnetic orientation accuracy tends to be more amenable to verification and internal checks. Since the orientation is based on a magnetic property of the rock, additional verification is possible as long as the core can be resampled. It may also be possible to verify the paleomagnetic results, if necessary, by sampling adjacent cores or even surface outcrops.

Paleomagnetic core orientation is not subject to a wide variety of operational difficulties that can compromise multishot data. High bottom hole temperatures work to the advantage of the paleomagnetic technique. Poor recovery will not affect paleomagnetic orientation accuracy if the rock recovered is at least competent enough to assemble a continuous interval.

Both orientation techniques fall...
short of being the total answer to all orientation problems in all circumstances. Rubble that cannot be fitted together to form a cylinder cannot be oriented by either technique. High latitudes are potentially troublesome for both techniques, and poor core handling and marking procedures are always a cause for concern.

Core orientation data can sometimes be derived from dipmeter and televiewer records. In cases where this is possible, more direct methods of orientation are unnecessary.

All drilling operations involve considerable expense and risk. Downhole, each special procedure increases the risk of sticking pipe, hole collapse or blowout. Although core orientation data may be valuable to the geologists and engineers engaged in reservoir studies, concern for losing a well can be the overriding consideration. Complete understanding of the procedures involved in core orientation and very close attention to quality control during every stage of an orienting operation can do much to alleviate the concerns regarding the quality of the results. Removing the orienting operation from the downhole environment, as is the case with the paleomagnetic technique, eliminates additional concerns related to hole risk and expenses associated with rig time and operations.

Reducing risks and associated costs while improving orientation reliability permits application in situations where the benefits of orienting core were formerly considered to be marginal.

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