A Coring Matrix for Success

Mike Gay
ExxonMobil Upstream Research Company

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ABSTRACT

The decision has been made to collect core during the drilling program. This decision is the foundation for the many critical elements that must be addressed in order to realize a successful and quality outcome to the coring program being established. It will be a joint effort between drilling, geology, formation evaluation, and a wide assortment of coring, core analysis and drilling fluid companies. Factors ranging from the analytical objectives for the core to how the core gets to the laboratory must be detailed and assigned. Deciding to take the core leads to assigning the job to qualified coring and core analysis companies. These companies need to have knowledge of the types of tools required for core collection and handling, the necessary analytical tests required to achieve coring objectives , and adjustments that may need to be made to the drilling fluid. The tools, handling, and tests are most often very specific to the type of lithology being cored and tested. The lab data acquired from the core itself will only be as good as the quality of core acquired. Acquiring the best quality core requires knowing what tools and handling techniques are best suited for a specific rock. Having a process flow diagram to determine the proper tools for the collecting and handling will help define the proper questions to ask beforehand, aid in tool specifications, and help determine how best to stabilize and/or preserve the core for shipment to the laboratory. This poster will take two examples and detail the thought process that might be followed to bring the best quality core from the wellsite to the laboratory.

Introduction

The two factors that will define the tools, handling and stabilization/preservation for the coring program are the lithology or type of rock being cored and the type of core analysis tests to be performed, the coring objectives. Once we know these we are able to develop a coring matrix and select the necessary coring tools, core handling equipment and the safest (for core integrity) transportation system to deliver the core to the laboratory.

The starting point is the decision to collect core material from the well. There is usually an objective for the core that could span several different disciplines such as reservoir evaluation, drilling and completions, geomechanical and many others. Knowing the uses for the core from these groups is necessary to adequately design the coring program so that full use of the core can be realized. Once we know the objectives we can start putting the program into bins which will lead us to the optimum tools, handling and transportation.

Collecting core that is of sufficient quality for sampling at some point in time and the data derived from the analyses be applicable to the objective is the basic set of criteria that should be implemented in any coring program. The objective or reason for the core, ultimately the extent of analyses, will establish how the core needs to be stabilized or preserved and what the coring tools and parameters should be to get the highest quality core for the analysis. There is an extensive list of objectives for which core material can be used. We can start to classify these into 4 main categories, Archival, Geomechanical/Geochemical Analyses, Routine Core Analyses and Special Core Analyses. There could be several sub-categories of each main type.

Archival Storage

Core destined for archival storage will require the least intensive handling and effort. This core may be used sometime in the future but has no immediate analyses planned. This core will be collected using coring tools adequate for the rock type and surface handling procedures that will insure the core is safely transferred from the well site to the storage facility.

Geomechanical/Geochemical Analyses

Samples for these analyses are often taken from core destined for other analyses. Since the core plugs sampled are in the 'vertical' orientation to the reservoir, they are generally used for horizontal vs. vertical permeability studies. However, in the case of shale or other water reactive rock, specific types of preservation need to be addressed to ensure the core does not become altered over time or during transport.

Routine Core Analyses

The basic information necessary to describe the rock of interest is collected using routine core analysis. These tests include porosity, permeability, grain density, core gamma, lithological descriptions and fluid saturations. Other more extensive routine tests could include CT scan imaging, grain size analyses and net confining stress measurements for permeability and porosity.

Special Core Analyses

SCAL or special core analyses builds upon the routine core analysis data. These tests include capillary pressure, relative permeability, wettability characteristics, pore volume compressibility, mercury injection, formation damage and a whole host of other experiments to help understand and evaluate the rock and reservoir.

In order to realize any of these objectives, it is critical to collect, preserve and ship the best possible quality of core from the well site to the laboratory. The starting point is to know or anticipate the end product. Core that will be for archival storage only will not have the same level of effort as core for some of the high-end special core analysis tests. Core solely destined for routine analysis will not have the same level of effort required for coring and preserving that the rock for special core analysis will have.

Following are two different scenarios for core analysis and the thought process that might be followed to bring the best quality core from the wellsite to the laboratory.

Scenario 1: Unconsolidated Sand for SCAL tests:

For this scenario, 'unconsolidated sand' is defined as a lack of cementation between grains but held together by a large saturation of oil with some low water saturation.

Routine core analyses for permeability, porosity and grain density, followed by Special core analysis tests which will include, relative permeability (oil-water), and capillary pressure (drainage and imbibition). Analyses may be delayed several months due to the well site location, the core analysis laboratory location and the need of export licenses for the core.

Coring Tools-

- The type of rock, unconsolidated sand, will require a full closure type catcher. This is necessary to capture and retain the core inside the inner core barrel. This catcher has two independent catching mechanisms, one for unconsolidated or soft core (full closure) and the other (collet or split ring) for more consolidated rock should coring terminate in that interval.
- A PDC type of bit will be necessary to cut the core at up to an optimal coring rate, <= 1 foot per minute (3 minutes per meter). The face mud discharge characteristics of the PDC bit is important to direct the mud flow away from throat of the bit where the force of the mud may wash the core away and/or cause substantial mud filtrate invasion.
- The inner core barrel must have one-way vent valves incorporated at 1 foot to 2 foot spacing and 120° rotational spacing to allow for solution gas to vent. This is necessary to prevent mechanical damage of the core due to gas expansion and release.
- The core barrel length should be tailored to the degree of unconsolidation of the sand. The nature of truly unconsolidated sand may limit the core barrel length to something less than a completely full barrel. The weight of the core above the core at the face of the bit may cause collapse of the core within the core barrel. In exploration wells it is better to start off short, 1 core barrel length, and progress to longer lengths if the actual rock will allow. The target sand should never be started after collecting a more dense formation above, i.e. cap rock or trap seal. A length of dense rock, >1 meter, may have enough weight to collapse highly unconsolidated sand. The weight of the mud column above the core inside the inner barrel should also be considered.

Coring Fluid-

- Although core analysis on clastic reservoirs has developed, via restoration techniques, to allow using either water based mud or non-aqueous fluids, it is best to implement a bland water based mud system prior to reaching core point. This would mean either swapping the drilling fluid for a coring fluid or eliminating some components of the drilling mud prior to reaching core point. The inclusion of mud tracer is often done to indicate invasion and help define what the in situ water saturation might be.
- A bland water base mud will have a pH between 7.0 and 8.5 and contain no chemical agents that will alter the wettability of the reservoir rock. Sized calcium carbonate can be used for pore throat bridging and salts for clay control. Above all, the mud must include all requirements for maintaining well bore stability and well control. The ideal mud will have a low spurt loss, low particle invasion, a non-damaging filtrate, prevent clay damage and prevent any wettability alteration.

Coring Parameters-

- To use a full closure catcher system it is necessary to keep the bit in contact with the formation at all times, otherwise the core will fall from the inner barrel. A low weight on bit (WOB) is typically all that is necessary to produce a reasonable rate of penetration (ROP).
- The RPM of the drill string should be slow enough that there is no high torque associated with the coring, i.e. sticking and slipping of the bit.

- The mud flow rate is a critical component. Too high a flow rate and the core can be washed away before going into the inner barrel or filtrate invasion may be high. Too low a flow rate and the cuttings generated will not flow up the well creating a situation where sticking the core barrel could become a factor.
- Constant observation of the resulting parameters, torque and stand pipe pressure (as well as ROP) will provide indication of actual coring or the indication of a jam. There are tools available to help evaluate this situation more easily.

Scenario 2: Carbonate for routine core analysis tests:
For this scenario, 'carbonate' is defined as limestone or dolomite. It may or may not contain surface or internal vugs and it may or may not be naturally fractured.

Coring Tools-

- Carbonate rocks are usually well cemented, consolidated and hard. There may be small to large vugs that will be visible on the core surface upon recovery. Having some information, from previously cored wells, imaging logs from nearby wells or from the original hole, if coring a sidetrack or by-pass core, will make choosing the coring tools easier and more definitive.
- There are two types of bits that will work in this formation. The PDC (Polycrystalline Diamond Compact) bit will provide a good ROP but may not be the best choice depending on the size of the vugs in the rock. If a PDC bit is chosen, a small diameter cutter would be the best choice with several blades for a less aggressive bit. This will allow a shallower cut per revolution on the bit minimizing the depth into which the cutter will attack a vug. This may help prevent loose rock cuttings from getting dislodged and causing a potential core jam inside the inner barrel.
- Using a TSP (Thermally Stable Polycrystalline) or natural diamond bit may make more sense if there are many known vugs or fractures. Since the cutting action of this type of bit is based on crushing the rock, the rate of penetration will be less but will allow for a better core gauge and decreased likelihood of dislodging rock pieces. Careful attention to the weight on bit is necessary. A higher weight will be required for the diamond bits over the PDC bits to achieve a reasonable ROP so understanding the mechanical characteristics of the rock will be helpful. Following the first core recovered, modifications can be made to the coring parameters to adjust for the rock type.
- The core catcher should be a collet or split ring type catcher. If the rock is found to be very fractured or rubbleized, the inclusion of a basket catcher above the collet catcher will aid in capturing the core. For longer core barrel runs, the collet catcher needs to be 'heavy duty' to adequately retain the core inside the inner barrel.
- Inner core barrels should have one-way vent valves incorporated at 1 foot to 2 foot spacing and 120° rotational spacing to allow for solution gas to vent. This is necessary to prevent mechanical damage of the core due to gas expansion and release.
- Long core barrels are generally available due to the consolidated and well cemented nature of the rock. Several core barrels may be strung together to get many feet or meters cored during one coring run.

Coring Fluid-

- Routine core analyses do not require any special treatment from a wettability standpoint. The normal drilling mud is acceptable as long as the pH is not so low that it dissolves the rock itself.
- Above all, the mud must include all requirements for maintaining well bore stability and well control. The ideal mud will have a low spurt loss, low particle invasion and a non-damaging filtrate.
- Mud tracers may be added if water saturation is an objective.

Coring Parameters-

- The weight on bit necessary to core will be dictated by the formation. After an initial low weight on bit to develop a coring pattern in the formation, additional weight will be applied to achieve a reasonable rate of penetration. The weight should be incrementally raised to a working weight instead of a large increase all at once.
- The RPM of the drill string should be slow enough that there is no high torque associated with the coring, i.e. sticking and slipping of the bit. This should be adjusted based on the weight on bit and rate of penetration.
- The mud flow rate should be high enough to sufficiently clean the bit of cuttings and rock debris and circulate it from the hole. Invasion is not an issue with routine analyses unless water saturation is of interest. Most diamond bits do not have face discharge mud ports so the mud flow is through the throat of the bit. Invasion and flushing can be substantial.
- Constant observation of the resulting parameters, torque and stand pipe pressure (as well as ROP) will provide indication of actual coring or the indication of a jam. There are tools available to help evaluate this situation more easily.

Common to both Scenireos:

Core Recovery and Lay Down-

- Whether the rock is hard or soft, the speed at which the core is pulled from the hole is a critical factor. Pulling too fast will not allow the gas sufficient time to ‘evolve’ from the core and avoid gas expansion damage. The ‘Trip-Out Schedule’ should have different specific steps, usually defined by proximity to the bubble point of the oil. It may be staged by depth or the number of pulled drill pipe stands, sometimes including a ‘wait’ period between stages. In all cases the last several stands of pipe should be pulled the slowest as the core approaches the surface and atmospheric pressure. This is helpful for allowing any non-desired gases (H_2S) to evolve prior to opening at the surface.
- Once at the surface the inner core barrel should be removed from the outer core barrel in a slow controlled manner. If there are multiple sections of inner barrel, these should be separated one at a time starting from the top down. Sufficient time to allow the mud to drain from the barrel is good. A core splitter should be used to separate multiple barrels using a splitting system that does not require hammering a plate through the core.
- Each inner barrel section should be removed and strapped onto or into a ‘core cradle’. This can be an “I” beam cradle or tubular ‘shuck’. This is critical to the operation to prevent the inner core barrel from bending of flexing (along with the core inside) while removing from the drill floor.

- Great care must be taken to avoid bumping and jarring while laying down the core.

Surface Handling, Preservation and Shipping-

- Once the top of the core has been located inside the inner barrel, it should be marked to include Well ID, Core#, Tube#, Top and Bottom Depths and a set of orientation stripes (Red on the right, looking from bottom to top, aside another color stripe, usually black).
- Wellsite Core Gamma may be run over the core.
- The core barrel is then cut into smaller sections, 3 foot or 1 meter. An end cap is placed on each side of the section, placed on a drain rack and the excess mud allowed to drain from the barrel.
- Into the annular space between the ID of the inner barrel and OD of the core there should be some PVC or other non-swelling rods or wedges inserted to prevent rolling or movement of the core inside the barrel.
- Once the section has been stabilized and preserved (if water saturation is an objective), it is placed into a multi-section core shipping box with padded shelves or foam sheets to isolate each section. Single wooden boxes have been used but are not as safe for the core as they can easily be mishandled.
- Once all of the core is collected and boxes it can be shipped to the laboratory. Shipping indicators can be included with the boxes to show signs of mishandling, i.e. shock sensors, tilt sensors, temperature and humidity loggers.

Coring Tools and their Application

Coring Bits	**Application**
PDC	Clay, Gumbo, Marl, Salt, Anhydrite, Shale, mudstone, Limestone, Dolomite, Siltstone, Sandstone
TSP	Shale, mudstone, Limestone, Dolomite, Siltstone, Sandstone, Quartzite, Volcanics
Natural Diamond	Shale, mudstone, Limestone, Dolomite, Siltstone, Sandstone
Core Catchers	**Application**
Collet / Split Ring	Any hard, competent rock, i.e. consolidated sand, limestone, dolomite, siltstone, shale, mudstone, quartzite, etc.
Basket	Rubbleized, soft, fractured rock. Used in conjunction with collet catcher.
Full Closure	Unconsolidated sand, rubbleized rock
Slip-Dog	Fractured, hard rock. Oriented core catcher.
Inner Core Barrels	**Application**
Steel	For conventional coring where the core is removed from the barrel on the rig floor or for HTHP coring.
Aluminum	Any rock type where the formation temperature is < 400°F or 205°C.
Fiberglass	Any rock type where the formation temperature is < 248°F or 120°C.
PVC	Usually used in cooler formations for heavy oil sand.