MAXIMIZING THE VALUE OF CORE

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ABSTRACT

Core provides the ground truth for fine-tuning all other sources of formation evaluation information. Used to calibrate log and geophysical data, it also provides mountains of detailed geologic and engineering information. Unfortunately, it is relatively simple to compromise the accuracy of this data as the rock is being cut, and as it is packaged, transported, stored, and finally sampled. Fortunately, it is just as simple to maximize the accuracy of this data through thoughtful planning. Coring is an expensive proposition and would not be done if the value of the data was not expected to greatly exceed the cost of acquisition. Drilling rig time will often be the largest cost factor in a coring program, followed by the cost of special drilling fluids. It is possible to reduce rig time by cutting longer cores. It may not be possible to influence the choice of drilling fluid, but it is crucial to anticipate the effect of mud filtrate and plan to deal with it. Core handling, preservation, and transportation decisions will be made on a case by case basis. Rock type, oil composition, location, climate, and capability will all factor in the decision process. The key is to have a plan agreed to by all stakeholders. This takes time and several rounds of discussion to finalize. Sequencing of sampling is the last issue examined. Prioritizing the analytical program from rock chips to SCAL helps ensure samples will be available for the most valuable studies. A good plan provides a template for sampling and a time-line for results. Of course changes will always occur, but the plan will reduce the risk of compromising key data sets. In summary, this paper reviews factors affecting the cost of core acquisition, how data priorities change over the life of a project, and how careful planning and diligent execution of those plans can maximize the value of every core.

INTRODUCTION

Coring and core analysis programs should be an integral part of every formation evaluation program, because only core data can provide the ground truth for fine-tuning all other sources of formation evaluation information. The previous sentence was qualified to acknowledge that core data is only as accurate as one makes it. Many factors influence core quality and the accuracy of the resulting data sets. Some factors are set for us, such as well location and date of operations. Other factors such as rock strength and the presence of faults or fractures cannot be changed they can only be accounted for during planning. Then we come to the items we may be able to influence hole size, well angle, and drilling fluid composition. And, finally we come to items we do control: coring tools, trip rate, core handling and preservation protocols, and analytical procedures. If we planned well and are lucky then we head to the laboratory with the best core possible. Highest priority should be placed on delivering quality rock to the laboratory, where it can be marked, photographed, sampled and properly stored. I consider this the foundation for every data set. When questions arise during testing there is a starting point to which one can return with confidence. How often has someone asked can we re-run this test, is there any core left? This is not a problem if sampling and preservation were done according to the priorities in your plan. It may be a big problem if not. Taking core is expensive, with rig time and drilling fluid charges often outpacing coring tool and core analysis expenses. Planning costs money too, but not planning costs much more. By now you have noticed this is not your usual technical paper. Nor will it be a “cookbook” for designing coring programs. Rather I hope it servers to remind readers not to lose sight of the big picture while taking care of the myriad of details essential for the success of every core analysis program.

Reasons for Coring

The reasons given for coring are as numerous and varied as the companies and personnel involved. Time-honored reasons often stated include acquiring porosity, permeability and saturation values, performing special core studies and obtaining geologic data. More targeted goals might be to conduct fracture studies, measure rock strength, or collect reservoir tracer data. Data derived from core is used in almost every phase of oil and gas development, but that is not why we core. We core to make money. One does not need core to produce oil or gas in fact many small producers rarely core. They drill, log, perforate and produce, or not. It is only when the potential expense of not coring becomes great that we can justify cutting core. It is also true that the primary reasons for coring will change over the life of a field. Rock mechanics data is more valuable during the appraisal stage of a project when it can be used to answer questions about wellbore stability, the need for sand control, and subsidence potential. It is of less value during exploration and late in the life of a project when the results are not likely to influence operations. Figures 1 and 2 illustrate how core data priorities may shift over the life of a field. A final motive for coring may be that it is required by the lease agreement or partners. This may seem like a burden, but it should be considered an opportunity. Management has already agreed to the major expenditure you just need to take care of the details to ensure accurate results are acquired.

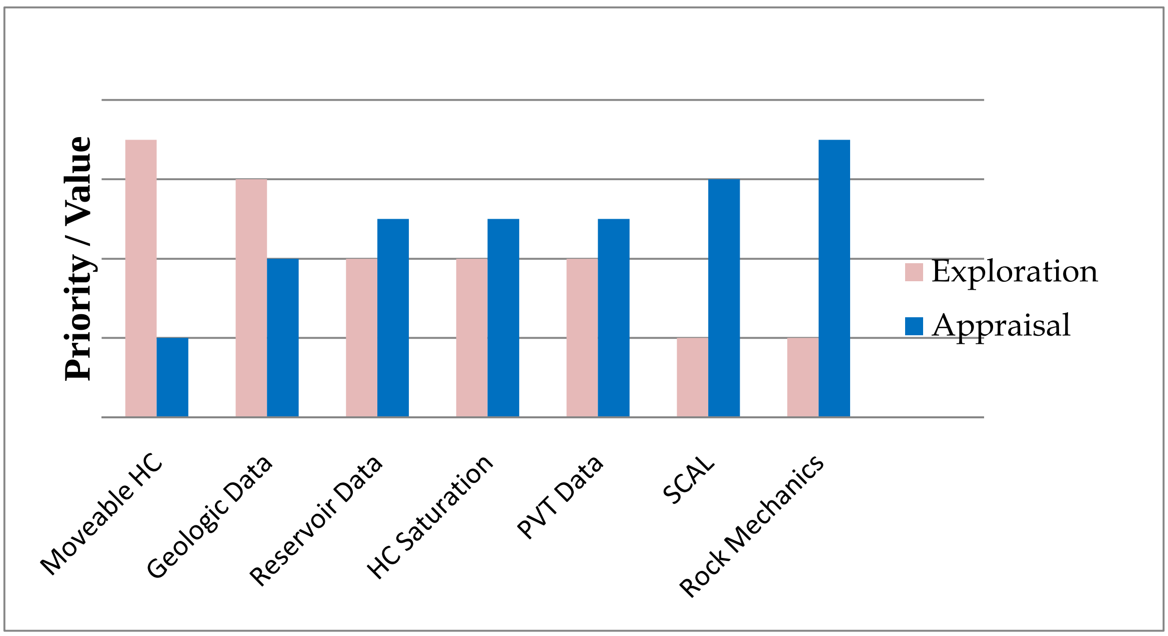

Figure 1. Coring Objectives: Exploration & Appraisal

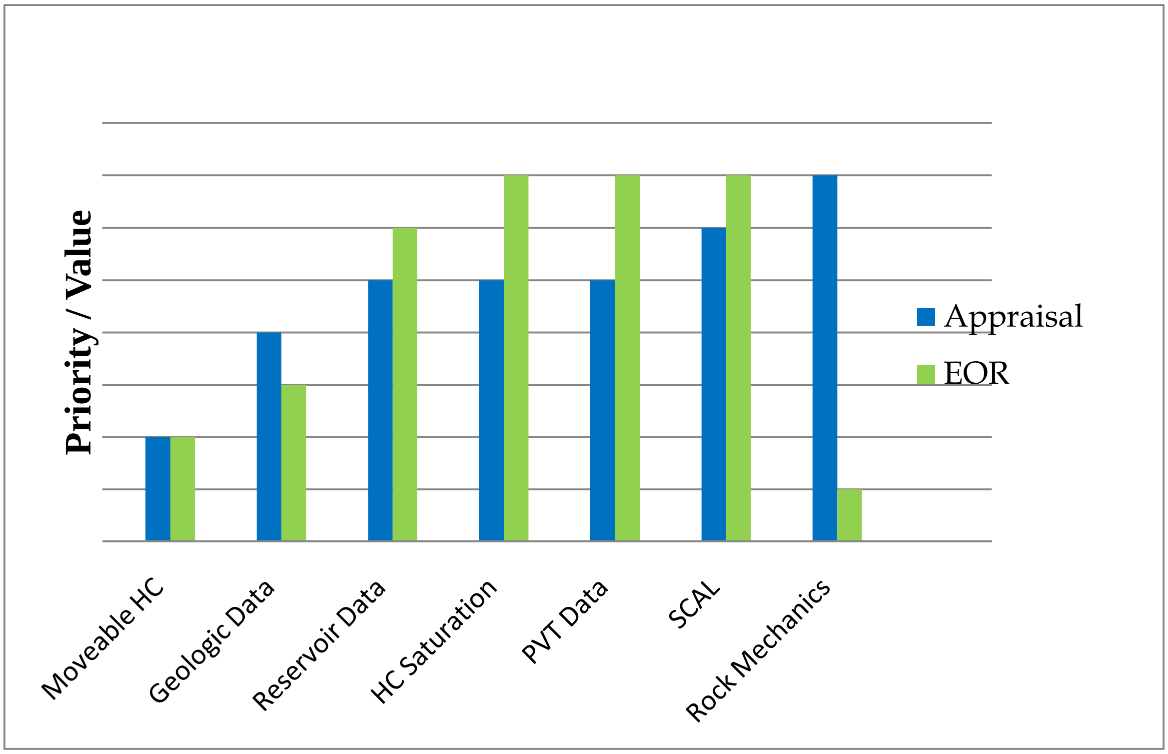

Figure 2. Coring Objectives: Appraisal & Enhanced Recovery

Command and Control

We might like to think we are in control of situations and can command others to act on our wishes. In reality we need each other, working as partners to achieve our goals. This does not mean a coring project coordinator bends to the will of every stakeholder encountered. It means a good project coordinator takes time to learn where others stand and why their positions are so. For instance, geologists focus on geology and reservoir engineers on SCAL data. No big surprise there, but if we leave core out uncovered for examination or slab it before plugging, SCAL data may be compromised. The project coordinator makes sure this does not happen. Drillers are sometimes thought of as adversaries, and it is true the drilling department would rather be drilling. So, it is essential the coordinator can explain why and how he wishes to core to a skeptical audience. A reasoned explanation goes a long way towards convincing others of the value of the coring program. If one cannot justify the coring expense then he needs to revisit the why. Another other point to always remember is that drilling is a costly and potentially dangerous task. There can only be one person in charge of a drilling rig and it is not likely to be you. Safety is the card that trumps all goals of a coring program, so discuss it with your drillers, agree to procedures beforehand and acknowledge they have the final say. This is why meetings and discussions between groups are so essential months before a core is cut. It takes time to develop rapport and earn the trust of the people you will be working with at the rig. This applies to interactions with all service company personnel too.

Taking time to discuss your goals with contractors always results in a better outcome. It may seem like extra work or micro-managing, but done correctly it is not. Service company hands know what they are doing. Unfortunately, they may not know exactly what you want done. The coordinator needs to be able to explain the goals of the program, giving voice to preferences and concerns while remaining open to suggestions. The more open the discussion the better the final results will be. Be sure to make time to visit those in the back room, those who will actually handle your core. Taking time to discuss the reasoning behind analytical protocols gives people a sense of ownership in the outcome. And, as stated before it opens the door for them to communicate their thoughts on processes. Tasks which sound simple in your office may prove difficult or impractical in the laboratory or field.

Planning a successful coring program, including the analytical phase, requires a dedicated team leader. This person needs to be organized, willing to listen, and not afraid to question. He or she should be the point of contact for stakeholders and contractors alike. With input from others he puts forward recommendations on items ranging from coring tools and drilling fluids to core handling and analytical procedures. The biggest challenge for a leader is keeping communication open between groups and information flowing.

Concerns

There are a host of items to consider when setting out to plan coring and core analysis programs, and it helps to put the anticipated value of the project on page one. Let's face it there are alternatives to coring, including logs, well tests, geophysical data, existing core data sets, and yes, guessing, so expenditures need to be justified. We core to gain insight that cannot be gotten any other way, to reduce risk, and ultimately to reduce project cost. Unfortunately, we sometimes fail to present our reasons for coring in terms of the bottom line, and while some may feel the rationale is self evident, going through the exercise never hurts.

The value of a coring program can be greatly enhanced by maximizing the amount of accurate core analysis information obtained and by controlling costs.

$$\text{Program Value} = \text{Value of the Data} - \text{Cost}$$

Controlling cost is perceived as being easier than valuing data, so one might be tempted to act miserly during planning. This would be a mistake. The value of employing a particular coring or core analysis technology often greatly exceeds the cost of the service, even when the expenditure is significantly more than a competing technology. For example, using a coring bit that has been shown to increase the rate of penetration and reduce filtrate invasion over a less expensive alternative would be a good decision, provided the following are true. There is an extensive section to be cored and filtrate invasion is a major concern. Consider, most filtrate invasion takes place ahead of the bit so you are unlikely to eliminate contamination, and for short cores the majority of time will be spent circulating and conditioning the hole, tripping and handling tools. For short cores the savings in coring time may be lost to these other factors.

It helps to state what your primary concerns/fears are. These would be factors that if ignored would greatly reduce the value of your data. Identifying what you can least afford to lose reveals where to focus resources. Two major concerns are often the mechanical integrity of the rock and wettability. Mechanical integrity is required for most core measurements and geologic studies. True, we can learn quite a bit from broken or disaggregated rock, but we learn more, add more value, with a continuous core. The second major concern is that the accuracy of many special core studies relies on samples having the appropriate wetting state. How one arrives at that state can be debated, but most analysts agree that less alteration during coring, handling, and preservation is better. We know most drilling fluid additives can alter wettability, so to maintain the value of the core data one has two options. The first is to core with a relatively inexpensive drilling fluid containing a minimum amount of wettability altering additives that can be effectively cleaned off pore walls. The second strategy would be to core with a more expensive fluid designed to minimize the potential for wettability altering chemicals to enter the core. This fluid would contain tracers to help determine the depth of filtrate invasion, and you would employ all technologies available to reduce filtrate invasion during the coring process. Then the question becomes how much does one spend on special drilling fluids, tracers, and coring technology versus core cleaning and restoration.

Core Data

Many readers will have their own list of core analyses and measurements they order up on a recurring basis. That is a reasonable starting point, but conscientious core analysts should ask why are these tests being run on this particular core, and where will the data be used. It may turn out your standard analytical program is the result of years of discussions and refinements, however even well accepted procedures may contain costly flaws, so it is prudent to review every detail before beginning. I encourage you to always consider the larger picture, and how biases and small gaps in planning can compromise the value of your core data. Table 1 lists items often included in core analysis programs. Every effort should be made to ensure the core arrives in the laboratory physically intact, and with records of all events that could have altered wettability. A list of drilling fluid additives, and descriptions of how smoothly or roughly the handling and preservation steps went go a long way towards preserving the value of the core data. Core will freeze sitting on the Tundra waiting for transport in winter, and be heated beyond recommended levels in tropical and desert environments in the summer. Knowing what actually happened allows you to account for additives and environmental effects. The unavoidable delay in shipping cannot be reversed, but it can be accounted for when evaluating results. The reliability of certain tests may be reduced due to factors beyond your control. However, it may also be possible to add analytical steps, such as extensive cleaning and wettability restoration which could improve the accuracy of results. Knowing exactly what happened during coring, handling, and transportation gives the analyst the ability to adjust procedures to maintain the overall value of a program.

Table 1. Common Core Studies				
Analysis/ Task	*Cost*	*Frequency*	*Core Integrity*	*Wettability*
Core Gamma Log	Low	High	Minor	NA
CT Imaging	Low - Moderate	Low -High	Minor	NA
Porosity	Low	High	Important	NA
Permeability, Ka	Low	High	Important	NA
Fluid Saturations	Low	High	Minor	Minor
Slabbing	Low	High	Important	NA
Photography	Low	High	Important	NA
Wettability	Moderate	Low	Important	Important
Capillary Pressure	Moderate – High	Low	Important	Important
Permeability, Kw	Moderate	Low	Important	Important
Electrical Prop. a, m & n	Moderate – High	Low	Important	Minor-Important
Relative Permeability	Moderate – High	Low	Important	Important
Pore Volume Compressibility	Moderate - High	Low	Important	NA
Formation Damage	Moderate	Low	Important	Important
Mineralogy, XRD, FTIR	Low	Moderate	NA	NA
Thin-Sections	Low	Moderate	Important	NA
SEM	Low	Low	Minor	NA
Rock Mechanics Testing	Moderate - High	Low	Important	NA
Fracture Study	Moderate	Low	Important	NA
Sonic Velocity / ASR	Moderate - High	Low	Important	NA
Lithology Log	Moderate – High	Moderate	Important	NA

The Plan and Execution

A written plan is best, but we often rely on verbal instructions hoping others write down our wishes or at least remember what was asked for. My strong recommendation is for you to make time to write out your plan. This is not always easy, especially when you are informed core will be cut within the next few weeks or days. Tables and checklists help organize the mountain of details and reveal areas where value can be added, see Table 2. Knowing exactly where and when coring will occur reveals if there is an opportunity to influence how. Encountering cores planned for next week move directly to handling, preservation and transportation issues, then on to laboratory concerns. With more time, start with the drilling profile, selecting the best coring and drilling fluid technology for your program. Planning for the most successful coring operations begins six months to a year before drilling, in phase with the drilling program development.

The biggest mistake made with fresh core is allowing sampling before it is properly marked and inventoried. Removing pieces of whole core before marking destroys the continuity of the core for oriented measurement. Reconstructing core and applying a master orientation line (MOL) as shown in Figure 3 preserves that continuity. Should questions arise about fracturing or directional properties a MOL will serve as a reliable reference, even after sections of whole core have been removed. Core properly marked with a MOL can be oriented paleomagnetically linking features and results accurately to the reservoir.

Figure 3 Core Marked with a Master Orientation Line

A second area where many of us can improve is in matching the core gamma log with the open hole gamma log. The closer these pieces of information are paired the more accurate all of your core-log comparisons will be. If we claim core is the ground truth for calibrating logs then we had better be sure the ground hasn't shifted. In situations where the gamma log is indistinct, fractures or other features seen on core and image logs may prove to be the best way to depth match. With the core properly marked and depth matched, sampling may begin. The plan should set forth sampling priorities, for example, begin by determining the need for whole core analyses, then take a minimum number of plugs for routine analysis and sample or preserve materials for SCAL studies. Slabbing should begin after the need for whole core and plug samples has been satisfied. Core cut in liners may be oriented by CT imaging and edge slabbed prior to plugging, but if longer plugs are needed orient, plug and then slab. Do not rush the sampling process and do not change priorities without consulting stakeholders. It is exciting to see a new core, and tempting to charge into the analytical process, fight those impulses. Follow your plan making changes only as needed to improve the accuracy of results, and you will maximize the value of your core. There are those who argue for extensive wellsite handling and sampling. I do not. My experience has been that the best results are obtained by preserving the core at the well, and expediting transport to the laboratory.

However, I do acknowledge the following exceptions: pressure core should be analyzed on-site, anelastic strain recovery and coal bed methane measurements should begin as soon as possible, and plugs for tracer studies should be cut on-site if additional tracer is likely to be imbibed with time. However, if one is very concerned with tracer imbibition I suggest considering a sponge or gel core to keep drilling fluid away from the rock once coring is complete.

Table 2 Sample Planning Guide

Core Date		Core Handling	
Formation		Wellsite Tests	
Depth		Preservation	
Interval to Core		Transportation	
Special Concerns	fractures, unconsolidated	Laboratory	
Hole Size		Core Marking	depth,orientation,MOL
Hole Angle		Core Gamma	
Drilling Fluid		CT Imaging	
Additives		Sampling	Routine & SCAL
Rig Size	big, small, floater	Photography	
Location		Routine Analyses	
Air Temperature		Special Analyses	
Access	Roads, airports, seaports	Geologic Studies	Slab 1/3 after SCAL sampling is complete.
Key Personnel	Contact & Distribution List		

CONCLUSIONS

Planning should begin six months to a year before coring.

The objectives of the coring program must be defined and prioritized with input from all stakeholders.

Teamwork across traditional organizational boundaries is essential for maximizing value.

Designating a project coordinator simplifies communication and ensures reasonable adherence to the plan.

Coring equipment and core analysis procedures should be specified on a case by case basis taking into account the drilling equipment, the specific formation, and analytical goals.

Service providers need to be contacted early in the planning process, so their insights can be used to improve the overall plan.

It takes many small steps to maximize the value of a coring program, and just one or two missteps to compromise the value of the data. Success will be achieved through careful planning, open communication, and attention to detail.

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