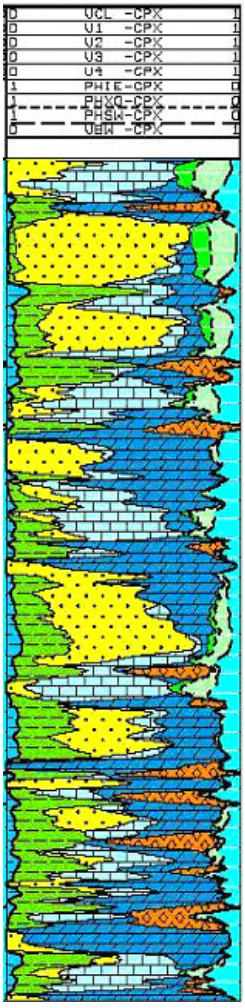
GeoScience – Essentials



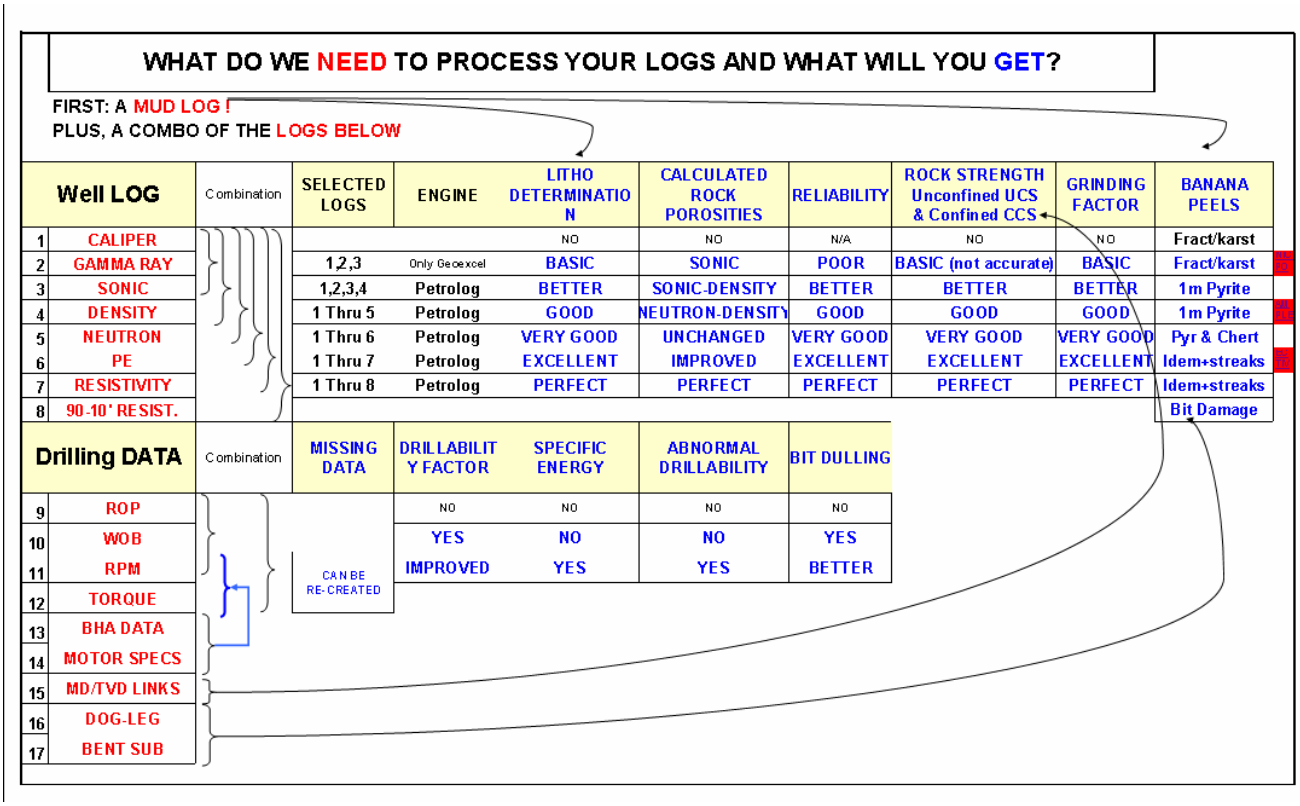
What is GeoScience? **GeoScience** is Varel's trade name for a log analysis method for improved bit selection and optimization. We use the **wire line log** data to determine the lithology, and then calculate rock compressive strength and abrasiveness. We use the **drilling logs** to evaluate drillability and the effectiveness of the bit in rock destruction. The **master log** is used to adjust the log interpretation to improve the lithology definition.

What is our method? Varel has selected the software Petrolog from Crocker Data. Petrolog is reservoir evaluation software. From the log data, Petrolog's lithology models determine the types and percentages of minerals in the formation and the porosity. Varel has added its proprietary model to the Petrolog software to determine the compressive strength and abrasivity. Varel's proprietary model has been verified by using formation cores. The verification with core shows good correlation with sandstone and limestone. Other formation types will be verified when they are present in the core.

What electric logs are needed to perform the analysis? The logs used to achieve an accurate lithology description are the ***Gamma Ray*** (GR), the ***sonic travel times*** (DT), the ***density*** (RHOB), the ***photo electric*** (PE), ***Spontaneous Potential*** (SP), the ***porosity*** (NPHI), the ***resistivity*** (one or more of these measurements MSFL, LLS, ILD, LLD or AIT) and the ***caliper*** logs. With these eight logs we will be able to provide an accurate rock description.

Why do we need the mud log? Electric logs are measurements of particular properties of the rock, not direct identification of the rock. Many times all of the logs above will not be available. Also, there can be errors in the logs or sections of the well will have inaccurate log data. **The mud log gives a direct description of the minerals and allows us to verify and adjust for inaccuracies.**

How do we use the drilling log? With the drilling logs, we are able to evaluate the drilling process and determine how to optimize it. We can design or modify bits to work with your drilling platform for improved performance. The data required for this are ***ROP, WOB, RPM, and the Torque versus depth.*** These numbers are also used to calculate the ***Drilling Factor***, (WOB*RPM/ROP/Bit Diameter^2). The drilling factor shows us the relationship between the energy applied during drilling, (WOB and RPM,) to the ROP. It is divided by the hole size, (Bit Diameter^2) so that we can compare the performance in



WHAT DO WE NEED TO PROCESS YOUR LOGS AND WHAT WILL YOU GET?

FIRST: A MUD LOG !
PLUS, A COMBO OF THE LOGS BELOW

	Well LOG	Combination	SELECTED LOGS	ENGINE	LITHO DETERMINATION	CALCULATED ROCK POROSITIES	RELIABILITY	ROCK STRENGTH Unconfined UCS & Confined CCS	GRINDING FACTOR	BANANA PEELS
1	CALIPER				NO	NO	N/A	NO	NO	Fract/karst
2	GAMMA RAY		1,2,3	Only Geoexcel	BASIC	SONIC	POOR	BASIC (not accurate)	BASIC	Fract/karst
3	SONIC		1,2,3,4	Petrolog	BETTER	SONIC-DENSITY	BETTER	BETTER	BETTER	1m Pyrite
4	DENSITY		1 Thru 5	Petrolog	GOOD	NEUTRON-DENSITY	GOOD	GOOD	GOOD	1m Pyrite
5	NEUTRON		1 Thru 6	Petrolog	VERY GOOD	UNCHANGED	VERY GOOD	VERY GOOD	VERY GOOD	Pyr & Chert
6	PE		1 Thru 7	Petrolog	EXCELLENT	IMPROVED	EXCELLENT	EXCELLENT	EXCELLENT	Idem+streaks
7	RESISTIVITY		1 Thru 8	Petrolog	PERFECT	PERFECT	PERFECT	PERFECT	PERFECT	Idem+streaks
8	90-10' RESIST.									Bit Damage

	Drilling DATA	Combination	MISSING DATA	DRILLABILITY FACTOR	SPECIFIC ENERGY	ABNORMAL DRILLABILITY	BIT DULLING
9	ROP			NO	NO	NO	NO
10	WOB			YES	NO	NO	YES
11	RPM		CAN BE RE-CREATED	IMPROVED	YES	YES	BETTER
12	TORQUE						
13	BHA DATA						
14	MOTOR SPECS						
15	MD/TVD LINKS						
16	DOG-LEG						
17	BENT SUB						

different hole sizes. When the Drilling Factor is low, it indicates better the performance by the bit. **By comparing the drilling factor to the lithology we can determine when and why the bit begins to dull and consequently, improve our bit performance in subsequent runs.**

What do we do if all these logs are not available to us? Many times, the available logs are limited to the sonic log, the neutron density logs, and the gamma ray log. We can do some work with fewer logs, but the results will be less accurate. Above is a chart that shows what kind of results can be expected with different combinations of logs.

What format of log do we need? The computer software reads digital data. Today, logging companies provide the data to the operators in a digital format. We can receive data in an ASCII format from our customers to load into our software. **Paper logs, other than the Mud Log, cannot be used without costly digitizing.** You can recognize the file types by the file extension. The most common are .las, .txt, .xls, .dlis and .lis.

What information can be expected from the GeoScience analysis? The exact format will be determined by company preference; however, a few traits can be found on all analysis. The first few columns are reserved for wireline data. In particular, the first column is the gamma ray and caliper log.

The second column is the depth in meters or feet. The third column is resistivity, if available, and the fourth column has the remaining primary logs (neutron porosity, density, sonic, photoelectric). The fifth column is the lithology column. It is the percentage of various minerals expressed as parts per unit—in other words, it is a graphical representation of the rocks. The sixth column is the Unconfined Compressive Strength expressed as color coded shading. The Unconfined Compressive Strength is the strength of the rock formation; it ranges from 0 to 50,000 psi with the low end (0 psi) colored green and the high end (50,000 psi) colored red. The seventh column is the Grinding Factor and Rate of Penetration (when available). The Grinding Factor is also color coded in shades of gold-brown with light yellow/tan as least abrasive and dark brown as most abrasive. Areas where rock strength (UCS) is red and Grinding Factor is dark brown are most dangerous for PDC bits. The Rate of Penetration (ROP) is also color coded similar to UCS with green meaning high ROP (good drilling conditions) and red meaning low ROP (tough drilling). In general, red UCS (high rock strength) will correspond with red ROP (tough, slow drilling) and visa versa. The next columns contain plots of the remaining drilling logs, (RPM, Torque and WOB.) The last column shows Formation or Bit data.

Why does the GeoScience analysis not include a bit selection? The bit selection should not be done by **GeoScience** alone. Good bit selection requires knowledge of local conditions and practices, customer preferences, and commercial conditions. The final selection is made by the local Varel representatives who possess regional knowledge. **GeoScience** is a supplement to this local knowledge, not a substitute.

Who does the log analysis and how long does it take? Varel has geologists both in Tarbes and in Houston. Michel de Reynal, in Tarbes, has many years of experience in analyzing logs for drill bit applications. See the bio's below. Stefani Bennett, in Houston, has field experience as well as analysis experience. **You should plan for a GeoScience analysis to take up to a week.**

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Michel de Reynal is an application engineer for Varel International. Prior to being with Varel, he spent 9 years in log analysis and as Applications Design Engineer at SDBS and a number of years as Mud Logger for Geoservices. He has a Master of Science in Geology from Poitiers University. He currently performs GeoScience for bit selection and performance evaluation for the Eastern Hemisphere. He is based in Tarbes, France. ***mdereynal@varelintl.com***

Stefani Bennett is the product applications technician for Varel International. She has a Bachelors of Science in Geology from New Mexico Institute of Mining and Technology. After graduating she spent a year as a wireline engineer. She performs GeoScience studies for the Western Hemisphere. She is based in Houston, TX. **sbennett@varelintl.com**