Rock
Properties
Division

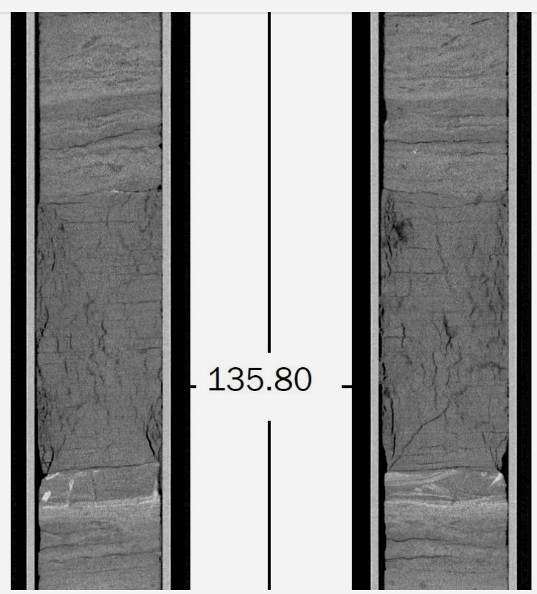
AGAT Laboratories

CRISP - Cyclically Restored In Situ Petrophysics

CRISP – Cyclically Restored In Situ Petrophysics – is a new analytical method and instrument developed at AGAT Labs. CRISP has been designed for improved analysis of petrophysical properties in unconsolidated formations, especially oilsands and heavy oil plays. Measuring porosity and permeability in unconsolidated formations is inherently difficult. There is no way to directly obtain undisturbed in situ samples. Drilling, tripping, freezing, preparation, and sampling can all disrupt the fine grain-to-grain microtexture, changing the petrophysical properties without necessarily being visually obvious.

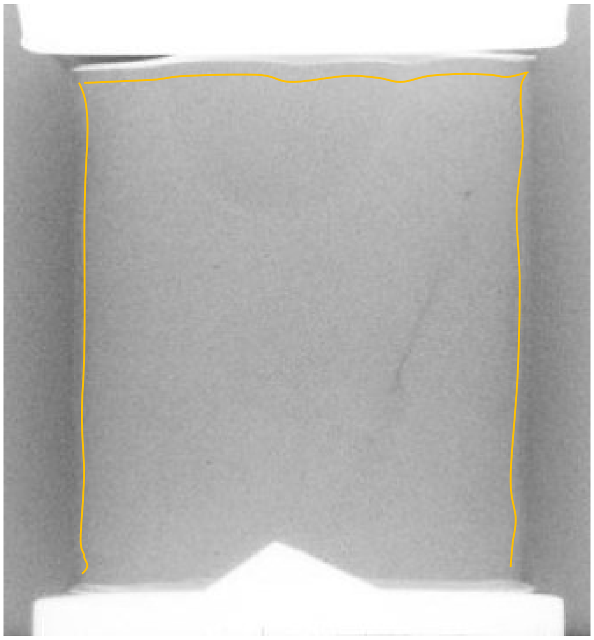
The aggregate effect is that we cannot be sure that the grain relationships in our core samples accurately reflect the in situ conditions that control the petrophysical characteristics of the formation. While fluid saturations, particle size distribution, and mineralogy will be minimally affected, the architecture of porosity and permeability are modified. Even where we can see well-preserved fine sedimentary structures, the microtextural changes are often sufficient to significantly affect petrophysical measurements. We find core porosities that are much higher than is expected in situ, and permeabilities are also inflated.

The historical method for analysis of porosity and permeability in unconsolidated sands is to punch a plug, encase it in a sleeve with screens at the ends, clean it of hydrocarbons and water, and load it into a Hassler cell which can apply a static confining pressure. Gases are passed through to obtain porosity and permeability data. The confining pressure used is typically selected to match the expected in situ net overburden pressure; as a result the test is often called a Net Overburden (NOB) plug analysis.



- Example of disruption via CT scanning: sand beds develop subvertical fractures, possible mud invasion at edges.
- Possible compression of sand by more cohesive and dense mud beds during coring, transportation and handling.

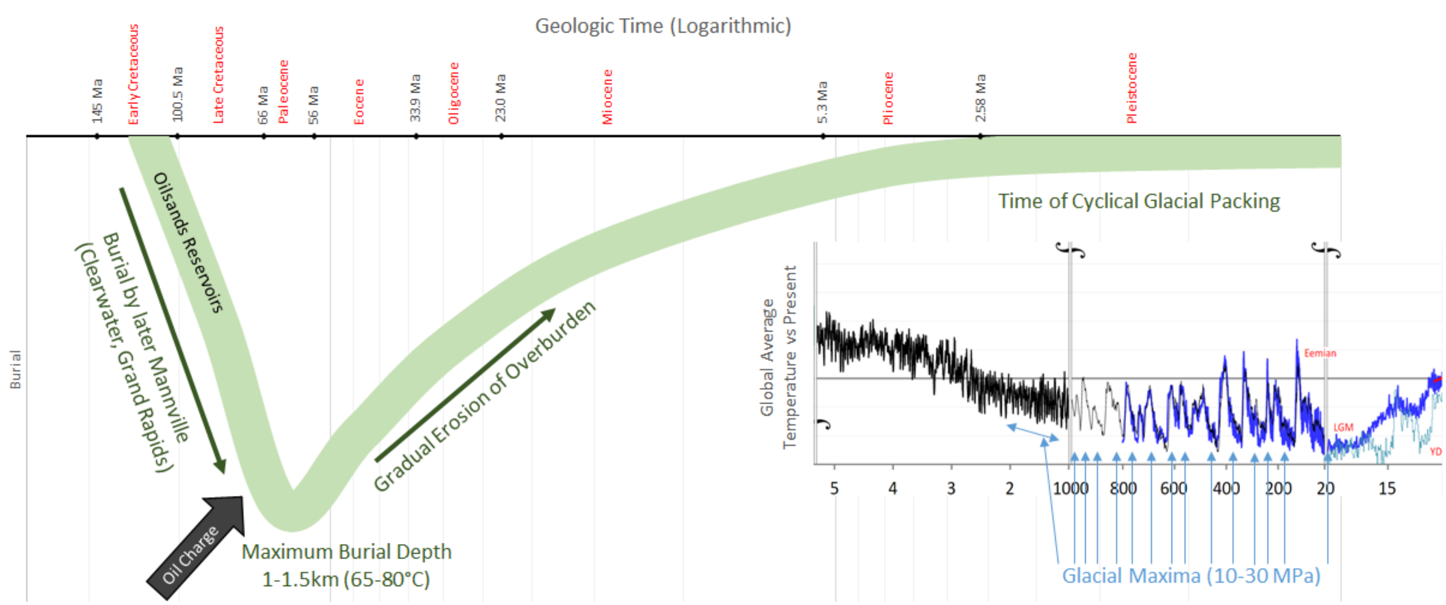
Another issue with the NOB plug approach is that the sample sleeves and holder geometry cannot force a true cylinder shape. This has implications for interpretation and processing of petrophysical data.



■ X-ray Image of NOB Plug. Yellow lines highlight irregular sample shape.

However, the grain relationships that exist in situ are not a product of present-day overburden pressures, but historical burial conditions. Historical burial depths were somewhat deeper than at present, reaching perhaps 1.5km during the Paleocene. However, the dominant influence on grain relationships will have been the repeated application and removal of 10-35 MPa of additional overburden pressure in 50-200 kyr cycles due to glaciations during the Pleistocene Epoch. There have been at least 18 and as many as 30 such cycles in the last 2.6 Myr. This cyclic pressure and relaxation has generated a well compacted (although not consolidated) microtexture within the sediment that cannot be reproduced by a single static application of confining pressure, even if higher confining pressures are used.

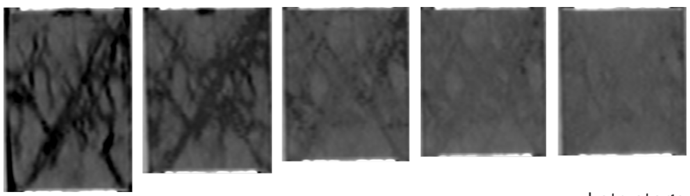
Significantly more accurate and representative data can be obtained using Special Core Analysis methods. This includes various preparation approaches, restoration of sample properties, and application of various fluids including both gases and liquids, under controlled pressure and temperature conditions. However, this testing tends to be more costly and may take weeks to complete, making it impractical as a routine analysis approach.



AGAT has developed a system – CRISP – for cyclic compaction of unconsolidated samples to achieve grain relationships and microtexture that more effectively simulate in situ conditions. CRISP consists of both instrumentation and the methodology to run samples and process the data. The instrument is built to provide the cyclic compaction of sample plugs and then maintain a static final pressure while permitting various fluids to be passed through the sample. The system is designed to yield representative, accurate, repeatable, and informative data, with testing costs and turnaround times in line with routine testing.

CRISP samples are not cleaned of hydrocarbons and water before analysis. They can be punched as 1” plugs from core, the same format as the NOB plug test.

CT Scans during cyclic compaction



Initial Stage

Late stage

The CRISP instrument and process involves several stages of flow. After being loaded into the instrument and cyclically restored to a compact state, the sample is then cleaned by flowing solvent through the system, which also allows a solvent permeability to be measured. The sample is then further cleaned and dried with additional fluids, and a steady-state nitrogen gas permeability is then obtained. Helium is used to obtain a total porosity. The sample is then flooded with brine, typically a synthetic formation brine, and an effective porosity is measured. Brine permeability is then measured, in both forward and reverse flow directions. The sample is then unloaded and weighed, and the dry and clean particles can be analyzed further for particle size distribution and mineralogy.

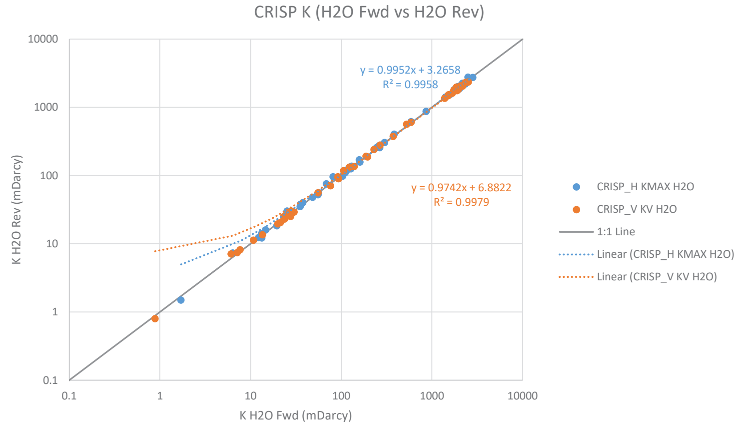
This process provides a large amount of information.

- Residual saturation data (oil by Direct Determination on effluent, solids by dry weight, water by difference)
- Porosities (He, brine, CalcPorosity from sats)
- Permeabilities (solvent, N2 gas, brine forward, brine reverse)
- Analysis time is several hours, but does not require several days in a Vapor Phase Extractor, so ends up being similar or slightly faster than NOB plug analysis.
- Significantly faster than Special Core analysis.
- Cost for the analysis is higher than NOB test but not dramatically. Designed to be a routine high-volume test.
- Process is flexible: different fluids can be used and brines customized to match formation brines.

Performance:

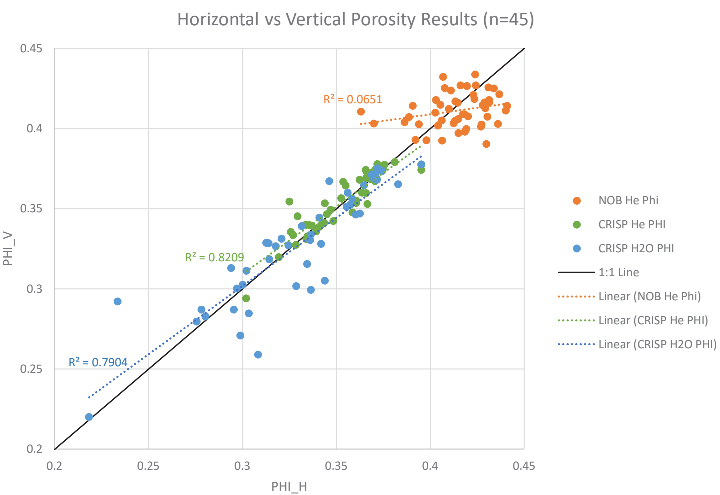
CRISP performs exceptionally well, with very high repeatability, good matches to standards, and petrophysical outputs in line with those expected for in situ conditions, as indicated by geophysical logs.

Testing programs in the last 5 years have included over 1000 runs with excellent precision over a wide range of permeabilities when comparing forward and reverse permeability data.



Recent testing has directly compared CRISP to NOB plugs, using both horizontal and vertical plugs for both methods through a Mannville core from the Lloydminster region.

In comparison to NOB testing the porosity and permeability values are lower. Comparing the same-depth horizontal and vertical, which aligns better with expected porosity values of an uncemented, grain supported reservoir. plug porosities shows much better conformance among the CRISP results as compared to NOB plug results.



CRISP appears to better reflect in situ porosity and permeability, yields more data with both gas and liquid permeants, and provides markedly better precision when compared to traditional routine methods in unconsolidated formations. We believe the adoption of CRISP could significantly improve the utility of routine core analysis for petrophysical model development.

CRISP can be run on old core or samples, and can even be run as a reconstituted sample from disaggregated oil sand samples such as Dean Stark duplicates, with some differing interpretation.

AGAT is offering CRISP analysis as an improved routine analysis for petrophysical properties in unconsolidated sand formations. We seek to work with industry partners to demonstrate the effectiveness and validity of the method, and to continue development of the approach including customizing it to meet operators' requirements. Further method development is already underway, including increased total capacity, partial automation, and reduced turnaround time.

For more information please contact info@agatlabs.com