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Geochemistry Moves to the Wellsite

The prolific marriage of mud logging with reservoir geochemistry for a better reservoir characterization in real-time

Geochemistry Evolution

Petroleum geochemistry became a consolidated discipline in the oil industry only in the 1970s, but its real boom was in the 1980s. At that time, it was mainly focused on understanding the origin of oil and gas and it quickly evolved through time becoming a fundamental technology in exploration; biomarkers, source rock evaluation, and gas isotopes became very popular tools, largely adopted by almost all oil companies. Later, only in the middle of the 1990s, geochemistry started to be considered as a suitable tool also for reservoir evaluation and for production optimization.

Detailed fluid and rock characterizations, obtained through different and advanced analytical tools, started to be used to better understand reservoir heterogeneities and to support production strategies. Reservoir geochemistry becomes more and more widespread, recognized as a useful tool in petroleum engineering.

The rapid evolution of instrumental analytical chemistry in those years greatly supported the grow of reservoir geochemistry. The availability of high-resolution Gas Chromatography (GC) and Gas Chromatography Mass Spectrometry (GC-MS), assisted by more and more powerful computers, the accessibility to many other innovative analytical instruments, significantly increased reservoir geochemistry reliability, making possible its diffusion and large adoption.

The further, quite recent and impressive improvements in instrumental analytical chemistry can be considered as a real game changer supporting an additional and even larger development of reservoir geochemistry. This last extraordinary progress in analytical instruments is due to two concurring factors. The first is the growing need of environmental monitoring, a very popular and urgent issue, determining the set-up of compact, portable and high performing equipment. Many instruments, developed for an efficient and distributed environmental monitoring, can be easily adapted for oil industry purposes improving sensibility and resolution standards. The second factor is the continuous development of nanotechnologies, with spectacular consequences on analytical capabilities. The lab on chips devices is a clear but not unique example of this. Finally, a significant contribution to analytical capabilities is also coming from space exploration: one of the most diffused XRD equipment, used by many service companies at wellsite, was set up for mineralogical analyses on Mars.

This new generation of instruments made possible a further important step in reservoir geochemistry: some activities have been moved from the lab to wellsite. Compact and robust instruments, designed to run environmental analyses everywhere needed outside the labs, can be easily installed in mudlogging units at wellsite. For the oil industry, it is a clear example of cross fertilization, technologies developed in another industrial sector can be easily adapted to its needs and quickly adopted.

This is in short, the reason for the marriage between reservoir geochemistry and mud logging.

Mud Logging Evolution

On the other side, mud logging was born a long time ago, long before geochemistry. Originally it was a basic tool to detect hydrocarbon hints in drilling mud: any fluorescence or gas bubbling, discovered at the surface, was considered as a positive sign, highlighting possible hydrocarbon presence. At the very early stage of petroleum exploration, this was one of the few tools available to detect hydrocarbon presence in the drilled sedimentary sequence. When, many years later, in the 1960s, gas detection became quantitative and enough accurate, mud logging turned out to be a fundamental service to monitor the amount of gas entering in the hole to prevent kicks and possible blow outs due to mud density lightening. Thereafter mud logging was considered as an important and essential tool for safety, but the growing accuracy in gas detection, including quantitative distinction among different gas species in the range C1-C5, largely extended its application also to reservoir evaluation. Mud logging became through time a more and more widespread tool both for safety and reservoir characterization, even if for this last target, wireline logging, and successively LWD, has always been considered as the reference tools.

A mud logging-geochemical unit operating in the USA for unconventionals

Nowadays mud logging, thanks to a systematic approach including well calibrated and standardized devices for gas extraction at a constant temperature, pressure and volume and to a full and reliable chemical characterization of extracted hydrocarbons in the range C1-C8, is continuously growing and constantly gaining credibility, eroding the predominance of wireline logs and LWD.

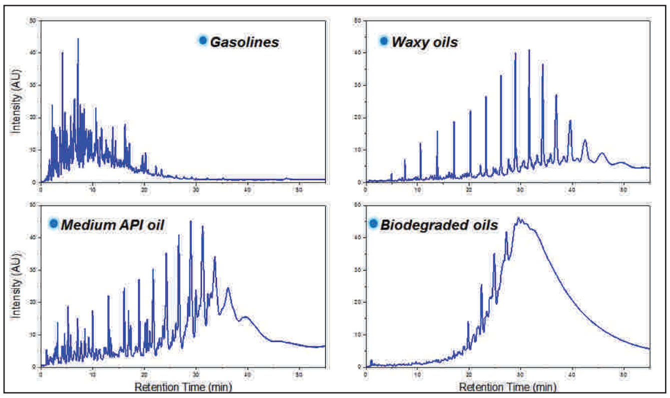
The Marriage of Mud Logging with Reservoir Geochemistry

Reservoir geochemistry, or more, in general, some lab activities, have been moved to wellsite in the mud logging units, already designed to host analytical instruments. The logical further step was to integrate the two approaches to provide more reliable and exhaustive answers to technical issues.

All images are courtesy of Geolog International

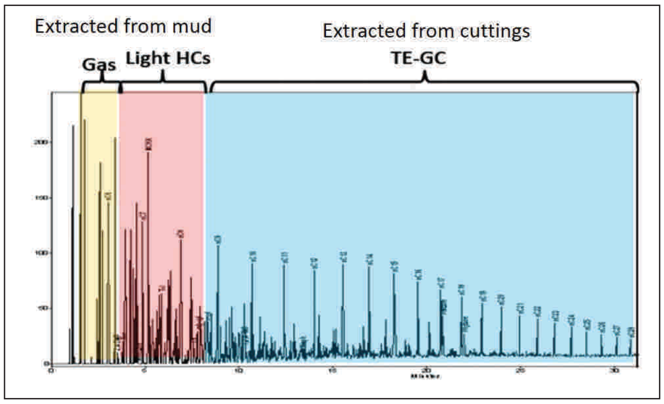
An example of this is the integration of chemical analyses performed on gas extracted from mud with isotopic carbon analyses. This additional characterization of gas composition can be used to get important information. In the case of gas shows in the cap rock, the isotopic value can clarify if the gas was generated in situ, if isotopic composition is typical of abiogenic gas, or if it is escaping or escaped from the reservoir, if isotopes shows an isotopic signature of a thermogenic gas, similar to that of reservoir gas. Isotopes can highlight if oil and gas in the reservoir migrated to the trap together or if they are the products of two different phases of source rock maturation or even if gas has a different origin from oil. All these pieces of information have a direct impact both on exploration, but also on field development and on the evaluation of the petroleum potential of an area.

Another example is the integration between mud gas data and geochemical analyses on cuttings. Very recently Thermal Extraction Gas Chromatographic (TE-GC) analyses of cuttings were introduced at the wellsite. These type of analyses are a very powerful tool to discriminate between different types of oils, providing in real time important information about oil type in the reservoir. The following figure is a clear example of this.



At the same time, other information can be obtained about oil origin by using pristane/phytane ratio. Pristane and phytane are two biomarkers that can be easily detected by using TE-GC analyses and their ratio can be used to understand oil origin and, if combined with concentration of other molecules like C17 and C18, to give an indication about oil thermal maturity.

A similar information can be indirectly obtained also from light hydrocarbon (C5-C8), extracted from mud and by combining these two pieces of information together, uncertainties can be drastically reduced and the final interpretation highly improved. The light fraction of hydrocarbons is always lost in cuttings during their preparation for TE-GC analyses. By combining light hydrocarbon extracted from mud and TE-GC trace we can have a full and complete analysis of hydrocarbon trapped in the reservoir, as shown in the following picture.



Sometimes mud contamination, mainly coming by oil base muds, can heavily interfere with both methodologies, but their integration can greatly reduce uncertainties and avoid misinterpretations. In case of different migration phases from the same source rock at a different level of thermal maturity or from different source rocks, the integration of the two methodologies can greatly help in reconstruction of the whole process in defining the true petroleum potential of the area.

Another example of fruitful integration between mud logging and reservoir geochemistry is given by the combination between mud gas data and X-ray diffraction (XRD) and X-ray fluorescence data (XRF). XRD provides a mineralogical characterization of reservoir by using cuttings, whereas XRF performs a chemical elemental characterization of cuttings. Both these techniques have been applied at wellsite some years ago, but nowadays dramatic improvements have been introduced by some companies, like Geolog. The combination of the two methodologies allows a detailed zonation of the reservoir according to different faces based on mineral occurrence and different ratios of elements detected by XRF, all this on the basis of well-established interpretation criteria defined in the frame of chemo-stratigraphy. Combination of reservoir zonation, obtained by using XRF and XRD, and hydrocarbon occurrence by using mud logging data can be very useful to determine and to characterize the most favorable intervals in the reservoir, to be easily recognized in appraisal or development wells.

The recent improvements obtained in clay mineral quantification by using new advanced instruments and sophisticated software for XRD data processing makes possible and fruitful the application of this integrated approach also in unconventionals where source rock and reservoir are the same geological object and clay minerals can be particularly abundant.

The Way Forward

It has been demonstrated by several field applications that the marriage between mud logging and reservoir geochemistry is very fruitful and can generate a lot of added value, but the process of integration is far from the end and still ongoing. Many other analytical techniques can be moved to the wellsite in the coming years and this will offer other opportunities like those just described. Many pieces of information will be provided at the wellsite with lab quality in real time, allowing better decisions to be taken at the right time to reduce costs and to improve integrated reservoir characterization. There will be additional clear benefits not only for exploration, but also for field development and production optimization, all this by exploiting technologies developed in other industrial sectors.