Hydrocarbon reservoir characterisation

Biostratigraphical, petrological and mineralogical techniques for improving production

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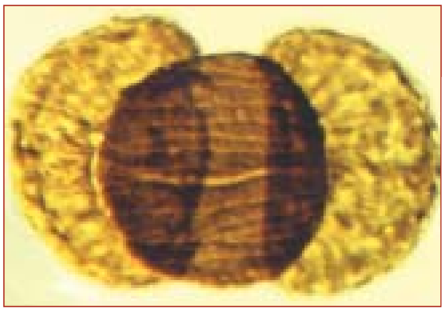
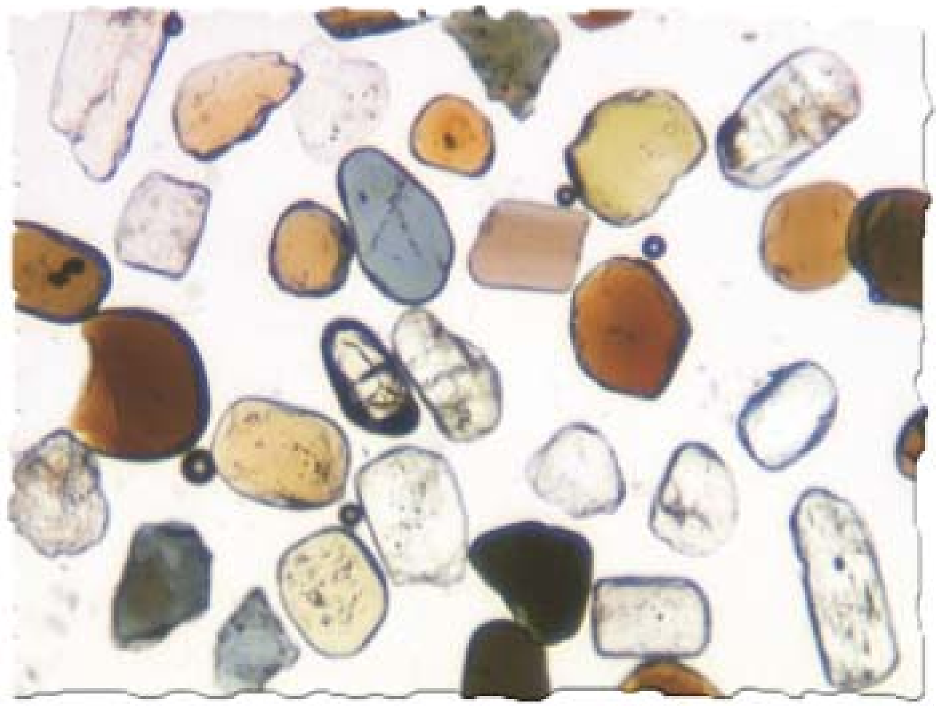


Fossil pollen grain — Strotersporites richteri.

The disciplines of stratigraphy and petrology have always been essential to the exploration geologist interested in regional hydrocarbon potential. But when a field has been found and drilled, the production geologist wants to maximise the value of the reservoir and needs to know the variability of reservoir quality, and how to plan and steer future wells. In the capital-intensive, competitive, and risky environment of today's oil industry, decisions on drilling and field development often have to be made quickly and may have considerable financial implications. Stratigraphical and petrological techniques — some developed at the BGS — are being used to support these decisions, particularly in offshore UK and the Middle East.

Biostratigraphers use microfossils, which are small enough to be recovered in large numbers from drill cuttings or core, to locate strata within a known sequence or to date rocks against a standard age scale. In the past this has been done by plotting first and last appearances of species, but more recently, to increase precision within a reservoir, more pragmatic, field-focused biozonations have been developed. These use all possible biostratigraphical events, be they acmes, first and last appearances, or climate proxy signals indicated by key species ratios. A field biozonation developed by the BGS in reservoirs in Oman uses climate proxy correlation within reservoirs allowing metre-scale precision. At this increased precision, the correlation of thin intra-reservoir mudstone barriers to fluid flow — known as 'baffles' — is possible. Baffles can be related to environments using their contained fossils so that predictions can be made about their lateral persistence, and therefore about the degree of compartmentalisation of the reservoir. A strongly compartmentalised reservoir is difficult to exploit because hydrocarbons cannot flow easily to the wells that drain the reservoir.

The sandstones that form most clastic hydrocarbon reservoirs are sometimes barren of fossils, but potential for correlation often lies in their mineralogy, which may reflect differences in prove-



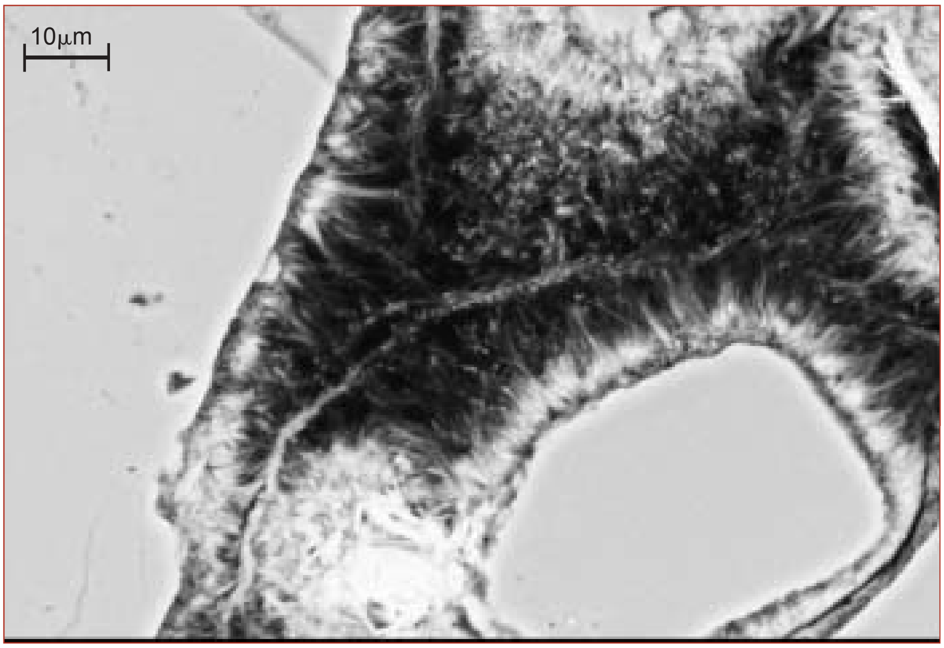
High density minerals in sandstones allow correlation and well steering.

nance. Petrologists measure the variation in the proportions and types of the major rock-forming minerals (primarily quartz and feldspar) through the study of thin sections. Detailed provenance information is obtained through the study of the accessory minerals, which, because of their high density, are referred to as 'heavy minerals'. This detailed mineralogical characterisation of rock units allows sandstone-rich sequences to be subdivided stratigraphically into heavy mineral zones. Very high resolution heavy mineral zonations developed by the BGS in several North Sea fields currently allow production geologists to 'steer' high-angle (i.e. near-horizontal) wells — in real time — along target beds within the reservoir sandstone.

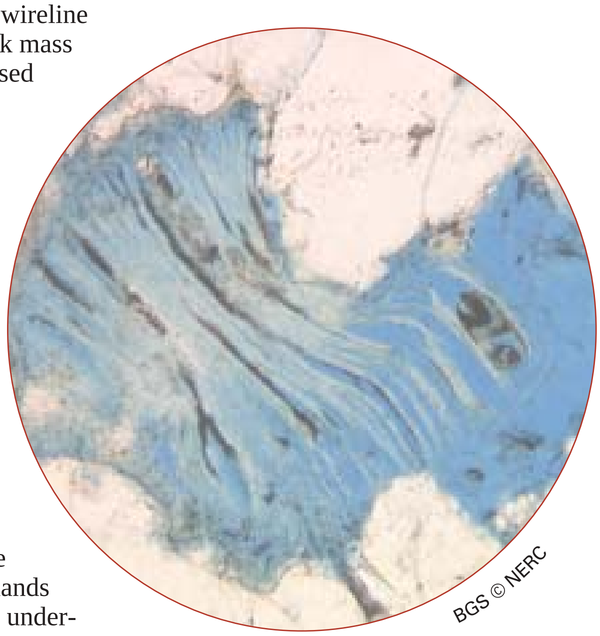
Apart from being able to correlate well sections and to steer wells, the production geologist needs to know about the variability and controls of porosity and permeability within a reservoir. If these controls are understood, predictions can be made about new, perhaps, unexploited parts of the reservoir. BGS petrologists use standard petrological microscopy as well as cathodoluminescence and scanning electron microscopy to reveal details of the rock fabric and cement stratigraphy. These techniques, coupled with the analysis of very small fluid inclusions in the cements, enable petrologists to piece together patterns of diagenetic and fluid evolution, and their relationships to the development of porosity and permeability during the burial history of the reservoir. Similarly, petrologists can advise on the practical problems of drilling by understanding the distribution of swelling clay minerals or loose mineral material in a reservoir rock, since these can have an adverse effect on drilling rate and permeability.

Like mudstone baffles, fractures and faults have an important influence on reservoirs, and may act either as conduits or barriers for fluid movement. Clay-rich fault rocks, formed by repeated grinding along fault planes, form impermeable barriers leading to reservoir compartmentalisation. Conductive fracture zones or faults may introduce fluids that lead to mineralisation and cementation or mineral dissolution and secondary porosity formation in the reservoir rock. BGS fracture specialists use a range of seismic, wireline geophysical, structural, and petrological methods to identify fracture flow-paths, characterise the fractured rock mass, and evaluate the impact of fracturing on reservoir properties. Attempts are also being made to develop methods that integrate structural, mineral, petrological, and fracture data as well as wireline logs to produce an 'atlas' of rock mass characteristics. This would be used to upscale core observations to reservoir scale.

The sciences of fracture modelling, petrology, reservoir-scale biostratigraphy and 'heavy mineral' stratigraphy allow greater technical understanding of hydrocarbon reservoirs than has been possible in the past. They help geologists to model, in precise detail, the variability of reservoirs kilometres below the surface, and to pinpoint to within metres the position of the drill or a 'paying' zone. In the hands of the production geologist, this understanding gives a competitive edge in a capital-intensive and risky environment where the business 'bottom-line' is paramount. BGS reservoir characterisation expertise is well known and valued for providing world-class technical and scientific advice to allow production geologists to make the right decisions and thereby improve reservoir yield.



Authigenic, fibrous illite cement destroys intergranular porosity in a sandstone reservoir (scanning electron microscope image).



Diagenetic alteration of mica grains in a sandstone reservoir causes increased porosity (stained blue). Field of view is five millimetres.