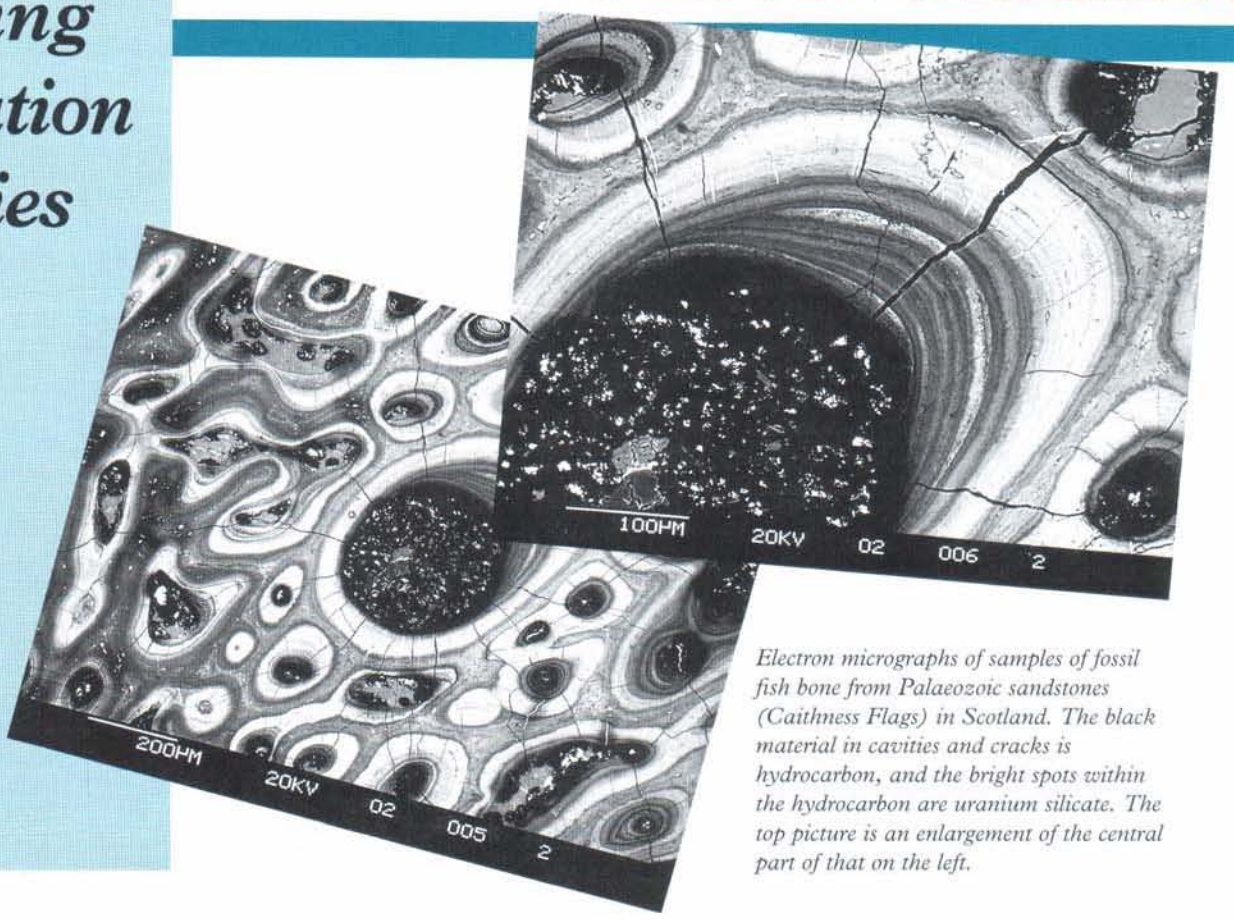
British Geological Survey

Unconventional

Changing exploration strategies



Electron micrographs of samples of fossil fish bone from Palaeozoic sandstones (Caithness Flags) in Scotland. The black material in cavities and cracks is hydrocarbon, and the bright spots within the hydrocarbon are uranium silicate. The top picture is an enlargement of the central part of that on the left.

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Early petroleum exploration usually entailed field mapping followed by drilling surface anticlines, in sedimentary rocks, preferably near oil seepages. Wells sited on no obvious surface structure or seep, as the majority are today, would have once seemed very unconventional. In Britain, an oil search, initiated by war shortages, was ridiculed by eminent geologists, who offered to drink any oil discovered. Advances in scientific knowledge have tended to make unconventional hydrocarbons acceptable exploration targets.

Since about 1960 exploration has diversified, reflecting wide-ranging technological innovations, targeting ever more subtle traps and extending into progressively deeper offshore and inhospitable areas. Unconventional exploration therefore depends on one's perspective. It is perhaps no longer an applicable term, as exploration techniques are improved and spread around the world. Exploration for coal-bed methane for example has spread from USA to the UK where the BGS has compiled a prospectivity report and published papers on the UK prospects.

Various developments in hydrocarbon exploration and production have stemmed from the market-driven investigation of prospects once considered unconventional. These include:

- **An increase in the depths of wells**. In 1985–7, 25% of wells in the USA between 5 and 6 km deep were producers (38 wells). The world's deepest producer is more than 7 km.
- **Production from older rocks** including Precambrian and Palaeozoic rocks. BGS scientists have suggested that there is hydrocarbon potential in Lower Palaeozoic rocks in central England. The maturity of the source in Palaeozoic and older rocks has been evaluated and prospects located.
- **The artificial fracturing of low-porosity and -permeability gas-bearing sandstones** to allow production. Nuclear devices have been used and proppants introduced down the wells to keep the fractures open. Shales are normally unattractive as reservoir rocks but siltstone bands and fractured shales may retain gas. UK Carboniferous shales have been suggested as targets of this kind.
- **The search for overpressured reservoirs** (high pore pressures). This results in higher porosities than would be normally expected at the depth of the reservoirs, enabling production from deep Chalk reservoirs in the central North Sea.
- **The realisation that not all hydrocarbons have a biogenic origin.** Some are abiogenic. Detailed investigation by BGS and university colleagues however has revealed firm evidence that all of the UK resources are biogenic.
- **Improved seismic interpretations**, particularly of low-angled thrusts. Wells have successfully proved younger reservoirs beneath older Precambrian rocks in the USA.
- **The recognition of unusual trapping mechanisms.** In the Western Canada Basin for example, tight underpressured, gas-saturated sands pass up-dip into porous water-saturated sands. This is a reversal of the norm where gas-bearing rocks lie above water-bearing rocks.
- **The discovery that some cratonic areas and subduction zones have**

hydrocarbons

low geothermal gradients retarding maturity. Boreholes into the ocean floor have encountered thermogenic methane in porewaters in thrust faults, which have migrated from depth.

'Unconventional' products

Heavy oil and tar

The surface presence of tar and seeping oil attracted the attention of ancient people, long before subsurface exploration was contemplated. Vast resources of heavy oil, in the form of tar sands, are known in western Canada and Venezuela. Techniques have been developed to exploit these resources and market the products.

Oil from shale

Immature, but rich source rocks were the first to be heated industrially to release oil by Young, in the UK (Earthwise no. 4, page 20). Coals, cannel coals and oil-shales have proved productive. Industrial heating completes the job left unfinished by burial. A Geological Survey memoir (1920) is one of the most complete references on the locations and analyses of these source rocks. The Kimmeridge Clay (source rock for North Sea oilfields) is largely immature onshore, but contains rich oil-shales.

Methane

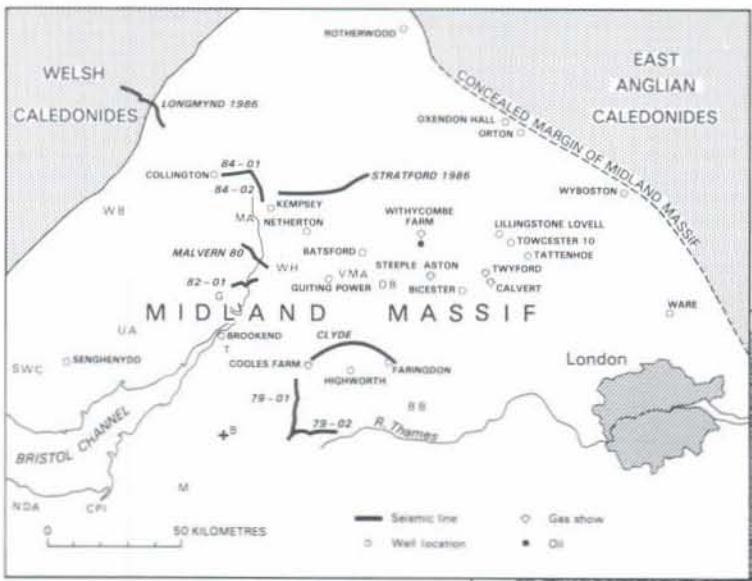
Methane hydrates are solids, composed of ice enclosing methane. They are widespread onshore in northern polar continents, trapped up to about 2 km beneath the permafrost, and offshore, in water depths of 300–500 m, as deep as 1100 m below the sea bed. The gas is a mixture of biogenic and thermogenic methane. The resource has not been satisfactorily quantified. In these regions they are difficult to exploit, and if naturally released by global warming, might intensify its effect.

Methane, dissolved in water, has been produced in the USA, Italy and Japan.

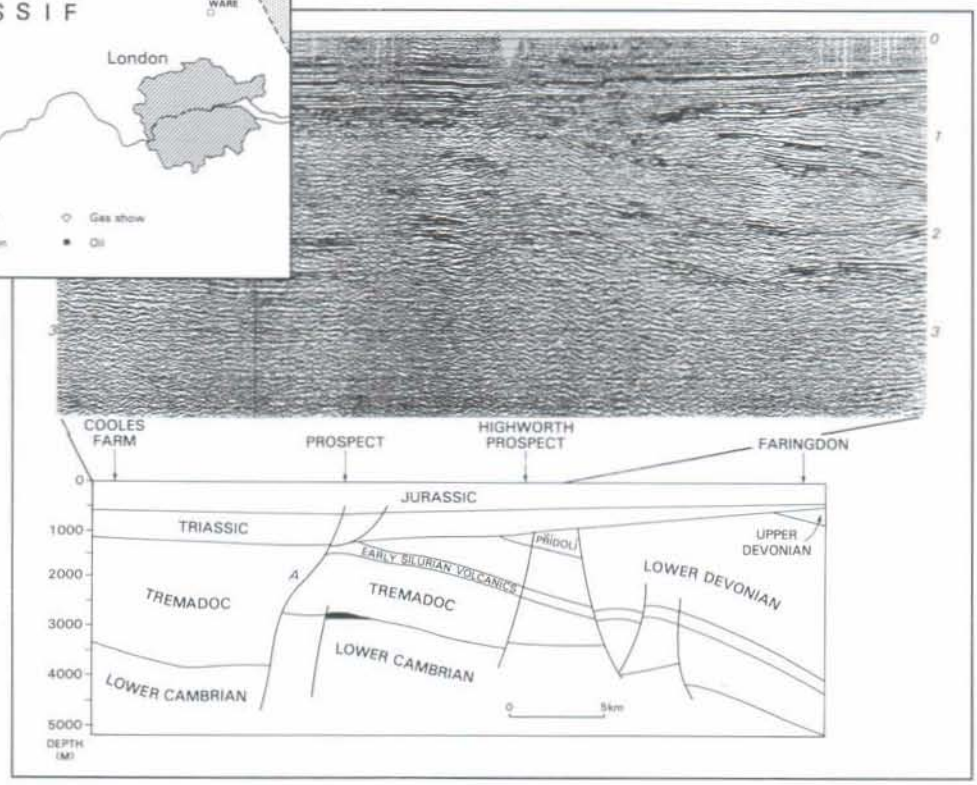
Methane generated in rubbish tips could be safely exploited thereby reducing some of the environmental problems such as venting to the atmosphere. The tips could be located purposely close to markets. Methane from abandoned coal mines might also be exploitable. Methane is produced by bacteria acting on dissolved magmatic carbon dioxide in Lake Kivu, and microalgae could theoretically produce biomass (to replace fossil fuels) from dissolved power station carbon dioxide.

Hydrogen

Hydrogen is not normally encountered in oil and gas wells. Increased hydrogen levels have been found at deep horizons in superdeep boreholes. Minor amounts of hydrogen are in gases from volcanoes. Larger concentrations are reported from ultramafic rocks, which are serpentinised in a low-temperature reaction.



Above *The locations of wells, seismic survey lines and hydrocarbon occurrences that provided data for a BGS assessment of the oil potential at deep levels in Palaeozoic sediments.*



Right *A seismic profile from Cooles Farm to Faringdon in south-central England (shown on the map above) and its BGS interpretation. A possible target for a deep well is shown in solid black.*