Hydrocarbon fluid inclusions and timing of oil migration

Information of importance in oil exploration can be obtained from studies of hydrocarbon-bearing inclusions in diagenetic cements using a range of analytical techniques.

Small amounts of parent fluids are commonly trapped within growing crystals, and studies of these primary inclusions provide information on temperatures and compositions of the fluids involved. In addition, the features of later fluids can be studied in secondary inclusions which form, for example, during the healing of microfractures. Though most inclusions are aqueous, any hydrocarbons present during the precipitation of diagenetic cements will also be trapped. Therefore, information on the timing of oil generation, rock permeabilities, and paths of migration can be obtained from a combination of fluid-inclusion and petrographic studies of the sequences of formation of cement minerals. The relative times of entrapment of hydrocarbons (which can range from methane to bitumens) can be documented simply by identifying primary and secondary hydrocarbon-bearing inclusions within sequences of transparent diagenetic minerals. A combination of this relative approach with burial history analysis from geological data can provide a chronostratigraphic timescale for petroleum migration during burial diagenesis. The isotopic compositions of cements can yield additional information on sources of diagenetic fluids and the extent of organic degradation processes.

Techniques

Hydrocarbons can be detected in fluid inclusions by a range of complementary techniques (Fig. 16). Most liquid hydrocarbons fluoresce under long-wave ultra-violet (UV) light; therefore UV microscopy is a rapid technique for the preliminary recognition of the presence of hydrocarbons in inclusions. The behaviour of included fluids after they have been solidified on a microscope freezing stage (microthermometry) can be used to detect (i) hydrocarbons as immiscible phases or dissolved in low concentrations in aqueous inclusions, because they form waxy phases during melting of the ice; and (ii) methane (with CO₂), which depresses the triple-point temperature of CO₂(56.6°C) and increases the temperatures of melting of gas hydrates (clathrates). The recently developed laser Raman microprobe offers a powerful technique for the in-situ identification of gases and liquified gases in inclusions (e.g., CO₂, N₂, CH₄, C₂H₆, C₃H₈), and for the detection of heavy aliphatic and aromatic hydrocarbons, by measuring the molecular vibration energy spectra (Dhamelincourt & others, 1979: Bulletin Mineralogique, 102, 600–610; Etminan, 1985: BMR Record 1985/33, 21–23) Further in-situ characterisation of hydrocarbons can be obtained by infra-red (IR) microprobe, which couples an IR microscope with a Fourier transform–IR spectrometer (Herres, 1985: Chimia, 39/2–3, 64–67); this technique has excellent sensitivity (picogram range), visible control of the measured sample area, and both reflectance and transmittance measurements in the one system.

These techniques are non-destructive. More detailed characterisation of organic compounds can be made by gas chromatography (GC) and gas chromatography – mass spectrometry (GC/MS), which are destructive techniques that require liberation of the fluids by heating (decrepitation) with or without crushing; their use is warranted only where a particular problem requires accurate characterisation of organic composition.

In BMR, heating–freezing stages, and long-wave UV microscopy are being used routinely in studies of hydrocarbon inclusions. Preliminary experiments on the application of GC and GC/MS are underway, and a multichannel laser Raman microprobe is currently being installed. Further assessment of the IR microprobe will be carried out in the near future when Hashem Etminan visits Europe in early 1987. The techniques can be used only on samples with medium to coarsely crystalline diagenetic cements. Five-to-ten-centimetre lengths of quarter-core should be adequate for cutting the polished sections required for the non-destructive analyses, but samples two to three times larger would be required for fluid extraction.

Examples

The presence of hydrocarbon inclusions in diagenetic cements has been recognised for some time, but their potential importance to oil exploration has been acknowledged only in recent years. From differences in UV fluorescence of primary and secondary hydrocarbon-bearing inclusions, Burris (1981: in Hollister & Crawford (Editors) Short course in fluid inclusions, Mineralogical Association of Canada, 138–156) reported three generations of hydrocarbons associated with different vein-filling cements and microfacturing in the Carboniferous Fayetteville Formation of Ark-ansas. By combining studies of relative ages of hydrocarbon inclusions with analyses of burial history from geological data, he was able to provide a chronostatigraphic timescale for hydrocarbon migration from source rocks in Mesozoic platform carbonates buried beneath the Oman fore-deep.

Fluid-inclusion research in the Baas Becking Geobiological Laboratory is presently focusing on the carbonate complexes of the Canning Basin (WA), which contain hydrocarbon inclusions in medium to coarsely crystalline burial diagenetic cements in areas of Pb-Zn mineralisation (Etminan & others, 1984: in Purcell (Editor) — The Canning Basin, WA, Geological Society of Australi/Petroleum Exploration Society of Australia; Etminan & Lambert, 1986: Abstracts, Eighth Australian Geological Convention, Geological Society of Australia, 66). Primary inclusions in

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The 1986 BMR Research Symposium will be held at the Australian Academy of Science building, Canberra, on 13-14 November. A registration fee of $95, payable by 7 November, covers morning and afternoon teas, lunches, the symposium dinner after the first day’s sessions, extended abstracts volume, and other conference materials.

Day 1. Thursday 13 November
9.00: Registration
Morning Tea
10.15: Official opening — Senator Gareth Evans, QC, Minister for Resources and Energy, and introductory remarks from Professor Royce Rutland, Director, BMR.
10.30: Contribution from the major to macro. R.W. Henley
Experimental studies combined with field observations of active hydrothermal systems have provided a quantitative framework for the guidance of gold search in older terranes, and new challenges in understanding the origins of ore-forming systems as integral parts of the evolution of the Earth’s crust.
Petrographic, isotopic, geochemical, fluid-inclusion, and other data have been integrated to provide information on processes involved in the genesis of Pb-Zn deposits on the Canning Basin. Metals were transported in hydrocarbon-bearing brines, of which numerous pulses migrated from deep basin sediments to permeable beds. Sulphides were generated by biological and thermochemical reduction of sulphate.
11.30: Distribution of precious metals in Precambrian ultramafic-ultrabasic suites. A.Y. Glikson
Platinum group element and gold studies of the late Archean Munnin Muni, Andover, and Sunnsville natic-mafic-ultramafic complexes of the Pilbara Block have been combined with petrological and geochemical investigations to determine the precious-metal potential of the region.
12.00: Origin of Argyll diamonds. A.L. Jaques
The nature of carbonates well removed from known mineralisations are being studied. A detailed picture linking hydrocarbon generation and maturation history. These studies are throwing light on the poor exploration returns to date, and suggesting future avenues of exploration.
12.40: Lunch
The 14 exploration wells drilled on the Exmouth Plateau proved uniformly disappointing. Acquisition of an extensive set of heatflow data on the plateau by BMR in early 1986 is allowing a re-evaluation of the plateau’s thermal maturation and hydrocarbon potential. These studies are throwing light on the poor exploration returns to date, and suggesting future avenues of exploration.
2.10: New clues to petroleum habitats of the offshore Otway Basin. P.E. Williamson
New seismic data collected from RV Rig Sesimic have been combined with industry well and seismic data and with geohistory analyses to assess the likely habitats of petroleum in this, the westernmost of the Bass Strait basins. These latest results clearly indicate good potential for hydrocarbon discoveries.
2.40: South Tasman Rise: an Otway fragment? J.B. Willcox
Recent studies have identified a large pull-apart basin and some small transcurrent basins flanking the Palaeozoic core of the South Tasman Rise. The studies suggest that the rise was once adjacent to the Otway Basin, and moved as part of the Antarctic plate until the Mesozoic. This paper examines the tectonics of the area, and the implications for basin maturity and hydrocarbon potential.
3.10: Afternoon tea
4.10: Future directions of BMR. R.W. Rutland
4.40: Future directions of BMR. Industry comment and discussion
5.00: Close, and presentation of Harold Raggatt Awards

Enquiries should be directed to Mrs Evelyn Young at BMR.

1st Asia/Pacific Mining Conference and Exhibition
The First Asia/Pacific Mining Conference and Exhibition will be held in Bangkok on 4-7 November 1987. The event is sponsored by the ASEAN Federation of Mining Associations and is endorsed by BMR.

The theme of the Conference is ‘Minerals and the economic development of the Asia/Pacific region’.

For further information, write to: The Secretariat, The ASEAN Federation of Mining Associations, 2151 Pasong Tamo, Makati, Metro Manila, PHILIPPINES.

Hydrocarbon fluid inclusions
(calcite, dolomite, sphalerite, and barite contain pure hydrocarbon inclusions and/or aqueous inclusions with variable hydrocarbon contents; in contrast, post-mineralisation calcite and barite do not appear to contain hydrocarbon inclusions. Therefore, hydrocarbons must have constituted a significant component of the mineralising fluids in this region. Attempts are being made currently to characterise the hydrocarbons in more detail, and to compare them with oil from the Blina field in the northern part of the basin. Isotopic compositions of the carbonaceous components are also being studied, and these indicate influx of basinal brines from several different source beds and areas of organic degradation. The major thrust of this research project in the coming year will be on carbonates well removed from known mineralisation. These studies should yield a reasonably detailed picture linking hydrocarbon generation and migration, permeabilities, and fluid migration paths.

For further information, contact Drs Hashem Etmian, Roger Sammons, or Ian Lambert (Bua Becking Geobiological Laboratory) at BMR.

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