Geofluids: introduction

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Geological fluids are a central theme linking the petrography and chemistry of all rock types, deformation processes on the microscopic to the continental scale, and the concentration of economic resources. The fundamental importance of fluid migration and evolution to rock composition and structure is reflected in a growing interest in fluid processes, including a series of successful conferences on water–rock interaction (Kharaka & Maest 1992). The papers in this volume are intended to give a state-of-the-art review of the whole spectrum of geofluids research.

In an introductory account, **Fyfe** summarizes the water inventory of the planet Earth, and emphasizes the importance of quantifying water fluxes at all levels within the crust, and in particular the fluxes resulting from subduction and continental collision. The relationship between fluid migration and heat flow helps to explain why fluid fluxes are of fundamental importance to the formation of mineral resources.

Large-scale fluid flow

In the past decade several models have been proposed for large-scale fluid flow at continental margins and across continental interiors. **Van Balen & Cloetingh** describe the constraints imposed by basin modelling upon theories for tectonic control of the sedimentary record and stress-induced fluid flow. They use a dynamic numerical model to investigate the effect of short-term variations in the level of intraplate stresses on fluid flow and sedimentation patterns. Increases in stress strongly influence the hydrodynamic regime during the post-rift phase of basins by causing an increase in meteoric water influx and compactional flow. **Deming** shows that the magnitude of convective heat transport through the upper continental crust is exponentially dependent upon fluid velocity and depth of fluid circulation. The major mechanisms for fluid flow in the upper crust are topography, fluid released by sediment compaction, phase changes or metamorphism, and free convection. The most effective mechanism for transporting heat is topographically-driven flow, which may be responsible for some ore-forming processes in the North American mid-continent. **Jessop & Majorowicz** emphasize that heat transport through fluid flow is as effective as conduction, leading to wide contrasts in both lateral and vertical heat flow in some basins. This applies not just to basins above sea level with an obvious topographic driving force, but also to some sub-sea basins. **Phillips *et al*.** review the nature of metamorphic fluids, and their role in ore formation. Metamorphic fluids in many gold provinces are dominated by water, carbon dioxide and hydrogen sulphide, with low salinity, reflecting an abundance of mica, carbonate and sulphide in the rocks. A less common metamorphic fluid involving evaporite-bearing sequences is saline, with the potential to transport both gold and base metals.

Deformation and fluid flow

Several contributions examine the interrelationships between deformation and fluid flow, in which fluids help to enable deformation, and faulting helps to facilitate fluid migration. **Sibson** discusses crustal stress, faulting and fluid flow. Deviatoric stress exerts both static and dynamic effects on rock permeability and fluid flow, modulating flow systems in the Earth's crust. Textural evidence from hydrothermal veins suggests that fluid flow in fault-related fracture systems generally occurs episodically, and that stress cycling effects may be widespread. **Muir Wood** shows how empirical observations of hydrological changes following major earthquakes allow the prediction of subsurface fluid flow during active tectonism. The type of change is dependent on the style of fault displacement: normal faults displace large volumes of fluid from the crust, while reverse faults draw fluids into the crust. **Knipe & McCaig** review the interactions between deformation and fluid flow. They show that the various deformation mechanisms possible in rocks have different effects on fluid flow which depend upon the associated volume changes. Microstructural analysis of deformed rocks provides information on fluid flow pathways, fluid chemistry and the amount of fluid involved. **Stephenson *et al*.**

discuss the importance of inter-related fluid flow and deformation during the evolution of accretionary prisms. With the aid of experimental data, they show that the permeability measured in an actively deforming material contains a dynamic component in addition to the classical notion of capacity to transmit fluid.

Fluid flow and reservoir evolution

Inevitably some of the most detailed studies of fluid flow in the past decade have been those related to the evolution of hydrocarbon reservoirs. **Bjørlykke** relates the flow of fluids through basins to transport of heat and dissolved ions, and consequent diagenetic reactions. The greatest potential for transporting mass and creating secondary porosity is through meteoric water flow, as the flow rate may be very substantially greater than typical compaction-driven flow. The flow behaviour of immiscible fluids in permeable sandstones is assessed by **Ringrose & Corbett**, who show that capillary forces result in significant amounts of both trapping and bypassing of the non-wetting phase. In a typical water-wet oil/water system the amount of trapped oil varies between 38% and 65% depending upon the patterns of rock heterogeneity.

Fluid chemistry; metal-organic interactions

Research on the chemistry of groundwaters and hydrothermal fluids in sedimentary basins has highlighted the role of organic species in complexing with organic species. **Hanor** reviews the origins of saline brines in sedimentary basins. Thermodynamic buffering by silicate–carbonate–(halide) mineral assemblages is a first-order control on subsurface fluid compositions. Where fluid composition is rock-buffered its ultimate origin may be obscured by its most recent history; however some non-buffered components, such as chlorine and bromine, can be useful in providing information on the original end-member fluid compositions. **Giordano & Kharaka** discuss the diagenetic processes involving dissolved acids. The dissolved acids are important as a control on pH and buffer capacity, as organic ligands to form aqueous complexes with metals and other inorganic species, as reducing agents controlling the Eh of fluids, and through breakdown as a source of carbon dioxide and hydrocarbon species. **Filby** describes the origin and nature of trace element species in crude oils, bitumens and kerogens. Nickel and vanadium metalloporphyrins are formed during sedimentation/early diagenesis of oil source rocks, and the relative abundances of the metals are related to depositional environment. Complexes of other trace elements in crude oils may be primary, including products of mineral–kerogen reactions, or secondary, from interactions between oils with mineral matter or formation waters during migration, maturation or biodegradation. **Nicholson** describes compositions of geothermal fluids which range from gold-depositing dilute waters to saline, oilfield brines, and proposes that techniques used to study active geothermal systems may be applicable to both gold exploration and hydrocarbon reservoir modelling.

Fluid evolution: migration and precipitation of hydrocarbons and metals

Fluids have a fundamental role as the agents of migration and concentration of hydrocarbons and metals. **Mann** presents an approach to the study of primary petroleum migration, integrating sedimentological, petrophysical, organic geochemical and numerical modelling methods. Primary migration probably proceeds through diffusion into pore/fracture systems where a petroleum bulk phase develops, possibly with aqueous solutions. **Simoneit** describes the alteration of sedimentary organic matter to petroleum hydrocarbons by reductive reactions in modern hydrothermal systems. This alteration occurs under high pressure, over a wide temperature range, and in a very brief geological time. Petroleum generation, expulsion and migration occurs as a single continuous process during hydrothermal activity. **Parnell** shows how paragenetic relationships between hydrocarbons and inorganic minerals provide information on the relative timing of hydrocarbon migration and the migration of other fluids. Co-migration of hydrocarbons and aqueous fluids is evinced by the occurrence of large quantities of authigenic silicate minerals within some hydrocarbon residues. **Fowler** describes the fluid pathways and driving mechanisms for lead–zinc mineralizing brines, and considers the possible role of overpressuring in their formation. Fluid flow must be fast to advect the heat needed in mineralizing fluids from deep within a basin. In shale-dominated basins, overpressured zones immediately below platform carbonate rocks can be a proximal source of heat and metals. The shales act as thermal barriers, and high fluid pressure ruptures the overlying rocks to provide vertical pathways for hot mineralizing brines into carbonate host rocks. **Metcalfe *et al*.** describe the chemistry of fluid-rock interactions during continental red bed diagenesis. Models for fluid evolution in this environment can be useful in understanding how the relatively high content of heavy metals in ferromagnesian/aluminosilicate detritus can be concentrated into red bed-hosted ore deposits.

Tracers of fluid evolution

Several highly specialized analytical techniques have evolved which help to trace the pathways and consequences of fluid flow. **Duddy *et al*.** explain how apatite fission track analysis can be used to determine palaeotemperature histories. Temperature–depth profiles can be used to distinguish the effects of flow of hot fluid through a basin from heating due to the simple conduction of basal heat flow. **Ballentine & O'Nions** show how the relative abundance of the rare gases helium, neon and argon in crustal, mantle and atmosphere-derived components of fluids can be distinguished according to their isotopic distribution. This data provides information on the physical processes experienced in the fluid and, combined with mass balance calculations, can be used to constrain fluid provenance and transport.

The Geofluids '93 conference, from which this volume developed, was an initiative in collaboration with Steve Lawrence (Quad Consulting) and Chris Cornford (IGI Ltd), and included a special session on Deformation and Fluid Flow organized by Rob Knipe (University of Leeds). The organizers were ably supported by a committee including Sally Cornford, Bert Kennedy, Richard Bray, Graham Harman, Janet James, Les Oldham, Des Horscroft and Dave Naylor, and also the editorial committee (editor, Alastair Ruffell and Norman Moles) and the staff of Quad Consulting and IGI Ltd. The conference was supported by The Geological Society of London, The Institution of Mining and Metallurgy and The Institute of Petroleum. Support from these bodies reflects the wide significance of fluids research and the potential for interchange of approaches between the hydrocarbon and minerals industries. This volume should help to foster a greater appreciation of how geofluids research can contribute to the understanding of the evolution of sedimentary basins and their resource potential.

Reference

KHARAKA, Y.F. & MAEST, A.S. 1992. *Water–Rock Interaction* (2 vols). Balkema, Rotterdam.