minerals

Editorial

Editorial for Special Issue "Fluid Inclusions: Study Methods, Applications, and Case Histories"

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The pioneering work of H.C. Sorby [1] in the mid-19th century highlighted the scientific importance of fluid inclusions in minerals; however, it was not until the mid-20th century that the fluid inclusion studies began to gather momentum and play a key role in the recognition and understanding of Earth's geofluid systems [2,3]. Indeed, fluid inclusion studies of geofluid systems that are associated with sedimentary, metamorphic, and magmatic environments continue to make significant contributions to our overall understanding of the character and genesis of economic mineral (including gem minerals) and hydrocarbon deposits, e.g., [4–7]. The diversity of fluid inclusion study applications is highlighted today by the investigations of microbial life on Earth and Mars using biosignatures that are trapped in evaporite (also known as Martian analogues) forming halite and gypsum [8]. Furthermore, innovative analytical techniques, e.g., microbeam technologies have greatly assisted the advancement of fluid inclusion study methodologies [9].

This Special Issue of *Minerals* highlights some of the study applications and methodologies that are currently used by the fluid inclusion research community. Anomalously high paleobrine temperatures (average 85.6 °C) are reported by Wang et al. [10] from fluid inclusions trapped in Cretaceous marine halites, the Maha Sarakham Formation, Khorat Plateau, Thailand. Petrographic textures show that these fluid inclusions were trapped from warm brines in which the halite formed. Paleobrine conditions are faithfully documented by the fluid inclusions. Hothouse, hydrothermal, and solar heating hypotheses are compared to explain the anomalously high surface paleobrine temperatures and Wang et al. [10] conclude that solar radiation is the most plausible explanation for the temperatures and may also explain high palaeobrine temperatures that were recorded from fluid inclusions in other ancient halites.

The source of hydrocarbon bearing fluid inclusions that are trapped in the Miocene Snoqualime granite (c. 17–20 Ma) basement (Green Ridge Breccia) from the North Cascades is investigated by Feely et al. [11]. Primary aqueous–carbonic fluid inclusions are trapped in quartz-amethyst euhedra (<10 cm in longest dimension) that occur in vugs within the Green Ridge Breccia. Most notable however, is the presence also of younger centimetric to millimetric scale hydrocarbon bearing fluid inclusions. Feely et al. [11] conclude that the likely source of the hydrocarbons is the Guye Sedimentary Member that forms the roof rock of the Snoqualime granite. Convective fluid flow before unroofing was probably the mechanism that is responsible for the trapping of the hydrocarbons in the quartz-amethyst euhedra.

Radiolysis of aqueous fluid inclusions as a mechanism for subsurface hydrogen generation is investigated by Parnell et al. [12] while using a suite of Permian sylvite samples from the Boulby Mine (A potash mine in Yorkshire, NE England offering an environment that is similar to that on the surface of Mars). Traces of hydrogen are consistently detected amongst the volatiles liberated from entrapped fluid inclusions in sylvite. However, accompanying halite samples do not yield hydrogen. This data suggests that the formation of hydrogen by radiolysis of water due to irradiation from the potassium in the host sylvite [12].

It is well documented that the integrity of fluid inclusion data is paramount when developing geofluid models that elucidate the PVTx (pressure, volume, temperature, and composition) conditions of fluid trapping. As stated by Bakker [13], post-entrapment modifications reduce the reliability of fluid inclusions to determine trapping conditions in rock. Processes that may compromise the integrity of fluid inclusions are experimentally identified this study using synthetic fluid inclusions in quartz with a well-defined composition and density [13]. This study concludes that the variability of re-equilibrated properties in fluid inclusion assemblages depends on time, temperature, diffusion distance, and the size of fluid inclusions.

The hydrothermal fluid evolution of vein sets at the Pipeline Gold Mine, Nevada is investigated by Blamey et al. [14]. The authors argue that the geochemical results from fluid inclusion microthermometry and gas analysis show that the fluids from which quartz deposited were sourced from condensing magmatic volatiles and were trapped at ~300 °C and 2 kbar lithostatic pressure (~8 km). Furthermore, ore fluids (enriched in CO_2 and H_2S) caused decarbonation and released Fe^{2+} that reacted with H_2S to form pyrite. Decreasing H_2S destabilized gold bisulfide complexes and deposited gold. This study [14] concludes that this process can occur in a single Cretaceous event in advance of potential Tertiary mineralization.

The petroleum charge history at Parsons Pond, Western Newfoundland is the location for this study by Conliffe et al. [15] of drill core and cuttings samples and utilises fluid inclusion petrography, microthermometry, and ultraviolet microspectroscopy of inclusion oil. The presence of multiple generations of hydrocarbon fluid, ranging in composition from ~33 API gravity petroleum to pure CH_4 are recorded. The authors suggest that hydrocarbons were generated multiple times during progressive burial and heating. They [15] also note that the distribution of hydrocarbon bearing inclusions with depth suggests that deeper levels are gas-prone, with petroleum being confined to relatively shallow depths.

The final study [16] in this Special Issue of *Minerals* focusses on the Poona emerald deposits, Western Australia. Emerald from the deposits at Poona displays micrometre-scale chemical, optical, and cathodoluminescence zonation. The authors report that this zonation when combined with results of fluid inclusion and isotope studies, indicates early emerald precipitation from a single-phase saline fluid of approximately 12 wt % NaCl equivalent, over the temperature range of 335–525 °C and a large pressure range from 70 to 400 MPa. These large ranges in P and T reflect multiple generations of emerald precipitation, different fluid compositions, and the presence of both metamorphic and igneous fluids trapped in emerald. A protracted history of emerald precipitation at Poona is posited by Marshall et al. [16] linked to igneous and metamorphic processes at different times during regional greenschist to amphibolite facies metamorphism over the period ~2710–2660 Ma.

I hope that this Special Issue will contribute to a better awareness of the application of fluid inclusion studies in the investigation of a wide range of geological processes, and also their potential to help target future economic mineral and energy resources.

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