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Metamorphic Fluids and Mineral Deposits

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A MEETING on 'Metamorphic Fluids and Mineral Deposits' convened by Drs A. J. Barker and R. P. Foster (Southampton University) on behalf of the Mineralogical Society (Metamorphic Studies Group) and Geological Society (Mineral Deposits Studies Group) as part of IGCP Project 291 ('Metamorphic Fluids and Mineral Deposits') was held at the University of Southampton, U.K., on 27–28 May 1992. The meeting covered a range of topics including the role of metamorphic fluids in the formation of ore deposits, experimental studies relating to metamorphic fluids and ore deposits, metamorphic fluid flow, the evolution of cupriferous deposits and various contributions relating to gold mineralisation. The conference was attended by delegates from various European countries as well as from Africa, North America and Australia. The total number of participants was 55. Invited lectures were given by Professor Neil Phillips (James Cook University, Townsville, Austrailia) and Dr. Richard Goldfarb (U.S. Geological Survey, Denver, U.S.A.). In the following section we present a brief introduction to the seven published papers arising from the meeting.

The paper by *Phillips* reviews the characteristics of fluids associated with gold deposits. He emphasizes that low salinity fluids with reduced S and modest CO_2 at $T > 200\,^{\circ}C$ and high geothermal gradients are a common feature of many gold deposits but that host rock and structural-metamorphic characteristics are highly variable from one deposit to the next. Metamorphic devolatilisation associated with the greenschist-amphibolite facies transition is identified as a major source of the required fluid, although mixing with other fluids may also occur prior to gold deposition. The contribuiton by *Goldfarb et al.* provides a comprehensive summary of Cretaceous and Tertiary gold-veining within the various allochthonous terranes of Alaska, again relating the ore-forming fluids to metamorphic devolatilisation reactions. The close temporal relationships between high-T tectonic deformation, igneous activity and gold mineralisation are emphasized. *Myers et al.* present a detailed account of part of the Witwatersrand Goldfields for which they conclude that extensive post-depositional sulphidation of detrital clasts and iron minerals has occurred and that this process may be significant in relation to gold mineralisation within the region. The study by *Yardley et al.* examines the detailed chemistry of H_2O–CO_2 fluids associated with post-metamorphic gold-quartz veins from part of the Italian Alps. They emphasize the uniformity of the ore fluid irrespective of host rock and, on the basis of halogen data, conclude that the fluid was probably of surface water origin rather than from a metamorphic source. *Seccombe et al.* describe the fluid evolution of a turbidite-hosted gold deposit from Australia. As with several other contributions to the meeting they document vein formation and gold deposition as being synchronous with deformation and metamorphism. The gold-related fluids are of low salinity. Those associated with the main episode of gold mineralisation are CH_4-rich whilst those associated with late-stage mineralisation are CO_2-rich. Analogous with the work of Yardley *et al.* from Italy, the study by Seccombe *et al.* also recognises an influx of meteoric water as being associated with the late-stage mineralisation, although the main gold mineralisation is ascribed to metamorphic devolatilisation. The final paper on gold mineralisation, by *Dee and Roberts,* examines the role of nitrogen associated with late stage mineralisation in an area of western Spain. They demonstrate that the N_2 content of veins with elevated gold grades is typically higher than those with low gold grades. The origin of the N_2 in the mineralisation fluid is explained in terms of interaction of fluid with the ammonium ion, NH_4^+, in micas and feldspars.

The final paper of the meeting, from *Hein,* describes Variscan siderite mineralisation from the Rhenish Massif, Germany. By a combination of fluid inclusion studies, *REE* patterns and isotopic characteristics, Hein demonstrates that the ore fluids responsible for siderite formation were produced and equilibrated during prograde metamorphism, but fluid ascent and siderite precipitation post-dated peak metamorphism.

It is perhaps unwise to make sweeping generalisations concerning the relationships between metamorphic fluids and mineral deposits, since in detail, the genesis of each individual deposit will be unique. However, the contributions from this meeting do highlight a number of key points. Most notably, prograde metamorphic devolatilsation reactions (especially at the greenschist to amphibolite facies transition) are identified as *significant in providing large volumes of fluid that* enable transport of metals through the crust and, under favourable conditions, precipitation of these metals as significant ore deposits. In adddition, several contributions note the importance of post-metamorphic meteoric fluids in producing late-stage mineralisation or remobilisation within previously mineralised rocks. An important and often stated corollary to this latter observation is that a complete understanding of the genesis of an ore deposit must take into account *and discriminate* all tectonic and hydrothermal processes that contributed to that genesis. Rarely, if ever, are the physical and chemical signatures of a deposit the product of a single tectonothermal event. Identification of the *key* event(s) is of critical importance to any further exploration.