A. M. Evans

Ore forming processes

THE MINERAL DEPOSITS STUDIES GROUP held its third residential conference at Sheffield University from 10 to 14 December 1977. Following two days' field excursions examining mineralization in northern Derbyshire twenty papers were presented by Group members. All but two were dominantly concerned with ore genesis and the majority of these dealt with deposits in the British Isles, four of them with Irish mineralization. A. M. Boast presented textural and isotopic evidence showing that much of the material, particularly the sulphur, of the Tynagh deposit was of synsedimentary origin. The weight of evidence for this and similar Irish ores undoubtedly suggests a very early time of deposition and M. J. Russell favoured a synsedimentary origin for all the larger Irish base metal deposits in the Lower Carboniferous. He discussed a mechanism whereby circulating sea water could have leached the metals from buried Lower Palaeozoic rocks. J. P. N. Badham put forward a fresh interpretation of the stratigraphy of the mineralized zones at Avoca and suggested that the stockwork feeder zone, a further possible orebody, has yet to be found. P. McArdle's work on Donegal base metal mineralization also suggests a revision of exploration philosophy in that he demonstrated that deposits in the Dalradian were originally of stratiform type.

Rock alteration processes in two very different environments and their relationship to mineralization were discussed by five workers. D. H. M. Alderton presented an excellent documentation of wall rock alteration assemblages developed in the Cornish granites. He made considerable use of isotopic and fluid inclusion data using the former to demonstrate the superposition of alteration zones. In discussing uranium mineralization related to granites in Great Britain, P. R. Simpson et al. suggested a two cycle system of uranium concentration; first a low level enrichment in granites generated above subduction zones, followed by release of the uranium during the alteration of biotite after consolidation of the intrusions. M. Harris described the complex alteration accompanying gold mineralization in a Spanish granite.

In the field of ultrabasic and basic rocks D. I. Groves showed how serpentinization and talc-carbonatization of ultramafic dykes in Western Australia had probably played an important role in the concentration of nickel during the formation of some of the larger nickel orebodies of that region. Concomitant liberation of gold might well have been the source of this metal in neighbouring gold deposits. Investigations of a Greenland gabbro (R. Elsdon) showed how an iron-charged late magmatic hydrothermal fluid can develop and this, under suitable circumstances, could form a pyrometasomatic iron deposit.

Two papers were concerned with the difficult problem of dating mineralization. P. R. Ineson and J. G. Mitchell used the K-Ar method to date wall rock alteration materials associated with mineralization in the Isle of Man together with some of the basic and acid igneous rocks of the island. D. I. Norman presented an entirely new approach to the problem, by using the Rb-Sr method on fluid inclusion waters.

Wall rock alteration in southwest England D. H. M. Alderton

The study of alteration assemblages adjacent to mineralized veins can provide much useful information, not least an indication of the chemistry of the hydrothermal fluids. Some problems encountered in a study in southwest England are outlined, as are the various methods adopted for their elucidation (e.g. oxygen isotope and fluid inclusion studies). Particular importance is attached to the superimposition of alteration assemblages which has resulted in zoned alteration profiles. These pose particular problems as regards the relative importance of fluids of 'magmatic', 'hydrothermal' and 'weathering' origins.

Gold mineralization and structural geology at the Gwynfynydd Mine, Dolgellau, North Wales J. H. Ashton

At the Gwynfynydd mine, gold was won from normal faults filled with large quantities of white quartz, fragments of wall rock, locally significant quantities of base-metal sulphides and irregularly distributed patches of gold. Most veins dip 30-60° northwards. The relationships between the wall rock geology and gold occurrences along three of the veins was examined. In the smallest vein, gold was mined where the footwall rocks consist of greenstone (altered microdiorite) and the hanging wall rocks are Clogau Shale (dark pyritic mudstones). The distribution of gold along the other veins was more complex and possible reasons for this are discussed.
Slumped sulphide deposits at Avoca, Ireland and their significance J. P. N. Badham

The ‘Kuroko’ model for ore deposition has proved useful in finding new deposits in fossil arc terrains. The model is, however, too simple to be useful in locating new reserves around any known deposit. This is because each is the result of a unique set of volcanic, sedimentary and tectonic processes. Thus the nature of depositional and deformational processes must be fully understood to locate orebodies. The Avoca deposits in southeast Ireland are exhalative deposits in an Upper Ordovician arc terrain. It is shown that parts of the deposits have been reworked by slumping such that the original nature and stratigraphy is obscure. An understanding of the nature and sense of the redeposition may help in locating stockwork ore and other nearby exhalative deposits.

Textural and stable isotopic evidence for the genesis of the Tynagh base-metal deposit A. M. Boast

Three main events in the evolution of the Tynagh base-metal deposit can be recognized: (1) early diagenetic growth of collomorphic pyrite, (2) rapid geopetal precipitation and subsequent disruption of fine-grained sulphides, largely sphalerite, in dilational fractures within the host ‘Waulsortian’ bank limestone, (3) later veining and replacement by tennantite, galena and baryte. Each stage is characterized by a distinct range of δ34S values. δ13C and δ18O data suggest that the ‘Waulsortian’ micrites were the main source of carbon and oxygen in ore stage carbonates. Isotopic exchange between the host and mineralizing fluids, extended beyond zones of visible alteration.

Some major lineaments in the Northern Pennine Orefield J. S. Carter

Five linear zones, running roughly northeast and northwest, traverse the Northern Pennine Orefield. These were detected by computer analysis of the vein outcrop pattern and are defined by slight changes in direction of all three vein sets and by local increases in vein density. The observation of directional distortion of the vein traces can be explained by postulating slight strike-slip movement of a system of faults in the pre-Carboniferous basement.

Implications of copper sulphide placers in Chile H. Clemmey

Recent alluvial and beach copper placer deposits in Chile suggest that certain copper orebodies can have a placer origin. The recent deposits have been partially oxidized and, therefore, ancient stratiform copper sulphide orebodies should be examined for resulphidation textures formed during diagenesis or metamorphism. Such textures are present in the Zambian Copperbelt ores. The existence of recent sulphide placers implies that fossil deposits do not indicate an anoxic paleoatmosphere and that exploration for such deposits should not be confined to rocks older than 2.2 b.y.

The lead and zinc deposits of the Bristol and Mendip Hills area, England S. A. M. Earle

Within this area lead and zinc mining has been pursued intermittently over the past 2000 years. Relevant features of the geology are summarized. Regional and local characteristics of these Mississippi Valley-type deposits based on field observations, geochemical studies and descriptions in the literature are presented. It is proposed that metalliferous solutions, derived from basinal sediments, migrated via a marginal breccia unit to tectonically opened fissures on plateaux flanking the basin. The importance of palaeotopography, palaeoclimate, relative mobility of metal complexes and spatial distribution of various lithologies is stressed.

Autometasomatic leaching of iron from a Tertiary gabbro R. Elsdon

Local areas of the Kap Edvard Holm layered gabbro, east Greenland, have been converted into quartz-albite-epidote-ilmenite rocks by leaching of iron involving a net mass loss. Among textural changes is the dissolution of the magnetite matrix of magnetite-ilmenite-lamellar intergrowths. This is an extreme example of a series of low temperature changes occurring throughout the intrusion due to the reaction of the gabbro with a volatile-rich phase which separated during the magmatic stage and remained trapped within the walls of the intrusion. The iron-rich fluid formed by this autometasomatic process is a potential ore-bearing fluid.

A new microphotometer for use in ore microscopy A. M. Evans

Reflectance measurements in monochromatic light have now become the prime quantitative factor for the microscopic identification of opaque minerals. The work of Bowie & Taylor (1958) acquainted mineralogists with the value of measuring this property in white light. Data are now available for monochromatic reflectance measurements and Simpson (1977) has recently described the development of linear charts for use with undergraduate classes (see below). For such classes a robust, sensitive, moderately priced microphotometer is essential. The McCrone microphotometer meets these and research requirements. This instrument1 and its performance are discussed.

Effects of serpentinization and talc-carbonation on disseminated nickel deposits, Western Australia D. I. Groves

Most massive pyrrhotite-pentlandite deposits in ultramafic dykes occur in amphibolite-facies metamorphic terrains. They appear to be metamorphically modified, magmatic deposits. In lower grade metamorphic areas, relic dunites containing only disseminated pentlandite contrast with altered dunites that contain additional pyrrhotite, chalcopryte, pyrite and magnetite. Comparison of ore element concentrations with platinoid element contents (co-operative study with R. R. Keays) suggests the addition of sulphur via the alteration fluids with subsequent combination with Fe (and minor Ni), released during alteration of olivines, to produce additional sulphide phases. In addition, significant Au is lost during talc-carbonation processes and may contribute to fringing Au mineralization. These processes may result in initial sulphide concentrations that are further up-graded during higher grade, dynamothermal metamorphism to produce nickel ores.

1Available from McCrone Research Associates Ltd., 2 McCrone Mews, Belsize Lane, London NW3 5BG.
Mineralization at the Salave Gold Prospect, Spain M. M. Harris

This prospect in the Hercynian Asturian Arc in northwest Oviedo contains disseminated gold concentrated in highly altered portions of a granodioritic stock intruded into Cambrian to Ordovician metasediments and a gabbro body. The gold is associated with needle arsenopyrite, anhedral pyrite, stibnite and minor sphalerite. Peripheral molybdenite-bearing quartz veins may represent a remobilization of SiO2 gold is associated with needle arsenopyrite, anhedral pyrite, Oviedo contains disseminated gold concentrated in highly stibnite and minor sphalerite. Peripheral molybdenite-and Mo from the main altered mass. Hydrothermal alteration associated with the gold mineralization included introduction of Na and CO2 accompanied by desilicification and destruction of the original igneous rock fabric and mineralogy.

One association of mineralization and evaporites in the Permian Lower Magnesian Limestone G. M. Harwood

Vugs in Permian dolomites are occasionally filled with varying combinations of calcite, marcasite, baryte, sphalerite, galena and micritic dolomite. The calcite and, sometimes, the baryte can be shown to be replacing pre-existing evaporite minerals, predominantly anhydrite and gypsum. It is suggested that these vugs were originally anhydrite nodules which grew in the sediment subsurface and that calcitization of the evaporites and mineralization took place during early diagenesis.

K-Ar ages from the ore deposits and related rocks of the Isle of Man P. R. Ineson & J. G. Mitchell

Thirty-seven new K-Ar isotopic ages are reported. The results indicate that at least five periods of metamatism have affected the rocks. The earliest phase (north of Foxdale) occurred at 310-320 Ma ago. Minor Triassic and Tertiary activity is recognized at 220 Ma and 50 Ma. The conformity of these ages to the general episodic pattern of ore deposition in the British Isles is demonstrated.

The significance of base metal mineralization in the Dalradian of Donegal, Ireland P. McArdle

The Dalradian metamorphic terrain of Donegal is characterized by a range of lead-zinc-baryte deposits which are re-interpreted as stratabound in the Lower and Middle Dalradian. The earlier horizons have marble-hosted stratiform mineralization which is remobilized in varying degrees to form vein-type deposits in adjacent quartzites and dolerites; in one example the known mineralization is entirely confined to quartzites. A later horizon has stratiform sphalidges within quartzites. This interpretation demonstrates the need for detailed stratigraphic and structural studies in defining exploration targets.

Analysis of Rb, Sr and Sr isotopes in fluid inclusions D. I. Norman

Two methods of liberating fluid inclusion waters for the analysis of Rb and Sr have proved successful: thermal decrepitation in a quartz test tube and crushing in 304 stainless steel tubing. Contamination levels for both methods are below the laboratory blank. Analyses have been successfully performed on fluids from inclusions in quartz, wolframite, pyrite and sphalerite. Levels of Rb and Sr in the fluid inclusion waters analysed are of the order of several hundred ppm. Rb/Sr appears to show a strong positive correlation with the temperatures at which the fluid was trapped. In some instances it has been possible to use the Rb-Sr data for dating and the 87Sr/86Sr ratio as a geologic tracer.

Tectonic controls on late Proterozoic stratiform copper mineralization J. G. Raybould

The consistent age, form and constitution of the major Precambrian stratiform copper deposits suggests a fundamentally similar mode of origin for each. Intra-cratonic and craton-margin rifts (aulacogens) of late Proterozoic age form the tectonic setting of a number of deposits, and it is suggested that mineralization resulted directly from deep-seated processes associated with contemporary rifting. The implication for the central African Copperbelt is that copper was derived from deep sources and not from surface weathering, as is still held to be the case. Since ancient rift systems can readily be identified by remote sensing techniques, the copper-rift association provides a framework for ground exploration.

Genesis of Lower Carboniferous ore deposits in Ireland M. J. Russell

The larger deposits, Navan, Silvermines and Tynagh, are synsedimentary in Lower Carboniferous Limestone. Carboniferous sea-water permeated downwards into the 12 km thick Lower Palaeozoic geosynclinal prism, leached trace elements, and the hot buoyant mineralizer returned to the sea-bottom. As the heat and ore solution constituents were extracted from the affected rocks, permeability increased, allowing the base of the convective system to migrate downwards to be driven by heat at ever greater depths until it ‘bottomed’ in the crystalline basement. This explains the long life of the hydrothermal systems attested by 200+ m of sedimentary metal at Tynagh.

The identification of ore minerals by optical methods—recent developments P. R. Simpson

Reflectance values are now used at several wavelengths in schemes for ore mineral identification such as the Bowie-Simpson system in which minerals are ordered by their reflectance at 546 nm on charts which have adequate space for additional minerals to be included. Further information is obtainable from the Commission on Ore Microscopy, (IMA-COM) Data File which contains over 200 cards.

Uranium mineralization and granite magmatism in Britain P. R. Simpson, G. C. Brown, J. Plant & D. Ostle

The uranium content of granites from the Caledonian, Hercynian and Tertiary provinces of Britain is reviewed in relation to their association with mineralization, age and structural setting. Uranium is positively correlated with intrusions characterized by high levels of incompatible elements, low K/Rb ratios, low total Sr, low initial 87Sr/86Sr ratios and emplacement in conditions of high geothermal gradients. Fission track studies indicate that the high ‘background’

1Both available from McCrone Research Associates Ltd., 2 McCrone Mews, Belsize Lane, London NW3 5BG.
uranium content of the granites away from mineralization is caused by uranium occurring in resistate primary phases.

The regional trend of uranium and incompatible elements shown by late Caledonian (Devonian) and Hercynian granites in Britain is related to dehydration reactions during subduction of oceanic crust. The importance of phlogopite breakdown in accounting for the characteristics of uraniferous granites is discussed in relation to magma generation using closed and open system models with partial fusion of ocean crust or upper mantle. Uranium enrichment by scavenging of subcontinental lithosphere is considered important but late stage assimilation of uranium from higher levels in the crust is relatively insignificant.

Some aspects of trace element content of minerals deposited from solutions  A. T. Small

Trace elements occur in mineral lattice sites or extra-lattice sites. Their present site may be different from the original site, and their incorporation in the mineral may be syngenetic or epigenetic. The relationship of trace element concentration in mineral and solution is discussed for two models—lattice sites and inclusion sites. Under favourable conditions the T–P environment of deposition can be established. Trace element concentration trends with progressive crystallization are modelled for closed systems and the effects of opening the system are considered.

References
