Conference Report

Stable isotopes in sedimentary geology

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In the opening session of this meeting John Hudson suggested that the measurement of $^{13}$C/$^{12}$C and $^{18}$O/$^{16}$O isotopic ratios in a Jurassic belemnite from the Isle of Skye had been ‘the most elegant geological experiment ever performed’. Nowadays isotope geology is a major branch of earth science studies and this pioneering work of Urey’s Chicago group in the early 1950s has blossomed, with stable isotope analysis particularly useful to the sedimentary geologist. The above-titled meeting was convened to provide a forum for discussion at a time when stable isotope techniques are becoming increasingly common in contributing to the solution of palaeoclimatic, sedimentological and palaeontological problems. One day was devoted to the presentation of papers and one day to a local field excursion. The meeting was attended by 55 British delegates, of whom 12 presented papers. Presentations included three reviews dealing with carbon and oxygen isotopes in rocks and fossils; carbon and sulphur isotopes associated with the burial of organic matter and stable isotopes as tracers in phospogenesis.

In the first review talk John Hudson (Leicester) discussed the history of carbon and oxygen isotopes in rocks and fossils. Hudson reminded delegates that the Quaternary ‘foraminiferal record’ of oceanic oxygen isotope fluctuations, caused by the storage effects of northern hemisphere ice sheets, had probably been the most successful employment of the oxygen isotope technique in sedimentary geology. No other fossil group equalled the resolving power of the foraminifers as a palaeoclimatic tool.

The major problem in studies of older rocks had been establishing whether seawater had remained isotopically constant during geological time, seawater being the obvious baseline for diagenetic studies. The approach to solving this problem had been made mainly via studies of marine fossil groups with CaCO$_3$ shells which had precipitated in equilibrium with ambient seawater, or through the analysis of ancient seafloor cements. Of these, preserved aragonite is considered the most reliable indicator of marine chemistry as it has escaped subsequent diagenetic alteration. Calcite mineralogies are unfortunately susceptible to subtle mineralogic ‘stabilization’ during diagenesis to low Mg-calcite. However, the degree of any such alterations can be monitored using cathodoluminescence, trace element concentrations and the convergence of separate $\delta^{18}$O and $\delta^{13}$C trends at their heavier values. Jim Marshall (Liverpool) in a discussion of carbonate cements, provided one example where marine skeletal elements yielded ambiguous $\delta^{18}$O values. Devonian stromatoporoid ‘skeletons’ with $\delta^{18}$O values around $-6$ to $-8\%$ were isotopically lighter than would be normally expected for marine fossils. The results might reflect inclusion of burial cements within intra-skeletal porosity, or partial neomorphism of the stromatoporoid walls.

Four case studies were concerned with the burial diagenetic cementation of sedimentary sequences and chemical modelling of the ‘parent’ fluid phases. Jim Marshall considered pore-water isotopic compositions and burial depths to explain $\delta^{18}$O and $\delta^{13}$C values in calcite and dolomite cements from the Devonian of Canada. Similarly, David Williams (Aberdeen) attempted to use carbon and oxygen isotopes as identifiers of fluid sources for burial diagenetic calcite cements in Carboniferous rocks from Derbyshire. The range of isotopic values necessitated careful consideration of meteoric versus basinal derived pore-waters, constrained within a geologically reasonable burial diagenetic setting.

In the study of sparry calcite, burial diagenetic cements from the Middle Jurassic Lincolnshire Limestone, Dominic Emery (Cambridge) successfully linked geographical trends in $\delta^{18}$O values of the calcites to thermal gradients and fluid flow within the pore-water system. Clearly, more studies linking the hydrology of aquifers and cement chemistry will aid the geologists’ understanding of regional cementation patterns.

Steve Crowley (Liverpool) gave an interesting account of deep burial silica cementation in the Carboniferous Great Limestone cyclothem. Crowley studied oxygen isotopes as a means of modelling the chemistry of quartz overgrowth cements on detrital grains. Given a common fluid phase for cementation, shifts in $\delta^{18}$O by 10\% were attributed to variation in pore-water temperature.

One speaker, Kevin Hird (Durham) considered the perennial problem of dolomite geochemistry. In this study the Precambrian Porsanger Dolomite of Norway contained well-preserved primary fabrics such as micrites, ooids and radially crystallized cements. $\delta^{18}$O values of these fabrics were $-8\%$ heavier than dolospar cements, suggesting the retention of early diagenetic isotopic signatures. Carbon isotope values showed little variation between early diagentic fabrics and cements, a feature commonly observed in Phanerozoic limestones.

An unusual application of carbon and oxygen isotope data from carbonate rocks was presented by Gordon Walkden and David Williams (Aberdeen). They described
altered limestones in a zone beneath a palaeokarst surface which had been covered by a contemporaneous lava flow. Consideration of the thickness of altered limestone and oxygen isotope value ($\delta^{18}O \sim -4\%$) argued against contact metamorphism. Trapped hot-spring waters were considered as a possible cause of carbonate alteration.

Maurice Tucker (Durham) presented interesting vertical profiles of $\delta^{13}C$ and $\delta^{18}O$ values across the Precambrian–Cambrian boundary in Morocco. Two positive excursions in $\delta^{13}C$ were recognized; the first shift (of $-8\%$) occurred just below the boundary and the second (of $-3\%$) immediately prior to the first appearance of trilobites. It is conceivable that these isotopic variations are related to levels of organic productivity, and furthermore that they are the expression of global processes.

Rob Raiswell (Leeds) reviewed the complex isotopic system related to the burial of organic carbon and pyrite sulphur in organic-rich sediments. In particular he demonstrated the redox balance which necessarily linked the large scale carbon and sulphur cycles to consumption or production of atmospheric oxygen. Quantification of this balance allowed the interpretation of secular variation in $\delta^{34}S$.

Sulphur isotope studies were used by Adrian Boyce and Mike Russell (Scottish Universities Research and Reactor Centre/Strathclyde) to demonstrate that Irish Carboniferous Zn, Pb and Ba ores were probably of synsedimentary exhalative origin. Preliminary results on the Navan Zn and Pb ores, also of the Irish Carboniferous, discussed by Adrian Boyce and Kerr Anderson (Scottish Universities Research and Reactor Centre/Strathclyde) identified two distinct $\delta^{34}S$ populations. Former carbonate allochems, now replaced by sphalerite had isotope values indicative of bacterial induced early diagenetic replacement ($\delta^{34}S -12$ to $-20\%$) whilst open space-filling sphalerite and galena ($\delta^{34}S 0$ to $+8\%$) had probable hydrothermal origins.

In some respects John McArthur (University College London) summarized the uses of stable isotopes to the sedimentologist in his review talk on the isotopic tracers of phosphogenesis. The phosphatic minerals contain oxygen, carbon and sulphur within their structure which can all be utilized for stable isotopic analyses. Phosphate $\delta^{18}O$ values have great potential for palaeothermometry, whilst $\delta^{13}C$ and particularly $\delta^{34}S$ are used as indicators of redox conditions. Phosphate minerals, in common with the carbonates, are susceptible to diagenetic alteration. In a case study, McArthur demonstrated that a combination of stable isotopes, cation concentrations and strontium isotopes could successfully identify subtle variations in the marine burial diagenesis of phosphate.

The range of topics discussed at this meeting are a measure of the importance of stable isotope techniques to the sedimentary geologist. In some cases, such as oxygen isotope palaeotemperature studies, the isotopic results alone are a sensitive measure of naturally occurring chemical reactions. Moreover, when stable isotope data are combined with cathodoluminescence, trace element concentrations and radiogenic isotope information, the earth scientist has a powerful means of quantitatively tracing the evolution of fluid and mineral chemistries. At no other time since Urey’s early work has stable isotope geochemistry seen broader application or been of greater value to sedimentary geology.