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Diagenesis and Low-Temperature Metamorphism—Introduction

RESEARCH into the transitional field between 'true' diagenesis and 'true' metamorphism comes in the guise of a number of different titles. These include burial diagenesis, burial metamorphism, very low-grade metamorphism, and incipient metamorphism—as well as the long established Russian terminology of epigenesis, metagenesis, and catagenesis. Investigation has been largely centred on well-defined fields according to specialism. The sedimentary petrographer and clay mineralogist have studied diagenesis, while metamorphic petrologists have confined their interest largely to meta-igneous rocks, rarely venturing to P/T regimes below those of the greenschist facies, and the reconstitution of organic matter has long been the exclusive domain of a few coal petrologists and organic geochemists.

The fact that there is much common ground between these different interests has long been neglected. Thus the idea developed to draw together an audience whose research areas overlapped but who approached the subject from different viewpoints and therefore rarely met at the traditional conferences. The idea came to fruition with a conference entitled, 'Diagenesis and Low-Temperature Metamorphism' held at the University of Bristol on 12 and 13 April 1984. The meeting was jointly sponsored and organized by the Clay Minerals and Geochemistry Groups (Mineralogical Society) and the Metamorphic Studies Group (jointly Geological Society of London and Mineralogical Society). One aim of the meeting was to examine the broad transitional area between the normally separated fields of diagenetic and metamorphic studies. The definition or discussion of boundaries was not within the terms of reference of the meeting, the aim being to integrate rather than subdivide. This issue is not meant to provide a comprehensive review of the field, or the range of interests and variety of techniques that can be applied to the study of very low-grade metamorphism. Certain aspects of the very broad range of interests were not represented at the meeting and perhaps the most unfortunate absence was that of presentations specific to the thermal maturation of organic material.

The seventeen papers in this thematic issue of the *Mineralogical Magazine* represent some of the presentations given at the conference. The papers are arranged into three broad groupings. The first seven articles are largely concerned with the application of various investigative methods, used in studies of very low-grade metamorphism, to some individual regions. The following five papers describe microchemical and microstructural studies of various phyllosilicates. The final five articles cover variable aspects but have a general theme of fluid movement and its effect on the enclosing rocks.

In the first group the investigation of mineralogical and 'crystallinity' variation in pelitic rocks is the main theme in five of the articles; the remaining two involve the analysis of mineral assemblages in the classic fashion of the metamorphic petrologist. Merriman and Roberts present a wealth of detail from a thorough investigation of 'mica crystallinity' and polytypic variation within the $< 2\ \mu m$ fraction of Lower Palaeozoic rocks in North Wales. This work must represent one of the most comprehensive examinations, by XRD methods, of crystallinity, polytypic, and mineralogical variation within a transitional sequence between diagenesis and metamorphism. A most valuable and welcome review of phase equilibria and mineral parageneses at sub-greenschist level in metabasites by Liou then follows. He presents many useful P/T diagrams and graphical presentations of mineral assemblages for the various low-temperature metamorphic facies. Particularly valuable is documentation of the effect of introducing Fe_2O_3 into the system converting facies boundaries into continuous reactions, and invariant points into discontinuous reactions. Liou advises caution in the interpretation of chemical variation in Ca–Al hydrosilicates in terms of grade, unless buffered assemblages are under investigation.

The importance of integrating regional metamorphic data into the interpretation of the geological evolution of an area is demonstrated by Kemp *et al.* They show how material of varying structural depth (metamorphic character) has been juxtaposed during the subduction-related accretion of the Southern Uplands during late Silurian times.

The researches of Marayuama *et al.* are in a region of classic low-temperature, high-pressure facies series metamorphism involving Franciscan greywackes in California. Variation in pyroxene compositions in response to increasing grade is related to a continuous reaction of clinopyroxene and albite in the presence of quartz. Some argue that this metamorphic field does not lie within the scope of 'normal' burial metamorphism. One aim of the conference was, however, to unite workers (and not separate on the basis of semantic terms). As the authors propose that reconstitution has occurred within the temperature range of 170–230 °C, their work merits inclusion in the volume.

Offler and Prendergaast use illite crystallinity and b_0 determinations to elucidate the metamorphic history of the North Hill End Synclinorium in Australia. Their data are compatible with an ensialic rift setting with local enhanced heat flow from granitoid intrusions. Some new data are then presented by Brime for the external zone of the Hercynides in NW Spain which show a transition from diagenesis to greenschist-facies metamorphism. A similar transitional sequence is also examined by Primmer involving a Variscan fold complex in SW England. This comprehensive account relates metamorphism to the structural pattern and derives metamorphic temperatures from isotopic data and the garnet–biotite mineral geothermometer. Isotopic temperatures for the anchizone and diagenetic fields were < 200 °C with 290–380 °C for greenschist facies, while the mineral geothermometer gave a value of 450 °C for a greenschist assemblage.

The second grouping of five papers has a common theme in being concerned with the analysis of chemical and/or microstructural information in the response of phyllosilicates to increasing temperature. The chlorites are often ignored during studies of very low-grade metamorphism. Here Curtis *et al.* use analytical transmission electron microscopy to examine chemical changes in material ranging from authigenic chlorite grain coatings to stilpnomelane-bearing rocks and chlorite-slates.

There has been considerable hope that the illite/smectite interlayering sequence could be utilized as a geothermometer. In the following two papers by Velde, and Nadeau *et al.* precautionary features are detailed. Velde demonstrates how a change in the oxidation state of iron might in turn cause a change in the smectite content of a mixed layer mineral sequence. The work of Nadeau *et al.* has great significance for a mixed-layer series such as the illite/smectites. They propose that the XRD identification of an illite/smectite series arises from an *interparticle* diffraction effect and that differences between random and regular sequences simply reflect a difference in size between the discrete illite particles. It appears that their work will attract much interest and 'alarm', and further testing of the proposals will be eagerly awaited.

The conversion of detrital phyllosilicates during very low-grade metamorphism is largely ignored in the attention given to neo-formed material. Wybrecht *et al.* examine a series of size fractions of Cambrian pelitic rocks from Morocco and itemize various mineralogical and chemical changes between the fractions. The usefulness of microstructural and microanalytical studies in conjunction with back-scattered SEM techniques is demonstrated by White *et al.* Variations in chemistry and intergrowth of phyllosilicates in some sedimentary and metamorphic rocks are detailed with the aid of some fine electron micrographs.

The final group of five papers covers a variety of topics but incorporates some aspects of isotopic and/or geothermal consideration as a unifying point. A stable isotope investigation of the fluids involved in the metamorphic and hydrothermal alteration of rocks in the Lake District region of England is presented by Thomas *et al.* They recognize three distinct fluid types involved in the alteration processes but have not been able to define the actual origin of the metamorphic fluids. Modern geothermal systems provide a unique opportunity to study active chemical and mineralogical transformations at low temperatures. Although these systems represent a specialized environment, they can provide valuable reference data for the more 'normal' processes and changes seen in very low-grade metamorphism. Schiffman *et al.* and McDowell and Paces investigate the clay–carbonate and carbonate rocks of the Del Puerto and Salton Sea systems respectively. In both systems mineralogical and chemical changes occurring over the approximate temperature range of 150 to 370 °C are examined. Bevins, in a short note, equates a pervasive alteration style in meta-igneous rocks of Ordovician age in the Builth region, Wales, to the presence of an Ordovician geothermal system.

Hutcheon *et al.* report on the formation and geochemistry of calcite cements in a Cretaceous sandstone from the Labrador Shelf. The chemical data are interpreted as indicative of meteoric water influence upon the cement while the diagenetic temperature range of cement formation was calculated from oxygen isotope data.

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