APPLICATIONS OF PALEOMAGNETISM TO SEDIMENTARY GEOLOGY

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APPLICATION OF PALEOMAGNETISM TO SEDIMENTARY GEOLOGY

**Purpose**

With the publication of Applications of Paleomagnetism to Sedimentary Geology, the Society for Sedimentary Geology and the Special Publication Series embark on an exciting new direction regarding the geological interpretation, age-dating, correlation, and diagenesis of sedimentary deposits. The goal of both the 1991 SEPM Research Symposium and the results presented in this follow-up volume is directed towards bringing the disciplines of paleomagnetism and sedimentary geology closer together. Advances in the field of sedimentary geology will likely result from continued development of new ideas, questioning of old dogma, and, most importantly, providing the means for testing these new hypotheses. It is hoped that the union of these two disciplines will help address many fundamental geological questions, such as the perennial problems of precise age-dating, stratigraphic correlation and geometries, understanding the timing and nature of post-depositional diagenetic fabrics, and the intriguing relationship between hydrocarbons and magnetization. The reader of this Special Publication will find an unusual diversity of research topics presented under this cover. We believe this diversity serves as a testimony to the potential applications awaiting the sedimentary geologist willing to explore these new paleomagnetic tools.

The recent growth in the number of paleomagnetic laboratories around the world, newly gained access to many regions of the world, and recent emphasis on global-scale geological problems provide an exciting challenge to the combination of paleomagnetism and sedimentary geology. This newly found interaction between sedimentary geologists and paleomagnetists promises even more creative application of paleomagnetism to the interpretation of the geologic record. A few of the challenges that immediately come to mind include testing the isochronous nature of sequence stratigraphic boundaries; relative timing of hydrocarbon migration and accumulation; high-resolution stratigraphic correlation, enabling enhanced interpretation of climate and faunal archives; the cause/effect relationship between sedimentation and tectonism, resolvable on the basin scale; through paleomagnetism; magnetostratigraphic dating of carbonate rocks that record major changes in sea level; refined timing of major diagenetic/remagnetization events related to tectonism, regional hydrogeochemical regimes, and normal compaction/cementation reactions; to name just a few. Clearly, as editors of this Special Publication, we sense an untapped potential in the marriage of these two disciplines. Below is a short introduction to the manuscripts included in this Special Publication.

**Contents**

The various mechanisms by which sedimentary rocks acquire a remanent magnetization form one of the fundamental aspects for the use of paleomagnetism and have been the focus of considerable attention. In the first section of Special Publication 49, entitled Magnetization of Sediments, we have compiled a collection of three papers that addresses the origin of magnetic grains incorporated into sediments and their subsequent preservation during diagenesis. The first paper by Hawthorne and McKenzie addresses the origin and preservation of magnetic grains deposited during the last 300 years in Lake Greifen, Switzerland. Both authigenic single-domain biogenic magnetite and multidomain detrital titanomagnetite were preserved within the bioturbated marls. Based on mineralogical, geochemical, and rock-magnetic investigation of these sediments, these authors suggest that microbially mediated processes contribute to the authigenesis of magnetite as well as its destruction. The second paper by Brennan is an integration of results from Natural Remanent Magnetization and Anisotropic Magnetic Susceptibility that demonstrates how depositional and post-depositional processes can modify the original inclination recorded by magnetite grains within glacio-lacustrine varved clay of late Wisconsinan age in western New York. This work is an example of the complex behavior of detrital magnetite in natural systems where shape and size may affect considerably the resulting magnetic properties of sediments. Similar work on the behavior of magnetic minerals during carbonate crystallization is needed to discriminate further the different magnetic signatures that carbonate rocks display. The third paper by Verosub and Summa addresses a most fascinating, complex, and relatively new subject involving diagenetic alteration of tephra layers and its effects on rock magnetic and paleomagnetic signals. The results in this paper have very significant bearing on paleomagnetic orientation data and on the wide-open subject relating interstitial water geochemistry to sediment magnetization.

The second section is devoted to Magnetostratigraphy. This section explores the refinement and confirmation of the magnetic reversal record and discusses the use of global magnetostratigraphic correlations. In their paper, Steiner, Morales, and Shoemaker present eight magnetostratigraphic sections within the Middle Triassic portion of the Moenkopi Formation, northeastern Arizona. The magnetostratigraphic signature was used to test the time relationships of numerous vertebrate faunal occurrences and to test the synchronicity of a major change in facies over this part of the depositional basin. This study is a clear illustration of how magnetostratigraphy offers an alternative tool to date continental sedimentary strata and to correlate intrabasinally. The next paper, by Tailing and Burbank, explores the uncertainties in magnetostratigraphic dating of sedimentary deposits based on the Late Cretaceous to Eocene from Axhandle in central Utah. These authors review the assessment (qualitative and quantitative) of the confidence in correlations between the magnetostratigraphic sequences recorded in sedimentary strata and the geomagnetic time scale. This paper is significant in that it involves a discussion of some of the working problems associated with magnetostratigraphy where deposition is either intermittent or variable in rate.
By investigating the lacustrine sediments from Pringle Falls, Oregon, **Herrero-Bervera and Helsley** document the paleomagnetic record of the Blake magnetic episode, which is either an excursion or a true reversal event (a matter still under discussion). The global correlation throughout the world and the discussion on the virtual geomagnetic pole path (plot of the changes in the movement of the geomagnetic pole) provide insight to the understanding of the geomagnetic field behavior recorded at the Earth’s surface during polarity transitions. **Farr, Sprowl, and Johnson** show how to deal with the three magnetic components that are present in their study area. Their results provide a preliminary reversal stratigraphy of three Lower to Middle Ordovician sedimentary units in northern Arkansas, implying a global comparison of the European (Russian) and North American ages for the Ordovician.

As with many other sedimentary deposits, the Monterey Formation of California has been subject to considerable diagenesis that precludes its dating based on faunal markers or geochemical methods. By using magnetostratigraphy in the last paper of this section, **Omarzai, Coe, and Barron** have significantly refined the age of a large portion of the Monterey Formation, providing a quantitative framework for the understanding of its geological evolution and for using the rich archive that its lithologies record.

The seven papers in the third section of this volume illustrate the diversity of some of the applications of sedimentary paleomagnetism. The first paper, by **Elmore, London, Bagley, and Gao**, is an integrated approach to timing the diagenesis within Ordovician carbonates in the Arbuckle Mountains of southern Oklahoma. Because this diagenesis resulted in precipitation of iron oxides, the authors use paleomagnetism together with petrography and geochemistry to relate the diagenesis to the migration of basinal fluids. This study gives valuable insight to the dating of post-depositional modifications during basin evolution. By documenting the remagnetization of Paleozoic carbonates after chert nodulization and stylolitization, **Gillett and Geissman** demonstrate the value of integrating small-scale and mesoscale sedimentary textures with paleomagnetic data. Because these rocks do not offer the possibility of using a regular fold test, the authors have applied differential compaction around algal heads, boundstone reefs, or dewatering phenomena such as teepee structures to provide “nontectonic” fold tests. Their results demonstrate that the characteristic magnetization postdates both chertification and deformation associated with dissolution along stylolites. These types of field tests are of considerable importance for assessing the nature of magnetization and identifying remagnetization in ancient rocks.

**Gose and Kyle** provide detailed paleomagnetic data of the cap rocks from the Winnfield (northern Louisiana) and the Hockley (south central Texas) salt domes. Among the mineralization products associated with salt-dome formation, the magnetic mineral pyrrhotite occurs in both cap rocks. This mineralization makes it possible to use the remanent magnetization for dating the timing of salt-dome formation and for the estimation of salt diapir growth rates. This application related to salt dome formation has considerable economic potential given the structural and genetic relationships between hydrocarbons and metallic ore, respectively.

**Elmore, Imbus, Engel, and Fruit** address the relationships between the occurrence of hydrocarbons and the precipitation of magnetite and, hence, the subsequent remagnetization of hydrocarbon-bearing rocks, a subject that has attracted much-deserved attention recently, with the potential for assessing the relative timing of fluid migration and for characterizing the resultant magnetization of hydrocarbon reservoirs. The authors summarize some previous studies and present further results on how hydrocarbons can affect the magnetization in limestones and siliciclastic redbeds. This work provides evidence that the use of paleomagnetism can help resolve the timing of hydrocarbon migration or trapping through dating of the related magnetization, a method which has important implications for the various types of magnetic prospecting techniques that have been proposed.

The work by **Latham and Ford** is an investigation of the paleomagnetic properties of speleothems. Although these are not geological formations *sensu stricto*, they are examples of how carbonate precipitation acquires magnetization in natural systems. In these speleothems, detrital deposition by cave flooding and possible organic/biological-related magnetization, clearly indicate that cave deposits can obtain and preserve a remanent magnetization. Such magnetization makes these deposits useful for a variety of paleomagnetic studies, especially because they may be relatively stable over long periods of time.

The next paper, by **Reynolds, Goldhaber, and Tuttle**, shows how hydrocarbon seepage has changed the original magnetizations at Cement oil field (Anadarko basin, Oklahoma), at Simpson oil field (North Slope basin, Alaska), and above deep Cretaceous oil and gas reservoirs (south Texas coastal plain). Although Elmore and others focused on inferred genetic relations among magnetic iron-oxide minerals and hydrocarbons, the work by Reynolds and others documents post-depositional iron-sulfide minerals that can also change the original magnetizations of sedimentary rocks.

To further stress the importance of understanding the relationships between hydrocarbons and remagnetization, the intriguing paper by **Burton, Machel, and Qi** examines the theoretical geochemical conditions that may lead to the precipitation of magnetic minerals within hydrocarbon-bearing formations. This discussion is of considerable importance for reconstructing conditions favorable for the magnetization related to hydrocarbon migration and accumulation and may help constrain the geochemical conditions at the time of hydrocarbon emplacement and the associated magnetization.

**Summary and Acknowledgments**

Based on the nature of the results presented in this volume, most of the papers were reviewed by paleomagnetists working in sedimentary environments. We gratefully acknowledge the support of these reviewers in improving the content of this publication. The enthusiasm of the reviewers and their willingness to help support improved community engagement has been invaluable.
culation between the two communities are reflected in the fact that not one of the reviewers contacted refused to take on the task of providing review and constructive criticism of the requested manuscript. Two reviews were even completed by several of the reviewers. A list of these invaluable assistants is provided on the following page. Within SEPM, Barbara Lidz and Tricia Auberle provided editorial guidance and assistance with final production. Their experience with preparing Special Publications was invaluable for keeping the project on schedule. We thank the SEPM Research Committee for their interest in new ideas, new tools, and their application to sedimentary geology. DFM acknowledges the support of the U.S. National Science Foundation for supporting his research during the editorial period of this publication. DMA acknowledges the French CNRS and ELF Aquitaine for their help. The editors would also like to thank G. M. Grammer for his last minute help in handling manuscript revisions.

In summary, we hope this volume helps contribute to the inertial forces driving continued interaction, communication, and collaboration between paleomagnetists and sedimentary geologists. Many advances in Earth science remain to be made through the interdisciplinary approach to Earth science, using new tools in new ways, and going to new places! This volume serves to introduce the sedimentary geologist to the multitude of paleomagnetic techniques. It is not meant to be a comprehensive guide to the subject, but hopefully the spark that promotes increased collaboration. For the sedimentary geologist, both siliciclastic and carbonate, who wants to learn more about paleomagnetism and measurement techniques, we have listed below some of the general reference text books on the subject. We hope this enthusiasm continues to expand in the sedimentary community, and we are ready to meet these new challenges!

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November, 1993

Several references for those new to paleomagnetism who wish to learn about its applications and techniques.

**Butler, R. F., 1991, Paleomagnetism, Magnetic Domains to Geologic Terranes: Boston, Blackwell, 319 p.** (a well written, well illustrated, up-to-date introduction to paleomagnetism and its applications; a good place to start for sedimentary geologists new to paleomagnetism).


**Irving, E., 1964, Paleomagnetism and Its Application to Geological and Geophysical Problems: New York, Wiley, 399 p.** (one of the classic textbooks on paleomagnetism, contains much of the fundamental basis for measurement and application of paleomagnetism).


**Kirschvink, J. L., Jones, D. S., and MacFadden, B. J., eds., 1985, Magnetite Biomineralization and Magnetoreception in Organisms: A New Biomagnetism: New York, Plenum Press, 682 p.** (a wide range of papers on biogenic magnetite, including how biogenic magnetite contributes to magnetization of sediments, paleomagnetic techniques and equipment).

**McElhinny, M. W., 1973, Paleomagnetism and Plate Tectonics: Cambridge, Cambridge Press, 358 p.** (also one of the longstanding texts for paleomagnetism, incorporates sea-floor spreading and plate tectonic applications).


**Thompson, R., and Oldfield, F., 1986, Environmental Magnetism: London, Allen and Unwin, 227 p.** (an easily readable introduction to some of the application of paleomagnetism and rock magnetic techniques, especially directed toward environmental systems).

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