Paleomagnetic data for reconstructions

Van der Voo, R. 1993. *Paleomagnetism of the Atlantic, Tethys, and Iapetus Oceans.* Cambridge University Press, Cambridge, U.K. Price £60.00, U.S. $85.95 (hardback).

Paleomagic, as the subject of paleomagnetics is often called, has for many Earth scientists been just a bit of black magic produced in a black box that was only of value if it provided data supporting one's latest model. Rob Van der Voo's new book *Paleomagnetism of the Atlantic, Tethys, and Iapetus Oceans*, devoted to the application of paleomagnetism to plate reconstruction, is intended for the geologic community as a whole. To accomplish this the book provides the non-paleomagnetist with a few of the basic tools for evaluating paleomagnetic data in the initial chapters. It then brings together a vast amount of paleomagnetic information from the continents surrounding these oceans and aims to integrate it with other data sets to construct a coherent picture of our current understanding of Phanerozoic tectonics. His intention is that this information be in a form which is accessible not only to paleomagnetists but to the earth science community at large.

The book is composed of nine chapters. Chapter 1 is, in reality, a prologue that sets the stage for the book as a whole. It explains the philosophy on which this book is based and a bit of the Greek, Roman and Earth science history which lies behind the names given to some of the oceans and continents that have existed since the beginning of the Phanerozoic.

In Chapter 2 the author explains the relevant aspects of the Earth's magnetic field and the concept of polar wander. He explains how to calculate a pole position from paleomagnetic data, and why it is preferable to use apparent polar wander paths as the method for describing the motion of the continents on the earth. In doing so he points out the various assumptions underlying the paleomagnetic method (i.e. the assumption of the axial, geocentric dipole) as well as the errors and ambiguities (hemispherical and longitudinal) inherent in paleomagnetic data and methodology. This chapter also contains a description of the statistical methods that are commonly used to analyze the distribution of points on a sphere (Fisher statistics) and gives some indication of how meaningful a data set might be. These discussions are brief and only the essentials are explained. The book does, however, provide numerous adequate references for those requiring more detailed discussions and derivations.

The purpose of Chapter 3 is to introduce, define and discuss the geologic/geographic elements that make up our planet. These include megaplates, microplates, blocks, terranes, suspect terranes, accreted slivers and olistostromes. He discusses the concept of the craton and the continental margin. After putting each of these crustal units into the context of the plate tectonic paradigm he mentions an example of each, explores the various problems and possibilities of using paleomagnetic techniques to make plate reconstructions and then refers to the subsequent chapters where these elements are discussed in greater detail.

Chapter 4 deals with the basic hows and whys of both laboratory and field techniques in paleomagnetism. The chapter begins by describing how a rock might acquire and retain a memory of a magnetic field. Emphasis is placed on the importance of a relatively precise determination of the age of acquisition of magnetization. A combined condition for a meaningful result is discussed in a qualitative way. The next part of the chapter deals with the theoretical and practical aspects of various alternative laboratory demagnetization techniques (chemical, thermal and alternating field). These techniques incrementally remove a sample's acquired magnetization with the aim of separating and removing the unstable components, which are commonly secondary and may overprint an original or primary magnetic direction. To follow the more theoretical aspects of this discussion, some familiarity with the terminology and concepts used in basic magnetic theory is necessary. The remainder of this chapter covers interpretation and analysis of data including: (1) how to read and interpret the vector diagrams generated by demagnetization experiments; (2) field tests to help constrain the age of magnetization (fold, conglomerate, baked contact) and the significance of each of these tests; (3) the importance of accurate paleohorizontal determination; (4) the reversal test, commonly used to indicate that secular variation has been sufficiently averaged out and that there is not a systematic overprint; and (5) the problems of remagnetization and imposed flattening, how they happen, and the possible ways of dealing with these problems. Remagnetization has been shown to have been at the root of many of the conflicts between geologists and paleomagnetists working on plate reconstructions. Finally, a list of seven criteria for data reliability are presented and explained. These criteria are used throughout the remainder of the book to assess the quality of published results.

Chapters 5–8 form the real core of the book. The vast data base compiled in the appendix of the book is used to reconstruct pre-Oligocene (<40 Ma) Phanerozoic polar wander curves for the geologic/geographic elements introduced in Chapter 3. Various models for plate reconstructions, incorporating data from other disciplines such as paleoclimatology, paleontology and marine geophysics, are discussed.

Chapter 5 deals with the major cratons. These include North America, Greenland, Europe, Siberia and North/South China in the northern hemisphere and the Gondwanan elements (South America, Africa, Madagascar, India, Australia, Antarctica) in the southern hemisphere. These units, which by definition contain a Precambrian core, are discussed in groups including a bit of the history of research, the geographical basis for the paleo-pole construction as well as the current ideas on the motion histories of these cratons. The chapter ends by discussing the evidence for alternative configurations for the Paleozoic to Mesozoic supercontinent of Pangea.

Chapter 6 is concerned with the opening of the Atlantic Ocean. It examines the paleopoles of the continents bordering the Atlantic (North America, Greenland, Europe, South America, Africa) from the middle Jurassic to the Tertiary. The reconstructions obtained from the paleomagnetic data are compared to those based on marine geophysical data (magnetic anomaly record and fracture zone orientations). In the case of the opening of the Atlantic these two data bases agree well and give one of the best examples of how paleomagnetism can be applied to plate tectonic reconstructions.

As the blocks get smaller their histories tend to become increasingly complex and less well understood. Chapter 7 deals with the multitude of continental fragments caught up in the wedge-shaped ocean, known as the Tethys, that existed between Gondwana and Laurasia in the Mesozoic. Today these fragments are strung out along the Alpine–Himalayan orogenic system that runs from Spain in the west to the mountain ranges of the far east (China and the Philippines). There is an enormous amount of paleomagnetic information available from these small crustal units, which is used to piece together some of their individual motion histories. There are short discussions of each block giving some indication of what issues have been resolved and what needs to be done.

The final chapter before the epilogue deals with the oldest and perhaps most obscure and controversial of topics, the Iapetus Ocean. This proto-Atlantic ocean probably existed from the Cambrian well into the Paleozoic. Data from this older period is much more fraught with uncertainties and problems, the least of which is remagnetization, but progress has been made and many people have attempted to reconstruct the history of the Iapetus with the aid of the paleomagnetic data summarized in this chapter. Although it presents no definitive answers, this chapter forms the basis for possible future work in this region.

Last but perhaps most importantly is the appendix of the book, which is a major resource for those wishing to use paleomagnetic data in their reconstructions. The appendix compiles paleopoles for all of the continental elements discussed in the book. For each pole, the age (max. and min.), pole position and accompanying Fisher statistics, and reliability criteria are presented. This is a good first-order reference but in may opinion should not be used as a replacement for the original literature. Dates published in older studies must be checked using new decay constants and the data used in any given study should be assessed on a site by site basis.

In general this book is well structured, informative and fulfills a useful purpose. It is written in a conversational style making it easy to read if you are reasonably acquainted with the English language. One of the strengths of this book is that it clearly shows what the state of the art is, where we are and what still needs to be done, in unravelling the history of motion of the continents over the globe through time. Like all books of this nature, however, it faces the problem that the information goes out of date and scientists working in the field will undoubtedly have to refer to the primary sources of information.

Finally, it should be noted, that this book presents a detailed discussion of one application of the paleomagnetic technique: that of plate reconstructions and polar wander. The book does not explore and does not pretend to address other applications of paleomagnetism that may be relevant to structural geologists, such as fabric analysis and determination of vertical axis rotations in deformed terranes. If you are interested in plate reconstructions, however, or in a good book that objectively discusses paleomagnetism pointing out the strong and weak points of the data and the method this book is a must.

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