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Preface

This special issue of *Tectonophysics* derives from a workshop that was held in Ann Arbor, MI in August 2000 on the general theme of 'Paleomagnetism, Global Tectonics and the Rock record'. The purpose of the workshop was to celebrate the 60th birthday of Rob Van der Voo, and to acknowledge his many contributions to the broad fields of paleomagnetism and tectonics as he reached that milestone. Some 30 people attended and were treated to 18 presentations on a broad range of topics, including tectonics, paleomagnetism and others. Several of the papers presented at the meeting are included in this issue, along with additional contributions from other individuals and groups, who wished to acknowledge Rob's contributions and achievements, as well as his inspiration to the field.

Paleomagnetism played a leading role in the early days of plate tectonics, providing some of the defining evidence for plate mobility, and remains the only quantitative tool for charting pre-Mesozoic plate motions. In recent years, there has been an increasing emphasis on understanding Pre-Palaeozoic plate motions, in particular the paleogeography of the late Neoproterozoic. This interest arises, in part, from the recognition that this period marks an important transition in Earth history, with the increasing dominance of complex multicellular organisms through the Precambrian–Cambrian boundary, concomitant with extreme climatic signatures and major changes in seawater chemistry, and major plate organisations. In addition it marks the possible breakup of the Rodinia Supercontinent and the subsequent reassembly of its constituent fragments as the major Paleozoic continent of Gondwana. The first two papers in this volume deal with the assembly and subsequent Precambrian and Paleozoic history of this continent. Meert presents a synopsis of the available chronologic and paleomagnetic constraints on the assembly of Gondwana. Although the assembly of Gondwana in the latest Precambrian has traditionally been viewed as marking a collision between east and west Gondwana, the evidence presented here suggests that eastern Gondwana was not an entity prior to overall Gondwana assembly in the late Cambrian. The subsequent Paleozoic history of Gondwana is addressed in a paper by McElhinny et al., who also address a long-standing controversy as to the validity of utilising paleomagnetic poles from the terranes of eastern Australia for Gondwana reconstructions. Their analysis indicates that the major Lachlan and Thomson superterranes appear to have been fixed with respect to the Australian craton since early Devonian time (c. 400 Ma), whereas the New England superterrane did not become fixed until late Permian (c. 250 Ma) time. The resulting Apparent Polar Wander path yields a complex drift history for Gondwana, and indicates that models that argue for Laurentia–Gondwana interaction in the early Paleozoic are possible.

These papers are followed by two papers that address a topic close to Rob's heart, the tectonic evolution of the Appalachian–Caledonian orogen. New paleomagnetic data from Arenig limestones from the SW margin of Baltica (Torsvik and Rehnström) agree with previously published data, and these data collectively indicate a mid-southerly latitudinal position for Baltica. This indicates a significant degree of separation from Avalonia, which occupied high southerly latitudes at this time. Convergence between the two paleocontinents is marked by the development of Andean-type magmatism in Avalonia, and Torsvik and Rehnström propose that this was the source for the large Kinnekulle bentonite of Caradocian age in Baltica. Torsvik and Rehnström also report the first evidence of a pervasive Late-Ordovician magnetic

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overprint in Baltica, which is likely linked to the convergence and eventual Late-Ordovician collision of Baltica and Avalonia. The collision of the combined Baltica–Avalonia continent with Laurentia is documented in the subsequent paper by Smethurst and McEnroe, who report new paleomagnetic data from Silurian sequences from the Central Mobile belt of Newfoundland, which mark the collision zone between Laurentia and Avalonia. These new data help resolve a long-standing dispute about possible inclination errors contributing to erroneous paleogeographic models, where some units had yielded paleolatitudes that implied oceanic separation between Laurentia and Avalonia persisting into the mid-late Silurian. These new data confirm that the various Paleozoic terranes that make up Newfoundland were assembled in the Silurian, but later underwent oroclinal bending by vertical axis rotations.

These contributions are followed by a series of papers that deal with more "regional" aspects of tectonics. The geology of western North America records a large portion of Earth's history, from the Archean to the present day, with changing tectonic environments, which encompass compressional, extensional, and strike-slip regimes. Three papers in this volume apply paleomagnetic techniques to understand parts of this long and complex history. Harlan et al. present new paleomagnetic data and U–Pb ages from an Early Proterozoic Quartz Diorite from the Wyoming craton. The paleomagnetic data are discordant when compared with coeval data from the Canadian Shield, and may call into question reconstructions in which the Wyoming and Superior provinces are in proximity in the early Proterozoic. Deformation and crustal uplift within the Superior Province, along the Kapuskasing structural zone, are documented by Halls and Zhang. They note a change in polarity with depth in the c. 2.45 Ga Matachewan dyke swarm. When mapped out regionally lateral changes in polarity are marked by major faults, which juxtapose zones of opposite polarity, and hence different structural depths. The Mesozoic and Cenozoic tectonic history of western North America has, of course, been dominated by the accretion of a number of terranes, which now lie distributed along the length of the Cordillera. The accretion history of several of these terranes has proven to be highly controversial, with considerable debate as to how far different terranes have been transported prior to their accretion to the North American margin. Harris et al. present new paleomagnetic and geochronologic data from a Jurassic (c. 173 Ma) intrusion from the northern Canadian Cordillera, which indicate a significant southward displacement of some 1700 km for the Cache Creek Terrane. The terrane also underwent a large clockwise rotation, and while the paleolatitude estimate for the Cache Creek Terrane is very similar to that of the Stikine terrane the amount of rotation is not. This suggests that the two terranes were not yet amalgamated in the Middle Jurassic.

The Mediterranean region has long provided a natural laboratory where the concepts of tectonic rotations have been developed and tested, and this area provided the focus for much of Rob's early work. One of Rob's earliest papers focused on the rotation of Iberia and this is also the subject of the paper by Larrasoaña et al., who document the results of a paleomagnetic investigation of a sequence of Triassic red beds from the western Pyrenees. The new data presented confirm the rotation pattern, and the origin of the primary remanence reported in previous work, and that these rotations are linked to the counterclockwise rotation of Iberia with respect to stable Europe. The results also indicate that the Mesozoic plate boundary between Iberia and Europe was a zone of distributed deformation, rather than a discrete plate boundary. Farther to the east, in the Apennines of Italy, Speranza et al. report new paleomagnetic results from the Gran Sasso range, which forms an arc marked by roughly rectilinear E–W and N–S limbs. They show that this arc is, in fact, a composite structure, consisting of an unrotated western limb, oriented E–W, and a highly rotated (c. 90° anticlockwise) eastern limb oriented N–S. The Cenozoic evolution of the eastern part of the Mediterranean is the subject of the paper by Kissel et al., who report the results of a paleomagnetic traverse through Anatolia. These results, when combined with previously published results, reveal that the Anatolian block has undergone some 25° of counterclockwise rotation relative to Europe since the Miocene. If this rotation has taken place about a constant rotation pole since this time, it indicates that Anatolia has moved by some 500 km westward, at an average displacement of about 40 mm a year. Comparison with geodetic measurements suggests that this rotation continues

to the present day. The final paper from the Mediterranean region deals with the paleomagnetic signature of Mesozoic units from South-East France. Paleomagnetic studies in this region have been plagued by problems with identifying primary remanences, and uncertainties about the ages of remagnetizations. Kechra et al. present some new data, which, in conjunction with published data, indicate that the entire region has undergone a pervasive remagnetization in the Eocene.

While the Cordillera of western North America and the Mediterranean region provide excellent examples of terrane accretion, collision and subsequent deformation, there is a certain irony that paleomagnetic studies of actively deforming regions are relatively scarce. This is particularly true of the South-West Pacific, a region that has often been invoked as an analogue for ancient orogens such as the Appalachian–Caledonide mountain belt and the North American Cordillera. The two papers in this volume by Klootwijk et al. go some way towards helping to remedy this situation. The first paper, on the terranes in the Papua New Guinea Highlands, identifies important differences in the deformation of the interior and exterior zones of New Guinea's central Cordillera. Cenozoic units of the interior zones of the central and eastern highlands are characterized by large scale counterclockwise rotations, whereas the exterior zone of the southern highlands yield evidence for large-scale clockwise rotations. These rotations are linked to nonrigid rotations of these terranes as they were transported onto the northward advancing Australian margin since the Middle Miocene. Similarly, the results reported from Cenozoic volcanic and cover sediments from the North Sepik region of Papua New Guinea, in the second paper, also reveal a pattern of anti-clockwise and clockwise rotations, and, additionally, provide evidence for significant latitudinal motions of the accreted arcs.

Whereas much of Rob's career has been dedicated to unraveling the paleogeography and tectonic evolution of ancient orogens and past plate reconstructions by applying modern day plate tectonic principles, he has always had an interest in periods of Earth's history where nonplate tectonic processes, such as True Polar Wander or non-dipole geomagnetic fields, may have played a greater role than at the present. The relative magnitude of True Polar Wander, which has occurred in recent times at rates much less than those of typical plate motions, may not always have been so low. Paleomagnetically determined plate velocities in the late Precambrian and at certain periods in the Paleozoic indicate that large plates may have moved at velocities in excess of 30 cm/year. Whether this is related to an artifact of the recording process, non-dipole fields, or changes in the relative rates of plate motions and true polar wander has been the subject of some considerable debate. The paper by Evans presents a model which links the apparently very high plate velocities at certain times in the Proterozoic and Paleozoic, to periods of rapid true polar wander, which are driven by cycles of supercontinent assembly and subsequent dispersal. While speculative, this model may explain certain persistent features of the geological record, such as why supercontinents appear to have generally dispersed while located over the equator. True Polar Wander has also been proposed to have occurred at much higher rates at the present day in the late Cretaceous, based on a mismatch between paleomagnetic reference data and the hotspot framework. New data presented here, by Cottrell and Tarduno, from the Late Cretaceous Detroit seamount in the NW Pacific provide an alternative explanation. They argue that their data, in conjunction with other published data, do not support large degrees of true polar wander, but, rather, indicate that the discrepancy between the paleomagnetically derived paleolatitudes for Pacific seamounts and the hotspot framework relates to drift of the hotspots.

The final two papers in the volume deal with aspects of paleomagnetic methodology, which have important implications for the application of the paleomagnetic technique to tectonic problems, and particularly to estimates of tectonic rotations. The amount of relative rotation of the Colorado Plateau with respect to stable North America has been a contentious issue for several decades. Beck et al. have revisited the problem by rigorously analyzing the spatial distribution of the virtual geomagnetic poles from several of the studies from the Colorado Plateau. The analysis indicates that the distributions are often highly elongated along the apparent polar wander path, which indicates that the magnetizations may have been acquired over an extended period of time. They caution that estimates of rotation may be inaccurate due to temporal smearing of the paleo-

magnetic signal. The final paper in the volume by Pueyo et al. also deals with erroneous estimates of tectonic rotations, and in particular with the errors than can be introduced by applying simple tectonic corrections in regions of conical folds. Using modeling and a case study from the southern Pyrenees they show that large amounts of spurious rotations can be introduced if simple tectonic corrections are used, without a complete understanding of the overall fold geometry.

A common theme that runs through all the papers in this volume is the power of paleomagnetism as a tool in understanding tectonics, from the scale of plates to individual folds. A recurring theme within the meeting, and we hope in this volume, is that its power is magnified by the integration of paleomagnetic results with those from other disciplines, a hallmark of Rob's research efforts at the University of Michigan. We trust that this issue will stimulate further development of integrated paleomagnetic and tectonic studies.

We wish to thank all the authors who submitted manuscripts for this volume, for their interest and patience in its gestation. Special thanks are due to all the referees who kindly gave of their time and expertise to review the manuscripts. We would also like to thank the staff of the Oxford Conference Centre, Ann Arbor for their help in running the symposium. Finally we wish to thank Rob, Tanja and family, for their hospitality in Ann Arbor and for a wonderful birthday bash. Het was gezellig.

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