The Geological Evolution of the Eastern Mediterranean

Geological Society Special Publications
Series Editor A. J. FLEET

GEOLOGICAL SOCIETY SPECIAL PUBLICATION NO. 17

The Geological Evolution of the Eastern Mediterranean

EDITED BY

J. E. DIXON AND A. H. F. ROBERTSON
Dept of Geology & Geophysics
University of Edinburgh
UK

Published by
The Geological Society
London

THE GEOLOGICAL SOCIETY

The Society was founded in 1807 as The Geological Society of London and is the oldest geological society in the world. It received its Royal Charter in 1825 for the purpose of 'investigating the mineral structure of the Earth'. The Society is Britain's national society for geology with a membership of around 8000. It has countrywide coverage and approximately 1000 members reside overseas. The Society is responsible for all aspects of the geological sciences including professional matters. The Society has its own publishing house, which produces the Society's international journals, books and maps, and which acts as the European distributor for publications of the American Association of Petroleum Geologists, SEPM and the Geological Society of America.

Fellowship is open to those holding a recognized honours degree in geology or cognate subject and who have at least two years' relevant postgraduate experience, or who have not less than six years' relevant experience in geology or a cognate subject. A Fellow who has not less than five years' relevant postgraduate experience in the practice of geology may apply for validation and, subject to approval, may be able to use the designatory letters C Geol (Chartered Geologist).

Further information about the Society is available from the Membership Manager, The Geological Society, Burlington House, Piccadilly, London W1V 0JU, UK. The Society is a Registered Charity, No. 210161.

Published by The Geological Society from:
The Geological Society Publishing House
Unit 7, Brassmill Enterprise Centre
Brassmill Lane
Bath BA1 3JN
UK
(*Orders*: Tel. 01225 445046
Fax 01225 442836)

First published 1984
Reprinted with additional material 1996

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

ISBN 1-897799-66-7
ISSN 0305-8719

Printed in Great Britain by Aldens, Oxford, Didcot and Northampton

Distributors

USA
AAPG Bookstore
PO Box 979
Tulsa
OK 74101-0979
USA
(*Orders*: Tel. (918) 584-2555
Fax (918) 560-2652)

Australia
Australian Mineral Foundation
63 Conyngham Street
Glenside
South Australia 5065
Australia
(*Orders*: Tel. (08) 379-0444
Fax (08) 379-4634)

India
Affiliated East-West Press PVT Ltd
G-1/16 Ansari Road
New Delhi 110 002
India
(*Orders:* Tel. (11) 327-9113
Fax (11) 326-0538)

Japan
Kanda Book Trading Co.
Tanikawa Building
3-2 Kanda Surugadai
Chiyoda-Ku
Tokyo 101
Japan
(*Orders*: Tel. (03) 3255-3497
Fax (03) 3255-3495)

Preface

In the years since the 1977 Aegean conferences in Athens and Izmir there has been an explosion of new information on the Eastern Mediterranean, particularly on the Turkish area. Some three years ago we sensed that the time might be ripe for a meeting to consider all aspects of geology relevant to the tectonic evolution of the Eastern Mediterranean. We sounded out opinion in most of the European laboratories involved and received enthusiastic support for the idea. The boundaries of the area to be discussed were fixed early on: the Apennines to the west, the Carpathians and Caucasus to the north, the Zagros to the east and North Africa to the south. The meeting concentrated on the Late Palaeozoic to Recent evolution, as few coherent tracts of older rocks exist in the area.

The conference was held in Edinburgh from the 28 to 30 September 1982 and was attended by 220 scientists from 13 countries, 88 papers were read and 22 given in poster form. Sixty one contributions are published in this volume.

One of the key starting points of Eastern Mediterranean geology is deceptively easy to state. Several global reconstructions of the continents for Permian time indicate that a substantial tract of ocean, the 'Tethys', existed between Africa, and a Eurasian landmass to the north. Since little or none of this oceanic crust remains, the history of the Tethys from the Late Palaeozoic onwards must involve destruction of this ocean area. Perhaps surprisingly, however, the geology of the Eastern Mediterranean land areas is not dominated by this process but by the products of Mesozoic rifting and the formation and destruction of new oceanic basins. From this it is evident that closure of the Palaeozoic Tethyan ocean can not simply have involved continuing subduction culminating in continental collision in the Neogene. Tectonic events must have involved comprehensive re-organizations of plate boundaries so that the distribution of continent and ocean is almost bound to have been complicated and frequently changing.

The book is organized by age of events discussed and by area within this framework, and it is in five sections. Following the editors' introductory chapter the first is concerned with early Mesozoic events linked to ocean closure and so by implication deals with the fate of the Palaeozoic Tethys or *Palaeotethys*. Later sections deal with events following the birth and growth of wholly Mesozoic ocean basins of the *Neotethys*. This division follows the interpretation of the contributors and is not inherently clear-cut. We use the term Palaeotethys to imply an ocean basin already in existence at the end of the Palaeozoic, but one that may have continued in existence in the Mesozoic and Tertiary. We argue, for example, in our own introductory chapter that the destruction of Palaeotethys in this sense was a long-drawn-out process lasting until Tertiary times, and even that early Mesozoic compressional events in the area, though related to Palaeotethyan subduction, could also have involved the formation of short-lived Neotethyan ocean basins. While questions of this kind dominate the book as a whole, much of the research documented here is also concerned with fundamental questions of continent–ocean dynamics. How do continental margins evolve from the early rift stage? Where are ophiolites formed and how are they emplaced? How do blueschist belts come to be created and exhumed? What is the relationship between consumption of oceanic crust and the construction of volcanic arcs? With its great geological diversity and relative accessibility the Eastern Mediterranean is an exceptionally valuable field laboratory, producing results complementary, for example, to those of the Deep Sea Drilling Project or marine geophysical exploration.

The reader will find disparity in the depth of knowledge and the coverage of different areas and processes. He may be disappointed that the jig-saw puzzle is not yet fully solved, but he may in return come to appreciate how many of the pieces are turning out to have the same pattern on them, and he may catch occasional glimpses of parts of the picture. He will also find amid the tentative models and the many expressions of uncertainty, flat contradictions and diametrically opposed interpretations. Perhaps these simply reflect the state of earth science a decade and a half after the plate-tectonic revolution. They are, none-the-less, a stimulus for us to question the validity of the ground rules. Do palaeomagnetic inclinations faithfully record palaeo-latitudes? Are ophiolites really remnants of oceanic crust, from marginal or any other kind of basin? Does calc-alkaline magmatism mean active subduction? Must blueschists and melanges also be linked to subduction? Whatever one's doubts, the philosophy behind a book like this is clear enough. Directing the contributors to the wider implications of their work should help progress towards greater

overall understanding which must come from the dynamic interaction of large-scale thinking and small-scale research.

ACKNOWLEDGEMENTS:

Esso Exploration Inc. provided generous financial support for which we are particularly grateful. Financial support was also received from BP.

We would like to thank Professor G. Y. Craig of the University of Edinburgh, Department of Geology, for making available to us the full range of departmental facilities both in initially organizing the conference, then editing this book. Our sincere thanks go to our secretaries Mrs M. Wright and Mrs H. Hooker for their unfailing help, particularly with retyping edited manuscripts. Mrs D. Baty assisted with photography and, together with Mrs F. Tullis, with drafting also.

Finally we wish to record out thanks to Mr N. Palmer of Blackwell Scientific Publications for his friendly advice and assistance at all stages.

Introduction to the reprint

Since its publication in 1984, *The Geological Evolution of the Eastern Mediterranean* has proved to be an invaluable aid to research in this important region. Many of the papers are classics that report basic data and tectonic interpretations that still remain valid today. The individual papers summarize a large amount of international research that was carried out in the Eastern Mediterranean region during the previous decade and this was the first attempt at overall synthesis. Those who have tried to obtain this book in the last few years have been disappointed, hence the decision to reprint. The editors have added an outline of the main research developments since 1984 and key references to the more recent literature. In addition, many of the figures in the chapter 'Introduction: aspects of the geological evolution of the Eastern Mediterranean' have been redrawn.

Recent research developments

The early 1980s saw the publication of several companion volumes on the Eastern Mediterranean region, both on land and beneath the sea. Aspects of the marine geology of the Mediterranean Basin were reported in 'Geological Evolution of the Mediterranean Basin' edited by Stanley and Wezel in 1985. In 1986, Dercourt *et al.* published an atlas of palaeogeographic maps of the Tethyan area which were accompanied by text, and incorporated data from the Eastern Mediterranean region. By the mid-1980s it was clear that different regional tectonic interpretations were mutually contradictory. Problematic aspects included the history of Africa–Eurasia plate motion, the nature of the crust beneath the Mediterranean Sea, and the origin of the ophiolites. This, in turn, stimulated an expansion of field-based research. The southern margin of Eurasia, represented by complex, often metamorphic terrains (e.g. the Pontides of N Turkey) emerged as a key study area. Attempts were renewed to resolve outstanding problems concerning the origin of Mesozoic ophiolites, particularly in the Greek and Turkish areas. Integrated field-based studies led to an improved understanding of the pattern of microplates that were rifted from Gondwana in the Early Mesozoic. The Eastern Mediterranean became established as one of the best areas in the world for study of processes of tectonic collision that include 'tectonic escape' and 'orogenic collapse'. In addition, much effort has recently gone into study of active and recently active tectonics, including seismicity and measurements of absolute plate motions. Finally, interest in the marine geology has a received a boost from the return of the R.V. *Joides Resolution* to the Mediterranean Sea.

Selected references

Some of the main literature sources published since 1984 are indicated below.

CHANNELL, J. E. T., WINTERER, E. L. & JANSA, L. F. 1991 Paleogeography and paleoceanography of Tethys. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **87**, 289–344 (papers dealing mainly with palaeoenvironmental aspects of Tethys).

DERCOURT, J. RICOU, L. E. & VRIELYNCK, B. (eds) 1993. *Atlas Tethys Palaeoenvironmental Maps*, Beicip-Franlab, 1992 (coloured palaeogeographical maps of Tethys as a whole and accompanying explanation).

—— ZONENSHAIN, L.P., RICOU, L. E., KAZMIN, V. G., LE PICHON, X., KNIPPER, A. L., GRANDJACQUET, C., SBORTSHHIKOV, I. M., GEYSSANT, J., LEPVRIER, C., PERCHERSKY, D. H., BOULIN, J., SIBUET, J.-C., SAVOSTIN, L. A. SOROKHTIN, O., WESTPHAL, M., BAZHRNOV, M. L. LAUER, J.-P. & BIJU-DUVAL, B. 1986. Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. *Tectonophysics*, **123**, 241-315 (synthesis of Tethyan geology and tectonics).

EMEIS, K., ROBERTSON, A. H. F. & RICHTER, C. 1996. *Initial Results of ODP Leg 160*, College Station, Texas (recent results from deep sea drilling in the Eastern Mediterranean Sea).

JACOBSHAGEN, V. 1986. *Geologie von Griechenland, Gebruder Börtraeger*, Berlin, Stuttgart (a comprehensive summary of information on Greek geology, in German).

MALPAS, J., MOORES, E. M., PANAYIOTOU, A. & XENOPHONTOS, C. (eds) 1987. *Ophiolites Oceanic Crustal Analogues*, Proceedings of Symposium 'Troodos 1987', Cyprus Geological Survey Department (includes a set of papers on Cyprus and other Mediterranean ophiolites).

MORRIS, A. & TARLING, D. H. (eds) 1996. *Palaeomagnetism and Tectonics of the Mediterranean Region* Geological Society, London, Special Publication, **105** (new palaeomagnetic data for the Mediterranean region).

OKAY, A. 1989 Alpine-Himalayam blueschsists. *Annual Reviews of Earth and Planetary Sciences*, **17**, 55-87 (survey of Tethyan blueschists).

PRICHARD, H. M., ALABASTER, T., HARRIS, N. B. W. & NEARY, C. R. (eds) 1993. *Magmatic Proceesses and Plate Tectonics*. Geological Society, London, Special Publication, **76** (includes review papers on Hellenic-Dinaric, and Troodos ophiolites).

ROBERTSON, A. H. F. 1994. Tectonic Facies Concept and its application to Tethys in the Eastern Mediterranean region. *Earth and Planetary Science Reviews*, in press (tectonic settings and modern counterparts).

—— DIXON, J. E., BROWN, S., COLLINS, A., MORRIS, A., PICKETT, E., SHARP, I. & USTAOMER, T. 1996 Alternative tectonic models for the Late Palaeozoic-Early Tertiary development of Tethys in the Eastern Mediterranean region. *In*: MORRIS, A. & TARLING, D. H. (eds). *Palaeomagentism and Tectonics of the Mediterranean Region*. Geological Society, London, Special Publication, **105**, 239–264 (discussion of the current alternative models pointing out the pros and cons of each).

—— GRASSO, M. 1995 Special issue-Later Tertiary-Quaternary Mediterranean tectonics and palaeo-environments. *Terra Nova*, **7**, 112-293 (set of papers dealing with later tectonic history, including overview paper).

TEKELI, O. & GÖNCÜOĞLÜ , M. C. (eds) 1984. Geology of the Taurus Belt, International Symposium, 26-29th September 1983 Ankara-Turkey. (regional geological data)

ŞENGÖR, A. M. C. 1987 Tectonics of the Tethysides: orogenic collage development in a collisional setting. *Annual Reviews of Earth and Planetary Sciences*, **15**, 213-244 (Eastern Mediterranean tectonics in a wider context).

—— 1990 Plate-tectonics and orogenic research after 25 years-a Tethyan perspective. *Earth Science Reviews*, **27**, 1–20 (Overview).

—— GÖRÜR, N. & ŞAROĞLU, F. 1985. *Strike-slip Faulting and Related Basin Formation in Zones of Tectonic Escape*. Society of Economic Mineralogists and Paleontologists, Special Publication, **37**, 227-264 (collisional and post-collisional history of mainly Anatolia).

STANLEY, D. J. & WEZEL, F.-C. 1985. *Geological Evolution of the Mediterranean Basin*. Springer, New York (papers on marine geology).

YILMAZ, Y. 1991. Allochtononous terranes in the Tethyan Middle East: Anatolia and surrounding regions. *In:* DEWEY, J. F., GASS, I. G., CURRY, G. B., HARRIS, N. B. W. & ŞENGÖR, A. M. C. (eds) Allochtonous terranes. Cambridge University Press, 155–167 (summary of data from allochtonous terranes is several areas of Turkey).

ZIEGLER, P. A. 1990. *Geological Atlas of Western and Central Europe*. Shell International Petroleum Company (relationship of Eastern Mediterranean to Western Mediterranean geology).

Contents