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The Caledonian–Appalachian Orogen

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Preface

This special publication of the Geological Society records papers read at the 5-day final symposium of IGCP Project 27 (the Caledonide Orogen) held at the University of Glasgow in September 1984 by courtesy of Principal Sir Alwyn Williams FRS and Professor Bernard Leake FRSE.

Special thanks are due to Dr D. S. Weedon, Glasgow, who ensured the high standard of the logistical and accommodation arrangements enjoyed by participants at the meeting.

Most previous symposia held under the auspices of IGCP 27 have focussed on the Caledonian–Appalachian geology of the various countries transected by the fragmented orogen and include that held in Dublin in 1978 and recorded in Geological Society Special Publication No. 8. The final symposium was intended to indicate the ‘state-of-the-art’ knowledge of the orogen in 1984, and this was attempted in the context of four time-periods. The periods were chosen to relate as closely as possible to significant (but commonly diachronous) stages in the complex history of the orogen. For each time-period, orogenic activity was treated in terms of process: cover–basement interaction, deformation, metamorphism, plutonism, volcanism, sedimentation, fauna and flora, which were integrated for each time-period by four synthesizing papers. Geophysical aspects of the orogen were treated separately, so that the importance of palaeomagnetism and of deep seismic experiments in understanding the orogen is explained. The papers published in this volume have in many cases been updated (July 1986) since the symposium.

The time-periods considered were convened and synthesized by Professor J. W. Skehan SJ, Boston Observatory, Dr W. S. McKerrow, Oxford, Professor R. D. Hatcher, S Carolina (now at University of Tennessee, Knoxville), and Professor John Rodgers, Yale. Dr R. T. Haworth, British Geological Survey, convened the section on geophysical aspects of the orogen.

The *pre-Arenig* described the pre-Iapetan and early Iapetan stages and includes the rifting of continental crust with related sedimentation, the products of early island arcs and the effects of their collision either with each other or with early oceanic margins to produce Grampian (early Caledonian), Finnmarkian, Penobscotian and Avalonian orogenesis. *Arenig–Wenlock* dealt largely with the main and waning stages of Iapetus as shown by the provinciality of fossils and the generation of island arcs by closure-related subduction. The period also saw the event,

important in N America, involving island-arc collision to produce Taconic deformation and metamorphism. The study of faunal provincialism was crucial in the recognition of the λ -shaped form of the orogen dating at least from this period and involving the still little known Tornquist Sea in addition to the Iapetan. The Wenlock–mid-Devonian was concerned with the major deformation and thermal activity (Acadian, Scandinavian and late Caledonian) related to the closing of Iapetus between Laurentia and Baltica and the attachment of Avalonia to N America and N Britain. Thrusting towards and onto the continental margins was of major importance in N America, Scotland and Greenland with the transport of previously deformed rocks and their cover sequences as major thrust nappes, an activity well documented in Scandinavia where the package of Finnmarkian nappes was reshuffled by Scandian thrusting. The *mid-Devonian–Permian* covered the waning of the orogeny after the final closing of Iapetus which is seen as a NE–SW diachronous wave. It is concerned with the history of rifted pull-apart basins whose fill was subsequently deformed by strike-slip movements and with the closure of the Theic Ocean lying between Laurentia and proto-Gondwana. The Upper Palaeozoic Variscan events in the southern part of the British Isles traditionally regarded by British workers as post-Caledonian are part of continuing Appalachian orogenesis (Alleghanian) in N America. The time periods used in the symposium are adhered to as far as possible in this volume. Inevitably, however, the time-based format could not always be used rigidly because activity in the orogen overlapped the somewhat arbitrarily determined time planes. Papers in which authors were obliged to ignore the time planes are clearly indicated.

The time-span of Project 27 has coincided with the blossoming of plate tectonic theory. As a result the project has seen the development of research into the Caledonian–Appalachian orogen from that of individuals who were concerned with small areas, largely in isolation, to the present when every worker can see his or her research in the context of a major orogen in which the full range of orogenic phenomena can be perceived as interrelated.

Mesozoic to present-day phenomena more obviously related to plate tectonic activity than those of the Caledonian–Appalachian chain have pointed to explanations of characteristics of the more ancient rocks. Fragments of crust of the major oceans hinted at by the pioneering work

on faunal provincialism are preserved as ophiolite complexes; sediments, related to rifting or shed into basins formed ahead of continental or obducted ophiolitic nappe complexes, were deformed and metamorphosed by the continuation of the tectonic processes by which they were initiated; waning faunal provincialism may be linked to coeval subduction-related magmatism and metamorphism during the closure of oceans or marginal basins.

Of exceptional importance in understanding Caledonian–Appalachian activity has been the escape from the simplistic view of orthogonal convergence of plates, based on increasing knowledge of more recent plate configuration. Models involving oblique collision and subduction, or the impingement of irregular continental margins against one another, have led to interpretations of Caledonian–Appalachian diachronism on orogen-wide and local scale. Recognition of strike-slip accretion in such orogenic zones as western N America has led to the application of terrane concepts to account for hitherto unexplained contrasts in contemporary geological history between areas in the Caledonide–Appalachian belt which are now adjacent.

IGCP Project 233 has been designed to study Palaeozoic terranes in the circum-Atlantic area and might thus be seen as a natural successor to Project 27 whose organizers wish the new venture every success.

The organizers of the Glasgow symposium wish to thank the national correspondents of participating countries for their help in organizing the meeting, particularly the Project Leader, Professor B. A. Sturt, Bergen, and the Project Secretary, Dr D. Bruton, Oslo Museum.

Everyone who participated in Project 27 benefited from the wisdom and friendship of Professor David Wones, Blacksburg, Virginia, and Professor Leo Hall, Amherst, Massachusetts, whose deaths are sadly recorded in this preface. The help of David Roberts (NGU) and Krishna Sinha (VPI Blacksburg) in bringing their articles to publication is greatly appreciated by the editors.

The International Working Group for Project 27 have recorded their appreciation of the

sustained high level of support enjoyed by the Project from the Royal Society and the Geological Society of London. The U.K. members wish to identify the help and encouragement received from Sir Kingsley Dunham FRS and the late Professor Janet Watson FRS through the U.K. National Committee for IGCP.

We thank Hilary Davies for her work in preparing the index.

The symposium was convened by Dr A. L. Harris, Liverpool, and Dr D. J. Fettes, British Geological Survey, Edinburgh, on behalf of the U.K. Working Group for Project 27. It was generously supported by the Royal Society, the Geological Society of London, UNESCO, B.P. Petroleum Development, B.P. Minerals International, Britoil, Esso Petroleum Company, Robertson Research International, Shell International Petroleum Company and Texaco.

Field symposium

The symposium in Glasgow was preceded by a field symposium which was supported by the NATO as Advanced Study Institute (984/83). The advice and cooperation of Dr Craig Sinclair of the NATO Scientific Affairs Division in organizing this symposium is gratefully acknowledged. The full proceedings of the field symposium have been published, and incorporate a detailed field guide to Caledonian and Precambrian rocks of Britain: *Synthesis of the Caledonian rocks of Britain* (eds D. J. Fettes and A. L. Harris) (Vol. C 175). Published by Reidel Publishing Company, Dordrecht, Holland.

Editors' notes

1 Individual authors were asked to make sure that their usage of Early/early and Late/late was consistent within individual papers. No attempt has been made to make the usage consistent throughout the book.

2 Because 'terrain' and 'terrane' are not distinguished by spelling in North America, it was decided to spell the word 'terrane' throughout the book, regardless of nuance.

A. L. HARRIS, University of Liverpool

D. J. FETTES, British Geological Survey, Edinburgh

Maps published under the auspices of Project 27

Scandinavia

Maps all available from the Geological Survey of Sweden, Box 670, S-751 28 Uppsala, Sweden and in *The Caledonide Orogen-Scandinavia and Related Areas* (eds Gee, D. G. & Sturt, B. A.) published by Wiley.

Scandinavian Caledonides: Tectonostratigraphic Map 1985 1:2M compiled by Gee, D. G., Kumpulainen, R., Roberts, D., Stephens, M. B., Thon, A. and Zachrisson, E.

Scandinavian Caledonides: Magnetic Anomaly Map 1985 1:2M compiled by Borg, K., Bergmark, T., Gee, D. G. and Kumpulainen, R.

Scandinavian Caledonides: Gravity Anomaly Map 1985 1:2M compiled by Henkel, H., Gee, D. G. and Kumpulainen, R.

Britain and Ireland

Maps all available separately from the Geological Society of London, Burlington House, Piccadilly, London W1V 0JU, UK and incorporated into Geological Society Memoir 9 (ed. Harris, A. L), coloured plates 1-3.

Plate 1: Caledonian Igneous Rocks of Britain and Ireland 1984 1:2M compiled by Brown, G. C., Francis, E. H., Keenan, P. S. and Stillman, C. J.

Plate 2: Time of Deformation in the Caledonide Orogen of Britain and Ireland 1984 1:1M compiled by Powell, D. and Phillips, W. E. A.

Plate 3: Grade and Time of Metamorphism in the Caledonide Orogen of Britain and Ireland 1984 1:2M compiled by Fettes, D. J., Long, C. B., Max, M. D. and Yardley, B. W. D.

Canada

All Canadian maps are available from the Department of Earth Sciences, Memorial University of Newfoundland, St Johns, Newfoundland A1B 3X5, Canada, attention Professor Harold Williams, apart from the map compiled by J. Hibbard which can be obtained from the Publications and Information Section, Mineral Development Division, Department of Mines and Energy, PO Box 4750, 95 Bonaventure Avenue, St Johns, Newfoundland A1C 5T7, Canada.

Tectonic lithofacies map of the Appalachian orogen (1978); Department of Geology, Memorial University of Newfoundland, Map 1,

1:1M; Map 1a, 1:2M. Compiled by Williams H.

Magnetic anomaly map of the Appalachian orogen (1980); Department of Geology, Memorial University of Newfoundland, Map 2 at scale 1:1M and Map 2a at scale 1:2M. Compiled by Zietz, I., Haworth, R. T., Williams, H. and Daniels, D. L.

Bouguer gravity anomaly map of the Appalachian orogen (1980); Department of Geology, Memorial University of Newfoundland, Map 3 at scale 1:1M and Map 3a at scale 1:2M. Compiled by Haworth, R. T., Daniels, D. L., Williams, H. and Zietz, I.

Geology of the Baie Verte Peninsula (1982); Newfoundland Department of Mines and Energy, Map 82-2, scale 1:100 000. Compiled by Hibbard, J.

Structural map of the Appalachian orogen in Canada (1982); Department of Geology, Memorial University of Newfoundland, Map 4, scale 1:2M. Coordinated by Keppie, J. D.

Magnetic anomaly map of Atlantic Canada (1984); Department of Earth Sciences, Memorial University of Newfoundland, Map 5, scale 1:2M. Compiled by Williams, H. and Haworth, R. T.

Bouguer gravity anomaly map of Atlantic Canada (1984); Department of Earth Sciences, Memorial University of Newfoundland, Map 6, scale 1:2M. Compiled by Williams, H. and Haworth, R. T.

USA

The following maps are in varying states of preparation, revision, review and publication.

Basement and basement/cover relations map of the Appalachian orogen in the United States, by Drake, A. A., Jr, Hall, L. M. and Nelson A. E.: US Geological Survey Miscellaneous Investigations Map, MI 1655, scale 1:1M. In press.

Time of deformation map of the Appalachian orogen in the United States, by Osberg, P. H. and others (under revision by Professor Osberg for publication by the US Geological Survey).

Metamorphism map of the Appalachian orogen in the United States and Canada, by Fisher, G. W. and Trzcieski, W. E., Jr. In preparation.

Plutonic rocks of the Appalachian orogen in the United States and Canada, by Wones, D. R. and Currie, K. L. In preparation (for publica-

Maps published under Project 27

- tion by the US Geological Survey after review and revision).
- Volcanic rocks of the Appalachian orogen in the United States*, by Rankin, D. W. and Blackburn, W. H. In preparation.
- Lithostratigraphy-faunal provinces* maps, all for publication by the US Geological Survey. Status in January 1988:
- Late Precambrian* (Proterozoic Z; Hadrynian), by Schwab, F. L. Under revision after review.
- Cambrian*, by Gundersen, L. C. and Palmer, A. R. Three maps. Under revision after review.
- Lower Ordovician (Tremadocian-Arenigian)*, by Dolfi, R. U. and many others. Under revision after review by Buyce, M. R.
- Middle Ordovician (Llanvirnian-Caradocian)*, by Thompson, A. M. Final compilation in progress.
- Late Ordovician (Ashgillan)*, by Thompson, A. M. Under revision after review.
- Early Silurian (Llandoveryan)*, by Thompson, A. M. Final compilation in progress.
- Mississippi-Pennsylvanian*, by Hines, R. A. and Thomas, W. A. Final compilation in progress.