

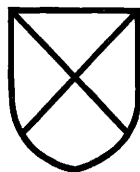
# MESOZOIC–CENOZOIC OROGENIC BELTS

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# MESOZOIC-CENOZOIC OROGENIC BELTS

*Data for  
Orogenic  
Studies*

Collated and Edited by A. M. SPENCER



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# PREFACE

The most dramatic new discoveries about the structure of the Earth in recent years have been those arising from the investigations of the ocean floors and the deep structure of the Earth (as it now is) by geophysical means. For a long time, however, a much larger bulk of information has been accumulating from the investigations of the continental masses; moreover, this information generally yields evidence of successively earlier stages in tectonic history. It is clearly essential in elaborating geotectonic hypotheses to take into account all the relevant evidence, and failure to do so may, in large measure, be attributed to the difficulty of searching through an enormous bulk of literature on continental tectonics and also to the subjective way in which much of it appears. It therefore seemed appropriate and timely to make available tectonic data aiming at a convenient and essentially objective presentation.

The intention has been to compile and analyse data related to the structure and history of selected orogenic belts throughout the world, by inviting contributions from those familiar with the various orogenic regions. At the same time, to achieve maximum objectivity and comparability of the contributions, it was decided to request the data by means of a carefully designed questionnaire.

The first part of the project, designed to highlight the methods and problems of orogenic analysis, resulted in publication in 1969 of a symposium volume—*Time and Place in Orogeny* (Special Publication No. 3, Geol. Soc. Lond.).

It became evident at an early stage that the total volume of information on the three main Phanerozoic orogenic periods would be far too large for compilation in a single operation. But since a major objective was to provide historic data relevant to modern concepts of continental movement derived from oceanic studies, it seemed not only desirable but logical to devote this volume to the Mesozoic/Tertiary orogenic episodes only and this was recommended to the Council of the Geological Society in October 1966. These are known world-wide in more detail than the older belts, and consequently permit a more complete presentation. Reference is made to the structure of the Hercynian and older 'Basement Rocks' where these are involved in the later orogenic belts, but their analysis is not attempted here.

The Questionnaire from which the present compendium was assembled is included as an Appendix to the volume. It took into

account the types of problem—of geometry and petrophysics—which would be of critical importance in the older orogenic systems, especially in those of the pre-Palaeozoic. To some extent this has proved unjustifiable since data of this kind are only available in exceptional cases in the late orogenic belts. Nevertheless it provides a potential link for future analyses of the older systems.

The Questionnaire was first circulated to about 40 contributors in July 1968. Rapid replies were expected but their arrival proved much slower than was then hoped for. These delays, plus the revision and re-writing of articles and drafting of diagrams (to enable uniform appearance) has led the project to take twice the original two years planned. A four-year gestation period during the present phase of extremely rapid development of the Earth Sciences inevitably leads to shortcomings in relating the tectonic data to the most up-to-date concepts. It is regretted that it was not possible to give authors the opportunity of major last-minute revisions as this would have incurred still further delay, but the volume is essentially to present *data* which should be independent of interpretation.

Each contribution has been reorganized in cursive form and largely re-written by Dr. A. M. Spencer. He and the members of the Committee are conscious of the imperfections which remain despite repeated checking and discussion of the final versions of the chapters with the various authors, but they hope that the flaws will be outweighed by the advantages of having so much data on the late orogenic belts collected in a single volume. The style adopted will, it is hoped, provide a model for the objective description of other orogens.

The treatment of the segments covered is less uniform than we would have wished. For a well exposed, long-studied fold belt the completion of the Questionnaire has been laborious and time consuming. In many other cases, however, data are deficient as a result of oceanic submergence, incomplete exposure or inadequate study. In consequence we have in some cases had to make a choice between accepting a compilation seriously incomplete through no fault of the author, or accepting an essay article. We have regarded these alternatives as better than entirely omitting treatment of particular belts, but we are particularly grateful to those authors who accepted the quite difficult task of putting the data in fully organized form.

It is a matter of regret to the Organizing Committee that the

American Cordillera within the United States is not included in this volume. Despite wide enquiry we were unable to locate an author or group of authors prepared to analyse and compile the very large amount of information available. Similarly we had hopes of a series of contributions from the USSR, but these have failed to materialize, and the post-Palaeozoic fold belts of eastern Soviet Asia are consequently unrepresented.

Among other matters, the compilation has emphasized the unsatisfactory nature of the current nomenclature of tectonic episodes. Some, such as Stille's 'Sub Hercynian' (surprisingly—a Cretaceous phase), were unfortunate from the outset; other local names (e.g. Nevadian, late-Cimmerian) become less and less significant as applied in different countries and continents, particularly when based on an assumed (and often erroneous) world-wide contemporaneity of tectonic events. There is a need for an agreed international scale for clearer communication with better scientific objectivity.

The Committee charged with the task of supervising this volume, and the Council of the Geological Society of London, wish to put on record their deep appreciation of the very many man-hours of work of the authors involved in answering the D.O.S. Questionnaires and dealing with subsequent compilatory scripts. As readers will find, the volume includes contributions of outstanding importance for the understanding of post-Palaeozoic movements. We have been able to draw on many international authorities for their wealth of knowledge and experience, and we are deeply grateful to them for their co-operation. We trust they will find the result justifies their labours.

The Natural Environment Research Council provided a research grant to Dr. Spencer for three of the four years he has spent on this compilation, and has covered also the fairly considerable costs of drafting the maps and sections. The compilation could nevertheless have foundered in the later stages as a result of the delays in obtaining the data without the help of The British Petroleum Company. BP not only provided a generous grant, but enabled Dr. Spencer to spend a

further year on this work after he had joined their staff, loaned Miss L. O. Scott to carry out the checking and proof handling after his departure, and made possible the use of expert draughtsmen and supporting services.

Personnel involved are listed as follows:

*Committee members*—Dr. J. F. Dewey, F. W. Dunning, W. B. Harland, Dr. P. E. Kent (Chairman), Dr. E. R. Oxburgh, Dr. N. Rast, Professor J. Sutton, Dr. D. H. Tarling, Professor J. G. Ramsay.

*Compilation and Editing*—Dr. A. M. Spencer

*Draughtsmen*—A. A. Miles, A. S. Meilak

*Sub-editing and Proof Handling*—Miss L. O. Scott and members of the BP Geological Division.

The author of this Preface, on behalf of the Committee, has been responsible for the major editorial decisions.

We are deeply grateful to The Royal Society, The Gulf Oil Company Ltd., The Burmah Oil Company Ltd. and The British Petroleum Company Ltd. for financial support at the publication stage, and to The Scottish Academic Press Ltd. which, under the direction of Mr. Douglas Grant, has not only undertaken production but has also assisted in financing publication.

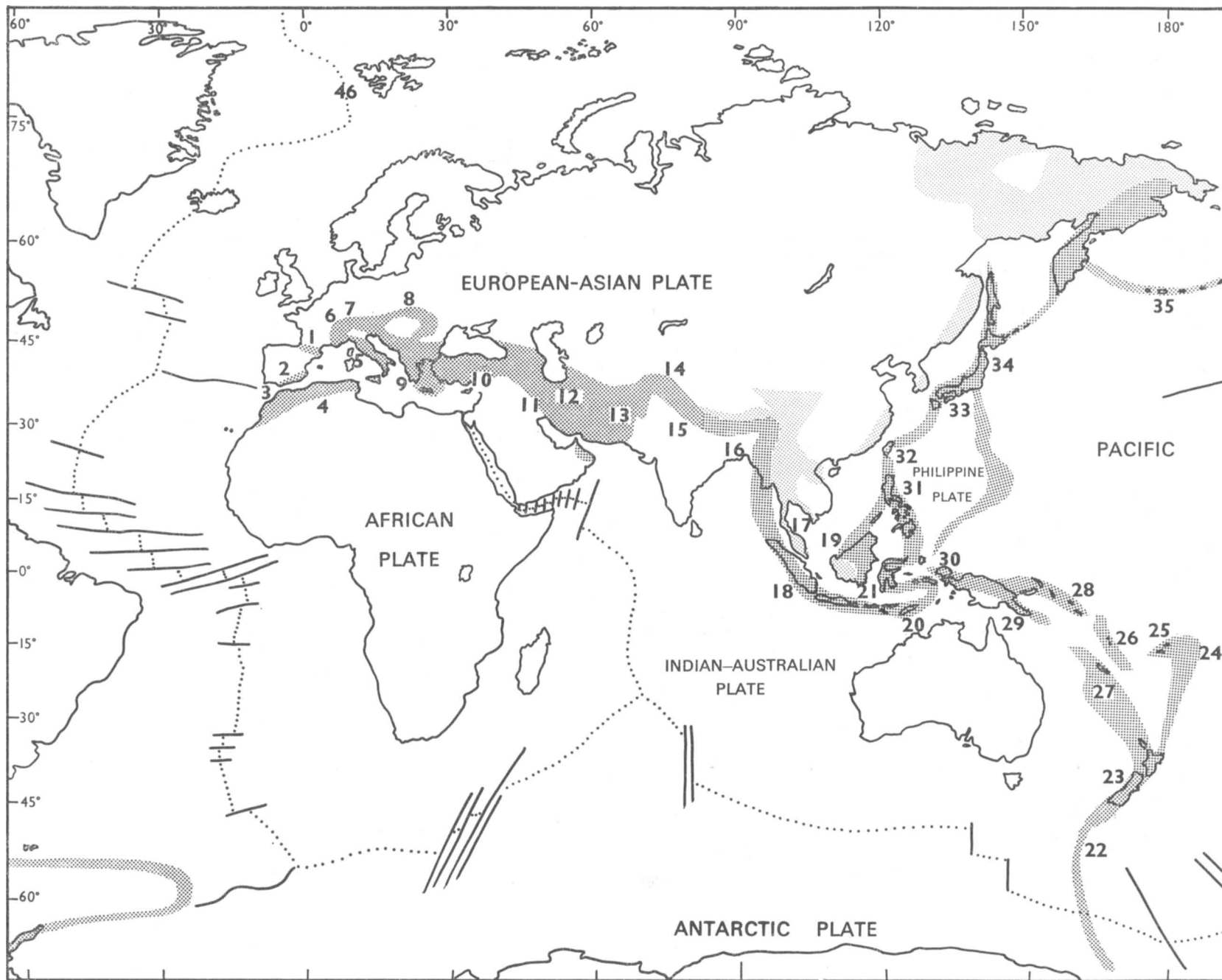
This Preface should not end without recording Dr. Spencer's efficient and wholehearted dedication to the project over four years. Virtually the whole operation has been in his hands since the contributions began to arrive; the Committee has been happy to leave to him not only the editing, re-writing and collating but all arrangements for drafting and correspondence with the contributors. It is appropriate that his name should appear alone on the title page.

P. E. KENT

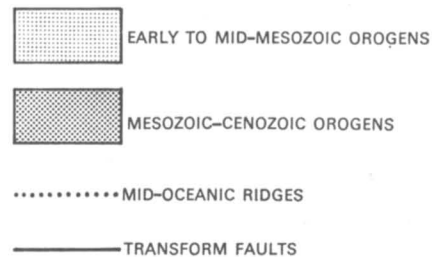
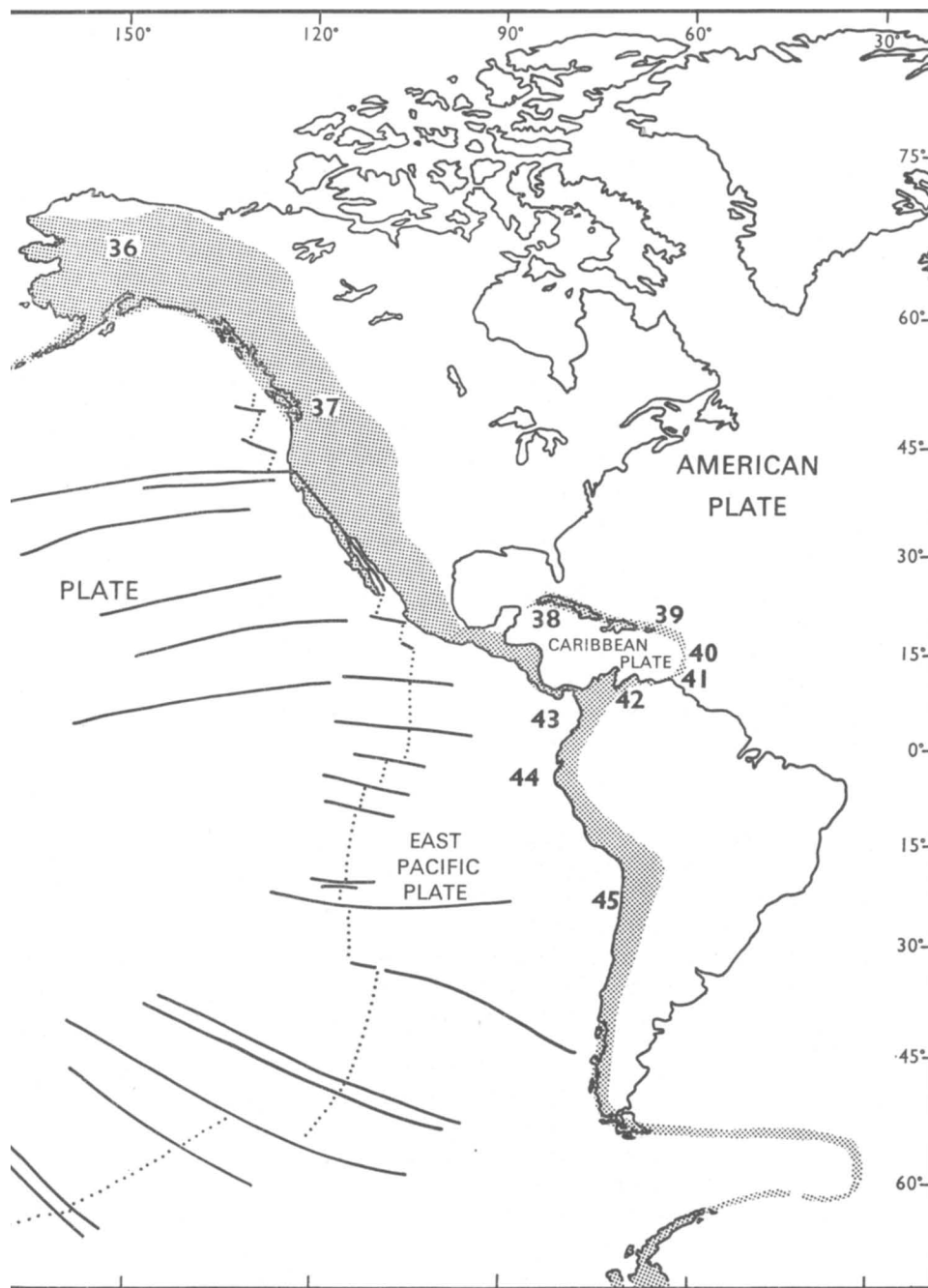
*Chairman, Data for Orogenic Studies Committee,  
Geological Society, London.*

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SHOWING OROGENIC SEGMENTS DESCRIBED







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# INTRODUCTION—THE USE OF THE VOLUME

A. M. SPENCER

The volume is not designed for fireside reading. The exigencies of presenting the data in compact form and of making it directly available for reference (the over-riding concern) have dictated an approximation to note-form in the text and the extensive use of tables. Nevertheless, most authors have included essays on the structural development of their chosen segments, and the outline summaries of the history of movement, stratigraphical features, volcanic episodes etc. provide interesting comparisons independently of formal analysis of the data.

## *Arrangement*

The arrangement of material within each article follows the standardized layout of the Questionnaire, which is reprinted for reference towards the end of this volume, and is given in outline in Table 1.

Uniform order and arrangement of data provide an immediate index and make clear the amount of data (and its nature) known for some areas, and the absence of large blocks of data for other areas. For those areas which are poorly known, limitation of the articles makes evident the extent and type of geological information which remains to be documented.

The Questionnaire itself was organized in three parts. In the first (General data on the orogenic belt) geographical and geophysical data are listed, overall geological data are summarized and selected topics of special interest are commented on. The second (Subdivision of the segment) provides the outline of the scheme of subdivision of the orogen into its constituent zones, and of the rocks of the orogen into the individual elements. In the third (Data on individual structural zones) the basic geological data are listed in a standard order.

## *Segments*

The Questionnaires were designed to be answered for a 'segment' stretching across each orogen from one margin to the other. Some general information relates to the region in which the segment lies

(*e.g.*) geophysical data commonly refers to the whole country). The greater part of the factual data, however, applies to the specific segment under description.

## *Questionnaire numbers*

All data in this volume are qualified by the original question asked. For this reason, Questionnaire numbers have been retained in the texts and appear as superscript numbers (for example—<sup>326-32</sup>). Their presence can be used to identify rapidly comparable data between or within articles, for example data on igneous activity are always listed under <sup>326-32</sup>.

## *Zones and elements*

These technical terms provide the basic framework by which most of the information is organized. Both terms are defined in the 'Notes for Contributors' which accompanies the Questionnaire but a brief explanation is warranted here.

Zones are used to subdivide the orogen into geographical belts or regions capable of description via the third part of the Questionnaire. Thus within each article the geological data requested are listed separately by zones.

In an ideal situation the numbering of the zones could have been formalized from, say, cratonic foreland to eugeosynclinal trough, but the variation of arrangement, and such problems as those of inter-cratonic orogenic belts, led us to adopt a basic geographic order of description. The zones have therefore been uniformly numbered from north to south (Alpine-Himalayan orogens) or from west to east (circum-Pacific orogens).

The Questionnaire made use of the concept of 'structural elements' in order to subdivide the rocks being described so as to assure that attention was focussed on the original geological observations and to facilitate reference to the rocks. Structural elements were defined as

Table 1  
ORGANIZATION OF THE DATA IN THE ARTICLES

<i>Subject headings</i>	<i>Questionnaire numbers</i>
<b>A. General Data on the Segment</b>	
1. The segment studied	
2. Shape of the orogen in plan	16-26
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'units within which deformation has been continuous and/or homogeneous on the scale of this study'. In practice, the majority of contributors have subdivided the rocks under description into stratigraphical units, and some have even employed 'elements' for distinctive geographical regions (*e.g.* in some zones in the Alaskan article). For this reason, the 'structural' part of the term has been dropped and the units are referred to simply as elements.

The elements are lettered in the text—a, b, c, d, e, etc. In order to avoid confusion with these, lower case letters are not employed for subheadings within the articles.

#### *Fold Styles*

Question 356 requested contributors to supply qualitative information on the shapes of folds according to a method and classification scheme outlined in the explanatory introduction to the Questionnaire. In the text of the articles data on fold styles are listed using the number/letter code of the classification scheme: in order to appreciate the styles referred to it will be necessary for readers to look at the diagram of fold classification given in the reprinted Questionnaire (p. 787).

#### *Abbreviations*

Throughout the articles the following abbreviations are commonly used:

<i>c.</i>	circa	
<i>m.y.</i>	million years	
<i>m</i>	metres	
<i>km</i>	kilometres	
<i>km<sup>3</sup></i>	cubic kilometres	
<i>&gt;</i>	greater than	
<i>&lt;</i>	less than	
<i>av.</i>	average	
<i>U.</i>	Upper	} as applied to stratigraphical units
<i>M.</i>	Middle	
<i>L.</i>	Lower	

#### *Stratigraphical Scale*

The contributors were all asked to give stratigraphical data in terms of the stratigraphical units in the scale given in Table 2. In the tables throughout the volume, and occasionally in the text of an article, the stratigraphical units are abbreviated in the standard form shown in this Table.

Table 2. Stages etc., as defined in *The Fossil Record* (Harland, W. B. *et al.* (Eds.) 1967, Geol. Soc. Lond., pp. 5-9) and the abbreviations used for them throughout this volume. The age in *m.y.* (million years) of the equivalent base of the unit is taken from *The Phanerozoic Time-scale* (Harland, W. B. *et al.* (Eds.) 1964, Geol. Soc. Lond., pp. 260-2) after Harland (1969, p. 120).

Table 2

<i>Age of base of selected unit (m.y.)</i>	<i>Selected unit (stage, series or other division) with abbreviated form</i>	<i>Some other divisions included in (but not necessarily equivalent to) the selected units</i>
<b>QUATERNARY</b>		
—	HOLOCENE	Holo
1.5–2	PLEISTOCENE	Pleist (Calabrian)
<b>TERTIARY</b>		
c. 7	PLIOCENE	Plioc (Astian, Piacenzian (Plaisancian))
c. 12	UPPER MIOCENE	U. Mioc (Messinian, Sahelian, Sarmatian, Pontian)
c. 18–19	MIDDLE MIOCENE	M. Mioc (Vindobonian, Tortonian, Helvetian <i>pars</i> )
26	LOWER MIOCENE	L. Mioc (Aquitanian, Burdigalian, Helvetian <i>pars</i> )
—	UPPER OLIGOCENE	U. Olig (Chattian)
37/38	LOWER and MIDDLE OLIGOCENE	L/M. Olig (Lattorfian and Rupelian)
c. 45	UPPER EOCENE	U. Eoc (Bartonian, Ledian, Priabonian)
c. 49	MIDDLE EOCENE	M. Eoc (Lutetian)
53–54	LOWER EOCENE	L. Eoc (Cuisian, Ypresian, Ilerdian <i>pars</i> )
—	PALAEOCENE	Palaeoc (Seelandian, Montian, Landenian, Thanetian, Ilerdian <i>pars</i> )
65	DANIAN	Dan (Danian 1–4 type area)
<b>CRETACEOUS</b>		
70	MAESTRICHTIAN	Maestr
76	CAMPANIAN	Campan
82	SANTONIAN	Santon
88	CONIACIAN	Coniac
94	TURONIAN	Turon
100	CENOMANIAN	Cenom
106	ALBIAN	Alb
112	APTIAN	Apt
118	BARREMIAN	Barrem
124	HAUTERIVIAN	Haut
130	VALANGINIAN	Valang
136	BERRIASIAN	Berr
		(Ryazanian, Purbeck <i>pars</i> )
<b>JURASSIC</b>		
—	'TITHONIAN'	'Tith' (Volgian, Purbeck <i>pars</i> , Portlandian, Kimmeridgian <i>pars</i> )
151	KIMMERIDGIAN	Kimm
157	OXFORDIAN	Oxf
162	CALLOVIAN	Call
167	BATHONIAN	Bath
172	BAJOCIAN	Bajoc (Aalenian)
178	TOARCIAN	Toarc
183	PLIENSACHIAN	Pliens
188	SINEMURIAN	Sinem
190–195	HETTANGIAN	Hett

<i>Age of base of selected unit (m.y.)</i>	<i>Selected unit (stage, series or other division) with abbreviated form</i>	<i>Some other divisions included in (but not necessarily equivalent to) the selected units</i>
<b>TRIASSIC</b>		
—	RHAETIAN	Rhaet
—	NORIAN	Nor
[205]	CARNIAN	Carn
—	LADINIAN	Ladin
[215]	ANISIAN	Anis
—	OLENEKIAN	Olenek
225	INDUAN	Induan
		} Scythian
<b>PERMIAN</b>		
—	DZHULFIAN	Dzhulf (Tartarian, ?Zechstein, Ochoan)
240	GUADALUPIAN	Guad (Ufnian, Kazanian, Zechstein, Word, Capitan)
[265–268]	LEONARDIAN	Leonard (Artinskian–Kungurian)
—	SAKMURIAN	Sakm (Upper Wolfcampian)
280	ASSELIAN	Assel (Lower Wolfcampian)
<b>CARBONIFEROUS</b>		
290–295	UPPER CARBONIFEROUS	U. Carb (Kasimovian, Gzelian, Orenburgian, Stephanian, Missourian, Virgilian)
[306]	MOSCOVIAN	Moscov (Westphalian C,D?, Atokan, Des Moines)
[317]	BASHKIRIAN	Bashk (Namurian C, Westphalian A,B)
325	NAMURIAN	Namur (Namurian A,B)
335–340	VISEAN	Viséan
345	TOURNAISIAN	Tourn
<b>DEVONIAN</b>		
353	FAMENNIAN	Famenn
359	FRASNIAN	Frasn
—	GIVETIAN	Givet
370	EIFELIAN	Eifel
374	EMSIAN	Ems
390	SIEGENIAN	Siegen
395	GEDINNIAN	Gedinn
<b>SILURIAN</b>		
—	LUDLOVIAN	Ludl
—	WENLOCKIAN	Wenl
430–440	LLANDOVERIAN	Lldov
<b>ORDOVICIAN</b>		
—	ASHGILLIAN	Ashg (Richmond)
445	CARADOCIAN	Carad (Porterfield, Trenton, Eden, Maysville)
—	LLANDEILIAN	Lldeil
—	LLANVIRNIAN	Llvirn (Lower Champlainian)
c. 500	ARENIGIAN	Arenig (Upper Canadian)
—	TREMADOCIAN	Tremad
<b>CAMBRIAN</b>		
515	UPPER CAMBRIAN	U. Camb
540	MIDDLE CAMBRIAN	M. Camb
570	LOWER CAMBRIAN	L. Camb
<b>PRE-CAMBRIAN</b>		