

## Contents

<i>List of tables</i>	viii
<i>List of figures</i>	viii
<i>Preface</i>	xi
<i>Postscript added to proofs in October 1989</i>	xiii
<i>Abbreviations and acronyms used in this work</i>	xiv
<b>1 Introduction</b>	1
1.1 Objective	1
1.2 The traditional chronostratigraphic scale (TCSS)	1
1.3 Standardization of the global chronostratigraphic scale (GCSS)	2
1.4 The global chronometric or geochronometric scale (GCMS)	3
1.5 Statement of age	4
1.6 Natural chronologies (NCS) and event sequences	4
1.7 Local rock units	5
1.8 Geochronologic scales (GCS)	5
1.9 Procedures adopted in the construction of this time scale (GTS 89)	9
<b>2 The chronometric (numerical) scale</b>	13
2.1 Essentials of the chronometric scale	13
2.1.1 Mean solar second	13
2.1.2 Ephemeris second	13
2.1.3 Atomic second	13
2.1.4 Conventions	13
2.2 Chronometry for Earth history	13
2.3 Nomenclature for a geochronometric scale	14
2.3.1 Geological Survey of Canada publications	14
2.3.2 United States Geological Survey publications	14
2.3.3 International proposals	14
2.4 Chronometric divisions of Precambrian time	16
2.4.1 Priscoan time	16
2.4.2 The Archean Eon	16
2.4.3 The Proterozoic Eon	16
2.5 Geochronology – the term	18
<b>3 The chronostratigraphic scale</b>	19
3.1 Introduction	19
3.1.1 Chart conventions in Chapter 3	19
3.2 Requirements of a chronostratigraphic scale	20
3.2.1 Classification	20
3.2.2 Nomenclature	20
3.2.3 Definition and standardization	21
3.3 Time and rock terminology	21
3.3.1 Age and stage	21
3.3.2 Chron and chronozone	21

3.4 The Precambrian chronostratigraphic scale – introduction	21	3.15.5 The Late Triassic Epoch
3.4.1 Displays of Precambrian stratigraphy in this volume	22	3.15.6 The Triassic chart
3.5 Precambrian chronostratigraphic eras	22	3.16 The Jurassic Period
3.5.1 Hadean Era	22	3.16.1 History and classification
3.5.2 Isuan Era	24	3.16.2 The Lias (Early Jurassic) Epoch
3.5.3 Swazian Era	24	3.16.3 The Dogger (Middle Jurassic) Epoch
3.5.4 Radian Era	25	3.16.4 The Malm (Late Jurassic) Epoch
3.5.5 Huronian Era	25	3.16.5 The Jurassic charts
3.5.6 Animikian Era	26	3.17 The Cretaceous Period
3.5.7 Riphean Era	27	3.17.1 History and classification
3.5.8 Sinian Era	27	3.17.2 Early Cretaceous Epoch
3.6 The Sturtian Period	28	3.17.3 The Gulf (Late Cretaceous) Epoch
3.7 The Vendian Period	28	3.17.4 The Cretaceous charts
3.7.1 Introduction	28	3.18 The Tertiary Sub-era
3.7.2 The Varanger Epoch	28	3.19 The Paleogene Period
3.7.3 The Ediacara Epoch	30	3.19.1 Introduction
3.7.4 The Vendian chart	30	3.19.2 The initial Paleogene boundary
3.8 The Phanerozoic Eon	30	3.19.3 The Paleocene Epoch
3.8.1 The name Phanerozoic	30	3.19.4 The Eocene Epoch
3.8.2 The Paleozoic Era	30	3.19.5 The Oligocene Epoch
3.8.3 The Mesozoic Era	31	3.19.6 The Paleogene charts
3.8.4 The Cenozoic Era	31	3.20 The Neogene Period
3.9 The Cambrian Period	31	3.20.1 Introduction
3.9.1 History and classification	31	3.20.2 The Miocene Epoch
3.9.2 The initial Cambrian boundary	32	3.20.3 The Pliocene Epoch
3.9.3 The Caerfai Epoch	34	3.20.4 The Neogene charts
3.9.4 The Saint David's Epoch	34	3.21 The Quaternary Sub-era (Pleistocene Period)
3.9.5 The Merioneth Epoch	34	3.21.1 The Pliocene–Pleistocene boundary
3.9.6 The Cambrian chart	34	3.21.2 Division of the Pleistocene Epoch
3.10 The Ordovician Period	34	3.21.3 Pleistocene terrestrial sequences
3.10.1 History and classification	34	3.21.4 Pleistocene marine sequences
3.10.2 Canadian (Early Ordovician) Sub-period	36	3.21.5 The Pleistocene–Holocene boundary
3.10.3 Dyfed (Mid Ordovician) Sub-period	36	3.21.6 The Holocene Epoch
3.10.4 Bala (Late Ordovician) Sub-period	37	3.21.7 The Quaternary chart
3.10.5 Conclusion	37	
3.10.6 The Ordovician chart	37	<b>4 Isotopic methods, dates, precision and database</b>
3.11 The Silurian Period	37	4.1 Introduction
3.11.1 History and classification	37	4.2 Closure temperatures
3.11.2 The Llandovery Epoch	37	4.3 Interpretation of K–Ar dates
3.11.3 The Wenlock Epoch	39	4.4 Analytical precision of K–Ar dates
3.11.4 The Ludlow Epoch	39	4.5 Interpretation of Rb–Sr dates
3.11.5 The Pridoli Epoch	40	4.6 Analytical precision of Rb–Sr dates
3.11.6 The Silurian chart	40	4.7 Interpretation of U–Pb dates
3.12 The Devonian Period	40	4.8 Analytical precision of U–Pb dates
3.12.1 History and classification	40	4.9 Interpretation of fission-track dates
3.12.2 The Early Devonian Epoch	40	4.10 Precision of fission-track dates
3.12.3 The Mid Devonian Epoch	42	4.11 Interpretation of Sm–Nd dates
3.12.4 The Late Devonian Epoch	42	4.12 Analytical precision of Sm–Nd dates
3.12.5 The Devonian chart	42	4.13 The isotopic database
3.13 The Carboniferous Period	42	4.14 Chronometric errors
3.13.1 History and classification	42	4.15 Concluding remarks
3.13.2 The Mississippian Sub-period	43	
3.13.3 The Pennsylvanian Sub-period	45	<b>5 Chronometric calibration of stage boundaries</b>
3.13.4 The Carboniferous chart	46	5.1 Introduction
3.14 The Permian Period	46	5.2 Estimating the boundary age of adjacent stratigraphic units
3.14.1 History and classification	46	5.2.1 Essentials of the method
3.14.2 The Rotliegendes (Early Permian) Epoch	47	5.2.2 Minimum dates
3.14.3 The Zechstein (Late Permian) Epoch	47	5.2.3 ‘Bracketed’ dates
3.14.4 The Permian chart	49	5.3 Chronostratigraphic errors
3.15 The Triassic Period	49	5.4 Chronograms
3.15.1 Introduction	49	5.5 Glauconite and non-glauconite dates
3.15.2 The Paleozoic–Mesozoic boundary	50	5.6 Chronogram data
3.15.3 The Scythian (Early Triassic) Epoch	50	5.7 Interpolation methods
3.15.4 The Mid Triassic Epoch	50	5.7.1 Relative stratigraphic thicknesses

5.7.2 Relative biostratigraphic discrimination	116	<b>Appendix 1. Origins of some stage names.</b> Reprinted with permission from <i>General Stratigraphy</i> by J. W. Gregory & B. H. Barrett	180
5.7.3 Relative ocean-spreading rates	116		
5.7.4 'Tie-points'	116		
5.8 Interpolation between tie-points using Phanerozoic chronos	117	<b>Appendix 2. Recommended three-character abbreviations for</b>	
5.8.1 Cenozoic	117	chronostratigraphic names with alternative symbols.	186
5.8.2 Cretaceous	120	<b>Appendix 3. Calculation of isotopic dates</b> using conventional decay	
5.8.3 Jurassic	122	constants (with conversion table for older K-Ar dates).	
5.8.4 Triassic	124	190	
5.8.5 Permian	126	<b>Appendix 4. Chronograms</b> (as explained and used in Chapter 5).	
5.8.6 Carboniferous	128	Figures A4.1 to A4.125.	197
5.8.7 Devonian	131	<b>Appendix 5. Linear plot of magnetic polarity reversal time scale 0 to</b>	
5.8.8 Silurian	132	<b>160 Ma</b> in 16 figures each spanning 10 Ma. Figures A5.1	
5.8.9 Ordovician	134	to A5.16.	212
5.8.10 Cambrian	136	<b>Appendix 6. A geologic time scale wall chart 1989.</b>	221
5.9 Initial Cambrian and Vendian chronometry	136		
5.10 Concluding remarks	138	<b>References and selected bibliography</b>	223
<b>6 The magnetostratigraphic time scale</b>	140		
6.1 Geomagnetic polarity reversals	140	<b>General index</b>	247
6.1.1 Global synchronicity	140		
6.1.2 Excursions	140	<b>Stratigraphic index</b>	249
6.1.3 Polarity intervals, chronos and subchronos	141		
6.2 Isotopically dated time scale 0 to 3.4 Ma	142		
6.3 Marine magnetic anomalies: background to earlier work	142		
6.3.1 Introduction	142		
6.3.2 Resolving power	142		
6.3.3 Names and numbers of polarity chronos	142		
6.3.4 Calibration by direct isotopic dating	144		
6.3.5 Calibration by indirect biostratigraphic correlation	144		
6.3.6 Calibration problems	145		
6.4 This work: the GTS 89 time scale 0 to 83 Ma	147		
6.4.1 Relative spacings of anomalies	147		
6.4.2 Direct isotopic dating of the magnetic anomalies	150		
6.4.3 Indirect dating via biostratigraphic correlation	154		
6.4.4 Calibration of the modified Heirtzler <i>et al.</i> (1968) relative			
6.4.5 Comparison with other recent time scales	156		
6.5 This work: the GTS 89 time scale 83 to 200 Ma	158		
6.5.1 Relative spacing of anomalies 83 to 158 Ma	158		
6.5.2 Direct isotopic dating of the magnetic anomalies	159		
6.5.3 Indirect dating via biostratigraphic correlation	159		
6.5.4 Calibration of the Kent & Gradstein (1985) ages with			
chronogram ages	160		
6.5.5 Comparison with other recent time scales	162		
6.5.6 The polarity reversal scale 158 to 200 Ma	163		
6.6 Summary of polarity reversal time scale 0 to 200 Ma	163		
6.7 Polarity bias superchrons	163		
6.7.1 The phenomenon of polarity bias	163		
6.7.2 Nomenclature	165		
6.7.3 Ages of polarity superchrons	165		
<b>7 Geologic events and the time scale</b>	169		
7.1 Introduction	164		
7.2 Natural time scales	169		
7.3 Geologic event charts	169		
7.4 The geochronologic time scale GTS 89	169		
7.5 A new wall chart	170		