

Sedimentary Environments and Facies

The book describes the present day sedimentary environments and discusses the recognition of ancient analogues. It emphasises processes and their products, the use of facies, facies associations and sequences in interpretation of ancient rocks and how environmental recognition illuminates understanding of past climates, oceanography, biological evolution and tectonics.

Contents: Facies; Alluvial and fluvial environments; Lakes; Deserts; Deltas; Clastic coastlines; Arid coastlines and evaporites; Shallow silica-clastic seas; Shallow water carbonate environments; Pelagic environments; Deep clastic seas; Glacial environments; Sedimentation and tectonics; Problems and perspectives.

Also of interest:

Carbonate Sediments and Their Diagenesis

Second Enlarged Edition

by Robin G. C. Bathurst

The first edition of this volume, published in 1971, responded to a need for a critical review of the various advances in carbonate sedimentology and their significance. Rapid expansion of the field since then necessitated the publication of a new volume which encompassed more recent information. In 1975 the author up-dated the original edition by the addition of a 38-page appendix. The resulting second enlarged edition also treated four fields – deep-sea sediments and their diagenesis, carbonate sediments in lakes, calcrete, and hydrogeology and karst – not dealt with in the first edition.

The main body of *Carbonate Sediments and Their Diagenesis* treats three fields – the deposition of carbonate sediments, their diagenesis, and the detailed microstructure of the sedimentary particles. Since limestones are rocks composed of the remains

of shell sands, coral reefs and other tropical sea floor sediments made of calcium and magnesium carbonates, modern deposits of these in the Bahamas, the Persian Gulf and elsewhere are treated at length. Knowledge about the genesis of limestones and related rocks is critically analyzed, and new details of the microscopic structure of sedimentary grains are given, based on work with the electron microscope. A major portion of the book is devoted to a consideration of the physical and chemical properties by which the unconsolidated sediments are changed to solid rock.

CONTENTS: Chapters: 1. Petrography of Carbonate Grains 1: Skeletal Structures. 2. Petrography of Carbonate Grains 2: Ooids, Pisolites, Peloids and Other Micritic Fabrics. 3. Recent Carbonate Environments 1: General Introduction and the Great Bahama Bank. 4. Recent Carbonate Environments 2: Florida, Gulf of Batabano, Persian Gulf, British Honduras. 5. Recent Carbonate Algal Stromatolites. 6. Some Chemical Considerations. 7. Growth of Ooids Pisolites and Grapestone. 8. Diagenesis in the Subaerial, Fresh Water Environment. 9. Diagenesis on the Sea Floor. 10. Cementation. 11. Pressure-solution. 12. Neomorphic Processes in Diagenesis. 13. Recent Dolomites.

APPENDIX. Recent Developments in Carbonate Sedimentology.

Petrography of carbonate grains. Recent carbonate environments. Recent carbonate algal stromatolites. Chemical considerations. Growth of Ooids. Fresh water diagenesis, cementation and neomorphic processes. Diagenesis on the sea floor. Pressure-solution. Recent dolomites. Diagenesis under the deep sea floor. Lake sediments. Calcrete. Hydrogeology and karst.

Glossary of Sedimentological Terms not Defined in the Text. References. References in the Appendix. Index.

1975, xx plus 658 pages, \$17.50

ISBN 0 444 00293 6

PRINTED IN GREAT BRITAIN

Contents

Authors, ix

Preface, xi

1 Introduction, 1

H.G. READING

- 1.1 Development of sedimentology, 1
- 1.2 Scope and philosophy of this book, 2
- 1.3 Organization of the book, 3
- 1.4 Appeal of the book, 3

2 Facies, 4

H.G. READING

- 2.1 Facies construction, 4
 - 2.1.1 Facies definition, 4
 - 2.1.2 Facies relationships, 4
- 2.2 Interpretation of facies, 9
 - 2.2.1 Hypotheses, models and theories, 9
 - 2.2.2 Normal v catastrophic sedimentation; abundant and rare sediments; exceptional events, 10
 - 2.2.3 Preservation potential, 12
- 2.3 Factors controlling the nature and distribution of facies, 12
 - 2.3.1 Sedimentary processes, 12
 - 2.3.2 Sediment supply, 13
 - 2.3.3 Climate, 13
 - 2.3.4 Tectonics, 13
 - 2.3.5 Sea-level changes, 14
 - 2.3.6 Biological activity, 14
 - 2.3.7 Water chemistry, 14
 - 2.3.8 Volcanism, 14

3 Alluvial Sediments, 15

J.D. COLLINSON

3.1 Introduction, 15

3.2 Present-day alluvial fans, 15

- 3.2.1 Setting, 15
- 3.2.2 Gross morphology, 16
- 3.2.3 Channel patterns, 17
- 3.2.4 Depositional processes and products, 17
- 3.2.5 Post-depositional processes, 18
- 3.2.6 Distribution of fan processes and products, 19
- 3.2.7 The semi-arid fan model, 20
- 3.2.8 Humid fans, 20

3.3 Present-day pebbly braided rivers and humid fans, 20

- 3.3.1 Bedforms and processes, 20
- 3.3.2 Directional properties, 24
- 3.3.3 Sedimentation model for pebbly braided streams, 24

3.4 Present-day sandy low-sinuosity rivers, 25

- 3.4.1 Bed features of low-sinuosity rivers, 26
- 3.4.2 Effects of water stage fluctuations, 28
- 3.4.3 Overall organization and current vectors, 29
- 3.4.4 Semi-arid ephemeral streams, 29

3.5 Present-day meandering streams, 31

- 3.5.1 Meander belts, 31
- 3.5.2 Channel processes, 32
- 3.5.3 Channel cut-offs, 35

3.6 Inter-channel areas, 38

- 3.6.1 Overbank environments, 38
- 3.6.2 Areas beyond river influence, 39

3.7 Ancient alluvial sediments, 42

3.8 Ancient pebbly alluvium, 42

- 3.8.1 Facies and their distribution, 42

3.9 Ancient sandy fluvial systems, 48

- 3.9.1 Introduction, 48
- 3.9.2 Fine member (inter-channel) deposits, 48
- 3.9.3 Coarse member (channel) deposits, 50
- 3.9.4 Coarse member organization, 51

3.10 Changing alluvial systems and their controls, 58

- 3.10.1 Controlling variables and their effects, 58
- 3.10.2 Examples of changes in channel pattern from geomorphology, 59
- 3.10.3 Changes of channel type in vertical sequences, 59

4 Lakes, 61

J.D. COLLINSON

4.1 Introduction, 61**4.2 Present-day lakes, 61**

- 4.2.1 Lake water, 61
- 4.2.2 Sediment supply, 64
- 4.2.3 Clastic sediment deposition, 64
- 4.2.4 Chemicals and biological sediment deposition, 65

4.3 Ancient lake sediments, 67

- 4.3.1 General criteria of recognition, 67
- 4.3.2 Green River Formation (Eocene) of the Western USA, 68
- 4.3.3 Triassic basins of Eastern North America, 71
- 4.3.4 Upper Palaeozoic basins of the Maritime Provinces of Canada, 74
- 4.3.5 The Devonian Orcadian basin of north-east Scotland, 75
- 4.3.6 Minor lake basins, 78
- 4.3.7 Conclusions, 79

5 Deserts, 80

J.D. COLLINSON

5.1 Introduction, 80**5.2 Present-day deserts, 80**

- 5.2.1 Introduction and setting, 80
- 5.2.2 Desert climates, 80
- 5.2.3 Tectonic setting of deserts, 81
- 5.2.4 Sand-dominated deserts, 82
- 5.2.5 Loess, 89
- 5.2.6 Playas and inland sabkhas, 89
- 5.2.7 Overall desert models, 91

5.3 Ancient desert sediments, 91

- 5.3.1 Introduction, 91
- 5.3.2 Ancient aeolian sandstones, 92
- 5.3.3 Ancient loess, 94
- 5.3.4 Ancient playa and inland sabkha deposits, 95
- 5.3.5 Ancient desert alluvium, 95
- 5.3.6 Overall desert facies patterns, 95

6 Deltas, 97

T. ELLIOTT

6.1 Introduction, 97**6.2 Development of delta studies, 97****6.3 A conceptual framework for deltas, 98**

- 6.3.1 Hinterland and receiving basin characteristics, 99

6.4 Delta models, 100**6.5 Facies associations in modern deltas, 101**

- 6.5.1 The delta plain, 101
- 6.5.2 The delta front, 111

6.6 Delta abandonment, 121**6.7 Ancient deltaic successions, 125**

- 6.7.1 Delta plain facies association, 125
- 6.7.2 Delta front facies association, 127
- 6.7.3 Delta abandonment facies association, 129
- 6.7.4 Recognition of delta type in the geological record, 129

6.8 Sediment-induced deformation, 138

- 6.8.1 Deformational processes, 138
- 6.8.2 Deformational features, 139
- 6.8.3 Sediment-induced deformational features in exposed deltaic successions, 142

7 Clastic Shorelines, 143

T. ELLIOTT

7.1 Introduction, 143**7.2 Modern beaches and barrier islands, 143**

- 7.2.1 Wave processes and sediment transport, 144
- 7.2.2 The beach face, 146
- 7.2.3 Facies profiles of the beach face, 149
- 7.2.4 Tidal inlets, 152
- 7.2.5 Lagoons, 158
- 7.2.6 Beach and barrier island migration, 161
- 7.2.7 The genesis of barrier islands, 164

7.3 Ancient beach and barrier island facies, 165

- 7.3.1 Facies associations in progradational systems, 165
- 7.3.2 Facies associations in transgressive systems, 168

7.4 Cheniers, 169**7.5 Modern estuaries, 170**

- 7.5.1 Estuarine facies, 171

7.6 Modern tidal flats, 174**7.7 Ancient estuarine and tidal flat facies associations, 175****8 Arid Shorelines and Evaporites, 178**

R. TILL

8.1 Introduction, 178

- 8.1.1 History of research, 178

8.2 The Trucial Coast, Arabian Gulf, 178

- 8.2.1 General setting of the Abu Dhabi region, 178
- 8.2.2 The coral/algal facies, 178
- 8.2.3 Tidal channels and deltas – oolitic sands, 179
- 8.2.4 The lagoons – subtidal to lower intertidal pellet mud, 180
- 8.2.5 The upper intertidal zone – the algal mats, 181

- 8.2.6 The supratidal zone – the sabkha, 186
- 8.2.7 Terrestrial environments, 189
- 8.2.8 A stratigraphic cross-section, 189
- 8.3 Baja California, Mexico, 190**
 - 8.3.1 Introduction, 190
 - 8.3.2 Salina Ometepe, 190
- 8.4 Ancient sabkhas, 191**
 - 8.4.1 Introduction, 191
 - 8.4.2 The Lower Purbeck of southern England, 192
 - 8.4.3 The Middle Carboniferous of the Maritime Provinces, Canada, 197
- 8.5 Ancient salt deposits (saline giants), 198**
 - 8.5.1 Introduction, 198
 - 8.5.2 The Upper Elk Point (Middle Devonian) Basin, 198
 - 8.5.3 The Zechstein (Upper Permian) Basin of Europe and the North Sea, 200
 - 8.5.4 Deep-water evaporite models, 204
 - 8.5.5 The Mediterranean Messinian Basin, 205
- 8.6 Conclusion, 206**

9 Shallow Siliciclastic Seas, 207

H.D. JOHNSON

- 9.1 Introduction, 207**
 - 9.1.1 Historical development, 207
- 9.2 Modern siliciclastic shelf models, 208**
- 9.3 Geological controls of shelf sedimentation, 208**
 - 9.3.1 Rate and type of sediment supply, 209
 - 9.3.2 Type and intensity of the shelf hydraulic regime, 209
 - 9.3.3 Sea-level fluctuations, 209
 - 9.3.4 Climate, 209
 - 9.3.5 Animal-sediment interactions, 210
 - 9.3.6 Chemical factors, 212
- 9.4 Physical processes (general), 212**
 - 9.4.1 Oceanic currents, 212
 - 9.4.2 Tidal currents, 214
 - 9.4.3 Meteorological currents, 215
 - 9.4.4 Density currents, 216
- 9.5 Tide-dominated shelf sedimentation, 216**
 - 9.5.1 Sedimentary facies along tidal current transport paths, 217
 - 9.5.2 Sediment dispersal patterns, 219
 - 9.5.3 Tidal sand ridges, 219
- 9.6 Storm-dominated (wind- and wave-driven) shelf sedimentation, 221**
 - 9.6.1 Introduction, 221
 - 9.6.2 Storm-dominated (wind- and wave-driven) sedimentation on the Oregon–Washington shelf, 222
 - 9.6.3 Storm-dominated (wind-driven) sedimentation on the North-West Atlantic shelf, 224

- 9.7 Comparison of tidal and storm-generated sand ridges, 228**
- 9.8 Criteria for recognizing ancient shallow marine siliciclastic deposits, 229**
- 9.9 Summary of shallow marine siliciclastic lithofacies, 233**
- 9.10 Tide-dominated facies: recognition and models, 235**
 - 9.10.1 Sedimentary structures due to tidal currents, 235
 - 9.10.2 Palaeocurrent patterns: tidal versus wind-driven circulation patterns, 237
 - 9.10.3 Blanket sandstones, 238
 - 9.10.4 An example of ancient sand waves, 240
 - 9.10.5 Linear sand bar deposits, 245
- 9.11 Wave- and storm-dominated facies: recognition and models, 247**
 - 9.11.1 Wave-formed sedimentary structures, 247
 - 9.11.2 Sublittoral sheet sandstones, 251
 - 9.11.3 Sublittoral sheet sandstone facies associations, 252
 - 9.11.4 Wave-dominated facies model, 253
 - 9.11.5 Storm surge ebb facies model, 254
- 9.12 Ancient muddy shelf deposits, 256**
- 9.13 Siliciclastic sediment supply to shallow shelf seas, 257**

10 Shallow-water Carbonate Environments, 259

B.W. SELLWOOD

- 10.1 Introduction, 259**
 - 10.1.1 Historical background to research, 259
 - 10.1.2 Major controls on carbonate production and distribution, 260
- 10.2 Subtropical carbonate shelves, 264**
 - 10.2.1 General settings, 264
 - 10.2.2 Major environments, sub-environments and facies in 'warm-water' carbonate systems, 265
 - 10.2.3 Examples of open shelves, 275
 - 10.2.4 Examples of rimmed shelves, 280
 - 10.2.5 Ancient analogues of subtropical carbonate shelves, 287
- 10.3 Examples of temperate water carbonate shelves, 296**
 - 10.3.1 Mannin Bay, western Ireland, 296
 - 10.3.2 Ancient examples of possible temperate water carbonates, 298
- 10.4 Carbonate buildups through time, 299**
 - 10.4.1 Modern buildups, 299
 - 10.4.2 Ancient analogues, 303

11 Pelagic Environments, 314

H.C. JENKINS

- 11.1 Historical introduction, 314**
 - 11.1.1 Pelagic sediments in the oceans, 314
 - 11.1.2 Pelagic sediments on land, 315

11.2 Definitions and classifications, 315**11.3 Pelagic sediments in the oceans, 317**

11.3.1 Introduction to pelagic sedimentation, 317

11.3.2 Spreading ridges, 320

11.3.3 Aseismic volcanic structures, 326

11.3.4 Deep ocean basins, 330

11.3.5 Small pelagic basins, 333

11.3.6 Continental-margin seamounts, banks, plateaus and basins, 336

11.4 Pelagic sediments on land, 339

11.4.1 Introduction, 339

11.4.2 Pelagic sediments with inferred oceanic basement, 340

11.4.3 Deposits of small pelagic basins, 349

11.4.4 Continental-margin facies, 352

11.4.5 Deposits of epeiric seas, 363

11.5 Conclusions, 370**12 Deep Clastic Seas, 372**

N.A. RUPKE

12.1 History of the turbidity current theory, 372**12.2 Processes of clastic sediment transport in the deep-sea, 373**

12.2.1 Mass gravity transport: general, 373

12.2.2 Slumping, 375

12.2.3 Debris flow, 377

12.2.4 Turbidity currents: high density, 379

12.2.5 Turbidity currents: low density, 385

12.2.6 Other mass flow processes, 387

12.2.7 Thermo-haline ocean bottom currents, 388

12.3 Discovery of deep-sea clastic environments, 389

12.3.1 The Atlantic tradition: abyssal plains, 389

12.3.2 The Pacific tradition: channels and fans, 390

12.4 Modern basin plains, 390

12.4.1 General characteristics and classification, 390

12.4.2 Open oceans, 392

12.4.3 Deep-sea trenches, 393

12.4.4 Enclosed seas: mediterraneans and marginal seas, 395

12.4.5 Borderland basins, 395

12.4.6 Miscellaneous, 395

12.5 Modern turbidite fans, 396

12.5.1 General characteristics and classification, 397

12.5.2 Abyssal cones, 400

12.5.3 Deep-sea fans, 401

12.5.4 Short headed delta-front fans, 402

12.5.5 Continental rise fans, 402

12.5.6 Mixed-type fans, 402

12.6 Flysch facies, 402

12.6.1 Early interest: definition and bathymetry, 402

12.6.2 Palaeocurrent analysis, 403

12.6.3 Facies analysis: proximal versus distal, 403

12.6.4 Facies classification, 404

12.7 Ancient basin plains, 405

12.7.1 General characteristics, 405

12.7.2 Examples of ancient basin plains, 405

12.8 Ancient turbidite fans, 407

12.8.1 Growth of the ancient fan model, 407

12.8.2 General characteristics, 407

12.8.3 Examples of ancient turbidite fans, 411

13 Glacial Environments, 416

M.B. EDWARDS

13.1 Historical background, 416**13.2 Present-day glaciers, 416**

13.2.1 Glacier flow, 417

13.2.2 Thermal regime, 417

13.2.3 Mass balance, 417

13.3 Glacial and related environments, 417

13.3.1 The basal zone, 418

13.3.2 The supraglacial and ice-contact proglacial zone, 419

13.3.3 Glaciofluvial environment, 420

13.3.4 Glaciolacustrine environment, 421

13.3.5 Aeolian environment, 422

13.3.6 Pedogenic environment, 422

13.3.7 Glaciomarine environment, 422

13.4 Glacial sedimentary facies, 424

13.4.1 Subglacial deposits, 424

13.4.2 Supraglacial and proglacial deposits, 428

13.4.3 Glaciomarine and glaciolacustrine deposits, 428

13.4.4 Bedded mixite and tillite, 429

13.5 Ancient glacial facies, 430

13.5.1 Late Cenozoic glaciation, 430

13.5.2 Late Palaeozoic glaciation, 432

13.5.3 Late Ordovician glaciation, 432

13.5.4 Late Pre-Cambrian glaciation, 433

13.5.5 Early Proterozoic glaciation, 433

13.6 Facies associations and glacial models, 435**14 Sedimentation and Tectonics, 439**

A.H.G. MITCHELL and H.G. READING

14.1 Introduction, 439**14.2 The geosynclinal theory, 439**

14.2.1 Early American and European views, 1859-1920, 439

14.2.2 Concepts and classifications of geosynclines in Europe, 440

14.2.3 Concepts and classification of geosynclines in North America, 442

14.2.4 Concepts of geosynclines and metallogenesis in USSR, 443

14.2.5 Geosynclinal facies and cycles of sedimentation, 444

14.2.6 Plate tectonics and geosynclines, 446

14.3 Modern plate-tectonic settings, 446

14.3.1 Spreading-related settings, 447

14.3.2 Subduction-related settings, 454

14.3.3 Transform/strike-slip fault-related settings, 460

14.3.4 Continental collision-related settings, 463

14.4 Ancient plate tectonic settings, 465

14.4.1 Spreading – related settings, 465

14.4.2 Subduction-related settings, 468

14.4.3 Transform/strike-slip fault-related settings, 471

14.4.4 Continental collision-related settings, 473

14.5 Geosyncline evolution, 474

14.5.1 The Wilson cycle, 474

14.5.2 Strike-slip orogenic model, 476

15 Problems and Perspectives, 477**H.G. READING****References, 480****Index, 545**