

Contents

Preface to the Second Edition.....	vii
Preface to the First Edition	ix

1. Introduction and Source Materials	1
Sand and Sandstone Defined	1
Relative and Absolute Abundance	3
Distribution, Past and Present	5
History of Investigation.....	7
Economic Value of Sand.....	10
References	11
General Sources for the Study of Sand and Sandstone	13
General	13
Sandy Environments and Depositional Systems	14
Specialized Studies.....	16
Sedimentary Petrology.....	19
Manuals, Encyclopedias, and Special Tables	20

PART I. THE FUNDAMENTAL PROPERTIES OF SANDSTONES

2. Mineral and Chemical Composition	25
Introduction	25
Weathering.....	25
Transport	25
Diagenesis	26
Mixing of Sources.....	26
Sedimentary Differentiation	26
Rock Fragments	27
Detrital and Chemical Minerals	27
Sandstone Mineral Ages	27
X-Ray and Other Methods	28
Surface Appearance	29
The Detrital Minerals.....	29
The Silica Minerals.....	29
Feldspars	32
Micas, Chlorites, and Clay Minerals	38
Heavy Minerals.....	41
Rock Fragments	43

The Chemical Minerals	46
Carbonates	46
Sulfates	48
Sulfides	49
Other Minerals	49
Organic Matter	52
Relation of Mineralogy to Texture	53
Mineralogy and Size	53
Mineralogy and Resistance to Abrasion	53
Chemical Composition	54
Chemical Composition as a Function of Mineral Constituents	54
Isotopic Composition	56
Chemical Classification of Sandstones	57
Chemical Composition as a Function of Sandstone Type ..	58
Chemical Composition and Tectonic Setting	58
References	60
3. Texture	69
Introduction	69
Grain Size	69
Meaning of Size	69
Techniques	70
Statistical Measures	72
Shape and Roundness	77
Surface Textures	80
Textural Maturity	82
Evaluation	83
Control of Physical Properties	85
Fabric	85
Porosity and Permeability	87
References	92
4. Sedimentary Structures and Bedding	97
Introduction	97
Current and Deformational Structures	99
Bedding	99
Contemporaneously Deformed Bedding	113
Biogenic Structures	118
Chemical Structures	122
Obtaining Maximum Value from Sedimentary Structures ...	124
References	132

PART II. THE PETROGRAPHY OF SANDSTONES

5. Petrography of Common Sands and Sandstones	139
Nomenclature and Classification	139
Defining Parameters	140
Major Trends in Sandstone Classification	141
Making a Choice	144
Introduction to Petrography	147
Feldspathic Sands and Arkose	148
Definitions	148

General Description	149
Varieties and Types of Arkose	150
Field Occurrence and Examples	153
Provenance and Tectonics of Arkose	155
Significance and Origin	155
Lithic Arenites and Related Rocks	156
Definitions and Nomenclature	156
General Description	156
Special Types	158
Field Occurrence and Examples	159
Origin and Significance	163
Graywackes and Related Rocks: The Wackes	163
Definitions and History of Term	163
General Description	164
Varieties and Types of Graywacke	166
Field Occurrence and Examples	167
The Matrix Problem	172
The Problem of Na ₂ O	174
Significance of Graywackes	175
Quartz Arenites (Orthoquartzites)	176
Definitions and Nomenclature	176
General Description	176
Varieties	178
Field Occurrence and Examples	179
Distribution in Space and Time	184
Significance and Origin of Quartz Arenites	184
Miscellaneous Sandstones	186
Hybrid Sands and Sandstones	186
Greensands	187
Phosphatic Sandstones	189
Calcareneous Sandstones	189
Tuffaceous Sandstones	190
Relative Abundance of Sandstones and the "Average"	
Sandstone	192
Sandstone Petrogenesis	193
Glossary of Rock Names Applied to Sands and Sandstones	196
References to Glossary	205
References	206
6. Volcaniclastic Sandstones and Associated Rocks	215
Introduction	215
Characteristic Petrographic Features	216
Petrographic Classification	222
Volcaniclastic Deposits	224
Pyroclastic Flows	224
Air Falls	229
Debris Avalanches	229
Lahars	230
Redeposited Volcaniclastic Sandstones	231
Examples	233
Tectonic Setting	237
Plate Boundaries and Intraplate Volcanism	237
Plate Tectonics and Basin Fill	240
Glossary	243
References	244

PART III. PROCESSES THAT FORM SAND AND SANDSTONE

7. Production and Provenance of Sand..... 251

 Introduction..... 251

 How Sand is Formed..... 251

 Weathering..... 252

 Volcanism..... 253

 Crushing and Fracturing..... 253

 Pelletization..... 253

 Precipitation..... 253

 Summary and Grain-Size Distribution..... 254

 The Problem of Provenance..... 254

 Definitions and Concepts..... 254

 Evidence from Detrital Components..... 255

 Mineral Stability, Climate, and Provenance..... 261

 Reading Provenance History..... 263

 Provenance and Plate Tectonics..... 266

 Examples of Provenance Studies..... 268

 References..... 269

8. Transportation and Deposition of Sand..... 275

 Introduction..... 275

 Fluid Flow and Entrainment..... 276

 Aspects and Fluid Flow..... 276

 Settling Velocity..... 280

 Entrainment of Single Grains..... 283

 Suspension and Discontinuities in Grain-Size Curves..... 285

 Bedforms in Flumes and Alluvial and Tidal Channels..... 286

 Paleohydraulics and Open Channel Flow..... 293

 Transport and Bedforms on Sandy Shelves and Beaches..... 296

 Subaqueous Gravity Flows..... 303

 Wind..... 310

 Fabric..... 312

 Glossary..... 313

 References..... 315

9. Paleocurrents and Dispersal..... 321

 Introduction..... 321

 Dispersal Patterns Defined by Composition and Texture..... 322

 Dispersal Patterns Inferred from Primary Structures..... 326

 Deducing Current Direction from Sedimentary Structures..... 327

 Paleoslope and Current Directions..... 328

 Paleocurrent Models..... 329

 Alluvial..... 329

 Shoreline and Shallow Marine Shelf..... 330

 Basinal Turbidite Models..... 333

 Eolian Paleocurrent Patterns..... 334

 Volcanic..... 334

 Summary..... 335

 Paleocurrents and Time..... 335

 Paleocurrents and Basin Analysis..... 336

 Paleocurrents and Plate Tectonics..... 336

 References..... 337

10. Sandy Depositional Systems	341
Introduction	341
Concepts and Methods	343
Depositional Strike, Paleoslope, and Walther's Law	343
Associated Lithologies, Vertical Sequence, and Memory ..	345
Geophysical Logs	347
Seismic Stratigraphy	350
Compaction	351
References	353
Alluvial	354
Meandering Streams	355
Braided Streams and Alluvial Fans	361
Anastomosing Streams	363
Coal Measures and Other Economic Deposits	363
Summary	364
References	366
Deltas	368
River-Dominated Deltas	372
Tide-Dominated Deltas	374
Wave-Dominated Deltas	376
Summary	377
References	378
Fan Deltas	379
References	381
Sandy Coastlines and Shelves	381
Sandy Coastlines	381
Sandy Shelves	388
Summary	393
References	394
Slope and Deep Basin	396
Turbidite Model	397
Ancient Turbidites	400
Summary	403
References	404
Eolian	405
Summary	410
References	411
Sandy Reservoirs	411
References	418
Epilogue; Unresolved Problems and Future Research	420
References	422
11. Diagenesis	425
Introduction	425
Aspects of Diagenesis	426
Diagenetic Textures and Compositions	427
Textures	427
Mineralogy	429
Physical Properties	429
Chemical Properties	429
Summary: Two Typical Examples	430
Physical Diagenetic Processes	431
Compaction	431
Bioturbation	431
Graywacke Matrix Formation	431

Clay Mineral Dehydration and Compaction	432
Brittle and Ductile Deformation	432
Chemical Diagenetic Processes	432
Precipitation	433
Dissolution	435
Recrystallization	438
Partial Dissolution and Alteration	439
Porewater Reactions and Formation Waters	442
Sequence and Timing of Mineral Transformations	444
Cement Paragenesis	444
Diagenetic Ages	446
Major Diagenetic Effects	447
Carbonate Cementation	448
Silica Cementation	452
Clay Minerals	456
Alteration of Volcaniclastics and Zeolites	458
Common Accessory Diagenetic Minerals	461
Porosity Reduction and Production	463
Burial Diagenesis	465
Conclusion	467
References	467
 12. Sandstones, Tectonics, and Continental Evolution	 475
Introduction	475
Sandy Basins	476
Plate Tectonics and Sedimentary Accumulations	478
Geosynclines—The Classical View	479
Plate Tectonic Settings	480
Plate Convergence Settings	482
Intra-oceanic Convergences	482
Oceanic-Continental (Andean-Type) Convergences	487
Continent-Continent Convergences (Himalayan-type)	490
Plate Divergence Environments	493
Mid-Ocean Ridges	493
Intra-Continental Rifts	493
Plate Transform Boundary Settings	498
Intra-Plate Settings	499
Oceanic Intra-Plate	499
Passive Continental Margins	500
Continental Intra-Plate	502
Evolutionary Sequences and Successor Basins	504
Sandstone in the History of the Earth	506
Sandstone Composition in Relation to Age	506
Sandstones in Relation to Evolutionary Changes in Earth History	509
Conclusions and a Look at the Future	512
References	512
 Appendix: Petrographic Analysis of Sandstones	 519
Introduction	519
Rock Description and Analysis	519
A Comprehensive Petrographic Analysis: The Trivoli Sandstone of Southern Illinois	525
References	531
 Author Index	 533
Subject Index	547