

H. Ibbeken R. Schleyer

---

# Source and Sediment

A Case Study of Provenance and Mass Balance  
at an Active Plate Margin (Calabria, Southern Italy)

With a Contribution by R. Valloni

Supported by Research of P. Ergenzinger, G. Mezzadri,  
J. Mouton, and J. Rumohr

With 161 Figures



Springer-Verlag  
Berlin Heidelberg New York London Paris  
Tokyo Hong Kong Barcelona Budapest

---

# Contents

<b>Introduction</b> .....	1
Why Provenance? .....	1
Why Calabria? .....	1
Problem and Concept .....	2
Contributors .....	3
<b>Part I The Source</b>	
<b>Chapter 1 Position and Geological Framework</b> .....	6
1.1 Position of the Research Area .....	7
1.2 Tectonic Setting .....	7
1.3 Neotectonics .....	13
1.4 Seismic Activity .....	14
1.5 Conclusion .....	14
<b>Chapter 2 Basins and Channel Network</b> .....	15
2.1 Digitization of Maps .....	15
2.2 Drainage Divides and Drainage Basins .....	16
2.2.1 The Classification of Drainage Divides .....	17
2.2.1.1 Order Classification .....	17
2.2.1.2 Length Classification .....	17
2.2.2 The Classification of Drainage Basins .....	18
2.2.2.1 Order Classification .....	18
2.2.2.2 Size Classification .....	19
2.2.3 The Physiographic Provinces .....	19
2.2.4 The Selection of the "19 Rivers" .....	20
2.2.5 Size, Arrangement and Shape of the Basins and Interfluves .....	20
2.2.6 Basin Size and Shelf Width .....	23
2.3 Channel Network .....	25
2.3.1 Stream Orders .....	26
2.3.2 Stream Length .....	28
2.4 Conclusion .....	29
<b>Chapter 3 Altitude and Slopes</b> .....	30
3.1 Altitude .....	30
3.1.1 Statistics .....	30
3.1.1.1 Altitude Frequency Distribution .....	30
3.1.1.2 Statistical Parameters, Relief and Hypsometric Integral .....	31
3.1.1.3 Relationships of the Variables .....	32
3.1.2 Regional Aspects .....	33
3.1.2.1 Altitude Map .....	34
3.1.2.2 Altitude Versus Distance from River Mouth .....	34

3.2	The Slopes (Gradients) .....	38
3.2.1	Statistics .....	38
3.2.1.1	Gradient Frequency Distribution, Non-Rock-Specific .....	38
3.2.1.2	Statistical Parameters .....	38
3.2.1.3	Gradient Frequency Distribution, Rock-Specific .....	40
3.2.2	Regional Aspects .....	41
3.2.2.1	Gradient Map .....	41
3.2.2.2	Gradient Versus Distance from River Mouth .....	41
3.3	The Slope Directions (Aspects) .....	43
3.4	Conclusion .....	44
<b>Chapter 4 Climate and Vegetation .....</b>		<b>46</b>
4.1	Climate .....	47
4.1.1	Temperature and Precipitation .....	47
4.1.2	Rainstorms .....	47
4.2	Vegetation .....	49
4.3	Conclusion .....	50
<b>Chapter 5 Rock Units and Their Regional Distribution .....</b>		<b>51</b>
5.1	Digitization of Geological Maps .....	51
5.1.1	Requirements for a Geological Map as Base for Digitization .....	51
5.1.2	The Information and Its Compression for Digitization .....	52
5.2	Regional Distribution of Rock Units .....	53
5.2.1	Granitic Rocks .....	53
5.2.2	Metamorphic Rocks .....	53
5.2.3	Sedimentary Rocks .....	57
5.2.3.1	Jurassic Limestones .....	57
5.2.3.2	Conglomerates .....	58
5.2.3.3	Sandstones .....	58
5.2.3.4	Siltstones .....	59
5.2.3.5	Argillites .....	61
5.2.3.6	Holocene Deposits .....	63
5.3	Conclusion .....	63
<b>Chapter 6 Erosion and Predicted Sediment Composition .....</b>		<b>65</b>
6.1	Erosion Rates .....	65
6.1.1	The Mid-Pleistocene Plain (MPP) and Its Use as Upper Enveloping Surface .....	66
6.1.1.1	Concept .....	66
6.1.1.2	Mid-Pleistocene Plain and Uplift .....	66
6.1.1.3	Dating of the Mid-Pleistocene Plain .....	67
6.1.1.4	Supporting Data .....	67
6.1.2	Erosion Rate Map .....	70
6.1.3	Statistics .....	71
6.1.3.1	Erosion Rate Frequency Distribution .....	71
6.1.3.2	Statistical Parameters .....	72
6.1.4	Relationship of the Variables .....	73
6.1.4.1	Erosion Rate Versus Distance .....	73
6.1.4.2	Erosion Rate Versus Altitude .....	73
6.1.4.3	Erosion Rate Versus Precipitation .....	73
6.1.5	Rock-Specific Aspects of Erosion .....	74
6.1.5.1	Mean Rock-Specific Erosion Rates and the "Energy Belts" .....	74

6.1.5.2	Rock-Specific Standard Deviations of Erosion Rates and the "Energy Belts" .....	75
6.2	Budget Calculations .....	75
6.2.1	The Erosional Budget .....	77
6.2.2	Effective Source Area Composition and Predicted Sediment Composition .....	79
6.3	Conclusion .....	79
<b>Chapter 7 Water Budget and Dissolved Load .....</b>		<b>81</b>
7.1	Effective Precipitation and Estimated Runoff .....	81
7.2	Composition of Rock Waters .....	82
7.3	Predicting Dissolved Load of River Water .....	84
7.4	Measured Dissolved Load of River Water .....	85
7.5	Comparison of Predicted and Measured River Water .....	86
7.6	Conclusion .....	87
<b>Chapter 8 Composition of Rocks and Soils .....</b>		<b>89</b>
8.1	Source Rocks .....	90
8.1.1	Granitic Rocks .....	90
8.1.2	Metamorphic Rocks .....	91
8.1.3	Sedimentary Rocks .....	93
8.1.3.1	Jurassic Limestones .....	93
8.1.3.2	Conglomerates .....	93
8.1.3.3	Sandstones (by Renzo Valloni) .....	95
8.1.3.4	Siltstones .....	100
8.1.3.5	Argillites .....	102
8.2	Source Soils .....	102
8.2.1	Types and Grain-Size Distribution .....	102
8.2.2	Sand Fraction (by Renzo Valloni) .....	103
8.2.2.1	Detrital Modes .....	103
8.2.2.2	Heavy Mineral Assemblage .....	105
8.2.2.3	Soil Composition .....	106
8.2.3	Silt Fraction .....	108
8.3	Conclusion .....	108
 <b>Part II From the Source to the River-Mouth Sediment</b>		
<b>Chapter 9 Development of the Chemical Composition of Sand .....</b>		<b>112</b>
9.1	The Oxides .....	114
9.1.1	Gain and Loss .....	114
9.1.2	Constant Oxide Calculation .....	115
9.2	The Parameters .....	116
9.2.1	TiO <sub>2</sub> % Versus Fe <sub>2</sub> O <sub>3</sub> + MgO % .....	118
9.2.2	Al <sub>2</sub> O <sub>3</sub> /SiO <sub>2</sub> Versus Fe <sub>2</sub> O <sub>3</sub> + MgO % .....	119
9.2.3	K <sub>2</sub> O/Na <sub>2</sub> O Versus Fe <sub>2</sub> O <sub>3</sub> + MgO % .....	119
9.2.4	Al <sub>2</sub> O <sub>3</sub> /(CaO + Na <sub>2</sub> O) Versus Fe <sub>2</sub> O <sub>3</sub> + MgO %; CIA .....	120
9.2.5	Al <sub>2</sub> O <sub>3</sub> /SiO <sub>2</sub> Versus K <sub>2</sub> O/Na <sub>2</sub> O .....	120
9.2.6	Trend and Single Measurement .....	121
9.3	Comparing Small and Big Rivers and the Problem of Na <sub>2</sub> O .....	121
9.4	Conclusion .....	122

<b>Chapter 10</b>	<b>The Development of the Grain-Size Distributions</b>	124
10.1	The Gravel Mode (First-Order Element)	125
10.1.1	The Gauss-Rosin Concept	126
10.1.2	The Sequence of the Five Environments	127
10.1.3	The Log-Hyperbolic Distribution	130
10.2	The Sand Mode (Second-Order Element)	133
10.3	The 1–20-mm Fraction (Third-Order Element)	134
10.4	Unimodal and Bimodal Distributions	135
10.4.1	Test Sampling	136
10.4.2	Modality and the Source Area Variables	138
10.4.2.1	Source Area Morphology and Modality	138
10.4.2.2	Source Area Petrography and Modality	138
10.4.2.3	Source Area Grain-Size Distributions and Modality	139
10.4.2.4	Petrography of River-Mouth Sediments and Modality	140
10.4.2.5	Packing and Refill of Interstices and Modality	140
10.4.2.6	Hydrodynamic Conditions and Modality	140
10.5	Conclusion	141
<b>Chapter 11</b>	<b>Development of Gravel Sphericity</b>	143
11.1	Overall Trends	144
11.2	Sphericity Versus Grain Size	144
11.3	Sphericity Versus Rock Type	144
11.4	Sphericity Versus Environment	145
11.5	Conclusion	145
<b>Chapter 12</b>	<b>Special Topics of Sediment Development of Lower River Course and Beach</b>	147
12.1	Laverde, Buonamico and the Bianco Beach	147
12.2	Longshore and Beach-Normal Development of Grain Sizes	150
12.2.1	The Beach-Normal Profile	150
12.2.2	The Longshore Section	151
12.3	The Reduction of Dark Gneiss	152
12.4	Downstream and Longshore Development of Sphericity	153
12.4.1	The Rivers Laverde and Buonamico	153
12.4.2	The Bianco Beach	153
12.4.2.1	The Beach-Normal Profile	153
12.4.2.2	The Longshore Section	153
12.5	Downstream and Longshore Development of Roundness	154
12.5.1	The Rivers Laverde and Buonamico	154
12.5.2	The Longshore Section	154
12.6	Conclusion	155
 <b>Part III River-Mouth Sediment and Provenance</b>		
<b>Chapter 13</b>	<b>River-Mouth Gravel</b>	158
13.1	The Petrographic Composition	158
13.1.1	The Petrographic Suite	158
13.1.1.1	Rocks	158
13.1.1.2	Minerals	159
13.1.2	Sample Reliability and Dependence of Petrographic Composition on Grain Size	159

13.1.2.1	Sample Reliability .....	159
13.1.2.2	Petrographic Composition and Grain Size .....	162
13.1.3	Reading Provenance from the Gravels .....	164
13.1.3.1	Trends Within the Basins .....	165
13.1.3.2	Comparison of the 19 Basins .....	167
13.1.4	The Correlation Effective Source Rock Composition Versus River-Mouth Gravel Composition .....	168
13.2	Conclusion .....	170
<b>Chapter 14 River-Mouth Sand, Silt and Clay .....</b>		<b>171</b>
14.1	The Mineralogical Composition of the Sand Fraction (by Renzo Valloni) .....	171
14.1.1	Texture (Roundness) .....	172
14.1.2	Framework Mineral Composition .....	172
14.1.2.1	Provenance Relations .....	175
14.1.3	Heavy Mineral (HM) Assemblage .....	178
14.1.3.1	Provenance Relations .....	182
14.1.4	Discussion .....	185
14.1.5	Conclusion .....	186
14.2	Mineralogy of Silt and Clay .....	187
14.2.1	Soils and Suspended Load .....	188
14.2.2	River-Mouth Sediment .....	188
14.2.3	Conclusion .....	189
 <b><i>Part IV Processes, Budget and Statistical Comparison</i></b>		
<b>Chapter 15 Mass Balances on Land .....</b>		<b>194</b>
15.1	The Buonamico Basin .....	194
15.1.1	Slope Stability .....	194
15.1.2	Landslides .....	195
15.1.2.1	Occurrence of Landslides .....	195
15.1.2.2	The Costantino Landslide .....	197
15.1.2.3	Mass Calculations of Landslides .....	197
15.1.3	The Sediment Trap Lago Costantino .....	201
15.1.4	Changing River Profiles .....	203
15.1.4.1	Cross Profiles .....	203
15.1.4.2	Long Profile .....	203
15.1.5	Buonamico's Export into the Ionian Sea .....	204
15.2	Paleovalleys and Volumes of Alluvial Deposits .....	205
15.3	Conclusion .....	206
 <b>Chapter 16 Mass Balances in the Marine Realm .....</b>		<b>207</b>
16.1	Shelf and Canyon Area and the Delta .....	207
16.2	Submarine Morphology .....	208
16.3	Sediments .....	212
16.4	Mass Balance .....	213
16.4.1	The Laverde Delta 1941–1983 .....	214
16.4.2	Shelf and Canyon 1877–1974 .....	215
16.5	Conclusion .....	216

<b>Chapter 17 Comparison of Source and Sediment: a Multivariate Approach</b> .....	218
17.1 The Source .....	219
17.2 The Sediment .....	222
17.3 Source and Sediment .....	224
17.4 Conclusion .....	225
<b>Chapter 18 Summary and Conclusion</b> .....	227
<b>Appendix A: Data Management</b> .....	233
<b>Appendix B: Graphic Representation of the Data Base</b> .....	236
<b>References</b> .....	278
<b>Subject Index</b> .....	283