

Contents

1	Contractional Theory, Continental Drift and Plate Tectonics	1
1.1	Plate Tectonics—A Change in the Paradigm of the Geosciences.....	2
1.2	Early History of Geodynamic Thought	2
1.3	From Continental Drift to Plate Tectonics.....	3
1.4	The Plate Tectonic Concept	5
1.5	The Pattern of Magnetic Polarity Stripes.....	8
1.6	Plate Motions and Earthquake Zones.....	10
1.7	Two Kinds of Continental Margins.....	11
1.8	Magmatism and Plate Tectonics.....	12
1.9	What Drives the Plates and What Slows Them Down?.....	13
1.10	Collision and Mountain Building	13
2	Plate Movements and Their Geometric Relationships.....	15
2.1	Helpful Transform Faults.....	16
2.2	Relative Movements and Triple Junctions	17
	Two RTF Triple Junctions off North America.....	19
2.3	Relative Plate Velocities—Past and Present.....	21
2.4	Direct Measurement of Plate Movements.....	23
2.5	Apparent Contradictions in the Plate Motion Pattern	25
	Fault–Plane–Solutions of Earthquakes.....	25
3	Continental Graben Structures	31
	Active and Passive Graben Structures	33
3.1	Symmetric and Asymmetric Crustal Extension	33
3.2	Sediments and Ore Deposits in Graben Structures	34
3.3	Volcanism in Graben Structures	35
3.4	The Upper Rhine Graben in Germany	35
3.5	The History of the Upper Rhine Graben	38
	The Upper Rhine Graben in the Middle European Stress Field	39
3.6	Magmatism and Heat Flow in the Upper Rhine Graben.....	40
3.7	The Large East African Rift System.....	41
	The Afar Depression.....	44
3.8	The Red Sea—From Rift to Drift	44
3.9	The Extensional Area of the Basin and Range Province.....	46
3.10	The Development of Metamorphic Domes.....	47
3.11	A Brief History of the Basin and Range Province	49
4	Passive Continental Margins and Abyssal Plains	51
4.1	Continuous Subsidence of the Continental Margins	52
4.2	The Sedimentary Trap at a Passive Continental Margin	53
	Tracts of Sequence Stratigraphy	54
4.3	Processes on Continental Margins.....	55
4.4	Petroleum Deposits—The Economic Significance of Passive Continental Margins	57
4.5	The Atlantic—An Ocean Opens in an Intricate Manner.....	58
4.6	Pangaea and Panthalassa	58
4.7	The Large Abyssal Plains	61
4.8	Sediments of the Abyssal Plains	62
	Manganese Nodules from the Deep Sea	64
4.9	Facies Changes on the Large Oceanic Conveyor Belt	66
	The Bengal Deep Sea Fan.....	66

5	Mid-ocean Ridges	69
5.1	Topography of the Ridges.....	70
5.2	Generation of Oceanic Lithosphere.....	71
5.3	Rocks of the Oceanic Crust	72
	Pillow Lavas.....	73
	Seismic Layers	75
5.4	Basalts of Mid-ocean Ridges.....	76
5.5	Fast and Slow Spreading Ridges and Rocks of the Lithospheric Mantle	77
5.6	Segmentation of Ridges by Faults	78
5.7	Graben Formation in the Atlantic.....	79
	An Oceanic Crustal Profile in the Atlantic Ocean	80
5.8	Black and White Smokers	80
5.9	Ocean Floor Metamorphism.....	82
5.10	Chromite Deposits	83
5.11	Ophiolites	83
5.12	The Ophiolite of the Semail Nappe in Oman	84
5.13	Alpine–Mediterranean Ophiolites	84
	Metamorphic Sole.....	85
6	Hot Spots.....	87
6.1	Hot Spots and Mid-Ocean Ridges.....	90
6.2	The Mysterious D" Layer and the Dented Earth	90
	Hot Spots of Pangaea	91
6.3	Hot Spot Tracks in the Ocean.....	93
	A Guyot Evolves.....	96
6.4	Hot Spot Tracks on the Continent	96
6.5	Flood and Trap Basalts	98
6.6	The Azores—Hot, Cold or Wet Spot?.....	99
6.7	Hawaii—A Typical Oceanic Hot Spot	101
6.8	Iceland	101
6.9	Yellowstone	102
6.10	The Superplume Event in the Cretaceous.....	103
7	Subduction Zones, Island Arcs and Active Continental Margins	107
7.1	Structure of Plate Margin Systems with Subduction Zones	109
7.2	Spontaneous and Forced Subduction: Mariana- and Chile-Type Subduction.....	111
	What is the Reason for the Arcuate Shape of Island Arcs?.....	111
7.3	Deep Sea Trenches as Sediment Traps.....	114
7.4	Accretionary Wedge and Outer Ridge	115
	The Accretionary Wedge of the Sunda Arc	116
7.5	Subduction Erosion Instead of Accretion	118
	Mud Volcanoes.....	119
7.6	The Forearc Basin	121
7.7	Earthquakes and Benioff Zones	122
	The Shigatse Flysch in Tibet	123
7.8	The Secret of Deep Earthquakes.....	126
7.9	High-Pressure or Subduction Metamorphism.....	128
	Ultrahigh-Pressure Metamorphic Rocks.....	131
	Rapid Burial, Rapid Uplift.....	133
7.10	Subduction-Related Magmatism—A Paradox?.....	133
7.11	Rocks of the Magmatic Zone	135
7.12	Zonation of Magmas in Space and Time	137
7.13	Explosive Stratovolcanoes as Indicators for Subduction Magmatism	138
	Isotopic Signatures and the Influence of Continental Crust.....	139
7.14	Metamorphism in the Magmatic Belt	140
	Paired Metamorphic Belts	141

Contents

7.15	Ore Deposits in the Magmatic Belt	142
7.16	The Backarc Basin.....	142
	Splitting of Intra-Oceanic Island Arcs	143
7.17	Gravity and Heat Flow	144
7.18	Subduction and Collision	144
8	Transform Faults.....	147
8.1	Oceanic Transform Faults	148
8.2	Fracture Zones in the Ocean Floor.....	149
8.3	Continental Transform Faults	151
8.4	San Andreas—The Dreaded Transform Fault of California.....	152
8.5	The North Anatolian Fault in Asia Minor and the Alpine Fault in New Zealand	155
9	Terranes	159
9.1	Documenting Terranes.....	161
9.2	Terranes in the North American Cordillera.....	163
9.3	Suspect Terranes in Mexico and Middle America.....	167
10	Early Precambrian Plate Tectonics	169
	The Oldest Rocks and Minerals	171
10.1	Greenstone-Granite Belts	172
10.2	Granulite-Gneiss Belts	175
	Komatiites	175
10.3	Towards an Archean Plate Tectonic Model	176
10.4	The Growth of Continents.....	177
10.5	Possible Younger Equivalents of Greenstone-Granite Belts	178
	The Great Dike of Zimbabwe	179
11	Plate Tectonics and Mountain Building.....	181
11.1	Types of Active Continental Margins Within Orogenic Styles.....	182
11.2	Continent–Continent Collision	185
11.3	Uplift, Erosion, and Elevation of Mountains.....	187
11.4	Collapse and Crustal Escape.....	191
12	Old Orogens.....	193
12.1	2500–2000 Million Years Old Ophiolites	194
12.2	The Wopmay Orogen in Canada.....	195
12.3	The Grenville Orogenic Cycle and the Formation of the Supercontinent Rodinia	195
12.4	The Panafrican Orogeny and the Formation of Gondwana	195
12.5	The Caledonides—A Wilson Cycle Around the Iapetus Ocean	196
	The Significance of Scotland and the Greek Mythology.....	197
12.6	The Variscides—A Broad Mountain Belt in Central Europe	199
	A Variscan Suture in the Southern Black Forest	200
12.7	The Variscan Orogen in the Alps.....	201
12.8	Paleozoic Mountain Building in Eastern and Southern North America	202
	How Many Orogenies?	205
13	Young Orogens—The Earth’s Loftiest Places.....	207
13.1	The Himalayas—A Mountain Range with Superlatives	209
13.2	Tectonic History of the Himalayas	209
	Nanga Parbat and Namche Barwa Syntaxis	211
13.3	The Alps—An Unusual but Classic Orogen	212
13.4	Brief History of Alpine Evolution	214
	Lateral Tectonic Extrusion in the Alps.....	215
13.5	The North American Cordillera—A Different Style of Orogen.....	217
13.6	Laramide Rocky Mountains—An Orogenic Mystery Solved.....	223
13.7	Epilog	225

Supplementary Information.....	227
Glossary.....	229
References	235
Index.....	241