

**Wolfgang Frisch / Martin Meschede /  
Ronald Blakey**

# **Plate Tectonics**

**Continental Drift  
and Mountain Building**

 **Springer**

# Content

<b>Preface</b> .....	XII
----------------------	-----

## **1** Contractual theory, continental drift and plate tectonics .....

Plate tectonics – a change in the paradigm of the geosciences .....	1
Early history of geodynamic thought .....	1
From continental drift to plate tectonics .....	2
The plate tectonic concept .....	4
The pattern of magnetic polarity stripes .....	8
Plate motions and earthquake zones .....	8
Two kinds of continental margins .....	11
Magmatism and plate tectonics .....	11
What drives the plates and what slows them down? .....	12
Collision and mountain building .....	12

## **2** Plate movements and their geometric relationships .....

Helpful transform faults .....	15
Relative movements and triple junctions .....	16
<i>Two RTF triple junctions off North America</i> .....	18
Relative plate velocities – past and present .....	20
Direct measurement of plate movements .....	21
Apparent contradictions in the plate motion pattern .....	22
<i>Fault-plane-solutions of earthquakes</i> .....	23
<i>Seismic tomography</i> .....	25

## **3** Continental graben structures .....

<i>Active and passive graben structures</i> .....	28
Symmetric and asymmetric crustal extension .....	28

Sediments and ore deposits in graben structures .....	29
Volcanism in graben structures .....	30
The Upper Rhine Graben in Germany .....	31
The history of the Upper Rhine Graben .....	32
<i>The Upper Rhine Graben in the Middle European stress field</i> .....	33
Magmatism and heat flow in the Upper Rhine Graben .....	34
The large East African rift system .....	34
<i>The Afar Depression</i> .....	37
The Red Sea – from rift to drift .....	37
The extensional area of the Basin and Range Province .....	39
The development of metamorphic domes .....	40
A brief history of the Basin and Range Province .....	41

## **4** Passive continental margins and abyssal plains .....

Continuous subsidence of the continental margins .....	43
The sedimentary trap at a passive continental margin .....	44
<i>Tracts of sequence stratigraphy</i> .....	45
Processes on continental margins .....	46
Petroleum deposits – the economic significance of passive continental margins .....	48
The Atlantic – an ocean opens in an intricate manner .....	48
<i>Pangaea and Panthalassa</i> .....	49
The large abyssal plains .....	51
Sediments of the abyssal plains .....	52
<i>Manganese nodules from the deep sea</i> .....	54
Facies changes on the large oceanic conveyor belt .....	55
<i>The Bengal deep sea fan</i> .....	56

<b>5</b>	<b>Mid-ocean ridges</b> .....	59	<b>7</b>	<b>Subduction zones, island arcs and active continental margins</b> .....	91
	Topography of the ridges .....	59		Structure of plate margin systems with subduction zones .....	91
	Generation of oceanic lithosphere .....	60		Spontaneous and forced subduction: Mariana- and Chile-type subduction .....	93
	Rocks of the oceanic crust .....	61		<i>What is the reason for the arcuate shape of island arcs?</i> .....	94
	<i>Pillow lavas</i> .....	62		Deep sea trenches as sediment traps .....	96
	<i>Seismic layers</i> .....	64		Accretionary wedge and outer ridge .....	97
	Basalts of mid-ocean ridges .....	65		<i>The accretionary wedge of the Sunda Arc</i> .....	99
	Fast and slow spreading ridges and rocks of the lithospheric mantle .....	65		Subduction erosion instead of accretion .....	100
	Segmentation of ridges by faults .....	67		<i>Mud volcanoes</i> .....	101
	Graben formation in the Atlantic .....	67		The forearc basin .....	103
	<i>An oceanic crustal profile in the Atlantic Ocean</i> .....	68		Earthquakes and Benioff zones .....	103
	Black and white smokers .....	68		<i>The Shigatse Flysch in Tibet</i> .....	104
	Ocean floor metamorphism .....	70		The secret of deep earthquakes .....	107
	Chromite deposits .....	71		High-pressure or subduction metamorphism .....	109
	Ophiolites .....	71		<i>Ultrahigh-pressure metamorphic rocks</i> .....	111
	The ophiolite of the Semail Nappe in Oman .....	72		<i>Rapid burial, rapid uplift</i> .....	112
	<i>Metamorphic sole</i> .....	72		Subduction-related magmatism – a paradox? .....	113
	Alpine-Mediterranean ophiolites .....	72		Rocks of the magmatic zone .....	114
<b>6</b>	<b>Hot spots</b> .....	75		Zonation of magmas in space and time .....	116
	Hot spots and mid-ocean ridges .....	77		Explosive stratovolcanoes as indicators for subduction magmatism .....	117
	The mysterious D" layer and the dented Earth .....	77		<i>Isotopic signatures and the influence of continental crust</i> .....	118
	<i>Hot spots of Pangaea</i> .....	78		Metamorphism in the magmatic belt .....	119
	Hot spot tracks in the ocean .....	80		<i>Paired metamorphic belts</i> .....	119
	<i>A guyot evolves</i> .....	82		Ore deposits in the magmatic belt .....	120
	Hot spot tracks on the continent .....	82		The backarc basin .....	120
	Flood and trap basalts .....	84		<i>Splitting of intra-oceanic island arcs</i> ....	122
	The Azores – hot, cold or wet spot? .....	85		Gravity and heat flow .....	122
	Hawaii – a typical oceanic hot spot .....	86		Subduction and collision .....	122
	Iceland .....	87			
	Yellowstone .....	87			
	The superplume event in the Cretaceous .....	88			

**8 Transform faults** ..... 123

Oceanic transform faults ..... 123

Fracture zones in the ocean floor ..... 123

Continental transform faults ..... 125

San Andreas – the infamous transform fault of California ..... 127

The North Anatolian Fault in Asia Minor and the Alpine Fault in New Zealand ..... 129

**9 Terranes** ..... 131

Documenting terranes ..... 132

Terranes in the North American Cordillera ..... 134

Suspect terranes in Mexico and Middle America ..... 138

**10 Early Precambrian plate tectonics** ..... 139

*The oldest rocks and minerals* ..... 140

Greenstone-granite belts ..... 141

Granulite-gneiss belts ..... 143

*Komatiites* ..... 144

Towards an Archean plate tectonic model ..... 145

The growth of continents ..... 146

Possible younger equivalents of greenstone-granite belts ..... 147

*The Great Dike of Zimbabwe* ..... 147

**11 Plate tectonics and mountain building** ..... 149

Types of active continental margins within orogenic styles ..... 149

Continent-continent collision ..... 152

Uplift, erosion, and elevation of mountains ... 154

Collapse and crustal escape ..... 158

**12 Old orogens** ..... 159

2500–2000 million years old ophiolites ..... 159

The Wopmay orogen in Canada ..... 160

The Grenville orogenic cycle and the formation of the supercontinent Rodinia ..... 160

The Panafrican orogeny and the formation of Gondwana ..... 160

The Caledonides – a Wilson cycle around the Iapetus Ocean ..... 161

*The significance of Scotland and the Greek mythology* ..... 162

The Variscides – a broad mountain belt in central Europe ..... 163

*A Variscan suture in the southern Black Forest* ..... 165

The Variscan orogen in the Alps ..... 165

Paleozoic mountain building in eastern and southern North America ..... 167

*How many orogenies?* ..... 169

**13 Young orogens – the Earth’s loftiest places** ..... 171

The Himalayas – a mountain range with superlatives ..... 172

Tectonic history of the Himalayas ..... 172

*Nanga Parbat and Namche Barwa syntaxis* ..... 174

The Alps – an untypical but classic orogen .... 174

Brief history of Alpine evolution ..... 176

*Lateral tectonic extrusion in the Alps* ..... 178

The North American Cordillera – a different style of orogen ..... 179

Laramide Rocky Mountains – an orogenic mystery solved ..... 185

Epilog ..... 187

**Glossary** ..... 189

**References** ..... 199

**Keyword Index** ..... 207