

# Contents

<b>Introduction</b> . . . . .	ix
Marc JOLIVET	
<b>Chapter 1. Introduction to Detrital Apatite and Zircon</b>	
<b>Fission-track Thermochronology</b> . . . . .	1
Matthias BERNET	
1.1. Introduction . . . . .	1
1.2. Principals of fission-track dating . . . . .	4
1.2.1. Basics of single grain apatite and zircon fission-track analysis .	4
1.2.2. Closure temperature concept . . . . .	6
1.2.3. Partial annealing zone concept . . . . .	9
1.3. Sample preparation and fission-track dating . . . . .	12
1.3.1. Sample preparation . . . . .	12
1.3.2. External detector method . . . . .	20
1.3.3. Track lengths measurements and track lengths distributions . .	23
1.4. Statistics of fission-track dating . . . . .	27
1.4.1. Age equation, pooled age, central age, $\chi^2$ -test and age dispersion . . . . .	27
1.5. Detrital thermochronology . . . . .	32
1.5.1. Continuous and discrete mixtures of detrital cooling ages . . .	32
1.5.2. Peak fitting and minimum age model . . . . .	34
1.5.3. Recognizing partial and full annealing in detrital fission-track data sets . . . . .	36

1.6. Applications of detrital thermochronology . . . . .	40
1.6.1. Studying source-to-sink relationships . . . . .	40
1.6.2. Exhumation studies . . . . .	43
1.6.3. Thermal histories of sedimentary basins . . . . .	47
1.7. Concluding remarks . . . . .	49
1.8. References . . . . .	49
 <b>Chapter 2. Thermal History Modeling for Thermochronology . . . . .</b>	 63
Kerry GALLAGHER	
2.1. Introduction . . . . .	63
2.2. Modeling diffusion and annealing . . . . .	66
2.2.1. Diffusion . . . . .	66
2.2.2. Annealing . . . . .	69
2.3. Thermal history modeling. . . . .	71
2.3.1. Forward modeling: making predictions to compare to observations. . . . .	71
2.3.2. Examples of forward modeling . . . . .	73
2.3.3. Inverse modeling: using observations to infer the thermal history . . . . .	78
2.3.4. Examples of inverse modeling . . . . .	81
2.4. Summary . . . . .	87
2.5. References . . . . .	88
 <b>Chapter 3. LA-ICP-MS <math>^{238}\text{U}</math> Determination for Fission-track Dating . . . . .</b>	 93
Nathan COGNÉ	
3.1. Introduction . . . . .	93
3.2. Zeta approach for LA-ICPMS . . . . .	97
3.3. Absolute versus relative determination of U concentration. . . . .	98
3.3.1. Absolute determination . . . . .	98
3.3.2. Relative determination . . . . .	101
3.4. Statistical data processing. . . . .	105
3.4.1. Data dispersion. . . . .	106
3.4.2. Calculation of the $^{238}\text{U}/\text{X}$ ratio error . . . . .	107
3.4.3. The problem of zero track crystals. . . . .	109

---

3.5. Sample preparation and data acquisition for LA-ICP-MS dating . . . . .	109
3.5.1. Preparing the mounts . . . . .	109
3.5.2. Crystal counting and coordinates . . . . .	111
3.5.3. Laser analytical conditions . . . . .	111
3.6. Comparison of EDM and LA-ICP-MS methods . . . . .	112
3.6.1. Advantages of the LA-ICP-MS method. . . . .	112
3.6.2. The problem of uranium zonation . . . . .	113
3.6.3. Comparison of EDM and LA-ICP-MS methods. . . . .	114
3.7. Conclusion . . . . .	115
3.8. References . . . . .	116
<b>Chapter 4. (U-Th-(Sm))/He Thermochronometry and Chronometry: Principles, Applications and Limits. . . . .</b>	<b>121</b>
Cécile GAUTHERON, Stéphanie BRICHAU, Raphael PIK and Laurent TASSAN-GOT	
4.1. Introduction. . . . .	121
4.2. Principle of the (U-Th-(Sm))/He . . . . .	122
4.2.1. ${}^4\text{He}$ production . . . . .	122
4.2.2. Ejection, implantation and He loss correction . . . . .	124
4.2.3. He diffusion . . . . .	128
4.2.4. Helium closure temperature and partial retention zone . . . . .	135
4.2.5. (U-Th-(Sm))/He methods. . . . .	136
4.3. Analytical methods (U-Th-(Sm))/He and ${}^4\text{He}/{}^3\text{He}$ . . . . .	138
4.3.1. Crystal sorting and selection . . . . .	138
4.3.2. Analysis of ${}^4\text{He}$ and ${}^3\text{He}$ concentrations . . . . .	142
4.3.3. Analysis of uranium, thorium and samarium concentrations . . . . .	142
4.3.4. Reproducibility of (U-Th-(Sm))/He ages . . . . .	142
4.3.5. Data inversion . . . . .	143
4.4. (U-Th-(Sm))/He and ${}^4\text{He}/{}^3\text{He}$ methods on various minerals . . . . .	143
4.4.1. Apatite . . . . .	145
4.4.2. Zircon . . . . .	150
4.4.3. Iron oxides and hydroxides (hematite, magnetite and goethite) . . . . .	153
4.5. Examples of geological applications. . . . .	154
4.5.1. Landform formation and evolution . . . . .	156
4.5.2. Records of landform formation in fore-chain sedimentary basins . . . . .	159

4.5.3. Long-term evolution of continental crust . . . . .	160
4.5.4. Faults and tectonics . . . . .	162
4.5.5. Early orogenesis and inversion of passive margins in the Pyrenees . . . . .	166
4.6. Limitations . . . . .	169
4.7. Acknowledgments . . . . .	169
4.8. References . . . . .	169
 <b>Chapter 5. Application of Low-Temperature Thermochronology to the Dating and Quantification of Tectonic Movements: The Example of Asia . . . . .</b>	187
Marc JOLIVET	
5.1. Introduction . . . . .	187
5.2. A few reminders of the principles of fission-track thermochronology . . . . .	190
5.3. The contribution of fission tracks to understanding the India–Asia collision . . . . .	192
5.3.1. Fission track ages in Asia and their relationship to landforms . . . . .	192
5.3.2. The exhumation of Cenozoic chains . . . . .	194
5.3.3. Areas with very low exhumation rates: the Mongolian and Siberian ranges . . . . .	209
5.4. Conclusion . . . . .	211
5.5. References . . . . .	212
 <b>Conclusion . . . . .</b>	227
Marc JOLIVET	
 <b>List of Authors . . . . .</b>	233
 <b>Index . . . . .</b>	235