

# Contents

<b>Acknowledgements</b>	<b>iii</b>
<b>Abstract</b>	<b>v</b>
<b>List of Figures</b>	<b>ix</b>
<b>List of Tables</b>	<b>x</b>
<b>1 Introduction</b>	<b>1</b>
References . . . . .	6
<b>2 Deformation in transcurrent and extensional environments with widely spaced weak zones</b>	<b>7</b>
2.1 Abstract . . . . .	7
2.2 Introduction . . . . .	8
2.3 Model setup . . . . .	10
2.4 Results . . . . .	12
2.5 Discussion . . . . .	16
References . . . . .	18
<b>3 Thermally induced brittle deformation in oceanic lithosphere and the spacing of fracture zones</b>	<b>20</b>
3.1 Abstract . . . . .	20
3.2 Introduction . . . . .	21
3.3 Numerical method . . . . .	25

3.3.1	Constitutive model for brittle and plastic deformation . . . . .	26
3.3.2	Thermo-mechanical coupling . . . . .	27
3.4	Model setup . . . . .	29
3.5	Results . . . . .	32
3.5.1	Models with weak crust . . . . .	32
3.5.2	Models with strong crust . . . . .	36
3.5.3	Non-associated plasticity . . . . .	38
3.6	Discussion . . . . .	40
3.6.1	Effects of crustal thickness and creep strength . . . . .	40
3.6.2	Implications of the sensitivity to crustal thickness and creep strength . . . . .	42
3.6.3	Flexure of the segments . . . . .	45
3.6.4	Implications for ridge axial processes . . . . .	45
3.7	Conclusion . . . . .	47
	References . . . . .	48
<b>4</b>	<b>Thermomechanics of mid-ocean ridge segmentation</b>	<b>55</b>
4.1	Abstract . . . . .	55
4.2	Introduction . . . . .	56
4.3	Numerical method . . . . .	59
4.4	Model setup . . . . .	60
4.4.1	Base model and its variations . . . . .	62
4.5	Results . . . . .	69
4.5.1	Variation of $\gamma$ . . . . .	70
4.5.2	Variation in rate of weakening . . . . .	76
4.6	Discussion and conclusion . . . . .	77
	References . . . . .	83
<b>5</b>	<b>Coupling models of crustal deformation and mantle convection with a computational framework</b>	<b>88</b>
5.1	Abstract . . . . .	88

5.2	Introduction . . . . .	89
5.3	Numerical method . . . . .	91
5.3.1	<b>SNAC</b> : Overview . . . . .	91
5.3.2	<b>StGermain</b> framework . . . . .	92
5.4	Coupling through <b>Pyre</b> . . . . .	92
5.4.1	Overview of <b>Pyre</b> . . . . .	93
5.4.2	<i>Coupler</i> . . . . .	93
5.4.3	Coupling <b>RegionalCitcomS</b> and <b>SNAC</b> . . . . .	98
5.5	Benchmarks . . . . .	101
5.5.1	Traction boundary conditions applied on <b>SNAC</b> . . . . .	101
5.5.2	The <b>RegionalCitcomS</b> -to- <b>SNAC</b> transfer of traction . . . . .	101
5.6	Application . . . . .	103
5.6.1	Model Setup . . . . .	103
5.6.1.1	A qualitative 3-D test . . . . .	107
5.6.2	Results . . . . .	108
5.6.3	Discussion . . . . .	109
	References . . . . .	113
<b>A</b>	<b>Algorithm of SNAC</b>	<b>117</b>
A.1	Governing equations . . . . .	117
A.2	Spatial discretization . . . . .	117
A.3	Nodal assemblage . . . . .	119
A.4	Damping and explicit time marching . . . . .	120
A.5	Mass scaling for numerical stability . . . . .	121
A.6	Constitutive update . . . . .	122
	References . . . . .	124
<b>B</b>	<b>Verification of plastic solutions</b>	<b>125</b>
B.1	Oedometer test . . . . .	125
B.1.1	Problem Setup . . . . .	125
B.1.2	Analytic Solutions . . . . .	126

B.1.2.1	Elastic solution . . . . .	126
B.1.2.2	Plastic solution . . . . .	126
B.1.3	Results . . . . .	129
B.2	Thick cylinder with a pressurized inner wall . . . . .	129
B.2.1	Problem Setup . . . . .	129
B.2.2	Analytic Solutions . . . . .	131
B.2.2.1	Elastic solution . . . . .	132
B.2.2.2	Plastic solution . . . . .	133
B.2.3	Results . . . . .	135
	References . . . . .	137