

Contents

<i>Preface</i>	page xi
<i>List of Abbreviations</i>	xiii
<i>Reproduction Permissions</i>	xv
Introduction	1
Section 1 Io, 1610 to 1995: Galileo to <i>Galileo</i>	
1 Io, 1610–1979	7
1.1 Io before <i>Voyager</i>	7
1.2 Prediction of volcanic activity	9
1.3 <i>Voyager</i> to Jupiter	9
1.4 Discovery of active volcanism	12
1.5 IRIS and volcanic thermal emission	18
1.6 Io: the view after <i>Voyager</i>	19
1.7 Summary	24
2 Between <i>Voyager</i> and <i>Galileo</i> : 1979–1995	27
2.1 Silicate volcanism on Io?	27
2.2 Ground-based observations	29
2.3 Observations of Io from Earth orbit	33
2.4 The Pele plume	33
2.5 Outburst eruptions	34
2.6 Stealth plumes	37
2.7 Io on the eve of <i>Galileo</i>	38
3 <i>Galileo</i> at Io	39
3.1 Instrumentation	41
3.2 <i>Galileo</i> observations of Io	46
Section 2 Planetary volcanism: evolution and composition	
4 Io and Earth: formation, evolution, and interior structure	53
4.1 Global heat flow	53
4.2 Planetary formation	55

vi	<i>Contents</i>	
4.3	Post-formation heating	58
4.4	Interior structure	63
4.5	Volcanism over time	70
4.6	Implications	72
5	Magma and volatiles	73
5.1	Basalt	73
5.2	Ultramafic magma	74
5.3	Lava rheology	76
5.4	Sulphur	78
5.5	Sulphur dioxide (SO ₂)	86
Section 3 Observing and modeling volcanic activity		
6	Observations: thermal remote sensing of volcanic activity	93
6.1	Remote sensing of volcanic activity on Earth	93
6.2	Remote sensing of volcanic activity on Io	95
6.3	Remote sensing of thermal emission	96
6.4	Blackbody thermal emission	97
6.5	Multi-spectral observations	98
6.6	The “dual-band” technique	99
6.7	Surface temperature distributions and effect on thermal emission	102
6.8	Hyperspectral observations	102
6.9	Analysis of hyperspectral thermal emission data	102
6.10	Analysis of SSI thermal emission data	107
7	Models of effusive eruption processes	108
7.1	Cooling of lava on Earth and Io	109
7.2	Modeling lava solidification and cooling	114
7.3	Volumetric rates (Q_F and Q_E)	127
7.4	Models of lava emplacement	132
7.5	Supply to the surface: conduit geometry	134
7.6	Crustal structure controls on ascent of magma on Io	137
8	Thermal evolution of volcanic eruptions	142
8.1	Effusive activity: landforms and thermal emission evolution	143
8.2	Flux density as a function of eruption style	150
8.3	Summary	152
Section 4 Galileo at Io: the volcanic bestiary		
9	The view from <i>Galileo</i>	155
9.1	Surface changes: <i>Voyager</i> to <i>Galileo</i>	156
9.2	Color and composition	159

<i>Contents</i>		vii
9.3	Discovery of widespread silicate volcanism	165
9.4	The rise (and fall?) of ultra-high-temperature volcanism	169
9.5	PPR observations	175
9.6	<i>Cassini</i> and <i>Galileo</i> observe Io	176
9.7	Adaptive optics and Hubble observations	176
9.8	Other discoveries	177
9.9	Summary	177
10	The lava lake at Pele	178
10.1	Setting	178
10.2	Observations of thermal emission	179
10.3	A lava lake at Pele	182
10.4	Importance of temporal and spectral coverage	183
10.5	Lava lakes	184
10.6	Implications for magma supply and interior structure	185
10.7	Plume composition and implications for volatile supply	185
10.8	Calculation of mass flux and flux densities	186
10.9	Further comparison with lava lakes on Earth	187
10.10	Summary	190
11	Pillan and Tvashtar Paterae: lava fountains and flows	192
11.1	Lava fountains: outbursts explained?	192
11.2	Pillan 1997: flood lavas and the emplacement of long flows	194
11.3	Tvashtar Paterae	200
11.4	Lava fountains on Io	201
11.5	Terrestrial analogues: flood basalts and fissure eruptions	202
11.6	Pillan comparisons with terrestrial eruptions	204
11.7	Summary: activity at Pillan in 1997 and at Tvashtar Paterae in 2000	205
12	Prometheus and Amirani: effusive activity and insulated flows	208
12.1	Volcanic activity at Prometheus	208
12.2	Comparison with Pu'u 'O'o-Kupaianaha, Hawai'i	213
12.3	Amirani flow field	215
12.4	Discussion and summary	216
13	Loki Patera: Io's powerhouse	217
13.1	<i>Voyager</i> to <i>Galileo</i>	218
13.2	Style of activity	219
13.3	Temporal behavior	220
13.4	Resurfacing of Loki Patera	222
13.5	Modeling the resurfacing process	225

viii	<i>Contents</i>	
	13.6 Magma volume at Loki Patera	227
	13.7 Summary: a class of its own	228
14	Other volcanoes and eruptions	229
	14.1 Tupan Patera	229
	14.2 Culann Patera and environs	230
	14.3 Zamama	230
	14.4 Gish Bar Patera	232
	14.5 Emakong Patera: sulphur volcanism?	232
	14.6 Balder and Ababinili Paterae: SO ₂ flows?	234
	14.7 The plumes of Surt and Thor	234
	Section 5 Volcanism on Io: the global view	
15	Geomorphology: paterae, shields, flows, and mountains	239
	15.1 Paterae on Io and calderas on Earth	239
	15.2 Shield volcanoes	245
	15.3 Lava flow morphology	249
	15.4 Lava channels	250
	15.5 Mountains and formation mechanisms	251
	15.6 Conclusions	252
16	Volcanic plumes	253
	16.1 Explosive activity on Io and Earth	253
	16.2 Io observations	256
	16.3 Plume types	257
	16.4 Plume models	267
	16.5 Summary	268
17	Hot spots	269
	17.1 Variability and style of activity	270
	17.2 Thermal emission comparisons	276
	17.3 Effusion rates	277
	17.4 Distribution of hot spots	278
	17.5 Heat transport by eruption class	280
	Section 6 Io after Galileo	
18	Volcanism on Io: a post-Galileo view	287
	18.1 Volcanism and crustal structure	287
	18.2 Magma composition	288
	18.3 Crust volatile content	289
	18.4 Hot-spot variability	290
	18.5 Eruption styles	290
	18.6 Plumes	291
	18.7 Volcanism on Io and Earth	292
	18.8 Questions	292

	<i>Contents</i>	ix
19	The future of Io observations	294
19.1	Spacecraft observations	294
19.2	Imaging Io	298
19.3	Artificial intelligence, autonomy, and spacecraft operations	300
19.4	Telescope observations	302
	<i>Appendix 1 Io hot-spot locations</i>	305
	<i>Appendix 2 Io maps</i>	310
	<i>References</i>	317
	<i>Index</i>	341
	<i>Color plates follow page 208</i>	