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Is Io Impossible (petrologically)?

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Outline

- What Io is supposed to do
- Io doesn’t listen…
- Maybe Io does this?

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Starting Postulates

- Io is erupting enough lava to resurface the whole body 1 cm/year.
- Io is made of the same (generally chondritic) stuff as the rest of the Solar System

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Conclusion:

- Each (silicate) part of Io should have been magmatically processed (undergone partial melting) an average of 400 times.
  - Io should have a 50 km thick low density alkali and Si-rich crust of feldspars and nepheline with melts <1100 ºC
  - The bulk of the mantle should be pure forsterite
  - An Fe+Ca-rich high density lower mantle?

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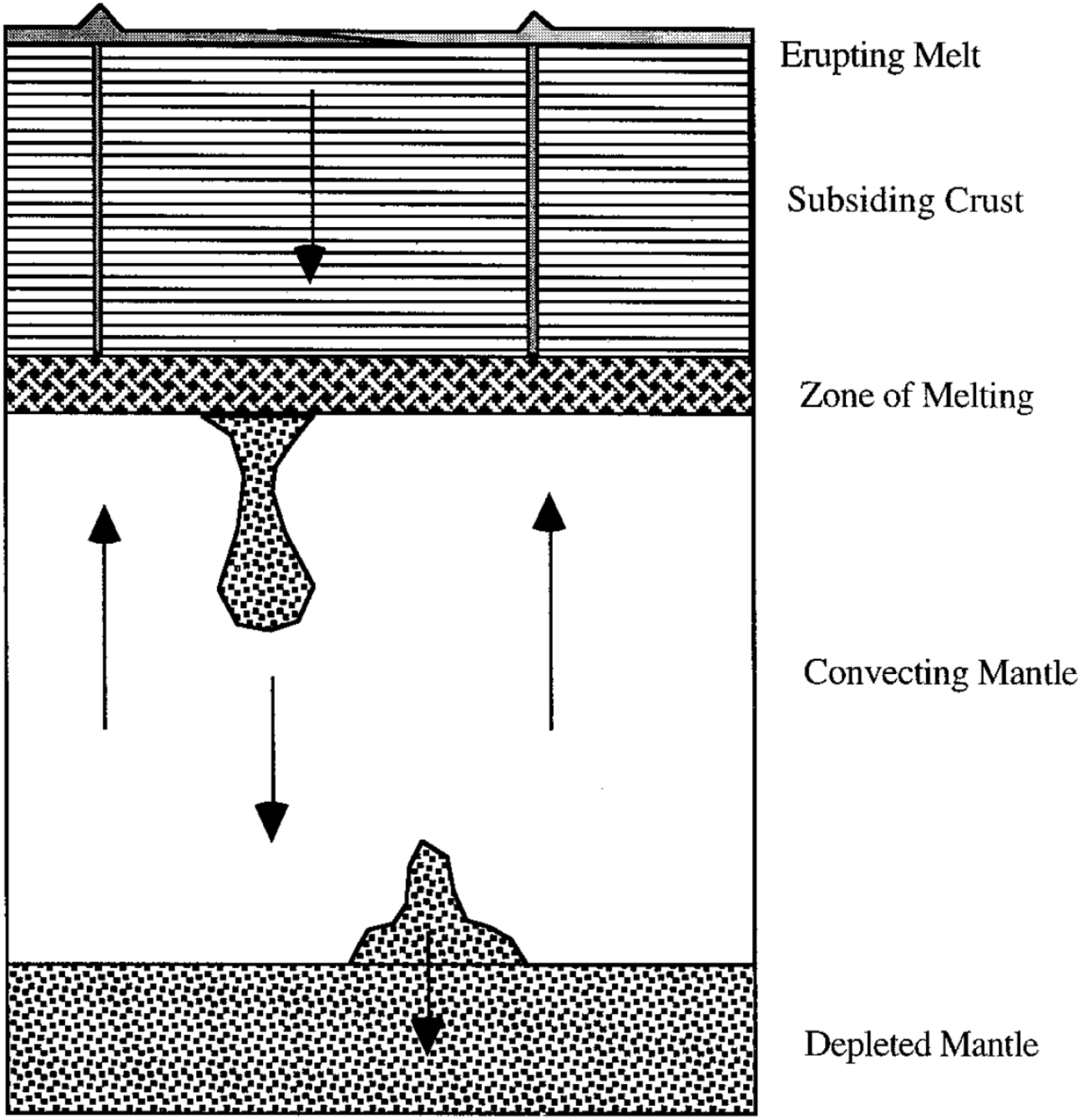
Erupting Melt
Subsiding Crust
Zone of Melting
Convecting Mantle
Depleted Mantle

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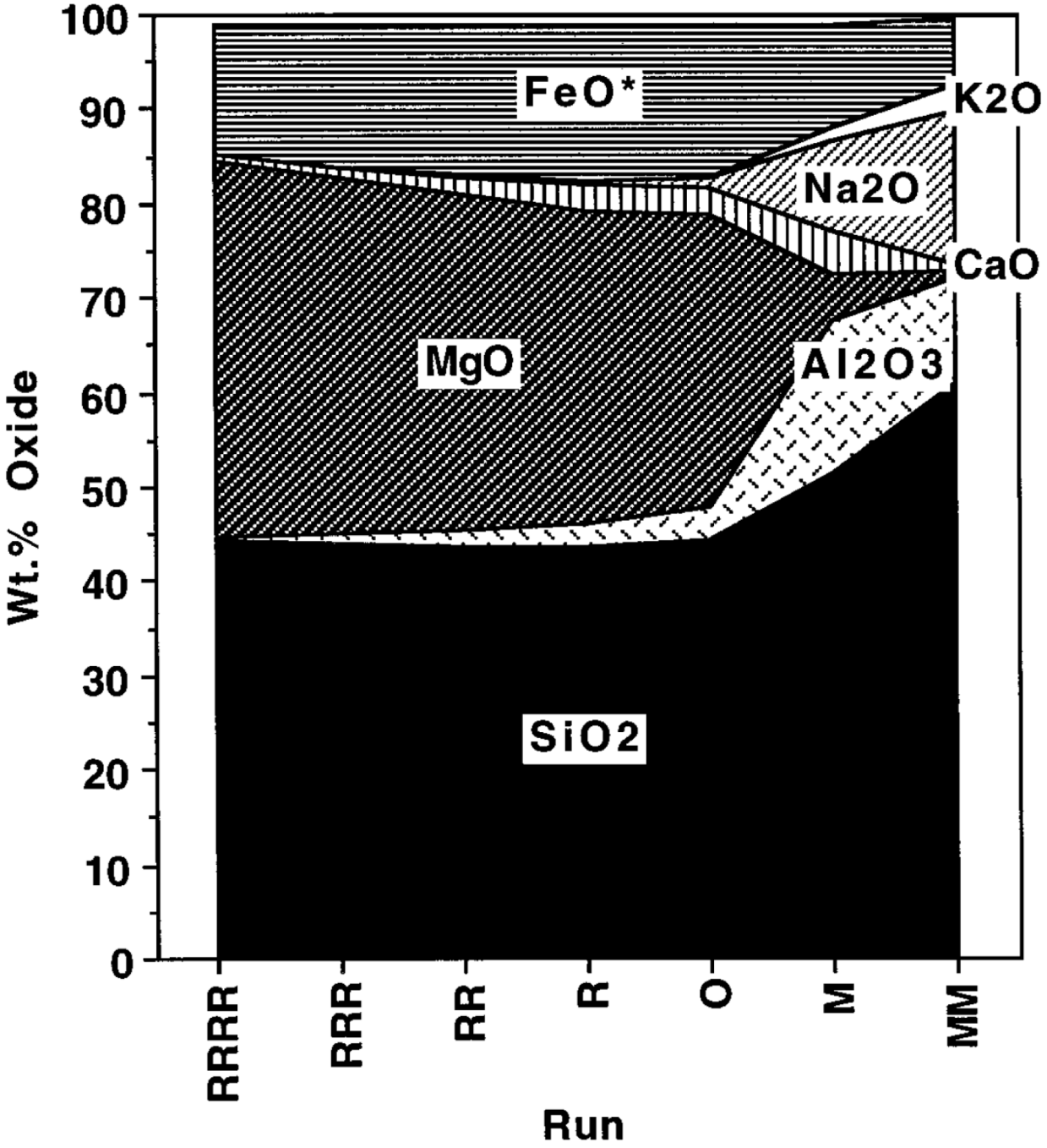
100
90
80
70
60
50
40
30
20
10
0
Wt.% Oxide
FeO*
K2O
Na2O
CaO
MgO
Al2O3
SiO2
RRRR
RRR
RR
R
O
M
MM
Run

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Robust Conclusion!

TABLE III
Comparison of Predicted Crustal Properties for the 5 Models

	BASELINE	P = 1 kbar	1 wt.% H_2O	F = 25%	fO_2 = QFM
Crust thickness	54 km	63 km	54 km	40 km	54 km
Crust density (g/cc)	2.87	2.69	2.65	2.78	2.91
Common lavas	andesite–baseltic andesite	rhyolite–dacite	andesite–baseltic andesite	baseltic andesite–basalt	andesite–baseltic andesite
Eruption temp. [°C]	1010–1067	1000–1117	625–1064	1020–1091	930–1065

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Io gets to speak…

Table 1
Previously reported ionian eruptions with temperatures >1200°C

Eruption	Date	Instrument[a]	Model eruption temperature	Reference
~North Pole	06OCT1996	IRTF NSFCAM	⩾1430°C[b]	Stansberry et al. (1997)
Kanehekili	03APR1997	Galileo SSI	⩾1270°C[b]	McEwen et al. (1998b)
	06MAY1997	Galileo SSI	⩾1210°C[b]	McEwen et al. (1998b)
Pillan	28JUN1997	Galileo SSI+NIMS	~1600°C[c]	Davies et al. (2001)
	08NOV1997	Galileo SSI	⩾1260°C[b]	McEwen et al. (1998b)
Marduk	08NOV1997	Galileo SSI	⩾1300°C[b]	McEwen et al. (1998b)
Pele	29DEC2000	Cassini ISS	⩾1350°C[b]	Radebaugh et al. (2004)
	16OCT2001	Galileo SSI	⩾1250°C[d]	Radebaugh et al. (2004)
	22FEB2000	Galileo NIMS	⩾1280°C[d]	Lopes et al. (2001)
	20JUL1998	Galileo SSI+NIMS	~1250°C[c]	Davies et al. (2001)
Tvashtar	22FEB2000	Galileo SSI	⩾1200°C[b]	Milazzo et al. (2005)

[a] IRTF NSFCAM = Infrared Telescope Facility–NSF Camera, sensitive from 1–5 μm; Galileo SSI = Solid State Imager sensitive from 0.4–1.0 μm; Galileo NIMS = Near Infrared Imaging Spectrometer sensitive from 0.7–5.2 μm; Cassini ISS = Imaging Sub System, sensitive from 0.4–1.0 μm.

[b] Unresolved hot spot; assumes eruption temperature is ⩾200°C above the measured color temperature.

[c] Fit to combined SSI and NIMS data.

[d] Select group of pixels from image that resolves the hot spot.

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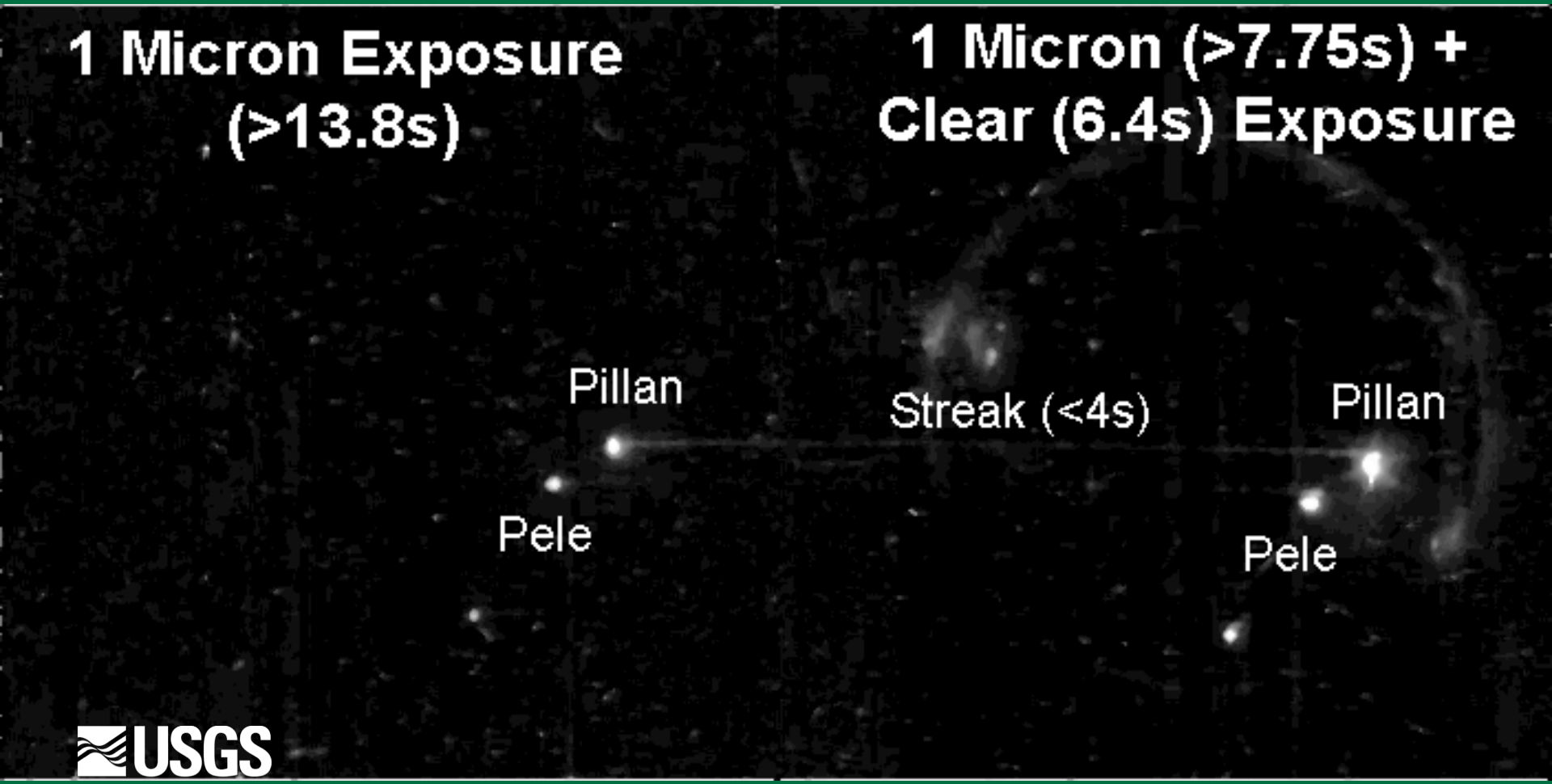
Pillan 1997


1 Micron Exposure
(>13.8s)
1 Micron (>7.75s) +
Clear (6.4s) Exposure
Pillan
Streak (<4s)
Pillan
Pele
Pele
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Conclusion:

- Io is not magmatically differentiated…
  - 100% recycling of erupted lavas back into the mantle (other than incompatible volatiles)
  - Composition of Io's crust is that of a 1st generation melt.
  - Composition of Io's mantle is fertile/primitive
- What happens if the top of such a mantle is at 1300 or 1600 ºC?

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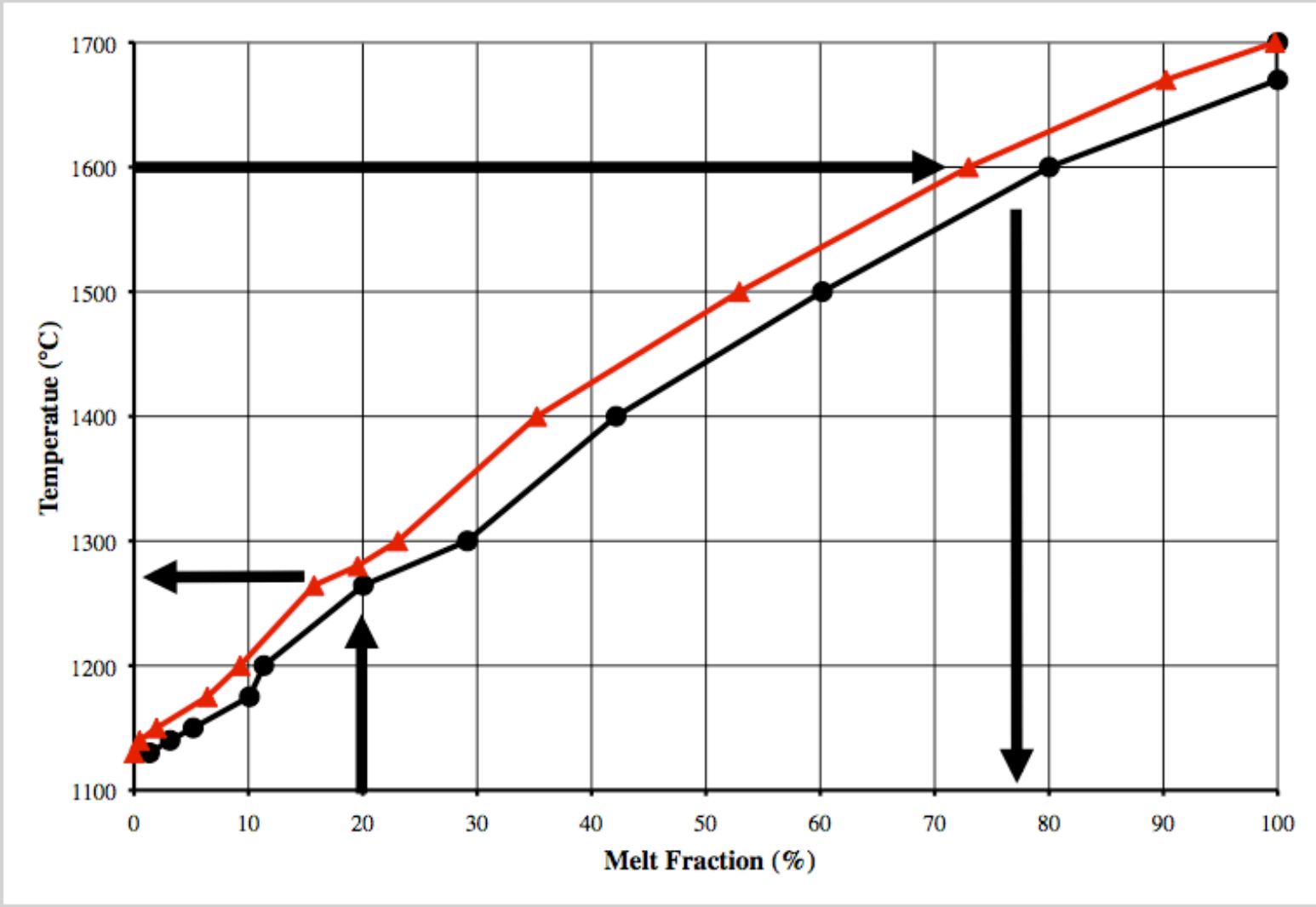
Mantle melting curve



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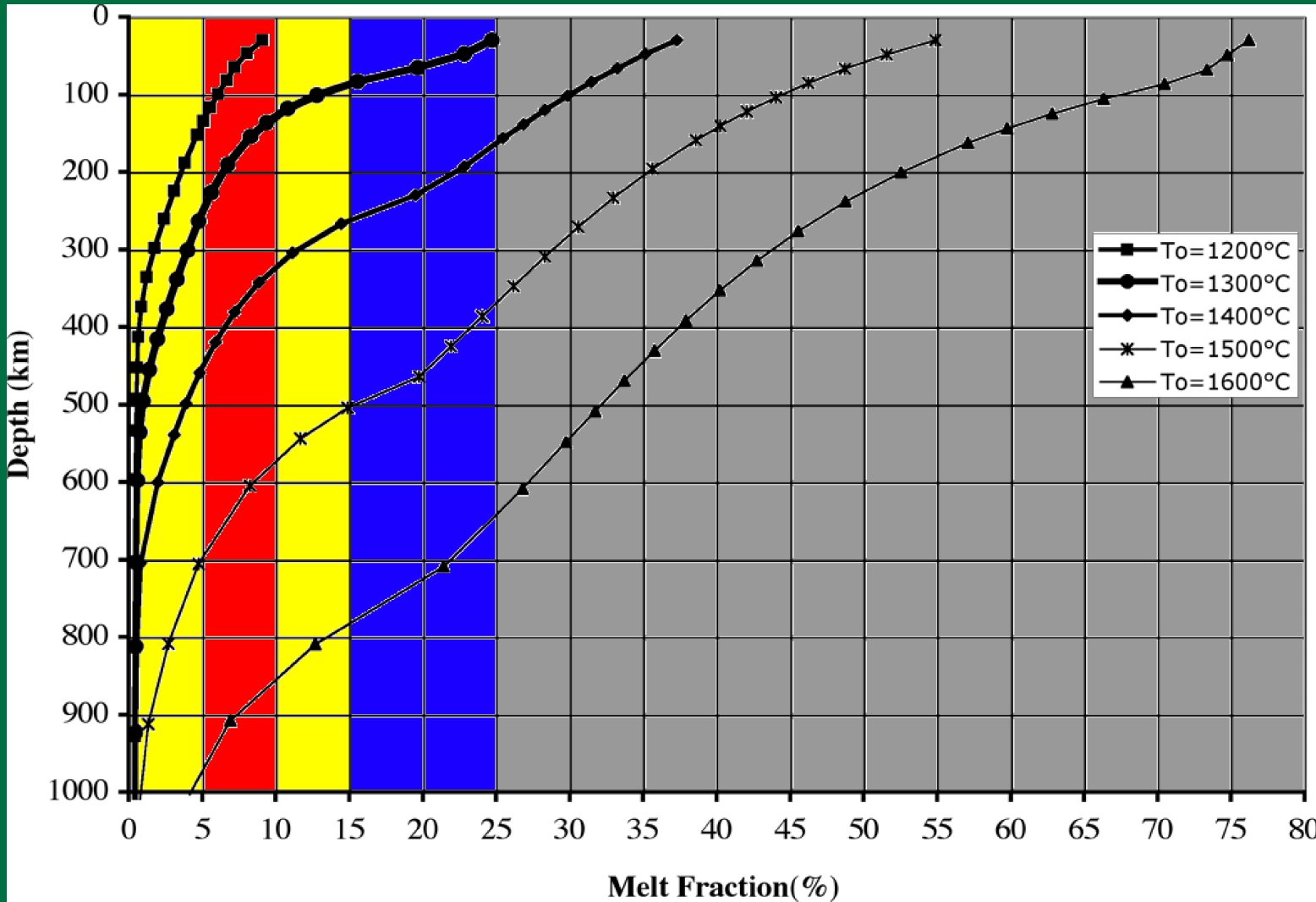
Adiabatic Temperature Profiles



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~1300 ºC is Self-Consistent?

- This is the amount of melting required to overcome the massive compressional stresses at the base of the lithosphere
- More melting results in melts too rich in Fe (and thus too dense) to want to rise through the dunite mantle

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Are 1600 ºC Lavas Possible?

- Yes, if the original assumptions are wrong:
  - If Io is not generally chondritic
  - If Io has been this volcanically active for <1% of geologic time

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