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What controls the explosivity of subglacial eruptions?

December 2014

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  1) Torfajökull (rhyolite)
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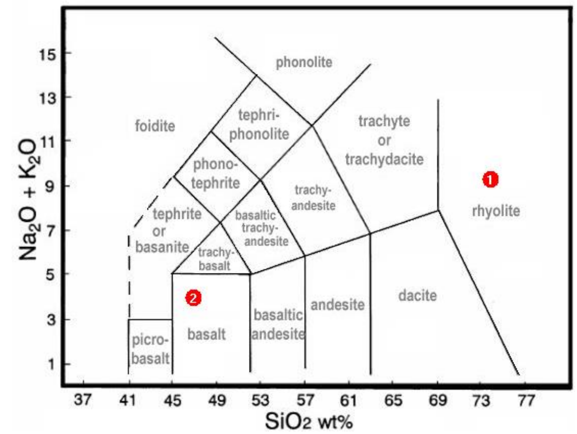
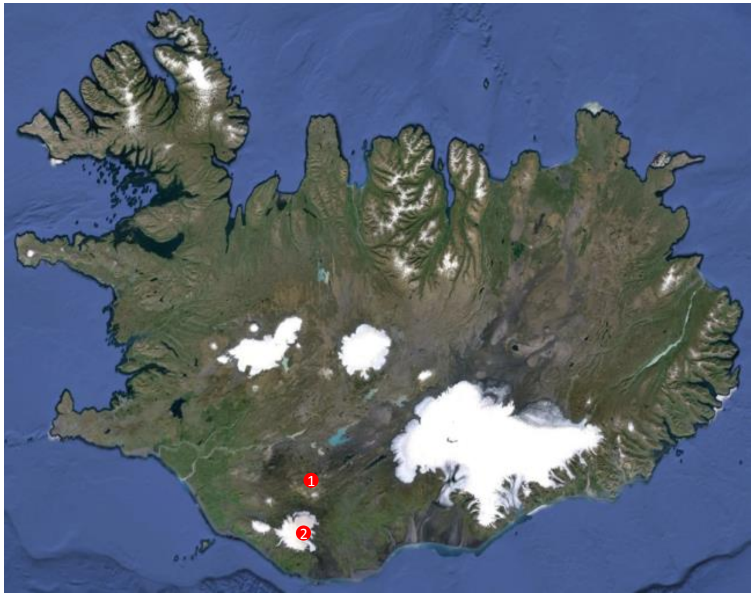
- Conclusion





The geology of Iceland

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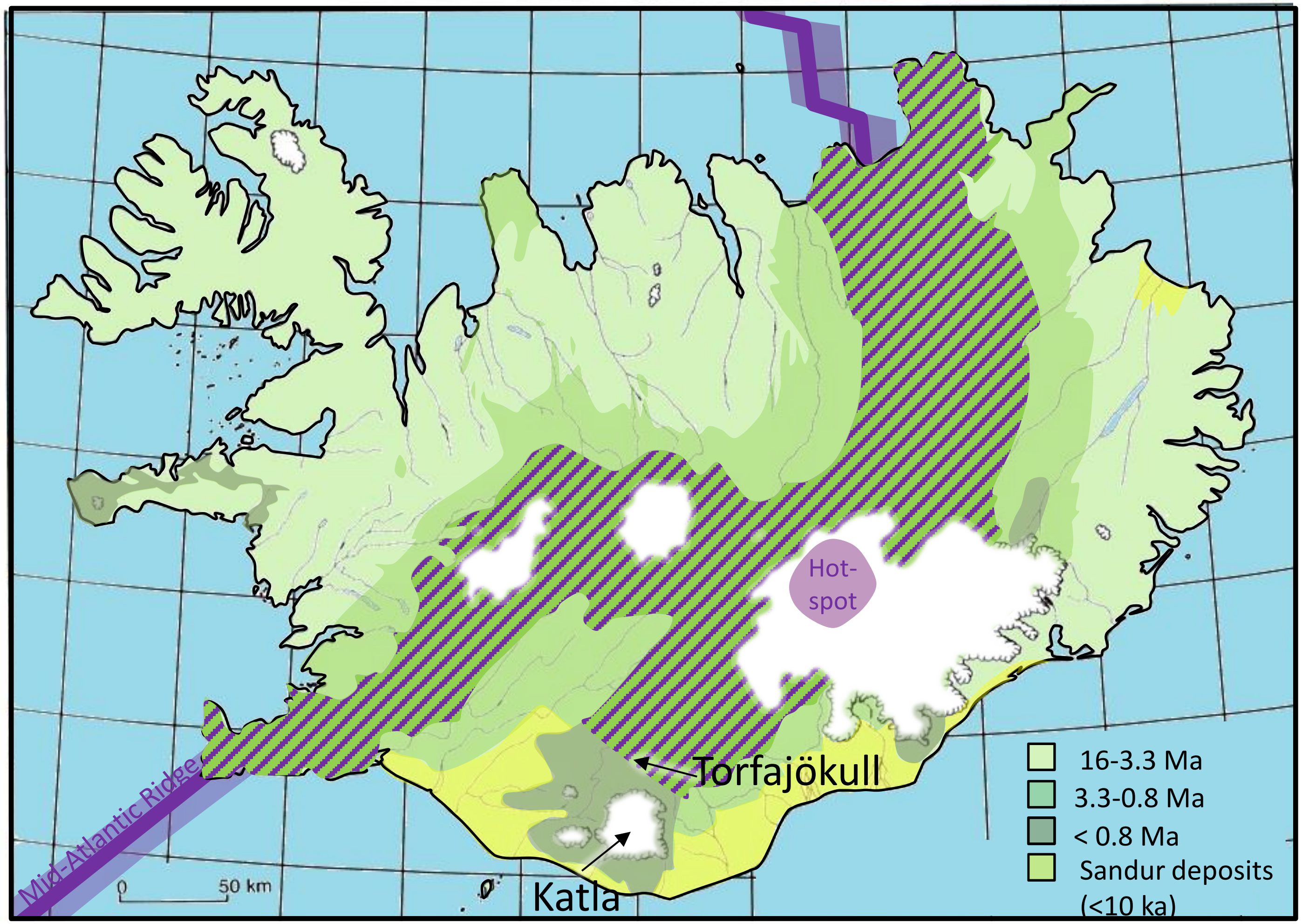
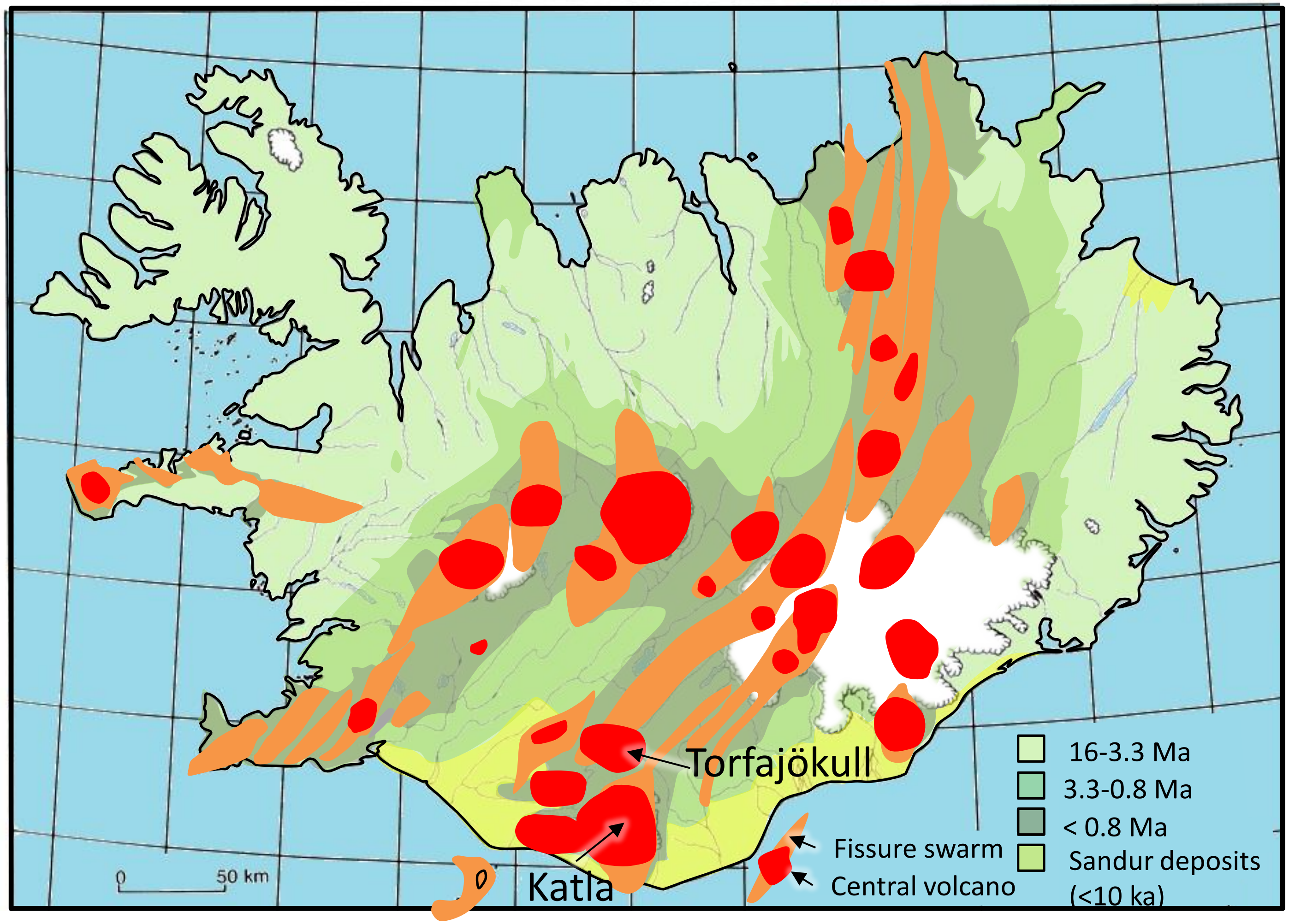
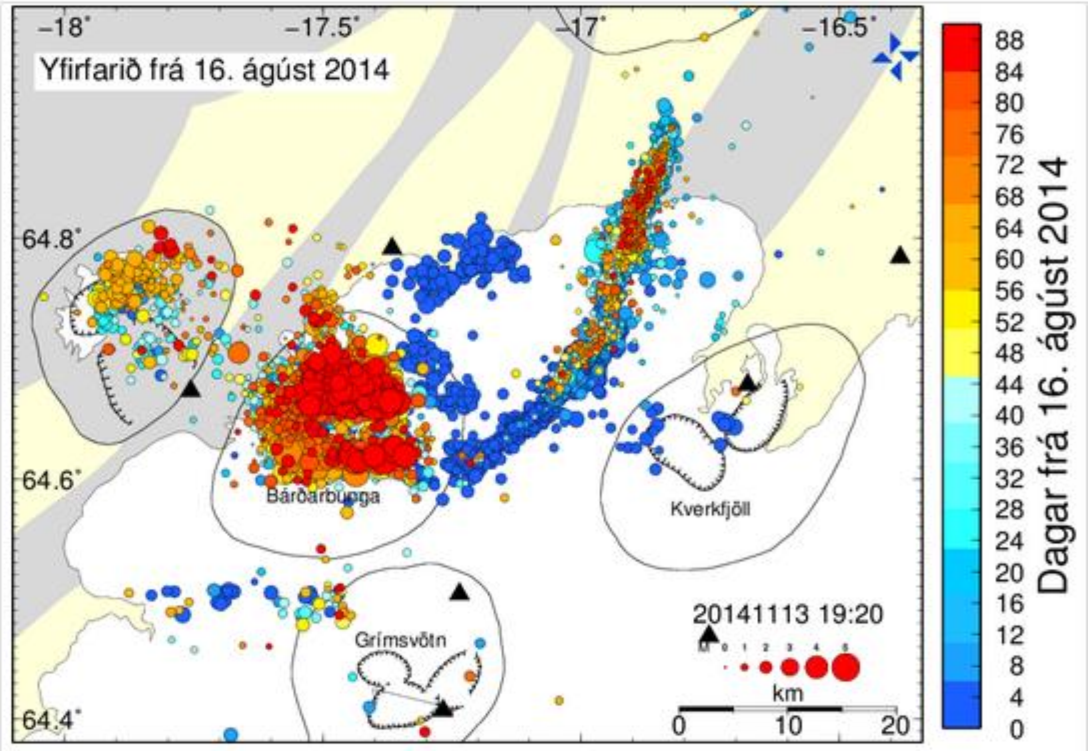
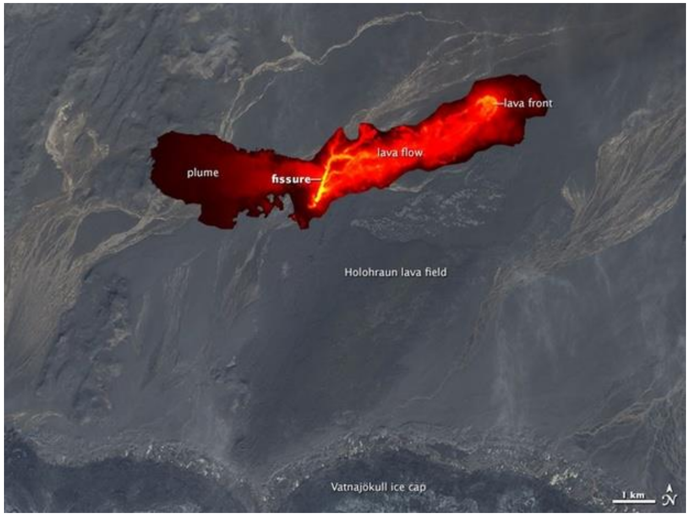


The geology of Iceland



Bárðarbunga





Icelandic Met Office

The geology of Iceland

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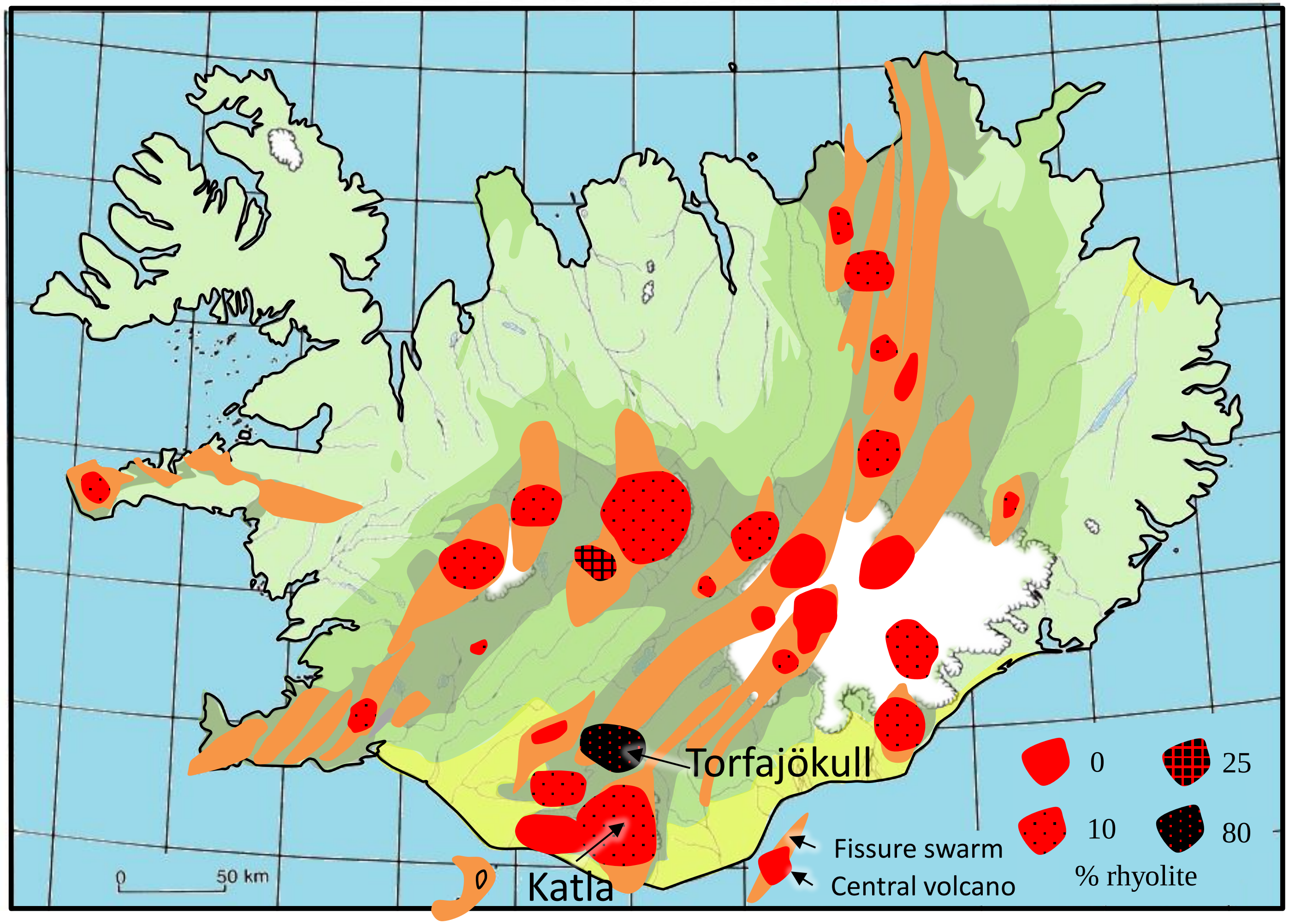

Torfajökull

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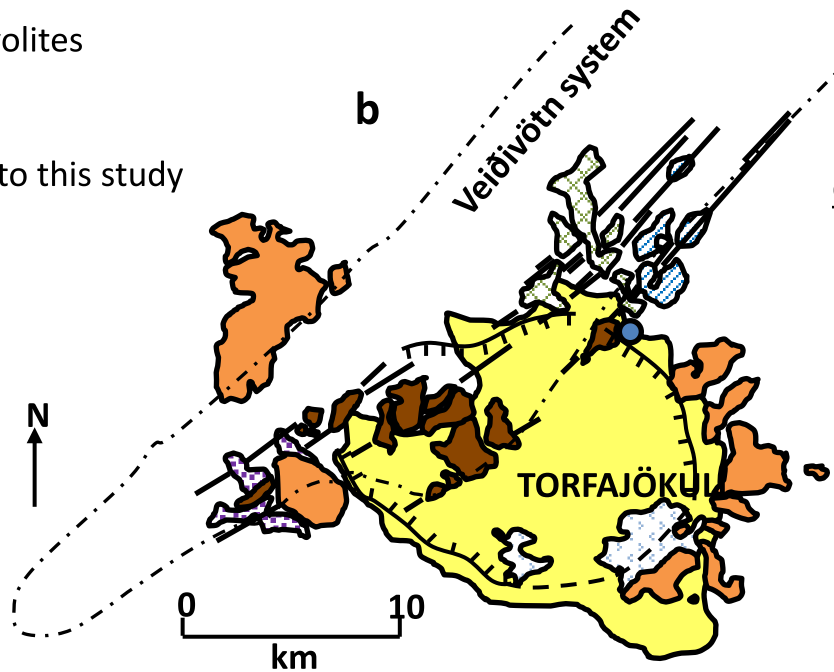
Torfajökull

Subglacial Torfajökull eruptions

- Ring fracture rhyolites
- Older rhyolite
- Edifices relating to this study



Other features

- Torfajökull glacier
- Caldera rim
- Boundary of Veiðivötn system
- Fissures/faults
- Landmannalaugar campsite

Postglacial Torfajökull eruptions

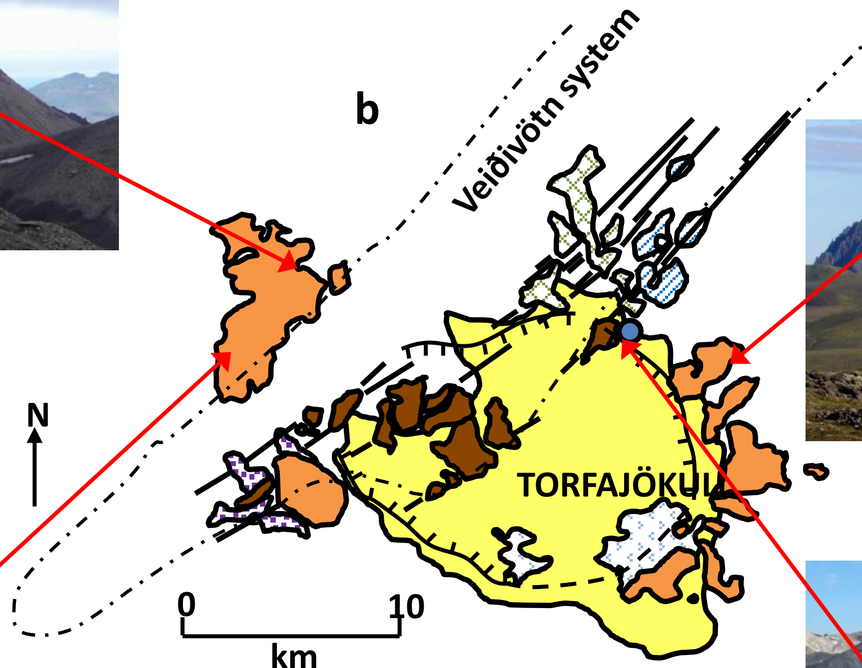
- Rhyolite
- Tholeiite
- Mixed rhyolite-tholeiite
- Alkali basalt

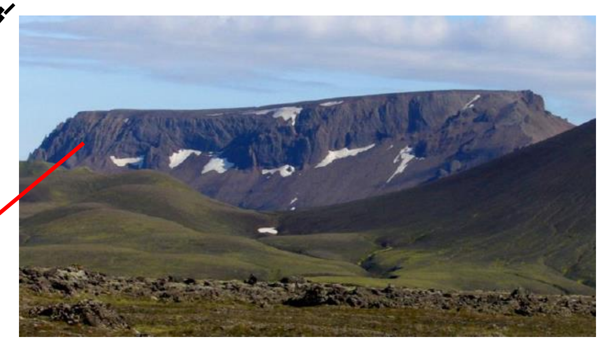
Modified from Owen et al., (2012) *B Volcanol*

Torfajökull

Meat Hook

SE Rauðfossafjöll

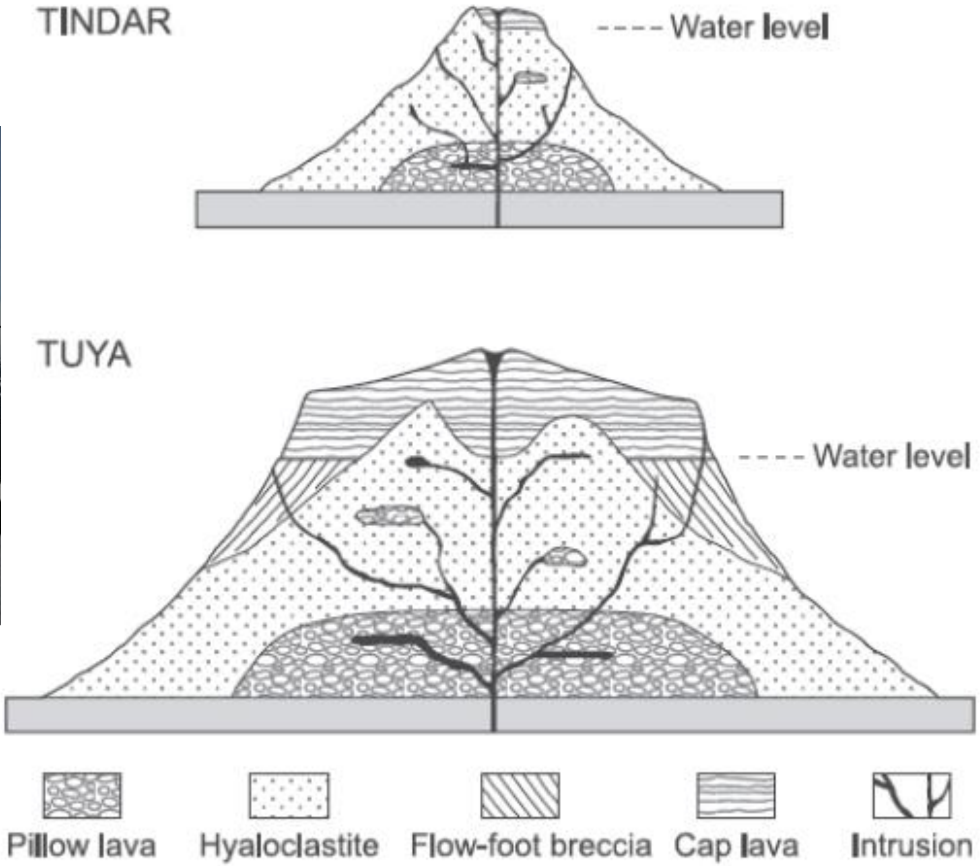




Kirkjufell

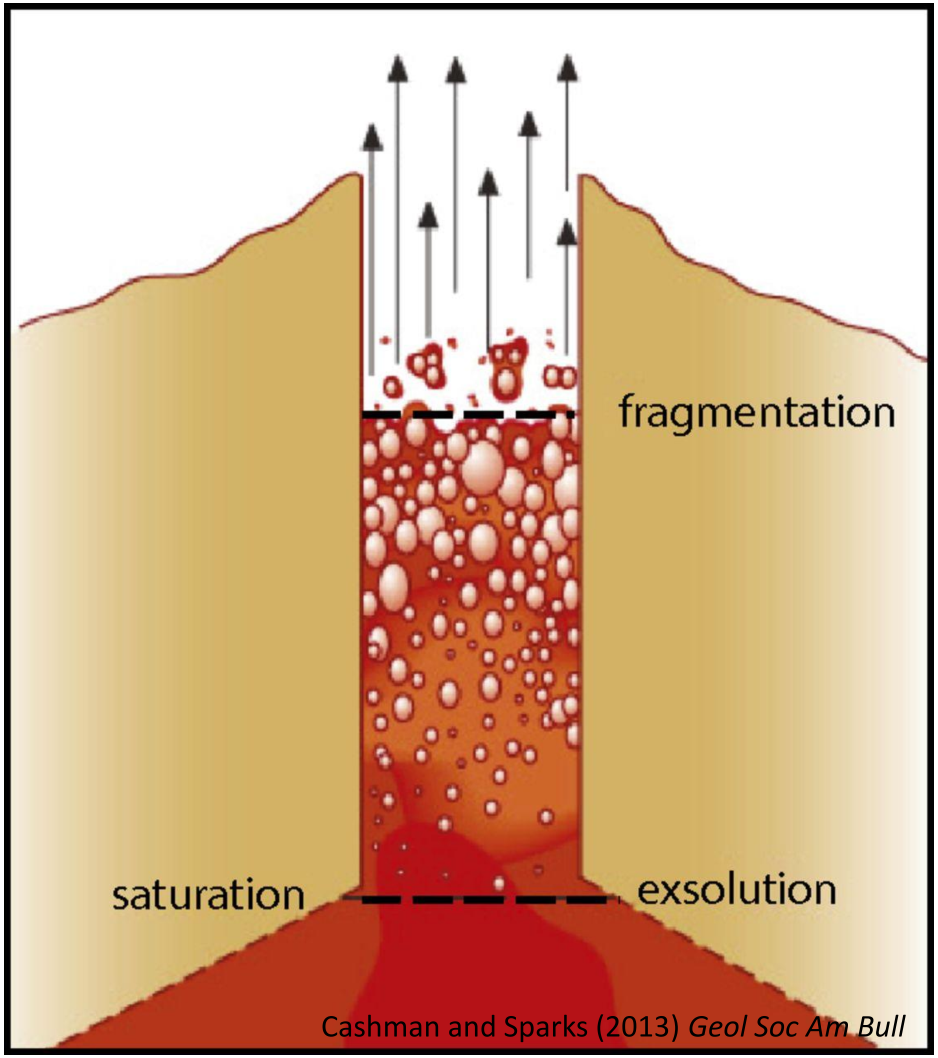
Bláhnúkur

Reconstructing palaeo ice thicknesses



Jakobsson and Guðmundsson (2008), *Jökull*

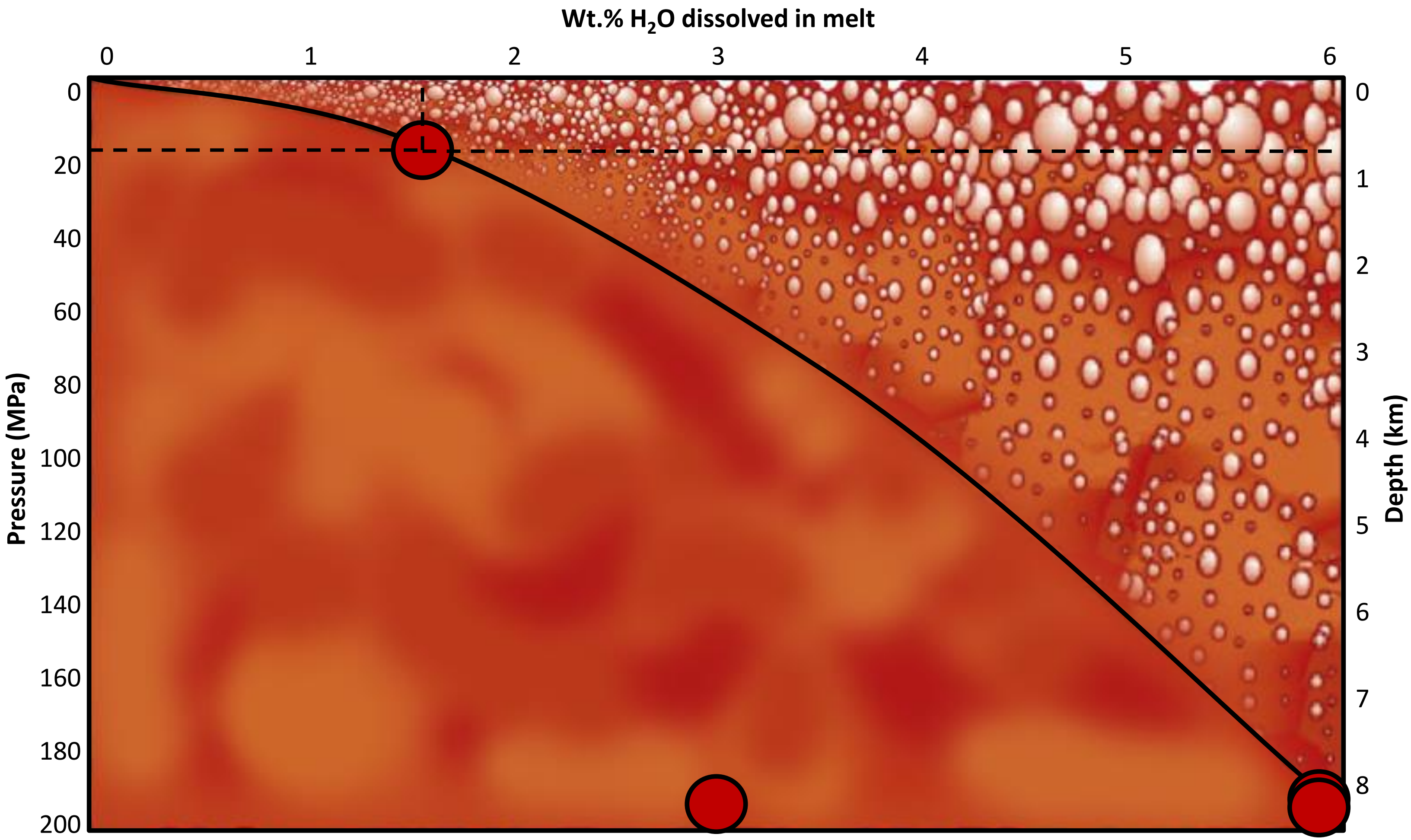
Reconstructing palaeo ice thicknesses



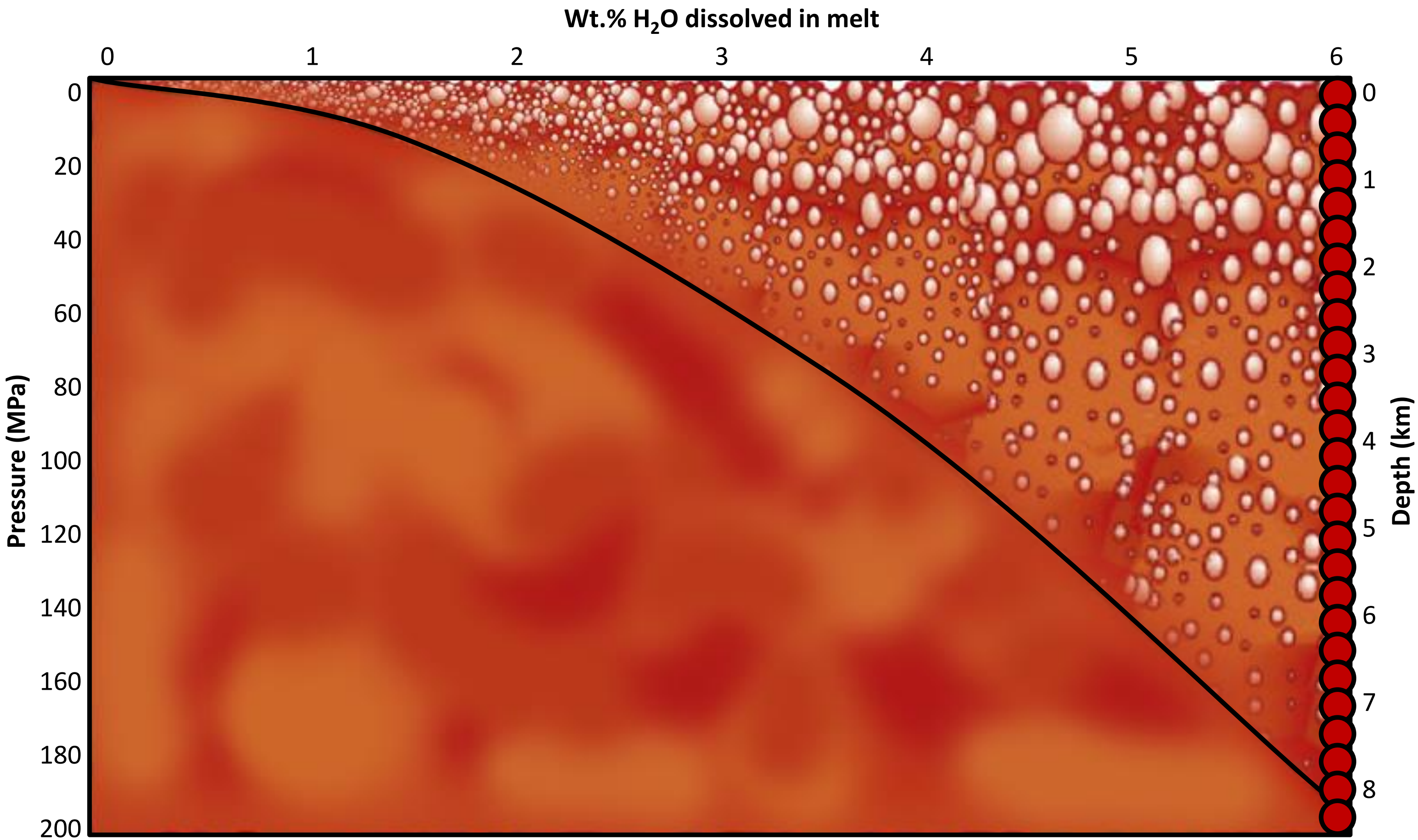
Cashman and Sparks (2013) *Geol Soc Am Bull*

Pressure decreases
Vesicularity increases
Dissolved volatile content decreases

Reconstructing palaeo ice thicknesses



Reconstructing palaeo ice thicknesses



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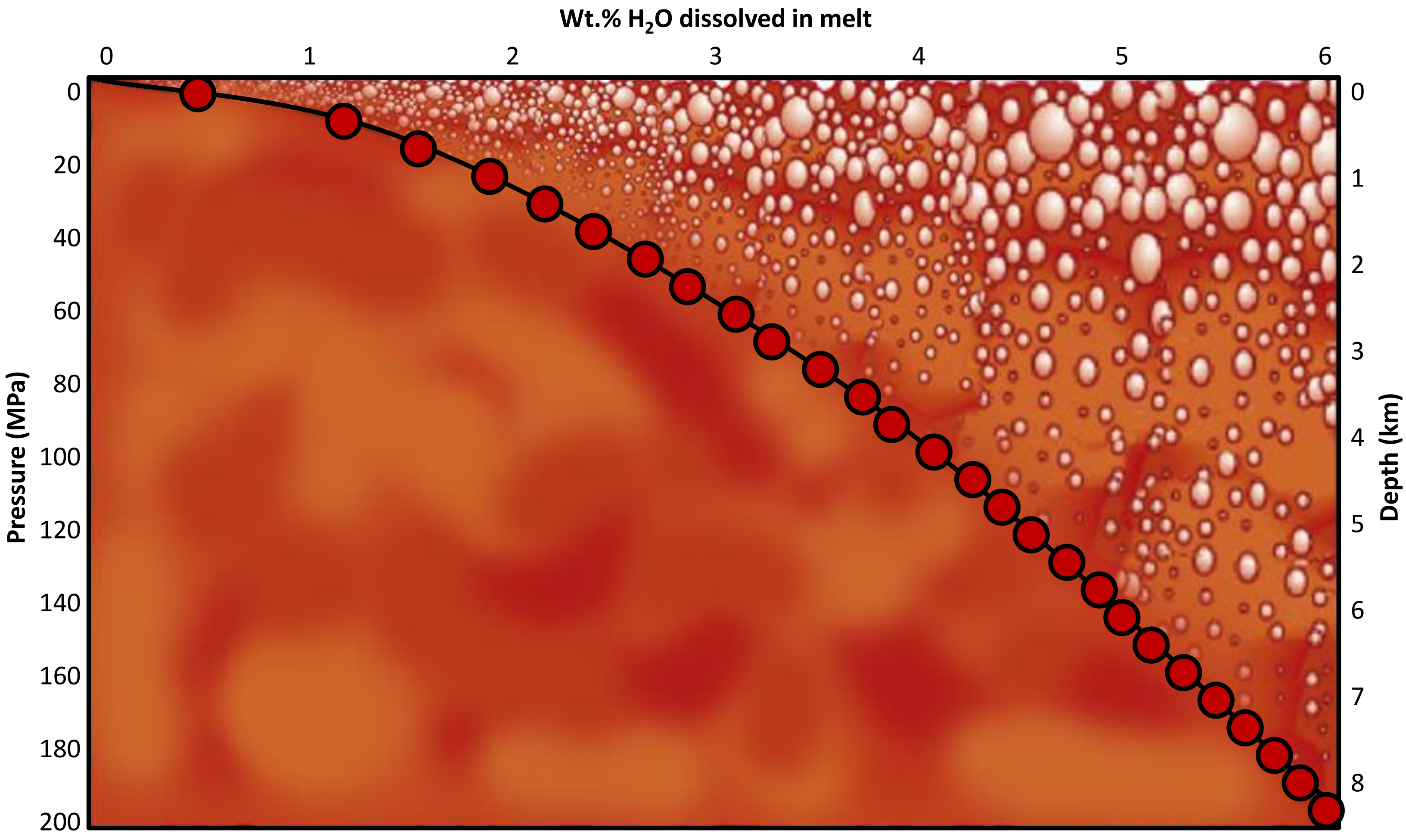
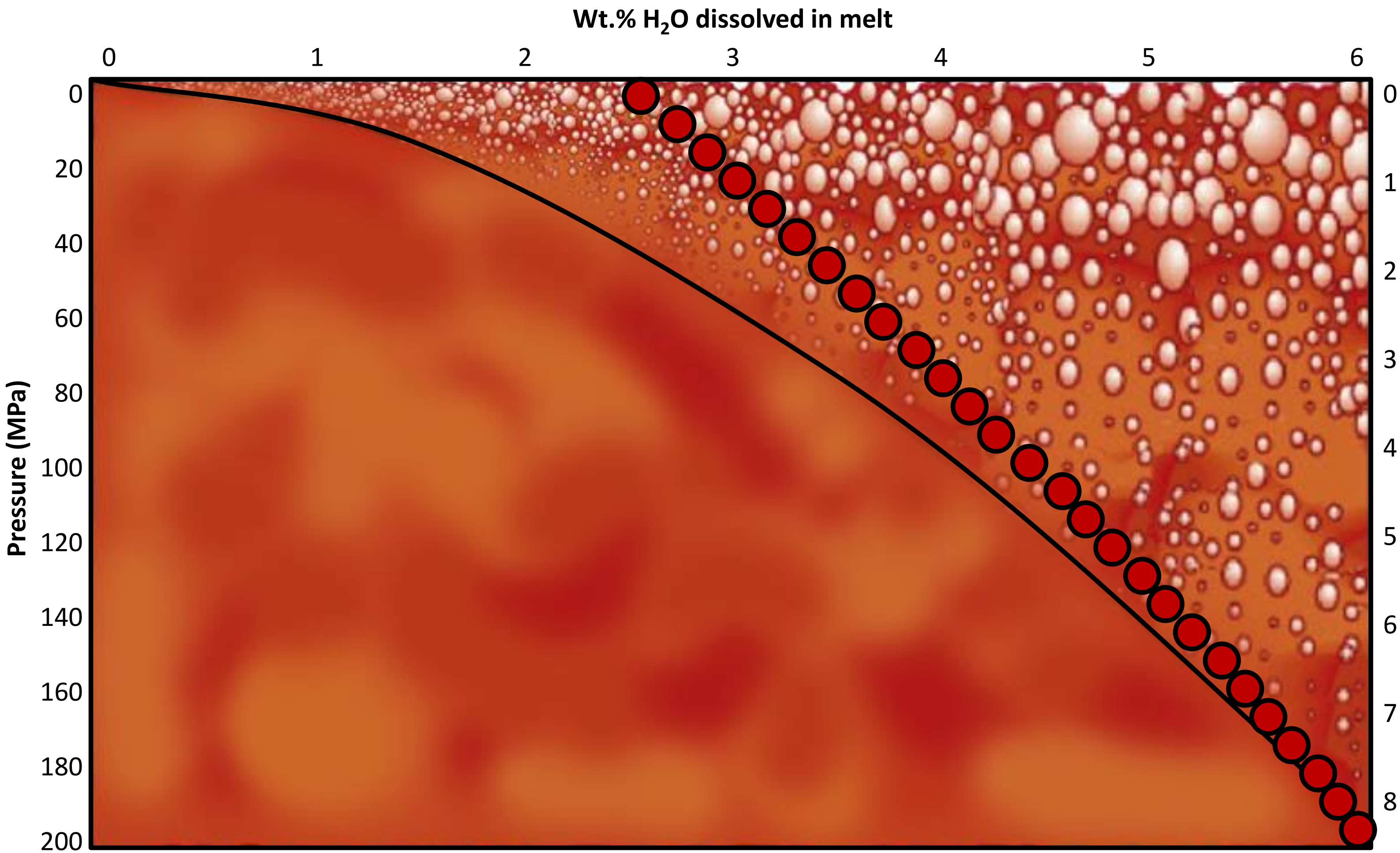
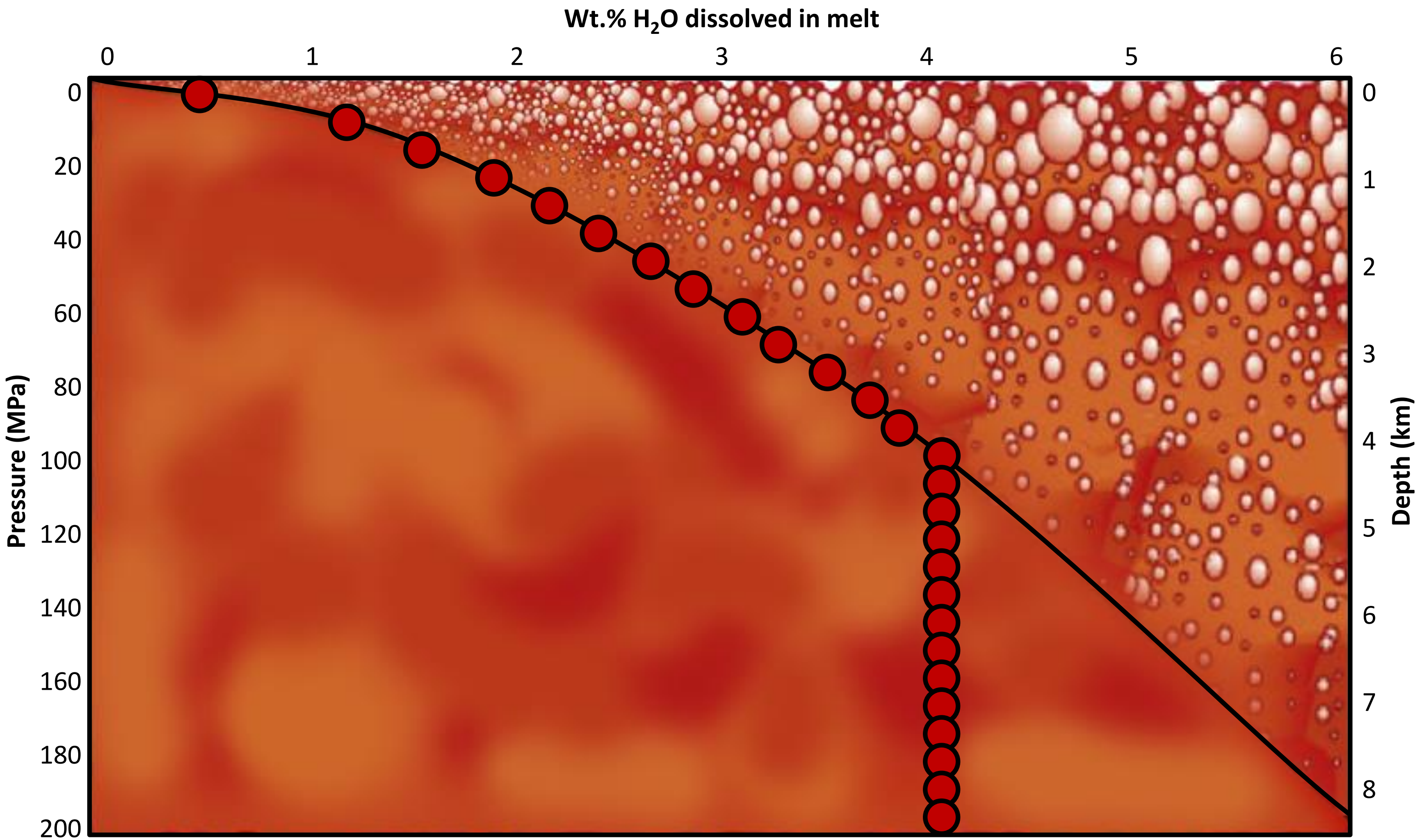


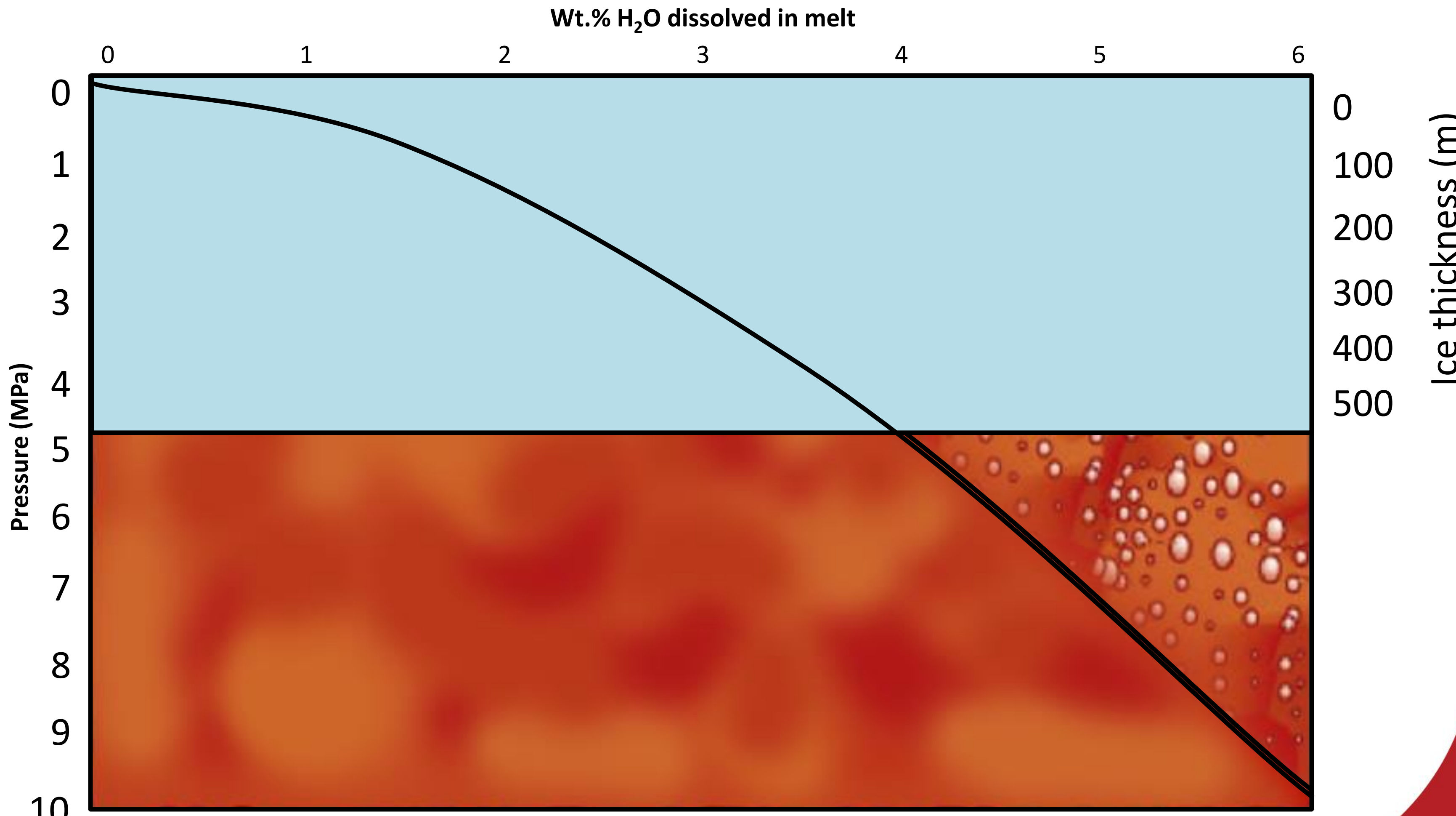
Reconstructing palaeo ice thicknesses



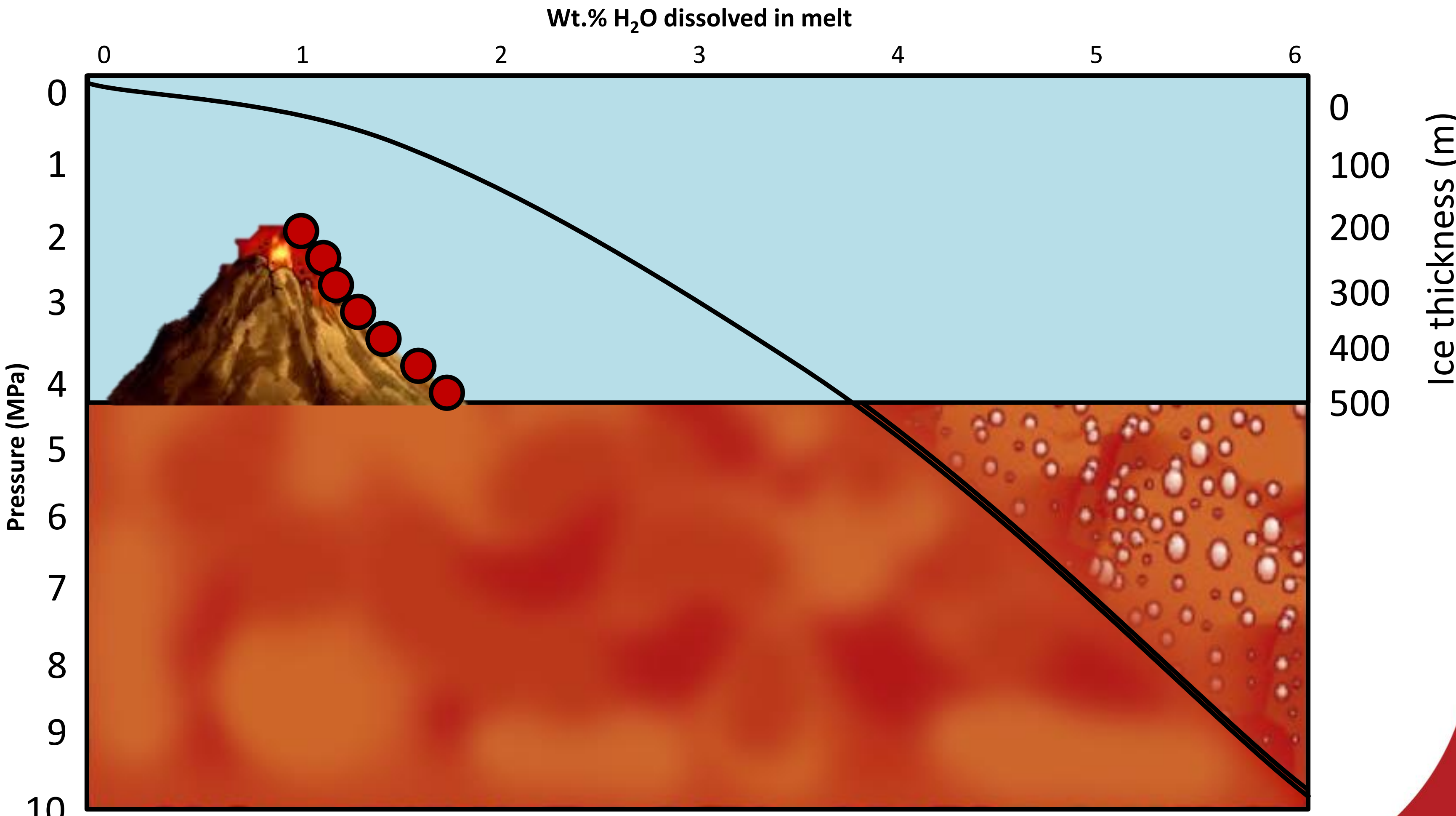
Reconstructing palaeo ice thicknesses



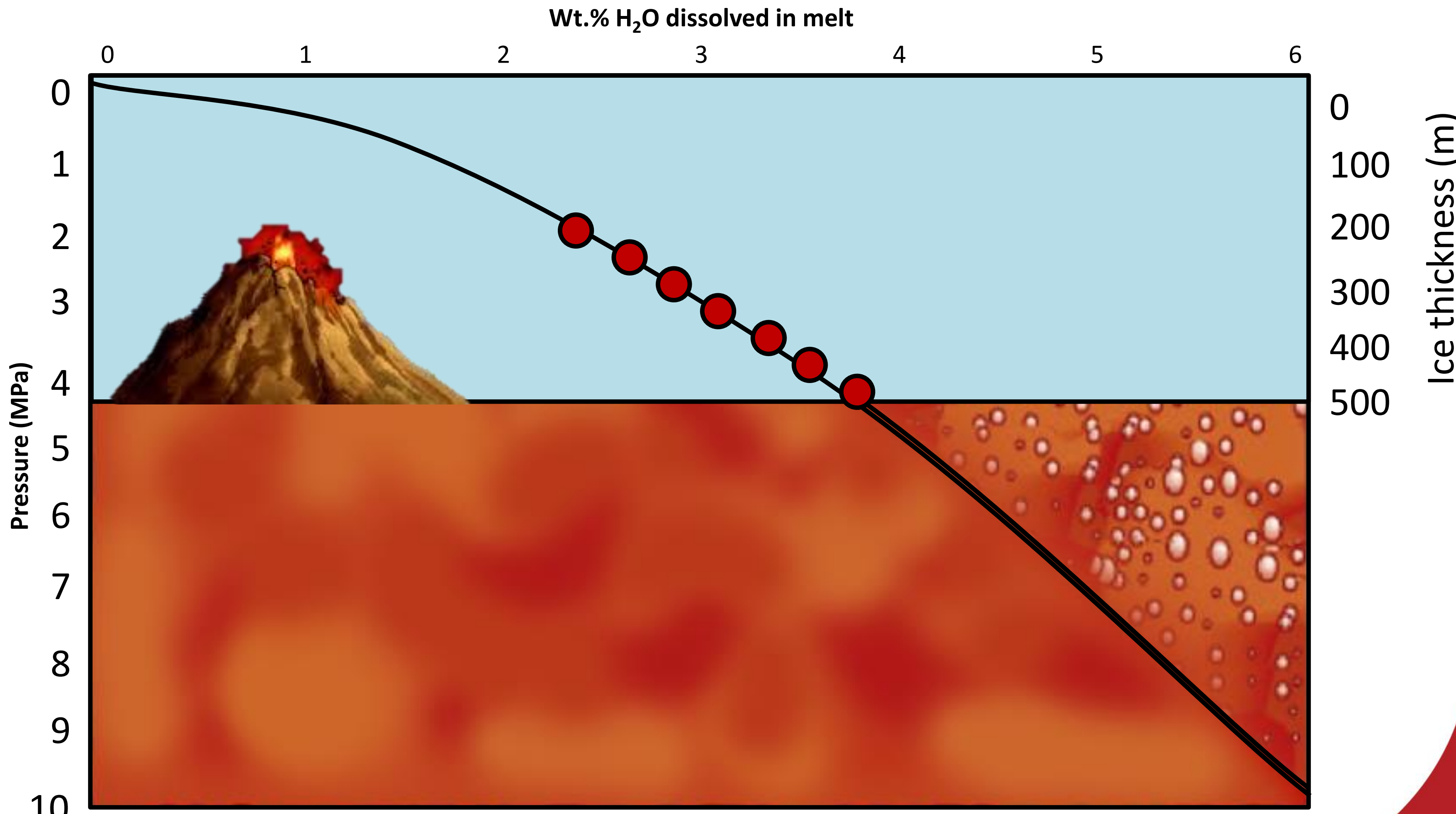
Reconstructing palaeo ice thicknesses



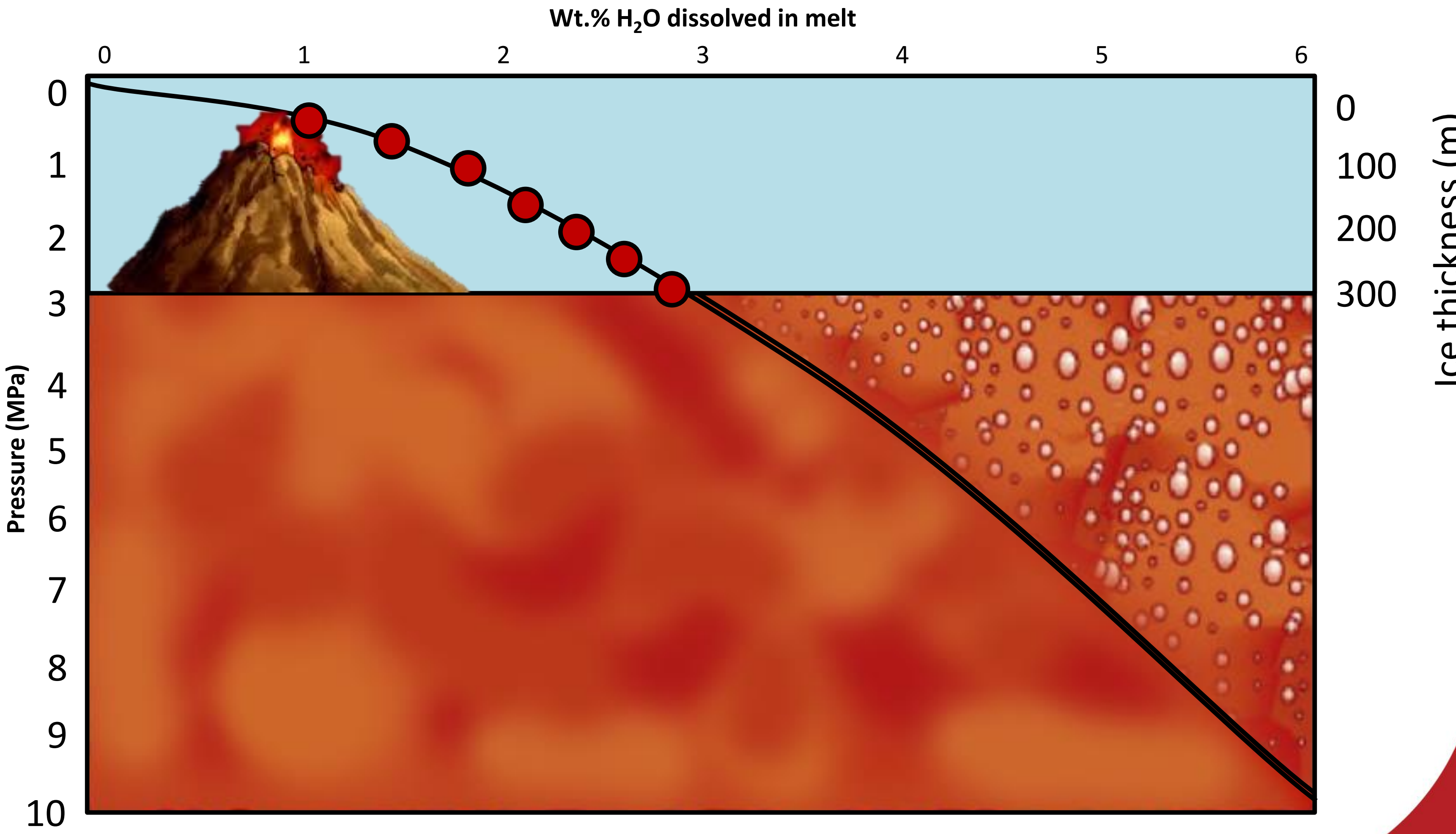
Reconstructing palaeo ice thicknesses



Reconstructing palaeo ice thicknesses



Reconstructing palaeo ice thicknesses



Reconstructing palaeo ice thicknesses

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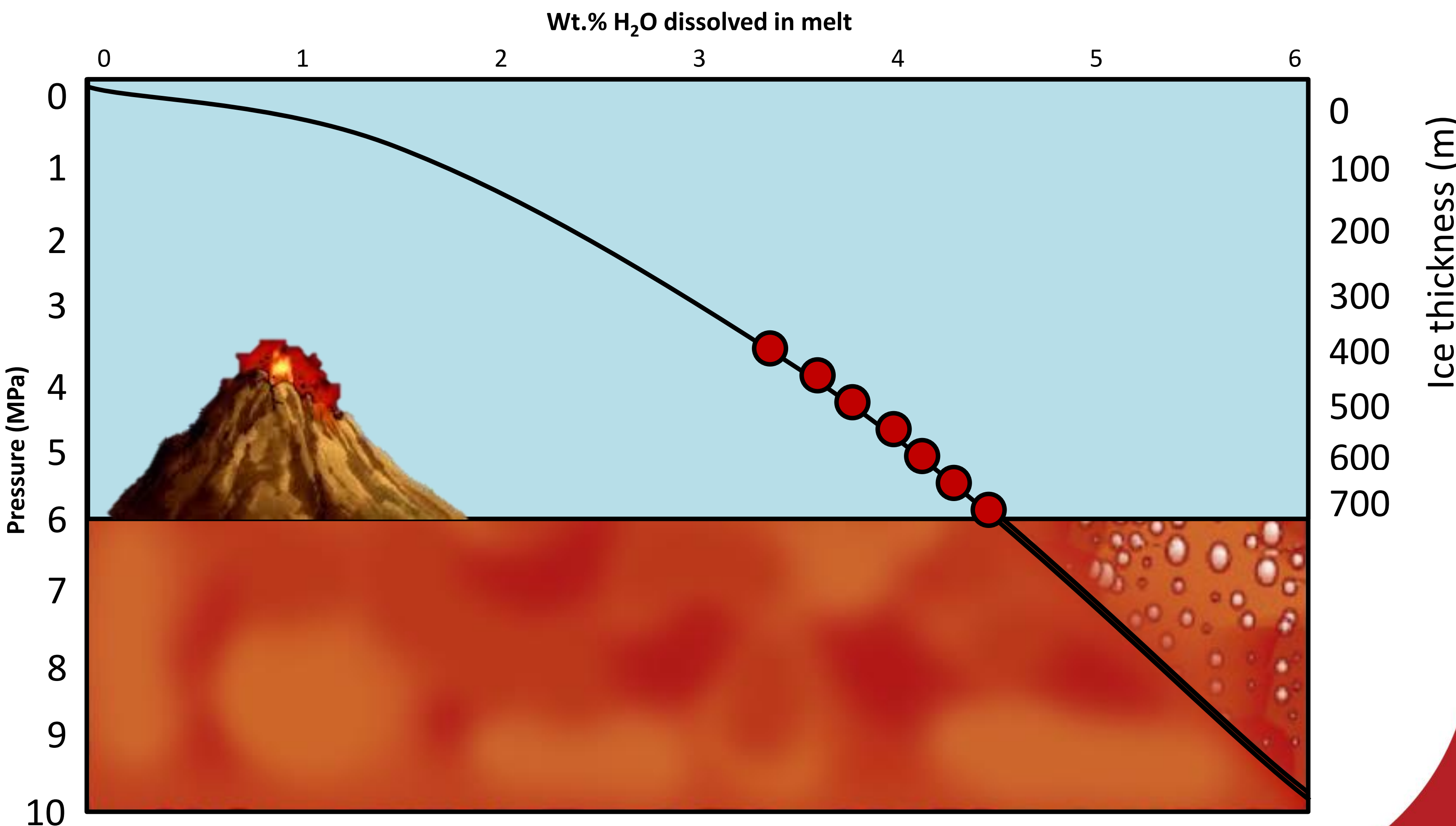

Angel Peak

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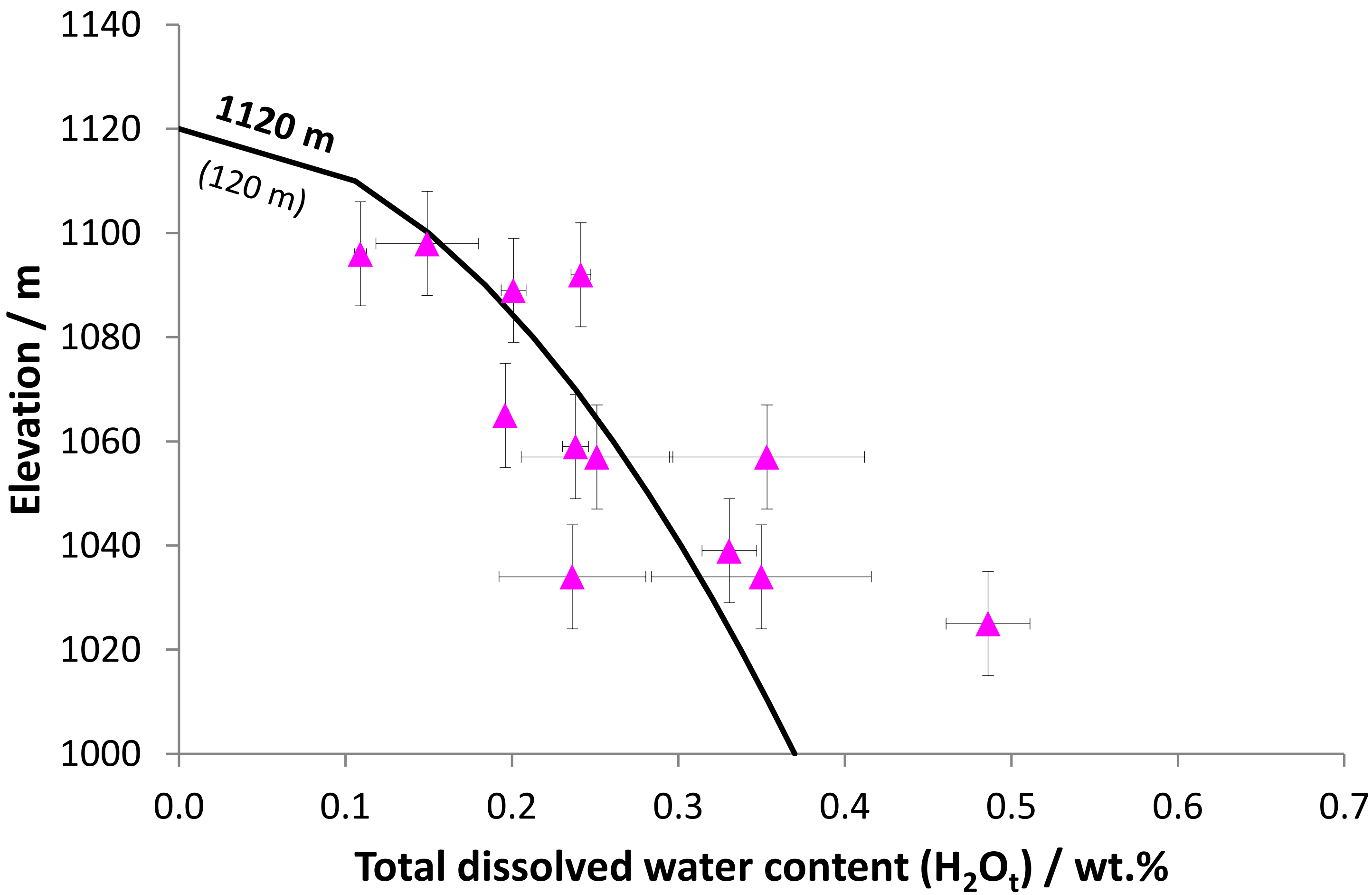

Explosivity vs ice thickness

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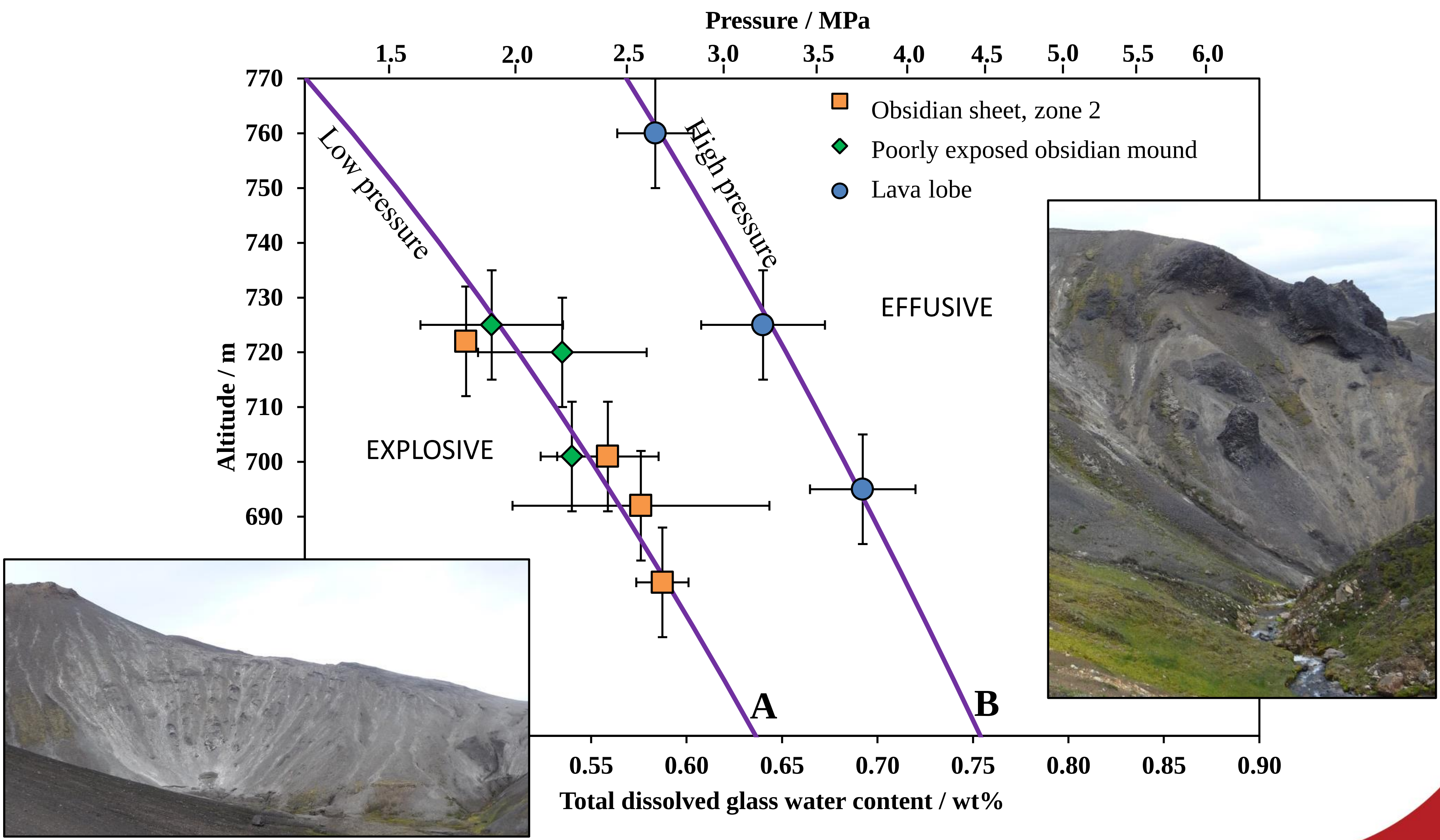
Edifice	Part of ring fracture unit?	Volume (km^3)	Eruptive environment	Inferred ice thickness (m)*	Inferred eruptive style
Angel Peak	Yes	<0.1	Subglacial	120[a]	Effusive
Bláhnúkur	No	<0.1[b]	Subglacial[b]	400[c]	Effusive[b]
Dalakvísl	Yes	<0.2[g]	Subglacial[†g]	330[a]	Mixed: effusive-explosive[g]
SE Rauðfossafjöll	Yes	~1[h]	Emergent[h]	290[i]	Explosive[h]
NW Rauðfossafjöll	Yes	~1	Emergent	290[i]	Explosive

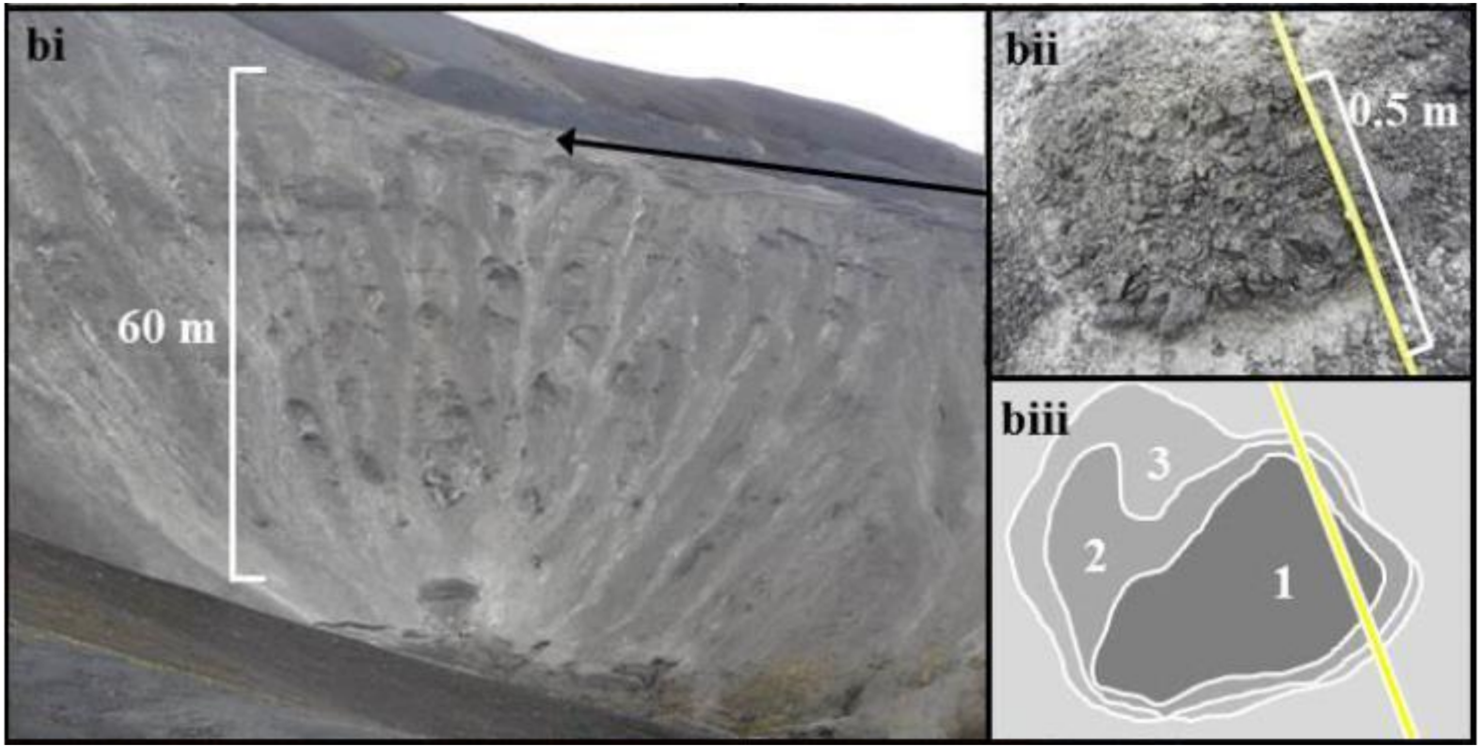
Owen et al., (2013), *Geology*

No relationship

Dalakvísl


Pressure / MPa
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
770
760
750
740
730
720
710
700
690
Altitude / m
Obsidian sheet, zone 2
Poorly exposed obsidian mound
Lava lobe
Low pressure
High pressure
EFFUSIVE
EXPLOSIVE
A
B
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
Total dissolved glass water content / wt%

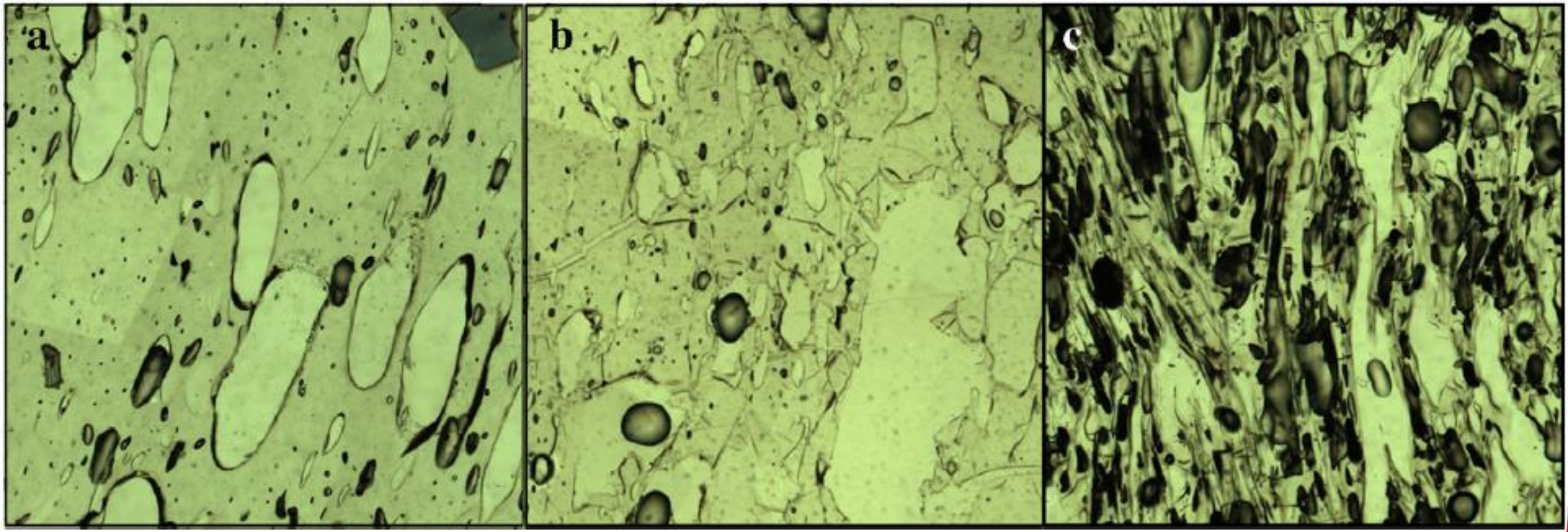
Dalakvísl obsidian sheets



Owen et al., (in prep.), *Jökull*

Dalakvísl obsidian sheets

core → margin



1000 µm

Owen et al., (2013), *JVGR*

Dalakvísl

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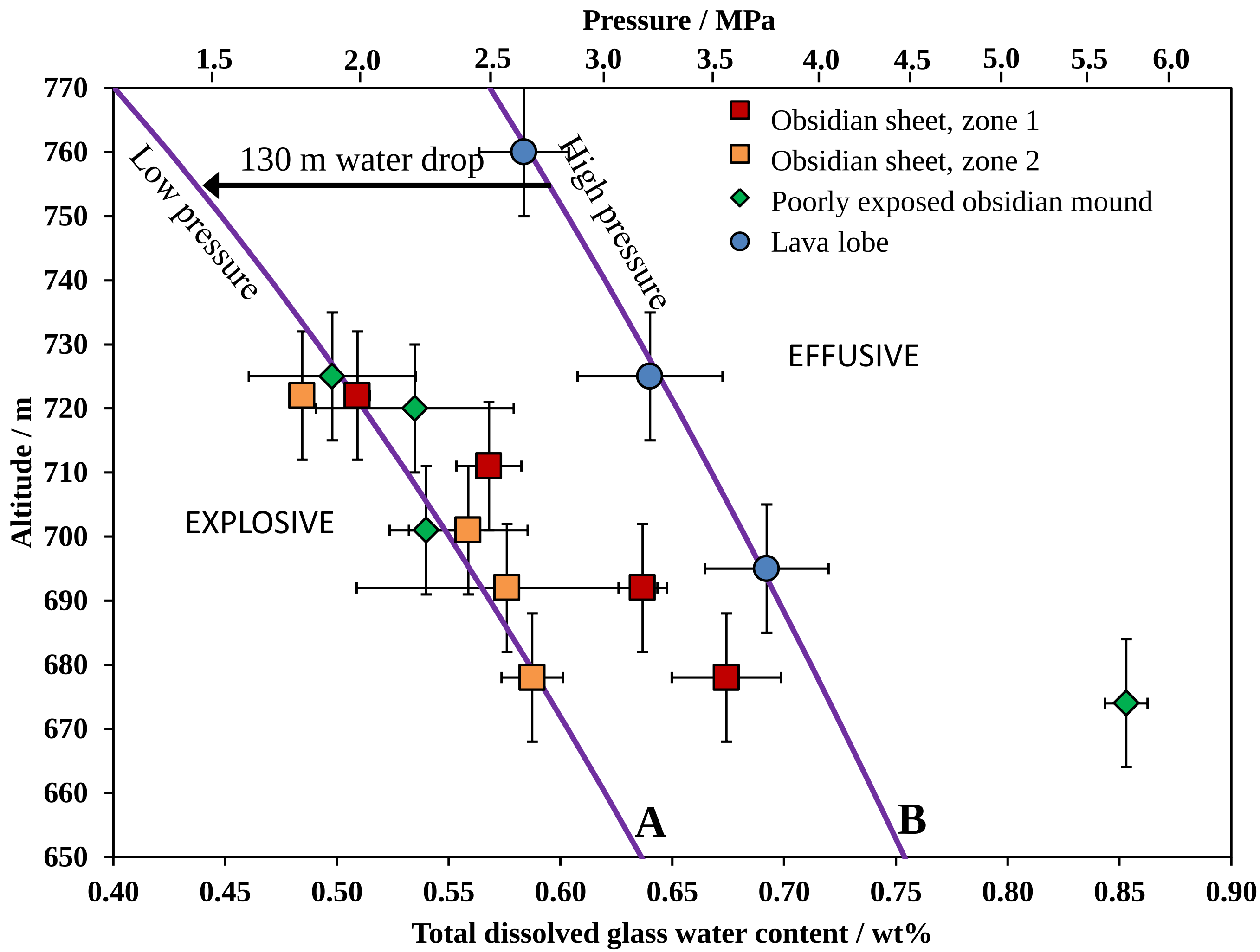
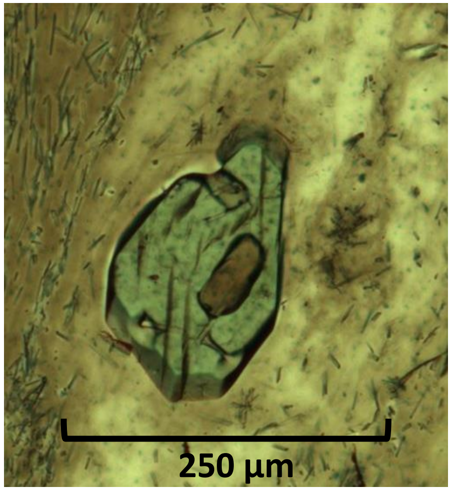


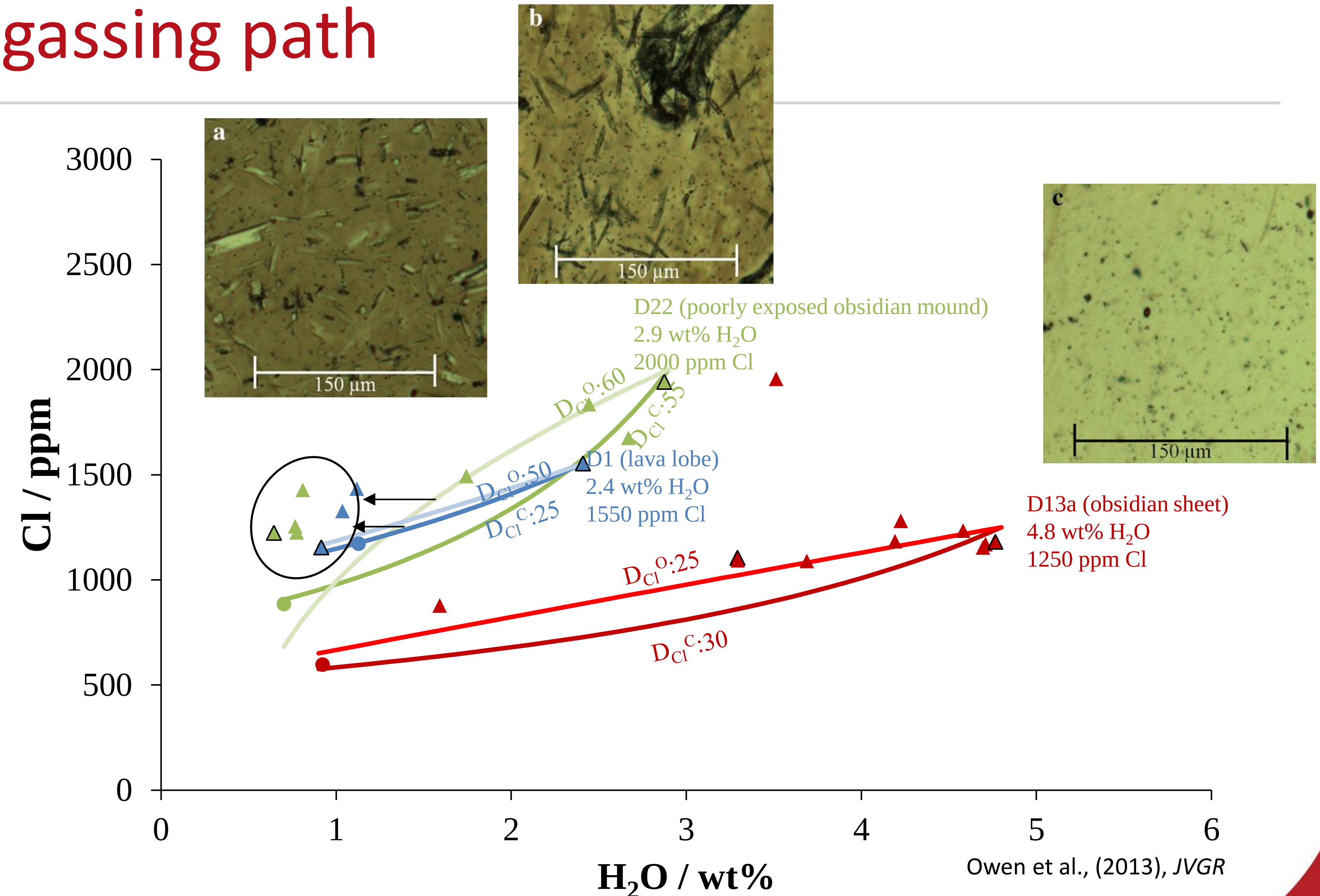
Dalakvísl
Pre-eruptive volatile content

Effusive lava lobes:
2.4 wt.% H_2O



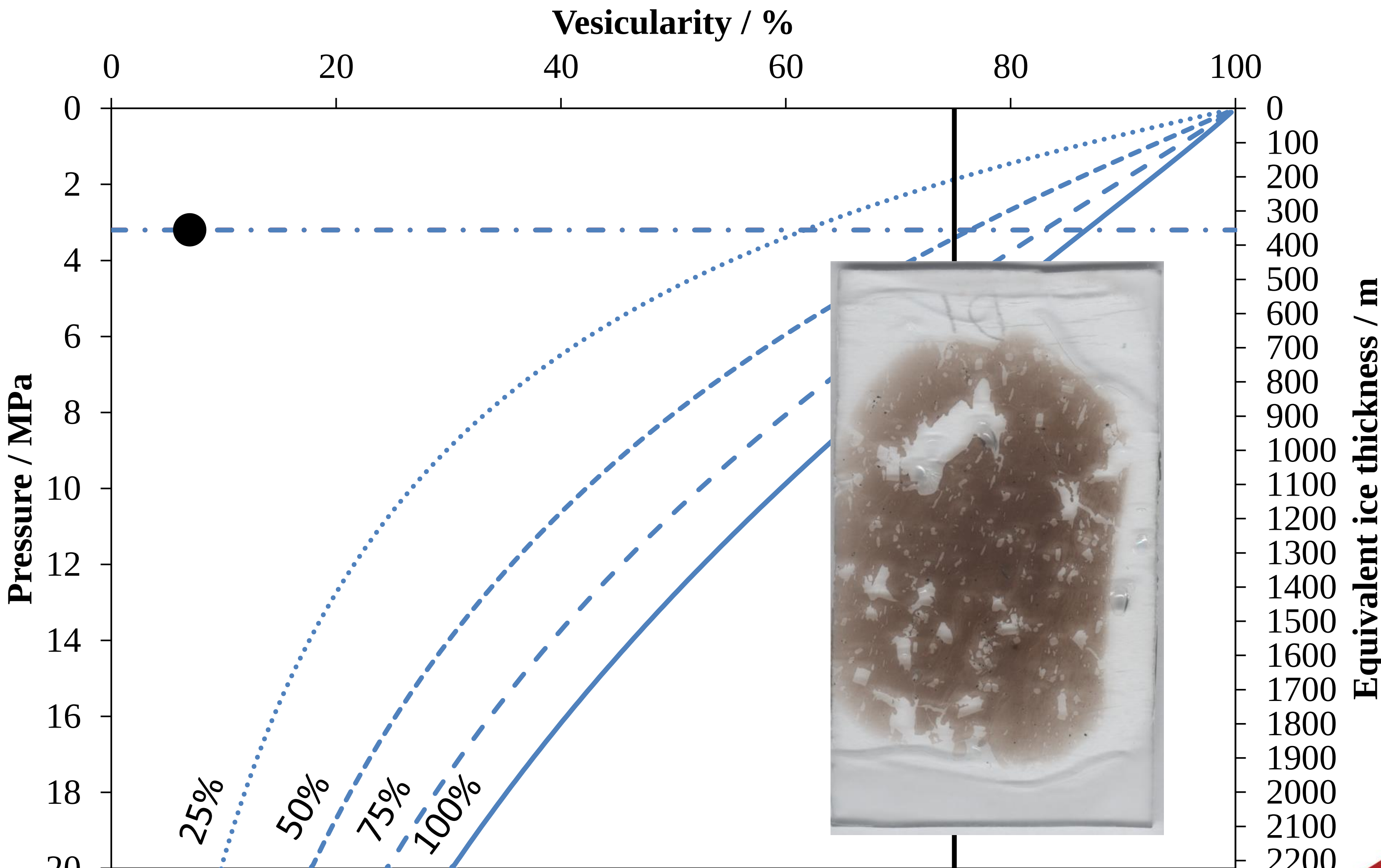
More explosive obsidian sheets:
4.8 wt.% H_2O

Dalakvísl degassing path



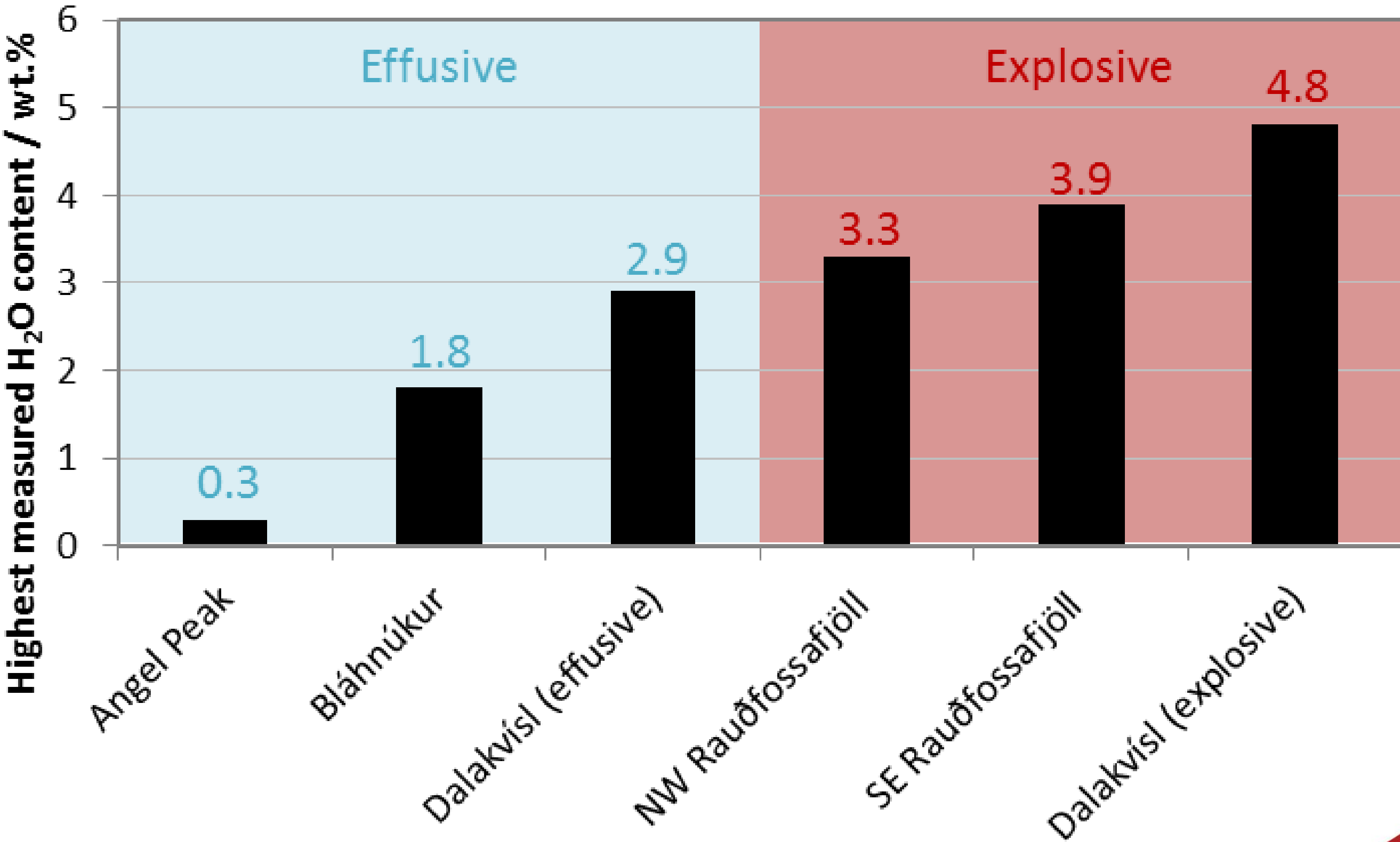
Owen et al., (2013), *JVGR*

Dalakvísl

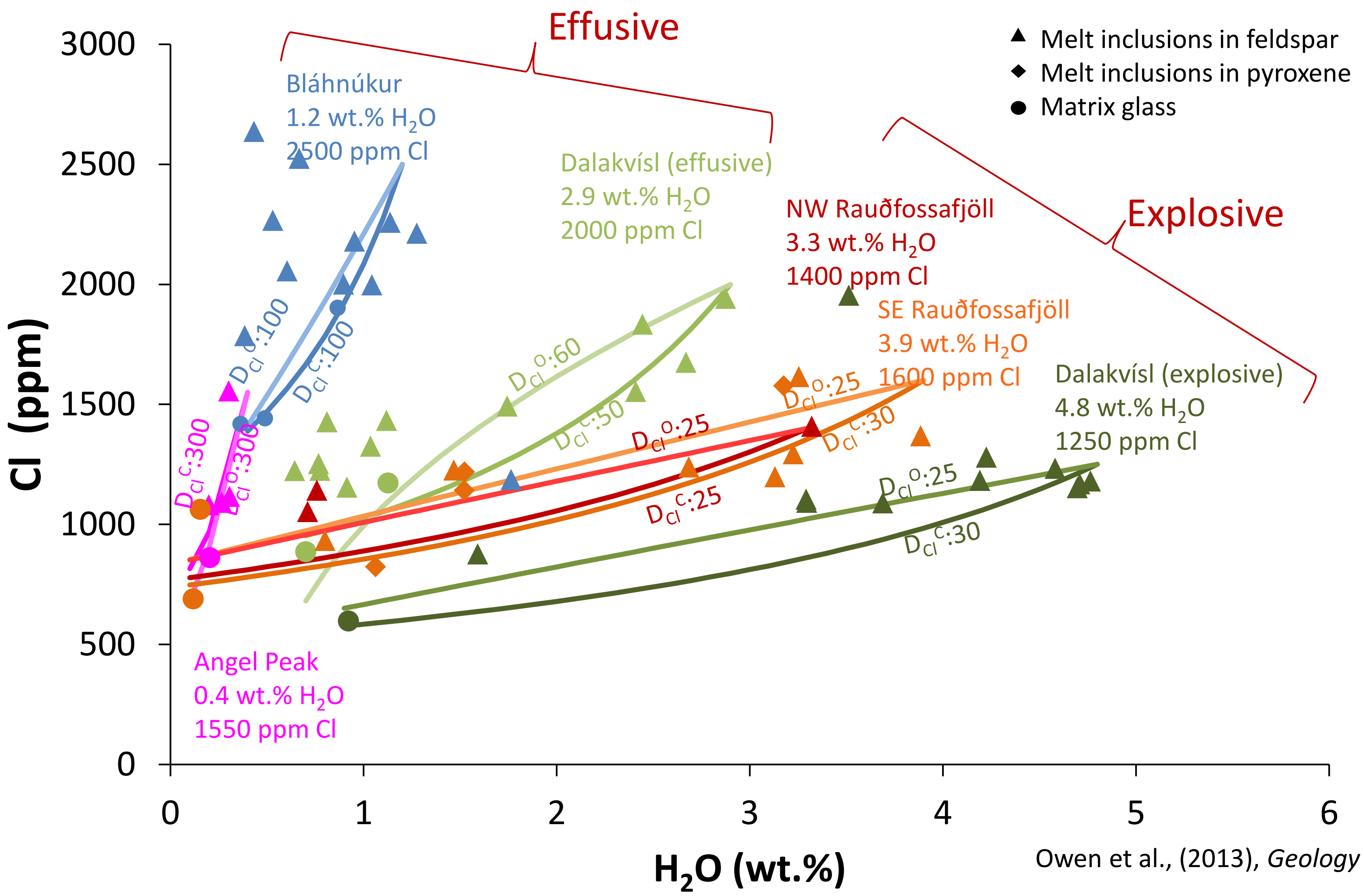


Owen et al., (2013), *JVGR*

Torfajökull
pre-eruptive volatile content

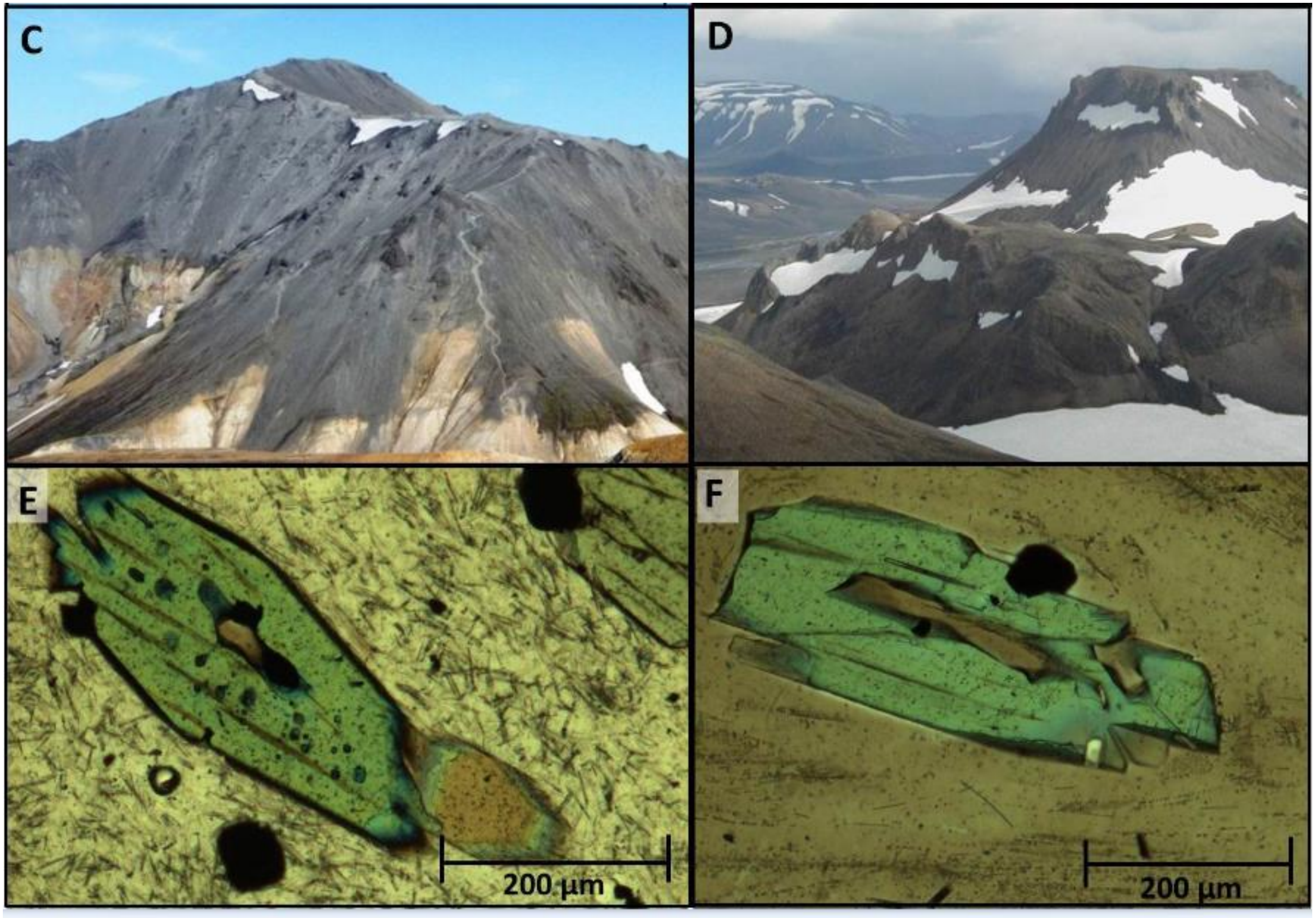


Torfajökull degassing path



Owen et al., (2013), *Geology*

Torfajökull degassing path



Owen et al., (2013), *Geology*

Torfajökull conclusion

The behaviour of subglacial rhyolite

- Is little affected by the quantity of ice loading
- However rapid decompression may trigger a transition to more explosive activity
- There is also a correlation between explosivity and
  - Pre-eruptive volatile content
  - Degassing path

Basalt in Iceland

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Eyjafjallajökull 2010

Grímsvötn 2011

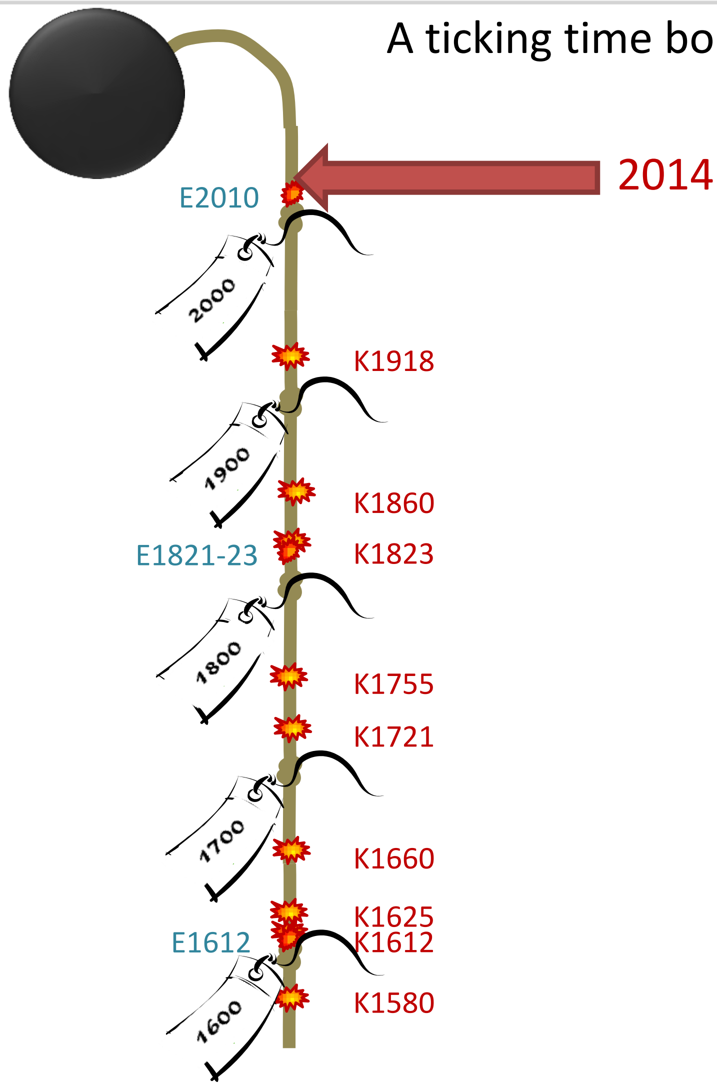
Holuhraun 2014

Katla

Environment Centre | Lancaster University

Katla

A ticking time bomb?



Katla

Environment Centre Lancaster University

2

Eyjafjallajökull 2010

+

Grímsvötn 2011

<

Katla1918

Katla vs Eyjafjallajökull

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	Katla 1918	Eyjafjallajökull 2010
Date of commencement	12th Oct 1918 [A]	14th Apr 2010 [G]
Duration of eruption	24 days [A]	39 days [G]
Composition	Basalt (47% SiO_2) [B]	Benmoreite and trachyte [H]
VEI	4 (at least) [C]	4 (upgraded from 3) [C]
Total erupted volume (DRE)	1 km^3 [D]	0.2 km^3 [H]
Max plume height	14 km [A]	10 km [H]
Volume of airborne tephra	0.7 km^3 [D]	<0.3 km^3 [H]
Area of tephra fall on land	50,000 km^2 [A]	12,000 km^2 [I]
Thickness of ice over eruption site	400 m [D]	200 m [H]
Volume of subglacial lavas	0.2 km^3 [E]	0.02 km^3 [H]
Time taken to melt overlying ice	2 hours [E]	3-4 hours [H]
Jökulhlaup volume	>8 km^3 [E]	<0.06 km^3 [I]
Flooded area	600-800 km^2 [F]	57.5 km^2 [I]
Max discharge rate of jökulhlaup	>300,000 m^3 s^{-1} [E]	2,600 m^3 s^{-1} [I]
Volume of flood transported tephra	0.7-1.6 km^3 [F]	0.03 km^3 [H]

A: Larsen (2010); B: Óladóttir et al., (2008); GVP (2013); D: Sturkell et al., (2010); E: Tómasson, (1996); F: Larsen (2000); H: Guðmundsson et al., (2012); I: Gylfason et al., (2012)

Map of Katla 1918 jökulhlaup

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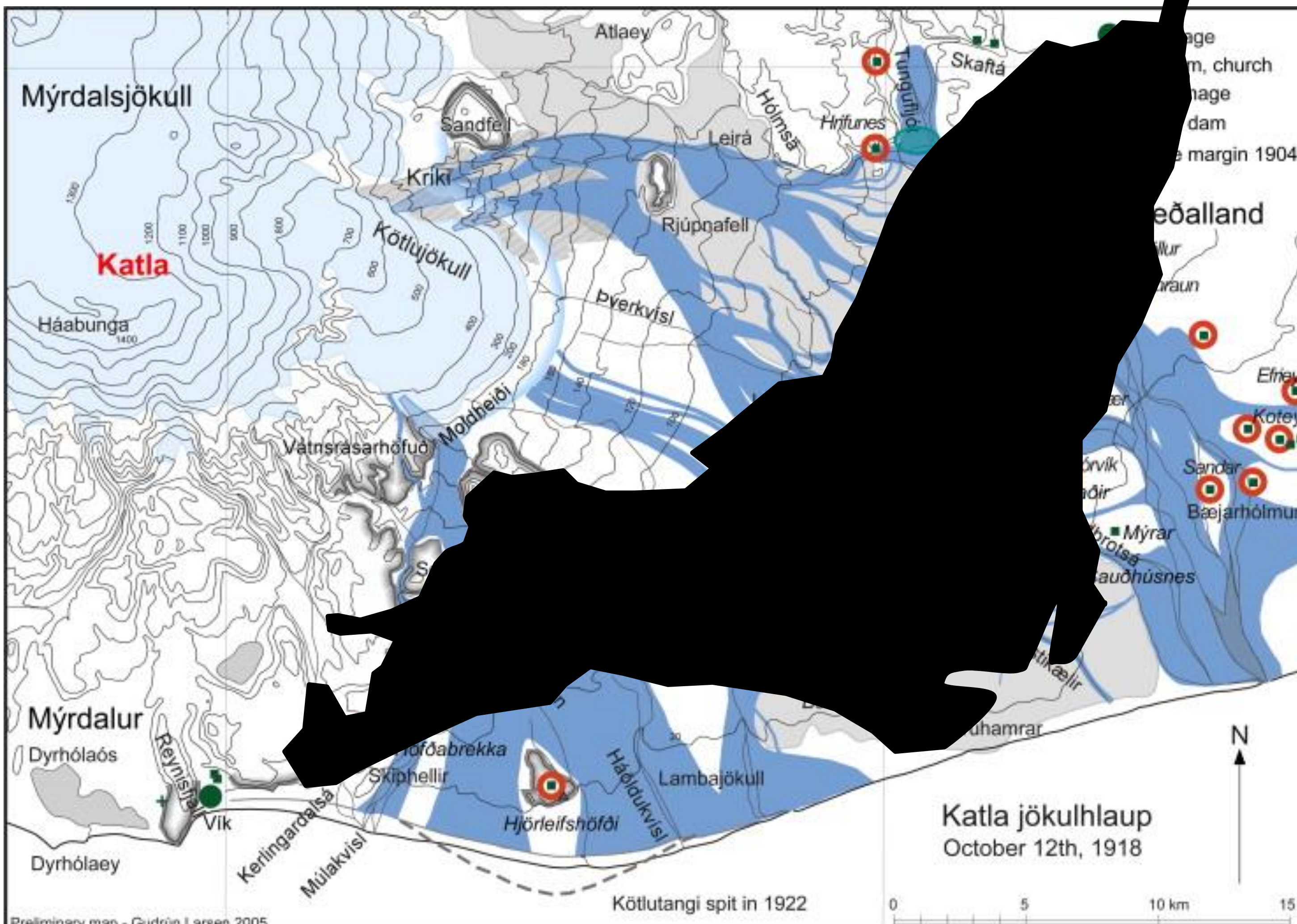

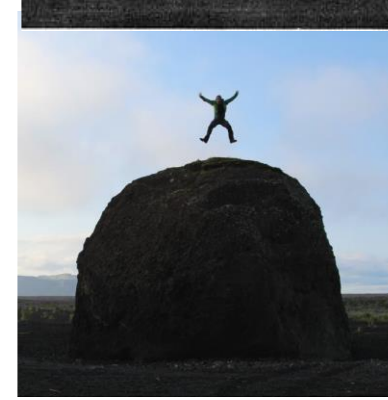

Map of Katla 1918 jökulhlaup

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Katla 1918 jökulhlaup deposits

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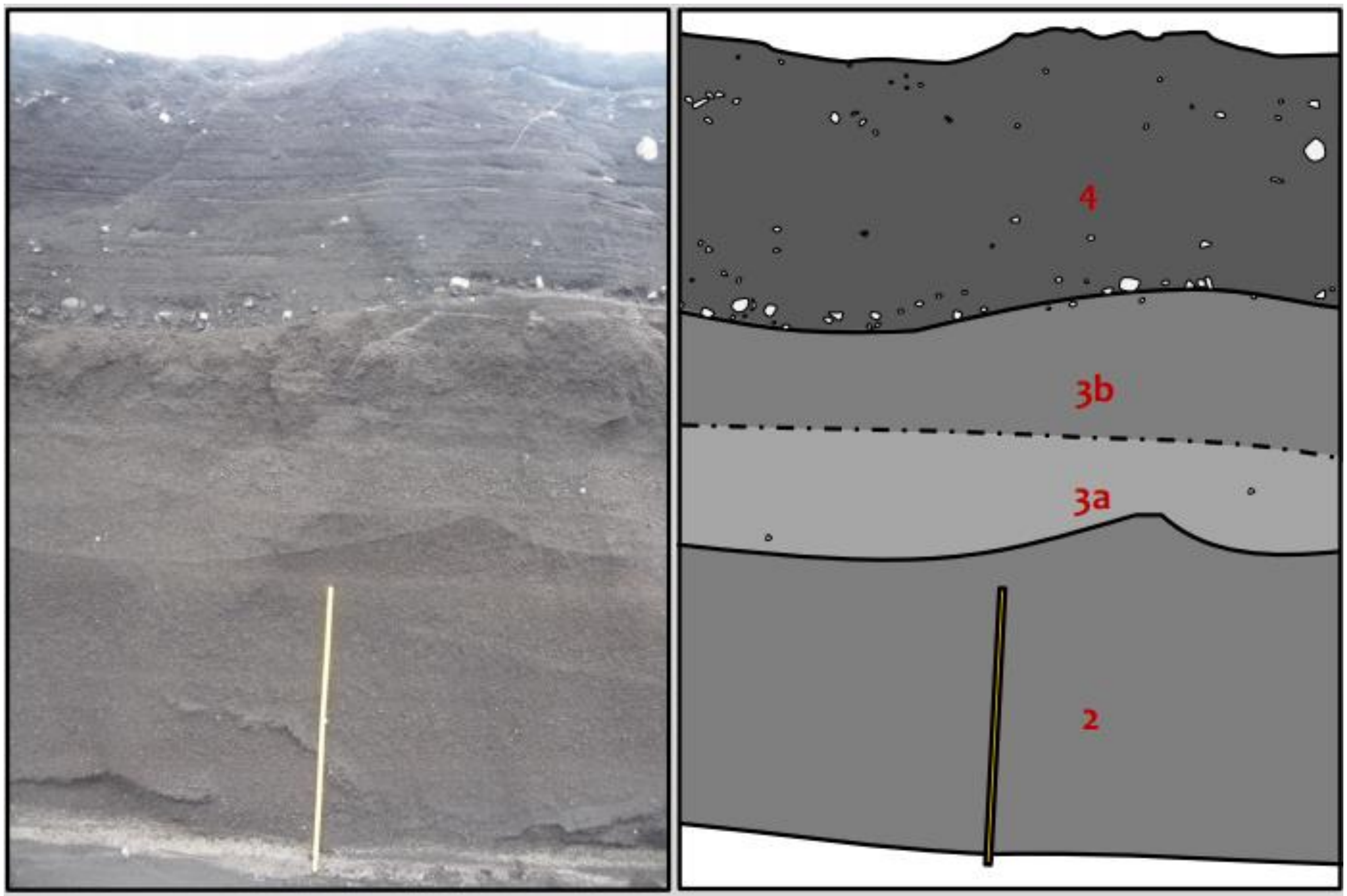
Katla 1918 jökulhlaup deposits

Environment Centre | Lancaster University

Katla 1918 jökulhlaup deposits

Katla 1918 jökulhlaup deposits



Katla 1918
air fall tephra

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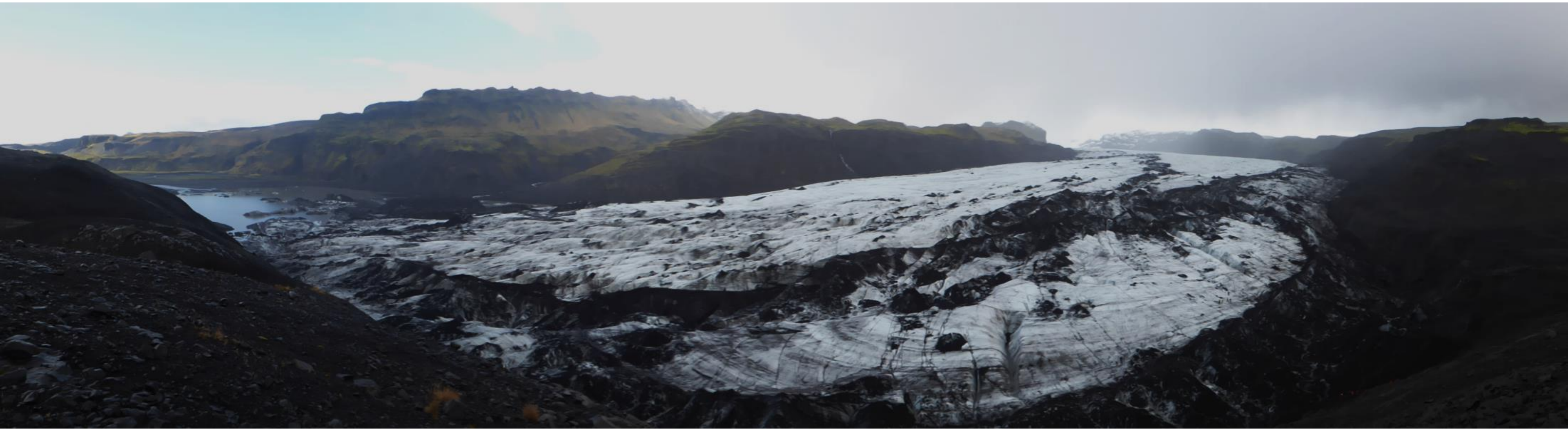
Katla1918
air fall tephra

Environment Centre | Lancaster University



Katla1918
air fall tephra

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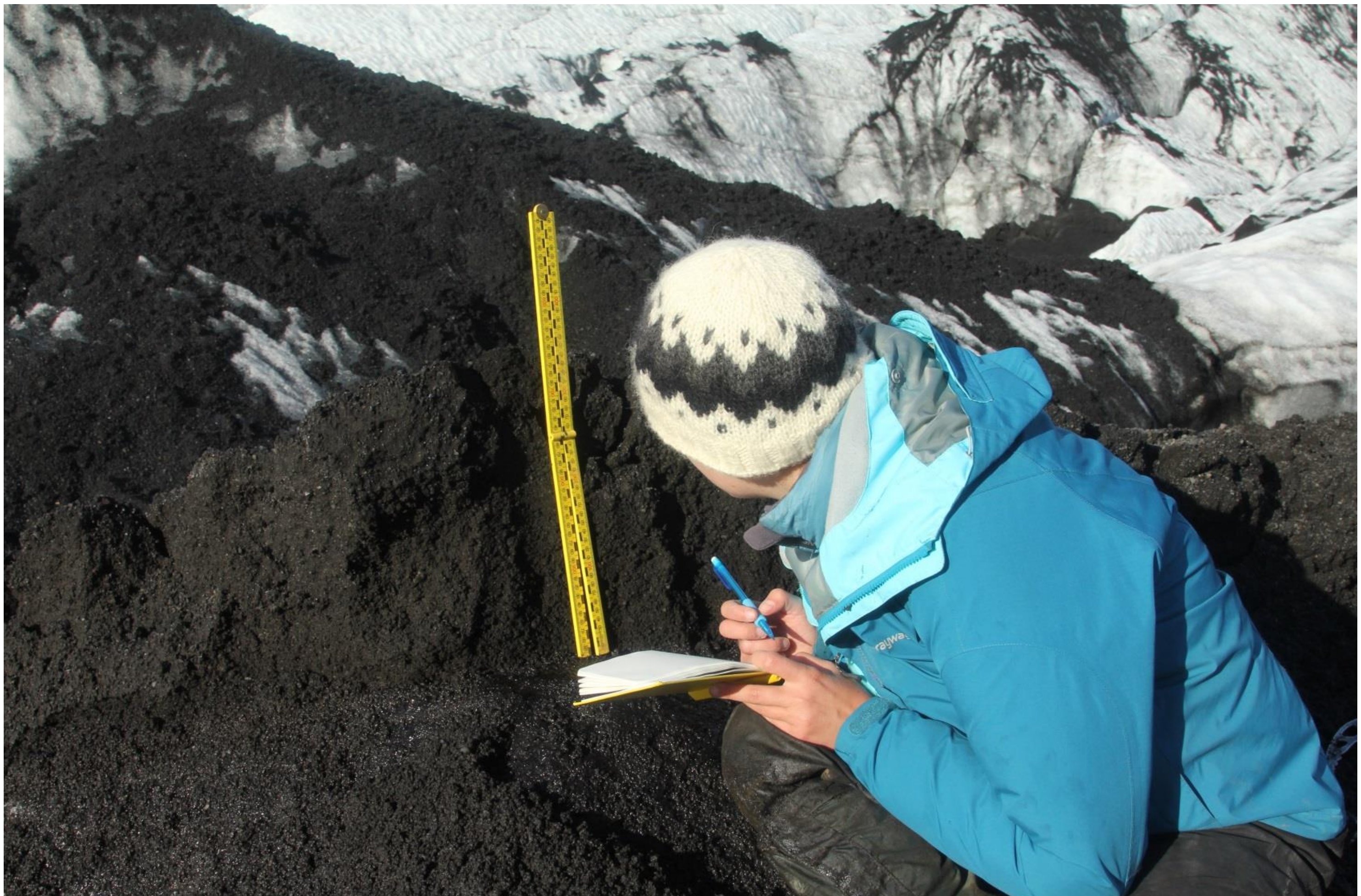
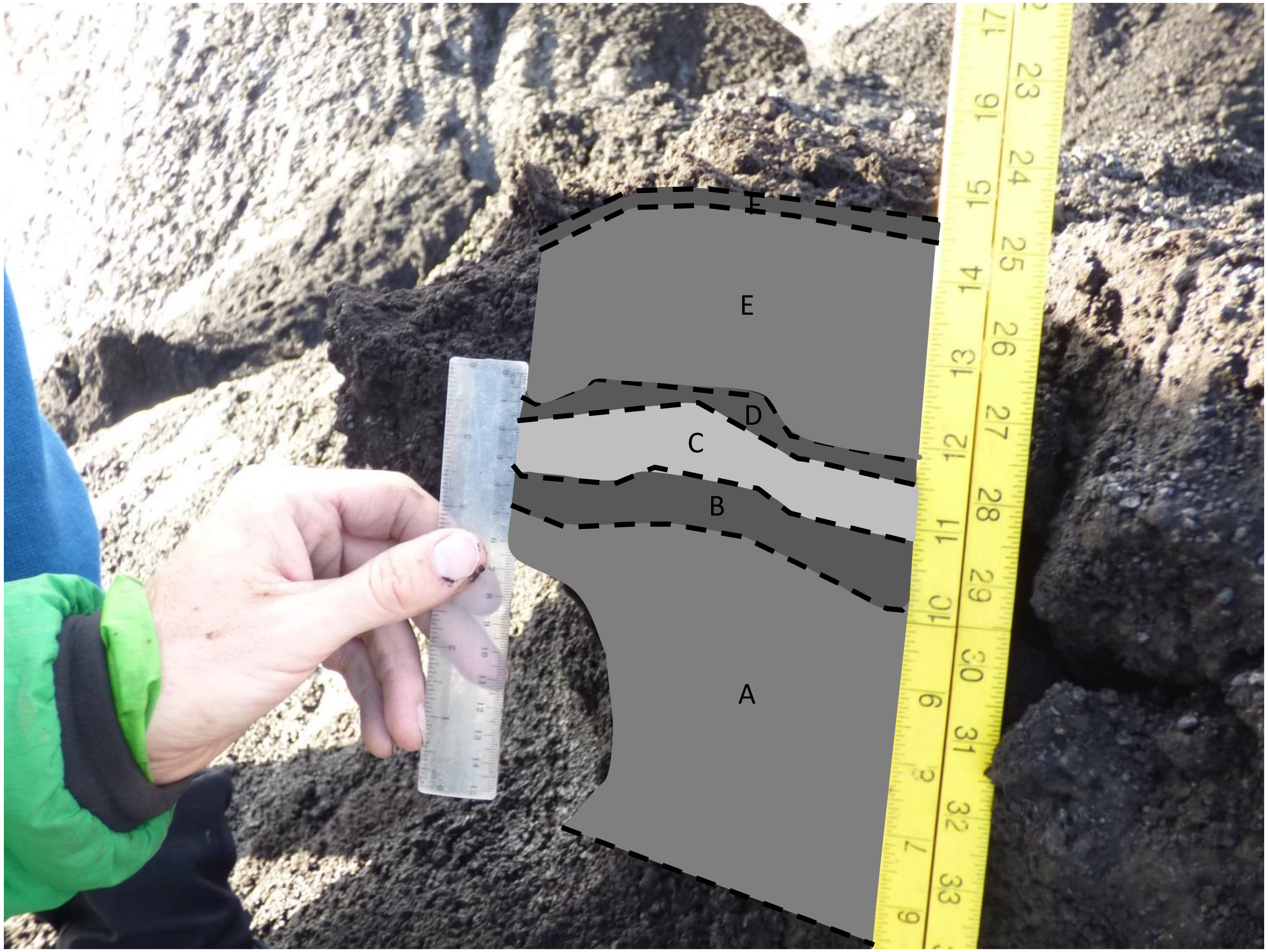
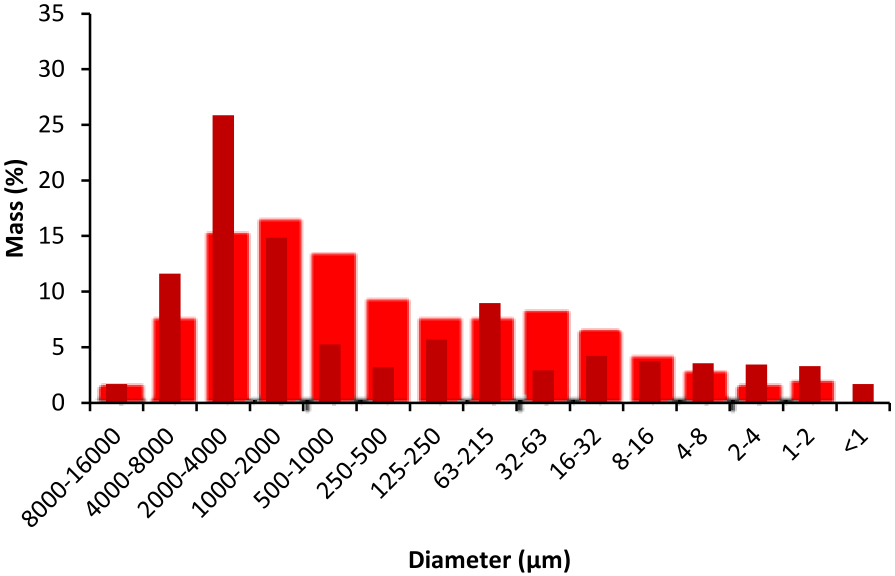


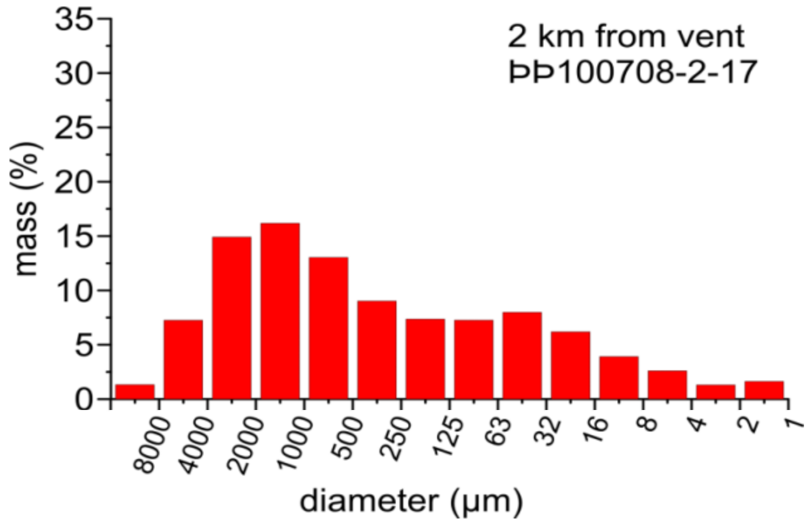
Katla1918
air fall tephra



Katla 1918
Grain –size distributions

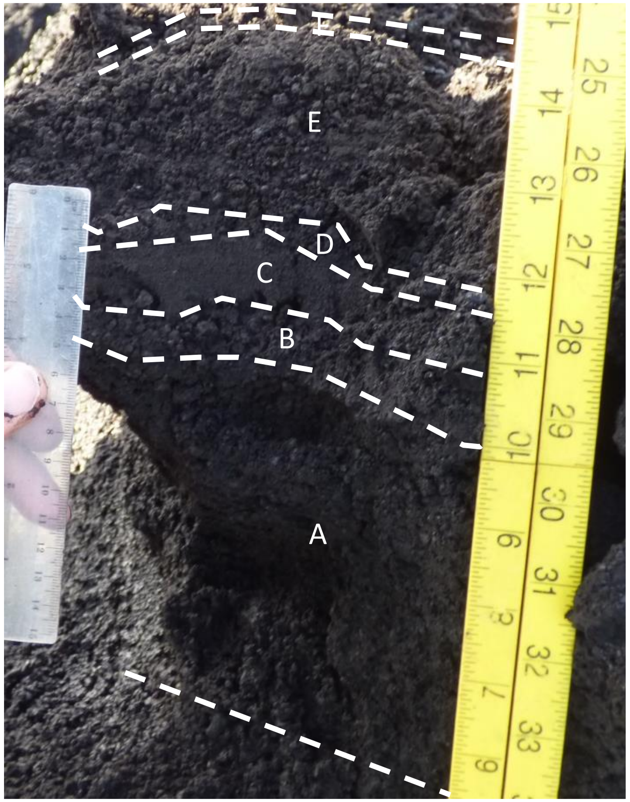


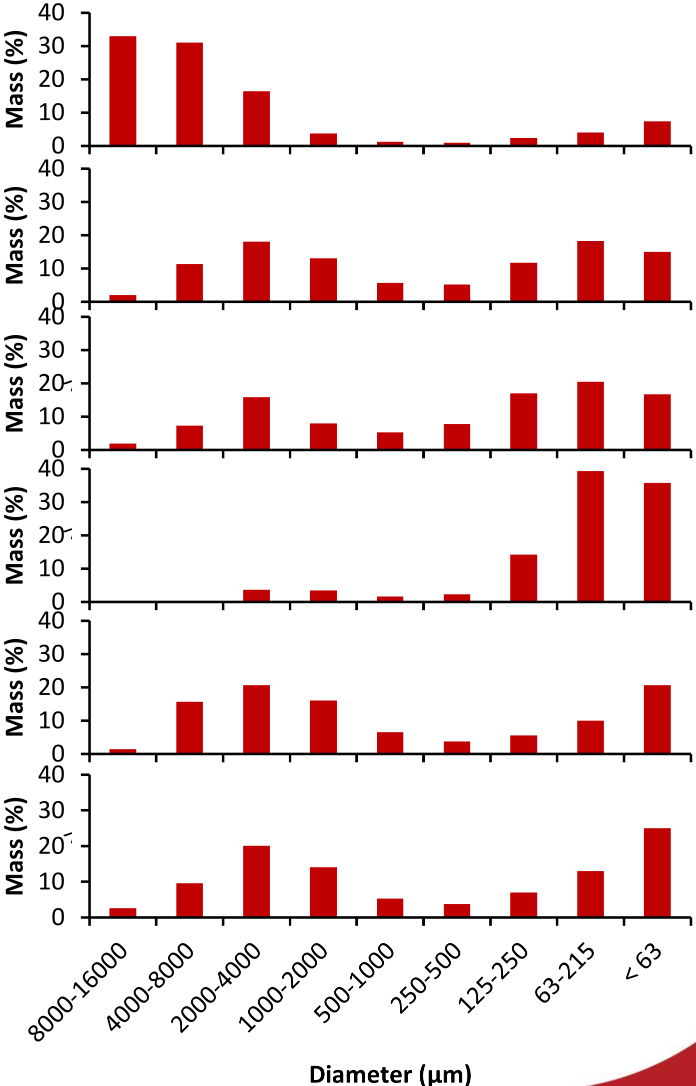
Eyjafjallajökull 2010



Guðmundsson et al., (2012), *Sci Reports*

Katla 1918
Grain –size distributions





Katla 1918
FTIR: air fall deposits

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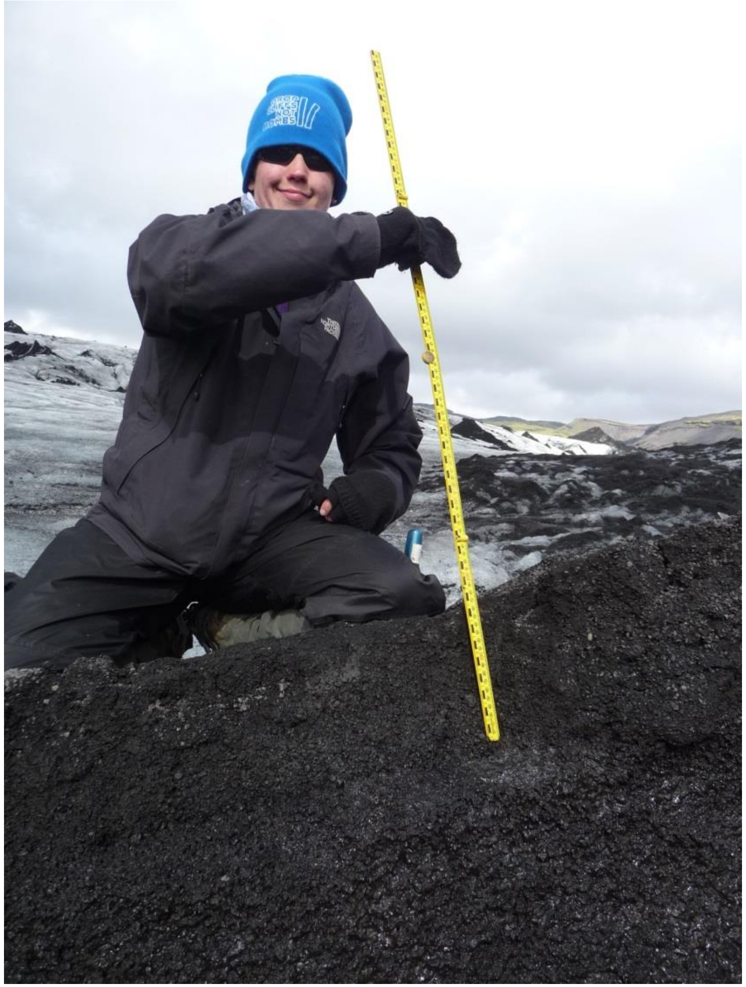
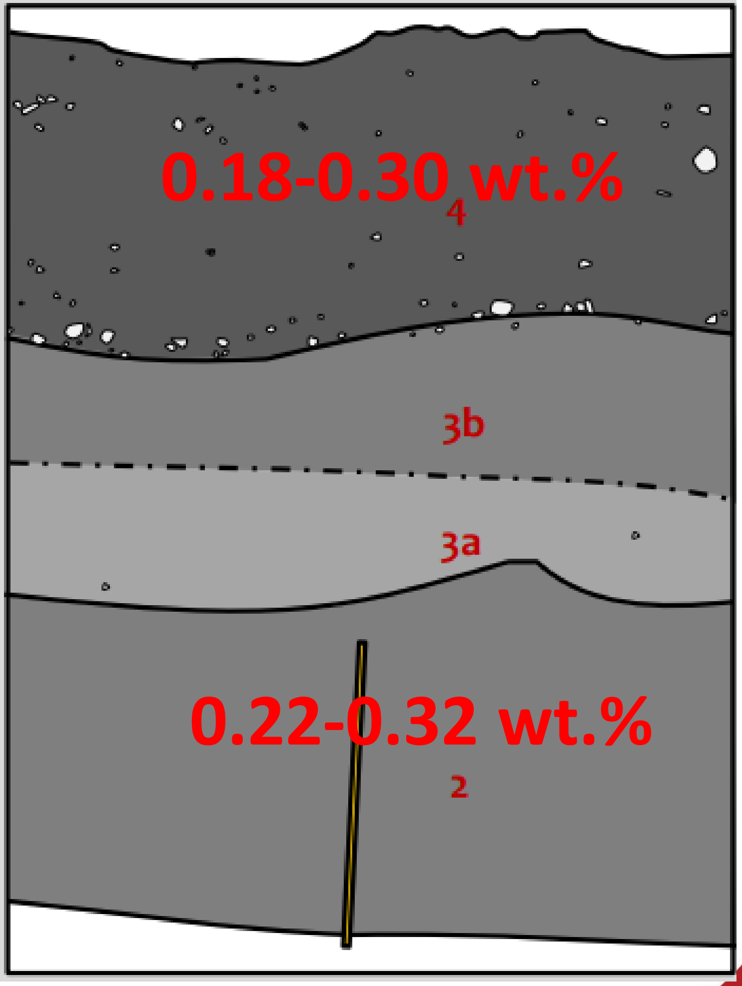


0.07 wt.%

Katla 1918
FTIR: jökulhlaup deposits



Katla 1918
FTIR: jökulhlaup deposits

- 130 m of meltwater
- 120 m of ice (full thickness ~400 m)
- 40 m of rock (e.g. if fragmentation occurred within the conduit)
- hydration

Katla 1918
TGA

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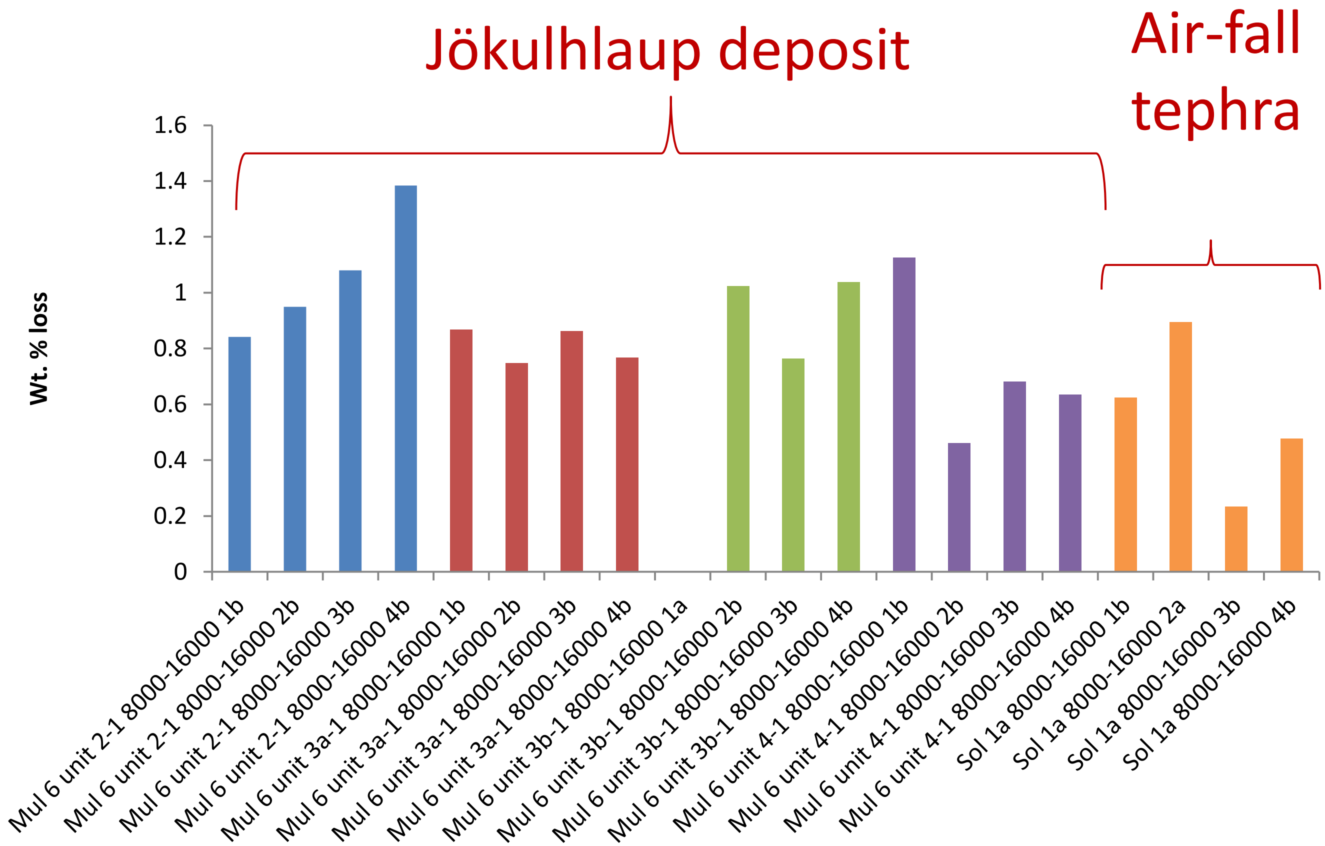

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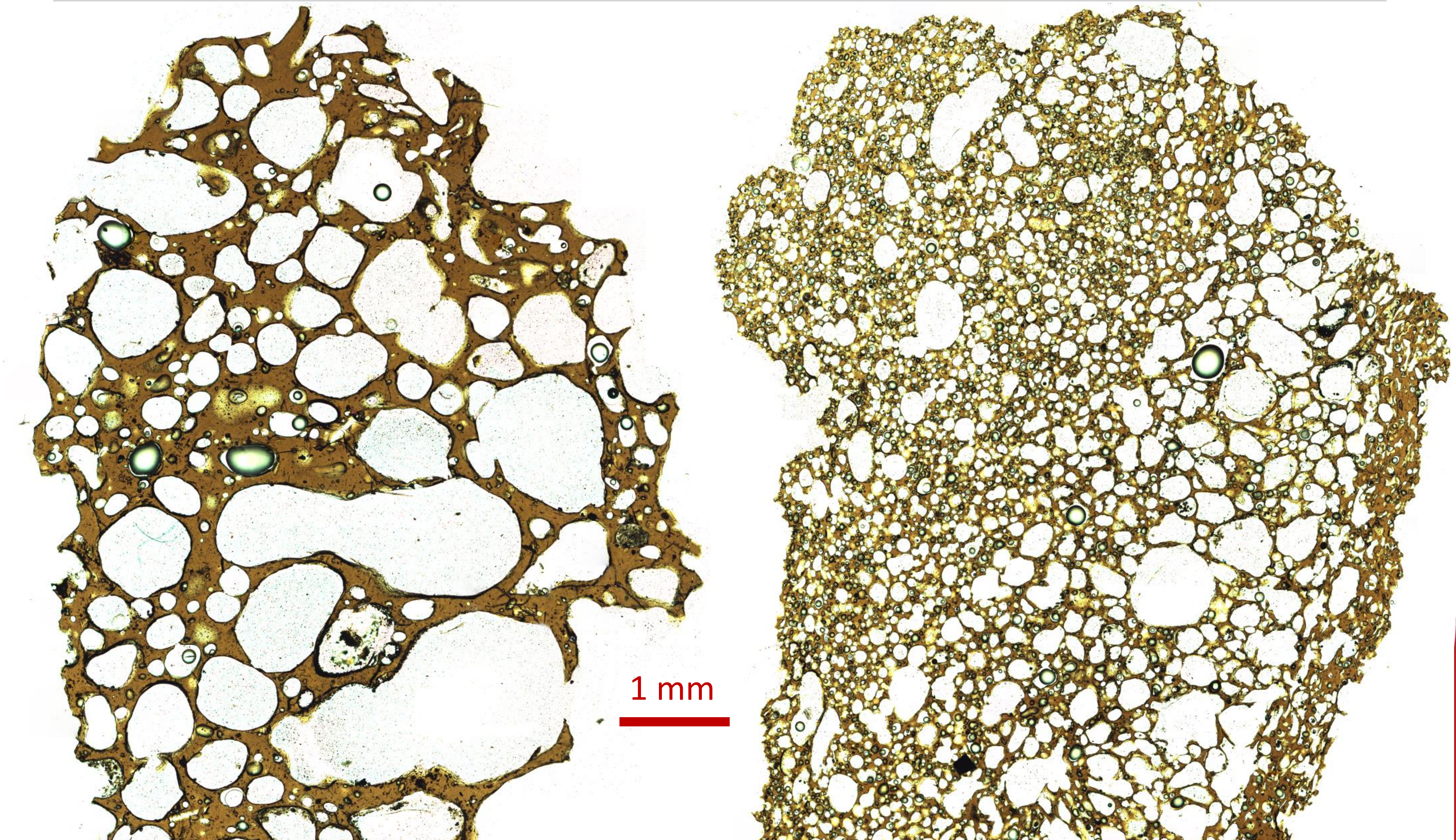
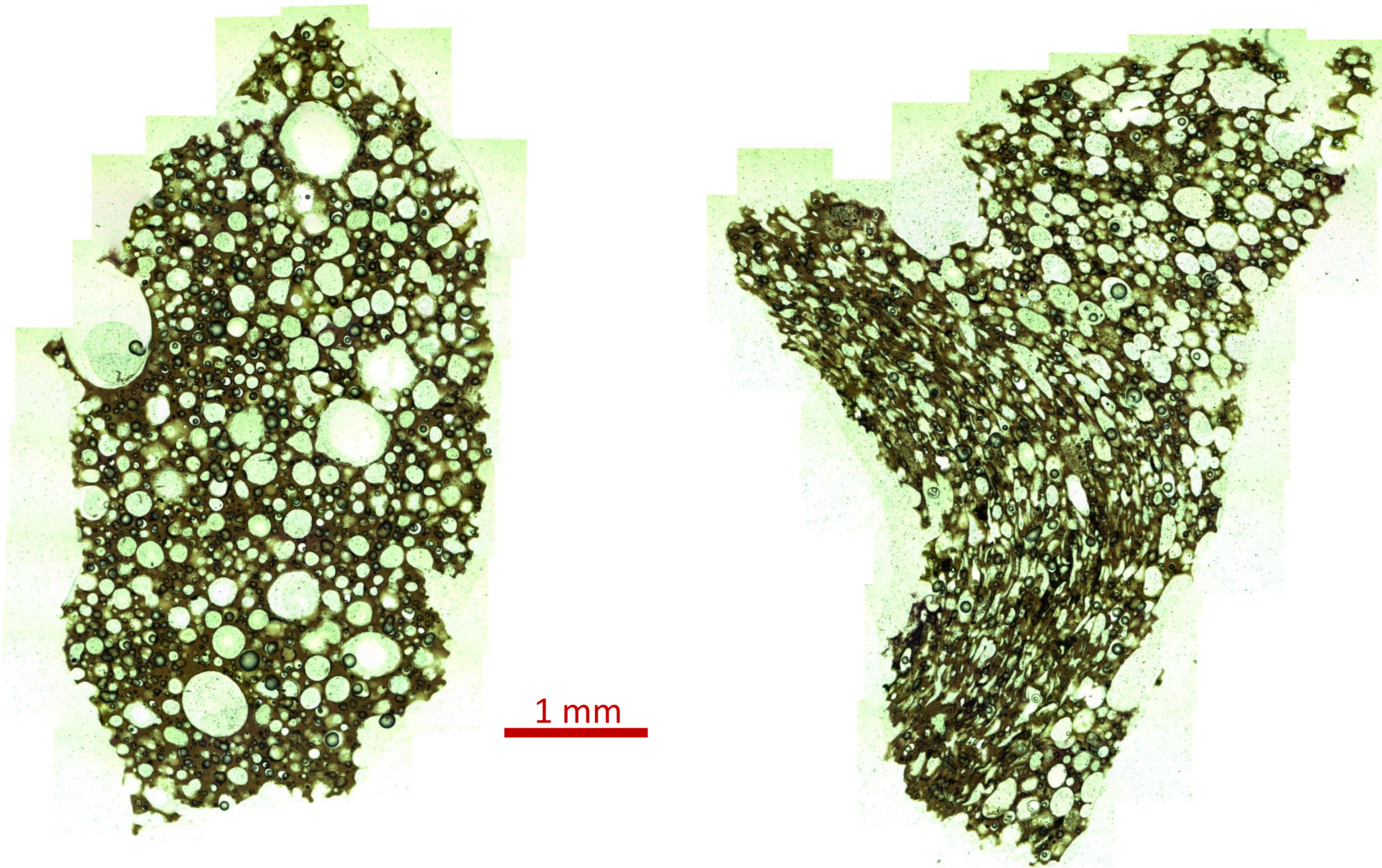
Katla 1918 textures – bubble size



Katla 1918
textures - shearing



Katla 1918
Textures – coalescence

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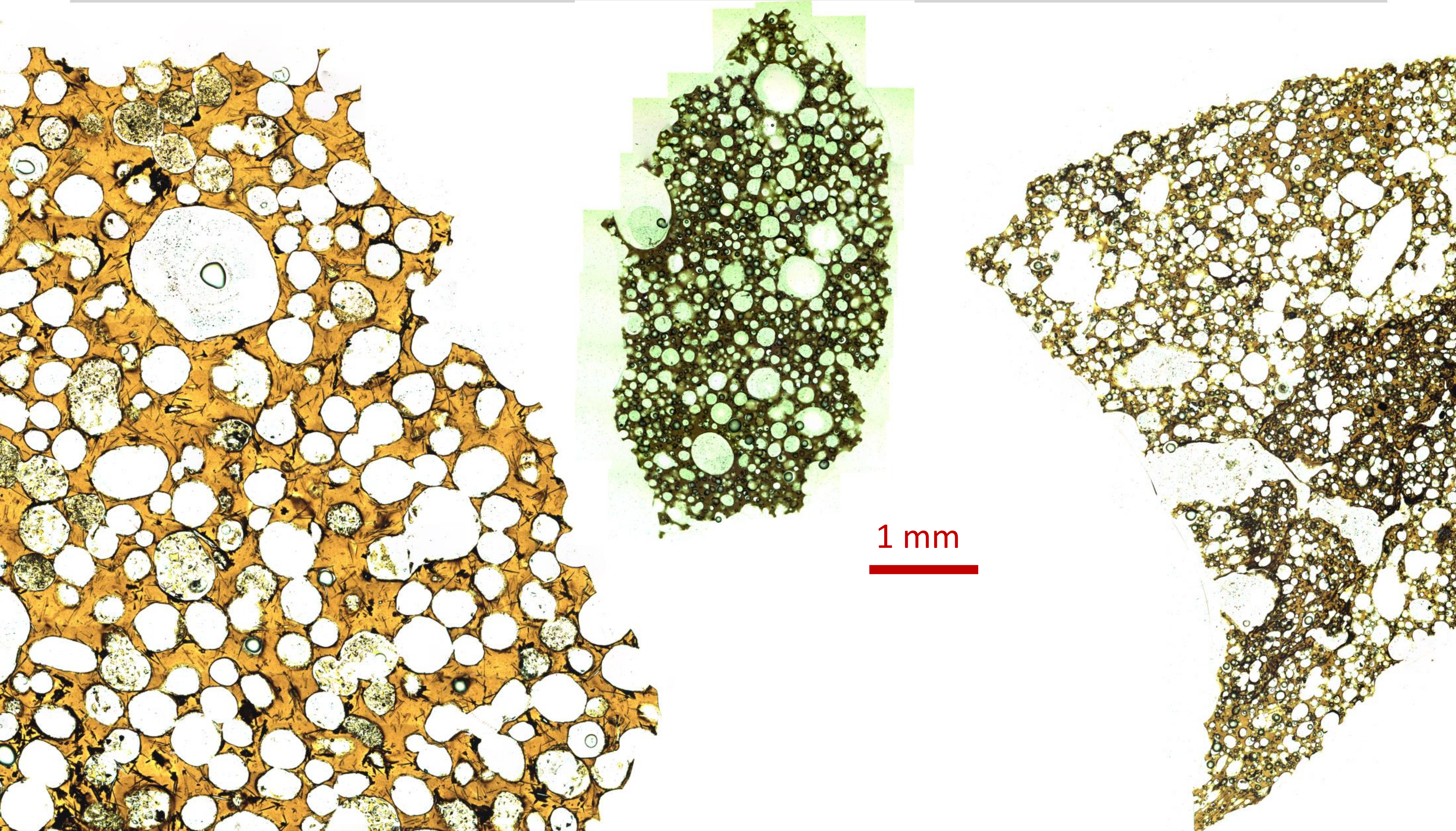
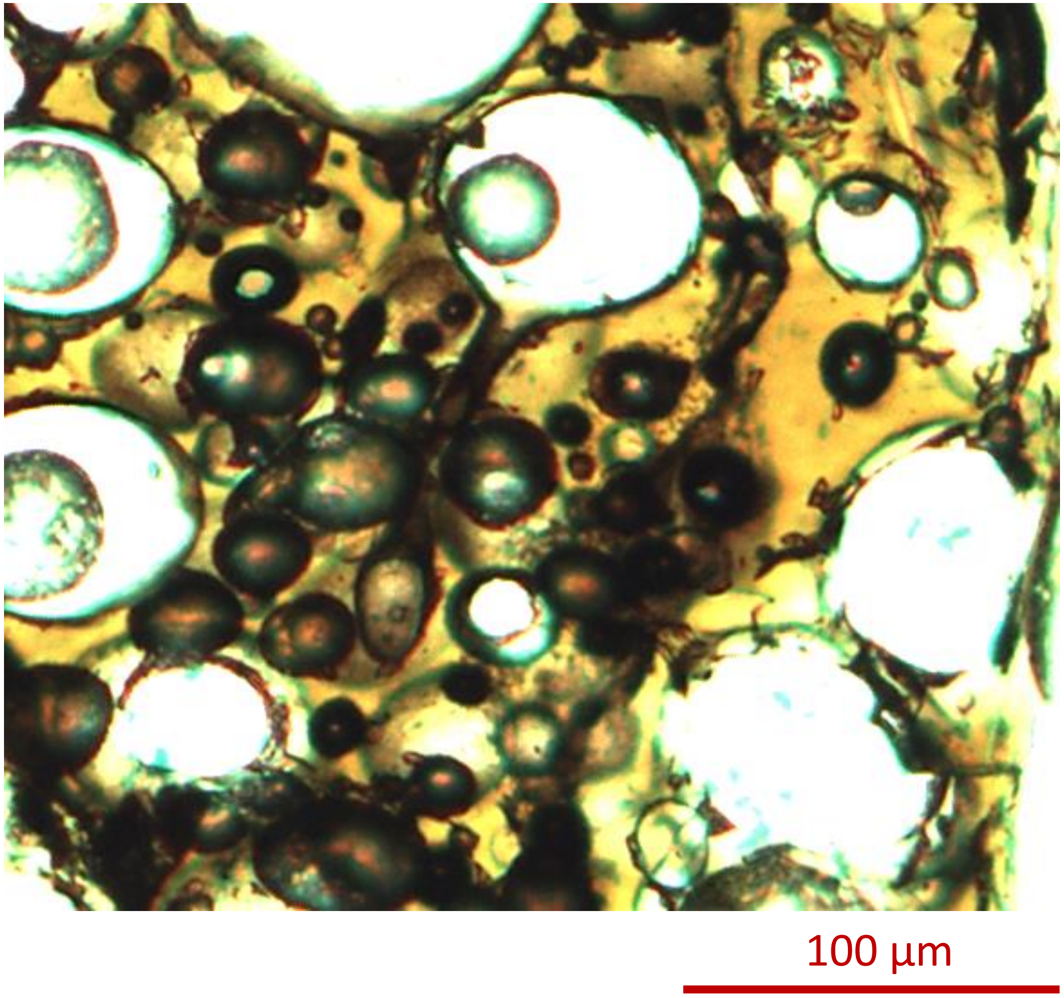


Katla 1918
Textures – connectivity



Katla 1918
Hostage – coalescence

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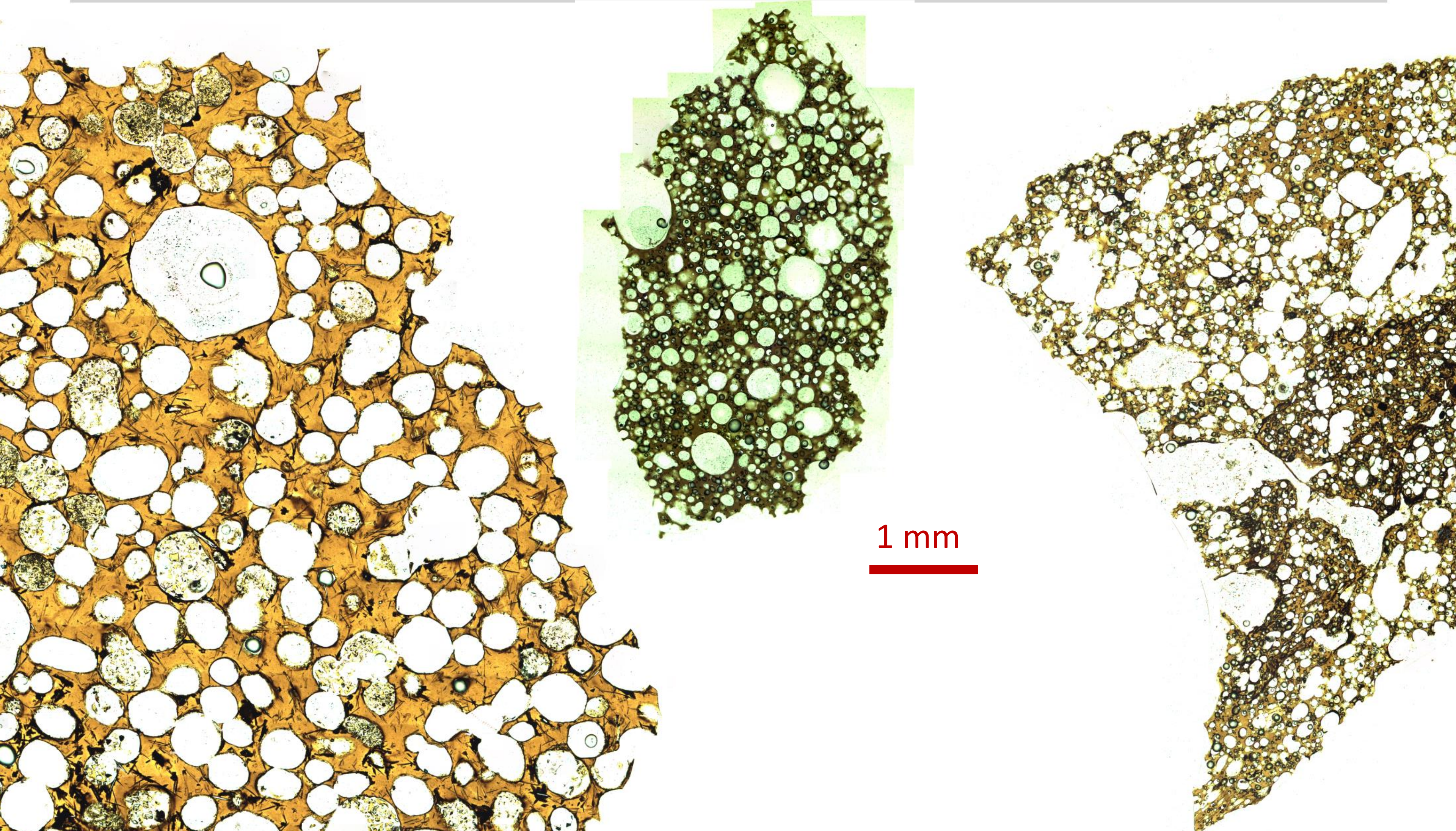
Katla 1918
Textures – coalescence



Katla 1918
Textures - microlites

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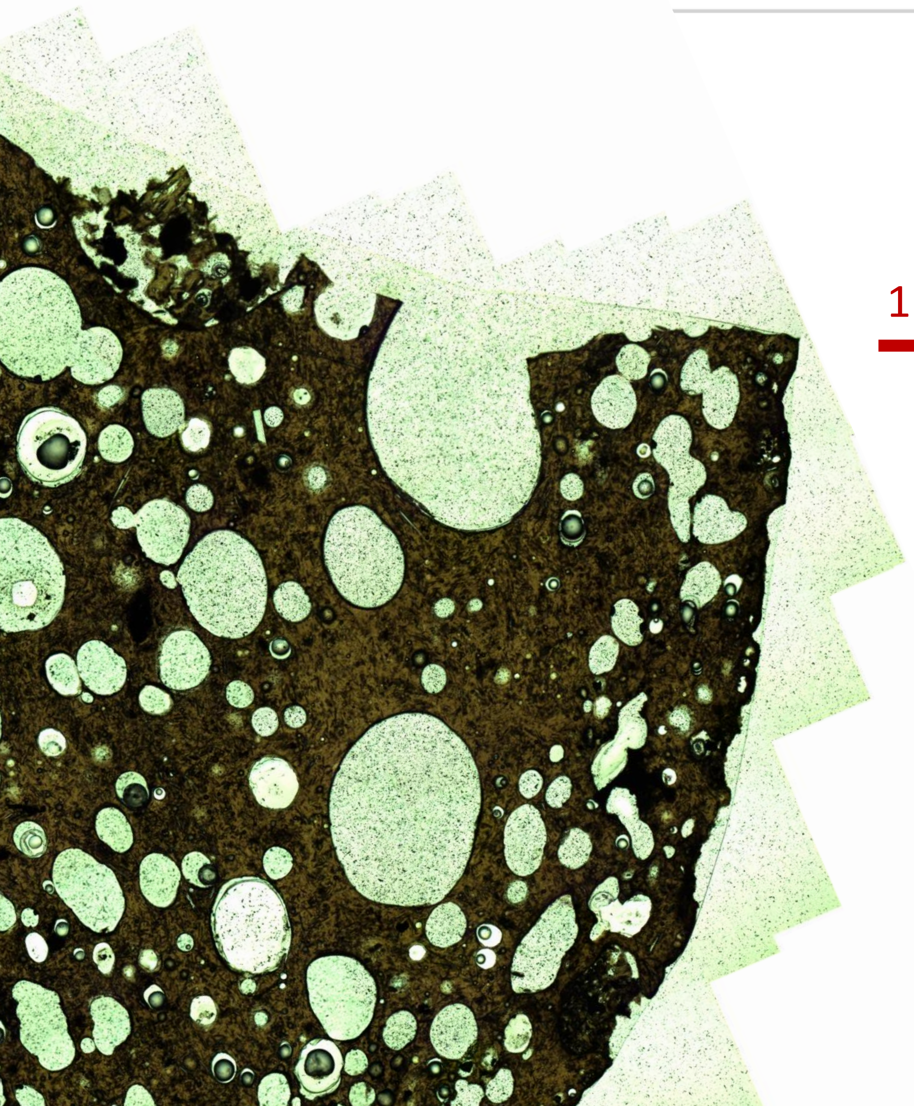
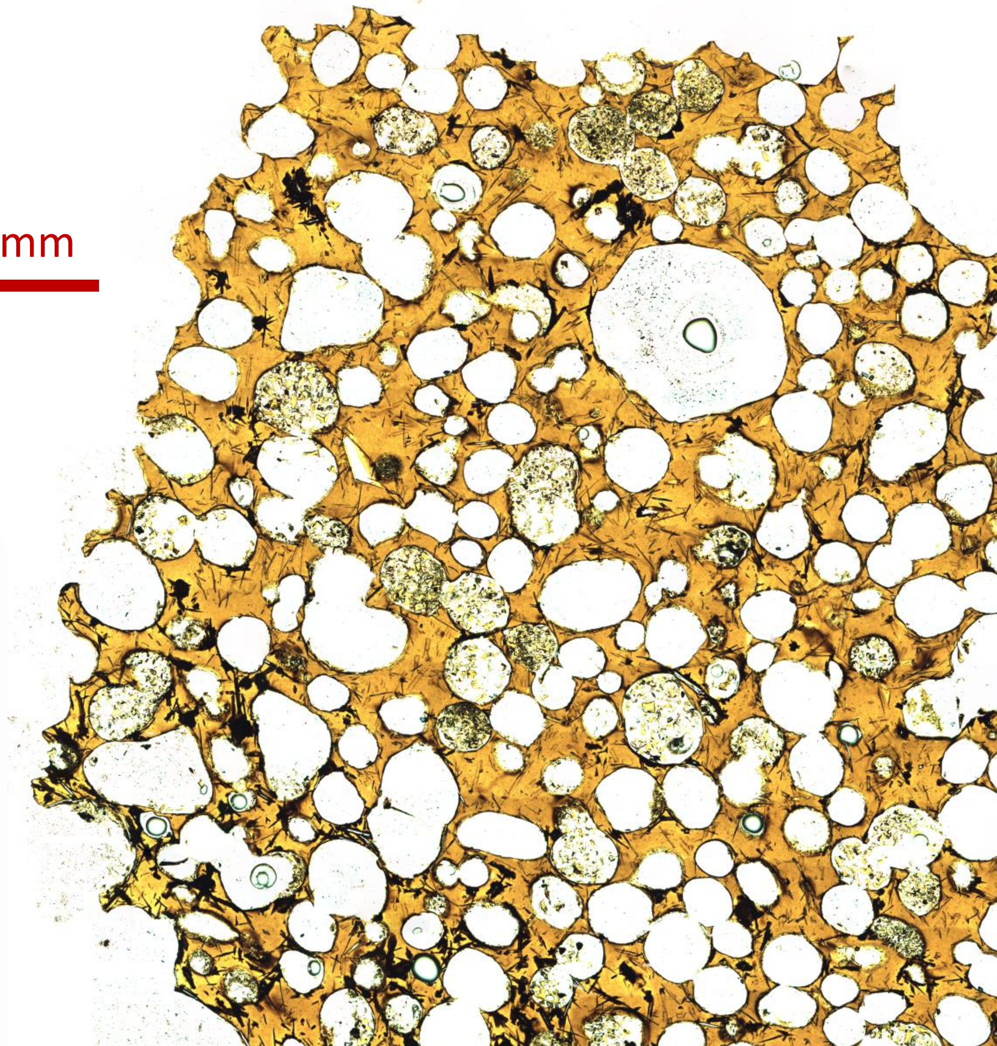
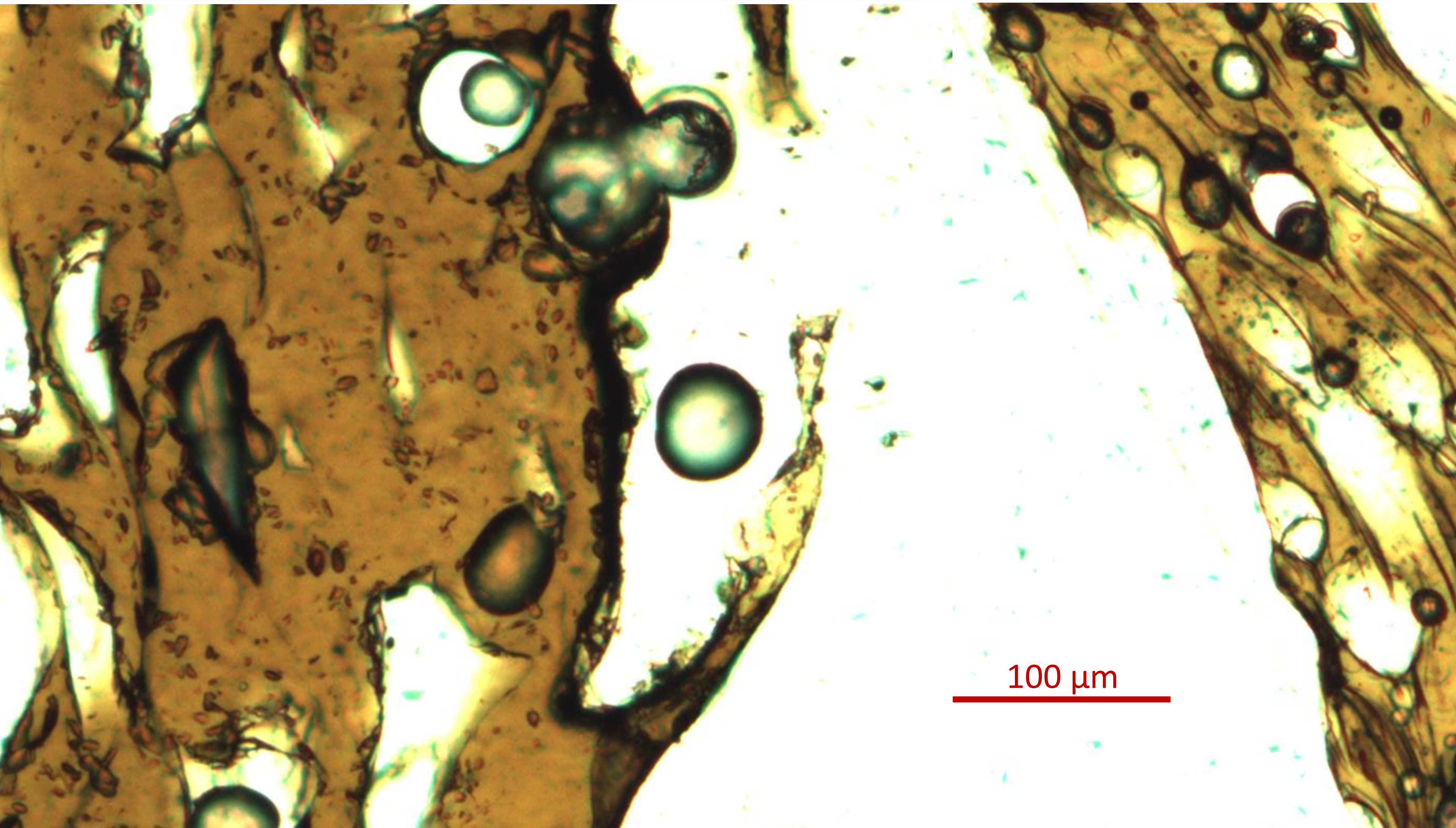


1 mm



Katla 1918
Textures – bubble collapse



Katla 1918
Textures - welding

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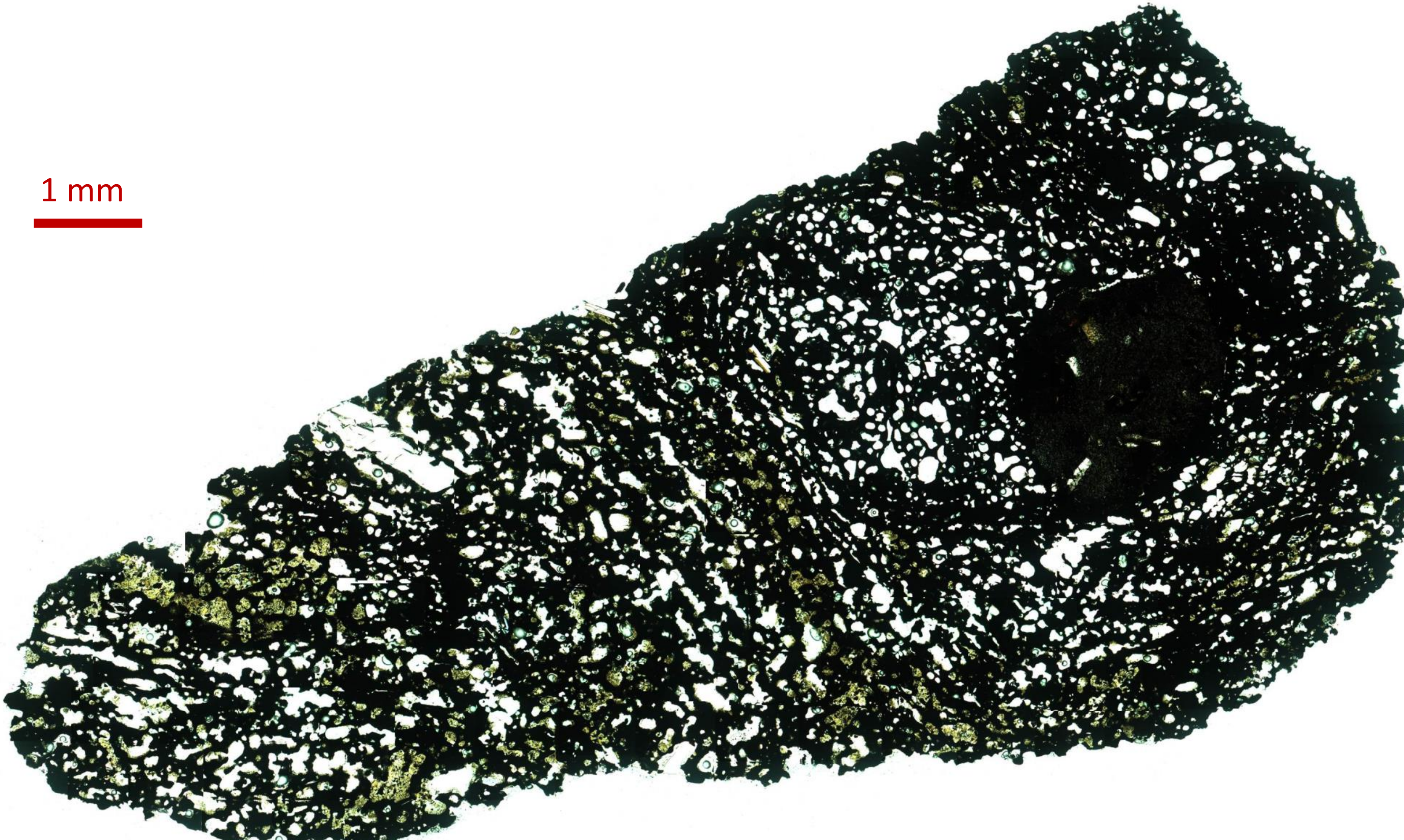

Katla 1918 textures - mingling

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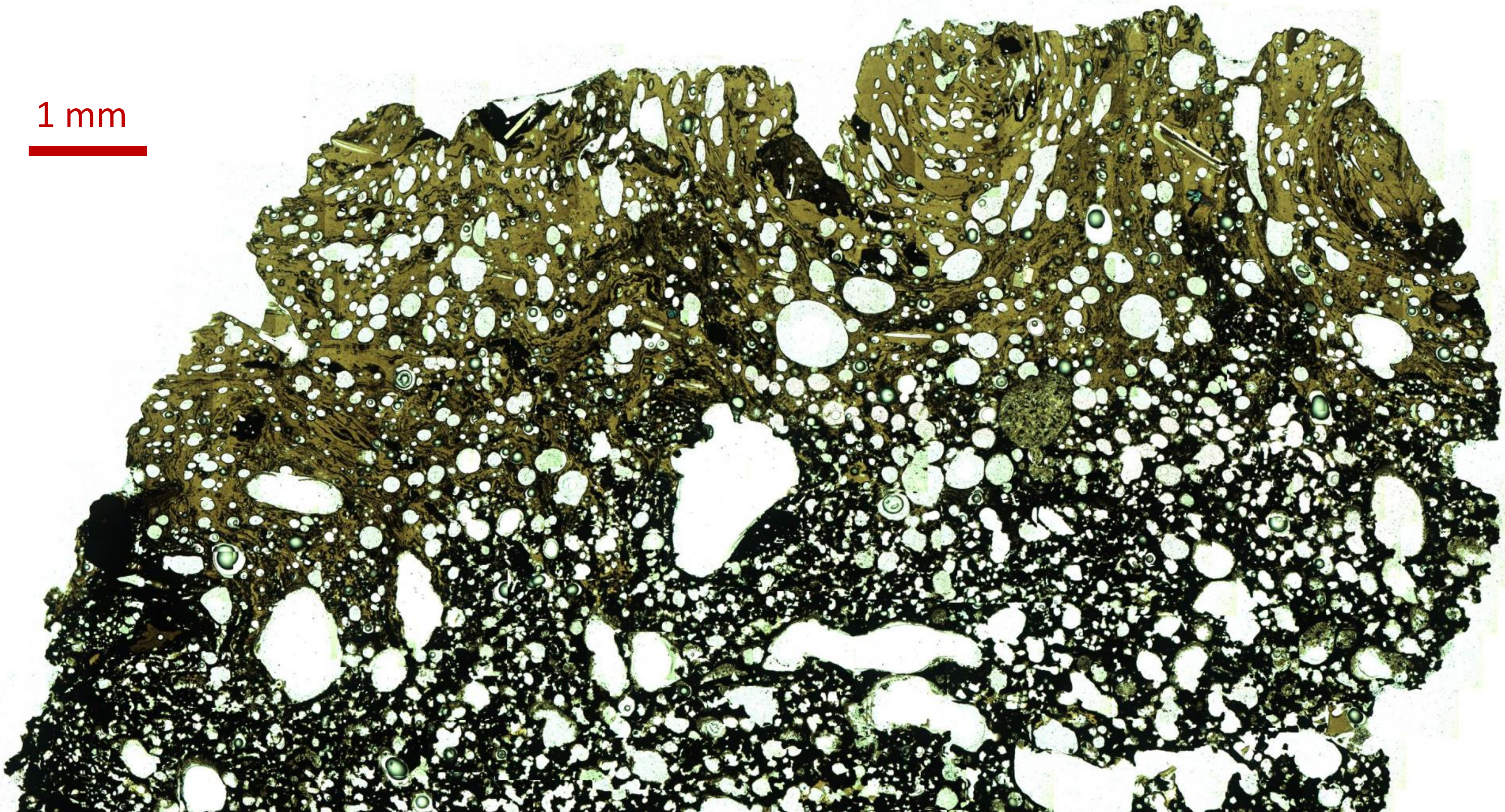
1 mm



Katla 1918 textures

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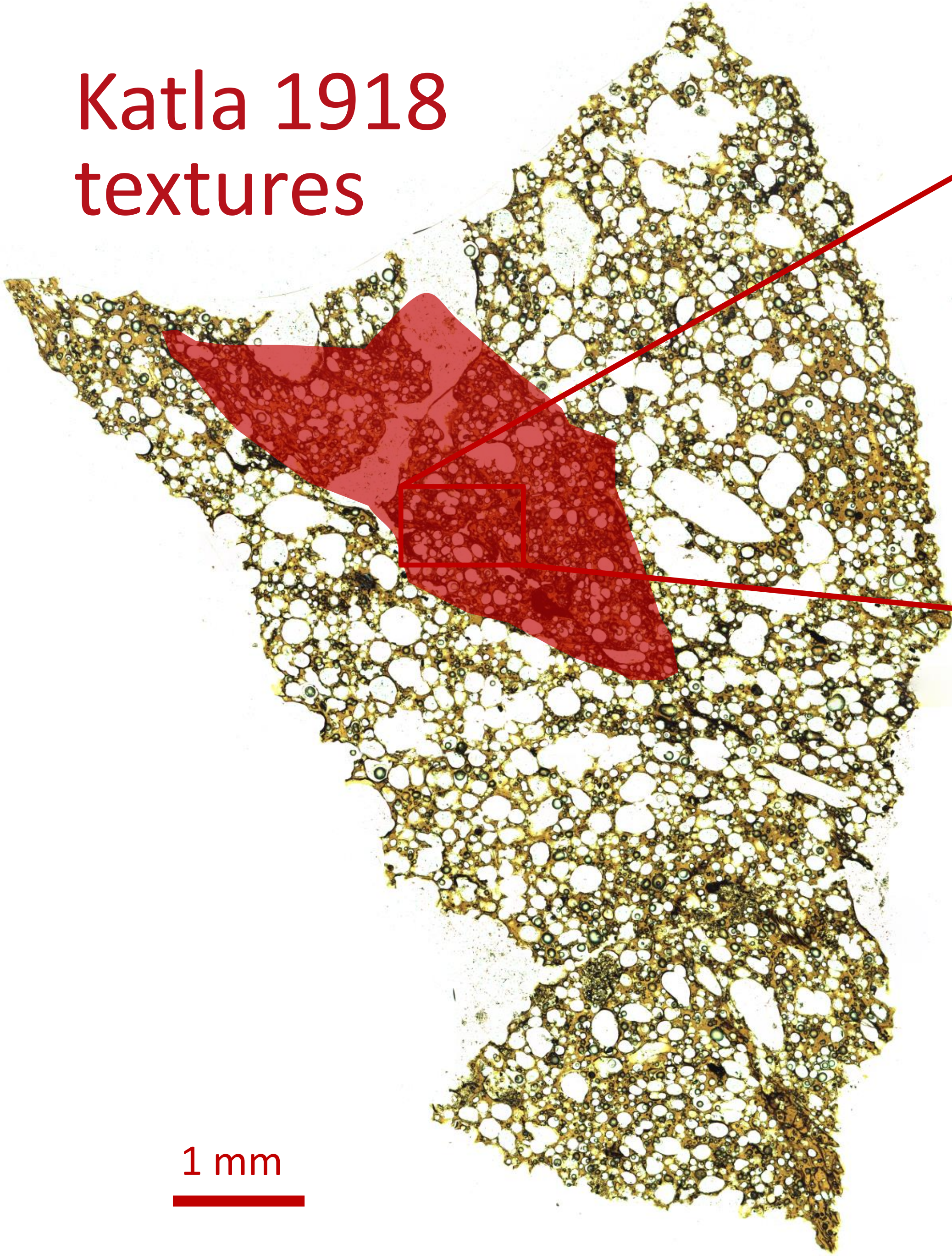
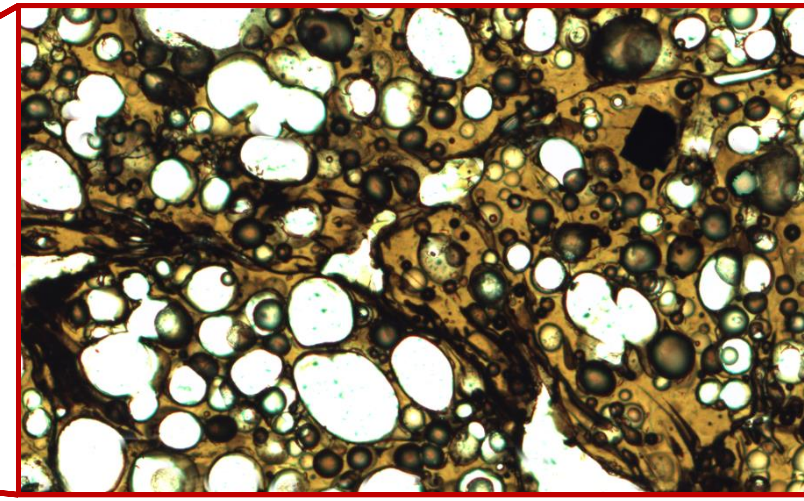
1 mm

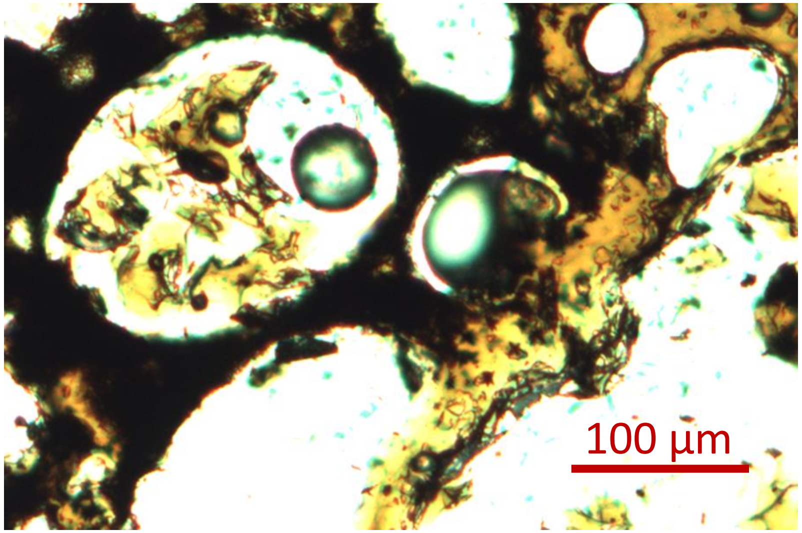
Katla 1918 textures

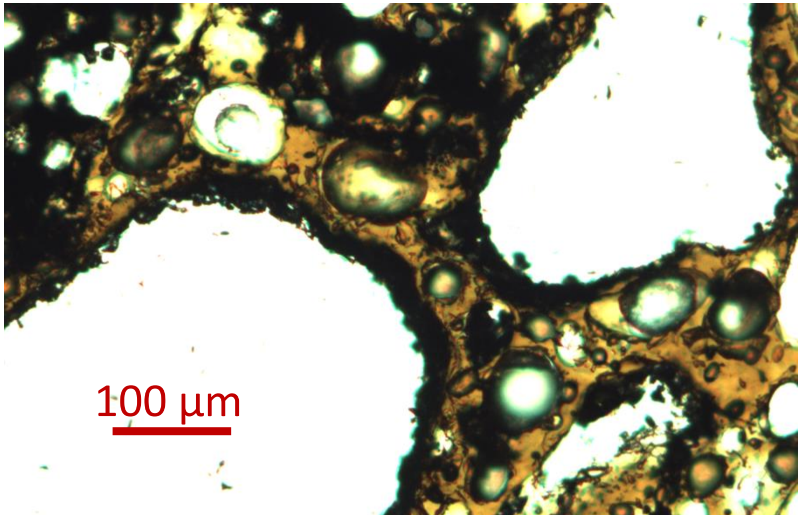


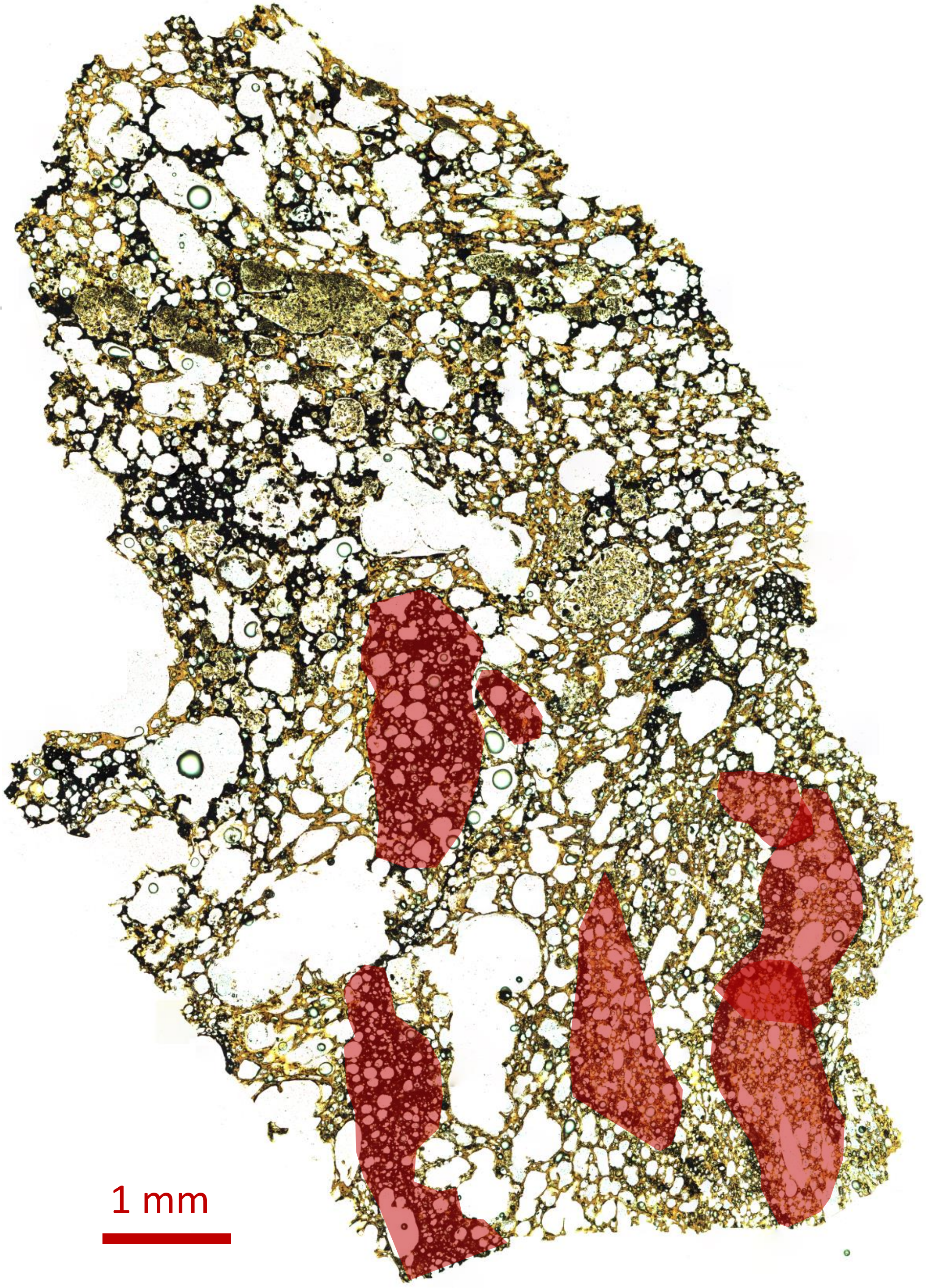


- Vesiculation
- Fragmentation
- Bubble collapse
- Welding
- Vesiculation
- Fragmenation

Katla 1918 textures







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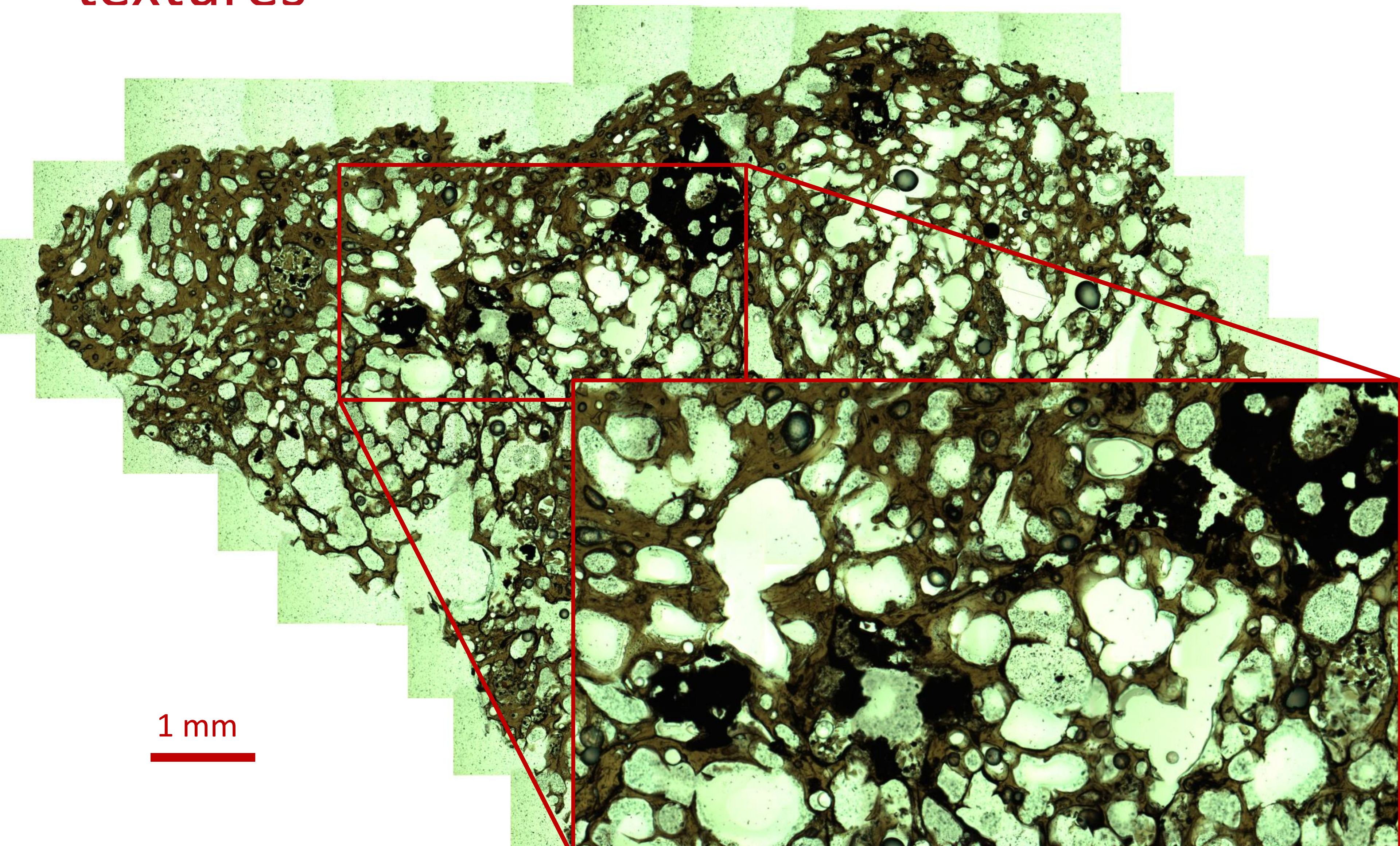
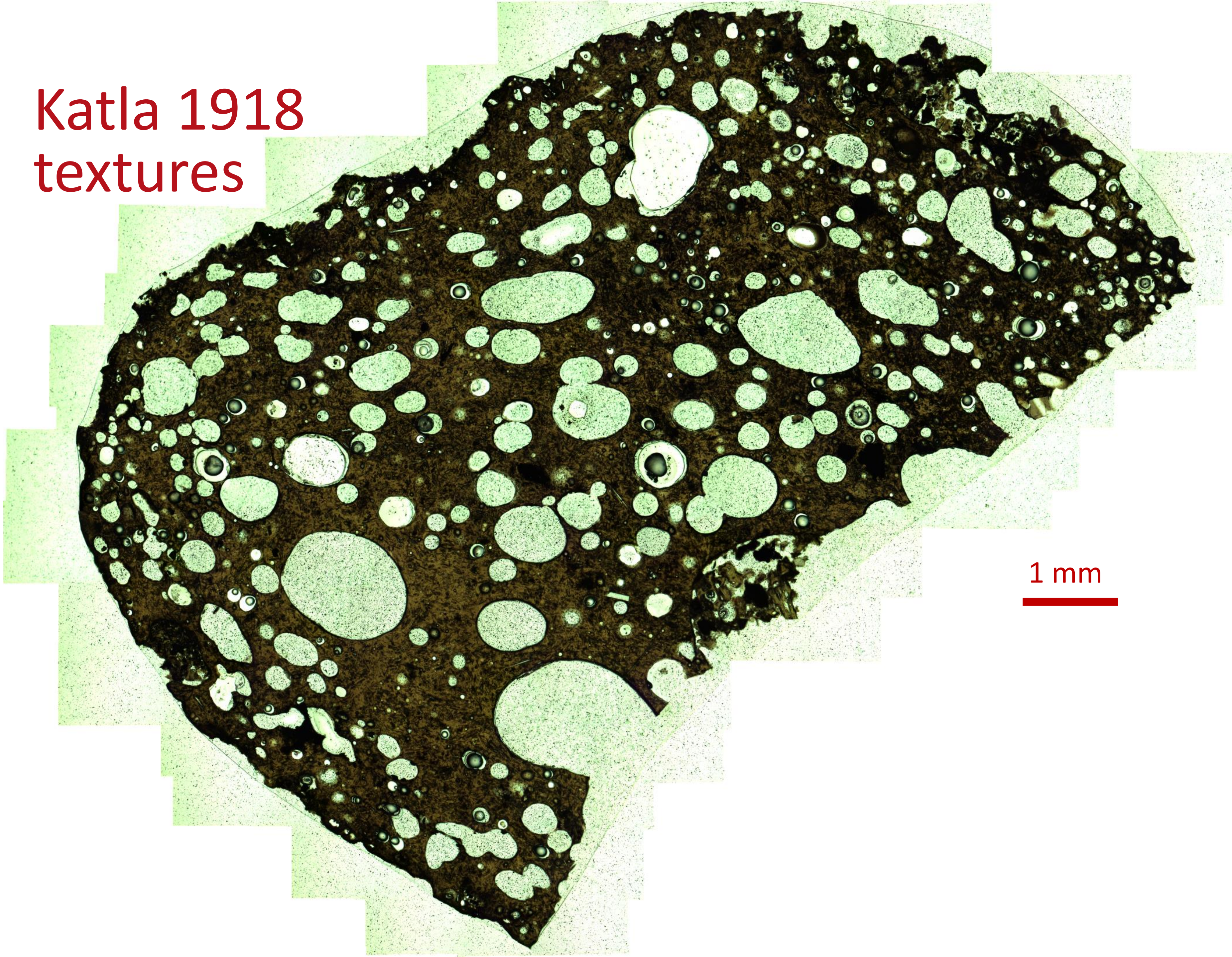
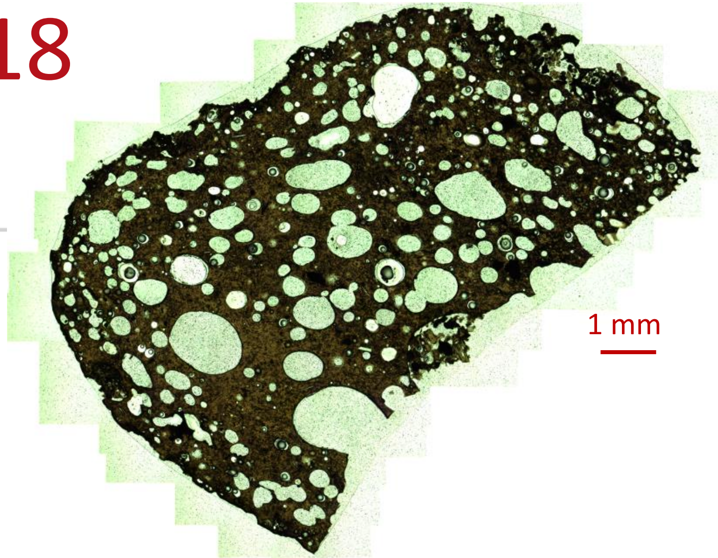
Katla 1918 textures

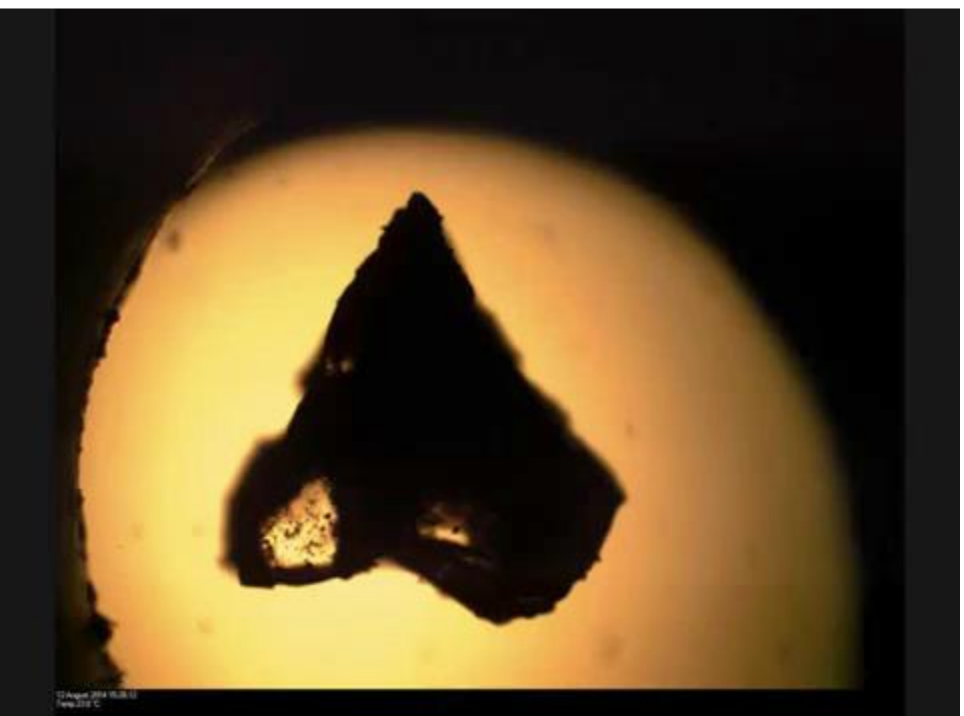


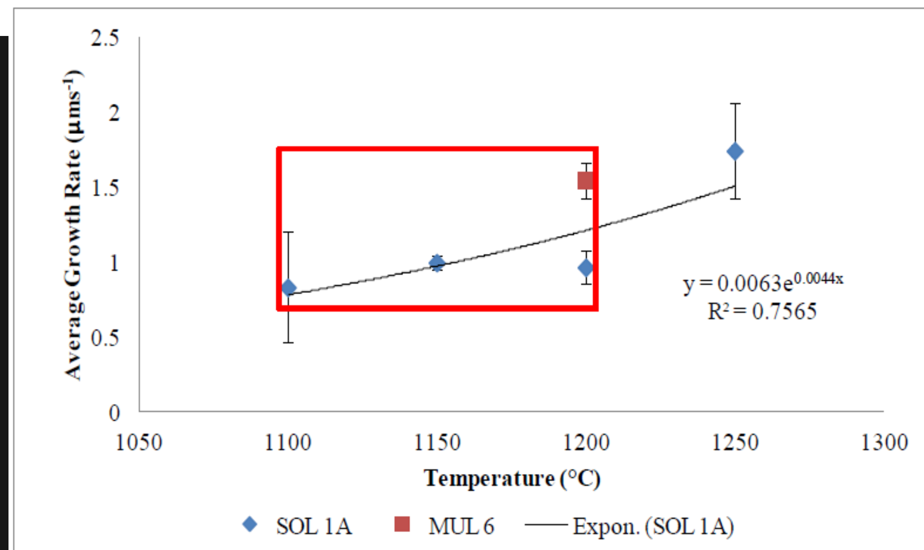
Katla 1918 textures



Katla 1918 hotstage







Conclusions

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- Torfajökull – the volatiles did it!
- Katla – the volatiles might've done it…. Lots of further work required
- Lots of evidence of repeated fragmentation (based on welded clasts) possibly with additional vesiculation and/or re-melting between the fragmentation events… so did fragmentation occur in the conduit????
- Some evidence that the jökulhlaup samples quenched rapidly in a water-rich environment under elevated pressure whereas the air-fall tephra cooled more slowly (high microlite content and larger bubbles in clast center) under atmospheric conditions (FTIR)

Further work

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- Detailed investigation of the different layers in the air-fall tephra collected this summer – (imaging, FTIR, TGA)
- Characterisation of external grain morphology
- SEM – vesicle size distribution and bubble number densities
- Chemical analysis: LA-ICP-MS for trace elements and EPMA for major elements and some volatiles

- Do the different grain sizes in the air-fall tephra layers represent different extents of fragmentation?
- And if so, what was causing the different eruptive behaviour???

Any questions?

Map of Katla 1918 jökulhlaup

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