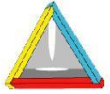

Deposition of volcanic ash in customised set-up for simulation of a turbine combustion chamber

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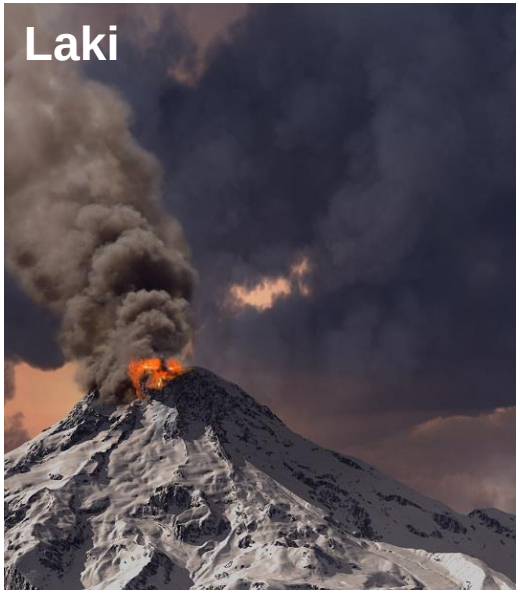
23th September, 2014, Cambridge

EPSRC Engineering and Physical Sciences Research Council

1. Selection of Volcanic Ashes

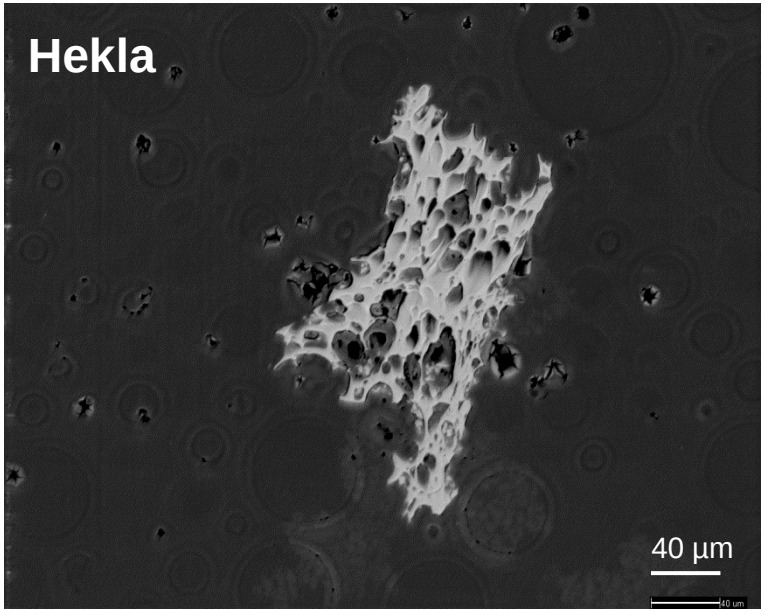


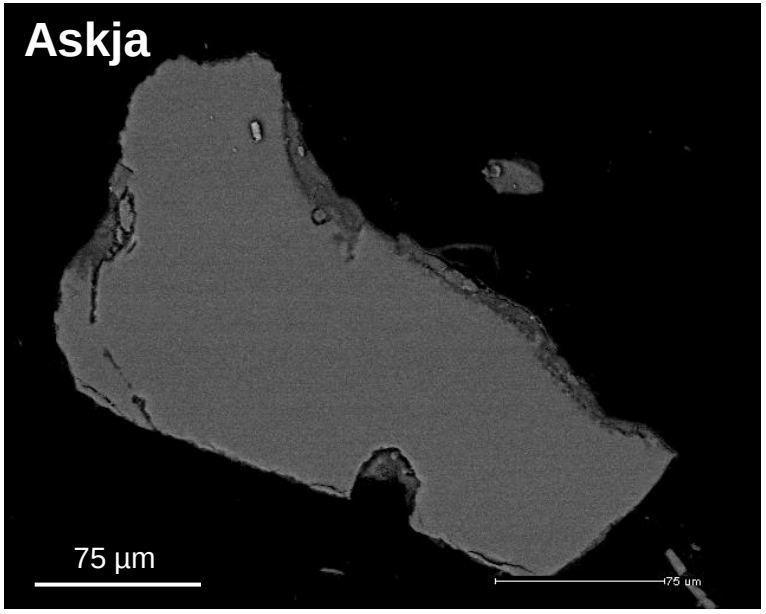
- **Particle Size**
- **Composition**
- **Glass Content**
- **T_g / T_m**

2. Sources & Characteristics of Ashes being Studied

Volcanic Ash	Particle sizes	Composition	Amorphous content (%)	T_g / T_m (˚C)
Laki	25/50/90 µm	Si/Ti/Fe/Mg… (oxides)	70	600 / 1100
Askja			100	700 / -
Hekla			100	1250 / -
Eldgja			23	700 / 1000
Eyjafjallajökul			40	700 / 1000

SEM micrographs of polished sections, showing different porosity levels





3. Compositions of the Selected Ashes

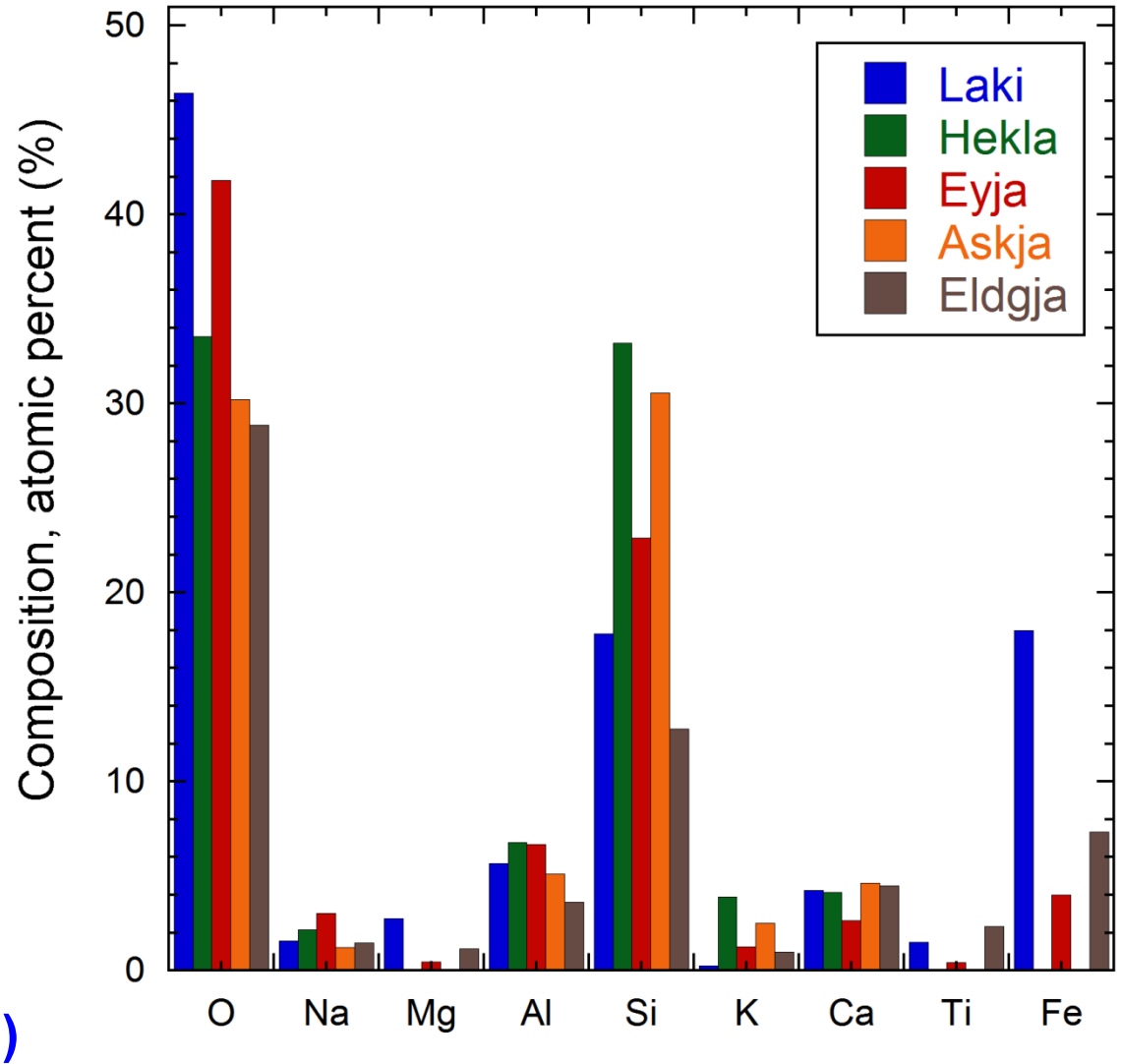
All broadly similar, but: • Laki high in Fe • Hekla & Askja high in Si

Difficult to relate these compositions to features such as glass content or T_g, or even to the crystalline phases that form.

However, note basicity index (Ca + Mg + Fe) / (Si + Al):

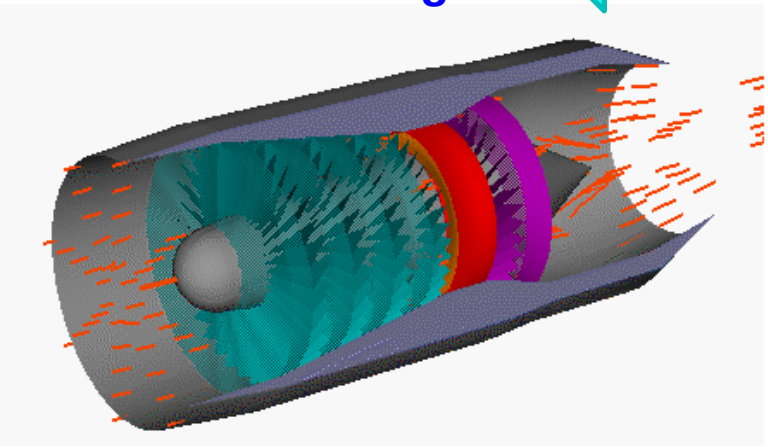
Laki ~ 1.0; Hekla ~ 0.1; Eyja ~ 0.3; Askja ~ 0.1; Eldgja ~ 0.7

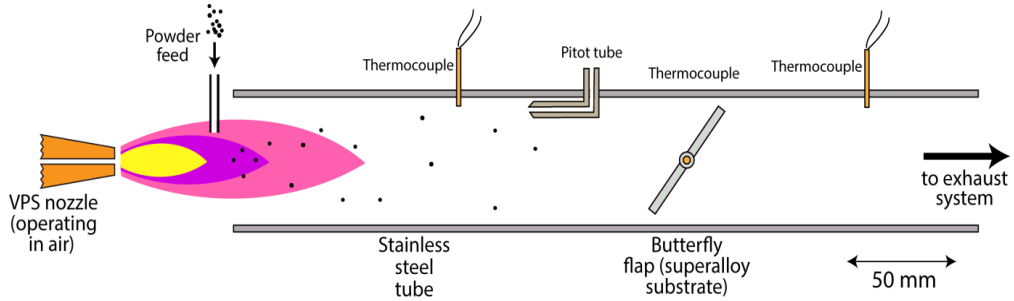
- ie most are rather acidic, except Laki & Eldgja. (Generally, basic slags have lower "melting temperatures")

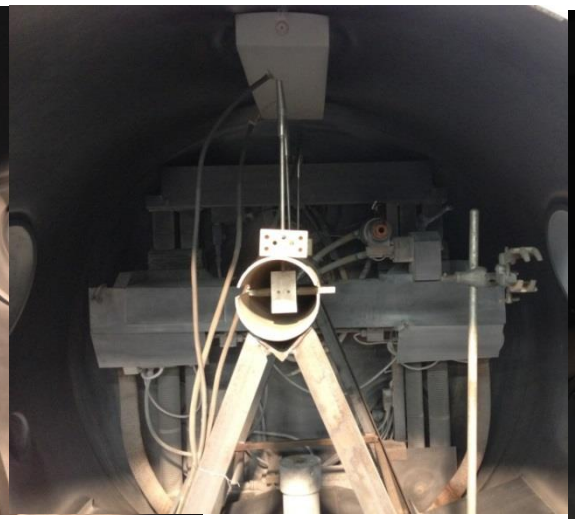


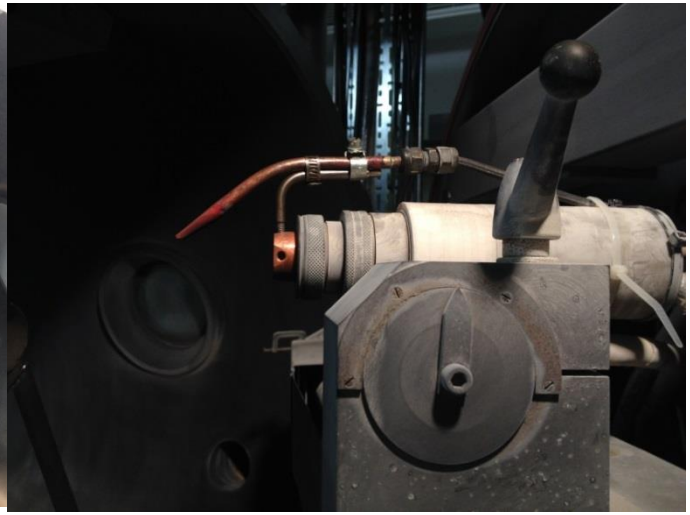
4. Study of Ash Particle Deposition Rates

Jet-Engine ⟷ **VPS customized set-up**





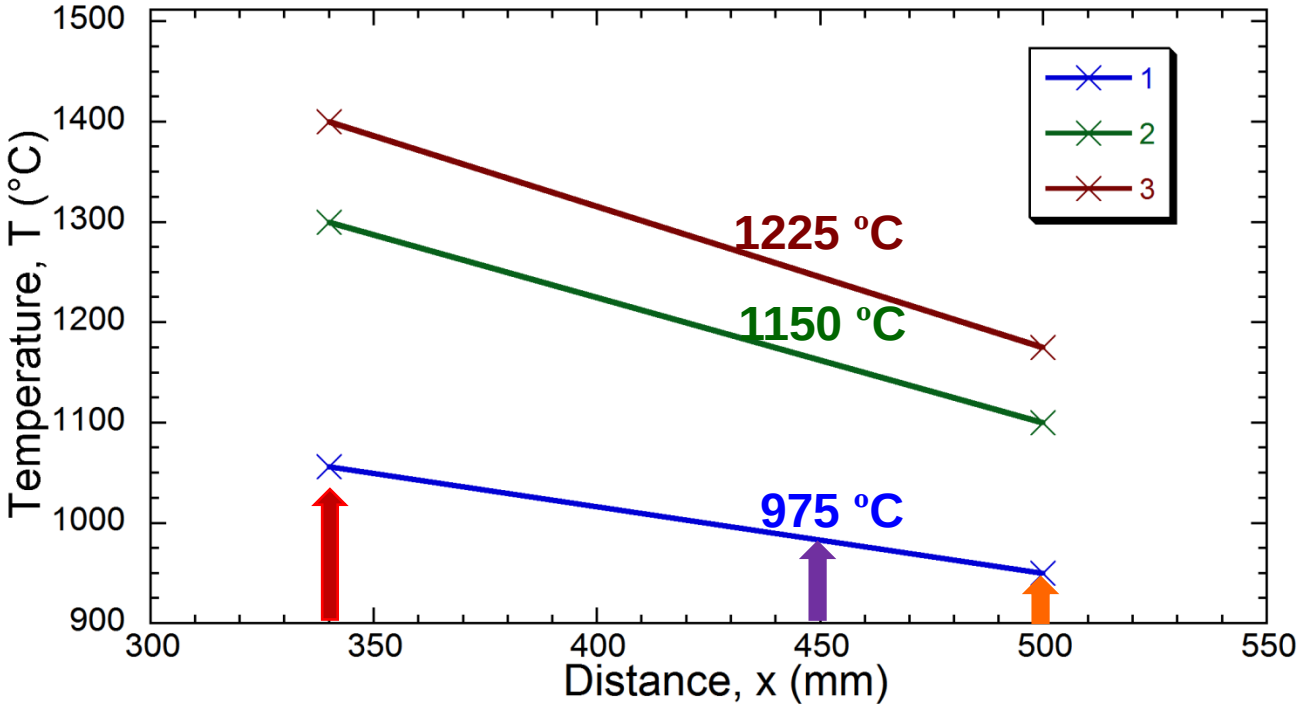




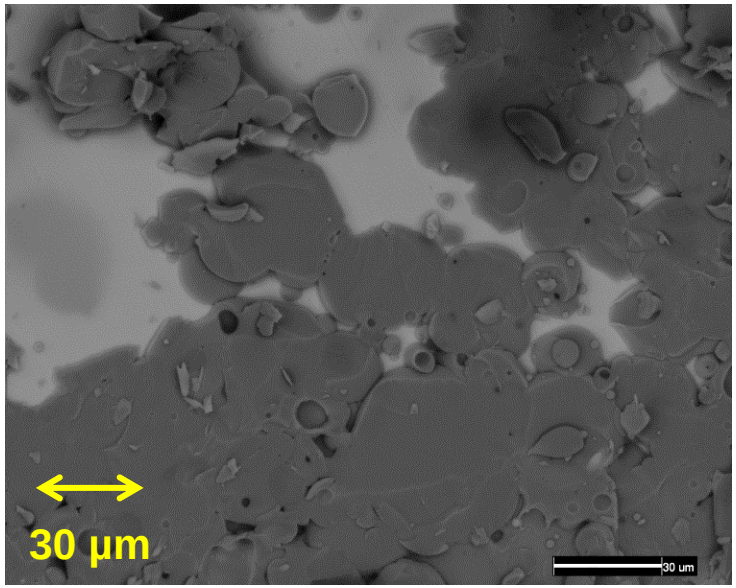
5. Conditions for Ash Particle Injection Experiments

Conditions	Power (kW)	Argon (L/min)	Hydrogen (L/min)	Current (A)	Pressure chamber
1	30	50	4	750	120 mbar
2	40	50	7	800	120 mbar
3	40	50	7	800	80 mbar

Axial Gas Temperature Profile along Tube

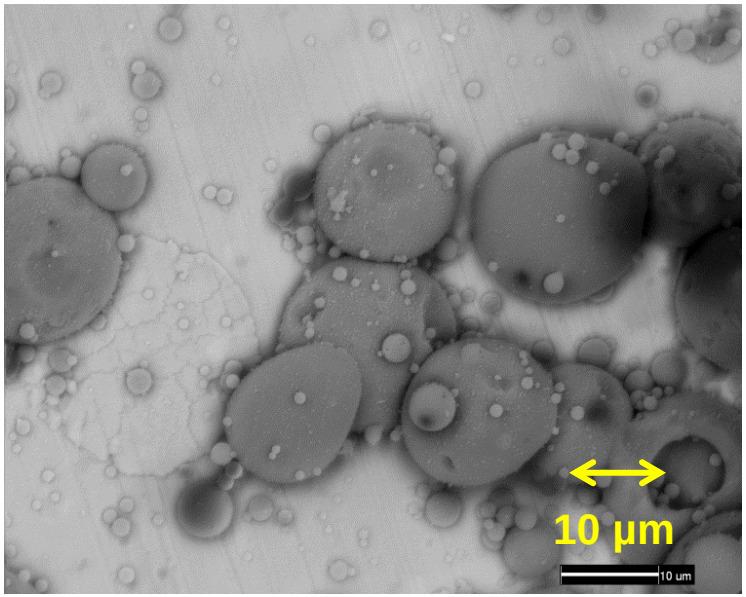


7. Observed Splat Morphologies - 25 µm Particles

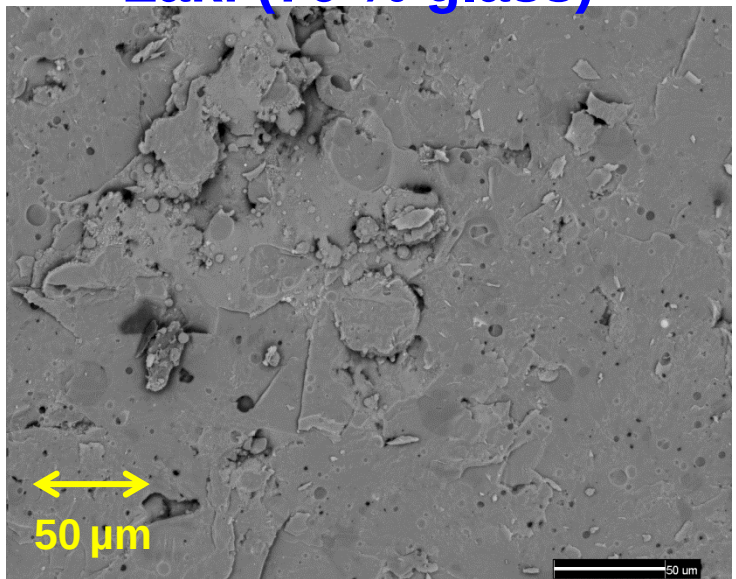


Gas *T* at substrate

975˚C

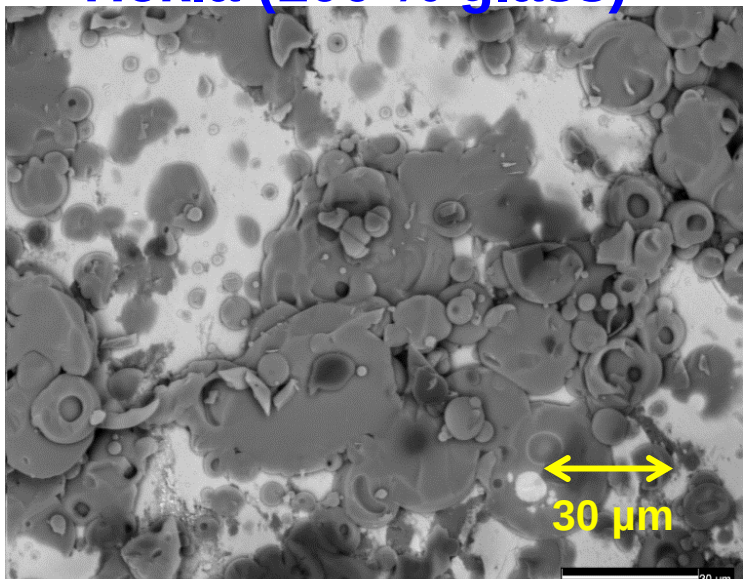


Laki (70 % glass)



1225˚C

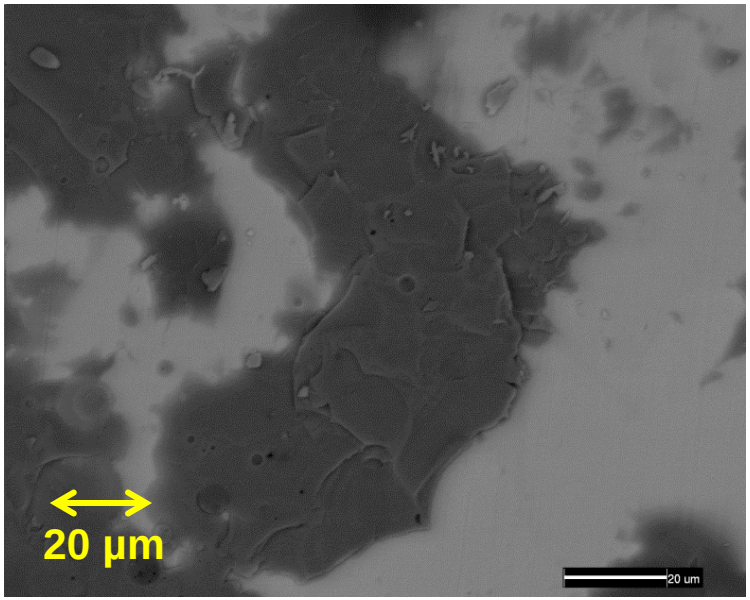
Hekla (100 % glass)

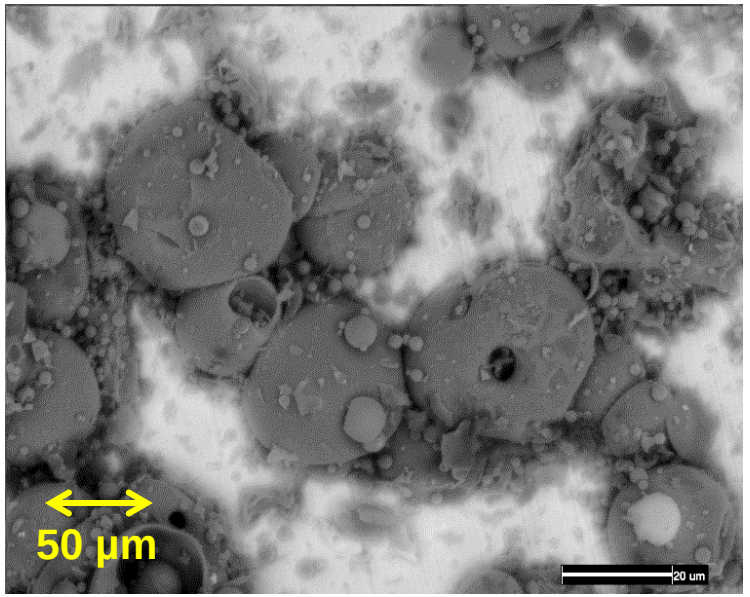


8. Observed Splat Morphologies - 50 µm Particles

Gas *T* at substrate

975˚C

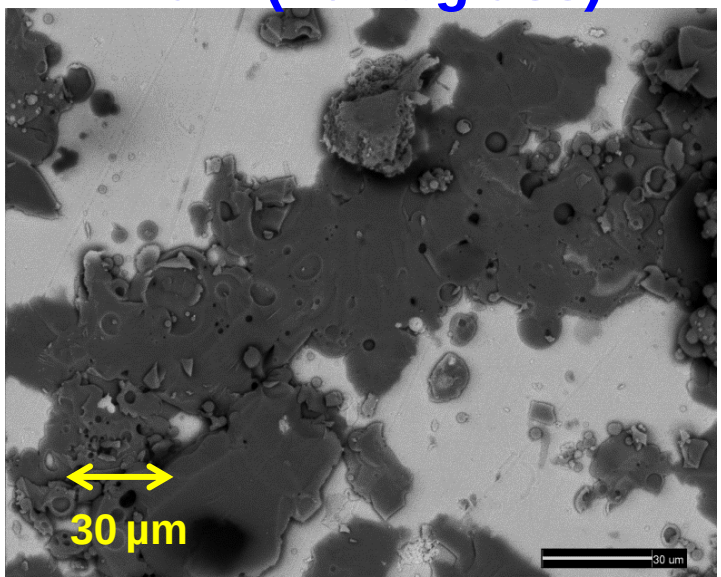


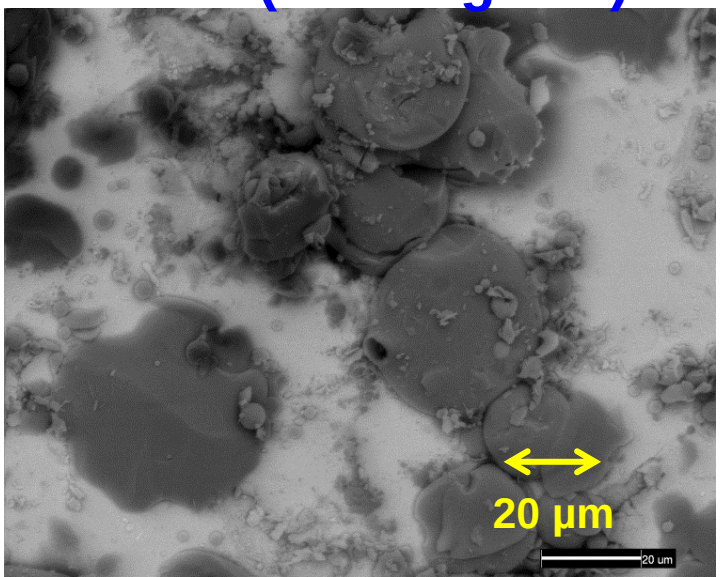


Laki (70 % glass)

Hekla (100 % glass)

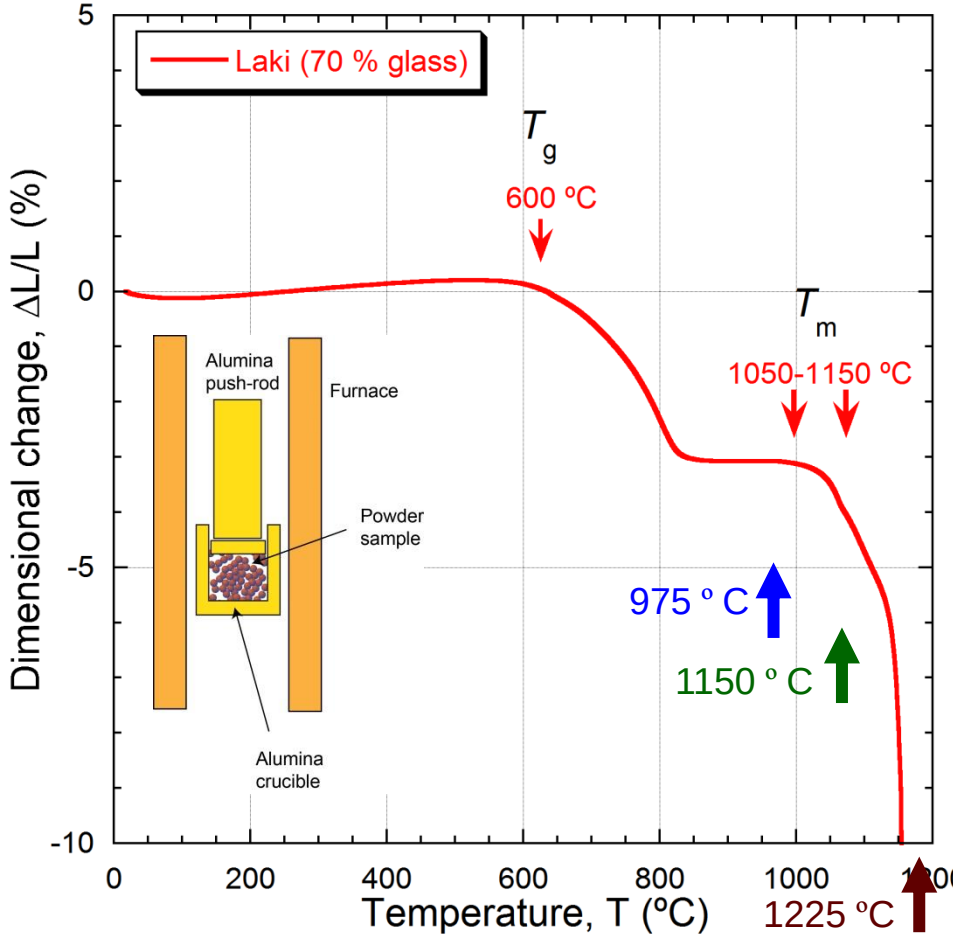
1225˚C





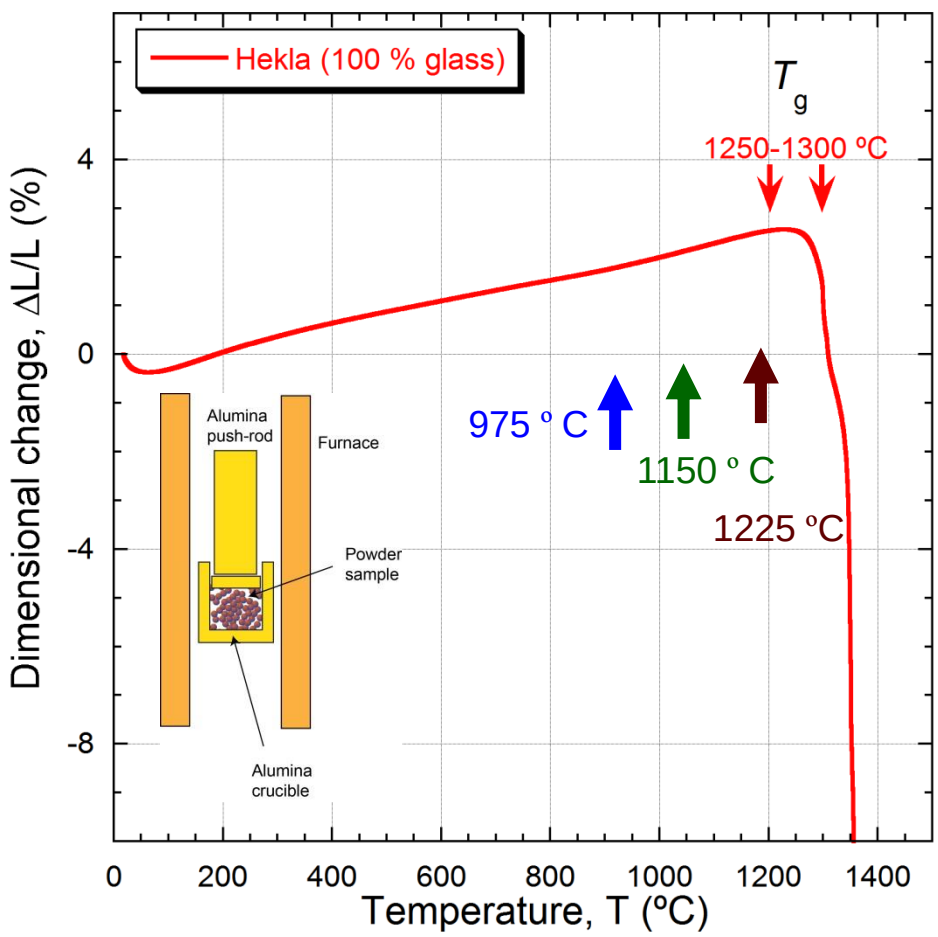
6. Evaluation of T_g and T_m via Dilatometry of Powders

Laki (70 % glass)



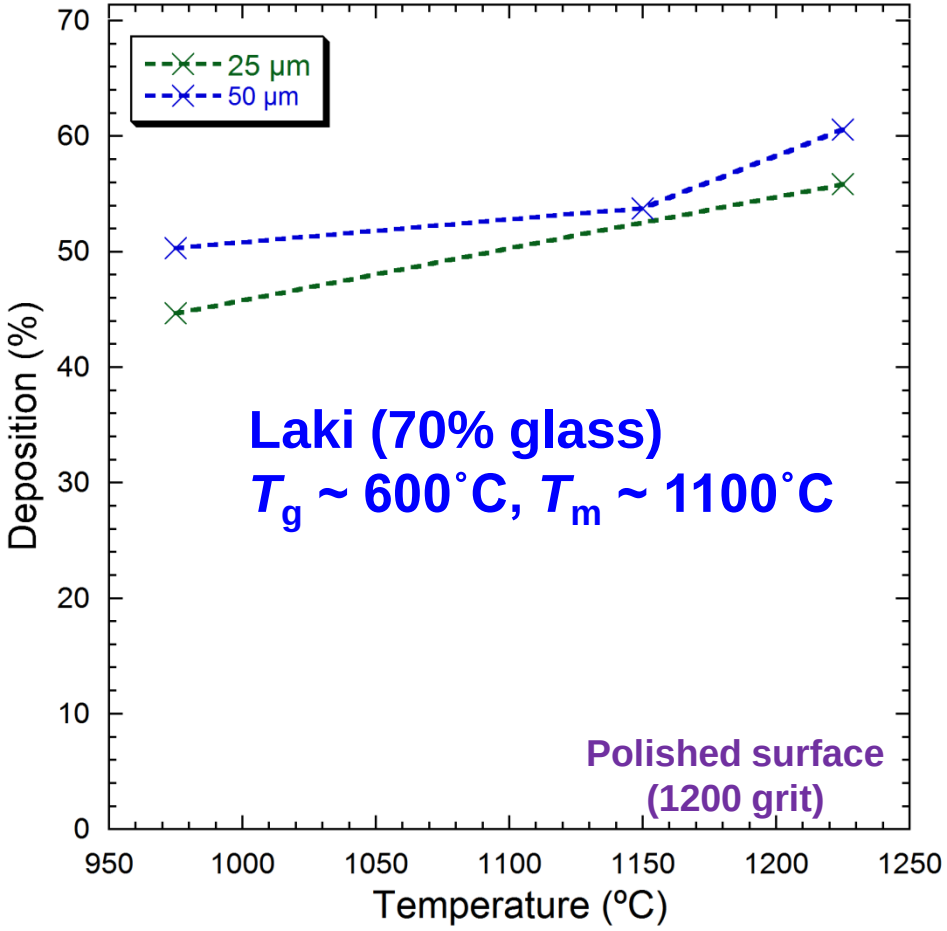
All gas *T*'s above T_g, highest above T_m

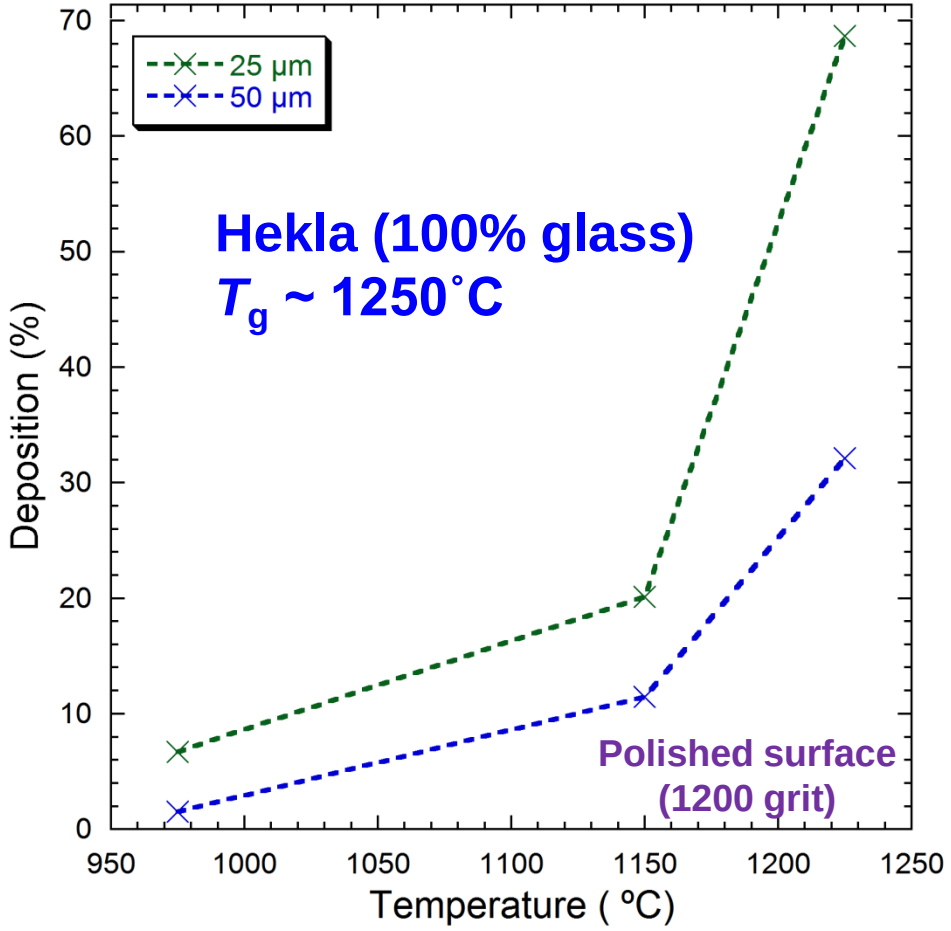
Hekla (100 % glass)



All gas *T*'s below T_g, highest ~ T_g

9. Ash Particle Deposition Rates (obtained by Weighing)





Laki: uniformly high deposition rates - most particles (including 50 µm) soften enough to adhere, even with lower gas *T*. Possibly losing some small particles via the gas streamlines.

Hekla: little adhesion at lower gas *T*'s - few particles reaching the (high) T_g. For the highest gas *T*, more particles are softening, particularly the smaller ones.

10. Summary

- ***Laki***, ***Eldgja***, ***Hekla*** and ***Askja*** VA's cover a suitably wide range of composition, glass content, T_g and T_m values: the project will focus on these.

- Initial deposition rate trails, using a plasma torch-based Combustion Chamber Simulation Rig, have involved ***Laki*** and ***Hekla*** ashes, with ***2 particle size*** ranges (centred on 25 μm & 50 μm) and ***3 gas temperature*** profiles (giving 975˚C, 1150˚C and 1225˚C on passing the substrate).

- ***Laki***, which is ***70% glass***, has a ***low T_g*** (~600˚C), such that ~ all particles softened for all gas temperatures, giving a uniformly ***high deposition rate*** (~50%). Slightly lower rates for 25 μm may be due to lower impact rates.

- ***Hekla***, which is ***100% glass***, has a ***high T_g*** (~1250˚C), such that ***few particles*** softened / adhered for the lower gas *T*'s. For the **highest *T***, however, softening and ***adhesion did occur***, particularly with small particles.

- These, and future, observations will be correlated with predictions from a ***numerical CFD model***, which will shortly be deployed.