Ground-Truthing Lava Flow Propagation Models With Examples From the 2018 Eruption of Kilauea Volcano, HI

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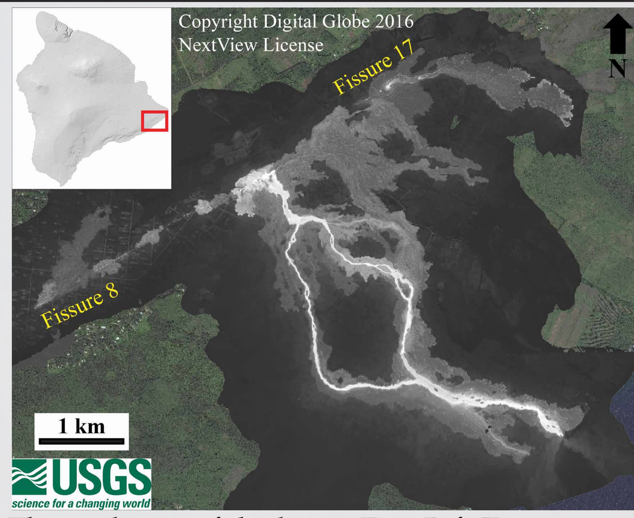
1. Eruption Summary

- Began May 3rd, and ended August 6th
- 24 eruptive fissures
- First documented eruption of andesite on Kilauea
- 35.5 km^2 covered by lava
- 716 structures destroyed
- Concurrent lava effusion and summit collapse



Thermal map of the lower East Rift Zone, captured on May 21,2018. Both flows of interest are visible, with fissure 17 still weakly fountaining. Inset DEM of the Big Island from USGS

Flows of Interest

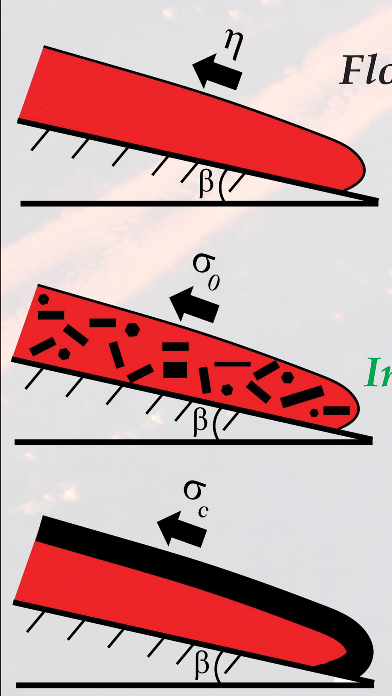
Early Fissure 8 (EF8)
- Active May 6-7
- Flowed ~1 km
- Erupted cool with ~20 vol. % crystals
- Basaltic composition (SiO_2 = 51%)

Fissure 17 (F17)
- Major activity May 13-16
- Flowed ~2.5 km
- Erupted cool with ~25 vol. % crystals at vent, ~50 vol. % at terminus
- Andesitic composition (SiO_2 = 58%)

2. Research Questions:

Can we accurately predict lava flow propagation?
In how much detail do we need to know lava material properties for accurate predictions?

3. Lava Flow Models



Flow Stopped By:

Lyman and Kerr (2006)
Holds input parameters constant

Castruccio et al. (2013)
Allows variables to change continuously

Viscosity

$$L = c_{vs}\left[\frac{g\Delta\rho\sin\beta q^2 t}{\eta}\right]^{\frac{1}{3}}$$

$$L = C_1\sum_{i=1}^{n}\left(\frac{V_i^2\rho g\sin\beta_i t_i}{\eta_i W_i^2}\right)^{1/3}$$

Internal Yield Strength

$$L = \frac{qg\Delta\rho\sin\beta}{\sigma_0}$$

$$L = C_2\sum_{i=1}^{n}\left(\frac{V_i\rho g\sin\beta_i}{\sigma_{0i}W_i}\right)$$

Crust Yield Strength

$$L = c_c\left[\frac{g\Delta\rho}{\sigma_c}\right]^{\frac{1}{2}} q(\kappa t)^{\frac{-1}{4}}$$

$$L = C_3\sum_{i=1}^{n}\left(\frac{V_i^2\rho g\sin\beta_i}{W_i^2\sigma_{ci}\sqrt{\kappa t}}\right)^{1/2}$$

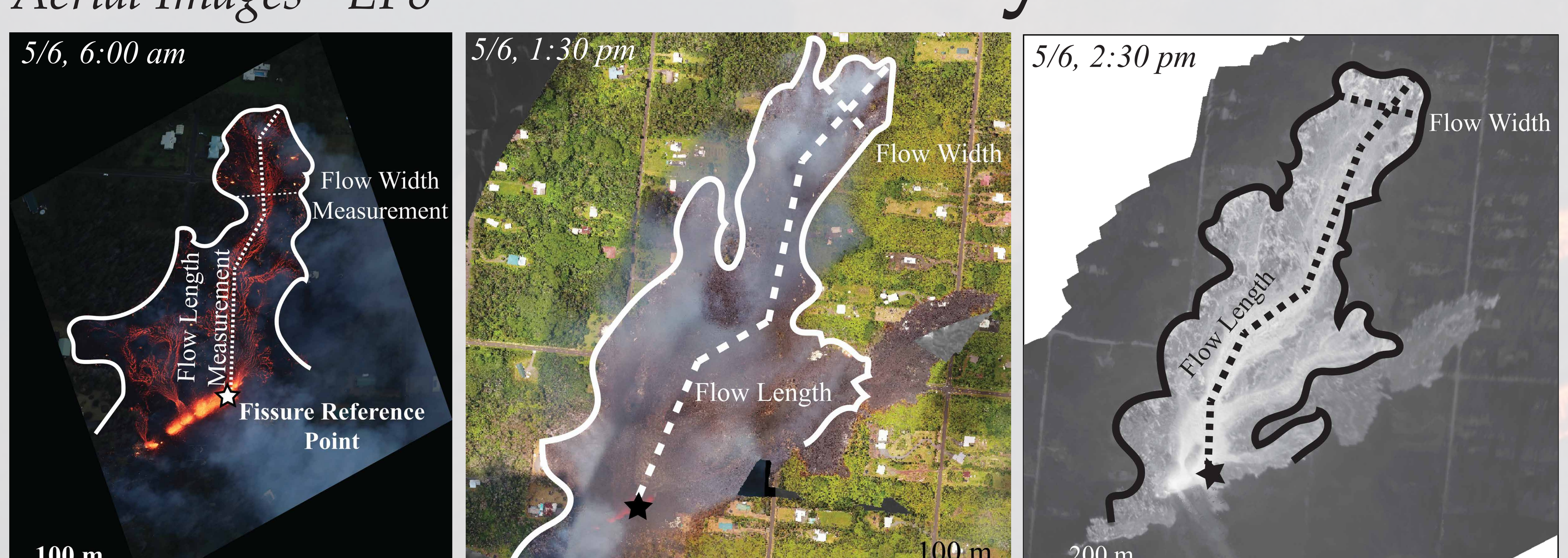
Dominant regime is the regime that predicts the shortest length

Symbol	Variable	Units	Data Source
L	length	m	Measured from imagery
g	gravitational acceleration	m s^{-2}	
β	slope	degrees	Measured from DEM
η*	**viscosity**	Pa s	Giordano et al. (2008), Costa et al. (2009)
t	time	s	
W	flow width	m	Measured from imagery
ρ	lava density	kg m^{-3}	Bottinga and Weill (1970)
q	time-averaged lava flux	m^3 m^{-1} s^{-1}	Measured from imagery
σ_0*	**fluid yield strength**	Pa	Pinkerton and Stevenson (1992)
σ_c	crust yield strength	Pa	Kerr et al. (2006)
κ	thermal diffusivity	m^2 s^{-1}	
V_i	incremental volume	m^3 s^{-1}	Measured from imagery

*properties are influenced by crystals

4. Remotely Measured Data

Aerial Images - EF8

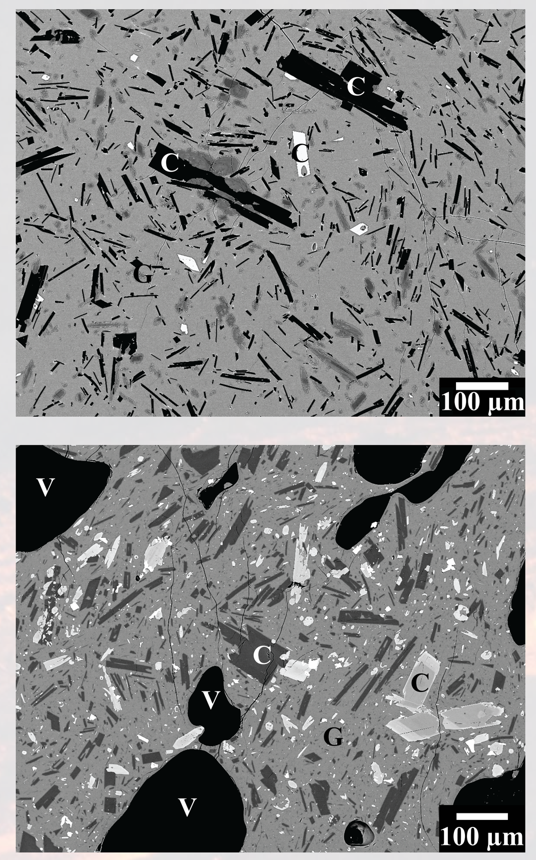


Aerial imagery was used to quantify macroscopic flow properties, such as flow length, flow width, fissure length, and area of flow, as outlined in the three images. Sources include, from left to right, still shots (corrected for look angle), drone orthomosaics, and thermal orthomosaics

- Flow volume estimated from final flow outline and field thickness measurements
- Raw mass flux estimated from flow volume min/max estimates of flow emplacement duration
- Flux is either normalized to fissure length (q) or flow width (V/W), depending on model
- Ground slope measured from 10 meter DEM

Fissure	High q (m^2/s)	Low q (m^2/s)	High V_i (m^3/s)	Low V_i (m^3/s)
EF8	0.0636	***0.0265***	***7.43***	3.09
F17	0.0510	***0.0117***	25.05	***5.77***

5. Microprobe Data



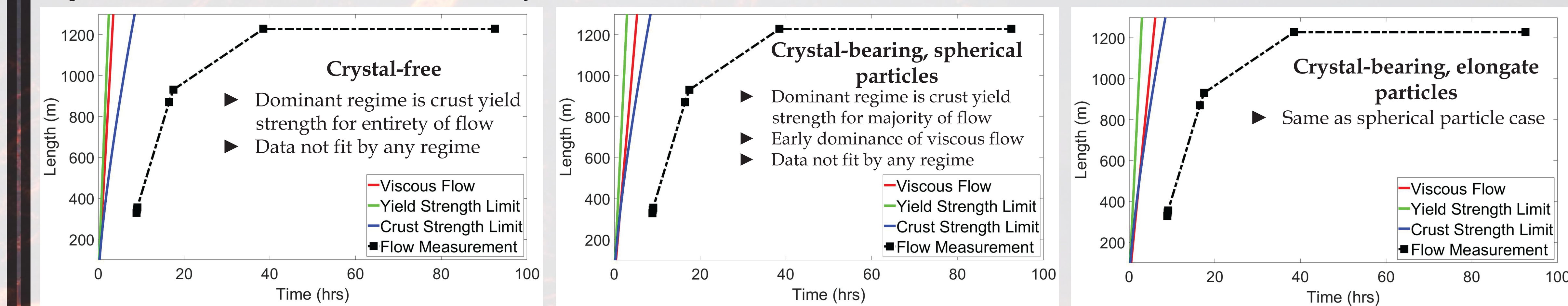
Example back-scattered electron (BSE) images of crystals from early fissure 8 (top) and fissure 17 (bottom). Phases are labeled as V=vesicle, C=crystal, G=glass

- Major element chemistry of glass measured
- Glass chemistry used to calculate fluid viscosity via Giordano et al. (2008)
- BSE images captured for crystal content and texture
- Images analyzed using NIH ImageJ
- Crystals incorporated into viscosity using the model of Costa et al. (2009) and fit parameters of Cimarelli et al. (2011)
- Crystals incorporated into yield strength using the model of Pinkerton and Stevenson (1992)

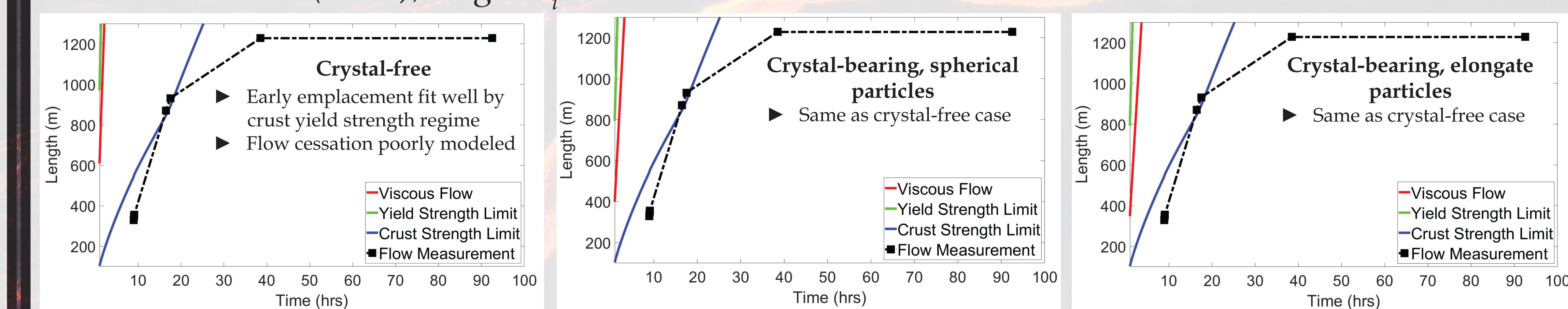
Fissure	Vent Crystal Percent	Terminus Crystal Percent	Average Crystal Percent	Average Aspect Ratio
EF8	25	25	25	3.3
F17	27	50	39	2.45

6. Model Results - Early Fissure 8

Lyman and Kerr (2006), Low q Results

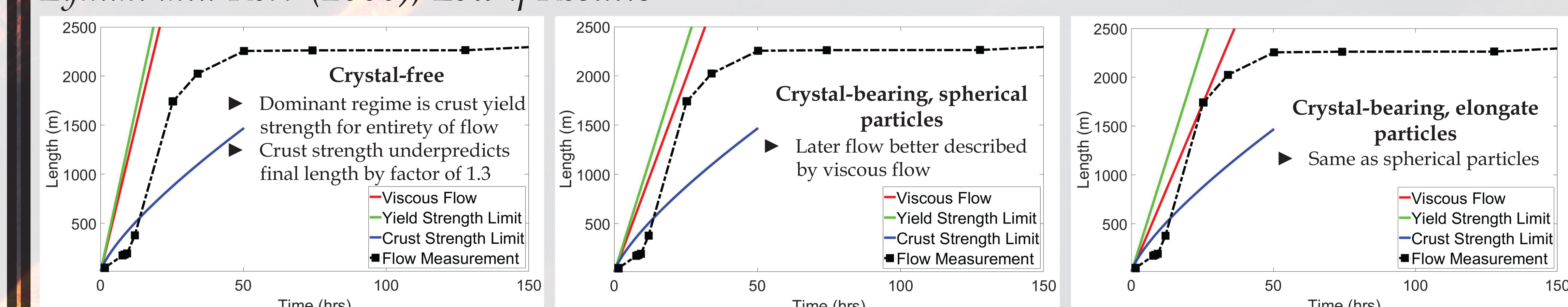


Castruccio et al. (2013), High V_i Results

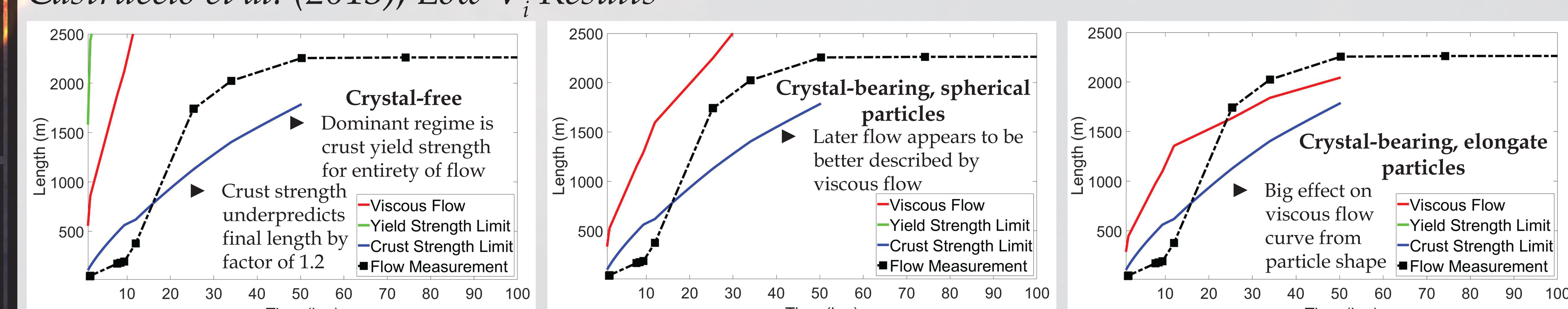


7. Model Results - Fissure 17

Lyman and Kerr (2006), Low q Results



Castruccio et al. (2013), Low V_i Results



8. Summary

Can we predict lava flow propagation?
- Both flows are predicted to be dominated by crust yield strength
- Models overpredict EF8 flow length and underpredict F17 flow length
- Blind application of models appears to be missing some important factors that are influencing both EF8 and F17
- Incorporation of crystals important for modeling subtleties in length vs time relationships for F17

Future improvements to models
- Include error envelopes on models to assess true goodness of fit
- Allow effusion rate to vary through time - potential factor that explains model misfit

9. Acknowledgements

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Background image by the USGS.

10. References

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