# OBSERVATIONAL CONSTRAINTS FOR LAVA FLOW MODELS

Einat Lev, LDEO

IAVCEI Benchmarking Workshop

Kagoshima, 2013

# WILL DISCUSS CONSTRAINTS FROM:

**Natural Flows**

**Analogue Experiments**

**Basaltic Experiments**

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**Natural Flows**

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**Basaltic Experiments**

# FIELD OBSERVATIONS – VELOCITY


Lev et al., 2012

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Lev et al., 2012

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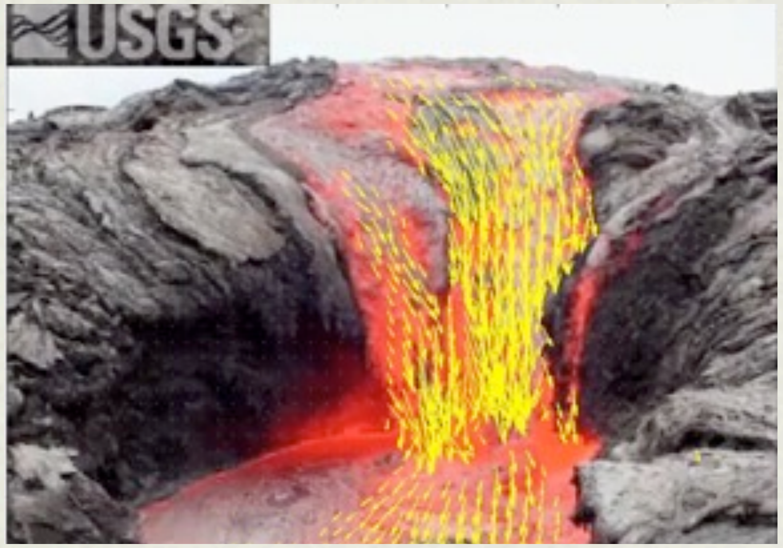
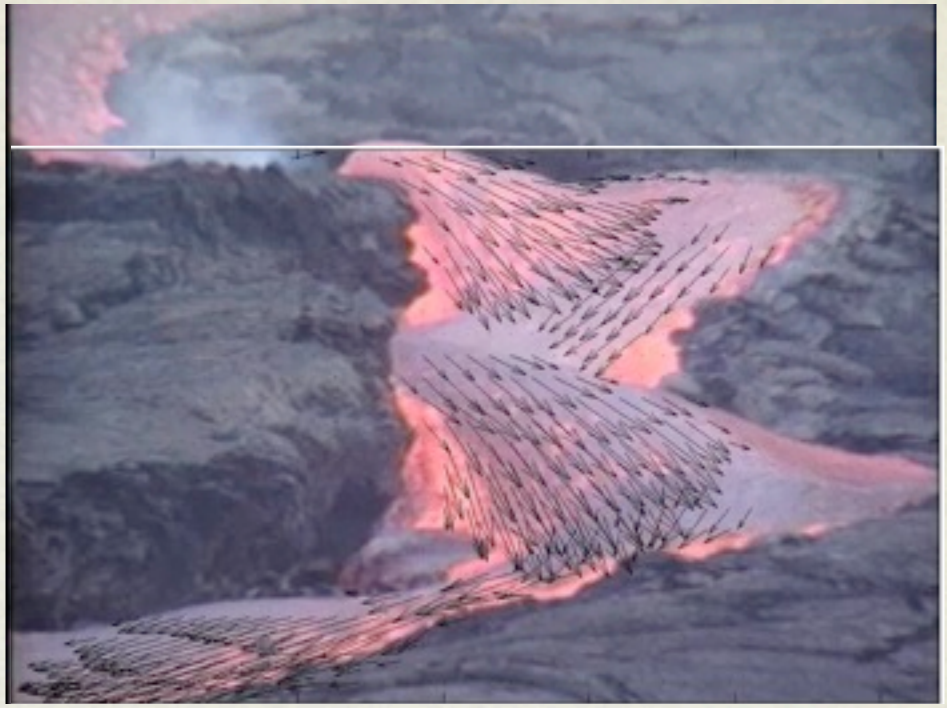
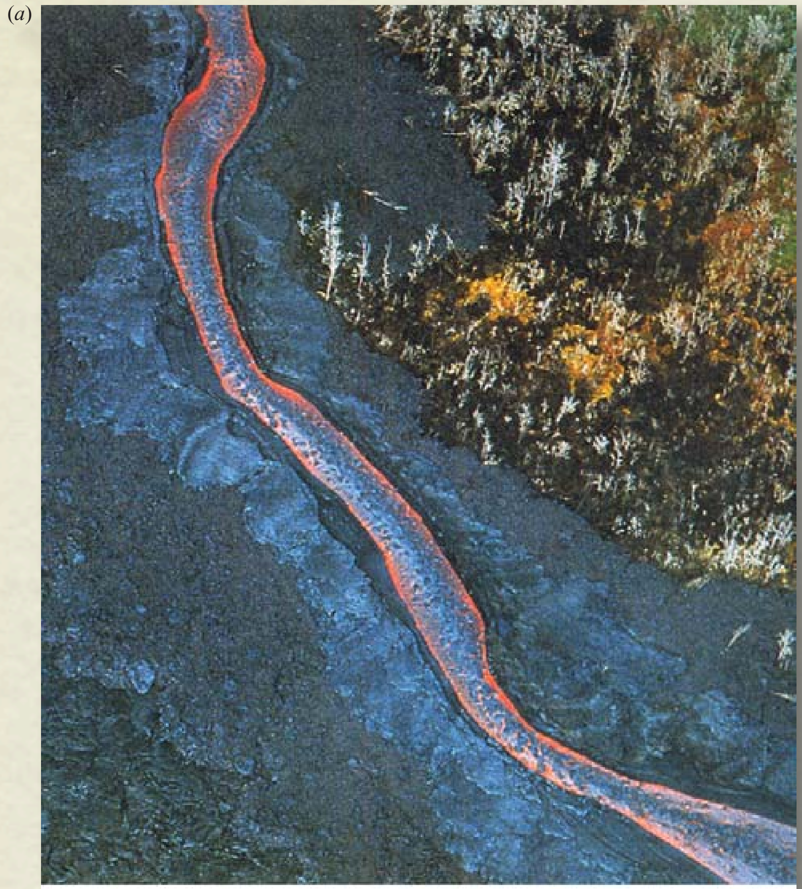




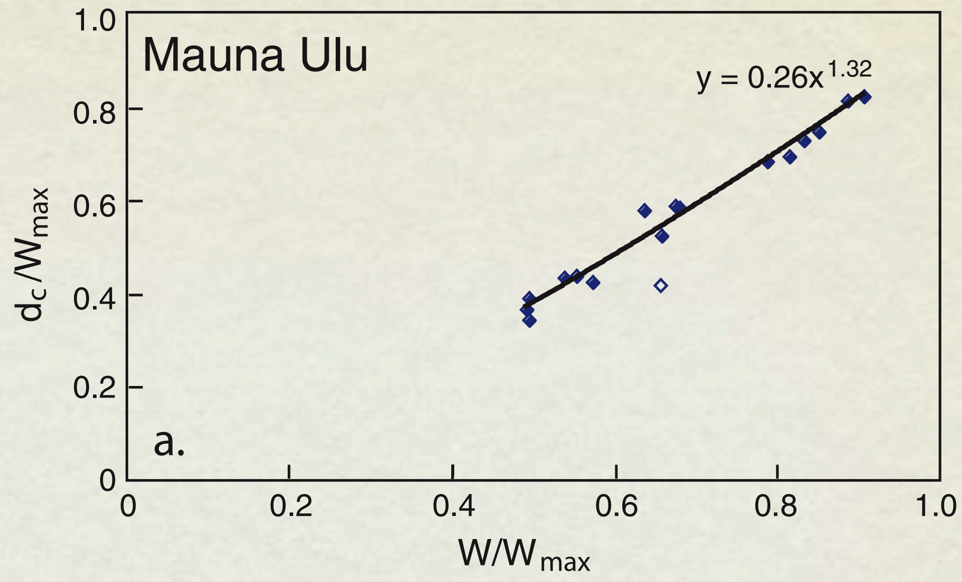
Lev et al., 2012

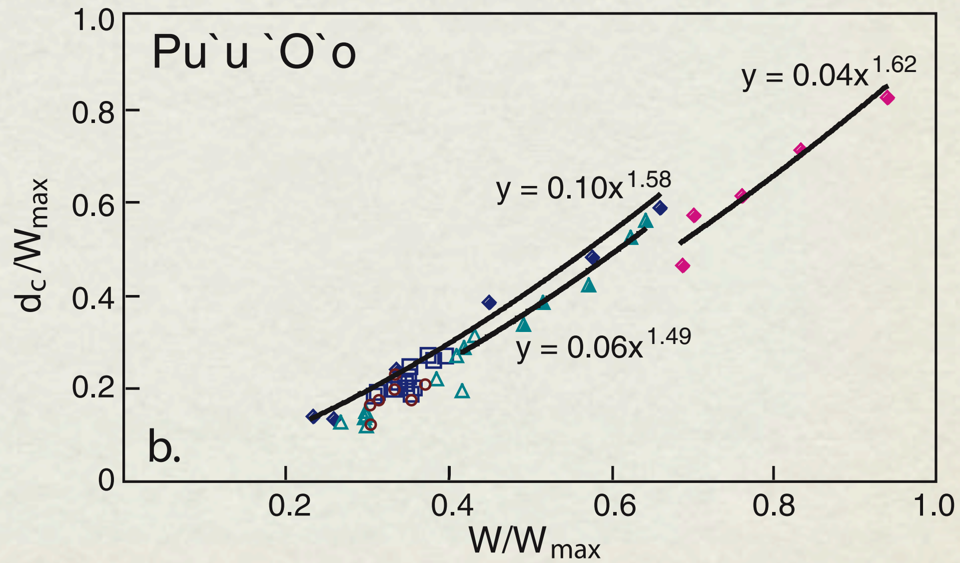
# FIELD OBSERVATIONS – CRUST COVER




from:
Tilling et al. 1987

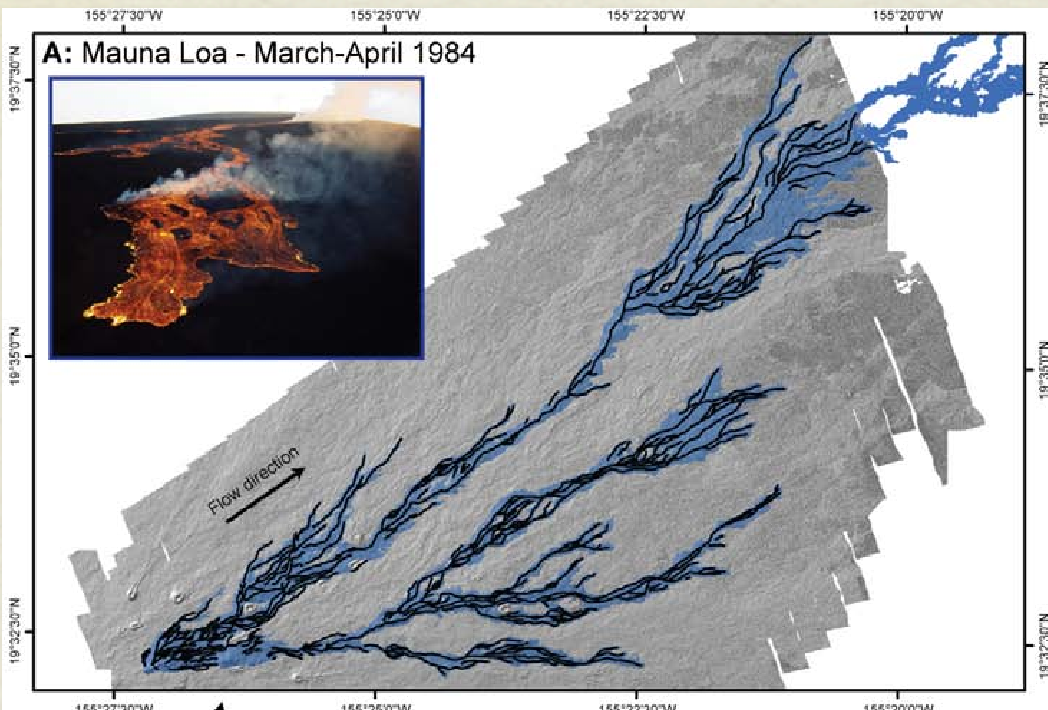

from:
Italy's Volcanoes: The Cradle of Volcanology




Cashman et al., 2006

# FIELD OBSERVATIONS – CHANNELS




Bifurcation on many levels

Observables include:

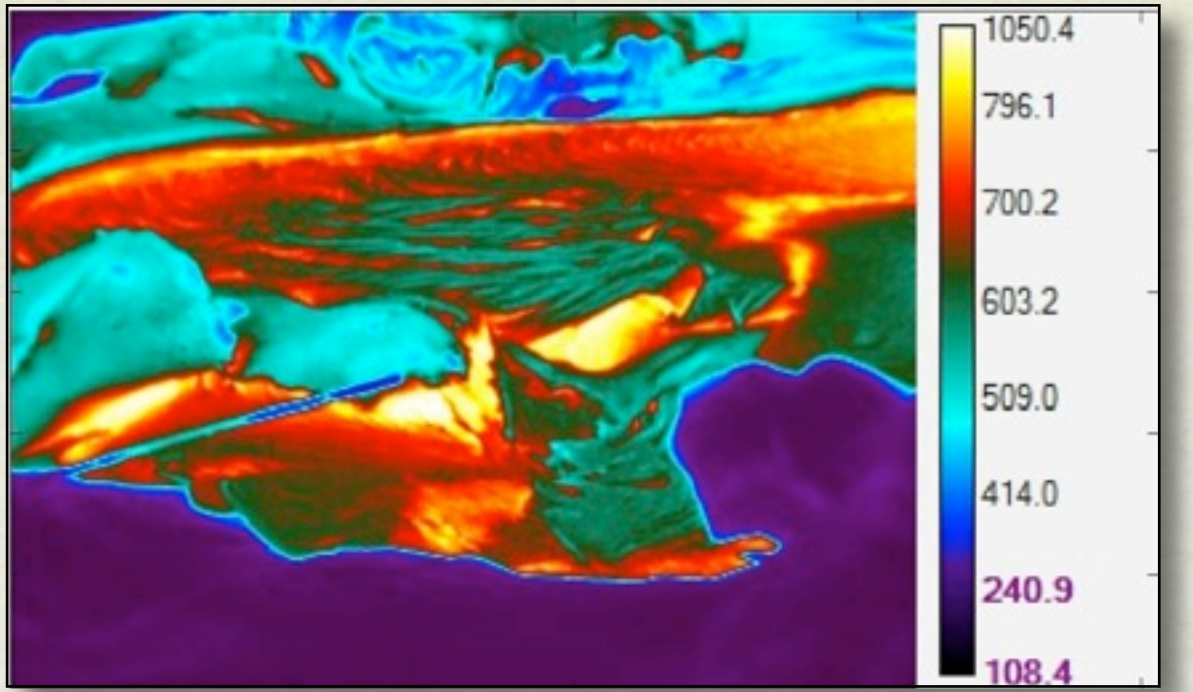
- Flow morphology
- Channel morphology
- Crust cover


October2007 obstacle movie

# FIELD OBSERVATIONS – THERMAL DATA

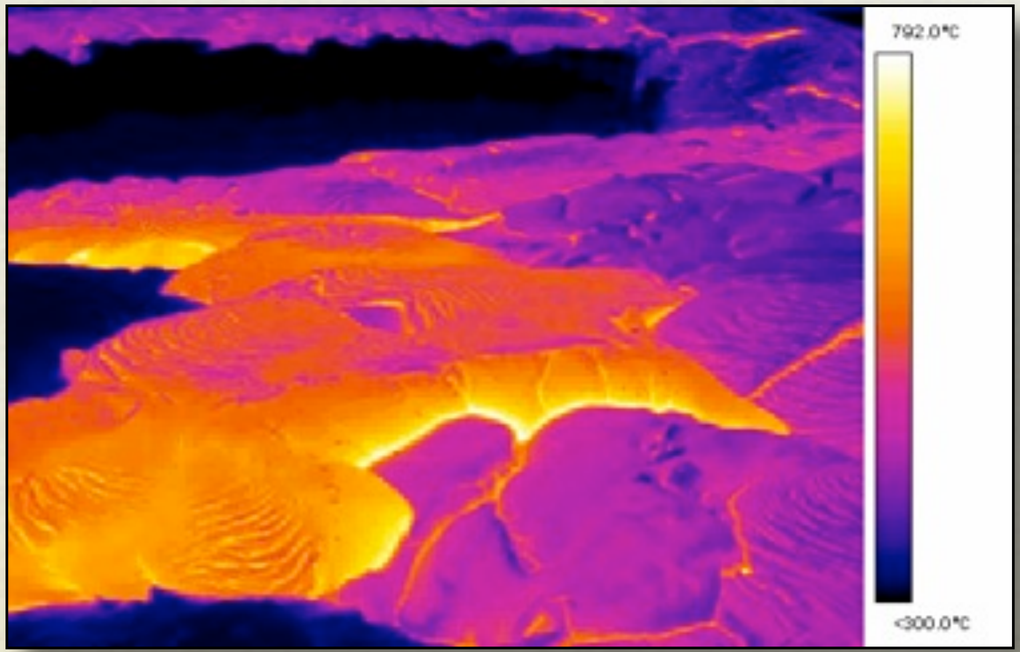
Pahoehoe channel+ropes

Kilauea (E. Lev)

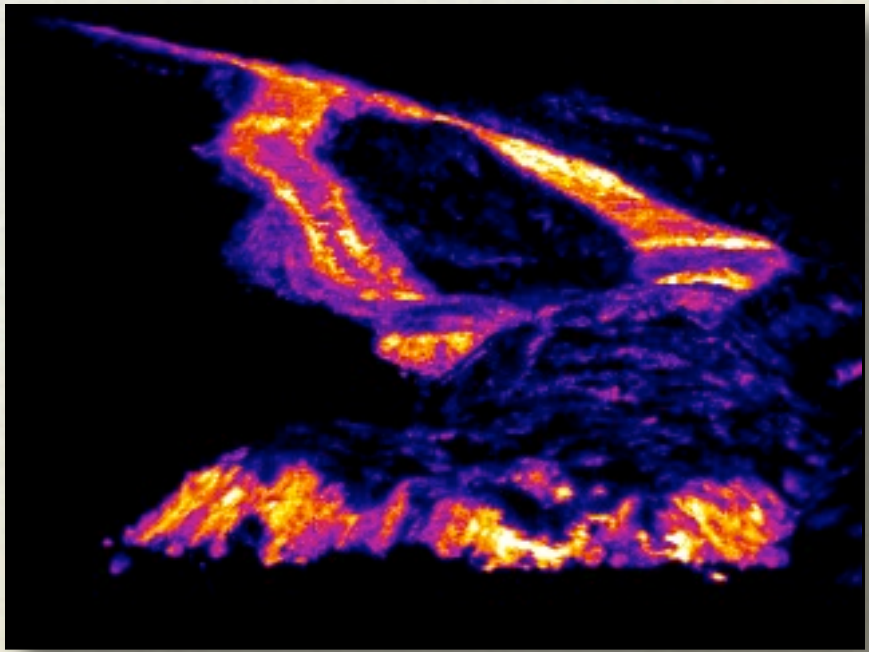



Discontinuous advance – crust breakage

Kilauea (M. Ramsey)




A'a channel+front, Etna (M. James)



# FIELD OBSERVATIONS – VISCOSITY

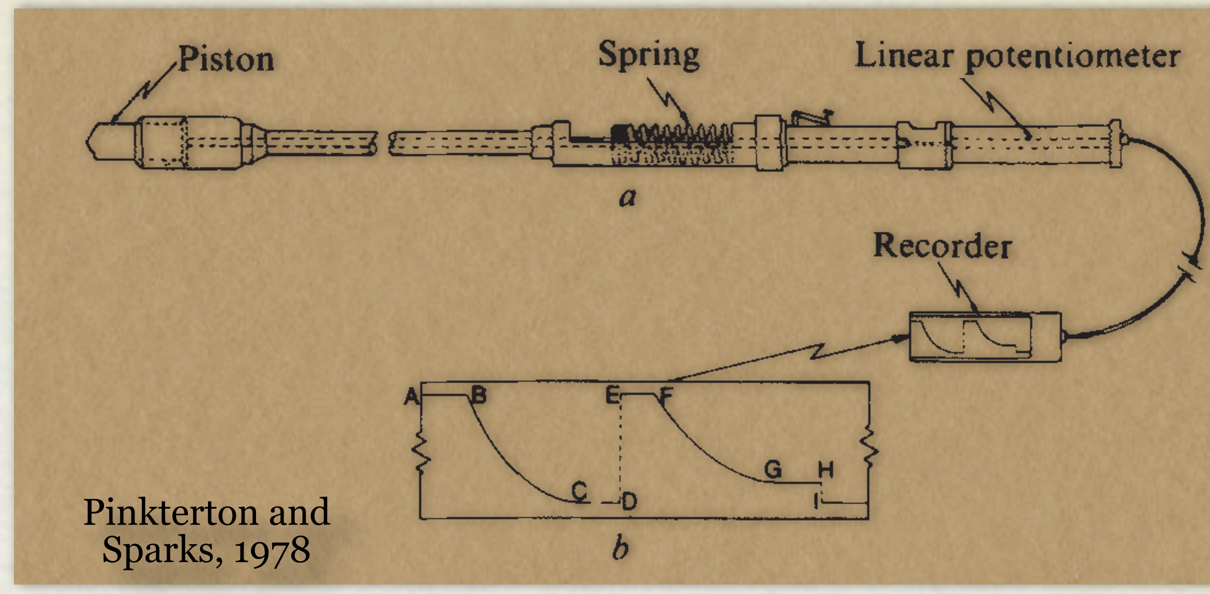
1558 VOLCANISM IN HAWAII

TABLE 57.3.—*Dimensions and characteristics of lava channels and their changes with time, 1984 Mauna Loa eruption*

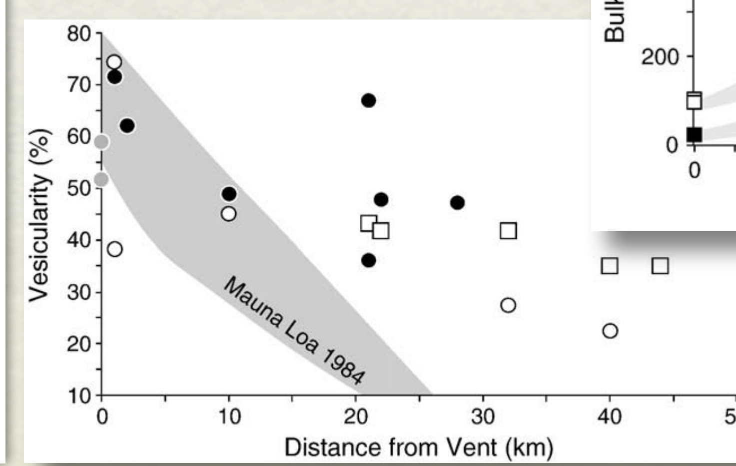
[Locations of channel stations on figure 57.1*B*. Distance, spacing of measuring points along channel bank. Depths estimated; see text for details. PWL, Peter W. Lipman; NGB, Norman G. Banks]

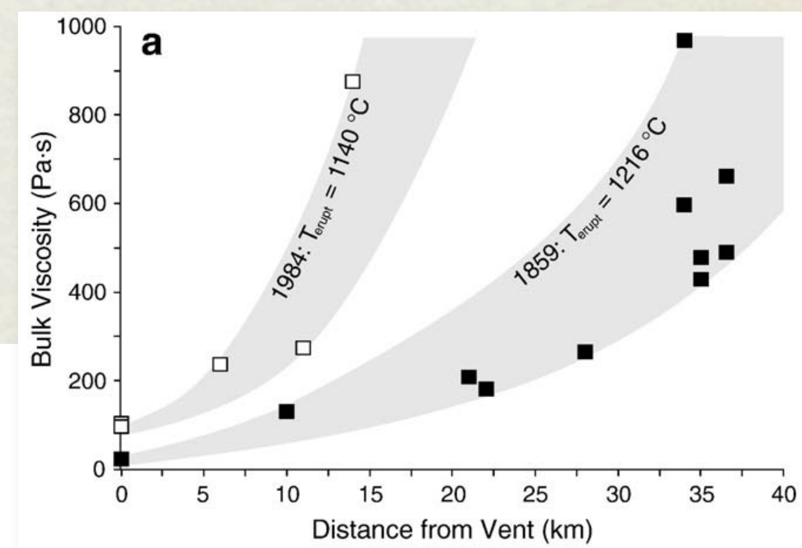
| Measurement | Date (mo/d) | Hour (H.s.t.) | Condition | Distance (m) | Time (s) | Velocity (m/s) | Width (m) | Depth (m) | Flow rate ($10^6$ m$^3$/h) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| **Station 1: Lower channel 1A, elevation 1,600 m** | | | | | | | | | | |
| 1 | 3/31 | 1130 | stable | 18 | 19 | 0.95 | 24 | 5 | 0.410 | Conspicuous marginal shears, with velocities about 1 m/min, next to central well-defined channel. Channel velocities slow during surges which contain more viscous material. Maximum velocities occur just after surges. Gradient about 3°. Measured by PWL, NGB, and J. Fink. |
| 2 | 3/31 | 1200 | surge | 18 | 22 | .82 | 24 | 5 | .355 | |
| 3 | 4/01 | 1200 | -- | 18 | 28 | .64 | 35 | 5 | .405 | Channel less defined than on 3/31, more choked with viscous debris. Although relatively steep gradient (about 5°) has migrated about 50 m downstream, adjacent to measurement site, velocities have still slowed. Because channel zone seems wider, flow rates have changed less than velocities. Measured by PWL and E. Wolfe. |
| 4 | 4/01 | 1300 | -- | 18 | 30 | .60 | 35 | 5 | .385 | |
| 5 | 4/02 | 1200 | full | 15 | 60 | .25 | 40 | 6 | .215 | Channel less well defined than on 4/01, and choked with rubble; velocities much slowed. Measured by PWL, J. Fink, and H. Moore. |
| 6 | 4/02 | 1230 | low | 15 | 110 | .14 | 40 | 6 | .120 | |
| 7 | 4/03 | 1520 | slow | 25 | 140 | .18 | 52 | 5 | .170 | New station; old one unusable because of inboard levees. Top of active channel varies, 3 m below to 1 m above levees. Gradient 4.5°. Measured by NGB. |
| 8 | 4/03 | 1550 | normal | 25 | 80 | .31 | 52 | 5 | .290 | |
| 9 | 4/03 | 1645 | surge | 25 | 90 | .28 | 52 | 7 | .364 | |
| 10 | 4/04 | 1350 | -- | 25 | 163 | .15 | 50 | 5 | .138 | Measured by NGB. |
| **Station 2: Upper channel 1A, elevation 1,700 m** | | | | | | | | | | |
| 11 | 4/03 | 1430 | stable | 15 | 45 | .33 | 50 | 5 | .295 | Measured by PWL, J. Fink, and H. Moore. |
| 12 | 4/03 | 1530 | surge | 15 | 30 | .50 | 50 | 5 | .450 | |
| 13 | 4/04 | 1345 | stable | 15 | 45 | .3 | 25 | 5 | .150 | Sensitive to release of ponded lava at 1,800-m blockage. Surge provides upper limit in flow rate; estimates for stable periods likely to be more meaningful. Gradient about 4°. Measured by PWL, T. Neal, and H. Moore. |
| 14 | 4/04 | 1430 | stable | 15 | 40 | .4 | 25 | 5 | .170 | |
| 15 | 4/04 | 1500 | surge | 15 | 25 | .6 | 25 | 5 | .270 | |
| **Station 3: Lower Powerline Road (flow 1, south side), elevation 1,800 m** | | | | | | | | | | |
| 16 | 3/28 | 1310–1335 | | 73 | 84 | 0.87 | 75 | 5 | 1.20 | Depth fluctuations of as much as 2–3 m in 5 min, associated with surges; channel in two branches—only southern strand measured; channel broad, measured by visual aerial comparison with distance between power poles. Channel gradient about 2.5°. Measured by PWL and D. Clague. |
| 17 | 3/28 | 1535–1605 | | 73 | 80 | .91 | 75 | 5 | 1.25 | |
| **Station 3: Lower Powerline Road (flow 1B), elevation 1,800 m** | | | | | | | | | | |
| 18 | 4/06 | 1400 | -- | 25 | 210 | 0.12 | 25 | 4 | 0.043 | The channel flow slowed, and its upper surface subsided as we made these measurements. When checked an hour later, the head of flow 1B was captured by other overflows, and its channel was drained and empty. Gradient: 2.5°. Measured by PWL and T. Neal. |
| **Station 4: Upper Powerline Road (site 1), elevation 1,900 m** | | | | | | | | | | |
| 19 | 3/29 | 1300 | blocks | 30.2 | 25 | 1.20 | 13 | 6 | 0.335 | Channel is within a gentle stretch related to large overflows and temporary ponding; probably deep as result. Higher velocities in center channel tend to push blocks to sides; more consistent measurements of maximum velocities obtained from small fragments in center channel. Channel gradient about 2.5°. Measured by PWL and E. Wolfe. |
| 20 | 3/29 | 1400 | fragments | 30.2 | 18 | 2.75 | 13 | 6 | .470 | |
| 21 | 3/31 | 1430 | stable | 30.2 | 23 | 1.3 | 13 | 6 | .365 | All measurements on small fast-moving fragments in center channel; lower level at 22 (about 1 m below levees) because of slightly higher gradient after drainage of ponded blockage downchannel. Gradient about 2.5°. Measured by PWL, NGB, and J. Fink. |
| 22 | 3/31 | 1530 | low | 30.2 | 18 | 1.7 | 13 | 6 | .470 | |
| 23 | 4/01 | 0830 | stable | 30.2 | 18 | 1.7 | 13 | 6 | .470 | Channel is sluggish and viscous; shear and pressure ridges are weakly developed on nearly stagnant channel sides. Measured by PWL and E. Wolf. |
| 24 | 4/01 | 0930 | blockage | 30.2 | 19.5 | 1.6 | 13 | 6 | .435 | |
| 25 | 4/02 | 1700 | -- | 30.2 | 31 | 1.0 | 15 | 7 | .370 | Levees have increased in height about 2 m and largely obscure view of the channel: could only measure large boats during high stand of channel. Measured by PWL, J. Fink, and H. Moore. |
| 26 | 4/03 | 1000 | -- | 30.2 | 32.1 | .94 | 18.3 | 7 | .431 | Levee height is 2.3 m above top of old ponded broad aa channel. Surge caused spreading of levee by 1 m in 15 min. Measured by NGB. |
| **Station 4: Upper Powerline Road (site 2), elevation 1,930 m** | | | | | | | | | | |
| 27 | 4/02 | 1600 | -- | 20 | 9.5 | 2.1 | 14 | 4 | 0.455 | New site, above upper cascade. Gradient about 3.5°. Measured by PWL, J. Fink, and H. Moore. |
| 28 | 4/03 | 1320 | -- | 20 | 12.6 | 1.6 | 14 | 5 | .399 | Measured by NGB. |
| **Station 4: Upper Powerline Road (site 2A), elevation 1,930 m** | | | | | | | | | | |
| 29 | 4/04 | 1200 | -- | 23 | 12.3 | 1.9 | 15 | 5 | 0.500 | Measured lava boats; low gradient due to blockages at head of middle cascade. Measured by PWL, T. Neal, and H. Moore. |
| **Station 4: Upper Powerline Road (site 3), elevation 1,900 m** | | | | | | | | | | |
| 30 | 4/04 | 1120 | boats | 20 | 7.5 | 2.7 | 15 | 4 | 0.580 | Boats are sparse; channel level is 0.5–1 m below recent levee overflows. Gradient about 3°. Measured by PWL, T. Neal, and H. Moore. |
| 31 | 4/04 | 1130 | fragments | 20 | 8.1 | 2.5 | 15 | 4 | .530 | |
| 32 | 4/04 | 1140 | fragments, surge | 20 | 7.2 | 2.8 | 15 | 4 | .600 | |
| 33 | 4/05 | 1100 | -- | 20 | 9 | 2.2 | 20 | 4 | .640 | Little change since yesterday. Channel low and boats sparse, indicative of pond and surge forming upchannel. Measured by PWL and H. Moore. |

Lipman and Banks, 1987




Pinkterton and Sparks, 1978




Riker et al. 2009

Friday, July 26, 2013

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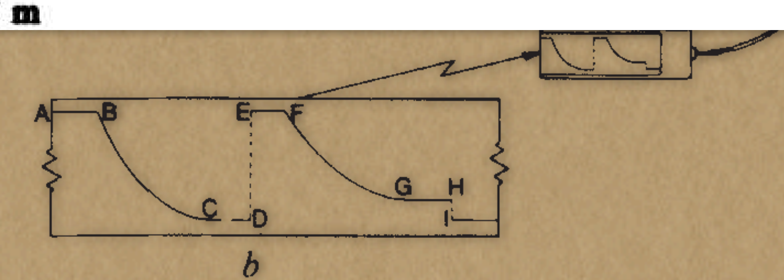
Lipman and Banks, 1987

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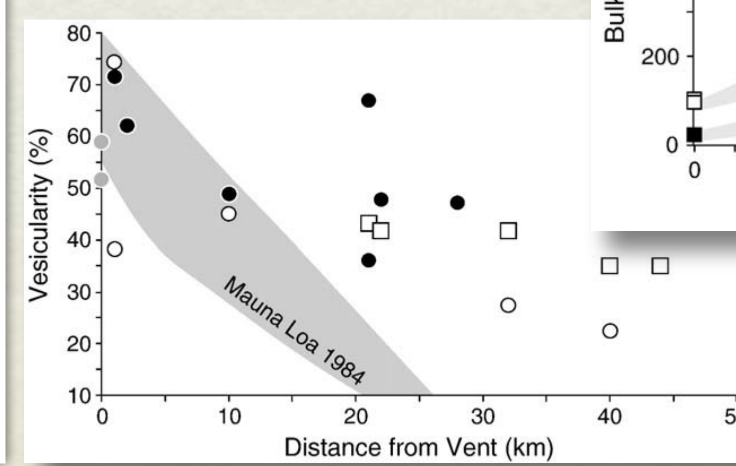
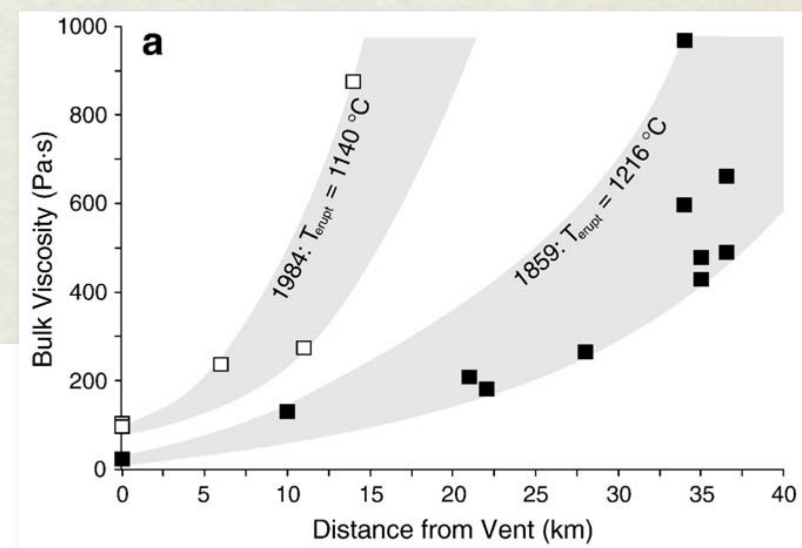
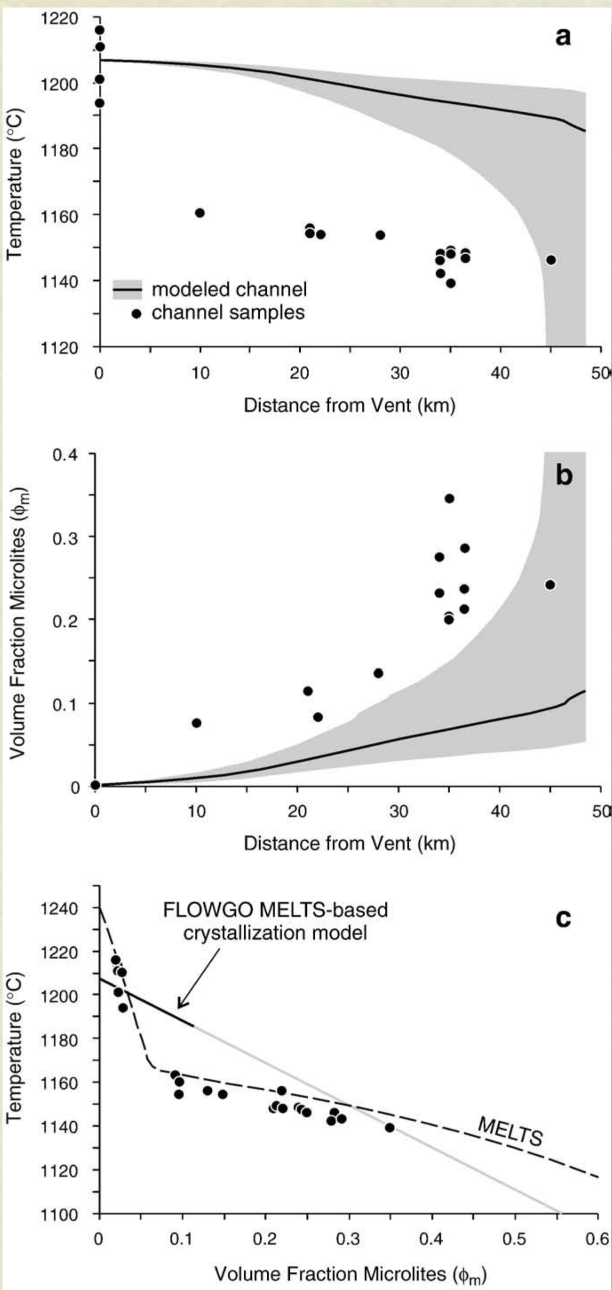


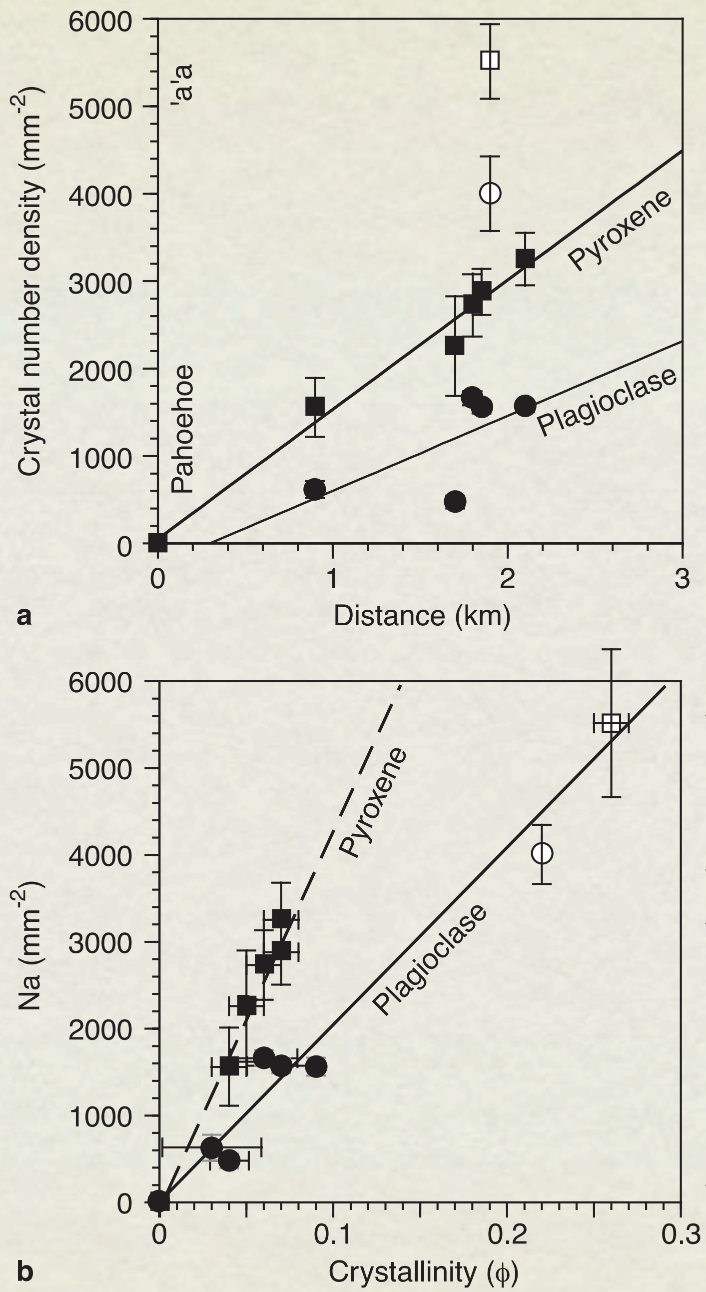



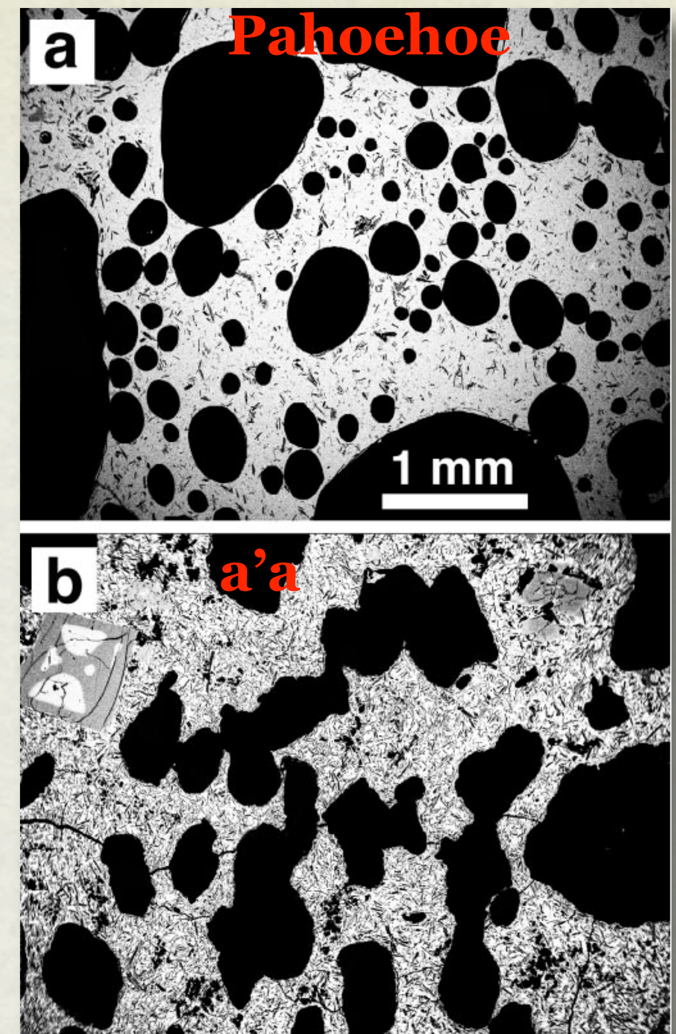

Riker et al. 2009

# FIELD OBSERVATIONS – CRYSTALS AND BUBBLES




Riker et al. 2009
Kilauea 1859 flow




Cashamn et al. 1999
Kilauea 1997 flow

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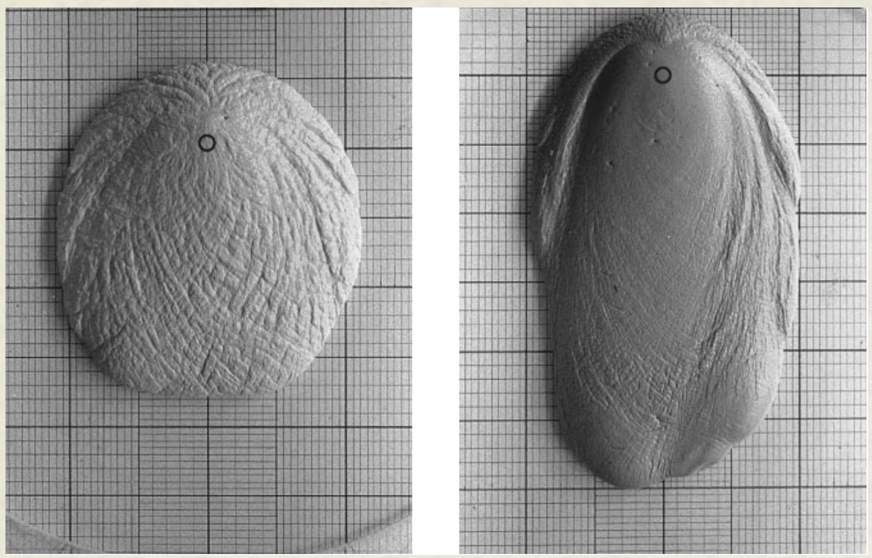
# ANALOGUE EXPERIMENTS – QUANTITATIVE, CONTROLLED

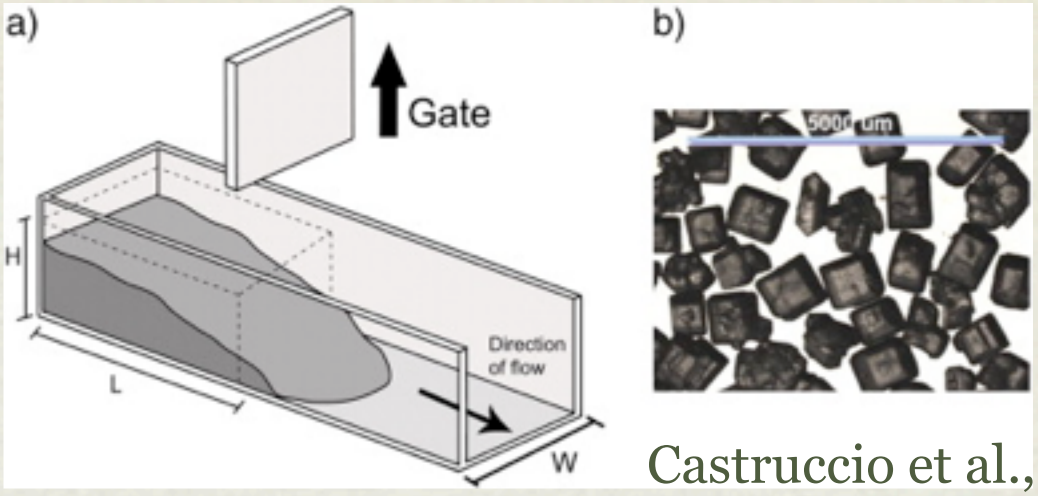
Isothermal

Osmond & Griffiths 1998)



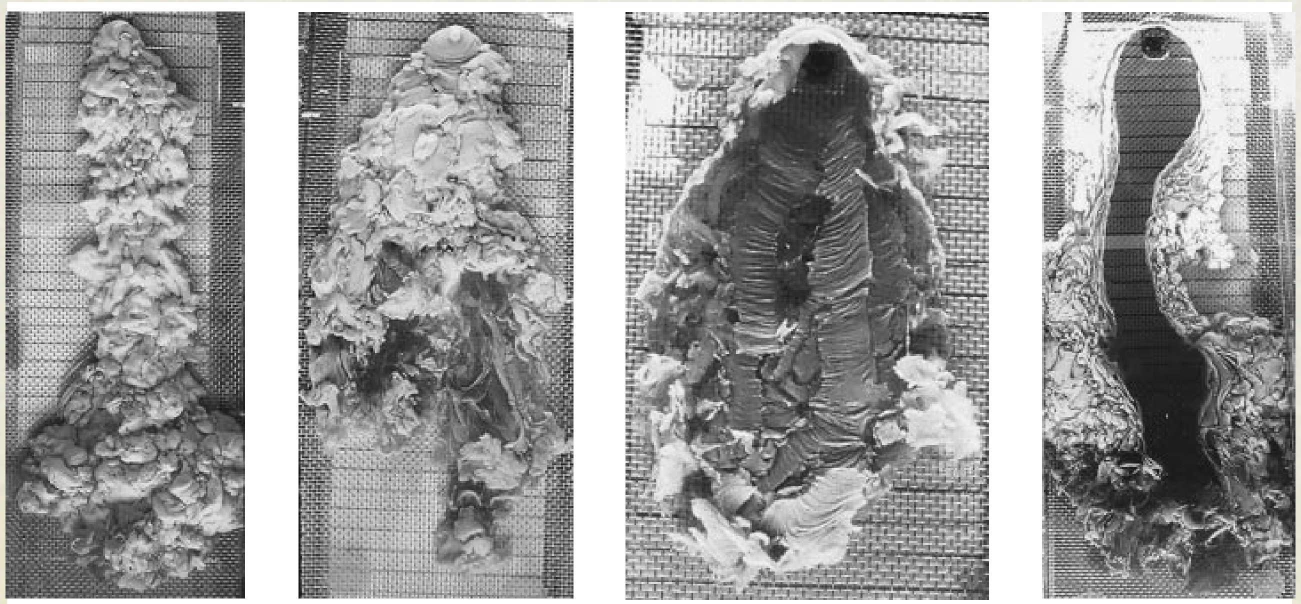
Kaolin/water slurry, slope b=12 deg    Kaolin/PEG slurry, slope b=18 deg

With crystals



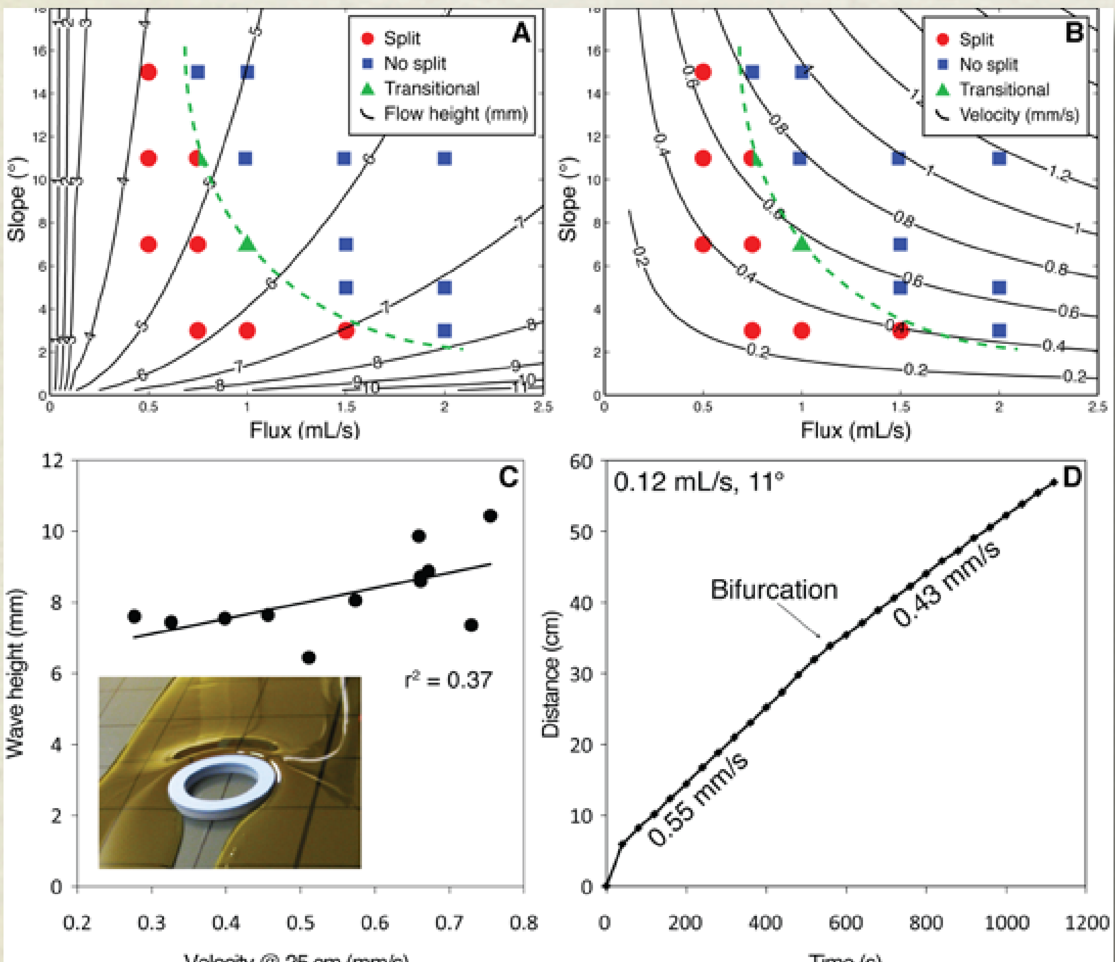

Castruccio et al., 2010

With cooling and crusting

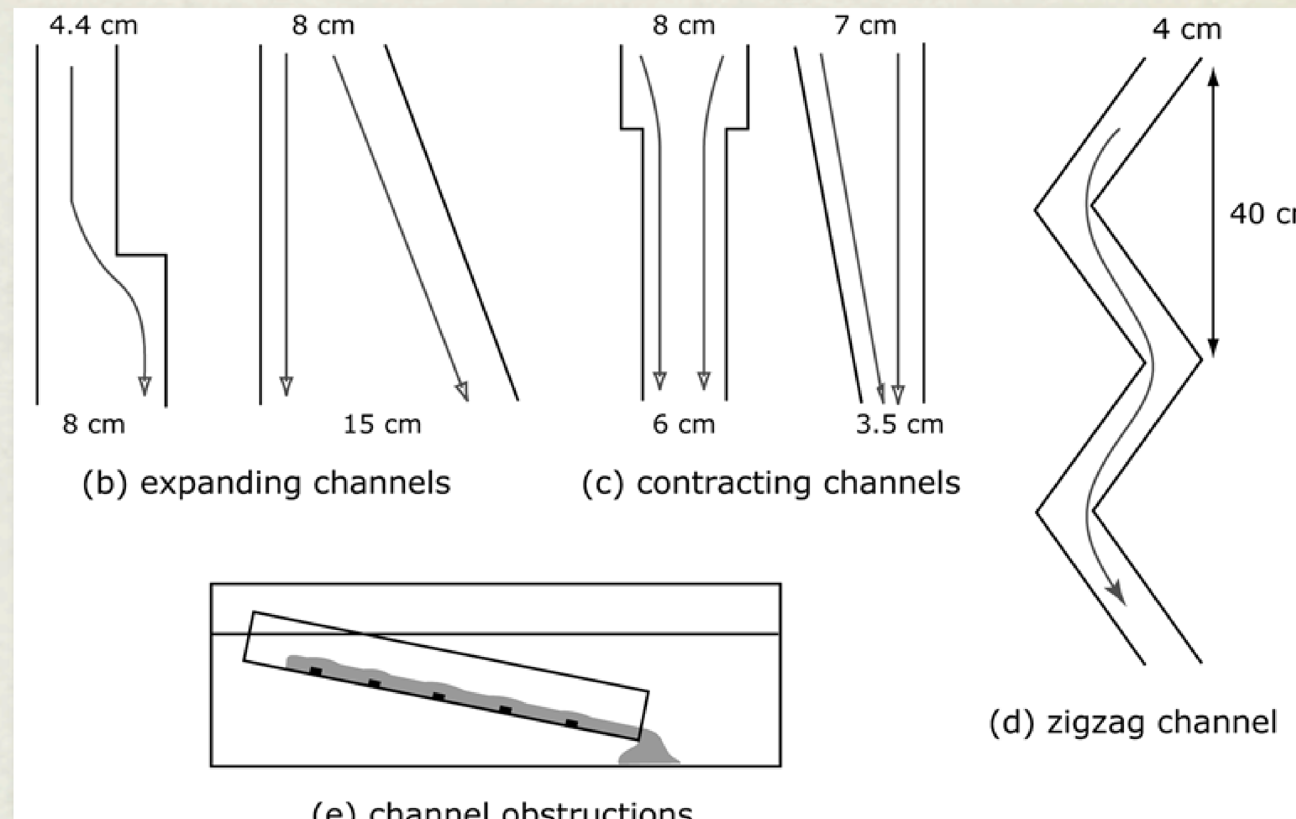


Griffiths et al., 2003

# ANALOGUE EXPERIMENTS – COMPLEX GEOMETRIES

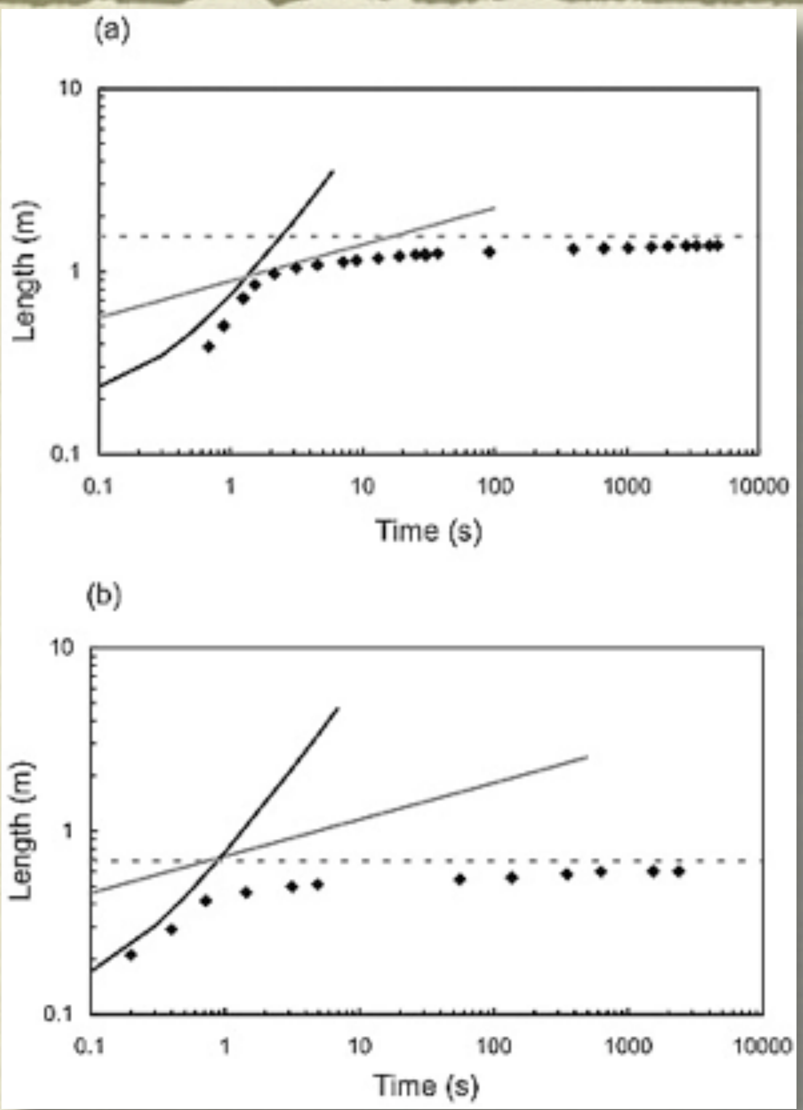


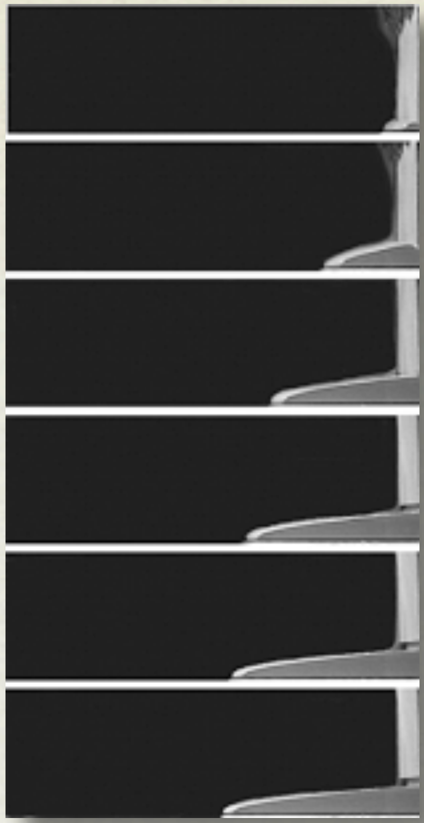

Dietterich and Cashman

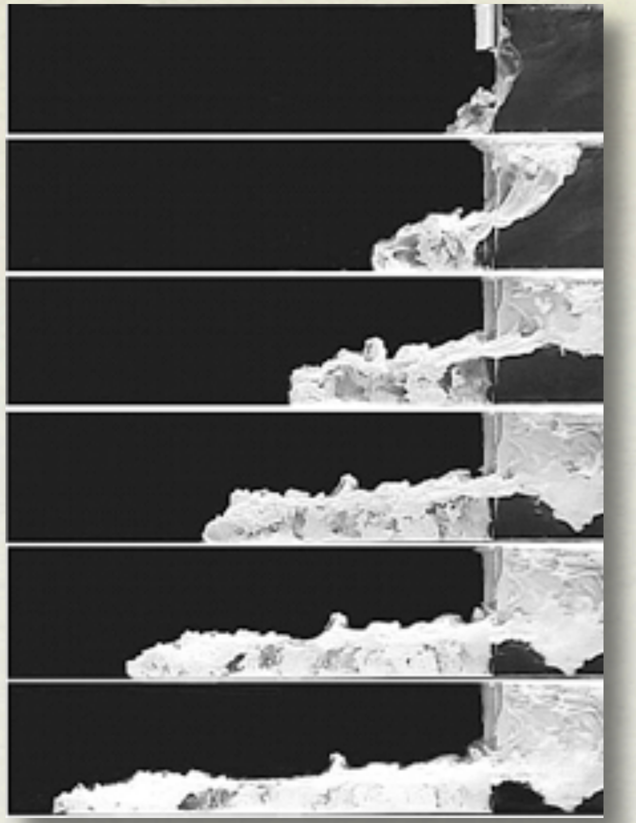



Cashman et al. 2006

# ANALOGUE EXPERIMENTS – QUANTITATIVE, CONTROLLED

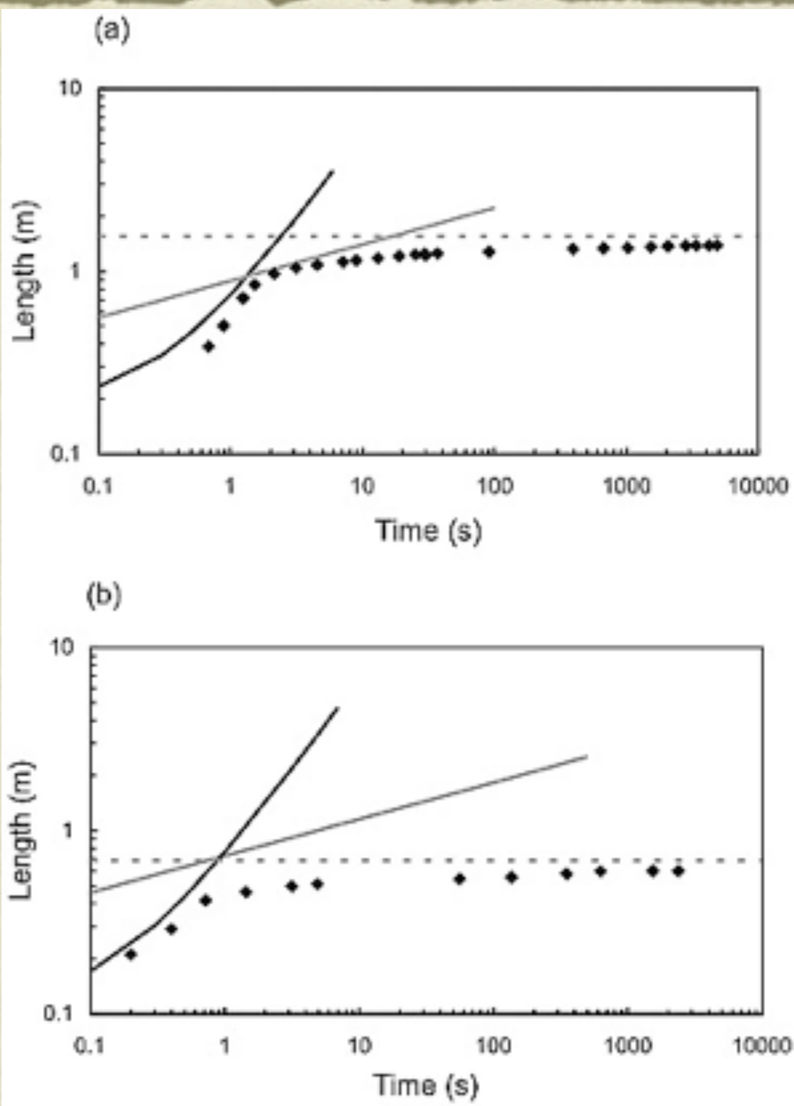


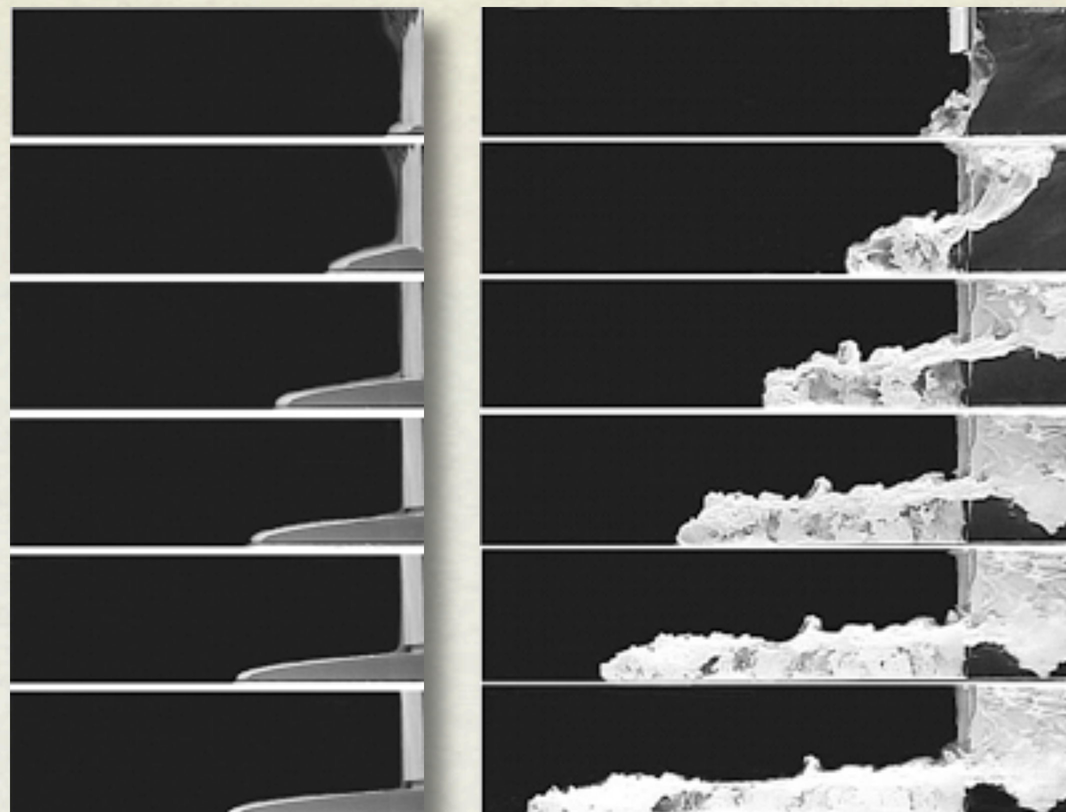





Lyman et al. 2005

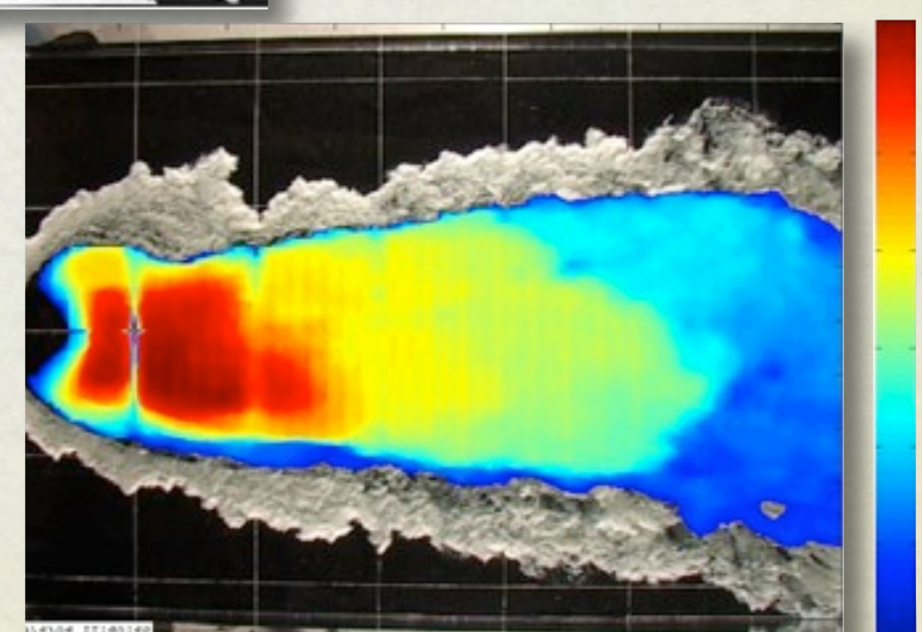
# ANALOGUE EXPERIMENTS – QUANTITATIVE, CONTROLLED



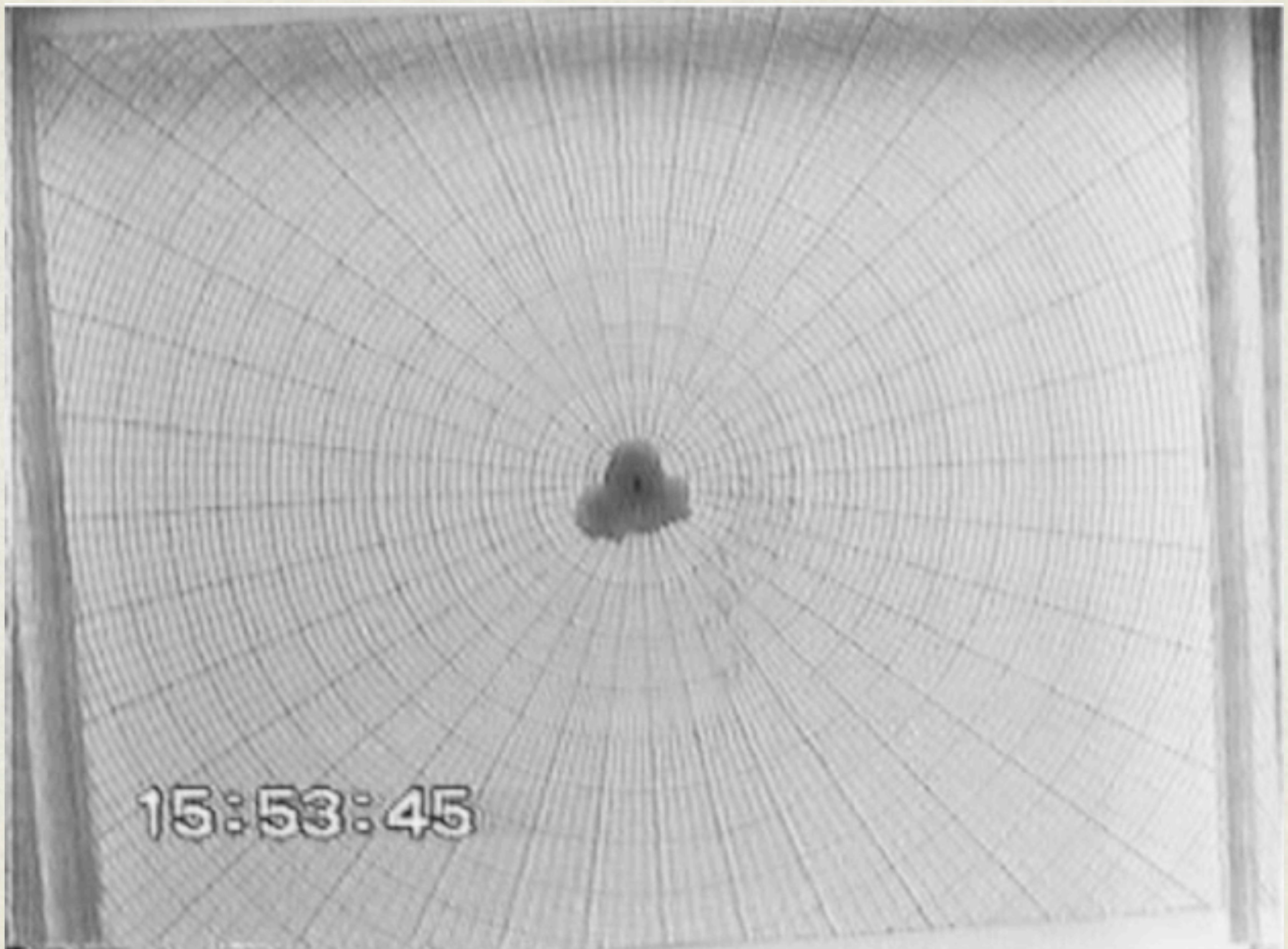
Lyman et al. 2005

Using Optical Flow
(Lev et al., 2012)



# ANALOGUE EXPERIMENTS – QUANTITATIVE, CONTROLLED

Discontinuous advance – Crustal breakage




Blake and Bruno, 2000

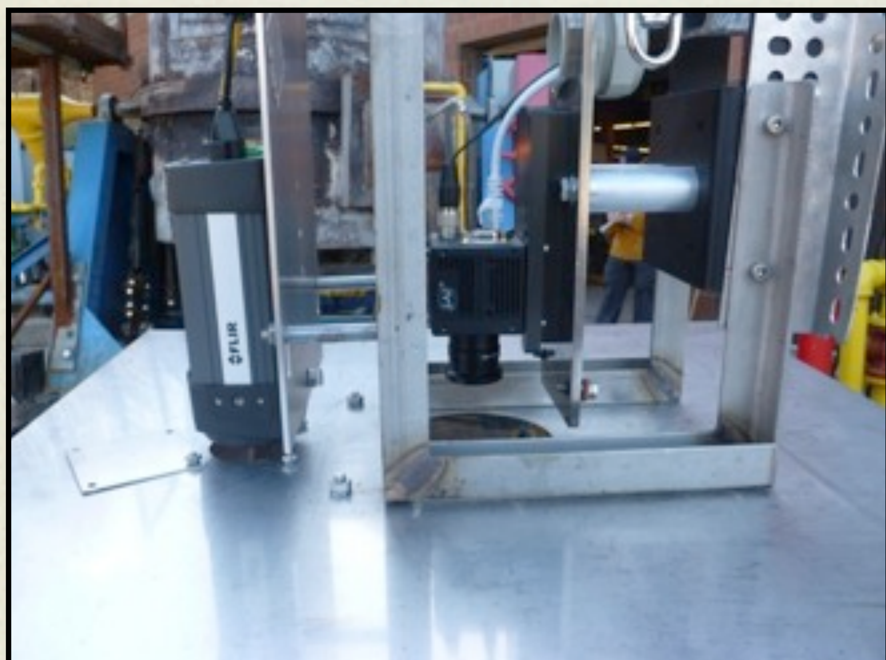
# WILL DISCUSS CONSTRAINTS FROM:

**Natural Flows**

**Analogue Experiments**

**Basaltic Experiments**

# BASALT EXPERIMENTS




# BASALT EXPERIMENTS

## Source material –

## Mid-continent Basalts

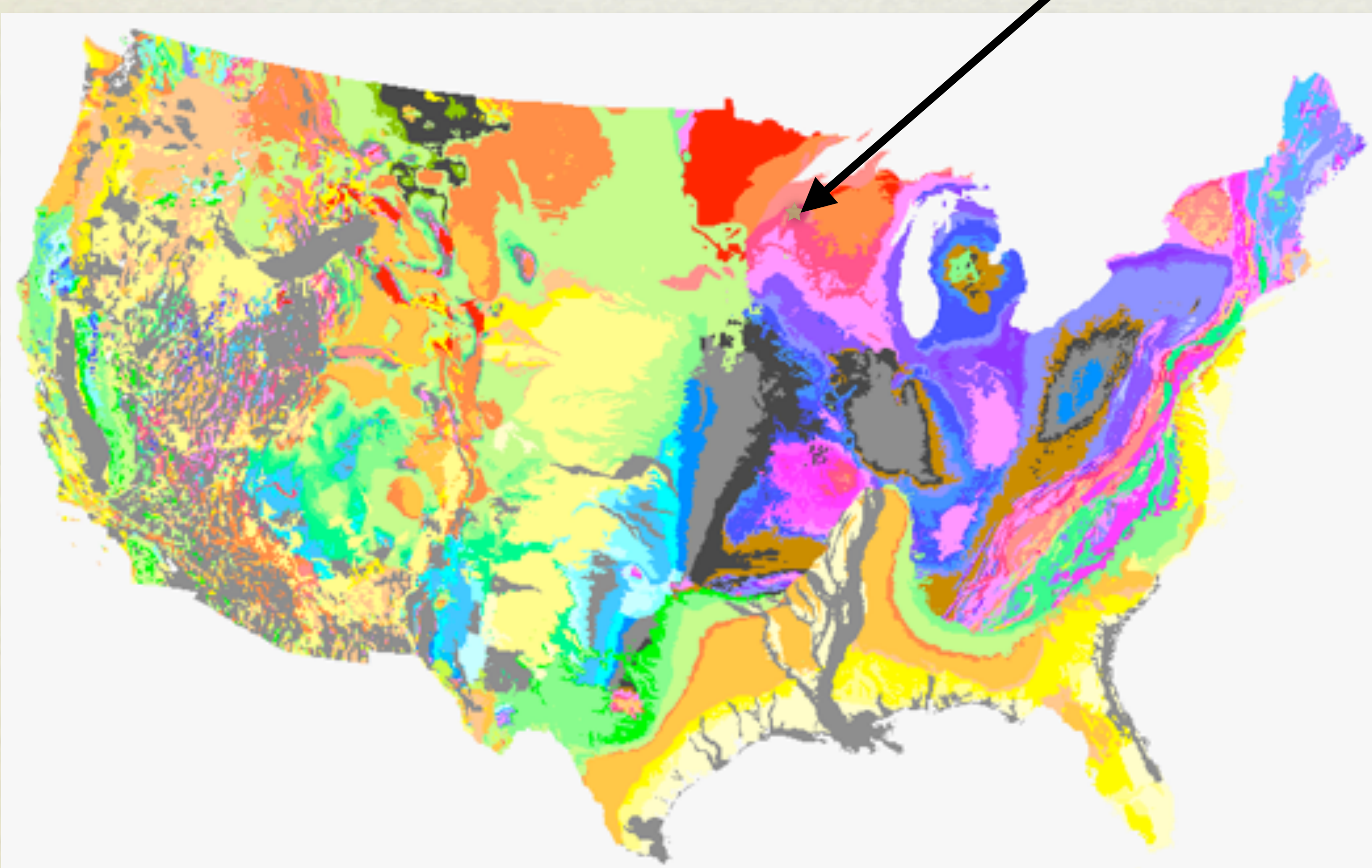


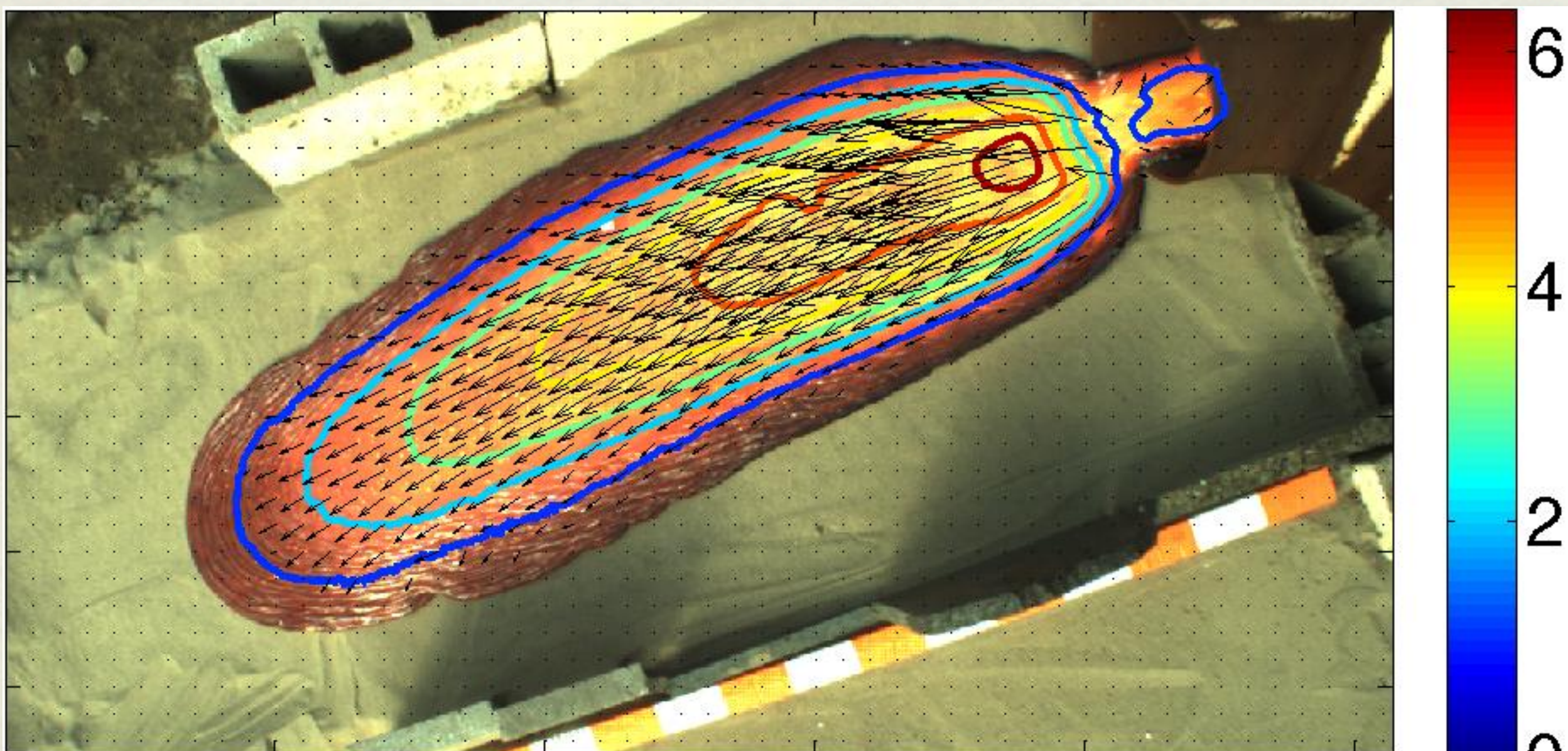
Table 1. Representative analyses of basalt and sedi
Falls and Clam Falls region.

| | basalt KC-1b | basalt KC-7 | basalt KC-70 |
|---|---|---|---|
| $SiO_2$ | 47.60 | 48.30 | 48.13 |
| $TiO_2$ | 1.69 | 1.71 | 2.64 |
| $Al_2O_3$ | 15.57 | 15.65 | 14.07 |
| $Fe_2O_3$ | 13.34 | 13.61 | 16.40 |
| MnO | 0.19 | 0.19 | 0.21 |
| MgO | 7.48 | 6.69 | 5.17 |
| CaO | 8.14 | 9.56 | 8.41 |
| $Na_2O$ | 2.38 | 2.60 | 2.45 |
| $K_2O$ | 1.13 | 0.55 | 1.43 |
| $P_2O_5$ | 0.16 | 0.19 | 0.31 |
| LOI | 3.09 | 1.63 | 1.25 |
| Total | 100.77 | 100.68 | 100.47 |
| Mg# | 0.57 | 0.43 | 0.42 |

Institute of Lake Superior
Geology Field trip guide, 1998

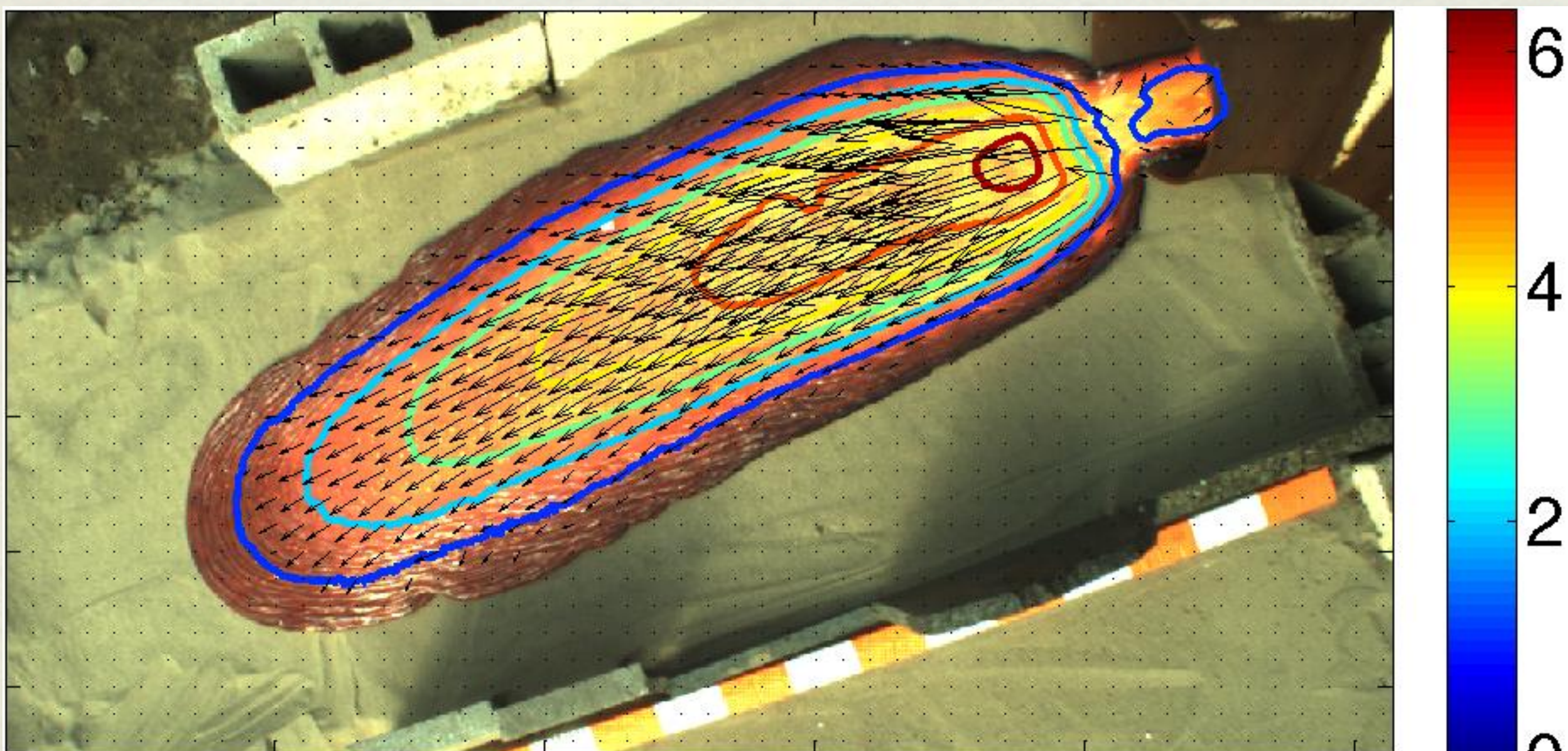
# BASALT EXPERIMENTS – VELOCITY, GEOMETRY

Unconfined flows on sand



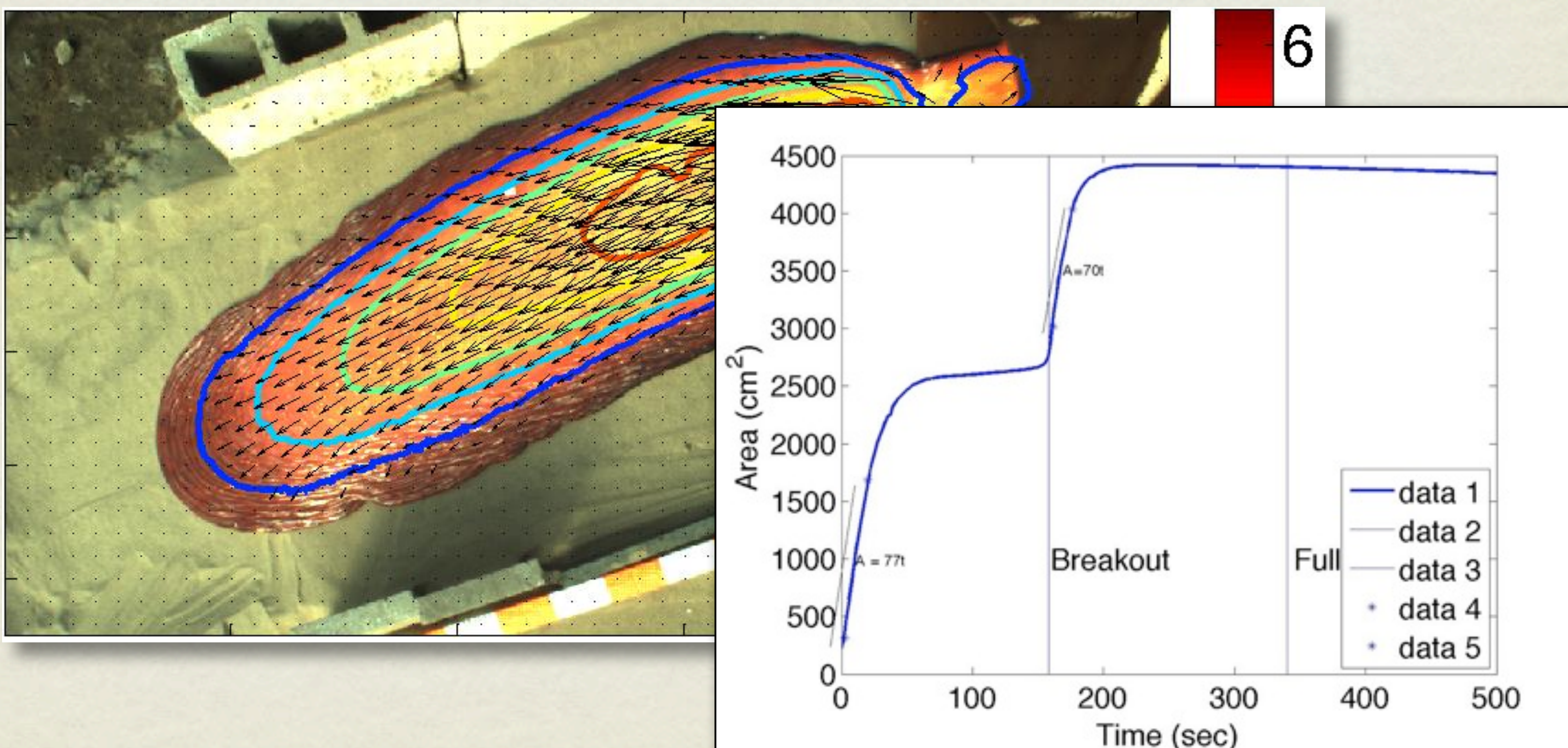
# BASALT EXPERIMENTS – VELOCITY, GEOMETRY

Unconfined flows on sand



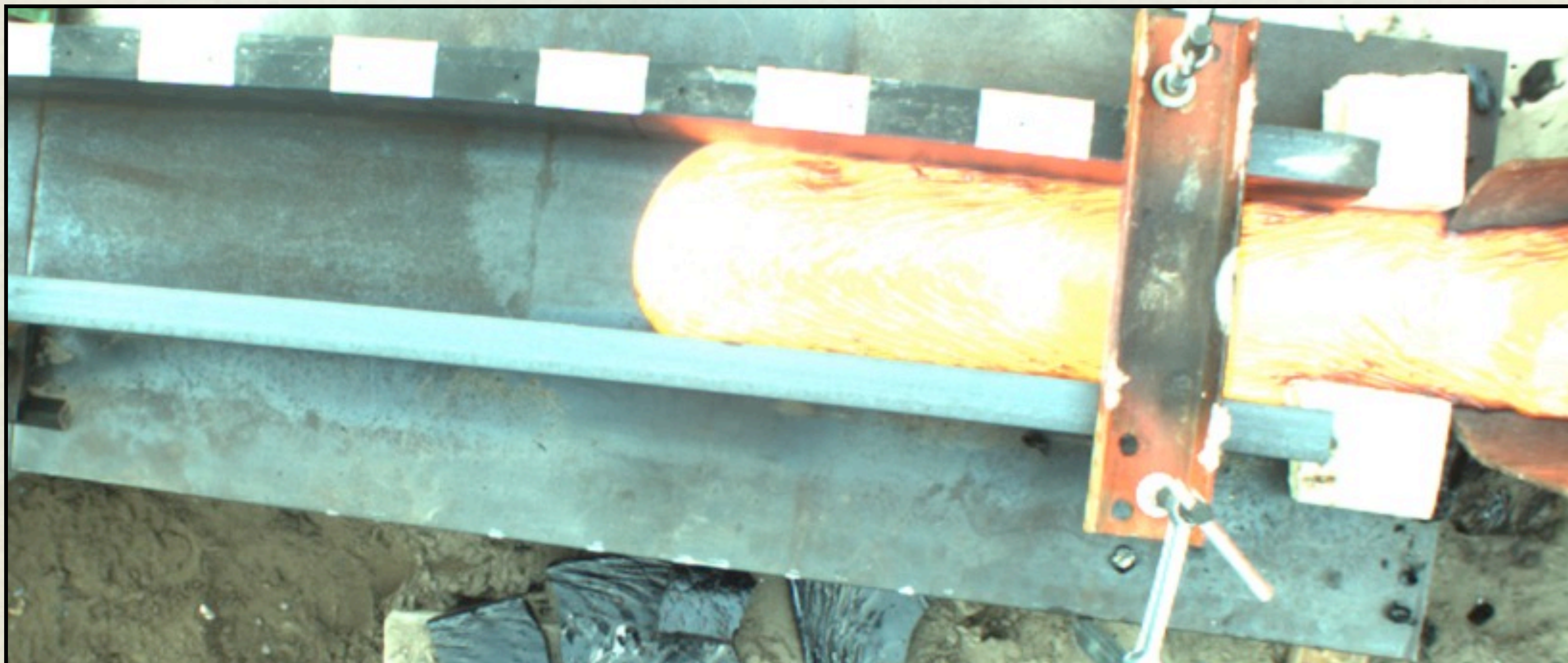
# BASALT EXPERIMENTS – VELOCITY, GEOMETRY

Unconfined flows on sand



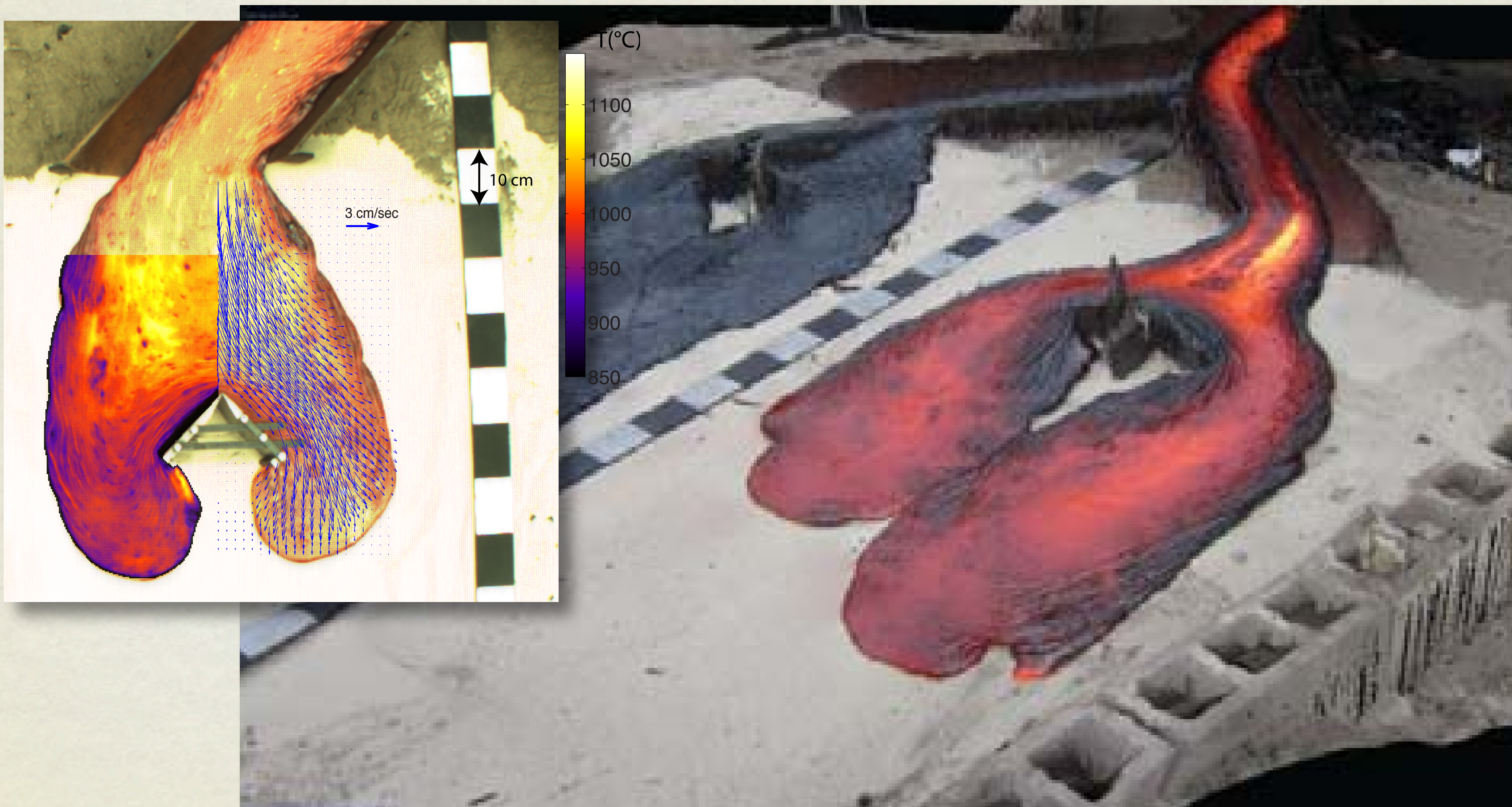
# BASALT EXPERIMENTS – VELOCITY, GEOMETRY

Channelized flows on steel

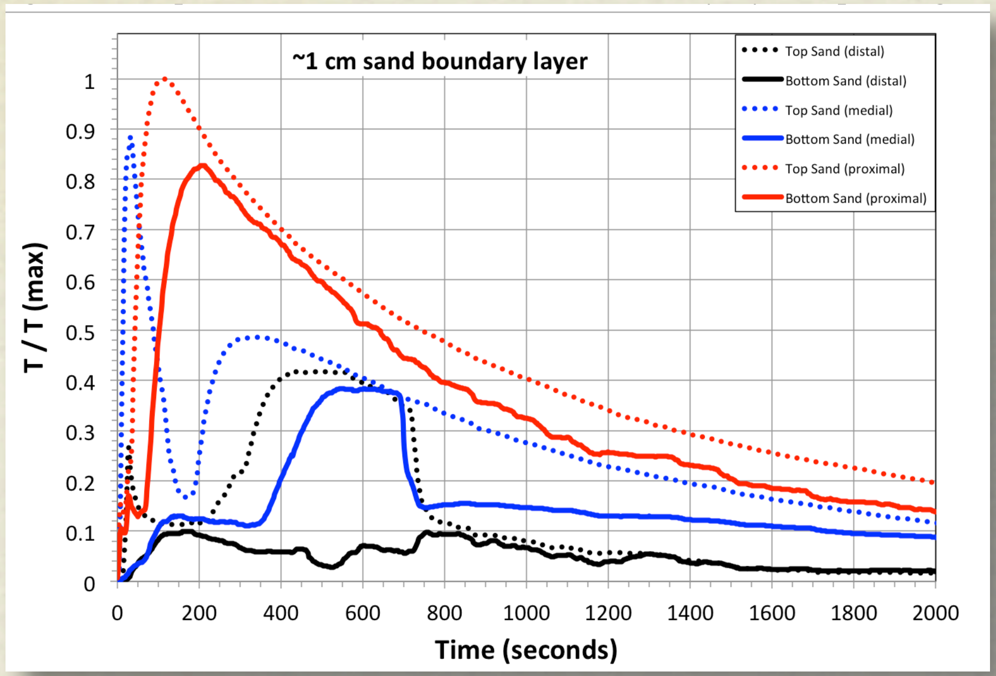


# BASALT EXPERIMENTS – VELOCITY, GEOMETRY

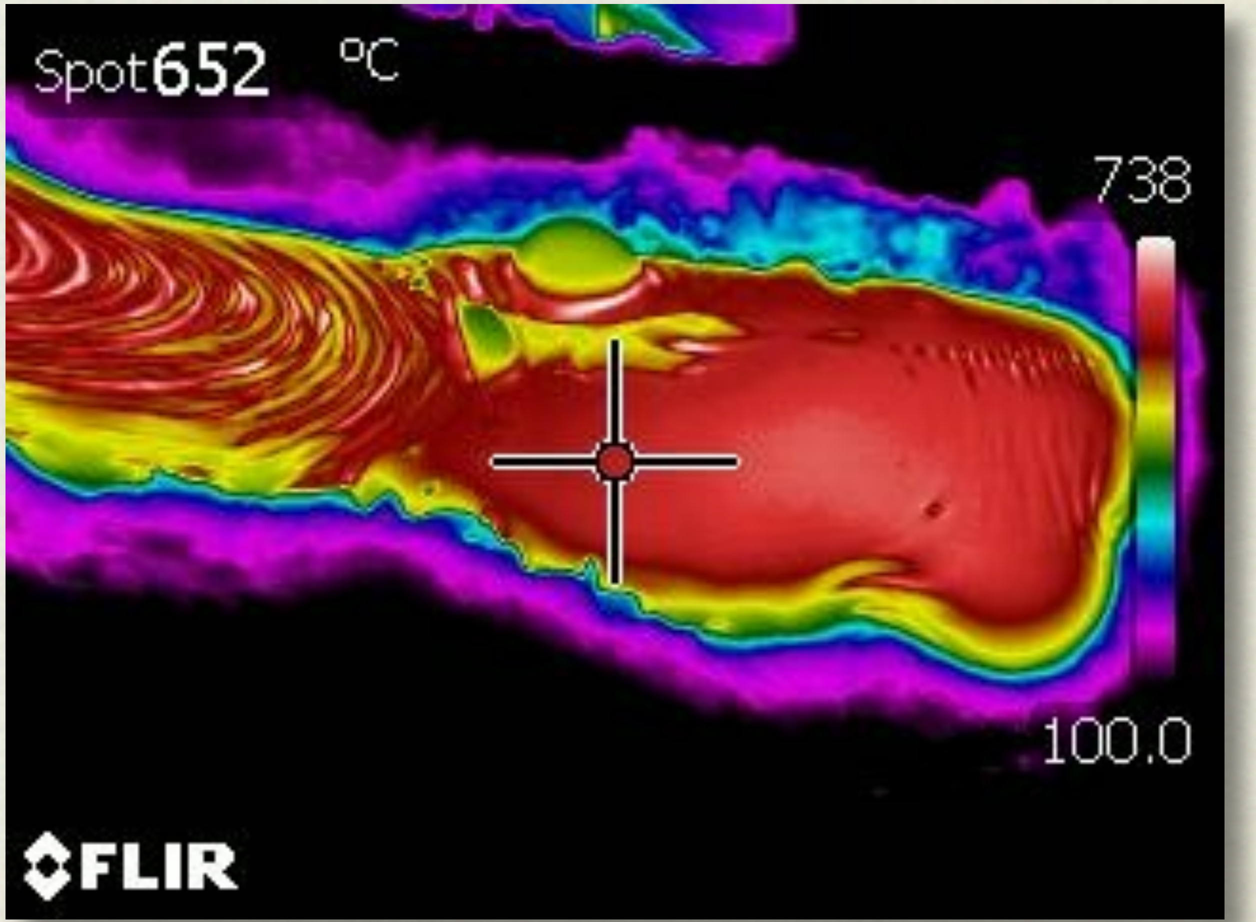
## Flows with Obstacles



# BASALT EXPERIMENTS – THERMAL EVOLUTION




Edwards et al., 2013




# SUMMARY

Models & tests should utilize quantitative input conditions and reproduce quantitative output observations:

**INPUT**

- Rheology
- Effusion rate
- Thermal model
- Ground geometry

→

**OUTPUT**

- Velocity
- Morphology
- Advance with time
- Temperature with time
- (vesicularity, crystallinity)