GSA Data Repository 2017348

Randolph-Flagg, et al., 2017, Evenly spaced columns in the Bishop Tuff (California, USA) as relicts of hydrothermal cooling: Geology, doi:10.1130/G39256.1

SUPPLEMENTARY INFORMATION

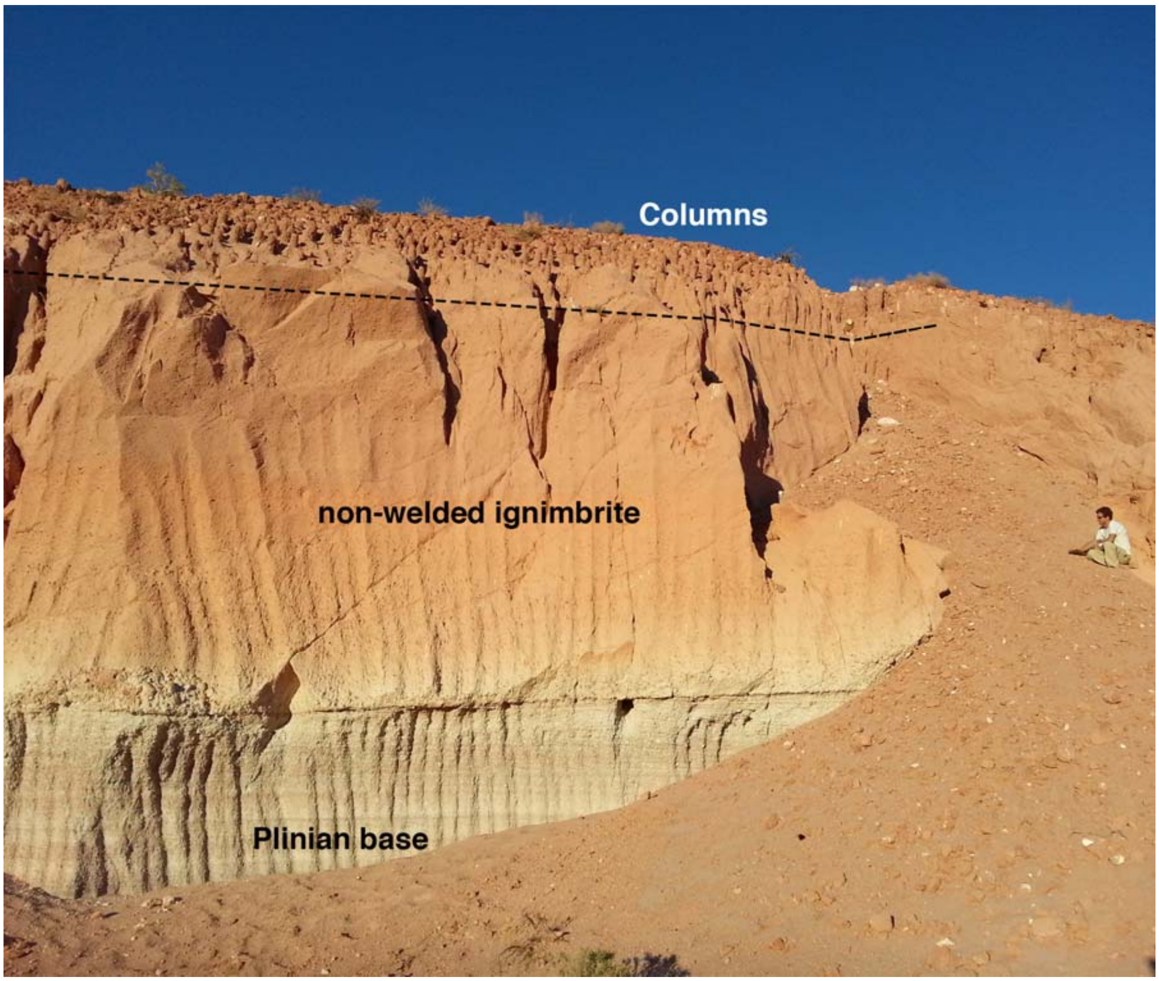


Figure DR1. Base of Bishop Tuff showing pinkish tuff overlying the white plinian airfall deposit. Dotted line shows where columns start. Note that runnels in the plinian base and tuff are erosional and are unrelated to compostion changes in the tuff.

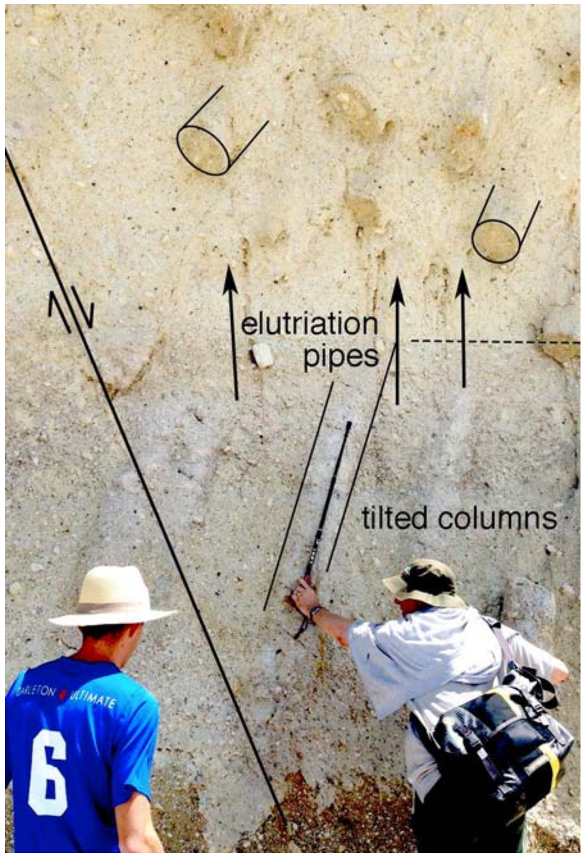
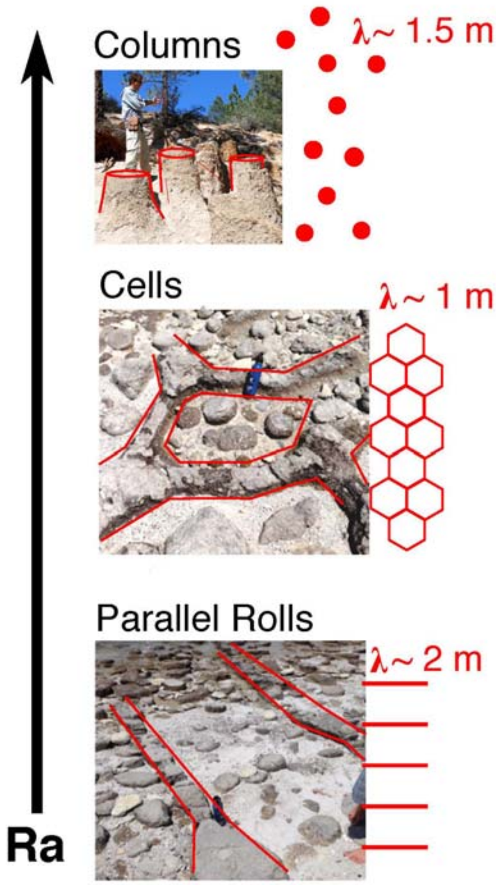


Figure DR2. Figure showing tilted columns and elutriation pipes. Elutriation pipes form vertically and show that despite faulting columns probably formed in their current orientation after the elutriation pipes formed.

A. 

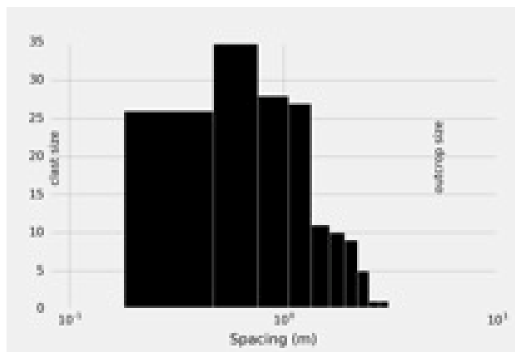
B. 

Figure DR3A. Range of 3D geometries observable in the Bishop Tuff. Red schematic drawings show idealized plan views of the outcrops. In single phase convection these patterns are anticipated at different Rayleigh numbers. **B.** Histogram of column spacing along beach outcrops.

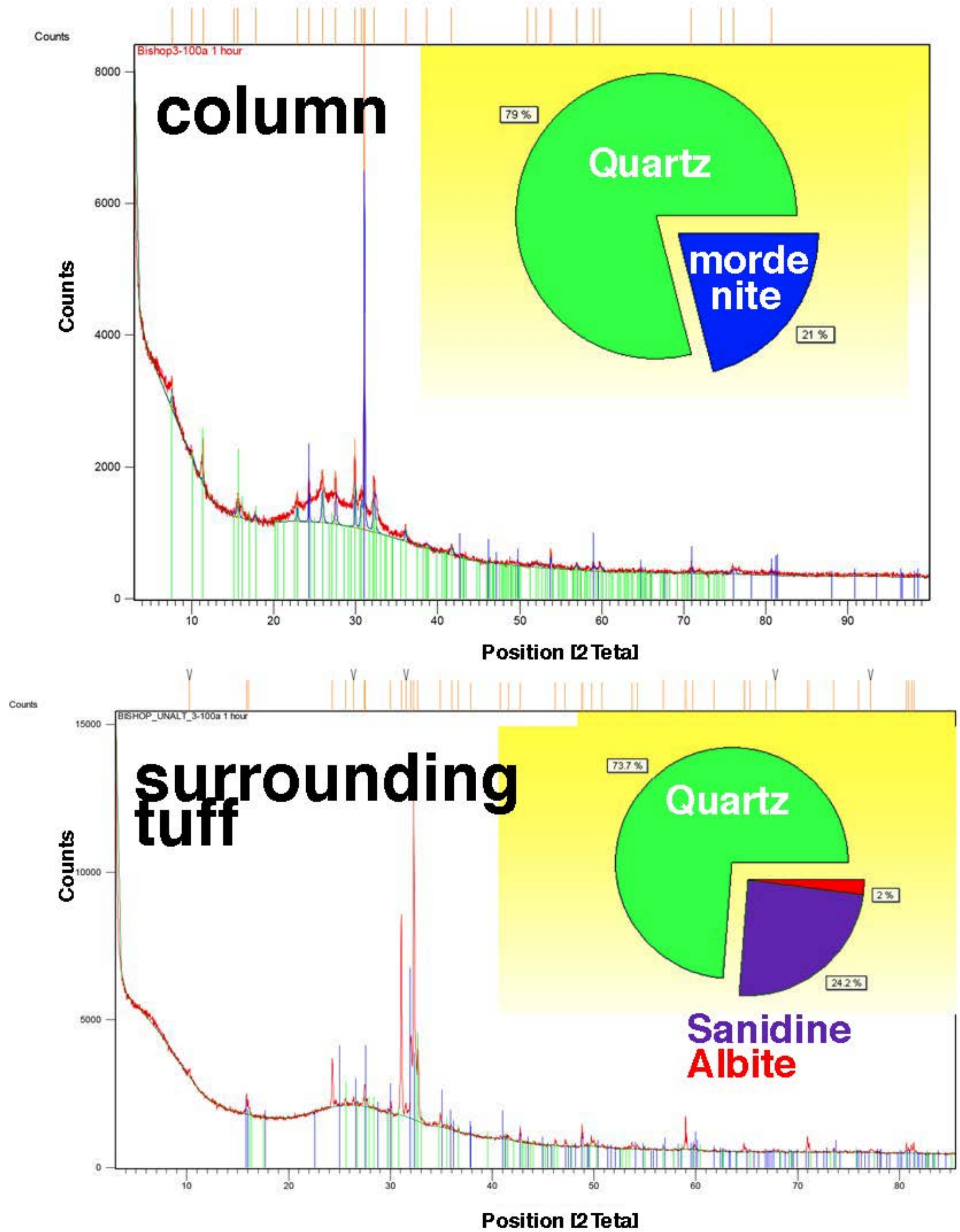


Figure DR4. 1 hour x-ray diffraction spectrum for columns and unaltered tuff surrounding a column. Green lines show peaks best explained by quartz while blue, purple, and red lines show peaks best explained by mordenite, sanidine, and albite respectively. Inset shows relative spectral strength of each mineral species. (37.47º N, 118.73º W)

TABLE DR1. CONSTANTS USED IN SCALING

acceleration due to gravity	**g**	9.81	m^2/s
column spacing	λ	0.5-2	m
convective layer thickness	h	0.1-100	m
density water - density of steam	$\Delta\rho$	994	kg/m^3
permeability	k	10^{-11}-10^{-15}	m^2
porosity	ϕ	0.1-0.7	
latent heat of vaporization	L	2,260	kJ/kg
thermal diffusivity	κ	10^{-6}	m^2/s
viscosity of liquid water	μ_l	3×10^{-4}	Pa s

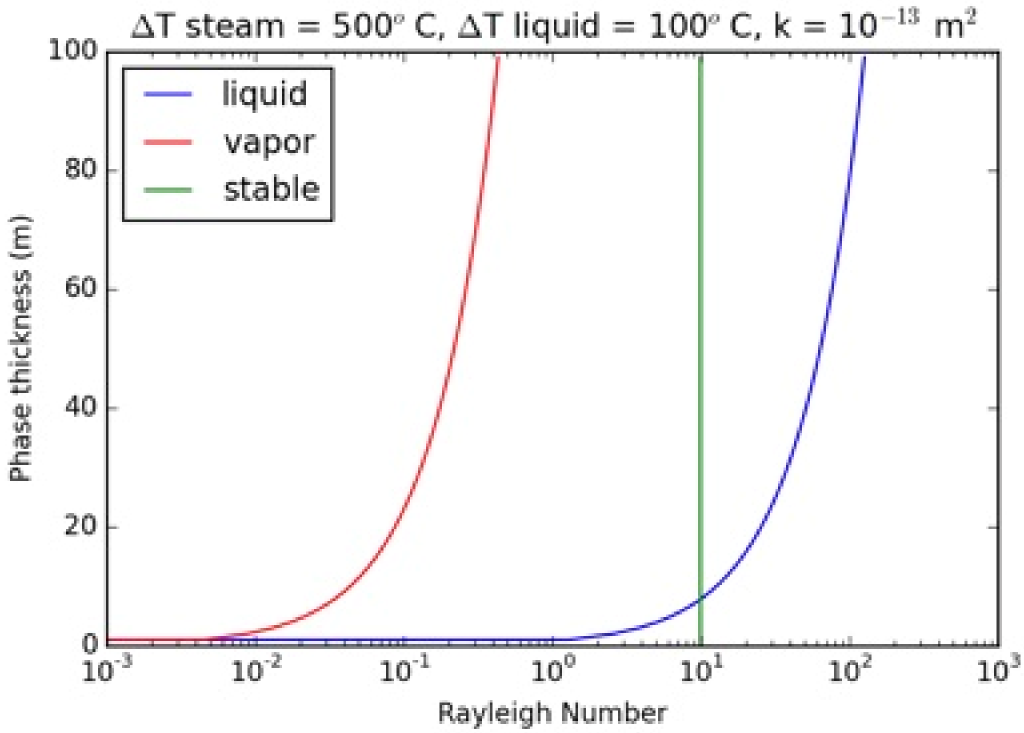


Figure DR5. Rayleigh number as a function of phase thickness. The vertical green line shows the critical Rayleigh number for porous media. This means when the liquid water (blue) extends beyond this critical Rayleigh number it is prone to thermal convection. In a porous medium, a measure of the gravitational instability is given by the ratio advective and diffusion timescales called the Rayleigh-Darcy number (Ra).

$$\mathrm{Ra} = \frac{\rho g \alpha \Delta T k h}{\mu \kappa} \tag{1}$$

where ρ is the density, g is the acceleration due to gravity, α is the thermal expansivity, ΔT is the change in temperature across the convective layer, k is the permeability, h is the convective layer thickness, μ is the viscosity of water, and κ is the thermal diffusivity. The most variable of these quantities is the permeability, which in tuffs ranges from 10^{-14} to 10^{-11} m^2 (Wright and Cashman, 2014).

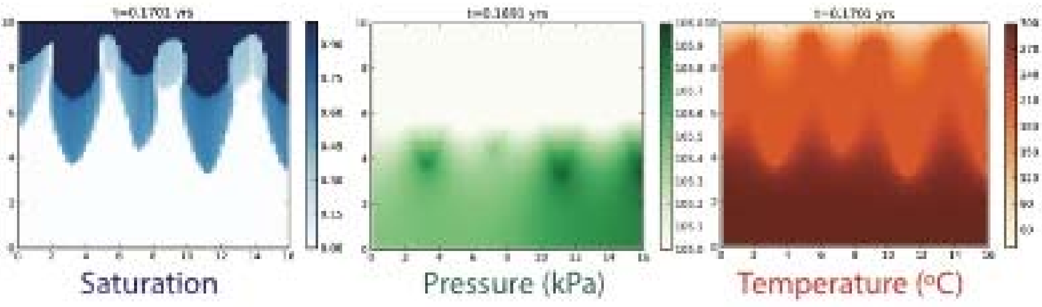


Figure DR6. Saturation (blue,) pressure (green) and temperature (red) for columns in 10^{-14} m^2 isotropic permeability 10 m x 16 m simulation. Upper boundary condition is 10 atm other boundaries are closed to fluid and energy flow.

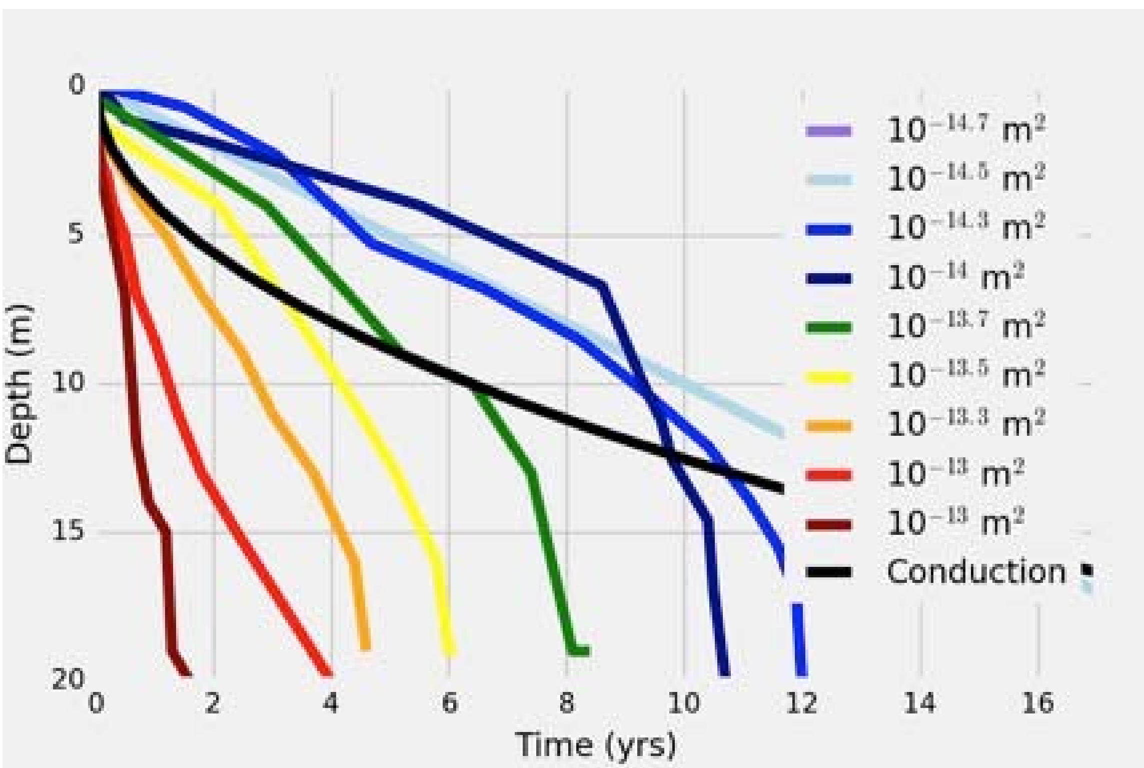


Figure DR7. Saturation depth through time for a range of permeabilities. From left to right: $10^{-12.5}$ m^2, $10^{-12.7}$ m^2, $10^{-13}m^2$, $10^{-13.3}m^2$, $10^{-13.5}$ m^2, $10^{-13.7}$ m^2, 10^{-14} m^2, $10^{-14.3}$ m^2. Black shows the conductive cooling profile.

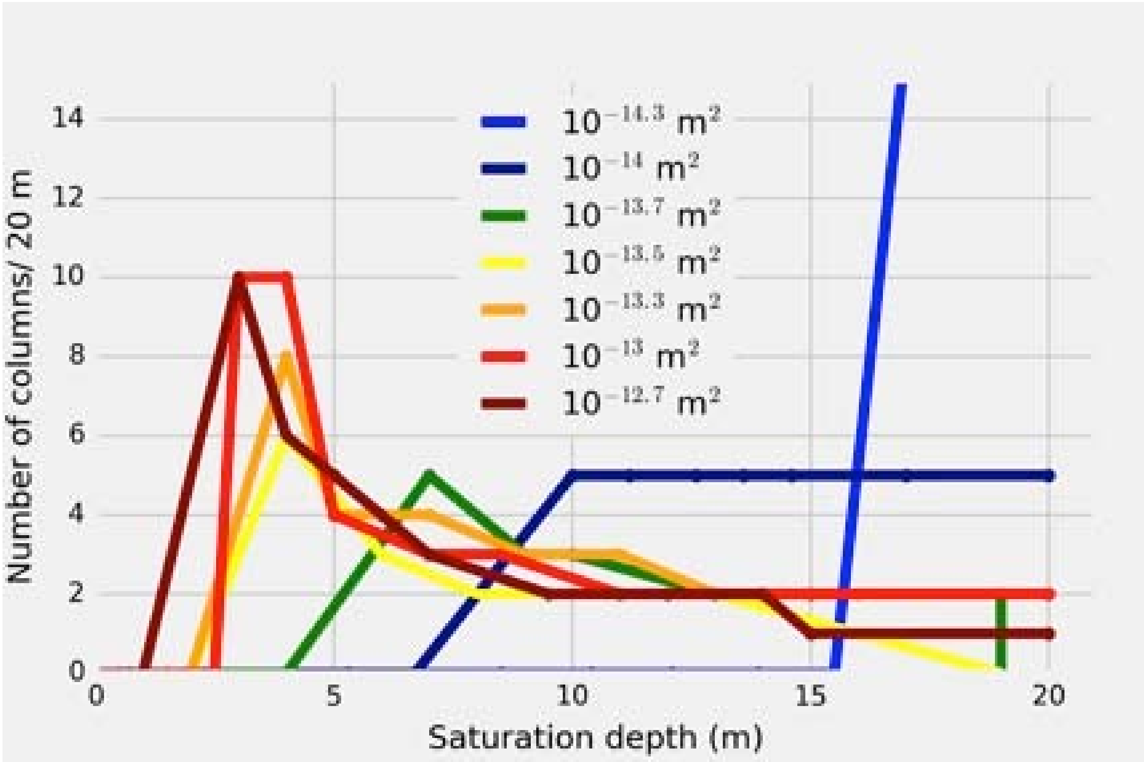


Figure DR8. Number of columns in 20 m simulations for a range of permeabilities. From left to right: $10^{-12.5}$ m^2, $10^{-12.7}$ m^2, 10^{-13}m^2, $10^{-13.3}$m^2, $10^{-13.5}$ m^2, $10^{-13.7}$ m^2, 10^{-14} m^2, $10^{-14.3}$ m^2. Black shows the conductive cooling profile.

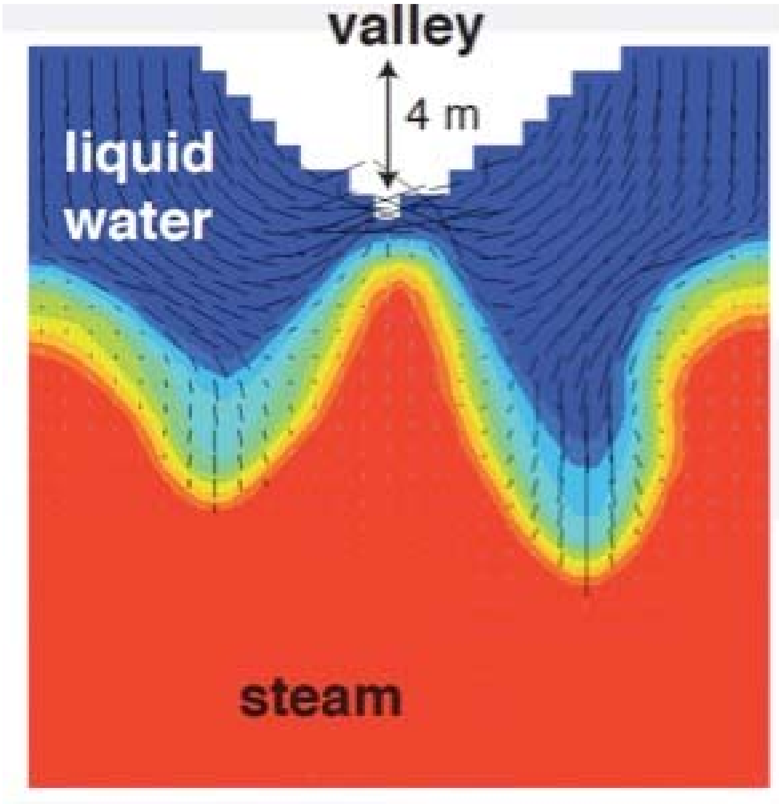


Figure DR9. Simulation of 10^{-13} m^2 domain including a 6 m x 4 m triangular drainage to drive topographic flow. Red is 100º C and blue is 30º C while black lines are liquid water velocities.

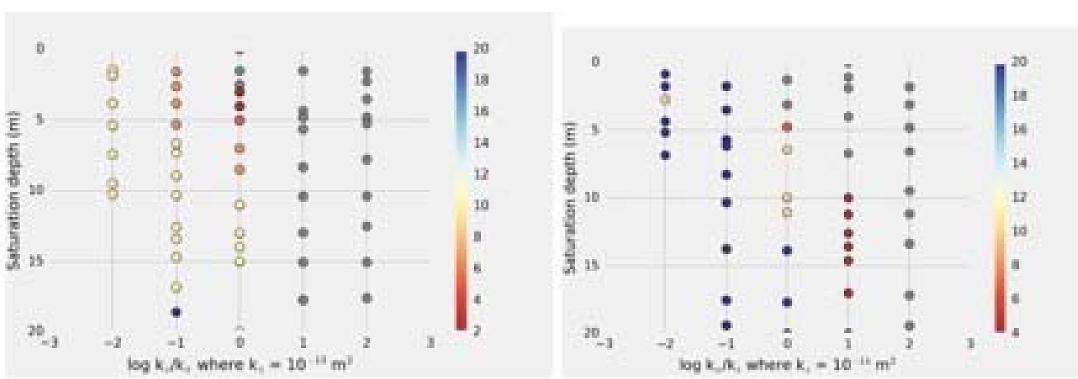


Figure DR10. Phase space of columnar flow for anisotropic permeabilities. Each vertical line of points shows a single simulation which progresses from 0 to 20 m in saturation depth. Gray circles show no columns. Colors show column spacing in meters.

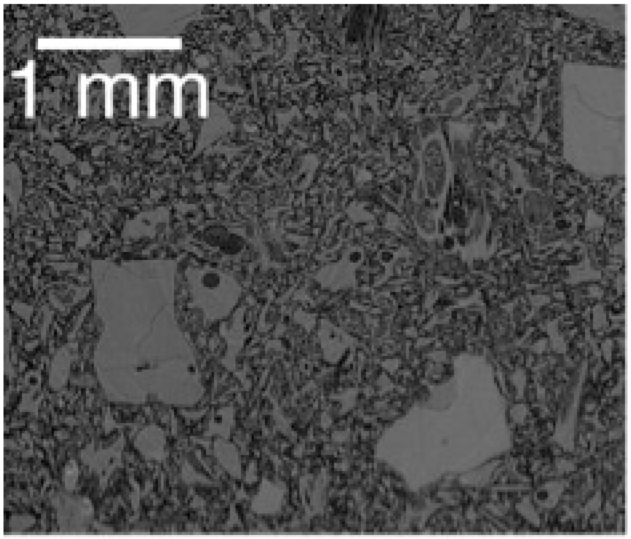


Figure DR11. X-ray computed microtomography scans of column. Gray blocks are crystals and volcanic glass. Circular features are vesicles. Fine fabric are ash shards. Note that mordenite crystals are not large enough to be seen. (37.47º N, 118.73º W)

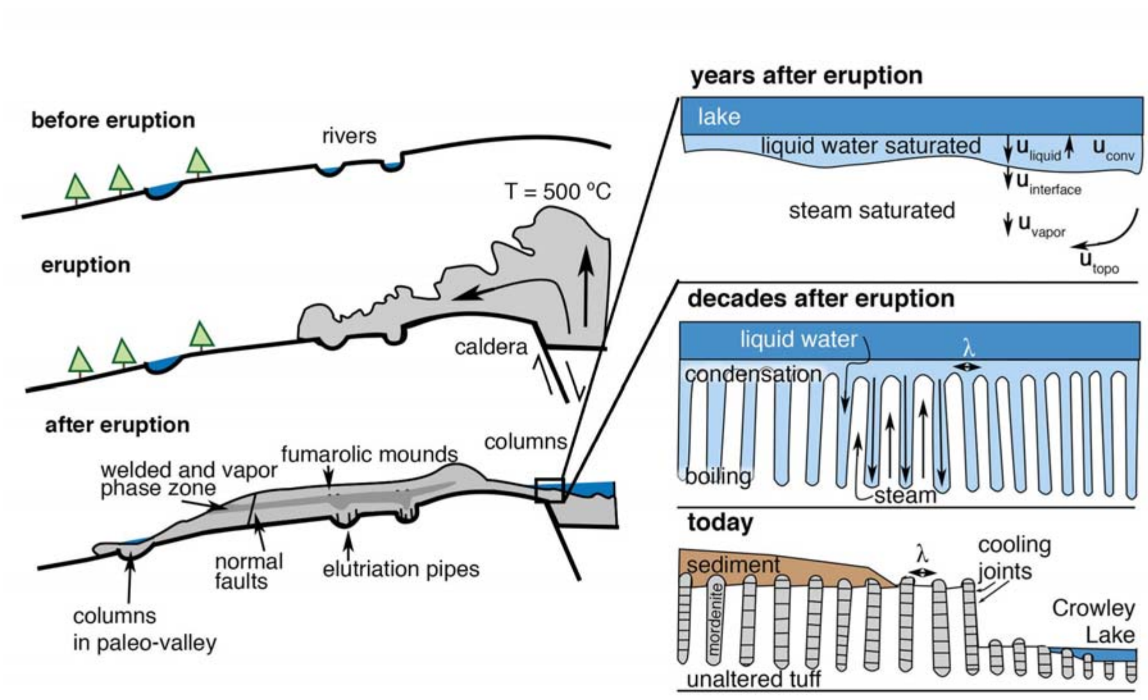


Figure DR12. Extended cartoon of cooling Bishop Tuff.

Supplemental File Description:
2017348_Supplemental data description.txt

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Supplemental Movie Files:
2017348_Movies.zip

- Animation_k13: b13_2020.gif
- Animation_k14: b14_20_S.gif
- Model Input: HYDROTHERM_input.ht