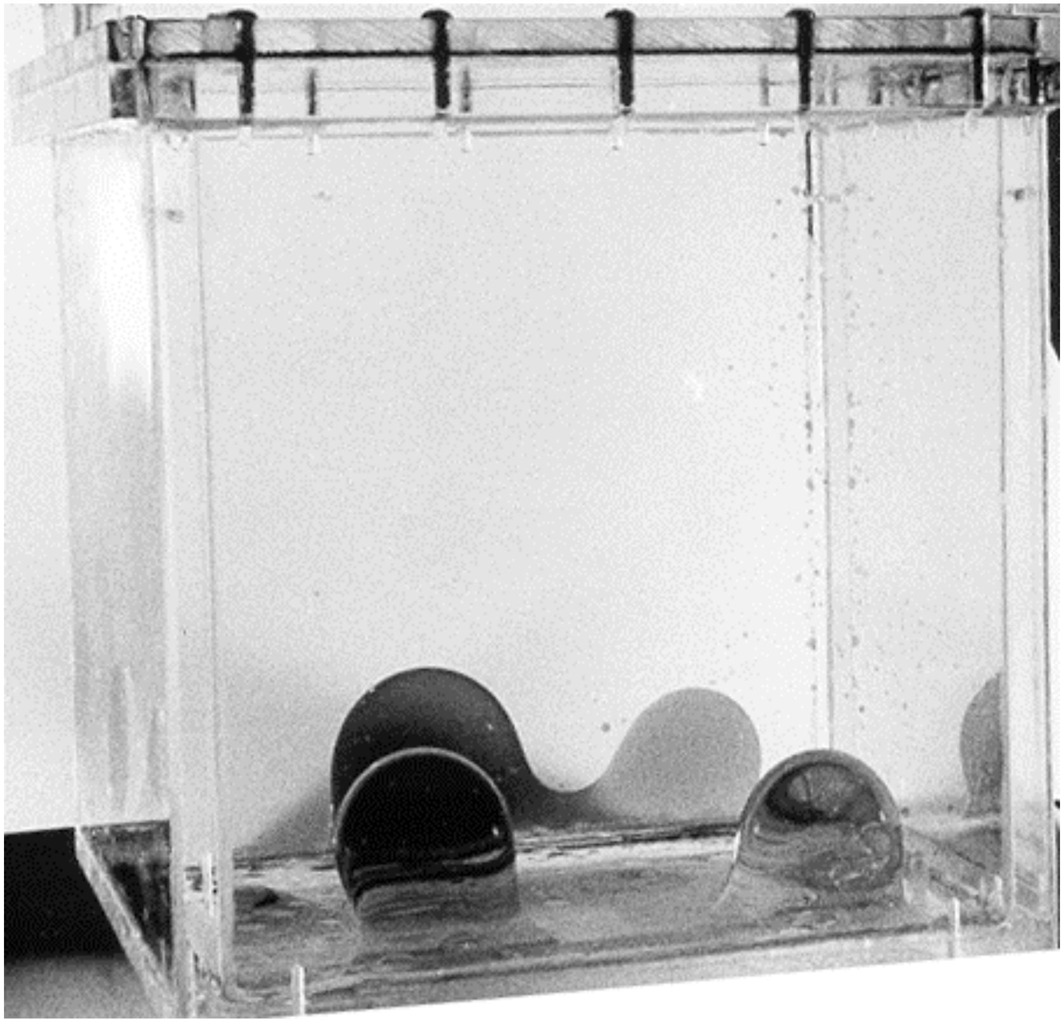
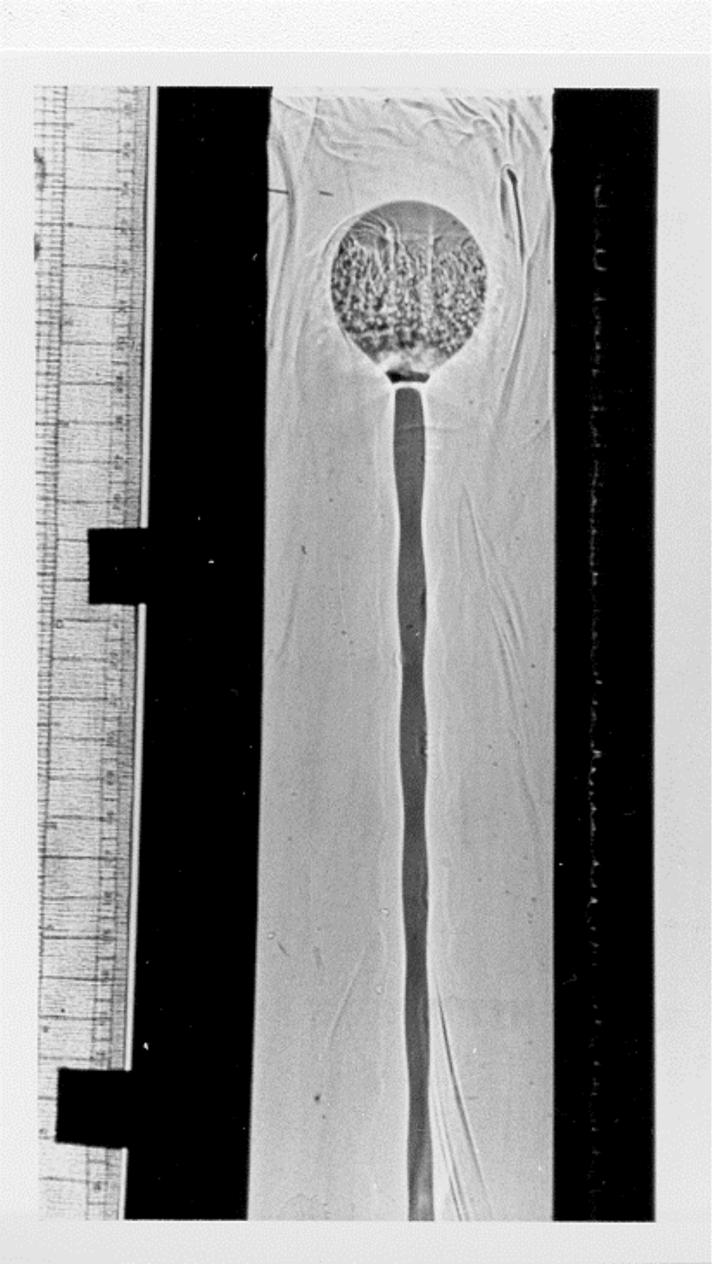
[redacted]

Rayleigh-Taylor Instability



Plume



Whitehead, J. A.& D. S. Luther, 1975.

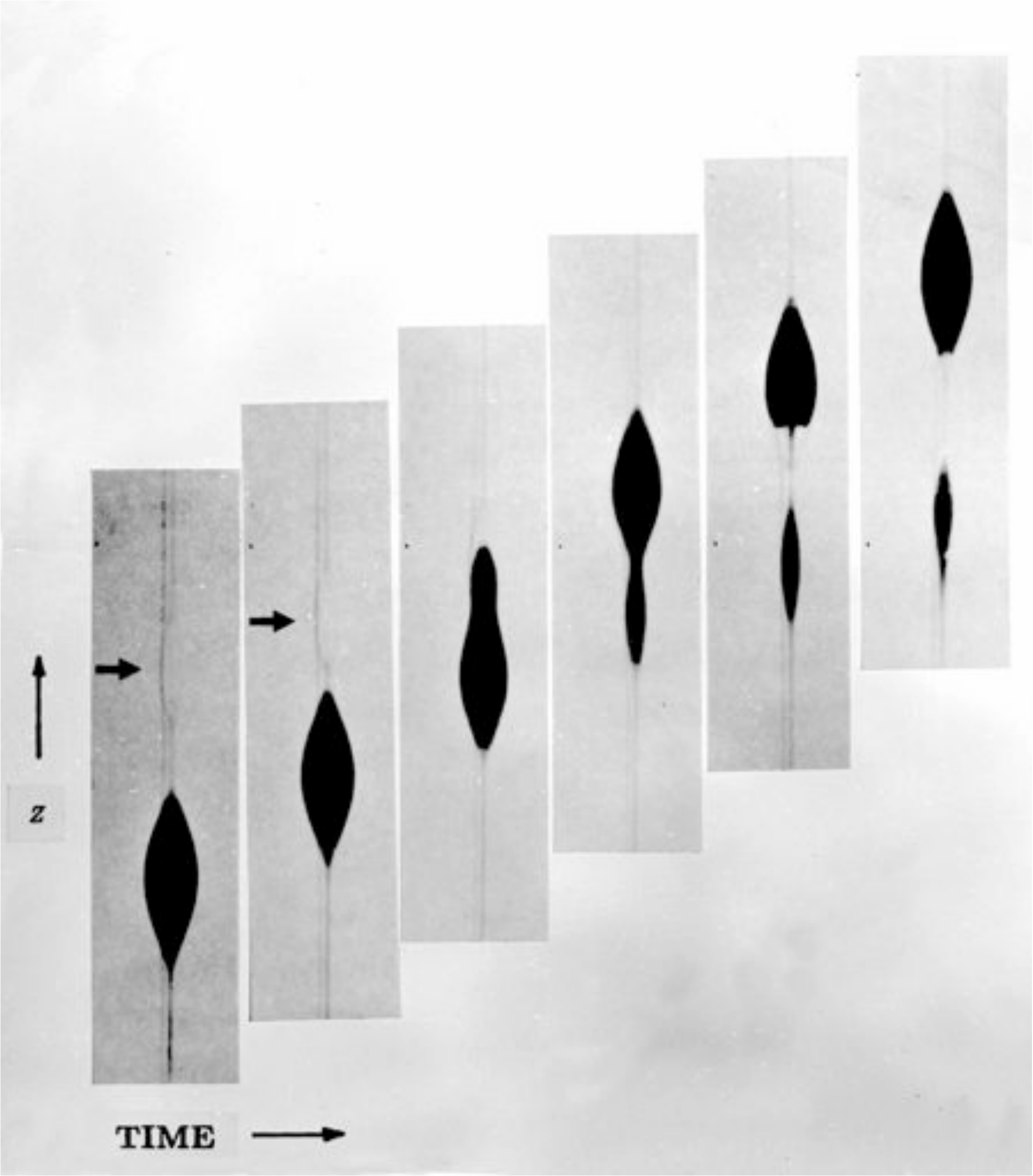
Dynamics of laboratory diapir and plume models

Journal of Geophysical Research, **80**, 705–717.

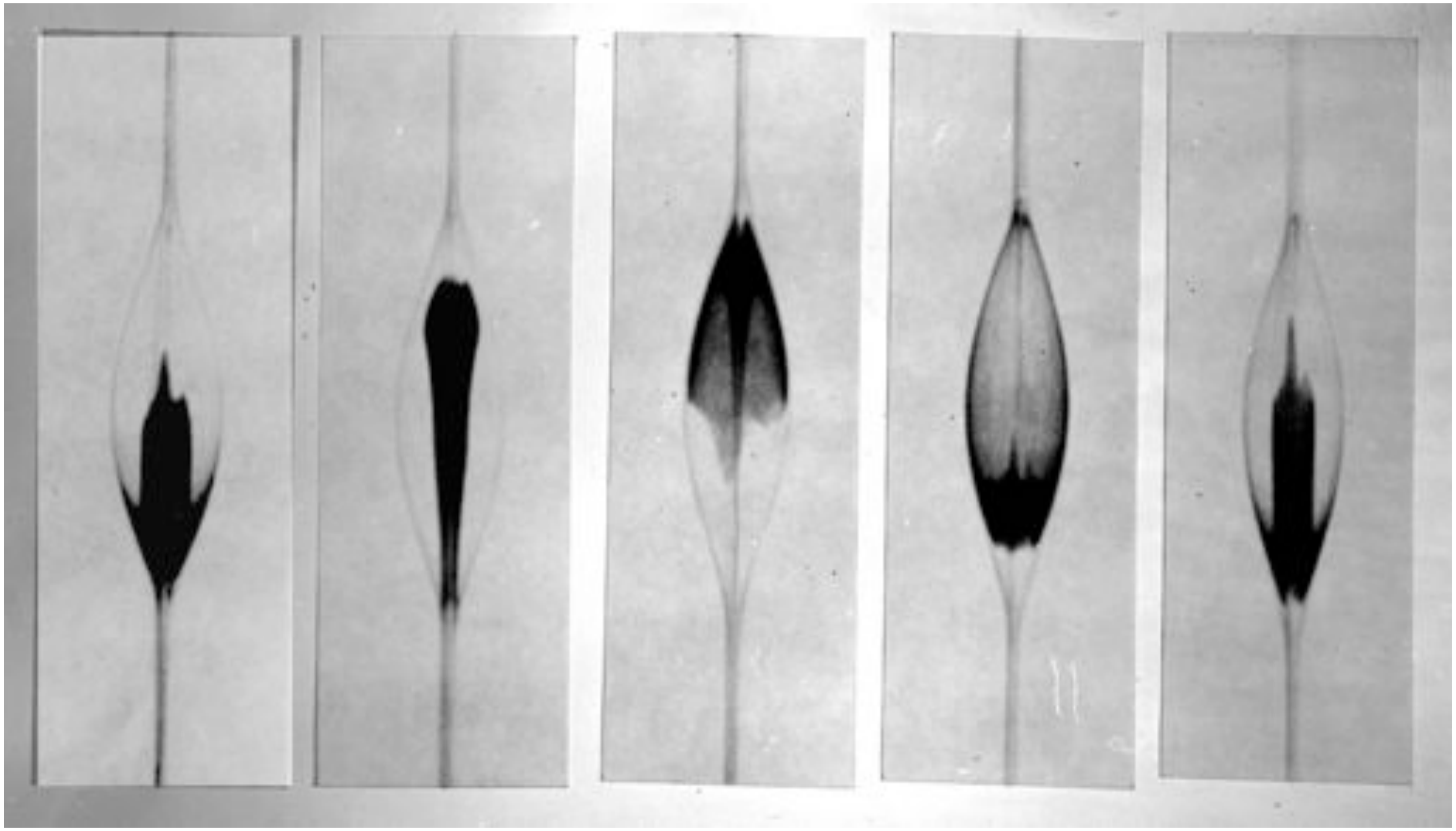
Tilted conduit

Solitary Wave collision

Scott, D. A., David J. Stevenson & J. A. Whitehead, 1986. Observations of solitary waves in a viscously deformable pipe. *Nature*, **319**, 759–761.

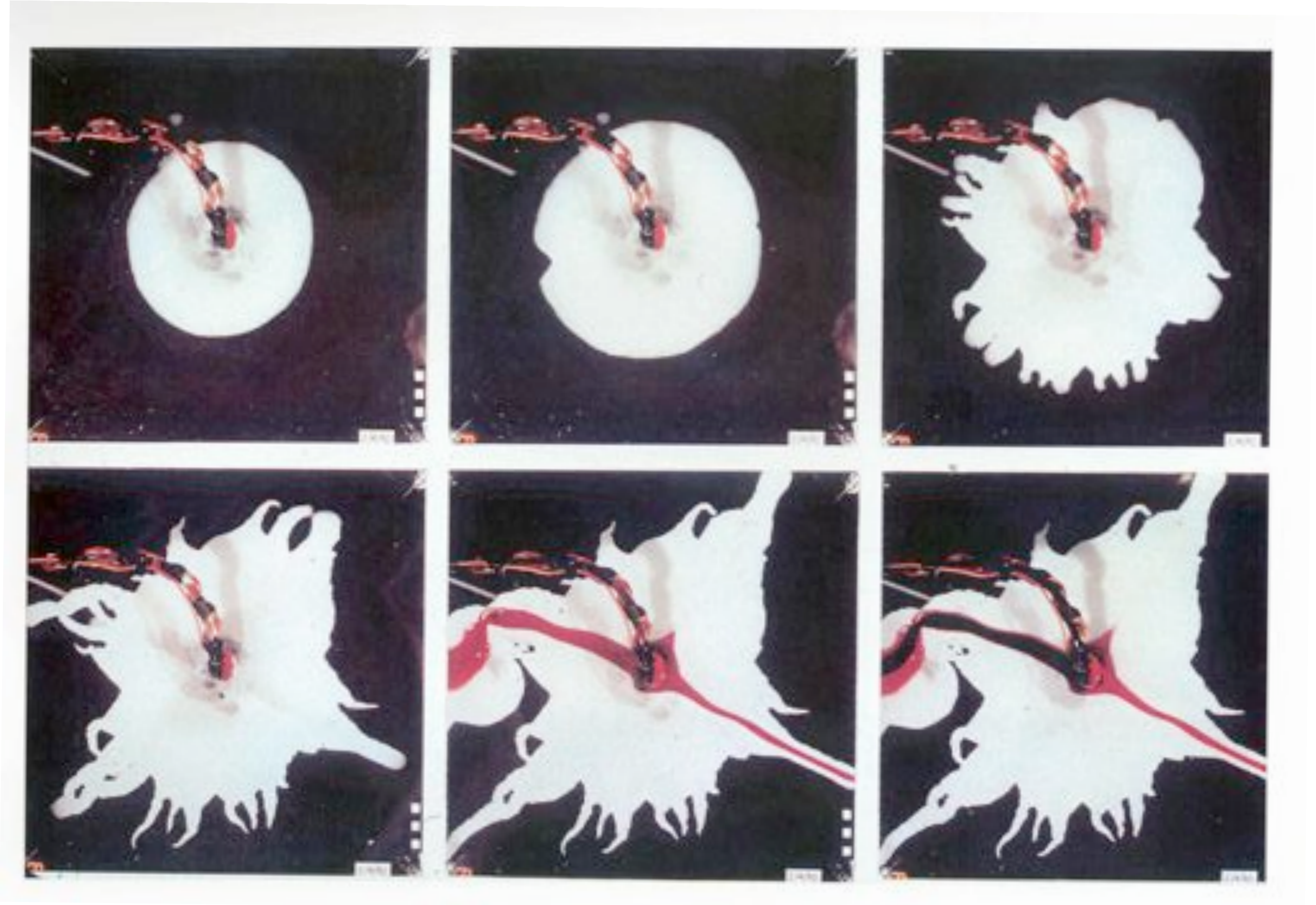


Material is conserved

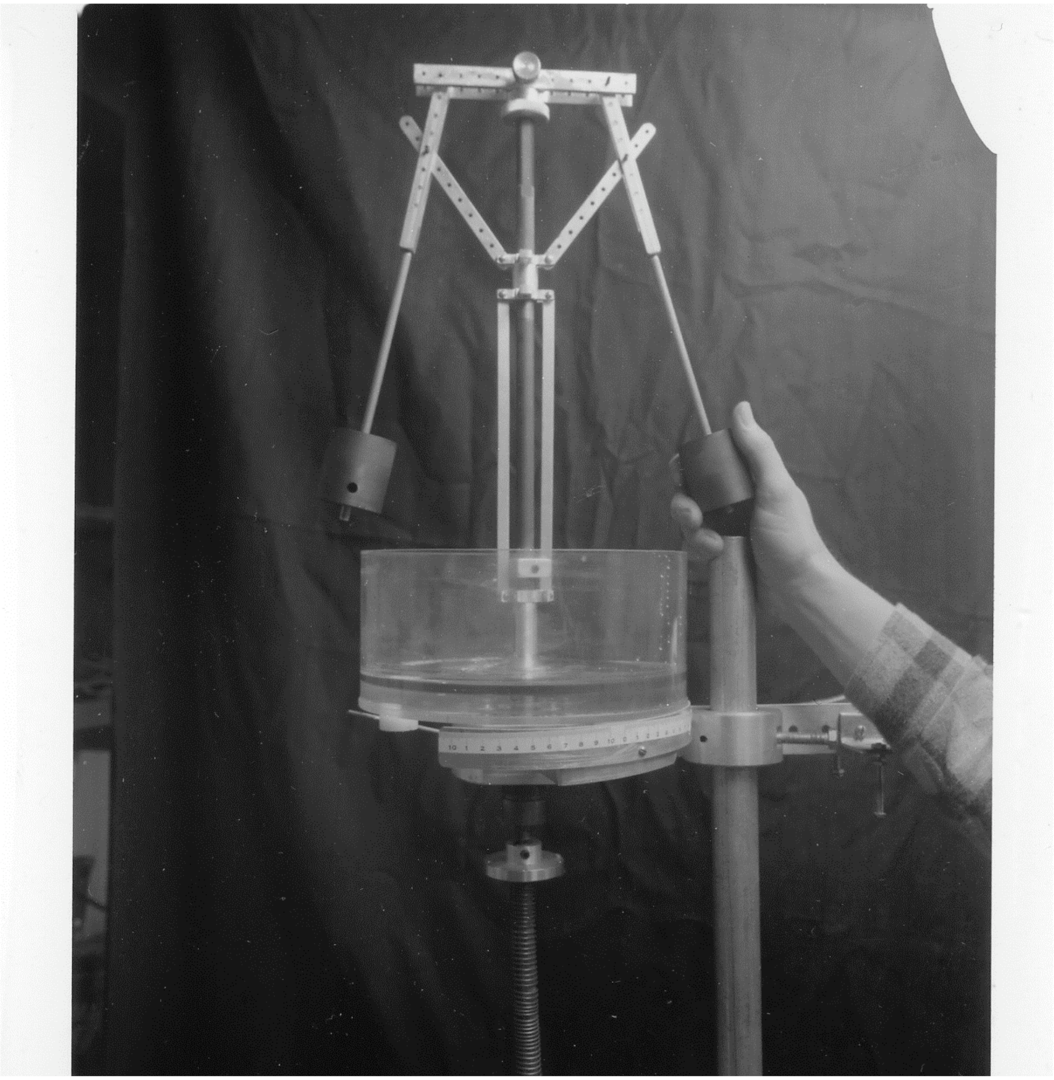


Paraffin on a cold plate with a clear lid-Transient t=2,7,9,12,25,59s

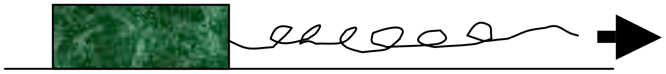
Pe=uL/κ



The earthquake machine



Earthquake Equations



dimensional equations

$$m\frac{du'}{dt'} + \frac{\mu}{d}\left[\frac{u' + \beta' u'^3}{1 + \alpha' u'^2}\right] = F'$$

$$\frac{dF'}{dt'} = C\left(U_0 - u'\right)$$

unprimed dimensionless

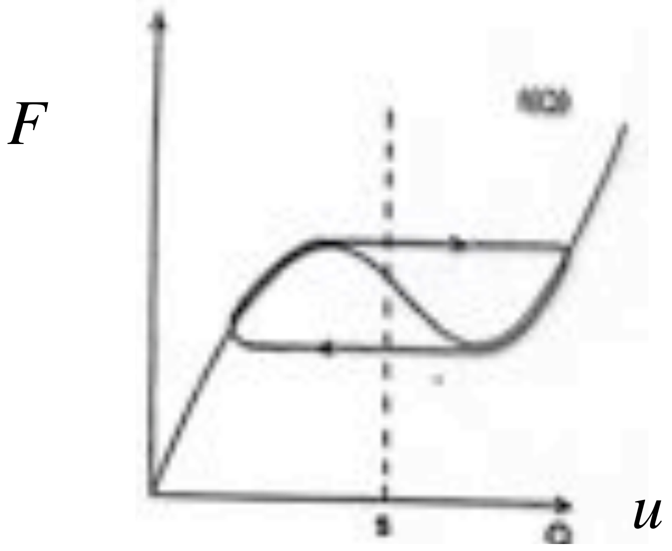
$$\gamma\frac{du}{dt} + \left[\frac{u + \beta u^3}{1 + \alpha u^2}\right] = F$$

$$\frac{dF}{dt} = 1 - u$$

stationary

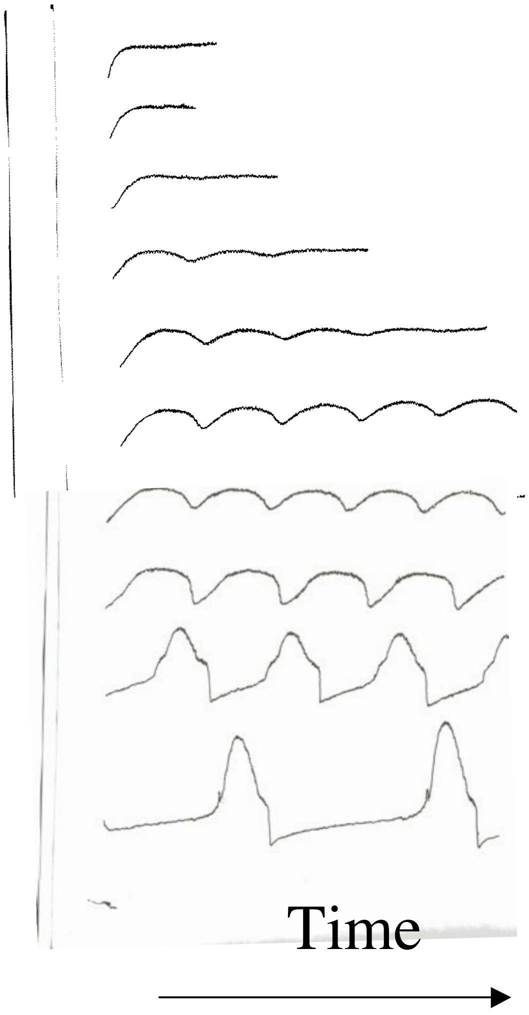
$$F = \left[\frac{u + \beta u^3}{1 + \alpha u^2}\right]$$

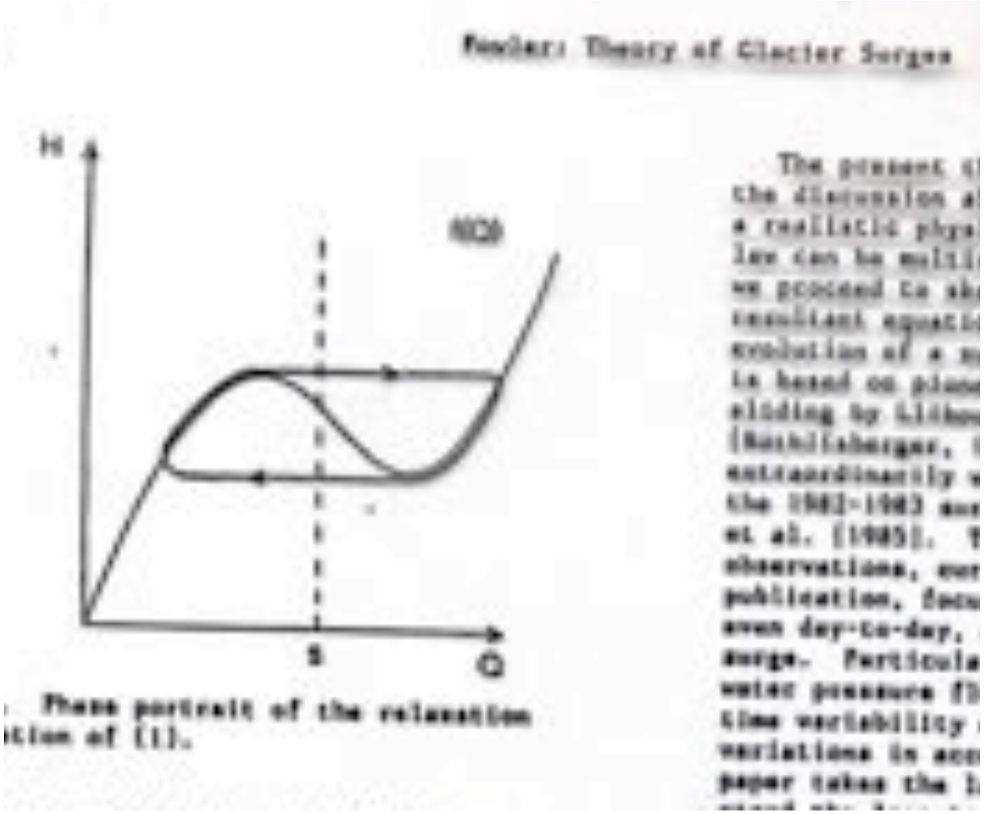
$$u = 1$$



Oscillations &--- Glacier theory

Laboratory experiment



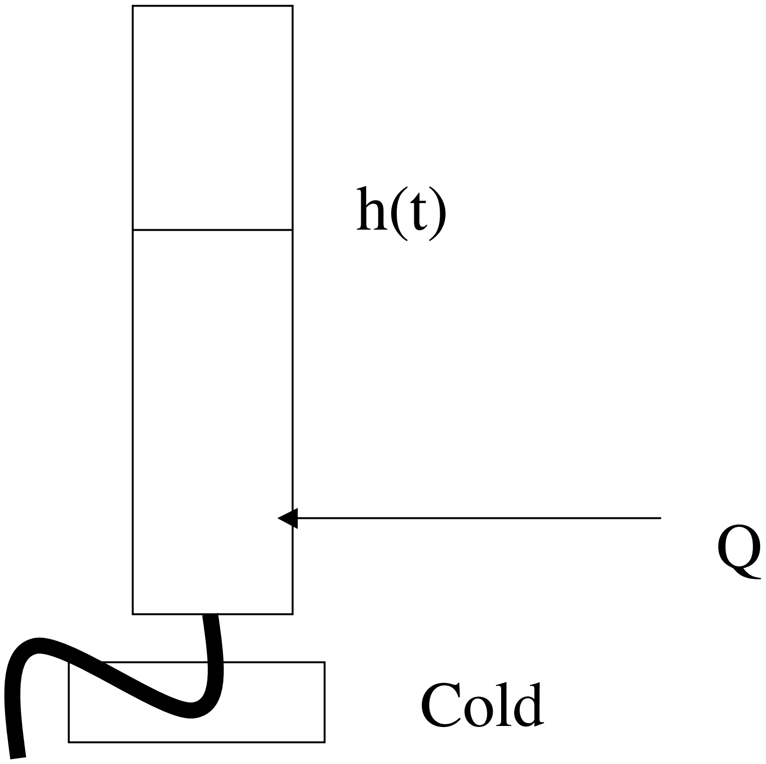


Fowler: Theory of Glacier Surges

Phase portrait of the relaxation
tion of (1).

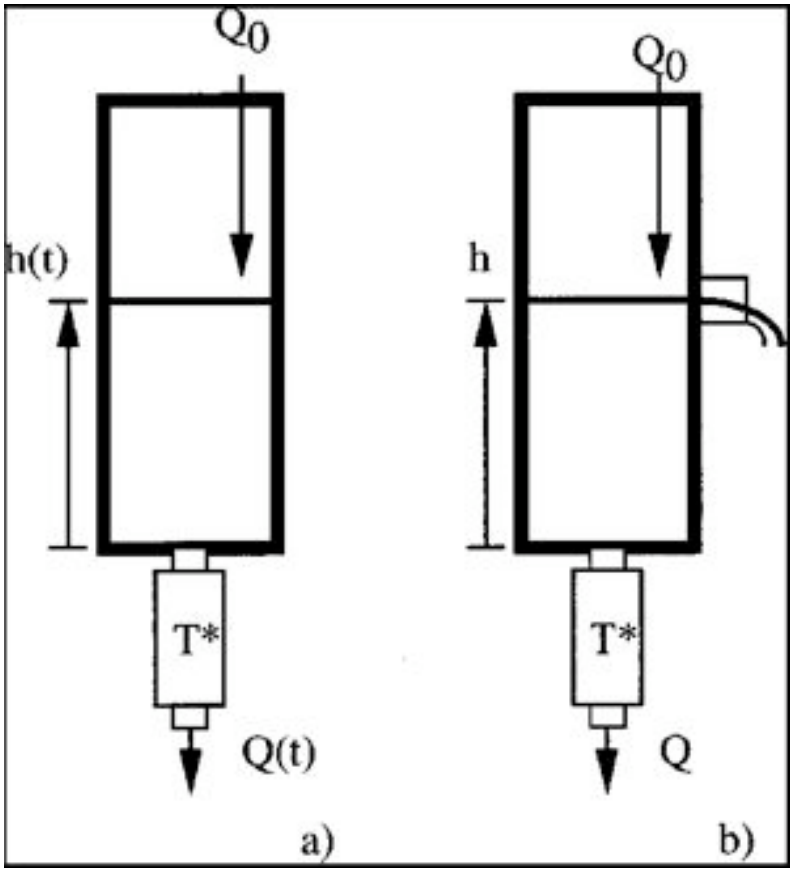
The present s
the discussion a
a realistic phys
law can be multi
we proceed to sh
resultant equati
evolution of a s
is based on plan
sliding by Llibou
[Röthlisberger,
extraordinarily v
the 1982-1983 sur
et al. [1985]. T
observations, eve
publication, focu
even day-to-day,
surge. Particula
water pressure fl
time variability
variations in acc
paper takes the l

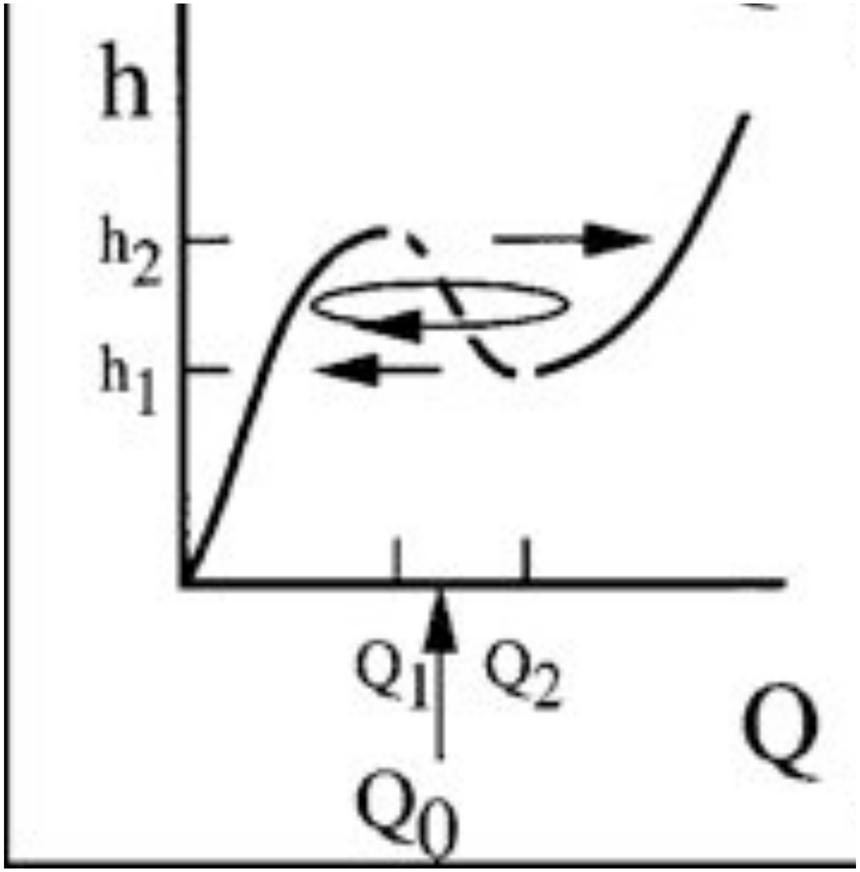
Why are Volcanos unsteady?



Oscillate or abrupt/hysteresis

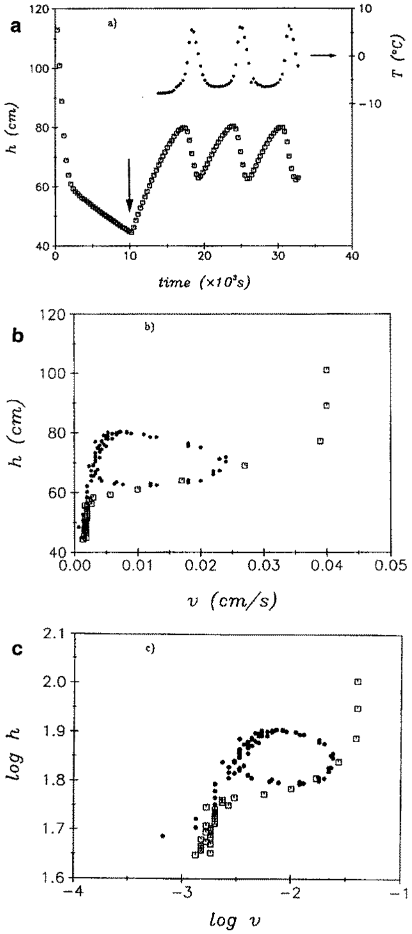
Whitehead, J. A. W. Gregory Lawson and John Salzig. 2001 Multistate flow devices for geophysical fluid dynamics and climate. American Journal of Physics, 69 546-553.





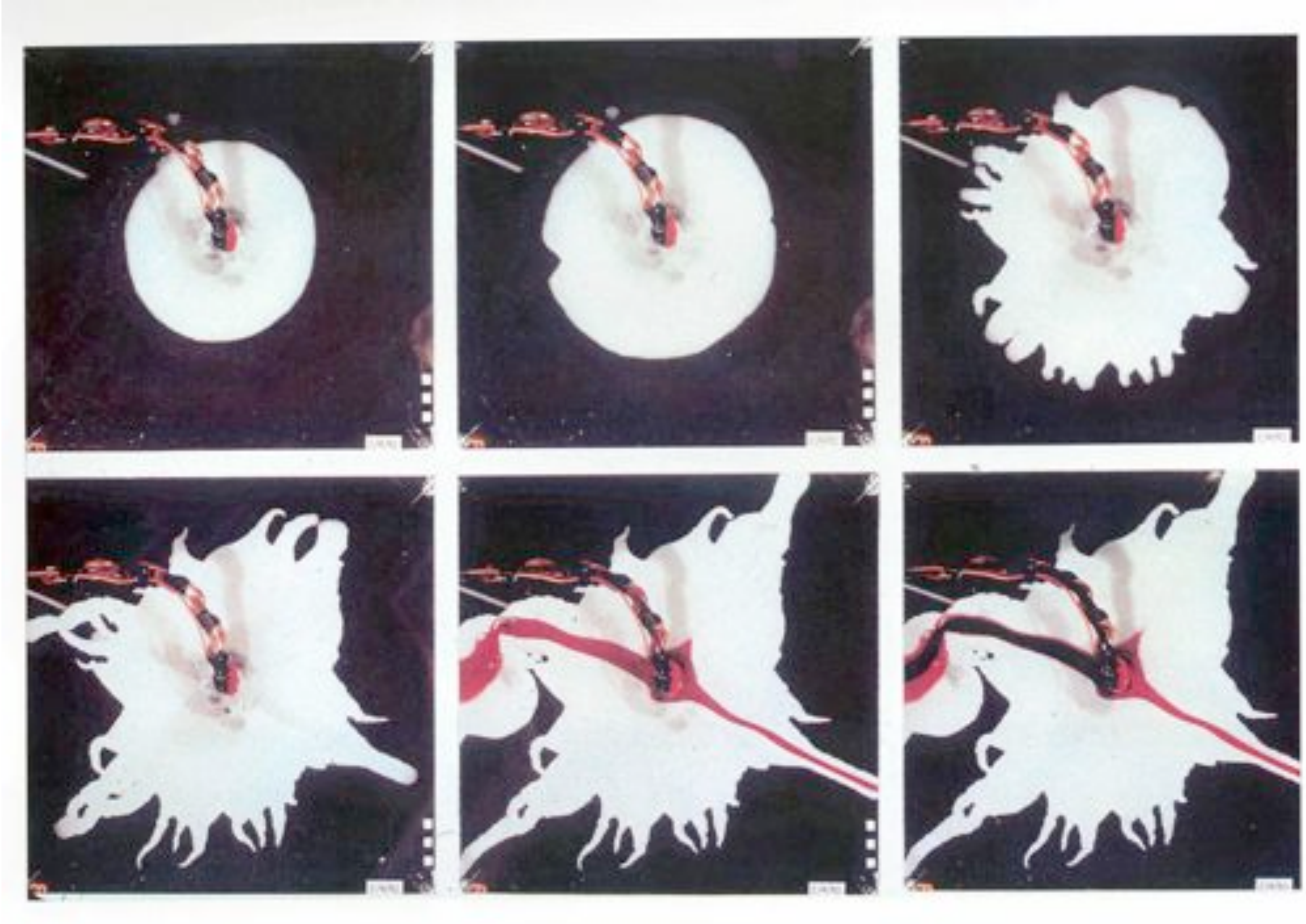
Nonlinear oscillations

Whitehead, J.A. and K. R. Helfrich, 1991. Instability of flow with temperature-dependent viscosity: a model of magma dynamics. Journal of Geophysical Research, 96, (B3), 4145-55.



Oscillations

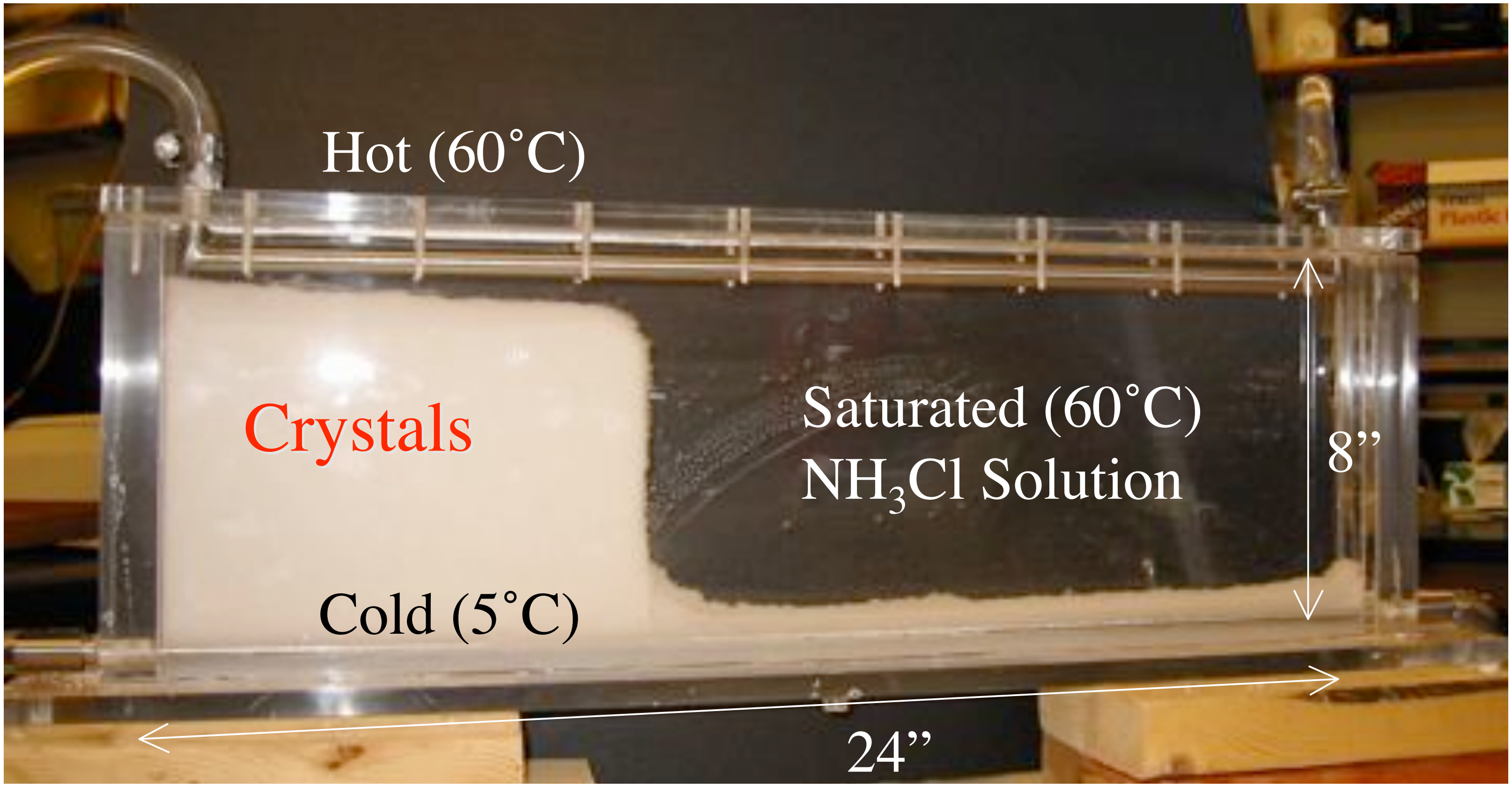
Evolution of channels if we have space variation rather than time variation, channels form



- A Broad, slow flow makes a lot of resistance whereas a narrow faster flow has less resistance.

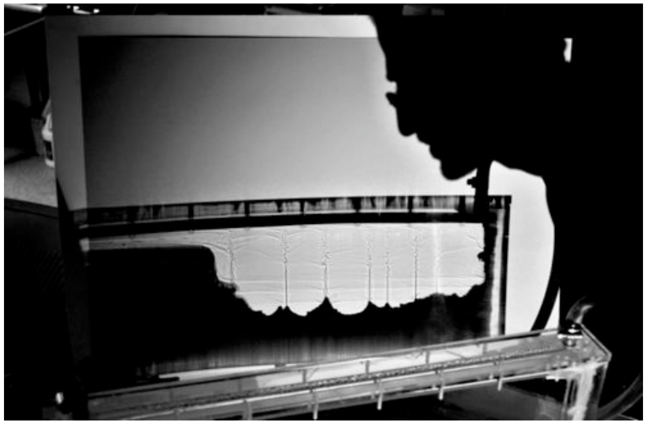
Convection in an Open Cell

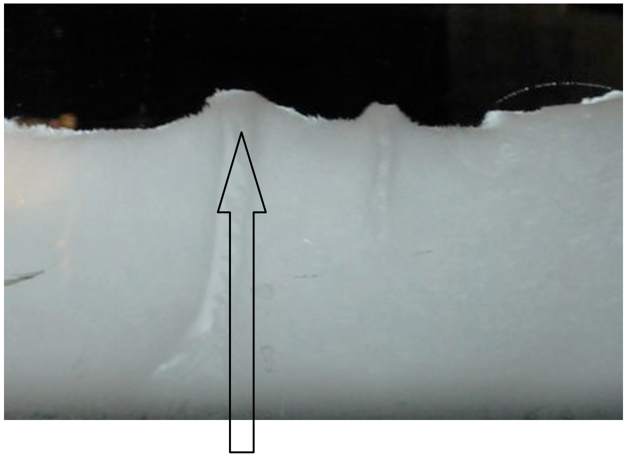
apparatus



a 2-D version of Tait & Jaupert, 1992; Tait et al, 1992

Channels in porous flow



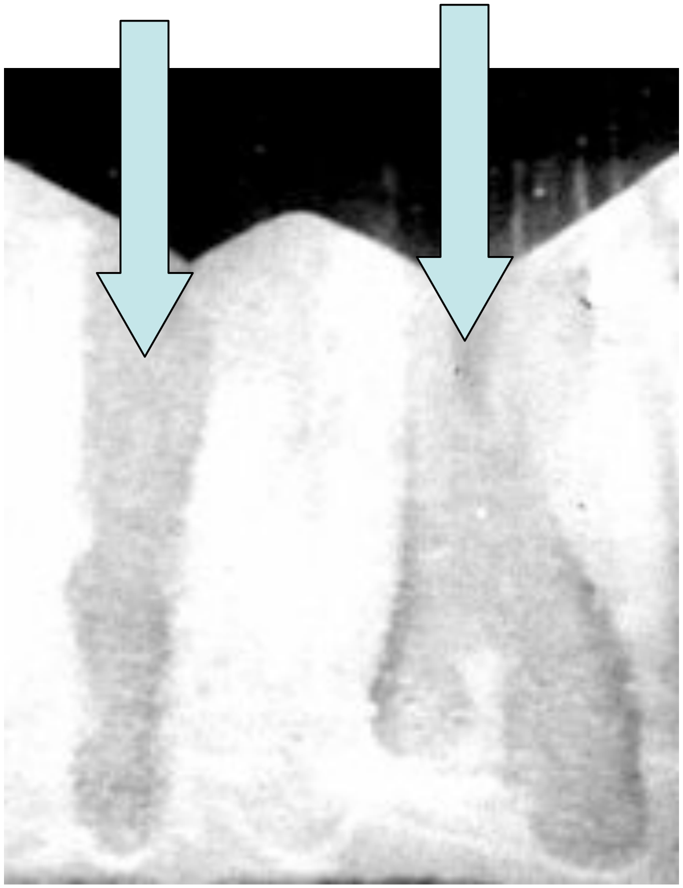


Cold,
depleted

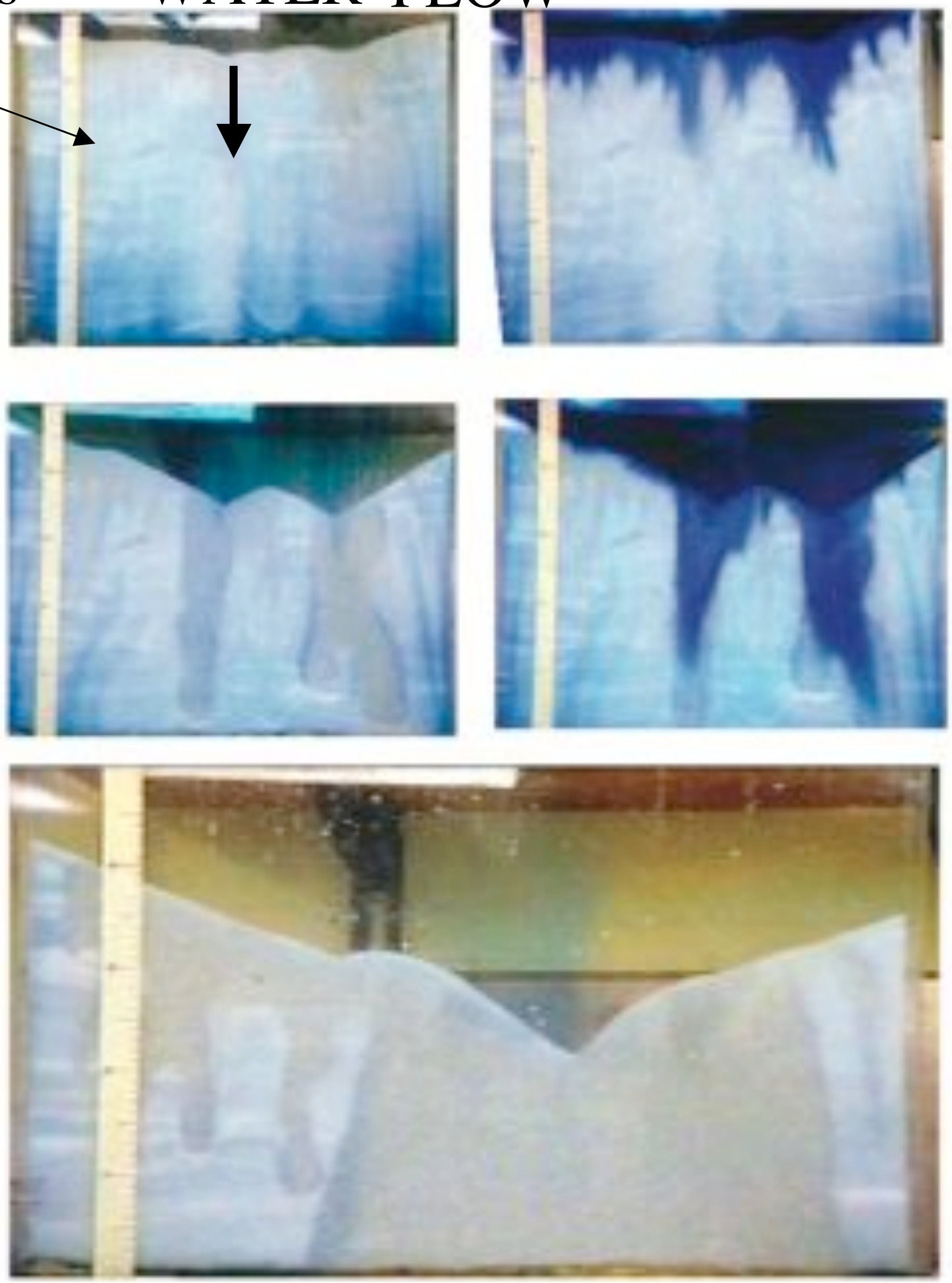
- Channels form within the mushy layer of crystals

Salt channelization

Fresh water sinking
Though salt crystals
And glass beads



Porous dissolution Channels

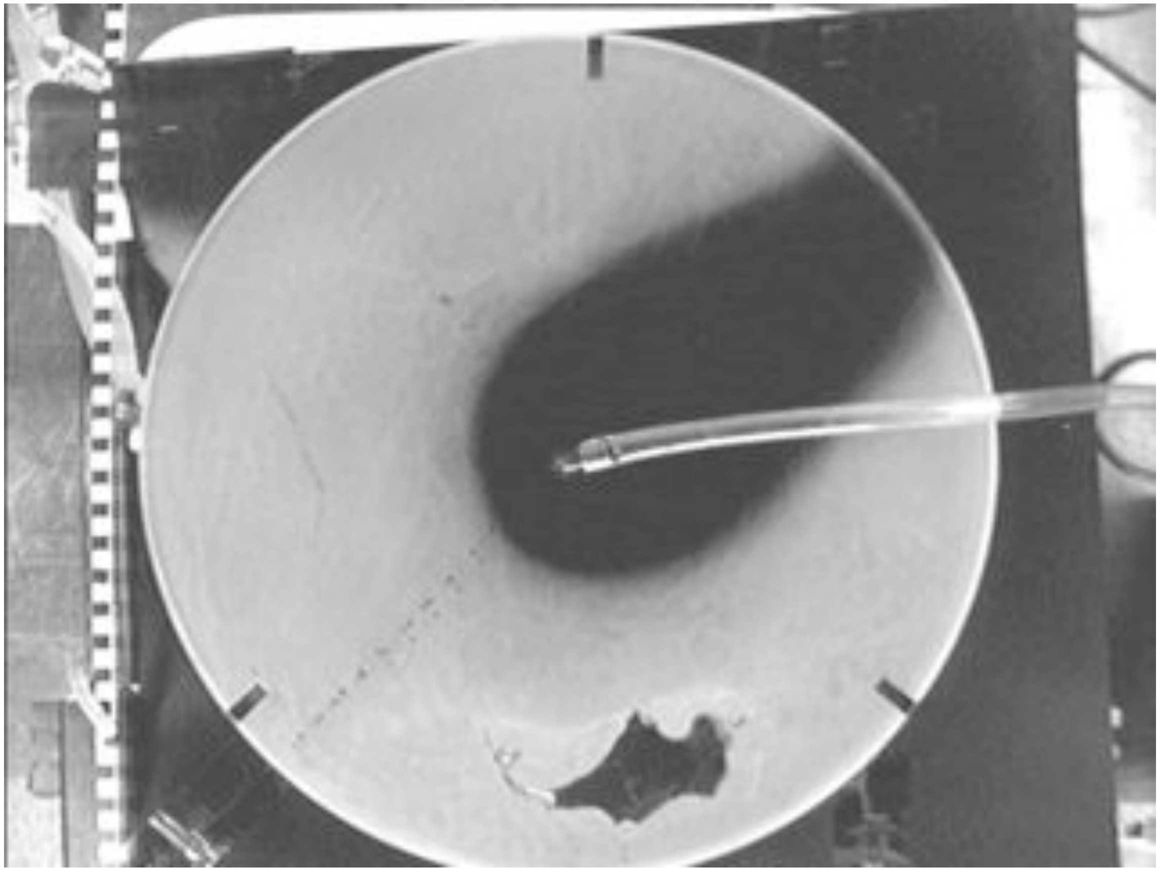


Salt and glass beads

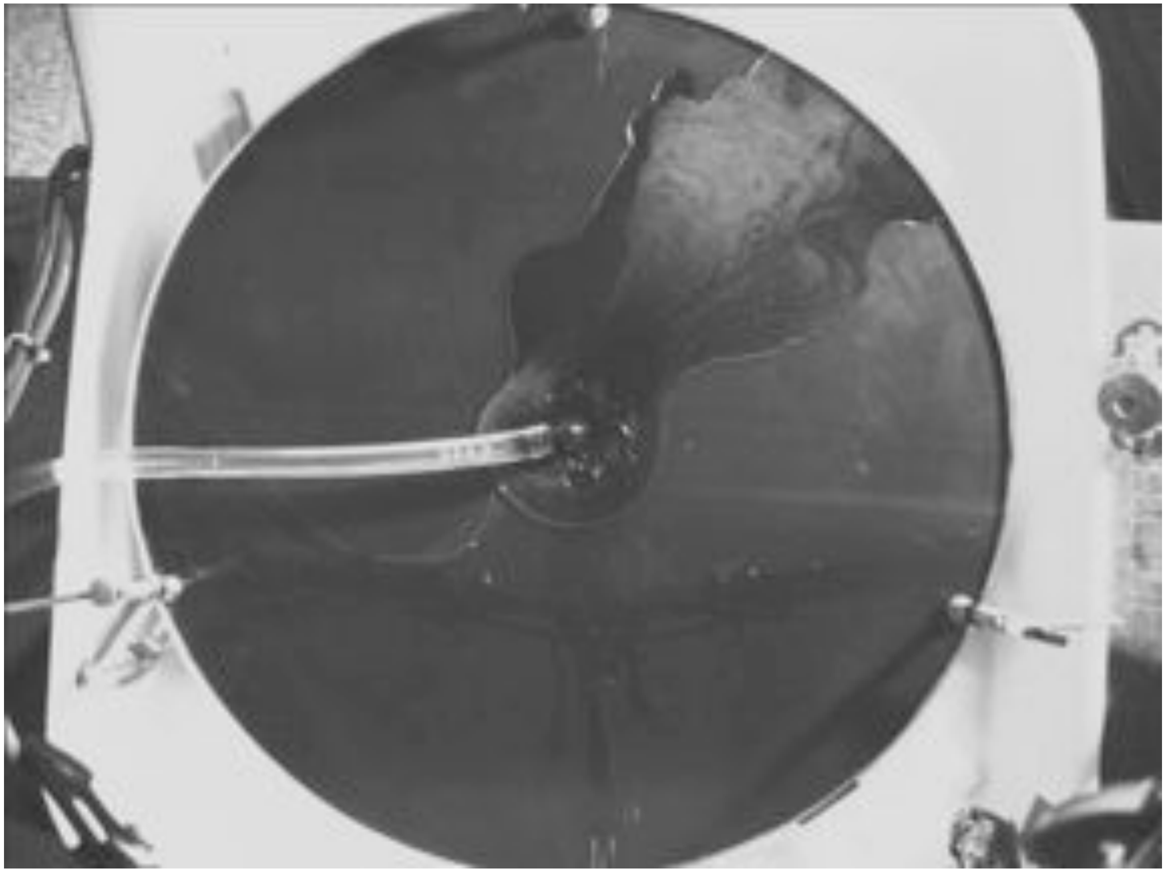
WATER FLOW

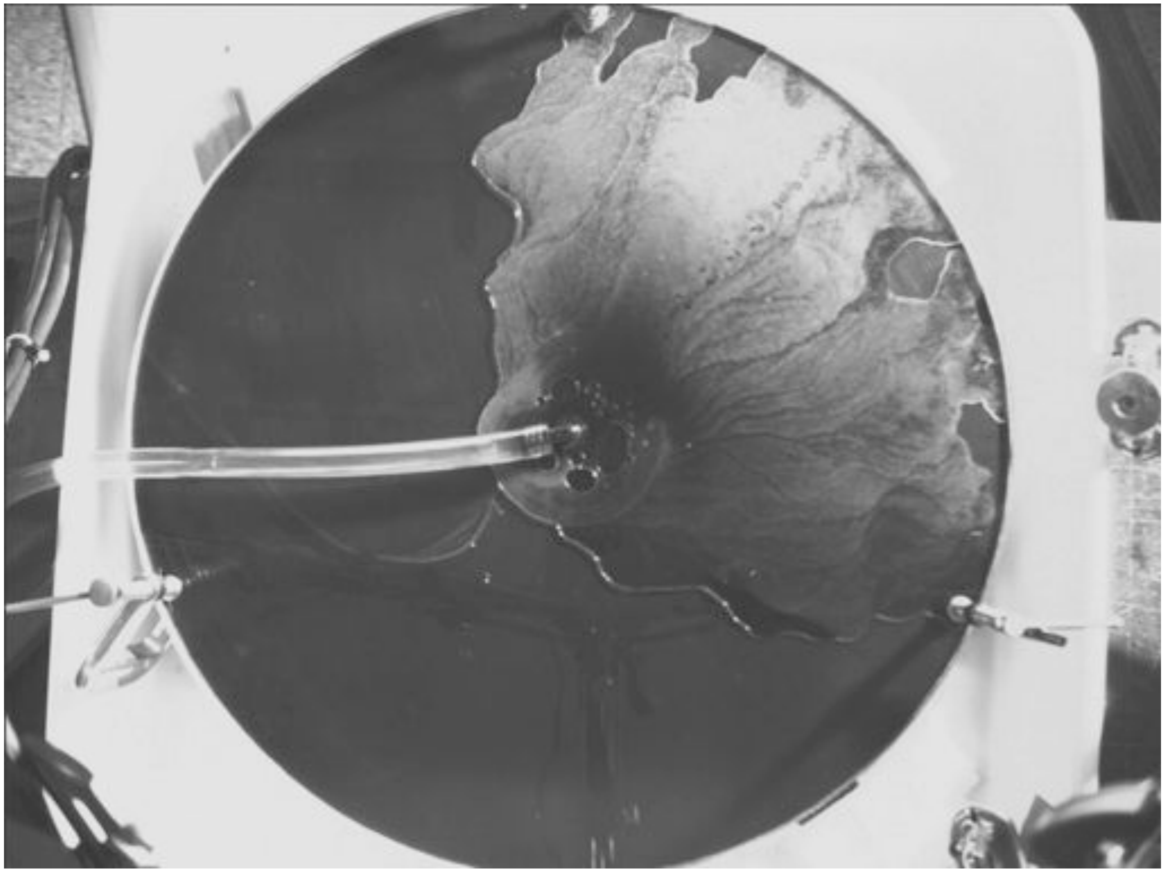
Aharonov, Einat, J. A. Whitehead, Peter Kelemen Marc Spiegelman, 1995. Channeling instability of upwelling melt in the mantl *Journal of Geophysical Res* **100**, 20,433–20,450.

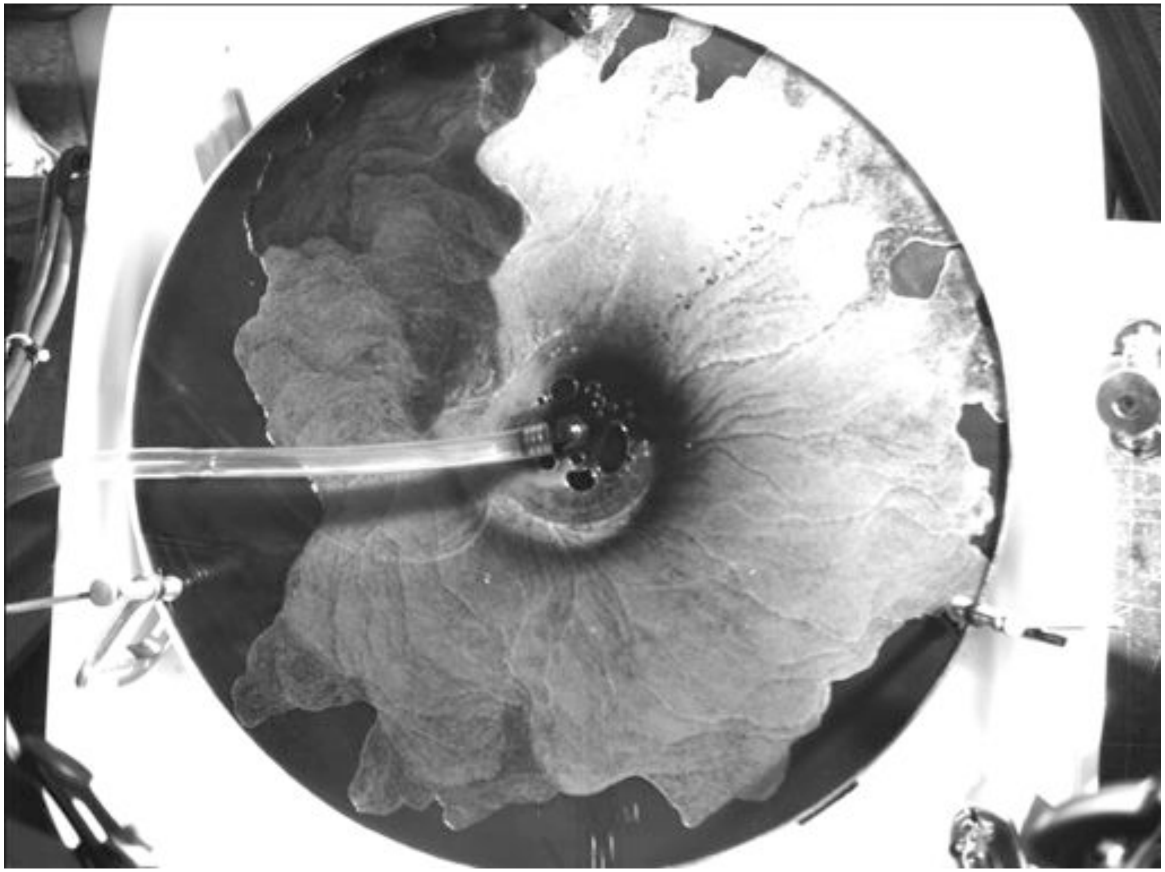
COLD DISK WITH PLEX LID WED WITH HEXADECENE (17 DEG MELTING POINT)

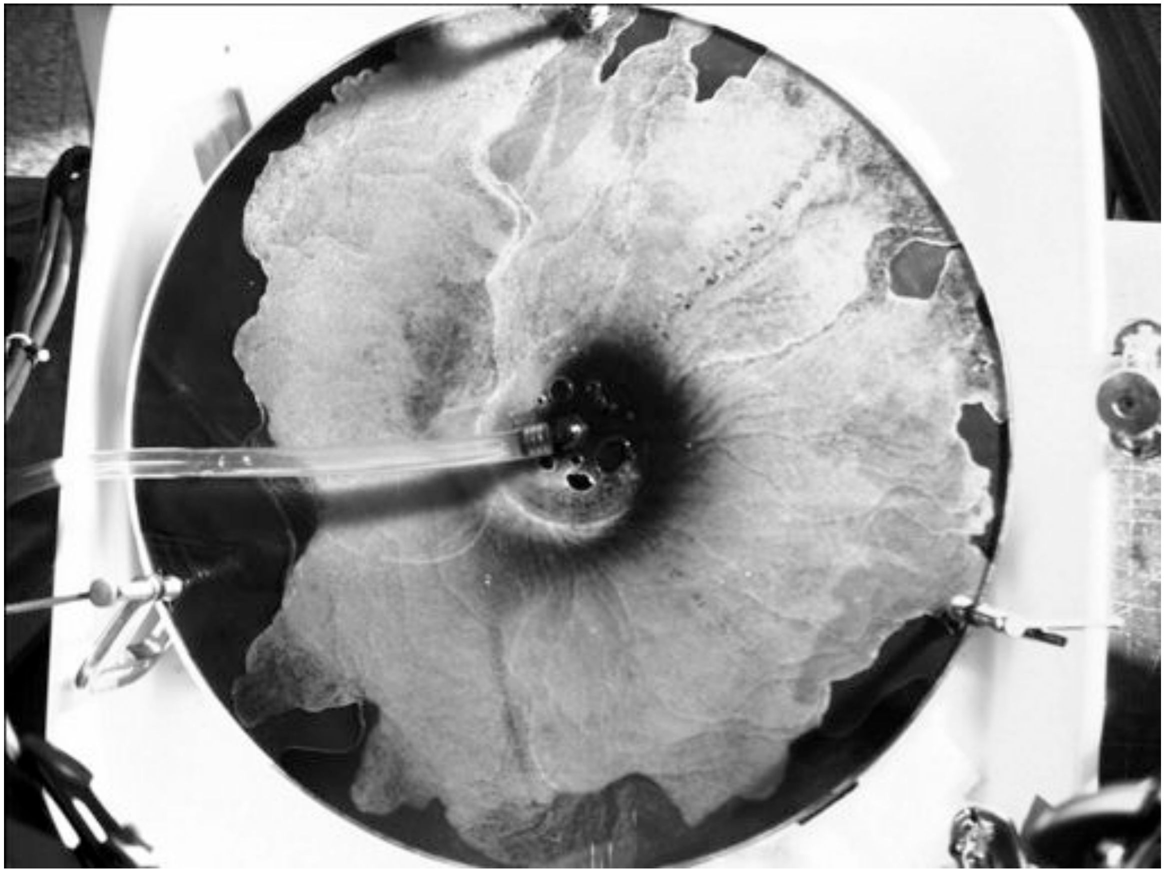


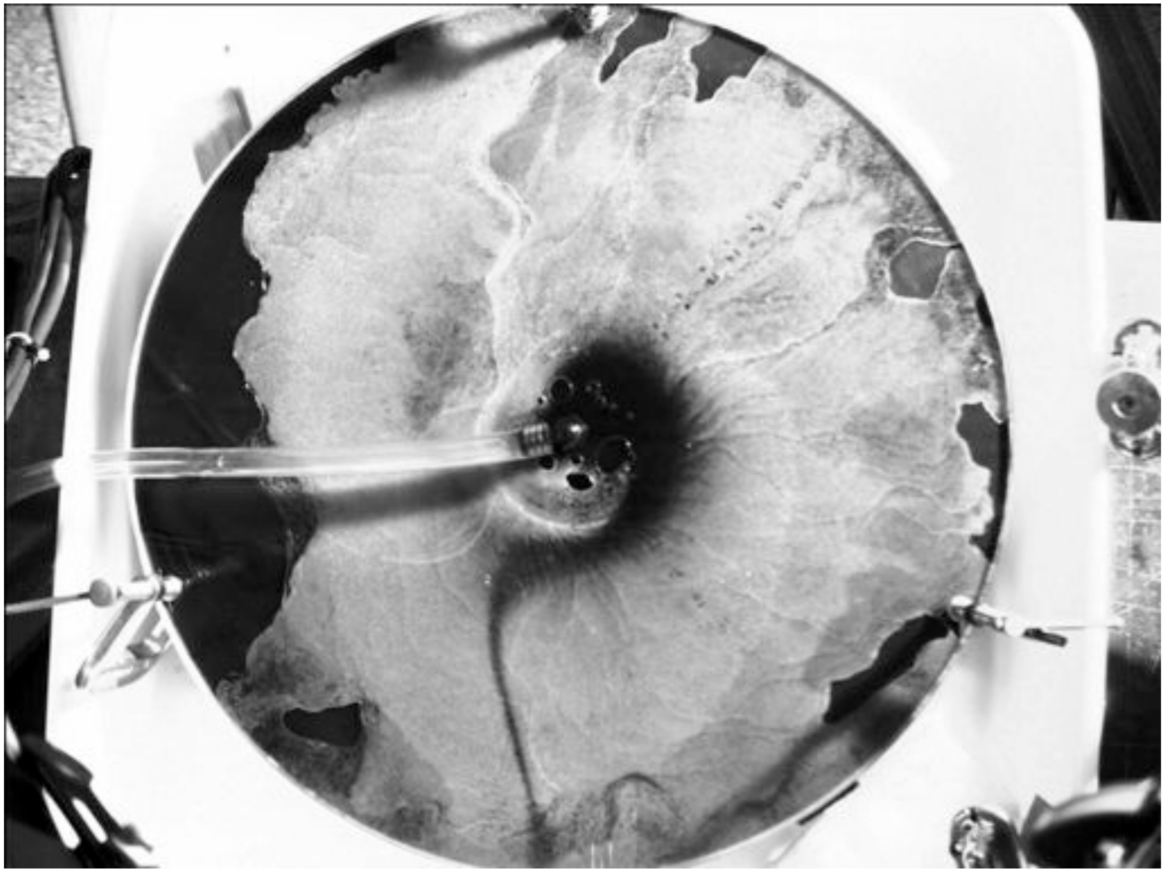
[redacted]



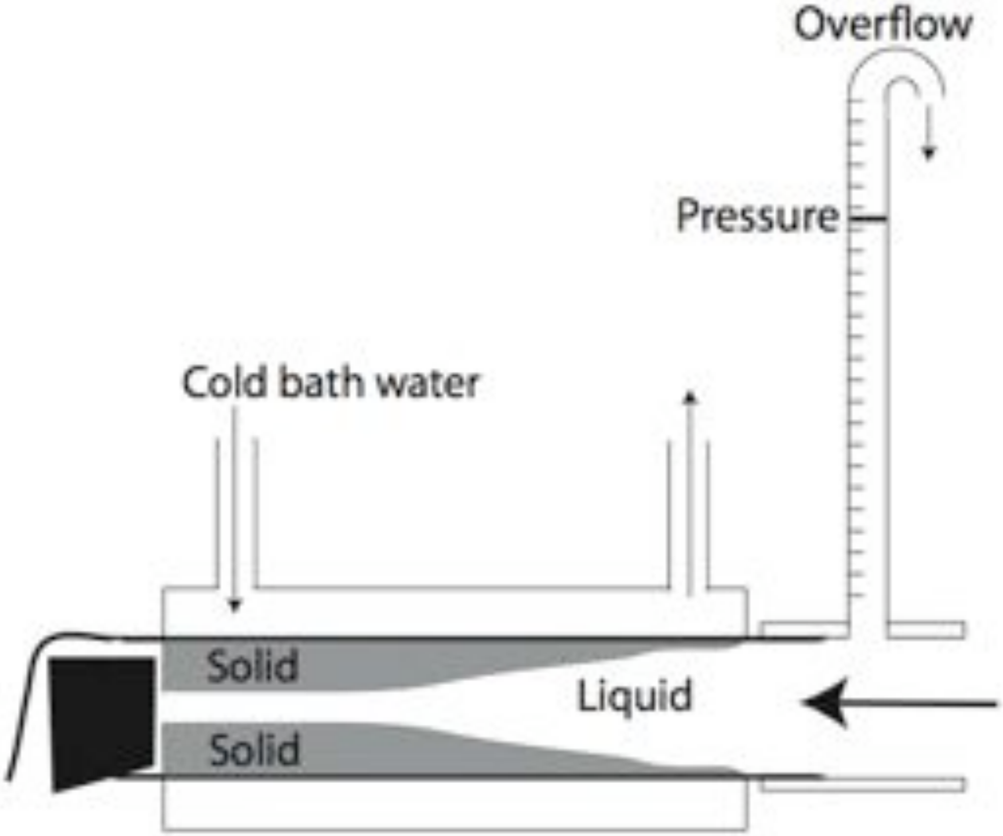




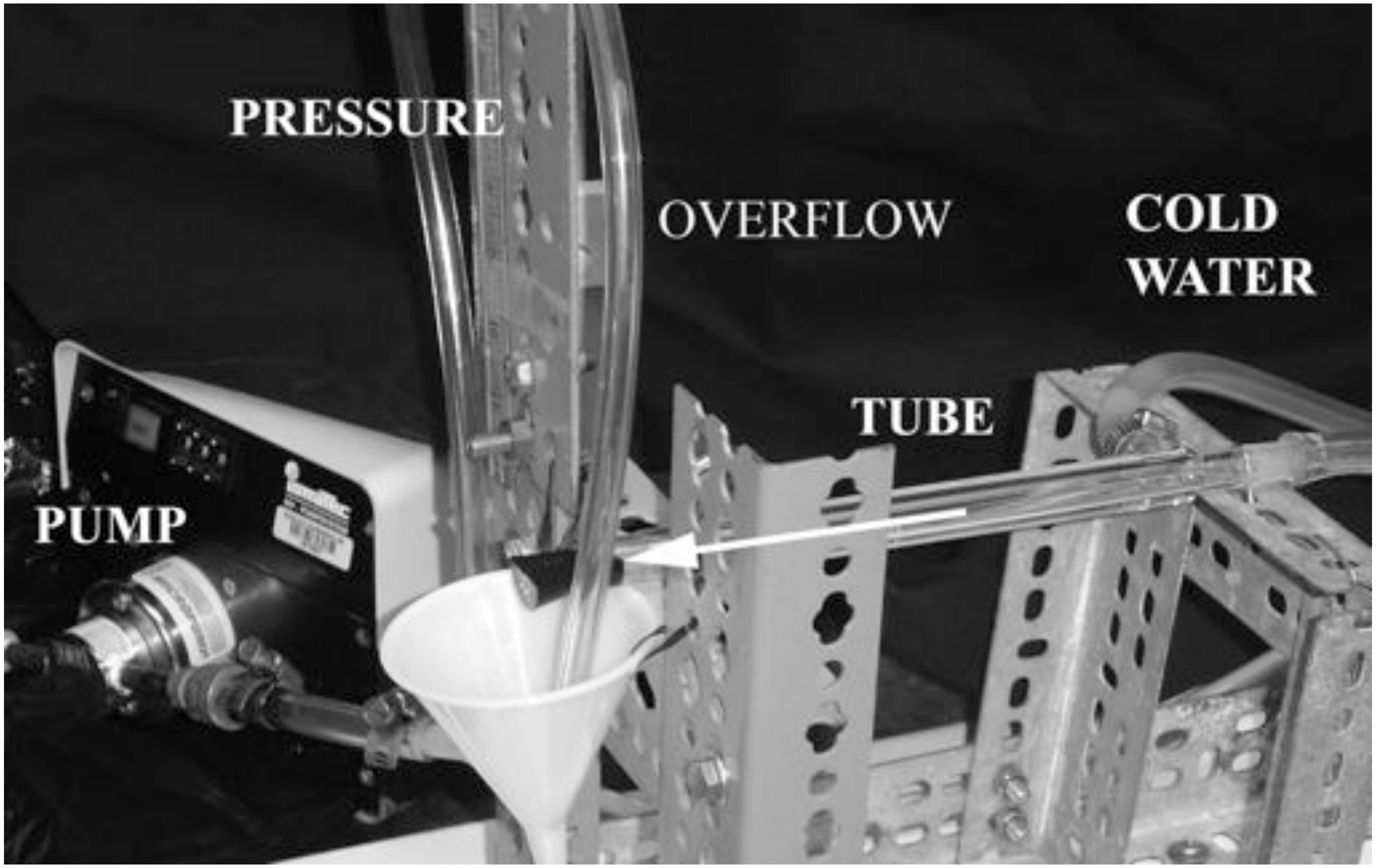




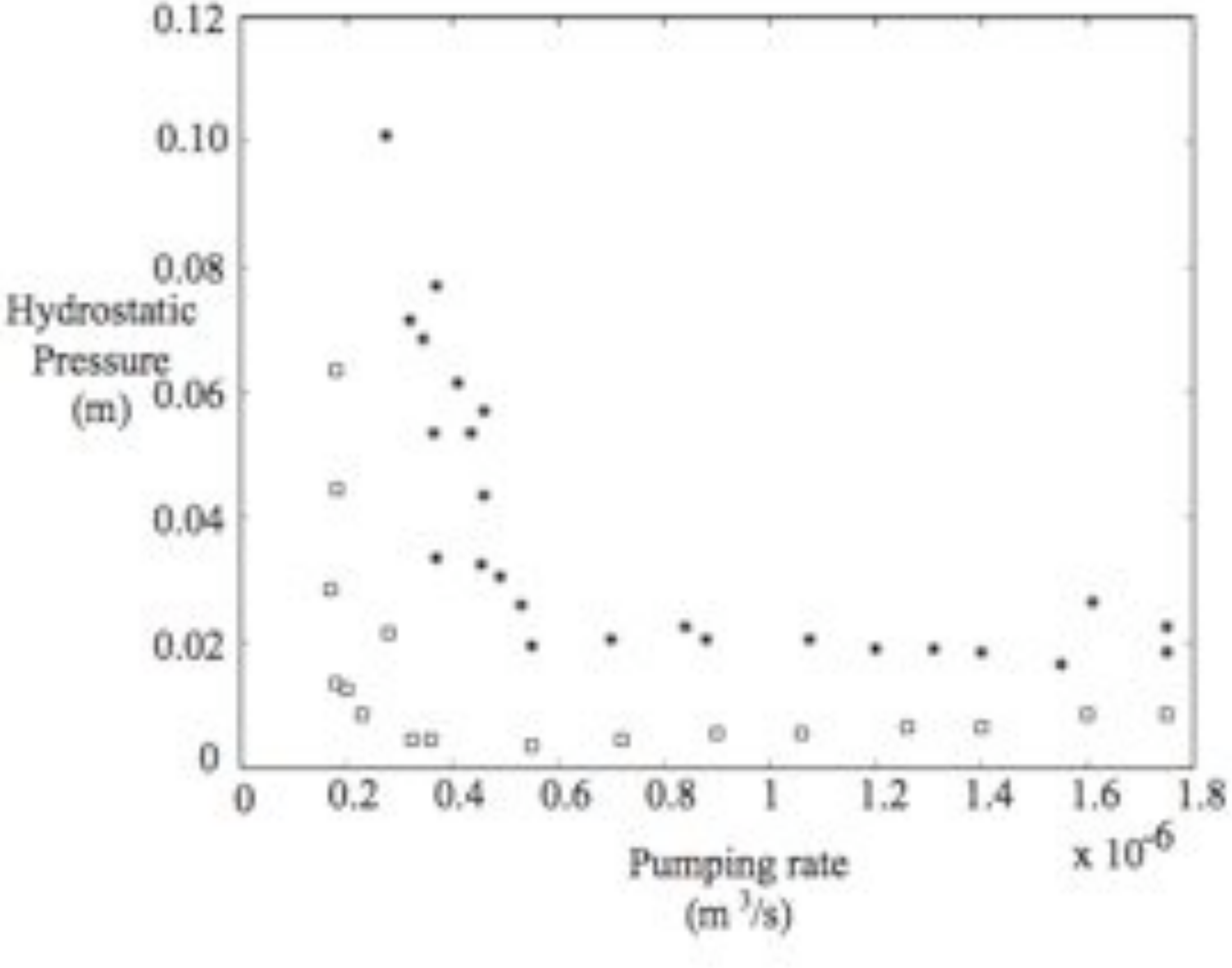
Sketch of lava tube apparatus



The apparatus



Results



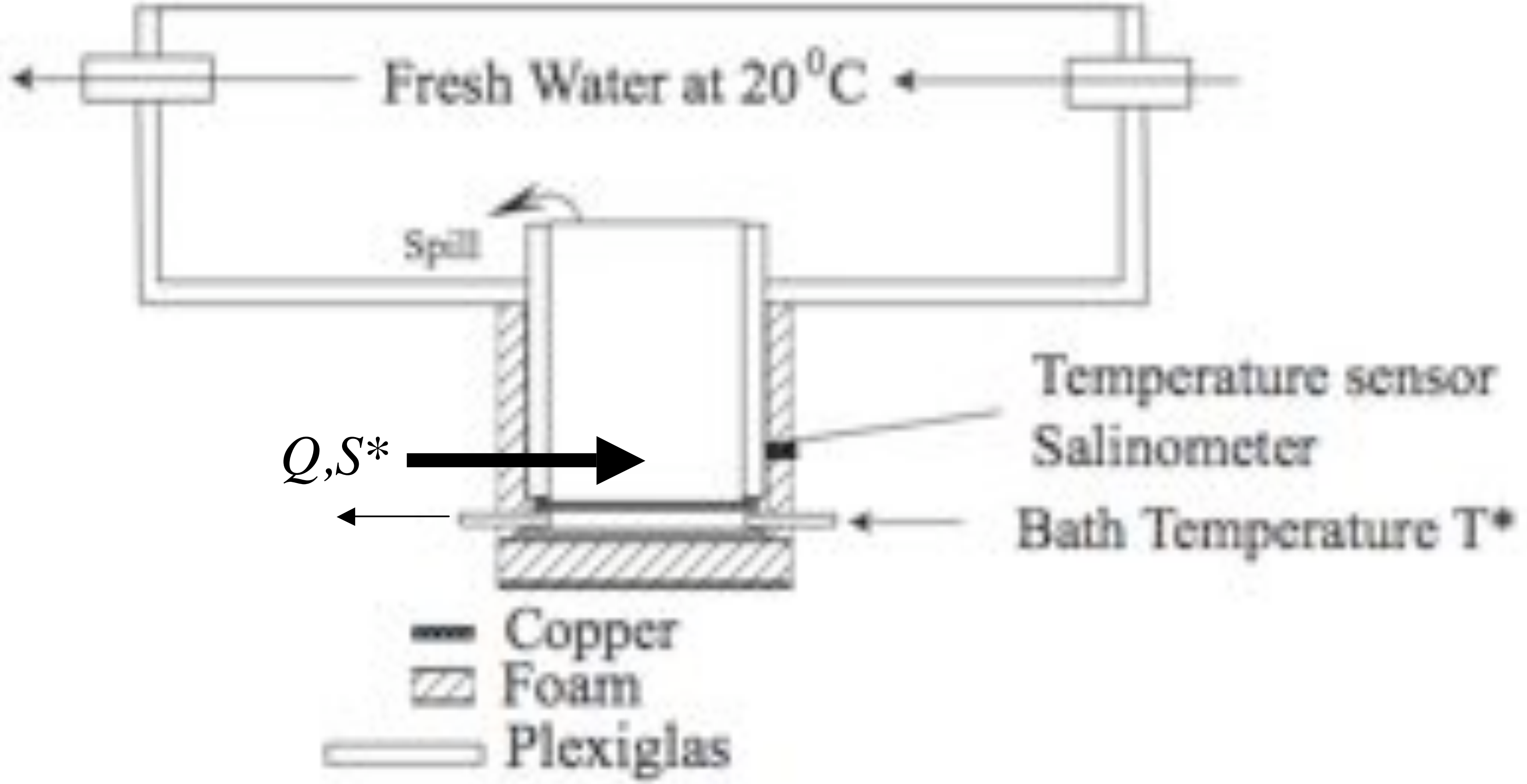
Hydrostatic Pressure (m)
0.12
0.10
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
x 10-6
Pumping rate (m 3/s)

OUTLET TO LAVATUBE CYLINDER

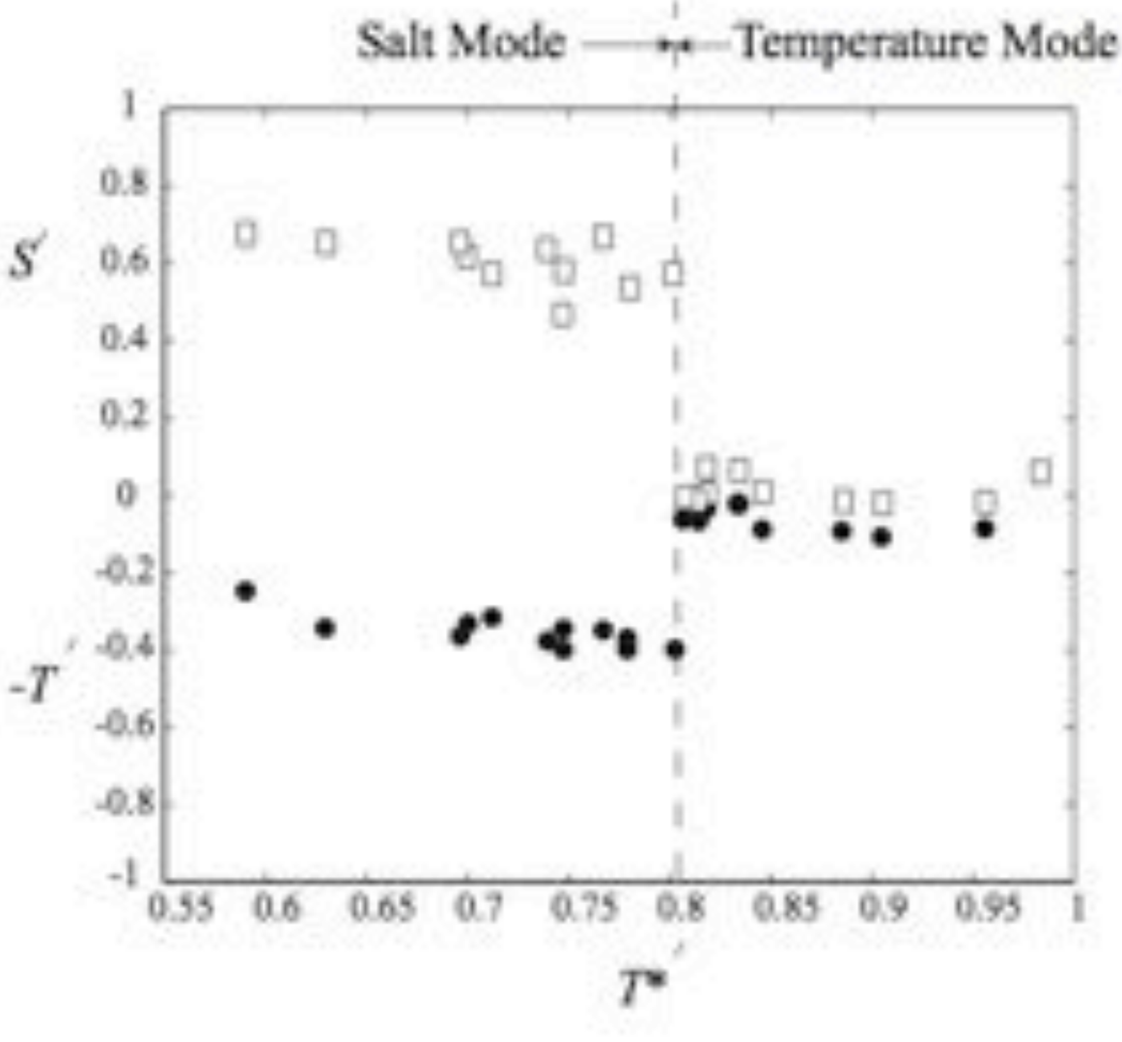
Summary

- Experiments that demonstrate nonlinear features produce examples of hard-to-predict dynamics such as
- Nonlinear spontaneous oscillations
- Fingering
- Each structure is found over a ***finite range***

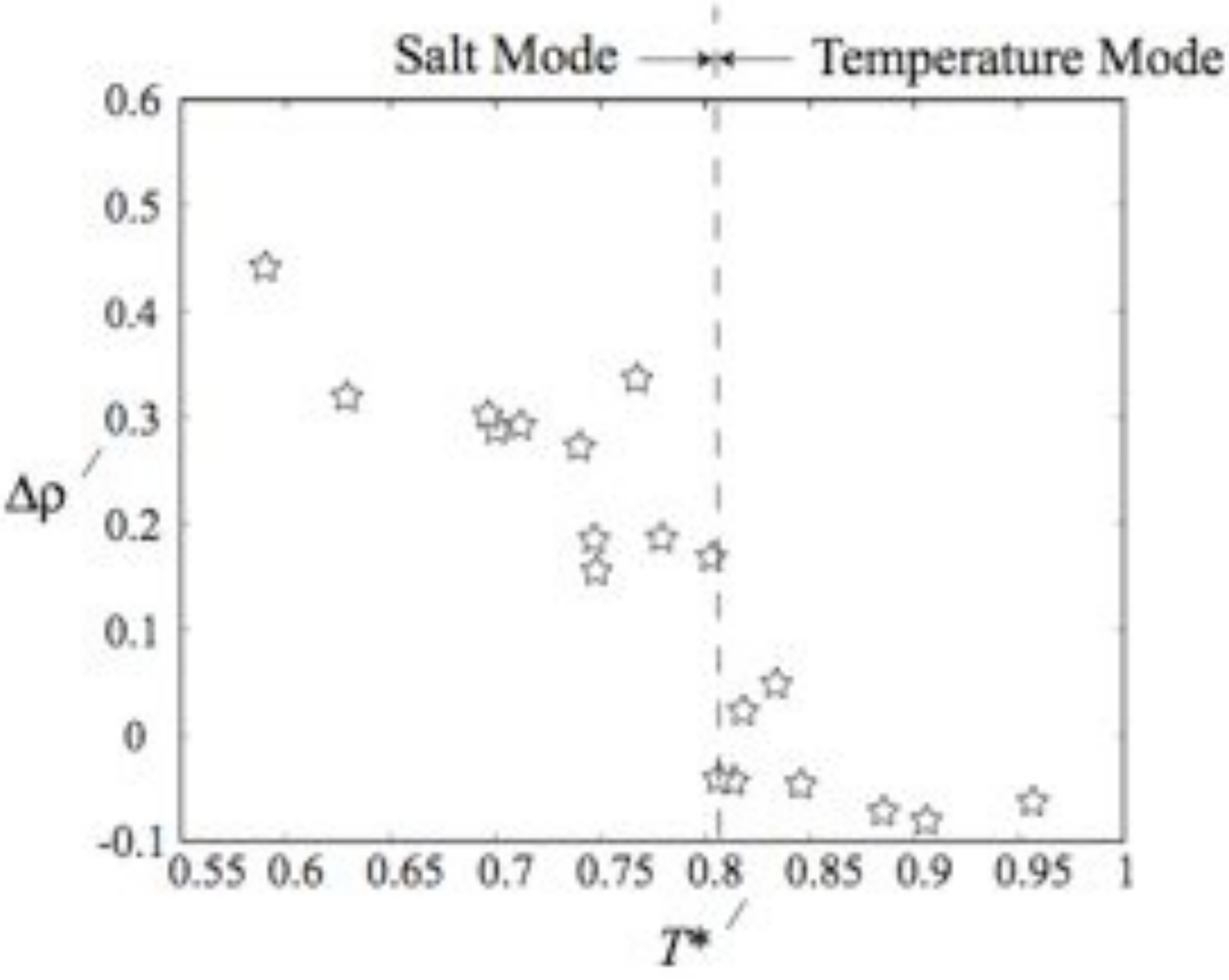
Climate experiment (In prep, JPO)



Temperature, Salinity jumps



Density jump



Classroom example

- With P. Baines, we find a supercritical current can develop a hydraulic jump that propagates upstream and makes a transition to subcritical flow.
- The possibility is found in his book and is worth seeing in reality.

The end

References available
In the front--see me

……… and Roger F. Gans, 1974. A new, theoretically tractable earthquake model. Geophysical Journal of the Royal Astronomical Society, 39, 11--28.

……… and K. R. Helfrich, 1991. Instability of flow with temperature-dependent viscosity: a model of magma dynamics. Journal of Geophysical Research, 96, (B3), 4145-55.

………1995 Thermohaline Ocean Processes and Models. Annual Review of Fluid Mechanics 27, 89-114.

……….1996 Multiple States in doubly-driven flow, Physica D, 97, 311-321.

……….1998 Multiple T-S States for Estuaries, Shelves and Marginal Seas. Estuaries, 21, 278-290.

Wylie, Jonathan J., Barry Voight, and ……….. 1999 Instability of magma flow from volatile-dependent viscosity, Science 285, 1883-1885.

…….2000 Stratified Convection with Multiple States. Ocean Modelling, 2, 109-121.

………W. Gregory Lawson and John Salzig. 2001 Multistate flow devices for geophysical fluid dynamics and climate. American Journal of Physics, 69 546-553.

……. 2002 A boundary layer flow with multiple equilibria, Physics of Fluids, 14, #7, 2575-2577.

Baines P. G. and …… 2003 On multiple states in single-layer flows, Phys Fluids. 15, #2, 298-307.

……, , M. L. E. Timmermans, W. Gregory Lawson, S. N. Bulgakov, A. M. Zatarian, J. F. A. Medina, and John Salzig, 2003. Laboratory studies of thermally and/or Salinity-driven flows with partial mixing: Part 1 Stommel transitions and multiple flow states, J. Geophys. Res. 108, No. C2, 3036, doi:10.1029/2001JC000902.

……., Lianke te Raa, and Keith Bradley, Laboratory Observations of Two Distinct Flow States and Oscillations in Salt-Stratified Thermal Convection,

……….., Tomoki Tozuka and Joseph B. Keller, Theory of Stratified Convection with Multiple States and Oscillations, Geophysical and Astrophysical Fluid Dynamics, Submitted.