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10.24.07
Image Assignment 3: Team Project 1

My third image submission is the product of team alpha's first group project working with the Hele-Shaw cell. Originally, we had hoped to document differences in Saffman-Taylor instabilities between Newtonian and non-Newtonain fluids. However, difficulties with the apparatus forced us to look at other phenomenon. The image I present in this report is the result of a perturbed two fluid system, allowed to approach equilibrium under gravity-driven flow.

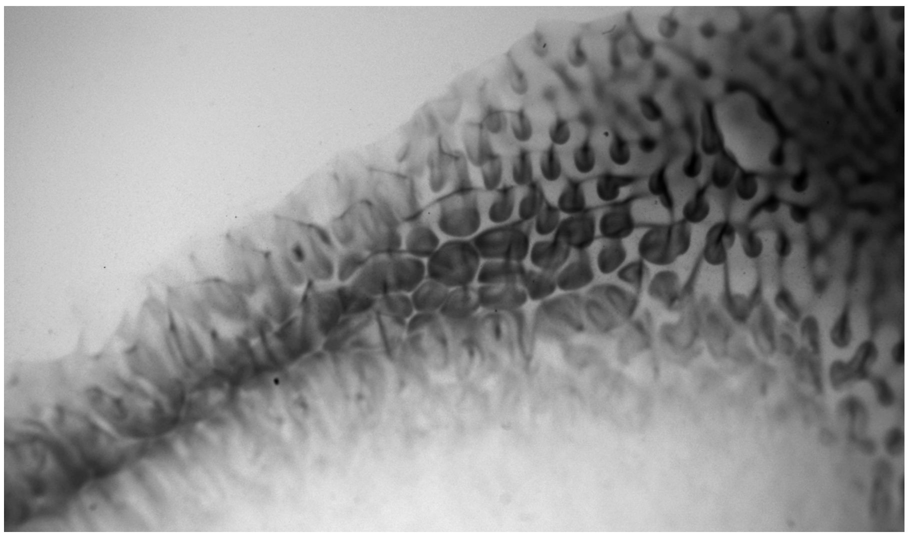

Figure 1. Two fluid system approaching equilibrium

The series of images from which figure 1 was selected were produced in two distinct steps. First, a 1~2mm layer of tap water was placed on acrylic. Dyed salt water was introduced to the perimeter of the stationary tap water using a small syringe as indicated in figure 2. The salt solution was prepared to its solubility limit at 20C; approximately 35g NaCl/100g H20. This solution, plus the food dye was sufficient to create a small density difference between the two fluids. Given the volume of the syringe, injection time and cross-section of the nozzle, the fluid jet velocity can be approximated at 360m/s. This gives a Reynolds number of 6.83E7 indicating turbulent flow, and Froude number of 257 indicating supercritical flow.

$$R_e = \frac{V\ell}{\upsilon} = 6.83*10^7 \qquad F_r = \frac{V}{\sqrt{g\ell}} = 257$$

Non-dimensional numbers calculated using kinematic viscosity (see ref 1), fluid velocity and characteristic length

As predicted by fluid theory, viscous forces produced a boundary layer below the injected fluid driving it to the free surface despite its greater density.

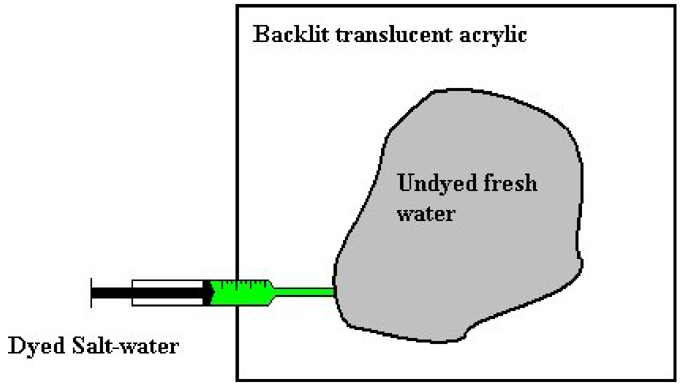

Figure 2. Schematic of system

Next, the fluid system was allowed to sit. Slowly, because of the small difference in densities, the green-dyed salt water solution sank to the acrylic surface. As portions of the dyed fluid sank, 'tails' of the dyed fluid were left leading to the free surface (thin dark portions in figure 1). The salt water that completely sank began to spread along the acrylic surface (amorphous grey areas in figure 1).

The visualization techniques used in this series were intended to maximize contrast and eliminate glare off the water surface. To that end, the less dense fluid was left transparent, allowing un-obscured view of the salt solution as it traversed from the free surface to the submerged acrylic. The dye used was a green food dye from Crown Colony consisting of water, propylene glycol, FC&C Yellow 5, and Blue 1. The system was lit from below with a single 500w halogen light and no overhead lighting. Indirect sunlight entered the room from two sides, but contributed little additional lighting. No flash was used. The light from the halogen bulb was diffused through the translucent acrylic backing.

Vital statistics for this image:

Field of view:	~3cm x 3cm
Distance from object to lens:	~10cm
Lens focal length:	80mm, F-Stop 6.3
Camera used:	digital, pixel dimensions 3008x1755, Nikon D50, resolution 300x300”
Exposure:	aperture value 5.0, shutter speed (exposure time) 1/400 sec, exposure bias value 0.0, ISO unknown
Photoshop processing:	Image was cropped to enhance framing; color curves were adjusted to increase contrast. Finally, color was removed for aesthetic reasons, and is justified because it added no additional information.

This image offers an interesting look at the settling of two miscible fluids of differing densities. The planar appearance of the photograph is enhanced by use of grayscale, which also contributes to an organic look that echoes the hide of an animal. I enjoy the overall composition, but wish we had been able to reduce noise within the image. Access to a Nikon macro lens will be critical if we continue to do short-range photographs for our projects. The basic concepts behind this image were explored extensively in the 'India ink' photographs from our Get Wet assignment. Further development of this idea would require a set-up designed to better isolate the physics of gravity-driven flow. Perhaps a

Hele-Shaw cell oriented vertically could be used.

Appendix:

1. *ITTC – Recommended Proceedures Testing and Extrapolation Methods, General Density and Viscosity of Water*, http://ittc.sname.org/2002_recomm_proc/7.5-02-01-03.pdf

2. Munson Young Okiishi. Fundamentals of Fluid Mechanics: John Wiley & Sons Inc., 2006.

3. *Solubility,* http://en.wikipedia.org/wiki/Solubility