Bubbles are the product of surface tension in fluids, and to the extent that fluids are ubiquitous in our Earth-surface environment, so are bubbles in most liquids. In your morning cup of coffee, the bubbles typically form a single layer and then evolve by merging and bursting. When bubbles form in a mixture of water and soap, R. J. St. B. Boréen and his team find them as thin-walled, dense. The foam photo left is red wine with a drop of dish soap to stabilize the bubbles for photographing. Note that one can see through some of the larger bubbles and see smaller bubbles beneath them; this would qualify as a thin film. You will note that all of the bubbles are touching other bubbles and very small bubbles fill in the spaces around the larger bubbles.

The arrangement of touching circles in two dimensions is called Apollonian packing; there is a mathematical relationship among all of the circles. For any four touching circles with radii $r_1$, $r_2$, $r_3$, and $r_4$ there is a mathematical relationship originally postulated by Descartes:

\[
(1 + 1/1 + 1/2 + 1/3 + 1/4 + 1/1 + 1/2 + 1/3 + 1/4)\cdot r_4^2 = (1 - 1/1 + 1/2 + 1/3 + 1/4)\cdot r_4^2.
\]

Using this relationship and starting with those touching circles the forth touching circle can be found. Actually owing to the quadratic relationship there are two “forth” touching circles; an inner and an outer.

In the figure to the right there are three large touching circles of equal size; one solution to the quadratic equation above is the large circle containing the figure; the other solution is the small blue circle in the center of the figure. In the foam above left you will see a similarity in the behavior of the bubbles; there is a tendency to fill the space with touching bubbles of the appropriate size. Apollonian packing is an ordered packing in which the corners of the adjacent touching circles form a packing that is much more complex.

Ice Nuclei Production in Volcanic Clouds

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Ice nuclei are produced in volcanic clouds and are a potential cause of ice formation in volcanic smoke and tephra. The ice nuclei are created when volcanic plumes rise through the atmosphere and cool. The ice nuclei can then act as cloud condensation nuclei (CCN) and can influence the cloud microphysical properties.

In the upper photo left a volcanic bomb is in place on the sandur; nearby there are smaller bombs. These bombs are all highlights of the volcanic eruption. In the lower left photo I am holding a volcanic bomb for a close-up photo. The volcanic bombs are highly detailed objects.

The explosive force of an explosive volcano is produced by the rapid expansion of water vapor bubbles. See the drawing to the left. In the magma chamber prior to the development of the conduit the magma contains water in solution; up to 7% of the mass. As the magma expands the pressure decreases and the water comes out of solution to form small water vapor bubbles. Evolution. The bubbles increase in number and size as additional water vapor expands. The bubbles greatly increase the volume of the magma and produce an upward force by the magma, which leads to the development of the conduit. As the magma with bubbles moves upward in the conduit, the decreasing pressure accelerates bubble production and growth. Near the top of the conduit the bubbles become a froth; instead of bubbles imbedded in magma, we now have magma imbedded in a froth of water vapor bubbles. In the vent the external pressure drops to local atmospheric pressure and many of the bubbles burst opening the thin film of magma coating. The fragments of froth bubble forms clouds of ash and the smaller ones are ice nuclei.

It is possible to estimate the size of the bubble fragments using the information provided by Sparks et al. above and shown in Figure 1. The results of magma in the magma chamber containing water in solution expands to 670 m of water vapor and magma in the vent.

In the nocturnal time exposure photo to the left, the prodigious lightning activity is in the eye catcher, but there are details of the volcanic plume that deserve closer examination. Note the superconic core of the plume and the interstices of the lower edges with the ambient atmosphere. This photo shows the thin clear tracks of glowing smoke.


The photo right is the Eyjafjallajökull volcano; this photo was taken on June 13, 2010, during an excursion of the AGU Chapman Conference on Vulcanism and the Atmosphere; Selfoss, Iceland, 10-15 June 2010. The Eyjafjallajökull volcano in southern Iceland began erupting on 2010 March 20, with a second eruption on 2010 April 14. Dust from the calcite wall allowing lava to flow out onto the glacier. The lava flow and fumes melt water are evident in the center of the photo.

The foreground is the sandur from the Eyjafjallajökull glacier; among the larger objects are many volcanic bombs; see photo below.

In the lower left photo I am holding a volcanic bomb for a close-up photo. Note the wide variation in sizes of the bubble remnants. Even the surfaces of the bubbles is evident; see a non-spherical petal produced by bubble merging.

I have used the bomb to the left to make further studies of bombs and their debris. When placed on my desk I noticed after several days that it was shedding small black particles. I moved the bomb to a shelf and placed it in a white printer paper. Every couple of days I would remove it to a different side so was down and I collected the fragments in the photo below. There is a broad range of fragment sizes. I placed a human hair in the photograph with a measured diameter equal to 0.04 mm. The smallest fragments are difficult to see; some appear gray rather than black, but they are ample examples of fragments of 0.04 mm.

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