term potentiation (*15, 16*). And yet, just imagining the potential for remodeling synaptic structures during learning (and in combating neurodegenerative diseases) is sufficient motivation to continue to search for structural changes in mature synaptic structures.

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VOLCANOLOGY

Listening to Pele

Sylvie Vergniolle

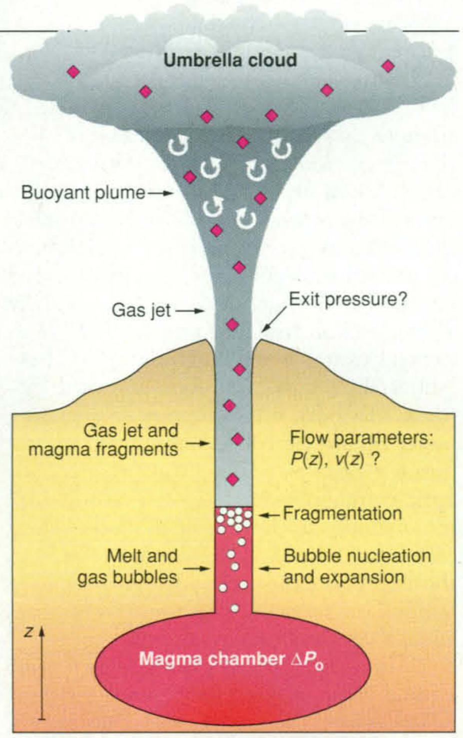
Volcanic eruptions are difficult to study rigorously for two main reasons. The first is that they are often so destructive that one cannot observe them closely and make measurements of important physical variables, such as the velocity, pressure, and proportions of gas and magma. The second reason is that they often start very suddenly after long periods of quiescence; volcanologists usually arrive after the initial phases, which are, unfortunately, often the most instructive. The new data on explosive eruptions reported on page 1290 of this issue by Morrissey and Chouet (*1*) are therefore most welcome.

Volcanic activity usually falls into two categories: (i) explosive—yielding eruptions, such as those of Mount St. Helens (1980), El Chichón (1982), and Pinatubo (1991), often associated with subduction zones—and (ii) basaltic—seen at volcanoes such as that at Kilauea Iki (Hawaii), which are often associated with hot spots, and at Stromboli. Explosive volcanoes involve very viscous magma and expel strong gas jets, called Plinian activity. The hot volcanic gas exits the volcanic vent at high velocity as a jet, then evolves into a buoyant plume into which air is dragged and heated, and finally spreads as an umbrella cloud when the density of the volcanic mixture balances that of surrounding air (see figure). Basaltic eruptions are more gentle, and the magma is much less viscous than that from explosive volcanoes, although it is still four orders of magnitude more viscous than water. The dynamical regimes of basaltic and explosive volcanoes are both directly and indirectly driven by the gas phase, and their major difference in behavior is a consequence of their large difference in viscosity (at least five orders of magnitude).

In the 1980s, the scientific community started modeling volcanic activity, both numerically and in the laboratory, first focusing on explosive volcanoes and later on basaltic activity. However, models need field observations to constrain them and to check their validity. In contrast to relatively safe basaltic eruptions, which have been monitored rather extensively, explosive volcanoes need remote, albeit precise, quantitative measurements. Therefore, the use of data obtained from several volcanoes with a network of microbarographs, such as in the report of Morrissey and Chouet (*1*), sounds very promising for estimating the exit pressure of the volcanic mixture at the very first instant of an eruption and constraining its gas concentration. It can also be used to monitor volcanic activity in a remote area (*1*).

Volcanoes inflate before an eruption, implying overpressure in the magma reservoir at shallow depths (*2*). Clearly this overpressure is part of the driving process during an eruption, making knowledge of its magnitude at depth very valuable. The first method of determining this pressure uses measurements of deformations at the surface of the volcano combined with an elastic model of the edifice and shows that tumescence and eruptive activity occur almost at the same time. The second method consists of measuring the air pressure at the eruptive vents and then combining them with a flow model to estimate the pressure in the magma reservoir.

An enhanced version of this Perspective, with live links, can be seen in *Science* Online on the Web at http://www.sciencemag.org/



An explosive eruption. When magma is expelled from a volcano it undergoes fragmentation, creating a jet of gas and magma droplets. Understanding this process requires knowledge of the complex changes in pressure P and velocity v as a function of height z in the exit channel.

When an explosive eruption starts, magma is expelled out of the magma chamber and rises, ultimately containing small gas bubbles, in the volcanic conduit (see figure). A critical change in the flow regime called fragmentation, which is still poorly understood, occurs somewhere in the conduit: the mixture is transformed into a gas jet containing magma droplets (*3*). The pressure and velocity of the volcanic mixture, which follow the equations of motion during flow in the conduit, vary together. Consequently, the volcanic mixture might reach the vent at an exit pressure different from the atmospheric value (*4*). Velocities are easier to estimate at the surface than pressures, and in the 1980s, researchers used empirical relations, derived for instance from ballistic studies, to deduce the exit pressure from the velocity. Recording pressures and velocities

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independently at the eruptive vent should provide strong constraints on the flow in the conduit and then on the pressure in the magma chamber. Seismicity measurements have also been used to probe the magma reservoir; however, path and site effects make the information of what happens at depth difficult to unravel from the seismic signature (5).

The structure of air low in the atmosphere is simpler than that on the ground, and measurements of pressure in air can easily be made either with acoustic devices (usually for frequencies > 20 Hz) or microbarographs (<1 Hz). Surprisingly, although the sound produced by a volcanic eruption is rather striking, only a few studies existed until a few years ago. Richards (6) observed that each type of volcanic activity emits a characteristic sound. Later, Woulff and MacGetchin (7) used the acoustic power radiated by an eruption to measure the gas velocity. Recent studies have shown that most of the acoustic energy is infrasonic (below 20 Hz), at least for basaltic volcanoes (8), although some information on the geometry of the volcanic system can be deduced from frequencies between 4 and 70 Hz (9). It is only today that the old network of microbarographs are used by Morrissey and Chouet to extract the exit pressure at the start of an explosive eruption and also to constrain the gas concentration in the volcanic column (1). Their study uses a low-frequency range for pressure waves in air (0.1 to 1 Hz) not explored before.

Such a method provides quantitative measurements of a key variable for understanding volcanic activity, at a low cost and remotely. This method could also be used to locate eruptions in difficult environments and to estimate eruption magnitude. In the future, by combining measurement of pressure waves in air with that of seismicity, one could hope to separate path and site effects from the seismic source at shallow depths. Furthermore, adding measurements of velocity at the surface, by visual observations whenever possible, will improve our understanding of what is happening at depth. These methods will help us to assess and mitigate the hazard related to explosive volcanoes.

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PLANETARY SCIENCE

Neptune's Deep Chemistry

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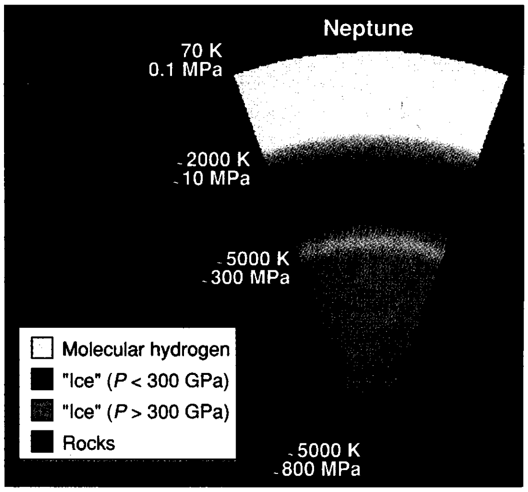
All four of the giant planets—Jupiter, Saturn, Uranus, and Neptune—have deep, massive atmospheres that superficially resemble the sun in composition (mostly hydrogen and helium). Yet they differ from the sun in that these atmospheres are composed of light molecules rather than thermally dissociated atoms. Thus, the composition of these atmospheres could well be modified by deep interior processes analogous to those familiar to terrestrial-planet geochemists. Giant-planet specialists have been aware for some time that in situ measurement of the composition of a giant planet's atmosphere, as was done for Jupiter's atmosphere by the recent Galileo probe (1), might need to be interpreted in terms of chemical processes in much deeper layers. Only recently have theory and experiment given specific results about the chemistry of relevant light molecules, such as H_2, H_2O, and CH_4, at pressures around P = 100 GPa. One such result is presented on page 1288 of this issue by Ancilotto *et al.* (2), who report simulations showing that some C_2H_6 in Neptune's atmosphere might come from deep within the planet.

In contrast to Jupiter and Saturn, the H_2- and He-rich atmospheres of the two smaller giant planets Uranus and Neptune only reach pressures of perhaps 10 GPa and comprise only ~5 to 10% of the planetary mass. The mean densities of Uranus and Neptune and data from their gravity fields indicate that below the atmosphere is a vast ocean of hot (several thousand kelvin) H_2O, NH_3, and CH_4, which are in a dense liquid phase but are customarily denoted as ices (see figure). The fate of the methane in this "ice" region is of particular interest: Remote spectroscopic analyses of Uranus and Neptune's atmospheres have for some time indicated that the abundance of CH_4 relative to H_2 is at least 10 times larger in the smaller and denser giant planets Uranus and Neptune than in the more sunlike giant planets Jupiter and Saturn. Could this enhancement be a clue to the existence of a methane-rich ocean below the atmosphere?

Also seen in the spectra of Neptune are the molecules C_2H_2 and C_2H_6, which, according to conventional wisdom, are products of ultraviolet photolysis of abundant CH_4 in Neptune's stratosphere (3). The former is seen at a mixing ratio of about 0.01 parts per million (ppm), and the latter, at about 1 ppm. Ancilotto *et al.* (2) offer the interesting suggestion that some of this atmospheric C_2H_6 may actually be a quenched reaction product from much deeper layers in Neptune, analogous to the quenched CO seen in Jupiter (4).

Earlier, Ross (5) considered the fate of methane in the deep interiors of Uranus and Neptune and concluded that at high pressures, the reaction would produce H_2 and pure C in the form of diamond crystals. The latter, if large enough, would irreversibly sink as sediment toward the center of the planet, whereas the hydrogen would rise to join the atmosphere. Estimates of the total mass of methane in Uranus or Neptune indicated that such decomposition would produce a significant but not dominant source of atmospheric hydrogen. In this picture, one would expect atmospheric methane to be depleted relative to solar abundance, not enhanced, so Ross's diamond-producing mechanism seemed to lack any observational confirmation.



Cross section of a typical interior model of Neptune (*8*); the interior of Uranus is predicted to be very similar. Ancilotto *et al.* predict that methane decomposes into saturated hydrocarbons in the upper "ice" layer.

The model of Ancilotto *et al.* (2) also predicts some dissociation of methane into free hydrogen molecules, but apparently to a lesser degree than in the diamond-forming

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