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ronmental settings across a broad area of the American Southwest. The mass spectrometry dates also suggest that substantial artificial terrace construction occurred over a short period of time. This sets Cerro Juanaqueña apart in terms of population size and the scale of labor investment both from contemporary river valley settlements of the arid Tucson Basin area as well as the seasonally occupied cave sites of the higher elevation Mogollon Highlands and Colorado Plateau (see map). In addition, a number of local nondomesticated seed plants appear to qualify as economically important "in-between" species, on the basis of their abundance and the associated high frequency of ground stone seed processing tools.

In these respects Cerro Juanaqueña adds to the set of alternative developmental pathways from foraging to farming documented for the southwestern United States in the past decade. It also adds to the growing suspicion that when maize and squash were introduced into the region, some southwestern societies were no longer pristine hunter-gatherers but had already established low-level food production economies centered on the management of indigenous "in-between" seed crops (*8*), and perhaps on as yet unrecognized local domesticates.

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MATERIALS SCIENCE

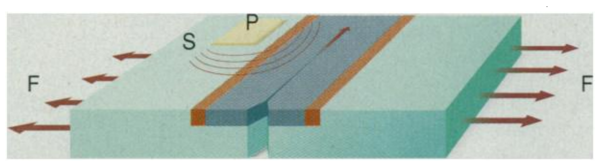
Sound and Fracture

Fernando Lund

When things break, they often do so with a loud noise. This is because the crack responsible for the breakup generates sound as it moves. Could the reverse occur? That is, could sound act back on a propagating crack? And modify its motion? The answer to these questions is yes and is the subject of a recent remarkable experiment by Boudet and Ciliberto (*1*).

What these researchers have done is to take plates of acrylic plastic (Plexiglas), typically 20 cm wide by 30 cm long and 5 mm thick, notch them, and pull them apart until they break (see figure). They measured the speed of the crack tip by monitoring the electrical resistance of a metal film painted on the side of the plate as it breaks, paying particular attention to what happens when the crack tip is hit by a sound wave generated by a ceramic transducer placed on the plate. Because cracks travel at speeds comparable to the speed of sound, this is a delicate experiment: First, the crack is allowed to reach a constant velocity, say 250 m s^{-1}. At this time, the transducer sends an ultrasonic pulse that reaches the crack tip about 40 μs later, at which time the crack abruptly increases its velocity to 340 m s^{-1}. This change is independent of the acoustic amplitude and frequency. Remarkably, this effect is absent when the crack's initial velocity is above 340 m s^{-1}.

The effect of sound on the dynamics of cracks was known at least as far back as the 1950s (*2*), as revealed by the wavy surface left behind, in glass, by a crack that had been hit by an externally generated ultrasonic wave. These early experiments appeared to be in accord with what one would intuitively expect: an acoustic wave of energy small compared to the amount of energy needed to break up a piece of material would perturb a crack path only in small amounts. In the case of small specimens such as glass fibers, however, acoustic waves are generated very efficiently by the moving crack itself, and they strongly influence glass fiber fragmentation. High-speed photography has showed, more recently (*3*), that acoustic waves affect the direction of propagation, the speed, and the possible branching of a crack. What is new in the Boudet-Ciliberto experiment (*1*) is the ability to quantitatively monitor this effect as a function of time as the crack progresses in the act of breaking, and the realization that a comparatively small amount of acoustic energy may strongly affect the crack dynamics.



About to crack. Sample used for studying the effect of sound on crack propagation. A piece of plastic is prepared with a metal layer on one side, and the specimen is notched to initiate a crack, which is driven by the applied forces, **F**. As the crack propagates through the specimen, the resistivity of the metal film is monitored to yield the crack velocity. When sound waves, **S**, are directed at the moving crack by the piezoelectric transducer, **P**, the crack velocity increases. [Adapted from (*1*)]

Before this experiment, the generation of acoustic waves by a moving crack under carefully controlled laboratory conditions such as those described above was studied as part of a program driven by the desire to understand a so-called dynamic crack instability (*4*): the measurement of crack velocity as a function of time revealed that the crack makes an initial jump in velocity and then proceeds to smoothly accelerate until a speed of 340 m s^{-1}, at which point it starts to oscillate. This fact appears to be independent of plate thickness and lateral dimensions, surrounding atmosphere, and external loading. Why this is so is at present unknown, but the question has been a major driving force for much experimental and theoretical work. The initial temptation is to say that a thin plate is basically two dimensional, that is, forget about the third dimension (thickness) and try to apply the existing, well-established, two-dimensional theory (*5*). This approach fails miserably: two-dimensional theory predicts that a crack will accelerate smoothly, without oscillations, until a limiting velocity (in Plexiglas) of about 1000 m s^{-1}. Experiments never find a limiting velocity beyond half this value, unless something really drastic, like scratching the surface, is done. The crack tip oscillations generate sound and are accompanied by the appearance of microbranches (*6*). Moreover, if the crack is allowed to reach a higher average velocity, a second instability appears at a speed of 450 m s^{-1}, at which point the roughness of the surface that is left behind by the crack greatly increases (*7*). The behavior of a crack

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in a thin, brittle plate is much more complicated than what would be inferred from simple-minded two-dimensional theory.

How can all this be explained? The mathematics of the generation of acoustic waves by a moving crack can be said to be reasonably well understood, although the practical problem of actually computing the exact nature of such waves given a specific crack motion may be quite formidable. This problem is analogous to determining the exact nature of the electromagnetic waves radiated by a specific antenna array. The answer to the converse question, what is the response of a moving crack to a given acoustic wave, is quite unknown. In the electromagnetic case, the analogous question would be what is the response of, say, an electron to a radio wave, and the answer is well known. The problem in the case of the crack is that it is not really an object that can be separated from the medium in which it lies, as an electron is an entity that is separate from an electromagnetic wave. The crack tip is, rather, what is called a "singularity": a region within an elastic solid where stresses are greatly concentrated, much as electromagnetic fields are magnified at the tip of a lightning rod. At regions where stresses are so concentrated, Hooke's law, according to which the deformation of a solid is linearly proportional to the applied stress, ceases to be valid. This nonlinear behavior is a major complication, and it is at the root of the difficulties encountered by attempts at a theoretical understanding of what goes on with a moving crack in a Plexiglas plate. In electromagnetism, however, it is possible to understand the dynamics of such singularities (*8*), and borrowing ideas from that field may well prove helpful in understanding the dynamic behavior of singularities within an elastic solid.

The fracture of solids belongs, like turbulence in fluids, to that fascinating class of problems that are of common everyday occurrence, have major technological importance, and yet, their basic physics remains a mystery. The Boudet-Ciliberto experiment (*1*) has isolated a clean effect that significantly advances our understanding of dynamic fracture.

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NEUROBIOLOGY

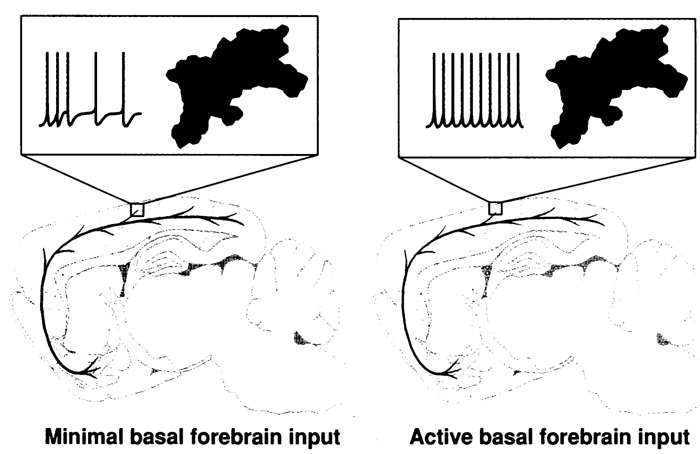
Mapping the Sensory Mosaic

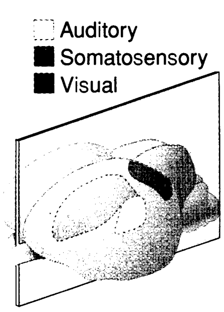
Sharon L. Juliano

Neuroanatomy texts often illustrate the somatosensory cortex of the brain with a homunculus, a distorted human figure laying on the surface of the brain, each body part over the area of the cortex that responds when its skin is touched. In fact, the whole sensory cortex is a mosaic of such maps of sensory space. Once thought to be static, these maps are in fact dynamic structures (*1*). Changes in sensory input produced by an event as traumatic as the loss of a limb or something as routine as daily violin practice can cause long-term changes in these maps, reallocating a lost limb's cortical space to other body regions or devoting more cortical space to an often-used digit. Changes also can occur quickly, in minutes to hours, in response to inputs from other brain regions. In a report on page 1714 of this issue, Kilgard and Merzenich explore the modulation of auditory maps by input from the lower part of the forebrain and show that this input may be responsible for shaping much of the form of cortical maps, both long and short term (*1*).

The basal forebrain is a region of the brain most known for its participation in certain kinds of learning (*2, 3*). But the projections from the basal forebrain also play a more global role in cortical processing. Their input signals the importance of sensory stimuli to the animal—enhancing the response to certain stimuli, diminishing responses to others. Alterations in the sensory maps of the cortex, often manifest as expansions or diminutions of specific representations, can be prevented by eliminating input from the basal forebrain. For example, after partial elimination of sensory input from the skin (such as a nerve lesion) in otherwise normal animals, the remaining intact regions of skin expand their representation in the contralateral somatosensory cortex. The expansion does not occur after a unilateral lesion of the basal forebrain, implicating this collection of nuclei in mediating the plastic changes (*4*).

Kilgard and Merzenich investigated how the projection from the basal forebrain might modulate the maps of the cortex. The authors electrically stimulated a nucleus in the basal forebrain [the nucleus basalis (NB)] of a rat while presenting a sound stimulus. They then compared the resulting map of the auditory cortex to maps from animals without NB stimulation. The map was dramatically altered by NB stimulation. An unexpected finding was that the changes were global, encompassing the entire cortical auditory map.





Basal forebrain input remakes maps. (**Left**) Without amplified input from the basal forebrain, neurons fire at a low rate and the representation of a theoretical sensory stimulus (blue) is small. (**Right**) With amplified basal forebrain input, neuronal firing is enhanced and more cortical sites are activated by the sensory stimulus (blue).

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