daunted, Neutel and colleagues have accomplished this for seven documented food webs in soil ecosystems. They find that the organization or architecture of these webs yields long loops that contain many weak links, a feature that enhances stability by reducing the average interaction strength of each loop. Longer loops are especially important in this respect because they are potentially destabilizing.

The groundwork for these ideas was laid by May's analysis of model systems (*3*). His analysis revealed that complex webs tended to be less stable than simple webs, a finding apparently at odds with the observation that real food webs are highly complex yet stable. One way in which this paradox can be resolved is if the average strength of interactions between species is low, and this is exactly what Neutel *et al.* have found. McCann and colleagues (*4*) came to similar conclusions, that is, a high proportion of weak interactions in webs contributes to their stability. However, Neutel and coworkers have gone a stage further by demonstrating that the organization of strong and weak linkages in food webs seems to be reflected in the shape of the biomass pyramid itself. This occurs because energy conversion efficiencies and body size depend on trophic levels. Thus, large long-lived animals with higher energy efficiencies, such as carnivores, are found in trophic levels near the top of the pyramid. It follows that the slope of the side of the pyramid may be a good indicator of web stability: Webs that give tall, thin pyramids are less likely to be stable than those with shorter, more squat pyramids (see the figure, B). A factor of 10 decrease in biomass with increasing trophic level would provide the patterns of interaction strengths necessary for stability, and these pyramids are not uncommon in nature.

The question remains as to how general these effects are. Fortunately, a compendium of food webs exists for exploring such ideas. Extending their analysis to systems across a range of habitat types and complexities has helped Neutel *et al.* to confirm the contention that observed biomass pyramidal shapes also have loops with weak links. However, several intriguing questions remain. For instance, not all systems have biomass pyramids, especially open-water marine and freshwater systems where the biomass of primary producers is typically low. Also, parasites can be considered the top consumers in most systems (*8*), and these species have life-history traits that are quite different from those of more traditional large and long-lived top predators. Doubtless these and similar considerations will stimulate extension and refinement of the ideas presented by Neutel and colleagues. I believe that the patterns they describe are likely to be sufficiently robust to accommodate such variants.

These authors have provided a valuable service for food web ecology by integrating early concepts of food web structure (biomass pyramids) with modern formal analyses to improve our understanding of the factors contributing to ecological stability. Hopefully, their findings will stimulate similar creativity in others.

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PERSPECTIVES: ASTEROIDS

Traces of an Unusual Impact

H. J. Melosh

Planetary scientist Peter Schultz was hailed as a public hero of Argentina when, in 1991, he and former Argentine air-force pilot Ruben Lianza announced that they had discovered Earth's most unusual meteorite impact crater (*1*). Ten elongated depressions near the small city of Rio Cuarto closely resembled the traces of a very oblique impact. The authors postulated that as recently as 10,000 years ago, a small, stony asteroid, 150 to 300 m in diameter, had grazed the Pampean plains at an angle of less than 7° and a velocity of about 25 km/s. After the impact, it split into fragments that ricocheted out of the first crater and gouged a series of smaller craters downrange.

Doubts about the impact origin of the structures were soon raised. Impacts at angles as low as 7° are very rare: Only 1 out of 67 impacts is this oblique. The occurrence of a low-angle impact by an asteroid of the required size in the past 10,000 years is thus extremely unlikely. Of all the thousands of fresh impact craters on the Moon, only one clear case of a ricocheting impact is known (see the figure).

But mere improbability is not proof that such an event did not occur. The discovery of meteorites and impact-produced glass in the craters swept away all criticism. A remarkably interdisciplinary investigation of the craters, reported by Bland *et al.* on page 1109 of this issue (*2*), now vindicates both the skeptics and Shultz and Lianza. The real story is both less and much more than the discoverers originally believed.

Bland and his associates became uneasy about the impact origin of the Rio Cuarto craters when satellite images revealed the nearby occurrence of nearly 400 elongated depressions of nearly identical morphology. The depressions seemed to be aligned with the prevailing wind direction, which gradually wraps around a nearby mountain range. Previous Argentine workers attributed the depressions to the action of the wind on the deposits of wind-deposited silt (loess) that mantles the Pampas, and many of their characteristics are consistent with such an origin.

Schultz and Lianza were aware of these problems. They even mentioned morphologically similar depressions in their original paper (*1*). However, the discovery of two fresh meteorites and impact-produced glasses in one of their craters convinced them (and most other workers in the field) that the craters were created by an impact.

Bland *et al.* also found meteorites in the craters. However, they are different classes of meteorite—a chondrite and an achondrite—and therefore seem unlikely to have been part of a single asteroid. Furthermore, ^{14}C dating revealed that the two meteorites fell at very different times, one 36,000 years ago and the other more than 52,000 years ago. They are thus much older than the craters, the age of which Bland *et al.* confirmed as about 4000 years. What are we to make of the conflicting data?

The presence of meteorites in the purported craters is consistent with the action of wind on the fine-grained loess of the Pampas. As wind blows away the loess, it leaves a residue of stones at the bottom of many of the depressions. Just as meteorites stand out on the ice fields of Antarctica, they are conspicuous on the Pampean

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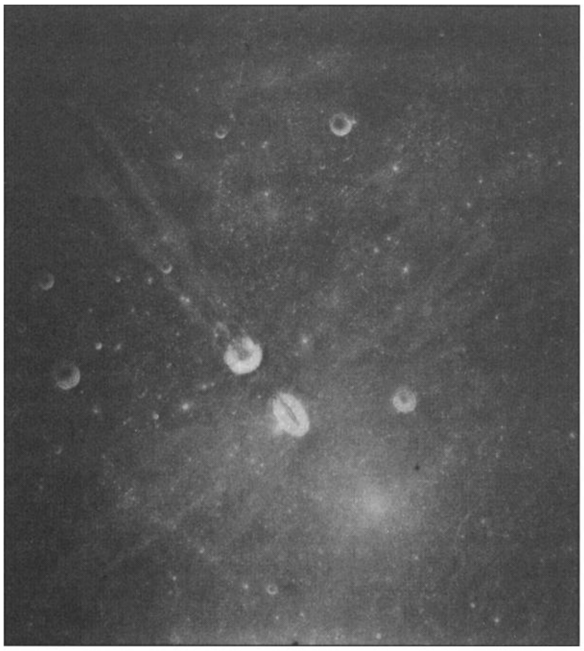

A rare event. The lunar craters Messier and Messier A are the only known example of a low-angle ricochet crater on the Moon. Messier, the elliptical crater, is 16.5 km long. Broad wings of ejecta extend perpendicular to the crater's axis, thrown out sideways as the meteorite grazed the Moon's surface. The bright streaks extend downrange and are probably composed of pulverized material shot out along the direction of motion. [Apollo 15 image AS15-2405(M).]

plains, where they are among the few solid rocks that accumulate on the surface. Similarly, most meteorite finds in the United States come from Kansas, which is covered by deposits of loess similar to the Pampas. On such plains, any stone is an oddity, and meteorites, while never common, are much more likely to be found.

The impact-produced glass is much harder to reconcile with this prosaic explanation. Bland *et al.* date the glass to about 500,000 years—much older than either the craters or the meteorites. The age of the Rio Cuarto glass is similar to ages reported for glass found in loess near the city of Necochea, nearly 800 km southeast of the Rio Cuarto site. Schultz also recovered very similar impact glasses about 500 km south of Rio Cuarto.

Impact glasses resembling those of Argentina are well known (*3*, *4*). Called tektites, these glassy stones are sometimes very beautiful and are often sold as gems. At present, four tektite strewn fields are recognized, three of which are associated with a known impact crater. The most famous is the Austral-Asian field, which extends more than 10,000 km. It seems to be centered on Southeast Asia, but a source crater has not yet been identified. The Moldavite field is associated with the 22-km-diameter Ries Crater in Germany. The North American field was created by the recently discovered Chesapeake Bay crater (*5*); its diameter is controversial, but the entire structure is some 90 km in diameter. The Ivory Coast field was formed by the 10-km-diameter Bosumtwi crater in Ghana. The Moldavite and the Austral-Asian tektites were created by impact melting of a surface layer of loess. Apparently the highly porous, silica-rich material of loess lends itself to strong heating by shock and readily forms glass.

Bland *et al.* propose that the Argentine glass is the product of a previously unrecognized impact somewhere near the Pampas. The size of the proposed Pampean tektite strewn field is intermediate between that of the Moldavite and the Austral-Asian fields. Modeling of slightly oblique impacts, also reported in the paper, suggests that glass melted from the surface could have been splashed sufficiently far to account for the Argentine glasses.

Much work remains to be done to confirm the reality of this new tektite strewn field. More glass must be collected to better define the extent of the field. Furthermore, to qualify as a bona fide strewn field, all the glass must have the same age. The case would be stronger if a source crater of the same age could be found and the chemistry of the source rocks compared with the chemistry of the ejected glasses.

It does seem, however, that Bland *et al.* have cut the Gordian knot of the Pampas and revealed, not an oblique impact crater, but a much larger strewn field of tektites. As terrifying as the original picture of an oblique impact that scarred the Pampas a few thousand years ago was, the present view of a shower of hot glass over a region as large as Texas suggests a far more lethal event half a million years ago.

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PERSPECTIVES: STRUCTURAL BIOLOGY

Not Just Another ABC Transporter

Amy L. Davidson

Gram-negative bacteria such as *Escherichia coli* have two protective membranes (outer and inner) that nutrients must traverse to reach the cytoplasm and nourish the cell. Small nutrients diffuse across the outer membrane into the periplasm through the water-filled pores of proteins called porins; meanwhile outer-membrane active transporters take up nutrients that are too big to squeeze through the porins (*1*). Once in the periplasm, substrate-specific transporters located in the inner membrane move nutrients into the cytoplasm. One class of these inner-membrane transporters, known as periplasmic binding protein–dependent transporters, belongs to the ATP-binding cassette (ABC) superfamily that couples ATP hydrolysis to active transport. These ABC transporter proteins operate in all species, from bacteria to human, mediating both uptake and efflux of a diverse array of compounds. A variety of human diseases, such as cystic fibrosis and macular degeneration, have been traced to defects in the genes encoding ABC transporters (*2*). On page 1091 of this issue, Locher *et al.* (*3*) present a high-resolution (3.2 Å) structure of the *E. coli* ABC transporter, BtuCD, that is responsible for transporting vitamin B_{12} into the cytoplasm of this bacterium (see the top figure). Their work contributes substantially to our understanding of the molecular mechanism of transport in this family.

The structure of the B_{12} transporter is the second high-resolution structure of a "complete" ABC transporter—that is, one containing two membrane-spanning domains or subunits (BtuC) and two ATP-binding cassettes (BtuD)—to be determined. (Six other cassettes have been crystallized in the absence of the membrane-spanning regions.) The first com-

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