Dill (*16*) of the finding of salt marsh peat in La Jolla Submarine Canyon with a carbon-14 age of 8800 years at a depth of 21 m below sea level provides further confirmation that at least this portion of southern California has been stable in recent times.

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References and Notes

1. R. W. Fairbridge, *Sci. Am.* **202**, 70 (1960); *Phys. Chem. Earth* **4**, 99 (1961).
2. H. N. Fisk, 8th Texas Conf. Soil Mechanics and Found. Engrg. (1956), p. 1.
3. E. McFarlan, Jr., *Bull. Geol. Soc. Am.* **72**, 129 (1961).
4. F. P. Shepard and H. E. Suess, *Science* **123**, 1082 (1956).
5. F. P. Shepard, *Essays in Marine Geology* (Hancock Foundation, Univ. of Southern California, Los Angeles, 1963), p. 1.
6. R. J. Russell, *Science* **139**, 9 (1963). According to several Australian geologists and archeologists with whom I have discussed these dates, the shells are thought to represent kitchen middens left on older terraces, probably interglacial.
7. H. R. Gould and E. McFarlan, Jr., *Trans. Gulf Coast Assoc. Geol. Soc.* **9**, 10 (1959).
8. D. W. Scholl, *Bull. Am. Assoc. Petrol. Geologists* **47**, 1581 (1963).
9. S. Jelgersma, "Holocene Sea Level Changes in the Netherlands," *Vitgeversmij "Ermest van Aelst"* (1961).
10. A. C. Redfield and M. Rubin, *Proc. Natl. Acad. Sci. U.S.* **48**, 1728 (1962).
11. M. Stuiver and J. J. Daddario, *Science* **142**, 951 (1963).
12. A. L. Bloom and M. Stuiver, *ibid.* **139**, 332 (1963).
13. W. G. McIntire and J. P. Morgan, *Atlantic Coastal Studies, Tech. Rept. 19A*, Louisiana State Univ. (1962).
14. D. Hafemann, *Deutscher Geographentag Berlin* (1959), pp. 218-231.
15. J. R. Moriarty, G. Shumway, C. N. Warren, *Ann. Rept. Archeol. Surveys of the Anthropological Soc. Univ. of Calif.* (1959).
16. R. F. Dill, personal communication.
17. Supported in part by the Office of Naval Research under contract Nonr-2216.

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Fossilized Stomach Contents of a Sauropod Dinosaur

Abstract. *A mass of petrified plant and bone fragments found in the late Jurassic Morrison formation of southwestern Emery County, Utah, appears to be the stomach contents of a sauropod dinosaur, skeletal remains of which were associated with it. The sauropods may have been more or less omnivorous.*

Fossilized stomach contents of animals are rare and much less common than coprolites or fossilized excrement. Stomach contents old enough to have petrified have been found in connection with marine carnivores—icthyosaurs, plesiosaurs, mosasaurs, marine crocidiles, and fish. Contents consist of hard parts such as bones, teeth and scales of fish, shells of ammonites, guards of belemnites, and hooks of squids. In most cases the ribs enclosing the remains have prevented scattering of the stomach contents.

A fossil specimen found in the late Jurassic Morrison formation of Emery County, Utah, almost certainly represents contents of the stomach or "gizzard" of a sauropod dinosaur, a nonmarine animal.

The specimen was found by Paul Shrum of Kanab, Utah, on the northwest side of a prominent butte in the southeast corner of Sec. 4, T23S, R7E, Emery County, Utah. Geologically, the site is in the Brushy Basin member of the Morrison formation.

When collected the weight was 40 kg, and the shape may be described as flattened ovoid. Since there has been some spalling and weathering of the mass, the original size and shape are unknown.

The rock is a partly silicified limestone in which recognizable fossil fragments make up at least half the total. The fossils are mostly silicified, but the matrix is only partly so. A few spots represent cavities, perhaps originally filled with gas, that are now lined or filled with crystalline material. Here and there are small rounded pebbles of amorphous siliceous material that may have been ingested as lumps of clay.

On the weathered exterior of the fossil the harder silicified wood fragments appear in relief over much of the specimen. Figure 1 is a cut and polished surface showing well-defined sections of the unoriented plant fragments within the structureless matrix of uncertain origin.

The fossil fragments are chiefly vegetal in origin and clearly represent sections of twigs and branches averaging about 2.5 cm long and 1 cm in diameter. There are no leaves, no large pieces, and no carbonized residues. Much of amorphous matrix may be replaced and unrecognizable plant material. The fragments are practically unoriented, fragmented, shredded, and vaguely stratified in one plane. They are unlike the woody fragments commonly seen in the fluvial sediments of the Salt Wash member of the Morrison in which the fragments are water-worn, rounded, carbonized, and mostly well stratified. No sand or fine clastic grains can be seen in this mass, which argues against the plant fragments having been transported and accumulated by running water.

Minor but significant fragments of bone and at least one tooth are visible on the cut surfaces. Very dense as well as very cellular bone fragments are seen. The largest is about 2.5 cm long; most are mere shreds only a few millimeters across. The cellular pieces are

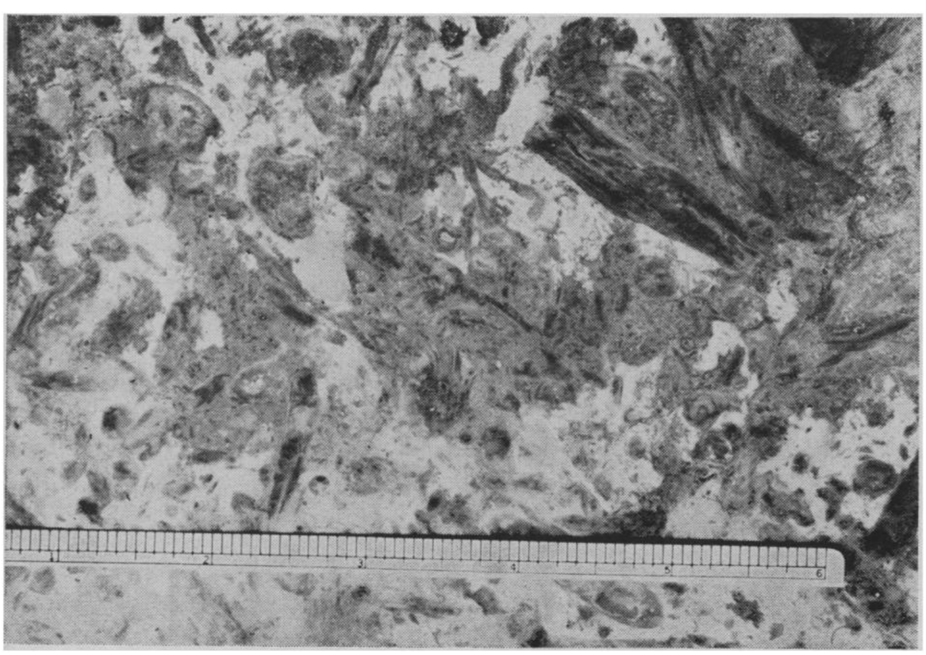

Fig. 1. Cut and polished surface of petrified stomach contents showing unoriented plant fossils, amorphous matrix, and rounded silicified pebbles. Scale in inches.

invaded by matrix and are extremely delicate. The tooth corresponds exactly in shape and size with an anterior tooth of the contemporary carnivore *Allosaurus*.

Strong evidence that this fossil mass is the contents of a stomach is the fact that it was found among the skeletal remains of a sauropod dinosaur. The bones had been exposed and were broken, scattered and weathered, as is usual in such instances. A few of the larger pieces were collected by Shrum and examined by me. Included are the distal end of a large fibula and the centrum of a cervical vertebra at least 45 cm long with the articulating surfaces preserved. These pertain to one of the large sauropods, but the exact species probably cannot be determined.

The diet and food preferences of the sauropods have been debated. The teeth provide no diagnosis; they are confined to the front part of the mouth, are blunt and relatively small, and in some cases are separated by gaps. The continuous replacement process evidently did not provide an even, regular tooth row, and the whole dental array would appear to be unequal to the task of food gathering for such massive animals. Although the sauropods are usually considered to have been herbivores, a few writers believe they had a mixed or even carnivorous diet. The present specimen strongly hints that the sauropods may have been indiscriminate in their food gathering to the point of being omnivorous.

Although most of the fossil fragments are woody vegetal material, there are enough pieces of broken or digested bone to show that a considerable amount of flesh must have been eaten. The amorphous material may be partly mud scooped up in the process of gathering other material, or it may represent organic-rich sediment or sapropel with enough food value to have been purposefully sought out. Only by utilizing abundant readily available food sources could the sauropods survive. They were apparently among the most effective harvesters of river and lake food resources ever evolved. After the Jurassic they were mostly replaced by the duckbill dinosaurs with teeth that were better suited for grinding and chewing tough, woody material.

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Electrochemical Coupling in Potentiation of Muscular Contraction

Abstract. *Diverse potentiators of contraction have basically identical, active-state mechanical effects, but act by different membrane-mediated electromechanical coupling mechanisms. The falling phase of the action potential is greatly prolonged by* Zn^{2+} *(0.1 m*M*) and* UO_2^{2+} *(0.5 to 1 μ*M*), neither of which affects the mechanical threshold. Caffeine (1 m*M*), like the lyotropic anions, acts conversely. Thus changes in the duration and mechanical threshold of the action potential determine independent electromechanical coupling processes which can act individually, or conjointly in the action of other potentiators, in determining the duration of the active state and thus the potentiation of twitch tension.*

Characteristically, potentiation of contraction is a great increase in twitch tension without change in tetanus tension. Such potentiation may be produced in skeletal muscle fibers by many substances remarkably diverse, both in chemical nature and in the concentrations at which they are most effective (*1*). For example, caffeine, an uncharged molecule, is very effective at a 1 m*M* concentration (*2*); lyotropic anions are most effective at a 0.1*M* concentration (*3, 4*); and certain heavy metal anions are most effective at smaller concentrations—Zn^{2+} at 0.05 m*M* (*5*) and UO_2^{2+} at 0.5 μ*M* (*6*). Potentiators modify still other mechanical features of contraction, but the basic alteration inducing all these effects is prolongation of the active state of the contractile component (*1, 3, 4*). The anions, however, and evidently all potentiators, do not act directly on this component but act at relatively superficial sites of the plasma membrane and perhaps the sarcoplasmic reticulum (*1; 3–5*). Accordingly, potentiators, after exerting their primary effects at these membrane sites, may cause potentiation by altering processes of excitation-contraction coupling that link reactions of the membrane to activation of contraction (*1, 7*).

It has been postulated (*4; 8–10*) that the potentiating alterations of excitation-contraction coupling are essentially electromechanical and are mediated by some combination of (i) prolonging the action potential, and (ii) lowering the mechanical threshold, which, as determined in potassium-depolarization contractures of muscle fibers (*4*), is the membrane potential at which the minimum mechanical response appears. While many potentiators prolong the action potential (*9, 10*), only lyotropic anions have been reported to reduce the mechanical threshold (*4, 11*). We therefore tested the effects of a number of potentiators on both action potential and mechanical threshold. We report here a general account of our results, which increase our knowledge of the mechanisms of potentiation, and which relate to the chemical differences of some of the potentiators.

We recorded action potentials of single fibers of frog sartorius muscles by standard techniques, using internal glass microelectrodes filled with 3*M* KCl. The excised muscle was mounted at about 1.2 times its rest length in a small Lucite chamber. Action potentials were obtained after successive periods of equilibration in Ringer's solution, test solution, and then, either in the Ringer's solution again, or some modification of it which would cause reversal of potentiator effects. We used square-wave shocks of 0.3 msec duration and of sufficiently low strength that, when applied to the surface of the muscle, they excited only a few fibers and thus reduced contractile movement and minimized loss of electrode impalement. Each action potential was simultaneously recorded on a fast and a slow sweep to facilitate temporal analysis of all phases of the potential. No simultaneous records were made of the mechanical responses, but average effects of the potentiators used in these experiments are well known from other work in our laboratory.

As shown in Fig. 1, 0.1 m*M* Zn^{2+} and 0.5 μ*M* UO_2^{2+}, which after 24 minutes and 60 minutes, respectively, produce maximum twitch potentiations of about 100 to 150 percent (*5, 6*), cause a 200 to 300 percent prolongation of the entire falling phase of the spike. The rising phase and other features of the response were somewhat modified,