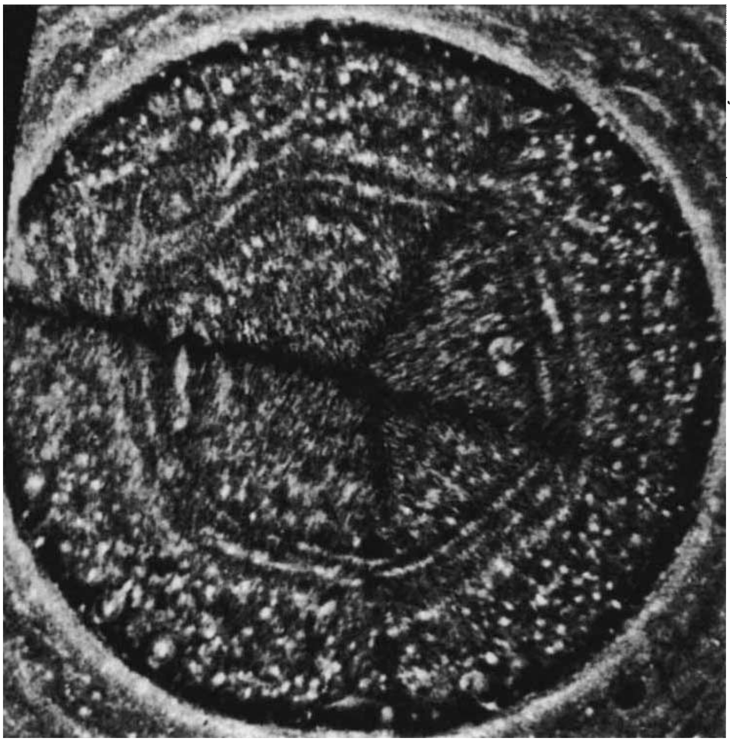
Hexagonal polar current on Saturn

THE remarkable hexagonal feature surrounding Saturn's north pole apparent in the figure was discovered by D. A. Godfrey (*Icarus* 76, 335–356; 1988) while making polar projections of Voyager images. The outermost circle is at about 65° latitude and represents the edge of a zonally symmetric current in Saturn's atmosphere. At the time of the spacecraft fly-by in 1981 the northern hemisphere was entering spring and the polar region was sufficiently illuminated to show features, although great care was necessary to remove shading due to twilight effects. The mosaic figure, one of six presented (each showing the hexagon), is made up of four images taken of the sun-lit hemisphere as the planet rotated. Because Voyager's orbit kept it close to Saturn's equator, Godfrey had to reproject the foreshortened images of the north pole to produce the view shown, looking down the planetary axis. The morphology of the clouds does not change a great deal during one 10-hour rotation period, so that the mosaic is not very much different from an instantaneous snapshot. The four 'spokes' are boundaries between images, and the streaked appearance near the pole is an artefact of the projection.



D. A. Godfrey

Small differences between sequential mosaics can be used to determine the drift rate of clouds, and it is here that surprises emerge. The hexagonal feature is an atmospheric jet stream whose position and configuration remain fixed, to within a few metres per second, but the current in the jet exceeds 100 m s^{-1}. In this context, 'fixed' means stationary in latitude at about 76°, and in longitude relative to the periodicities which appear in radio emissions from the planet, presumably linked to the magnetic field which in turn is anchored to the deep core of the planet. Thus this is a jet stream which follows a twisting yet stationary path, rather than meandering, as is the familiar case in Earth's atmosphere and oceans.

Godfrey discusses the possibility of a direct connection between the hexagonal structure and the magnetic field, but concludes that it is improbable. The clouds are ammonia crystals at a level where the atmospheric pressure is about half an atmosphere and the temperature is about 120 K, well within the 'troposphere' (lower atmosphere) rather than the ionosphere. The conductivity is low and magnetohydrodynamic effects should not exist. Also unlikely is a direct connection between the radio emissions and the planetary weather, as these emissions do not have the character of lightning bursts. The simplest idea is that the magnetic field and the atmospheric current both have longitudinal structure that is of deep origin, and hence they show closely similar rotation rates.

Godfrey's kinky current is one more example on a growing list of stationary, or at any rate slowly moving, flow structures on the outer planets. Since the time of Galileo we have known of the Great Red Spot of Jupiter, which drifts in longitude with speeds of only a few metres per second, although it is composed of (and resides in) currents whose speeds reach 100 m s^{-1}. Smaller spots on Jupiter also tend to be slowly moving. T. E. Dowling and A. P. Ingersoll (*J. Atmos. Sci.* **45**, 1380-1396; 1988) have shown that the circulation patterns near and within these spots can be used to infer the nature of flows at deeper levels, although they do not point to any particular reason for very slow motion of the spots. And there are slowly moving large-scale thermal features, discovered in the infrared by J. A. Magalhães *et al.* (to be published in next week's *Nature*) located at low latitudes on Jupiter, right where the broad equatorial current is also situated. The current is apparently perturbed by some influence that is nearly stationary.

All of these features could be providing information about deeper regions. Jupiter and Saturn have only small solid cores, unlikely to have any influence on surface motions. The vast bulk of these planets is fluid hydrogen and helium in roughly cosmic abundance. Heat emerges from the interiors in large quantities, comparable to the solar heating. The nature of the fluid motions which carry this heat to the surface has long perplexed astronomers and those studying convection. We may at last be seeing evidence, albeit indirect, for the morphology and flow speeds associated with this convection.

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Palaeontology

Fossil reptiles from ancient caves

Michael J. Benton

ONE of the problems of studying terrestrial fossil sites is that large plants and animals seem to be commoner than small ones, whereas the opposite pertains in nature. This could be because organisms were on average larger in the past; or because small ones are less likely to be preserved. The latter explanation seems to be the case as sites have been found, although only occasionally, which contain abundant small fossils. One such is the fossilized cave systems of south Wales and Bristol in the United Kingdom. In a new paper, N.C. Fraser[1] reports the discovery of small animals from an age where most sites reveal dinosaurs and other large animals.

The abundant small beasts of the Bristol–South Wales region offer a fascinating glimpse of life on land beneath the feet of the first dinosaurs. Despite their abundance and the good quality of preservation, the fauna is not perfectly fossilized. The skeletons are found at the bottom of fissures eroded into the ancient limestone hills. As the openings into the fissures are often small, the larger animals have effectively been filtered out. Nevertheless, the fissure animals provide unique

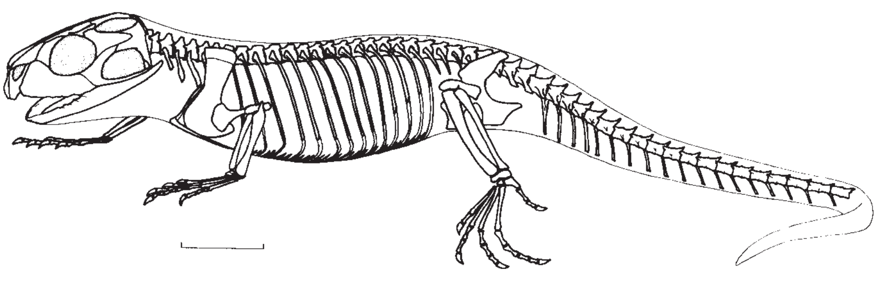

Fig. 1 Composite restoration of the entire skeleton of *C. hudsoni*. Bar, 2 cm. (From ref. 1.)

insights into the lives of the more abundant animals at this time of major faunal turnover. Some of the fissures were under water at the time of fossil formation.

The fossiliferous fissure deposits are dated as Late Triassic to Early Jurassic (about 220–200 million years old), the time during which the dinosaurs became established, and during which most 'modern' land vertebrates arose: mammals,' turtles, crocodilians and lepidosaurs. These smaller 'modern' vertebrates are best represented in the fissures and they have yielded significant new phylogenetic information.

Fraser's find[1] of the sphenodontid *Clevosaurus hudsoni*[2] allows him to perform a detailed analysis of this animal and of its relationship with other organisms. *Clevosaurus*, a small 250-mm-long reptile, is superficially like a modern lizard, with a slender body, long limbs and (probably) a long tail (Fig. 1). The teeth are chisel-like and, unusually for a vertebrate, fused firmly to the bone of the jaws (Fig. 2). The teeth and jaw bones of adult specimens of *Clevosaurus* show signs of heavy wear, and the jaw action was a shearing one, rather like the action of a well-adjusted pair of scissors. *Clevosaurus* probably fed on hard-skinned invertebrates such as centipedes, insects and snails. It may also have been a facultative herbivore, raking plant food together with its beak-like front teeth, and chopping it further back in the mouth. Young *Clevosaurus* specimens have small, sharp teeth which may have been used for eating soft-bodied invertebrates such as worms.

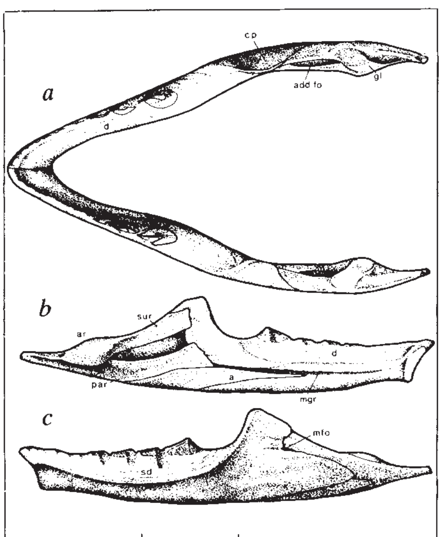

Fig. 2 Composite restoration of the mandible of *C. hudsoni* in: *a*, dorsal; *b*, medial; *c*, lateral views. Scale bar, 1 cm. (From ref. 1.)

Fraser[1] distinguishes two or more species in his material of *Clevosaurus*. The material is mainly disarticulated, and he examined more than 1,000 separate bones. Fortunately, he found a few more complete specimens which helped in the identification of isolated elements. The second *Clevosaurus* species, *C. minor*, is much smaller than *C. hudsoni*, reaching an estimated total length of 150–200 mm. They have adult patterns of tooth wear, so are unlikely to be juveniles of *C. hudsoni*. *C. minor* is found at different sites from *C. hudsoni*, so they are probably independent breeding species.

Other associated vertebrates from the Triassic fissures[3] include a gliding reptile, *Kuehneosaurus*; the early crocodilian *Terrestrisuchus*[4]; the dinosaur *Thecodontosaurus*[5]; the very early mammal *Kuehneotherium*[6]; various unidentified archosaurs[7]; and up to ten species of sphenodontid[1,8–10]. The Jurassic fissures contain a rather different fauna, consisting of the mammal *Eozostrodon*, the tritylodont *Oligokyphus*, the lepidosaur *Gephyrosaurus* and fish teeth[8].

The sphenodontids, such as *Clevosaurus* and its kin from the fissures, are of great phylogenetic importance. They are broadly similar to the living tuatara *Sphenodon* from New Zealand, a so-called living fossil. The fact that a complex fauna of up to ten sphenodontids coexisted in the south-west of Britain 220–210 million years ago suggests that the group was once as flourishing as the lizards are today[10]. □

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Daedalus

If I had a hammer

THE hammer is one of the most basic of implements. It exploits a simple newtonian principle: the deceleration of its head imposes a force on the object it strikes. In the hands of a skilled craftsman, it can crack a brick precisely in two, or make a controlled adjustment of 0.01 millimetres.

In the hands of unskilled amateurs, however, it produces a vast global total of bent nails, bruised thumbs, dented woodwork and smashed panes of glass. Daedalus is therefore updating this palaeolithic invention with the most advanced electronics. He has been inspired by the modern thyristor photographic flash unit. This integrates the light reflected off the scene and, when enough has been received for a good exposure, quenches the flash. It all happens in microseconds. In the same way, Daedalus's electronic hammer carries an accelerometer which integrates the momentum received by the target during the impact. When this exactly reaches a pre-set value, the impact is 'switched off'. A fast-acting trigger mechanism snatches back the hammer head and dumps the surplus momentum back into the handle and the user's arm.

This wonderful tool not only tames and directs the enthusiasm of the user: it educates him too. Set for a delicate task (such as tapping a ceramic tile into place on its mortar) it will transmute a wild swipe into a light and precise blow. But the excess momentum, returned to the user's arm as an unexpected 'kick', warns him that his blow was too heavy. His next swipe will not be so wild. Soon he will have a sound intuitive feeling for the exact use of the hammer in this task. Professionals and amateurs alike will welcome the electronic hammer: in all fields of engineering and domestic construction it will teach the subtle kinetic intuition of the true craftsman. Indeed, electronically controlled impact may become the preferred way of carrying out all sorts of tasks now conducted manually, from removing a stopper to advancing a pawn or shaping a cake. Daedalus is devising a 'personal electronic hammer' to fit in the pocket like a pen. The user will turn to it for any manual task as automatically as he reaches for a pen to write with, or a calculator to do arithmetic.

But the best strategy for developing a new invention is to launch a high-value product first, on whose profits the mass market can be attacked. So Daedalus's first commercial product will improve the most valuable impacts of them all — those of international golf. His electronic golf clubs, bringing calibrated exactitude to this most obsessive and unforgiving of games, should sell for tens of thousands of pounds.

David Jones