Galaxy structure

Two kinds of halo gas identified

from Joel Bregman

ALTHOUGH most of the cool gas in our galaxy lies in the galactic disk, it is not entirely confined there and the study of gas above and below the disk (halo gas) has been an especially vigorous area of research during the past few years. Unfortunately, it has frequently been difficult to discriminate between disk and halo gas, for it is not possible to determine distances to gas clouds and we can only look at the halo gas through the disk. In a recent paper C. E. Albert has used a new approach[1], a study of low ionization gas within 8,000 light years of the disk (the lower galactic halo). She has conclusively shown that a considerable amount of neutral (cool) gas exists in the lower galactic halo and that there are two kinematically distinct types of halo gas.

Gas is believed to exist in the halo in several different forms[2]. Weak radio continuum emission has been attributed to synchrotron emission from cosmic ray electrons that may extend up to 30,000 light years from the disk[3,4]. Plasma at temperatures of millions of degrees may also permeate the halo and be responsible for part of the diffuse X-ray background (0.1–2 keV)[5]. Virtually nothing is known about the vertical distribution of this gas except that it is unlikely to extend beyond 30,000 light years from the disk. Radio telescope surveys have revealed the presence of neutral hydrogen gas at a few hundred degrees kelvin but with unusual velocities[6,7]; this gas is presumed to lie in the halo as well. Finally, absorption line spectroscopy in the optical and ultraviolet bands has been used to demonstrate the presence of halo gas with a temperature in the range 10^3–10^5 K[8–10].

Optical and ultraviolet spectroscopy have been powerful tools for analysing the properties of halo gas. By detecting absorption lines caused by gas intervening between the Sun and a background source (a star or quasar), one is able to estimate the column density, vertical distribution, chemical abundance and temperature of the gas. Strong absorption is commonly detected for the ultraviolet resonance lines of C IV and Si IV, which is interpreted as evidence for warm gas (10^4–10^5 K) lying between 1,500 and 10,000 light years above the disk[9–11]. For neutral gas ($< 10^3$ K), a more precise study of the vertical distribution has been made by comparing the total column density (from the 21 cm HI emission line) with the column density between the Sun and a halo star (using the Ly α line of neutral hydrogen)[12].

There is a vast amount of gas above the thin disk of the galaxy (half-thickness about 300 light-years) and about one-third of the total column density of neutral gas is beyond a height of 3,000 light years. However, little neutral gas exists further than 6,000 light years from the disk. Albert has added to our understanding by comparing the difference in absorption for pairs of stars, one of which is just above the galactic disk and the other in the halo. She shows that the halo is rich in gas and distinguishes between two types of neutral halo gas: a layer of gas similar to disk gas that has a scale height of about 3,000 light years, and higher velocity gas richer in certain heavy elements (Ti, Ca, and Na) that is found only above the disk. Whether or not there is a true difference between the distribution of warm and neutral gas and how these components are related to the million degree gas and the cosmic rays remains to be seen.

The absorption-line gas is rotating, but not precisely with the galactic disk. This has been clearly shown by Albert and others[13] who demonstrated that the velocities at which absorption against halo stars is observed are considerably different from these expected for corotating gas. Evidently, these gas clouds have large peculiar velocities with respect to a corotating halo. The data are qualitatively consistent with features of a corona that rotates more slowly than the disk and of galactic fountain models. More data are needed before the various models can be tested critically and more studies along the lines of Albert's would be valuable. □

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Palaeontology

Small companions for early dinosaurs

from Michael Benton

FOSSILIZED cave systems around Bristol, England, have yielded an important fauna of small reptiles dating from the times of the early dinosaurs, about 200 million years ago. Until recently, these were thought to be specialized upland faunas because the animals were rather different from those of the typical lowland dinosaur beds. Strong evidence has now, however, been presented against this view, and new information on the dating and palaeoecology of these remarkable faunas has also been given[1–6].

Fossil mammal teeth were first found in the Bristol fissures by Charles Moore over 100 years ago[7], and the first reptile remains were described[8] in 1939. These consist of the bones of a small lizard-like animal (*Clevosaurus*), very like the unique living tuatara, *Sphenodon*, from New Zealand. Many more important mammal and reptile fossils have been collected since then from dozens of fossil caves in South Wales and around Bristol. The reptiles include a remarkable small gliding animal called *Kuehneosaurus*, isolated bones of the carnivorous crocodile-shaped *Rileya* and the dinosaur *Thecodontosaurus*, a crocodile, and various as yet undescribed sphenodontids and small archosaurs (crocodiles/dinosaurs/thecodontians). The latest new forms to be described have been *Gephyrosaurus*[5,6], a 40-cm long lizard-like animal, and *Planocephalosaurus*, a small sphenodontid[3].

The dating of the fissures has always been a problem. Some may be late Triassic (Norian) in age, others Rhaetic, and others early Jurassic (between about 190 and 225 million years ago). Some of the South Wales fissures have been dated as Rhaetic or early Jurassic on the basis of plants, spores and gastropods[9]. One of the fissures near Bristol has yielded more abundant spores which suggest a Rhaetic age[1]. The main fissure sites, and the reptiles that they have produced are described in references 1, 4, 9–11.

At the end of the Triassic period, the scenery around Bristol consisted of limestone hills in which deep fissures and caves formed. The climate was subtropical with wet and dry seasons, and the vertebrate fauna consisted of dinosaurs, small lizard-shaped reptiles and early mammals. Occasionally, these animals fell into the fissures, or were washed in by flash floods with mud and sand. The habitat was assumed to have been a rocky 'upland',

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well away from the lush pastured dinosaur country below. However, there is now strong evidence for marine influence in at least one fissure (Tytherington); marine microfossils (acritarchs and dinoflagellates) occur, kerogen derived from marine algae is abundant[1] and a glauconitic clay mineral has been found which could indicate brackish conditions[2]. This fissure at least must have been located near the coast with its base below sea-level. This would permit mixing of the meteoric waters that washed the debris into the cave with saline waters from the sea.

We must now view the fissure animals as representing a sample of a lowland fauna rather than a peculiar upland fauna. Very large animals are excluded — like the five-metre long dinosaur *Plateosaurus* which is found widely in Europe at the same time. However, many single bones of its smaller relative *Thecodontosaurus* have been found in various fissures. The most abundant animals, however, are lizard-sized, from 10–50 cm in total body length. A detailed study of the ecology of an assemblage of these small animals from Slickstones Quarry has just been published[4], and it gives us a unique impression of the fauna scuttling around beneath the shadow of the dinosaurs.

The Slickstones fauna consists of 12 or more forms, and includes abundant remains of six different sphenodontids. Most of these probably ate insects and other invertebrates, as does the living *Sphenodon*, but one form at least may have been herbivorous — a conclusion suggested by patterns of tooth wear. The authors go on to suggest that differences in the composition of the 'faunas' found in different fissures were caused by interspecific competition for food resources[4]. This seems to be stretching the evidence a little far, unless we assume that the beasts actually lived in the caves. The sphenodontids were preyed upon by dinosaurs and other archosaurs which are represented in the fissure fossils by a variety of jaws and isolated sharp knife-like teeth.

The Bristol fissures should produce a great deal more important information. Many of the fissure reptiles have yet to be described and the careful collecting techniques being used should also yield much new information on their palaeoecology. There is a rare satisfaction in finding out about some of the *small* reptiles that have now been shown to have lived during the Age of the Dinosaurs. □

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Archaeology

Stonehenge comes alive

From Julian Richards

THE antiquarians of the seventeenth and eighteenth centuries, the barrow diggers of the nineteenth, and the excavators, fieldworkers and astronomers of the twentieth have all been drawn to the Stonehenge area to observe, to dig and to speculate. To many it has long been apparent that the visible remains, barrows, henges and cursus monuments, while evidence of intensive and consistent activity during the Neolithic and Bronze Ages, provided only a partial picture of prehistoric society. Ideology and death left their enduring traces, but if we could see the dead, then where were the living?

"Stonehenge and Its Environs" (Edinburgh University Press) is the title of the survey carried out by the Royal Commission on Historic Monuments which has started to provide clues in the hunt for the living. Traces of now flattened prehistoric fields, small enclosures and boundary ditches point to an organization of the landscape beyond ritual and burial and provide an invaluable framework on which the next phase of investigation could be based. In 1980, the Trust for Wessex Archaeology began a programme of survey in the area of some 2,500 hectares studied by the Royal Commission. The overall brief of this Stonehenge Environs Project, commissioned by the Inspectorate of Ancient Monuments, was the location and evaluation of areas of prehistoric activity and the provision, by sample excavation, of firm indications of preservation for specific monuments.

With the exception of rare pockets of old grassland and woodland, and areas recently returned to grass by the National Trust, the arable landscape immediately dictated the most suitable field survey approach: surface collection 'fieldwalking'. The systematic collection of artefacts from the weathered surface of ploughed fields is becoming increasingly recognized as a major field survey technique. The use of flint and similar lithic material for tools throughout prehistory provides one enduring component of a total artefact assemblage that may also have included bone, metal and pottery.

The two-stage surface collection strategy used in this and other Trust for Wessex Archaeology projects aims initially to locate widespread patterns and anomalous areas. These are assessed in the light of localized topography and soil changes. Collection is initially by means of transects within hectare squares based on the national grid and provides an initial surface sample of approximately 8–10 per cent. The second stage of more detailed gridded collection tends to be reserved as an intensive pre-excavation sampling technique when it is carried out in conjunction with geophysical and geochemical surface surveys.

Over the past three winters more than 1,000 hectares have been examined and patterns of prehistoric activity have been recorded. Far from being a 'ritual landscape', devoid of inhabitants, the recent survey has shown areas of intensive domestic and industrial activity contemporary with the major ceremonial centres. Even within the relatively restricted study area, the patterns represented by the surviving monuments can be seen reflected in shifting zones of domestic activity culminating in the developed agricultural and territorial landscape of the later Bronze Age, *c.* 1000 BC.

Survey and sample excavation have thus provided a spatial, functional and chronological framework for prehistoric activity around Stonehenge, the only missing component being evidence for environmental change. The potential of upland chalk areas to provide environmental evidence is limited largely to land snails within protected contexts, particularly in buried soils and within ditch deposits. The palaeoenvironmental potential of the Stonehenge area, with its barrow mounds, ditches and other potentially dateable earth works, is thus extremely high and has been exploited in tandem with the main project. Research funding from the Society of Antiquaries, the British Academy and the Prehistoric Society has facilitated the investigation and analysis of a number of overlapping dateable environmental sequences.

The field aspects of the project are now almost complete, with only a short season of surface collection and recording of field monuments remaining. The project will then progress to a phase of full-time analytical work intended to produce both management strategies and a full synthetic publication of the projected results.

It is hoped to continue research in the area, particularly on the aspects of the prehistoric environment, but this will now depend on the availability of research funds other than from the UK Department of the Environment.

It is only by moving beyond empirical observations that we can hope to comprehend the societies in which Stonehenge was built. These must be understood if we are to preserve in a sensible manner their tangible, if ephemeral, remains. It is hoped that the Stonehenge Environs Project will not only have added to our understanding of the area, but also provided the means by which it can be both preserved and explained. □

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