Seismic stratigraphy and global changes

from A. Hallam

A MAJOR breakthrough in data processing in the 1960s has made seismic reflection profiling an immensely valuable tool in exploration for petroleum. Superbly clear representations of subsurface structures and stratal dispositions are now available from extensive sectors of the continental shelf and slope, as well as under the land surface, and have become virtually indispensable as guides to where the initial exploratory boreholes should be drilled.

For the last decade Peter Vail and co-workers at the Exxon exploration laboratories in Houston have been engaged in an extensive, world-wide programme of stratigraphic analysis of seismic reflection profiles and have come up with some impressive results. Vail has been lecturing frequently in the past few years in North America about the most striking of these, which support the concept of a series of eustatic cycles through the Phanerozoic, and to say that publication has been eagerly awaited is for once an understatement. This has now been achieved with the appearance last December of Memoir No. 26 of the American Association of Petroleum Geologists.

It was the eminent Austrian geologist Eduard Suess who at the turn of the century coined the term 'eustatic' for world-wide changes of sea level. While there has been universal acceptance of this phenomenon for the Pleistocene, with sea level falling and rising as a consequence of the waxing and waning of polar ice caps, the postulation of global sea level changes in earlier times has proved more controversial. It has been difficult, for instance, to persuade the sceptics that a given marine transgression in the region they were well acquainted with was a local expression of a eustatic rise rather than the consequence of a local increase in tectonic subsidence rate. The critical requirement is of course good biostratigraphic correlation, and as this has improved over the years there has been a gradual shift of opinion in favour of eustasy.

The importance of the new work in seismic stratigraphy is that a vast amount of new data has become available for analysis. What is particularly significant is that seismic reflections tend to parallel stratifications rather than gross boundaries of lithologic units that may cut across

stratification surfaces; hence they have chronostratigraphic value. Age and facies control must of course be achieved independently by study of fossils and sediments from boreholes.

The essence of the technique adopted by Vail and his colleagues is to define so-called 'depositional sequences', which are major unconformity-bounded stratal units, in a given region. Relative rise of sea level is indicated by coastal onlap of maritime deposits, stillstand by coastal toplap and relative fall by downward shift of coastal onlap. 'Sea level curves' are constructed by making chronostratigraphic correlation charts of successive depositional sequences and plotting the apparent rise and fall of sea level through time (correction is made as far as possible for differential subsidence). If good correlation exists between three or more regions in different parts of the world, eustatic control is inferred.

The end product of the exercise is a chart of global cycles, which is a modal average of regional cycles. Although the whole Phanerozoic is included, pre-Jurassic data are based entirely on North America and hence cannot be considered as reliable as those from the Jurassic to the present, which come from six continents. These show an overall rise of sea level from the early Jurassic to the late Cretaceous, followed by an overall lowering through the Cainozoic, made up of a series of eustatic cycles characterised by a gradual rise, period of stillstand and rapid drop. Calibration with a quantitative model of W. C. Pitman relating oceanic ridge volume to sea floor spreading rates suggests a drop of about 350 m from the late Cretaceous maximum some 80 Myr ago. A particularly dramatic drop of a few hundred metres early in the late Oligocene (30 Myr) is thought to have been accomplished within the limits of biostratigraphic resolution, about a million years.

There can be little dispute that this work represents one of the most significant advances in stratigraphy for many years, but problems quite

naturally remain. For instance, if we are to accept the reality of geologically frequent rapid drops of sea level, what can the causal mechanism be? It is not plausible to invoke glaciation before the late Cainozoic because there is no evidence of polar ice caps, but on the other hand changes of oceanic ridge volume appear to happen too slowly to account for the dramatic phenomenon in question.

A more serious difficulty perhaps concerns the reproducibility of the results. The raw data on which the analysis is based are likely to remain unpublished, having been classified as confidential. Would research groups from other oil companies come up with a closely similar chart? What, finally, of the poor old academic geologist who is denied access to the critical data—how much should he take on trust? We must hope that information will be released into the public domain in the tolerably near future because it is scientifically too valuable to be allowed to gather dust in unopened files. □

When C₄ plants do best

from Peter D. Moore

As more information accrues on the metabolic implications of the C₄ photosynthetic pathway, ecologists and biogeographers are presented with a variety of interesting problems. In how many taxonomic and geographic localities has this technique for accumulating CO₂ evolved? Under what environmental conditions does the C₄ system confer maximum advantage? Why are C₄ species so scarce in temperate latitudes? If the C₄ plants are as efficient as we are told in tropical and subtropical, dry environments, why have they not totally eliminated their C₃ counterparts? Some of these questions have recently been raised and possible answers constructed by Ehleringer (*Oecologia (Berl.)* **31**, 255; 1978).

In particular, Ehleringer is concerned with the reduced quantum yield for CO₂ uptake in C₄ plants which he and Björkman have examined (*Plant Physiol.* **59**, 86; 1977). The C₄ system, which involves the temporary fixation of CO₂ into a four carbon molecule, its transportation to the vascular bundle sheath cells and its subsequent release and refixation by the conven-

A hundred years ago

THE SATELLITES OF MARS—Professor Asaph Hall, to whom as the discoverer of these bodies, the right of selection of names appertains has definitely decided for *Deimos* for the outer moon and *Phobos* for the inner one, agreeably as he mentions to the suggestion of Mr Madan in these columns, founded on the lines in the "Iliad", which Pope thus renders:—

"With that he gives command to Fear and Flight
To join his rapid coursers for the fight;
Then grim in arms, with hasty vengeance flies,
Arms that reflect a radiance through the skies."

From *Nature* **17**, 28 March, 433; 1878.

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