Fossils are often used as indicators of past climatic conditions, but how reliable are they? **Ian Wilkinson** and **Jim Riding** examine the evidence available for an ancient 'greenhouse' climate.

# The Cretaceous greenhouse world

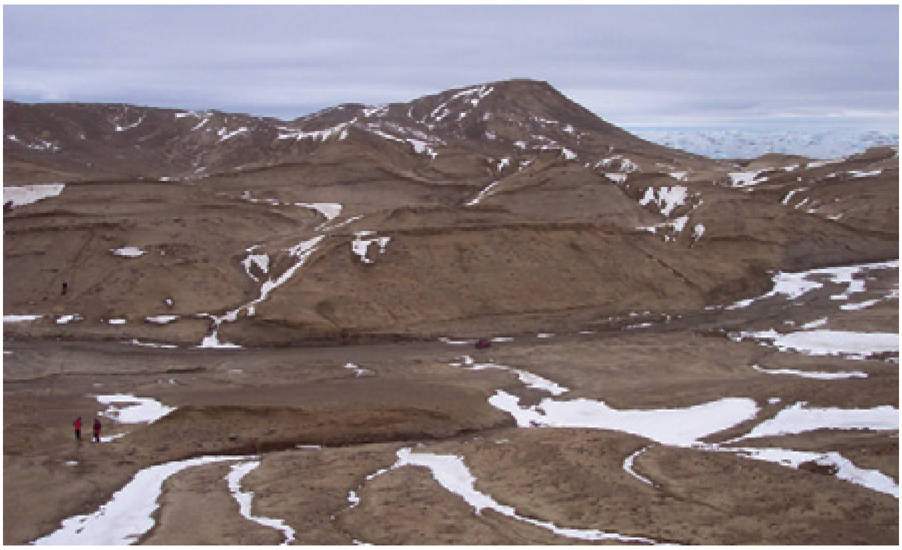
Fossils are used for a number of purposes such as understanding evolution, determining food chains in the geological past, dating and correlating rock successions and for reconstructing the environment of deposition for the rocks in which they are found. Among environmental factors, climate plays a leading role in determining the distribution of modern organisms, as well as those in the geological past.

When considering past climates, we have to recognise the limitations of the science. Many palaeoenvironmental reconstructions assume that fossil plants, animals and protoctids were controlled by climate in the same way as they are in the modern world. However, modern analogies become less reliable the further back they are traced into deep time, so that confidence limits are high for the Quaternary back to the Palaeogene, less so for the Mesozoic and only more generalised conclusions can be drawn from Palaeozoic organisms.

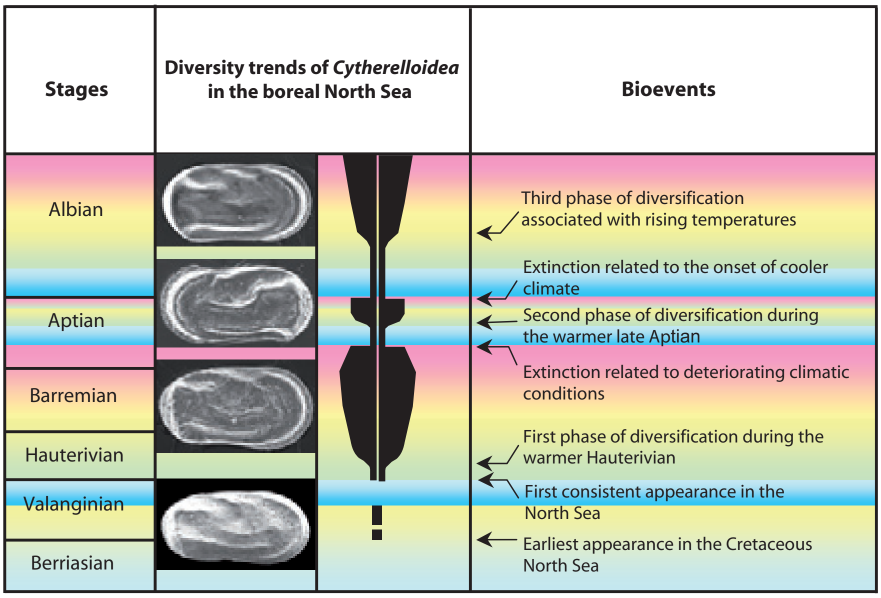
Until recently, the Cretaceous Period was regarded as an example of a greenhouse world. It was said that the poles were ice-free, the thermal gradient from equator to pole was much reduced, and terrestrial conditions were equable even at very high latitudes. At times, however, significant climate change punctuated this greenhouse world. In high latitude regions, ice-rafted rocks, glacio-marine pebble beds and the occurrence of glendonite indicate cold to glacial conditions. The climate is also reflected in the distribution of microfossil associations.

**Glendonite** is a calcite pseudomorph formed in shallow marine conditions by the replacement of ikaite — $Ca(CO_3)\cdot 6(H_2O)$ — where the sediment–sea water interface was at a temperature of less than about 4°C.

Perturbations in the early Cretaceous climate are indicated by the migration of ostracods (small bivalved crustaceans), from the warmer Tethyan Sea into the Boreal North Sea Basin. These migrations took take place when the climate was warm enough, but ended as the climate cooled. For example, *Euryitycythere* expanded into a transitional province briefly during the early Valanginian, but pulses of expansion into the Boreal North Sea could only take place during the latest Valanginian to early Hauterivian, the early Barremian and the early Aptian.



*Seymour Island, Antarctica where detailed analysis of high latitude biotas (such as ammonites, plants and palynomorphs, including pollen) will help to uncover climatic variability at the close of the Cretaceous Period.*




*Early Cretaceous ostracods such as* Cytherelloidea *migrated from the warm Tethys Ocean into transitional areas and the Boreal North Sea, at times when climatically controlled water temperatures permitted.*

**Protoctids** are members of a large grouping (kingdom) of living things including single-celled organisms (protists) and multicellular organisms with protist affinities.

*Cytherelloidea* is a genus that is restricted to modern seas where water temperatures do not fall below 10°C and this preference for warmer water has been traced back into deep time. During the Berriasian (earliest Cretaceous), for example, it was confined to the Tethys, but it was able to migrate northwards into the Boreal province on several occasions. The first species migrated into the North Sea during the Berriasian/ Valanginian transition at a time when oxygen and carbon isotope records indicate warm shallow marine palaeotemperatures (about 12–15°C). However, it was only in the mid- to late Hauterivian, the late Barremian and again in mid-Albian that diversification could take place in the Boreal North Sea. Intervening cold phases, expecially during the Valanginian and late Aptian, sent the genus into a decline.

*Ammonites were collected during a recent field season on Seymour Island, Antarctica in order to determine the nature of late Cretaceous climate change.*

Modern planktonic foraminifera (microscopic protoctids with a shell; 'armoured amoeba') are distributed in nine bioprovinces characterised by distinct assemblages at different latitudes and a decrease in diversity towards the poles. It seems likely that Cretaceous planktonic foramimifera behaved in a similar way, but it was not until the mid-Cretaceous that latitudinal bioprovinces developed, indicating temperature gradients from equator to poles.

Large, robust, often keeled, planktonic groups, intolerant to environmental change, are confined to low and mid latitudes where they form rich and diverse assemblages. Among the benthonic foraminifera, large species are found in low latitudes. In high latitudes, such as the Antarctic, planktonic foraminiferal assemblages are predominantly monospecific and composed of morphologically simple forms, with more common agglutinated benthonic foraminifera.

Several lines of geological evidence, including fossil plants, suggest that, after the peak Cretaceous greenhouse warmth, palaeoclimates cooled considerably during the Maastrichtian (latest Cretaceous) between about 71 and 65 million years ago. It is possible that this cooling was, at times, so severe that high latitude regions suffered short-term glaciations; these would have caused sea-level changes worldwide. This challenges the prevailing view that the late Cretaceous greenhouse world was entirely ice-free, implying instead that short-term glacial climates may have punctuated this supposedly stable, warm climate. Such dramatic environmental change would have both placed both terrestrial and marine biotas under stress, and made them particularly susceptible to early extinction related to the global environmental catastrophe at the end of the Cretaceous. Ammonites, belemnites and dinosaurs became extinct at the end of the Maastrichtian age. The nature and diversity of biotas, the sedimentological record, and geochemical signals in key Maastrichtian successions — for example on Seymour Island, Antarctica — are currently being investigated in order to determine the nature of latest Cretaceous climate change at the southern high latitudes. Marine fossils with original shell material may provide oxygen isotope data from which the Cretaceous sea-water temperatures, and hence the climate regime, can be determined.

*For further information, contact:*


**Ian Wilkinson, BGS Keyworth,**
**Tel: +44(0)115 936 3409**
**e-mail: ipw@bgs.ac.uk**