The idea that the mantle can be modified shortly before large-scale melting is not new, but only recently has the evidence come together to show how. That modifications may occur in shallow, laterally moving mantle emphasizes that variations in MORB in the most highly incompatible elements (such as Ba, Rb, Th and K), and at least some isotopic ratios, can only partly be ascribed to long-term variations in mantle source compositions. The exact nature of process-related modifications may vary with location, so evidence from multiple process-specific tracers (radioactive isotopes, volatiles) will become increasingly important as detailed case-by-case studies of individual sections of the ocean ridge system are carried out.

In addition, if we are ever to understand the complexities of compositional variability within the mantle and how they manifest themselves in MORB, more information is required about the inherent heterogeneities in the asthenosphere and in plume material away from the influence of ridges. Particularly, to what extent may a given plume vary over time (as indicated, for instance, by secular variations in the isotopic compositions of Hawaiian lavas[7])? If the composition varies both vertically and horizontally within a plume, then the material supplied to an adjacent ridge crest will vary with time. Moreover, the modifications to the moving plume material, where the pertinent processes take place, and how and where they are expressed in lavas on the ridge could change. Combined geochemical and geochronological studies of near- and on-axis lavas using different radioactive dating schemes should clarify matters; ^{226}Ra–^{230}Th, ^{230}Th–^{238}U and ^{40}Ar–^{39}Ar dating should be good for samples 0–8, 20–350 and over 70 thousand years old, respectively.

The true power of geochemistry comes from the most comprehensive data sets, based on the maximum possible number of tracers. Even with the tools available now, the prospects are good for understanding mantle variability and how it is modified. Therein lies the light at the end of the plume channel. □

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PALAEOCLIMATE

Back to the future

Gabrielle Walker

WHILE most climate modellers have their sights focused on the future, seeking to understanding how our world will respond to the threat of global warming, many are also looking to the past — for answers to the same question. This was evident at a Royal Society Discussion meeting last month*. The climate of the Mesozoic era (65–248 million years ago), the focus of the meeting, was generally much warmer than it is today, with globally averaged surface temperatures 6–14 °C higher than at present; understanding the reasons for the warmer temperatures then might help us to predict how increasing emissions of greenhouse gases into the atmosphere will perturb the Earth's climate in the future.

This point was illustrated by Eric Barron (Pennsylvania State University), describing experiments using a general circulation model called GENESIS to determine which of the geographical arrangement of the continents (the ancient supercontinent, Gondwanaland, was just breaking up) and the atmospheric carbon dioxide concentration was more responsible for the warm global temperatures in the Cretaceous period 65–144 million years ago.

In 1984, Barron and Washington[1] used an earlier, much less sophisticated model to address the same question. Then, they concluded that the Cretaceous distribution of the continents was the primary cause, with higher atmospheric CO_2 concentrations playing a minor role. This seemed to suggest that the Cretaceous might not be a good analogy for a future greenhouse world. But the earlier model included some rather crude assumptions. In particular, it incorporated only mean annual solar heating, and there was no thermal inertia built into the model ocean. GENESIS, on the other hand, allows for seasonally varying solar insolation, and has a mixed-layer ocean. And the results tell a different story.

To their surprise, Barron *et al.* found that changing from present-day to Cretaceous geography produced a mean global cooling of about 0.2 °C. It was only when the CO_2 content of the Cretaceous atmosphere was increased to four times the present-day value that global surface temperatures increased by 5.5 °C. Thus, it seems that the Cretaceous was, after all, a 'greenhouse' epoch, and might be able to tell us something about future climate change.

One of the most important unknowns in the quest to predict global warming is the climate sensitivity — the increase in global mean surface temperature associated with a doubling of atmospheric CO_2. Different climate models calculate different sensitivities, mainly because they parameterize features such as cloud cover in different ways. The sensitivity calculated by GENESIS, 2.3 °C, is more or less in the middle of the range of likely values put forward by the Intergovernmental Panel on Climate Change (IPPC) (1.5–4.5 °C; ref. 2).

But the results from this study allowed Barron to estimate the atmospheric CO_2 concentrations that would be required if the sensitivity of the atmosphere were at either extreme of the IPCC range. If the required Cretaceous temperature range is 6–12 °C, a climate sensitivity of 4.5 °C would indicate Cretaceous CO_2 levels 2.7–5.3 times the present concentration, in keeping with the 2–6 times present CO_2 estimated by Berner[3] using a geochemical model. On the other hand, a climate sensitivity of 1.5 °C would require atmospheric CO_2 concentrations to be 8–16 times the present concentration, higher even than Cerling's estimate of 4–9 times present using evidence from Mesozoic palaeosols[4]. So, when compared to geological evidence for the composition of the Cretaceous atmosphere, the model results from the Cretaceous suggest that the climate sensitivity to doubling of atmospheric CO_2 is at the higher end of the IPCC range.

This conclusion illustrates another purpose of the meeting, bringing together modellers and the geologists who piece together past climate from rock types and fossils. By the second day of the meeting, representatives of both groups were swapping ideas and planning collaborations. Meanwhile, there are various improvements for Barron *et al.* to make to their model. André Berger (Université Catholique, Louvain) pointed out that the model should take account of the lower solar irradiance in Cretaceous times (although this would probably drive the required climate sensitivity to even higher values). Mark Chandler (NASA GISS) and John Mitchell (UK Meteorological Office) both raised questions about the role that ocean heat transport might have played in the Cretaceous. But the overall message remains: the past seems to be yielding clues about the future. □

* *Palaeoclimates and their modelling*, 24–25 Feb. 1993.

Gabrielle Walker is an assistant editor of Nature.

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