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Geologists on the road to Kyoto

1.1 SCEPTICISM AND SCHOLARSHIP

Scholars are inclined to be sceptical, especially about the work of academic rivals. Awkward questions in seminars are admired, and established views are there to be challenged by new thoughts and new evidence. The academic cliché is that the passions run highest when the stakes are lowest. Some thirty years ago I had furious public arguments with distant colleagues, about the significance of variations in the thickness of sandstones formed hundreds of millions of years ago. These exchanges remained of very little interest to anybody but ourselves, even when later some of the ideas were put to use by the oil industry. But occasionally scientists do emerge blinking into the spotlight because they are arguing about something that really is important to everybody else. Around the turn of the century that became true for those studying climate change.

Just as climate change became a familiar headline in daily newspapers, as well as in academic journals such as *Science* and *Nature*, so the consensus amongst scientists that we did indeed have a problem became established (Oreskes, 2004). This is epitomised by the successive Reports of the Intergovernmental Panel on Climate Change (IPCC), which include the (1996) Report that immediately preceded the Kyoto Protocol of 1997. The IPCC is a scientific intergovernmental body set up by the World Meteorological Organisation and the United Nations Environment Programme: at time of writing its latest report was issued a couple of years ago (IPCC, 2007).

The notion of scientific agreement on climate change was spread to a wider public by former USA Vice President Al Gore in his film and book *An Inconvenient Truth* (2006). But once an issue such as climate change becomes public property, the habitual scepticism of scientists about conventional truths and consensus can be turned against them. This can be done with particular enthusiasm by those not habitually involved in the excruciating detail involved at the very core of the underlying scientific discussion. Climate-change sceptics such as Nigel Lawson (Lord Lawson) (2006, 2008) and Professor Bjorn Lomborg (2001), alerted by the implications for their own special areas of interest in economics, politics and finance, feel free to pick out the pips from fruity items of debate in the heavy crop of scientific agreement.

The public case for anthropogenic climate change, and a warming planet, has been made most strongly by climatologists using recent trends and computer forecasts. This focus on contemporary events has convinced the insiders, and the IPCC, but has dangers in carrying the case to the general public. Many people on this planet have livelihoods governed by weather. They are obliged to take a keen interest in weather day by day and season by season. They will therefore know at least something of the difference between weather and climate, and may with justice believe that they have already learned enough to take a view on present-day climate change. What happens to the scientists' case for anthropogenic climate change if it gets colder for a while, not warmer? It is conceivable – if perhaps unlikely – that the planet might be about to experience a natural, non-anthropogenic decade or so of global cooling that interrupts briefly the proven overall warming trend. Were that to happen, there would be public cries of triumph from the climate-change sceptics, and an even more elaborate global tour by Gore to explain that this was indeed just an interruption and, yes, we really did still have a problem.

At this point the scientific experts might reasonably become quite testy, sure in their belief that they are right and the public is being misled by unscrupulous characters who either don't understand the science properly or, even worse, are being deliberately misleading. To a degree that is happening already, even with the climatological data so strongly in favour of the case for

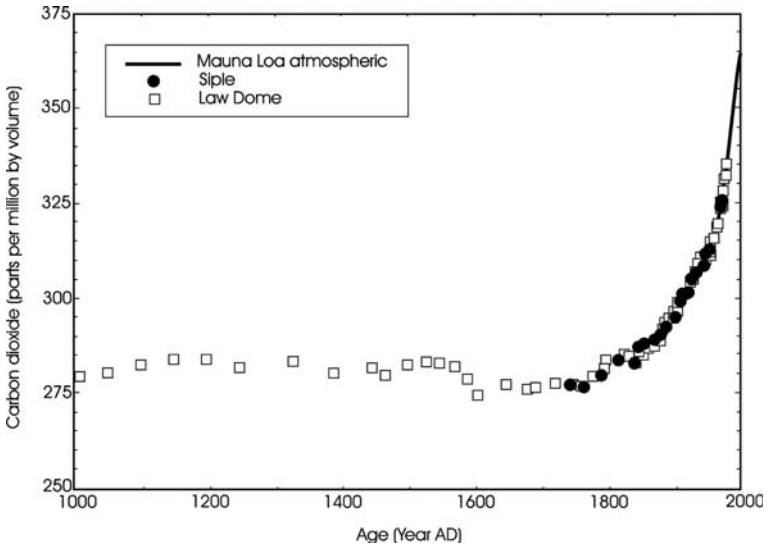

Figure 1.1 The increase in the concentration of carbon dioxide in Earth's atmosphere over the last 1000 years, in parts per million by volume. The historical evidence comes from gas trapped in Antarctic ice, supported by recent direct measurements of the atmosphere (see Figure 1.2). After a slide shown by Dr Eric Wolff of the British Antarctic Survey at the Geological Society meeting on *Coping with Climate Change* in March 2003.

anthropogenic climate change. To what evidence may the experts appeal to finally carry widespread conviction? A theme of this book, spelled out in the next chapter, is that the answer lies in the ground as well as in the skies.

We have some observational science to hand that no reasonable person can dispute. One observation is that the concentration of carbon dioxide in Earth's atmosphere has increased sharply since the Industrial Revolution (Figure 1.1, Figure 1.2) and that increase has been caused by us. Because carbon dioxide is a greenhouse gas, we would expect this increase in concentration to lead to higher temperatures at Earth's surface. The other observation is that the climate on this planet has changed a good deal in the past through 'natural' (non-anthropogenic) means, in some cases suddenly, long before we were around to understand any part of it (McManus, 2004) (Figure 1.3). Some of the more significant of these

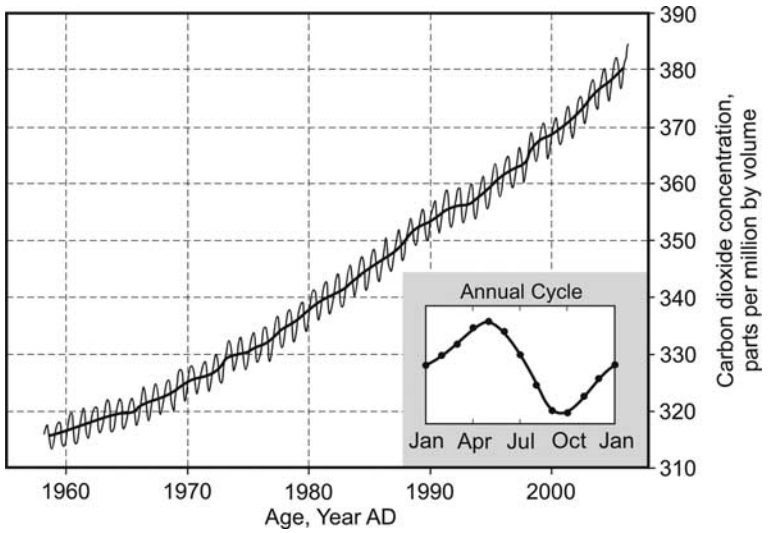

Figure 1.2 Detail from Figure 1.1 of the recent sharp increase in the atmospheric concentration of carbon dioxide recorded at Mauna Loa, Hawaii by Scripps Institution of Oceanography and US National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory. The annual cycle is not attributed to human activities, but we are held responsible for the overall trend.

changes appear to have been caused by 'natural' releases of carbon dioxide, a topic covered in some detail in Chapter 2.

There is a temptation to be fatalistic in reacting to this history of climate change in which we played no part. If all this change is going on anyway, why should we be concerned that we might now be interfering in some way? The answer comes from the geological record, and brings naught for our comfort. Study of past changes in climate, recorded in ice and rocks, has led many of us to believe that we are creating a serious potential problem for ourselves by releasing so much carbon dioxide into the atmosphere. A sudden warming event recorded 55 million years ago (55 Ma), caused by a natural, large and rapid release of carbon to the atmosphere, provides a particularly significant guide from the past to coping with our present concerns. The nature and origin of this 55 Ma event are discussed in Chapter 2. The official somewhat daunting official title of the event is Paleocene–Eocene Thermal Maximum, or PETM to its intimates.

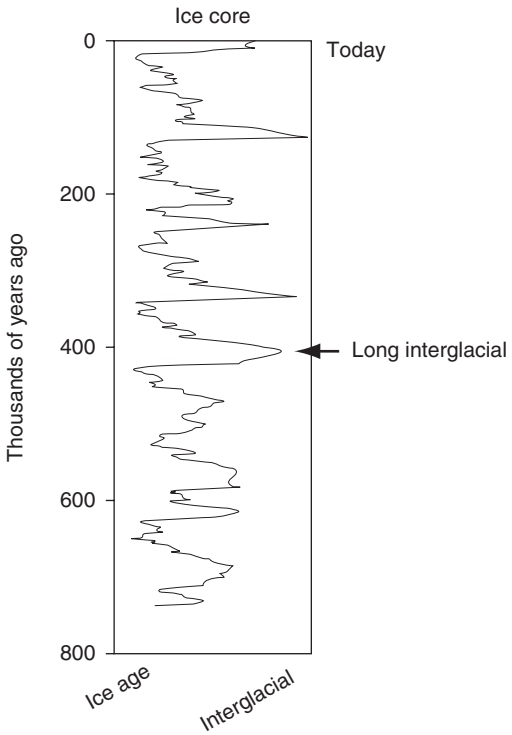

Figure 1.3 Rapid climate changes over the last 800 000 years recorded in Antarctic ice. This sketch is after a section of the figure in a 'News and Views' feature in *Nature*, 'A great grand-daddy of ice cores', by Professor Jerry McManus (2004), marking the publication of an article in that journal by the EPICA consortium (European Project for Ice Coring in Antarctica). The air temperatures over Antarctica are inferred from the ratio of deuterium and hydrogen in the ice at Dome C. The interglacial through which we are now living is thought likely to be of comparable duration to the 'Long interglacial' (more formally known as 'Marine Isotope Stage 11') indicated on this sketch (see also Figure 1.4).

Those same changes in climate deep in geological history have for many years been interpreted differently by others. These past changes have provided the basis for a scepticism that is different from that of Lawson and Lomborg and potentially far more damaging to us all in practice: the scepticism of the oil industry. Few of us involved in exploration and production in recent years can afford to be sanctimonious about the doubt

promoted by sections of our industry. Yet although cynics will rapidly point out that it was in our commercial interests to deny the scientific evidence, we did have reasonable as well as unreasonable concern about the rationale behind the attacks mounted on us by the environmentalists.

In the mid-1960s, some time before I came to work full-time in the oil industry, I was a research student at Harvard University, working in the diverse group led by the late Professor Raymond Siever. Siever was a scientist recognised for his rare ability to consider Earth as a whole, in particular as a pioneer of modern global geochemistry. In his classes he introduced us to quantitative analysis of Earth's carbon cycle, but he remained cautious at that stage and for some years thereafter in predicting the effects on climate of the excess anthropogenic carbon dioxide (Press and Siever, 1978, pp. 319–321). Later he became a good deal less cautious. In May 1997 I met Ray and his wife Doris for an elegant English afternoon tea in London. The slightly decadent air of the richly upholstered lounge of the Park Lane Hotel was the perfect setting for the new tale he had to tell me.

That afternoon, as we set about the scones, I proudly recited the key equations I had learnt in his class, alongside Miriam Kastner and Fred Schwab, both of whom were to become influential participants in the climate-change debate decades later (Professor Kastner was a contributor to the 2003 BP–ExxonMobil debate on climate change considered in detail in Chapter 3; see Professor Schwab's (2007) article in *Geotimes* for an example of his pungent approach to the issue). But Siever chastised me for 'characteristically remembering the relevant equations perfectly, except for the critical number giving the maximum rate at which excess carbon dioxide might be absorbed into the ocean'. He had recently made new calculations of global warming in the light of data showing a continuing rapid increase in the atmospheric concentration of carbon dioxide, collected from Hawaii by Professor David Keeling (Figure 1.2). Nodding emphatically over the Earl Grey tea, Siever assured me that we were indeed facing a serious problem.

During the years between these encounters with Siever, much of that time involved with and then embedded in the oil industry, I was not much concerned about climate change. I was

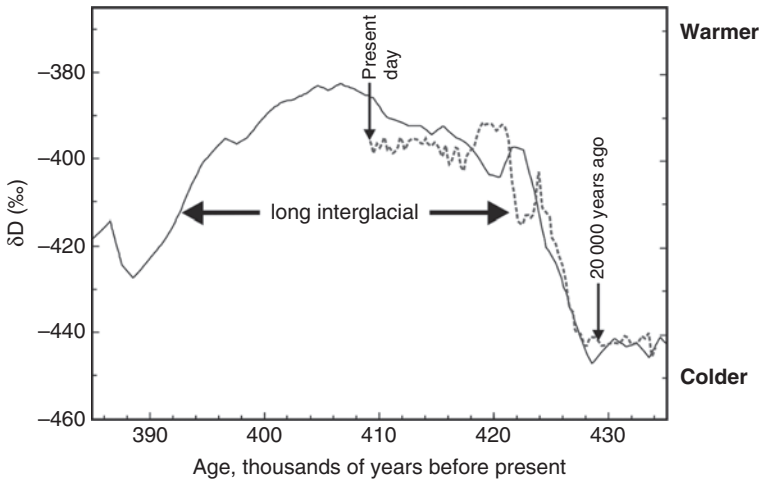

Figure 1.4 This sketch is after Figure 5 in the EPICA (2004) article in *Nature* (lead author Eric Wolff, see Figure 1.1), reporting on the 'great grand-daddy of ice cores' introduced in Figure 1.3. A measure of deuterium against hydrogen is plotted against the vertical axis. The lower the number (upwards on the graph) the higher the inferred temperature. Two ages are compared: the 'Long interglacial' of Figure 1.3, an interglacial 400 000 years ago (continuous line, lower horizontal axis) and the present interglacial (dashed line on same scale). The beguiling similarity of these two curves is being examined closely (Dickson *et al.*, 2009).

reassured by the belief that any global warming caused by our pursuit and use of fossil fuels was at worst postponing an oncoming ice age – or at least 'a long-term trend over the next seven thousand years … toward extensive Northern Hemisphere glaciation' (Hays, Imbrie and Shackleton, 1976, p. 1121). The last crumb of comfort on that score disappeared when I read the results of work on Antarctic ice cores by Dr Eric Wolff and his colleagues (EPICA community members, 2004, p. 623) who concluded: 'our results may imply that without human intervention, a climate similar to the present one would extend well into the future'. Figure 1.4 shows the basis for Wolff's conclusion that we cannot rely on an impending ice age to counterbalance anthropogenic warming.

In the face of the steadily growing evidence from both ice and rocks, even putatively self-centred oil folk can change their minds. But can they change their behaviour too? Does it matter if

they don't? For all our sakes the answer to those two questions had better be yes.

1.2 GEOLOGISTS, THE OIL INDUSTRY AND CLIMATE CHANGE

The oil industry has earned a reputation for being sceptical about the hypothesis that significant climate change is caused by the use of fossil fuels. The most obvious reason for this scepticism is self-interest. That unremarkable conclusion does not get us very far. There is another less obvious reason that lies in the educational background and technical expertise of those working in the oil industry.

Experienced, highly trained and scientifically literate geologists and engineers dominate the oil industry. They generally share the most senior positions and they certainly do a great deal of the work to find and produce the oil and gas. Their years of operational experience incline them to scepticism about computer-based models of complicated natural systems: their own forecasts on rocks and fluids and their interaction are constantly tested and at times found wanting. When it comes to considering climate change, they are more likely to be convinced by appeals to geological evidence, such as that from the 55 Ma warming event.

Like many others, I enjoy being part of a discussion that converts a sceptic to your cause. I have instigated conversations on climate change with colleagues in the oil capitals of North America, in Anchorage, Calgary and Houston, in the hope of such an outcome. Some of the best of these discussions have been with my friend Elsworth Boswell in bars in conservative Midland, Texas. Bars in Midland are not necessarily a natural habitat for a former resident of Massachusetts, even when he is fortified by Samuel Adams Boston beer. Boswell, a veteran oil man (and former Little League baseball coach of George W. Bush) was a welcome companion, although our discussions seldom ended with any change of mind or heart. Apart from the fun of the exchange itself, why persist with the argument? What is the practical use of convincing sceptical oil folk that we do indeed have a problem with climate change?

The answer is that these same petroleum geologists and petroleum engineers also have the expertise, possessed by few others, to work together to put large volumes of carbon dioxide into safe underground storage; a process now regarded by some politicians, scientists and oil folk as the ultimate carbon offset. The hard heads in the oil industry are not likely to talk of salvation, but they believe they can offer a solution. They might say: 'If carbon is the problem, we can deal with it. But we shall of course require a fee for doing so. You can pay us twice, once for taking fossil carbon out of the ground, then again for putting it back when you've had the use of it.'

A readiness to 'put it back' requires conviction on the part of a petroleum geologist that this is worth doing for reasons that lie beyond dollars. As noted, the scientific case for anthropogenic climate change has been presented most forcefully by climatologists, rather than by geologists, who have until quite recently tended to be more sceptical. As research into climate change has expanded, so a new breed of Earth scientist has evolved, with the ability to look both backwards and forwards in time. But it remains broadly true that climatologists focus on predictions of the future, relying on a combination of observation of past trends and computer modelling to make their forecasts. Geologists look back in time, using the present as the key to the past. They rely on observation of the geological record of past changes in climate to guide their views on what might happen in future: they are happiest when basing their predictions on the solid ground of rocks. They nurse suspicions of computer models that predict behaviour of planet Earth in the absence of an understanding of all the major controls, even in the face of crisp reassurance by the Royal Society (2007) (Table 1.1), presented in a tastefully green-shaded booklet that sets a standard for effective communication of multidisciplinary science to a wider audience.

So what does constitute really solid evidence for a geologist? As will be set out in some detail in Chapter 2, examination of cores of sediment recovered from drilling into layers of rock beneath the floor of the Atlantic Ocean shows clearly that an episode of global warming occurred 55 million years ago (Norris and Röhl, 1999). Thanks to major advances in dating of rocks

Table 1.1 *The Royal Society gives reassurance about computer modelling of future climate. Here is the answer to 'Misleading Argument 5' in the Royal Society's (2007) brochure:* Climate Change Controversies: A Simple Guide.

Misleading argument: computer models which predict the future climate are unreliable and based on a series of assumptions.

What does the science say?

Modern climate models have become increasingly accurate in reproducing how the real climate works. They are based on our understanding of basic scientific principles, observations of the climate and our understanding of how it functions.

By creating computer simulations of how different components of the climate system – clouds, the Sun, oceans, the living world, pollutants in the atmosphere and so on – behave and interact, scientists have been able to reproduce the overall course of the climate in the last century. Using this understanding of the climate system, scientists are then able to project what is likely to happen in the future, based on various assumptions about human activities.

It is important to note that computer models cannot exactly predict the future, since there are so many unknowns concerning what might happen …

… While climate models are now able to reproduce past and present changes in the global climate rather well, they are not, as yet, sufficiently well-developed to project accurately all the details of the impacts we might see at regional or local levels. They do, however, give us a reliable guide to the direction of future climate change. The reliability also continues to be improved through the use of new techniques and technologies.

made during the twentieth century, it is now possible to examine the evidence of that warming episode using a timescale with a resolution of thousands of years rather than the million or so years previously attainable.

The key to this high-definition timescale is the hypothesis advanced by Milankovitch (1941) that regular cycles in Earth's climate are caused by regular variations in the amount of heat received from the Sun. These periodic variations in insolation are related to three aspects of Earth's orbit around the Sun. These