VIEWPOINT

Global Warming

Climatic shifts, both worldwide and in so many separate regions, clearly indicate that global warming is upon us. Certainly its impacts on mankind are growing to unprecedented levels. But is this really the greatest of all geological events, or is it just a repeat of numerous climatic oscillations both in and before the Pleistocene? The latter option then raises the question of whether, or perhaps more truthfully, how much, global warming is natural or is man-induced.

It does seem perhaps a touch presumptuous, or even arrogant, to reckon that mankind can have a really major influence on the Earth's massive environmental systems. However, there is now plenty of clear evidence to show that some of man's activities are having an impact on global climates. But just how much remains open to debate - particularly by a geologist, who sees far greater environmental changes at many times in the past, when man was certainly not involved. The geological story seems to be rather overlooked in the rush to blame everything on man's current activities.

Effects and impacts

The effects of global warming will certainly be dramatic in the long term. They are already noticeable within lifetimes, and are likely to accelerate. On the small scale, there will be many notable weather changes. Britain will have wetter winters and warmer summers; the latter could be welcomed, but there will be more storms, and river flooding will increase. The worldwide retreat of glaciers will continue and may accelerate (Fig. 1). Half the Alpine ski resorts will be devoid of adequate snow. On the grander scale, ocean currents will shift, and there is a theoretical possibility of the Gulf Stream and North Atlantic Drift shutting down, with massive effect on our part of NW Europe.

Patterns of agriculture will shift, and cereal production will be greatly reduced or be forced to re-locate. Water shortages will become even more acute in some areas, and mass migrations of mankind may be driven by desperation. In the natural world, a third of animal species will face displacement or extinction. Some ice sheets will continue to diminish, particularly by break up of floating ice, though the Antarctica ice sheet may increase in mass due to increased snowfall. An ice-free Arctic Ocean by 2100 is a distinct possibility, perhaps bad news for polar bears (though they did seem to survive the far greater natural climatic changes in and since the Pleistocene).

Perhaps the greatest impact will be a rising sea-level - or to be precise a sea-level that continues to rise but at a greater rate. Only partly due to melting of the world's few remaining ice-caps, this is largely due to expansion of the sea-water as it is warmed. Sea-level rise within the next 100 years is expected to be about a metre (though there is a huge range in the predictions), compared too about 0.2 m in each of the last few centuries. Coastal flooding will occur, with notable impact in countries like Bangladesh, and in the huge number of coastal mega-cities around the world. Add to this, in some areas, the increased frequency of hurricanes and their resultant storm surges; New Orleans will not be the only one to suffer in a big way. Closer to home, the Thames Barrier is only designed to protect London until about 2030, and will need a major rebuild. Undoubtedly, sea-levels will rise, but the questions remain as to how much, and, more significantly - natural or man-made?

Man-made or natural?

Man's activity is undoubtedly part of the problem; the question is how big a part? On the grand scale, this question has been addressed by a succession of reports from the Intergovernmental Panel on Climate Change (IPCC), under the auspices of the World Meteorological Organisation and the United Nations. This panel is a very large group (of indeterminate size) of scientists who bring in a huge background of knowledge. There are however political undercurrents within the panel and in its report preparation, so that the group is discredited by various other groups of scientists. The facts gathered by IPCC are spectacular and undeniable, but the deductions from them are not all pure science. It is these deductions that are fed out

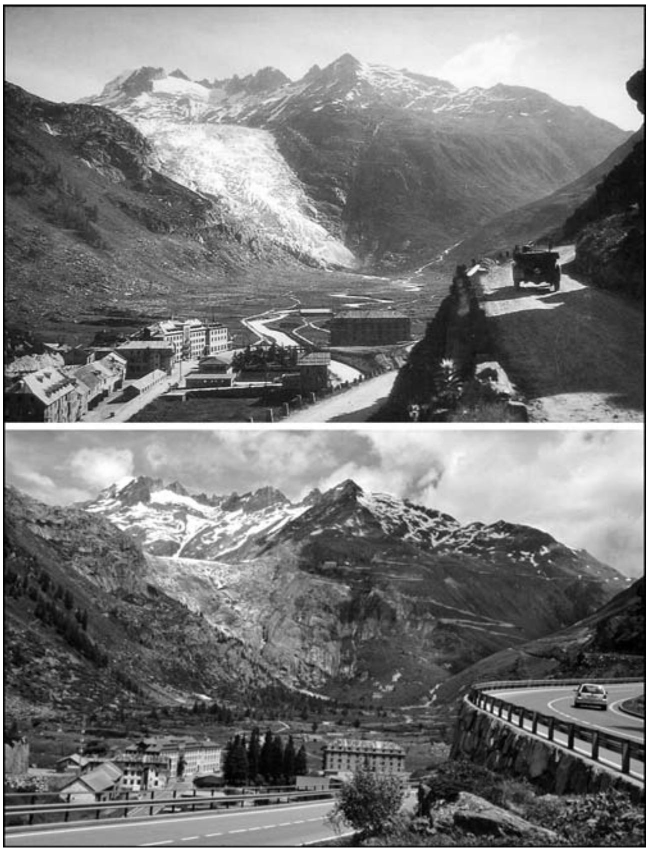

***Figure 1**. Retreat of the Rhone Glacier in Switzerland, seen in similar views from above Gletsch in 1932 and 2005.*

to the outside world, where the next link in the chain is the media - for whom a good story can be more important than real science.

In February 2007, publication of the IPCC Fourth Report produced a flurry of alarmist press headlines. In summarising that report, one respected newspaper stated that it was "unequivocal that climate change is happening and that humans are contributing". That was fine, but in the same newspaper the next day, this changed to "unequivocal that warming is almost certainly man-made". A rather different story, but environmental journalists have to hype their stories to keep their jobs. Another national newspaper said "the IPCC report says there is a >90% chance that mankind is to blame", whereas IPCC actually said only that there is a >90% chance that there is a link between man's activity and climate change. Again a significant distortion of the original.

The sceptic may also question the computer models from which the IPCC predictions are derived. Though these models are steadily increasing in capability, they are notorious for producing results so sensitive to their inputs that they have to be read with enormous margins of doubt; "junk in, junk out" is the old modellers' maxim. Memories might do well to reach back to *Limits to Growth*, the infamous doom-and-gloom publication of 1972 prepared by an independent group of scientists and thinkers known as the Club of Rome. They predicted, among many other things, when various mineral resources would run out - most conspicuously that the world's oil could be gone by 1990! They misjudged the scale of industrial development, totally under-estimated mineral exploration potential, and based their predictions on rather inadequate computer programmes. It was the best possible at that time. Its warning of resource depletion was sound in principle, but its predictions were so unreal as to earn a label of panic in the files of history. Comparisons with the global warming message may not be inappropriate.

The role of carbon dioxide

Much of global warming is based on carbon dioxide and the "greenhouse effect". This effect is created where there is an increase in atmospheric gases that are transparent to solar energy, which is therefore unabated as an input to the Earth system. While the same gases are barriers to terrestrially generated infra-red energy, which is therefore reduced as an output. Even though its total impact is far smaller than that of water vapour, carbon dioxide (CO_2) clearly has this effect. And CO_2 levels are rising at present. Bubbles extracted from ice cores, notably at Vostok in Antarctica, show CO_2 levels now far higher than at any time in the last 650,000 years. For most of that time, CO_2 levels have oscillated between about 180 and 300 ppm, but are now around 380 ppm; most of that rise is due to abnormal accumulation within the last 100 years (Fig. 2).

Isotopes of carbon show that the increased CO_2 is related to man's activities. Carbon-12 makes up the vast majority of carbon atoms, while carbon-13 makes up just over 1% of the atoms. Because some physical processes filter out the different isotopes, the hydrocarbons that make up wood, coal, oil and gas are depleted in carbon-13, in contrast to volcanic sources that are relatively rich in the heavier isotope. Tree-ring archives show that, since around 1850, the proportion of carbon-13 in the atmosphere has declined relative to carbon-12 (the decline in proportion is about 0.15%, which compares to a drop of only 0.03% during the post-Devensian glacial-to-interglacial warming). Over the same period, since 1850, the level of total atmospheric carbon dioxide has risen in a way that exceeds historical variability, and this coincides with mankind's increasing use of fossil fuels, firstly coal and then oil. Mankind does appear to account for a large part of the current rapid increase of atmospheric carbon dioxide.

There is however a word of caution. The Vostok ice cores do suggest a correlation between high CO_2 levels and high temperatures, but the CO_2 levels appear to have fluctuated with a lag of about 800 years behind the climatic changes. This suggests that the high CO_2 could be an effect of global warming, and not its cause. This is very reasonable, when it is known that warmer water can dissolve less CO_2 than cold water. Warm the oceans and they emit CO_2, and a few hundred years is required to establish any equilibrium across the enormous mass of ocean water. Though man-made carbon dioxide is cast as the ogre, the story may not be that simple.

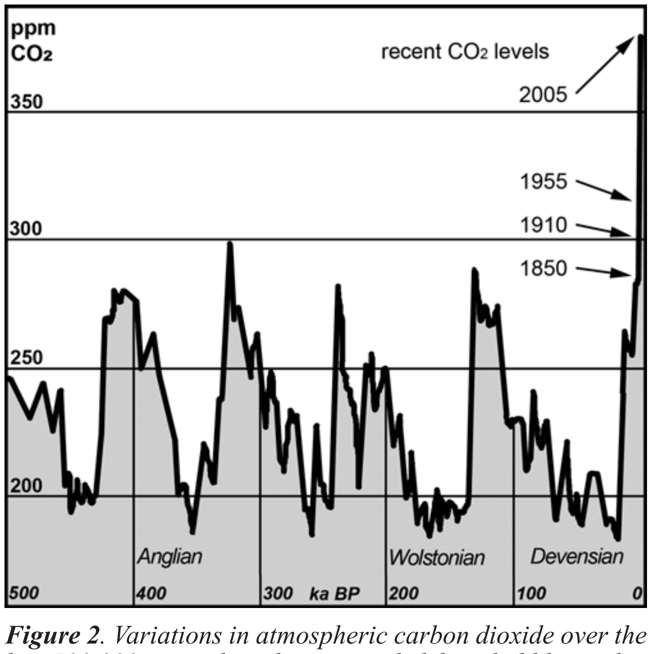

***Figure 2**. Variations in atmospheric carbon dioxide over the last 500,000 years, largely as recorded from bubbles within the ice cores at Vostok, Antarctica. The time scale is slightly distorted at the right where recent levels are dated on the steep graph (and go beyond 0 BP, which is 1950 AD).*

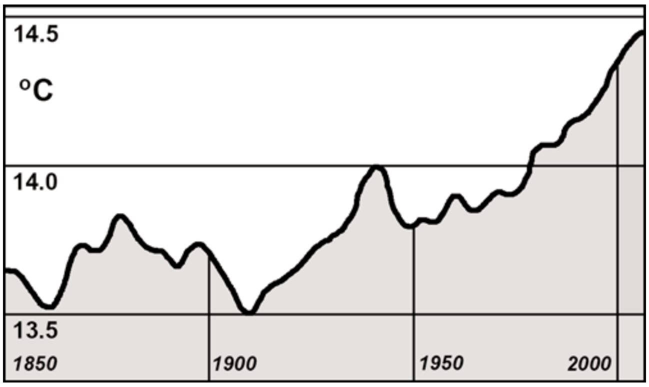

Figure 3. Rising mean global temperature from 1850 to 2006.

The geological record

Global mean temperature has risen by about 1ºC within the last 100 years (Fig. 3). Its slight acceleration around 1970 heralded the phase of global warming that is now blamed on man's own activities. But, if the geological record, from any time before 1850 AD, can show climatic changes that equal or exceed the current events, then natural global warming must be accepted as a reality - because man was not there to be the cause. It pays to look back through time.

The "Little Ice Age" (also known as the Neoglacial) started around 1300 AD, really got going around 1550, lasted about 200 years, and was then followed by almost continuous warming from before 1800 (the timing varies slightly between different continents). It is well documented. For much of the cold spell, Frost Fairs were annual events held on the ice of frozen rivers - including both the Thames and the Trent. Their demise pre-dates man's major impact on climate (the river warming by power-station water was even later). In mountain regions around the world, alpine glaciers have been seen to be in steady retreat ever since then; neoglacial retreat moraines are well known everywhere, many because they impound very scenic pro-glacial lakes.

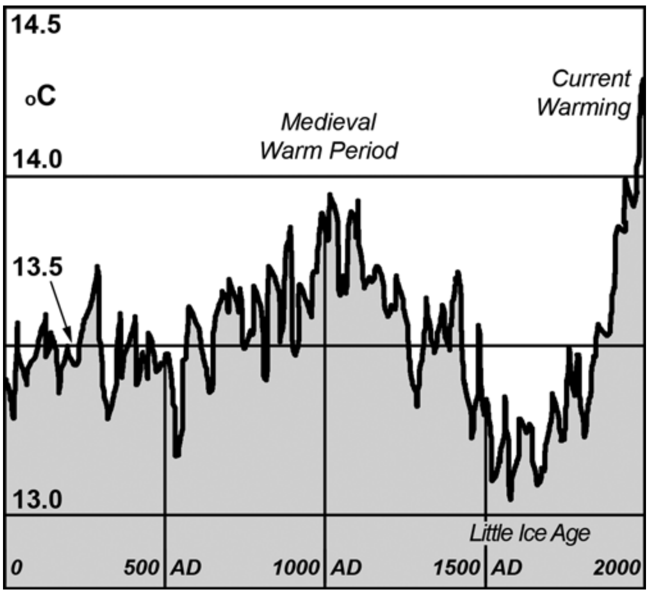

Figure 4. Mean global temperatures over the last 2000 years, spanning the Medieval Warm Period, the Little Ice Age and the current phase of warming.

Before the Little Ice Age was the Medieval Warm Period, which peaked around 800 to 1200 AD. This was the time when Greenland was colonised as a green and pleasant land full of opportunity, and the warmer climates throughout Europe are well recorded. Today's phase of global warming does not look much different from the change into that earlier warm period (Fig. 4). Today's warming is a bit greater and a bit faster, so mankind may have made the difference by increasing the current processes. But that is rather different from claiming that man caused the modern change.

A bit earlier in time, the Holocene warm period (also known as the Atlantic period), from about 8000 to 6000 years ago, was both wetter and warmer in Britain, with comparable changes elsewhere. There was a much smaller area of permafrost then, and probably much less sea ice than there is now. But this was a minor change compared with the Pleistocene Ice Ages. In each of these, global temperatures dropped by up to about 10ºC, and then rose very rapidly by an equal amount at the end of each (Fig. 5). These were phases of massive global warming, far in excess of the current events, and clearly unrelated to man's "carbon footprints". Ice cores from Greenland record a temperature increase of about 8ºC within a few decades when the Loch Lomond cold stage ended around 11,600 years ago (Fig. 6). In each full Ice Age, worldwide sea-levels dropped by more than 100 m, due to huge amounts of water trapped in the continental icecaps of the higher latitudes. When the Devensian glaciers melted, sea-level rose at a rate of about 12.5 mm/year. Compare this with the current rise rate of about 2 mm/year and rates of 3 to 9 mm/year predicted for the next century. And the 12.5 rate was without any help from mankind.

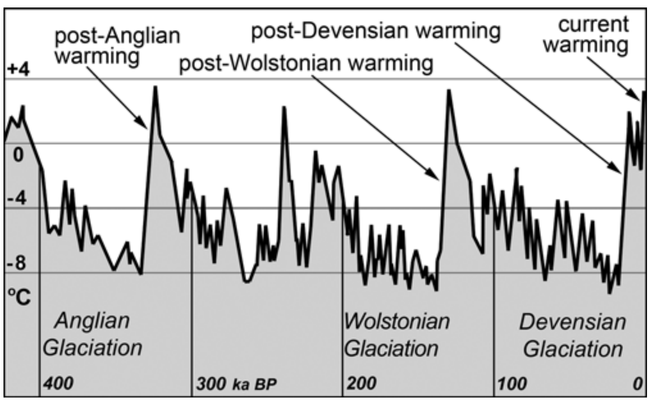

Figure 5. Variations in mean global temperatures, across an arbitrary datum, derived from ice core data, showing phases of rapid warming after each Ice Age.

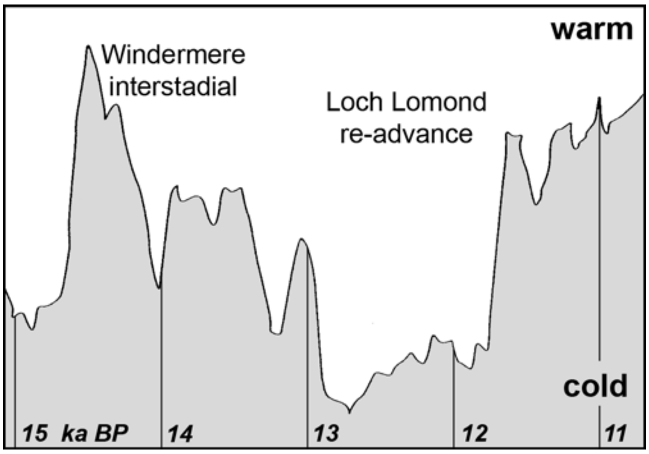

Figure 6. Global warming at the start of the Holocene, after the short-lived Loch Lomond re-advance (also known as the Younger Dryas). There is no absolute temperature scale on this ice core oxygen isotope interpretation, but it indicates a very rapid temperature rise of about 8ºC (from Peter Worsley's paper, Mercian Geologist, 2006, 16, 171).

On an even longer timescale, global climate changes were marked by extensive glaciations in the Carboniferous (the Gondwanan Glaciation) and in the Ordovician, with at least four more in the Precambrian. Each of these ended with massive global warming.

The natural causes of these pre-mankind climate changes are still not completely understood, which does allow some scope to those who blame modern global warming on man's activities. An Ice Age requires a large area of landmass at higher latitudes where icecaps can accumulate, and changes in the distribution of continents also influences the circulation of warmth by the ocean currents. But plate movements are too slow to account for the more rapid climatic oscillations within a cluster of Ice Ages, whether they are Gondwanan or Pleistocene.

The Milankovitch Cycles recognise three astronomical factors that influence the total amounts of solar radiation that reaches Earth. These factors are the variations in Earth orbit round the Sun, the changes in the Earth's axial tilt, and the precession of the Earth's axis of rotation. Each on its own is not enough to cause an Ice Age. But each has a different cycle length, and the different influences therefore coincide on longer and less regular cycles, which can account for the well-documented patterns of climate change within the Pleistocene.

On shorter time-scales, sunspot activity influences our dosage of solar energy, and this correlates very well with temperature change through the last few hundred years, notably the temperature decline through the 1940s that was in opposition to man's influence by the massive, post-war industrial growth. However, this data, often cited by sceptics, only correlates well with temperature up until about 1972 (when first recognised by Danish scientists), particularly when some of the temperature peaks are

There is a mountain of "Further Reading" relevant to the understanding of global warming. On the web, the latest report from the IPCC is a free download from www.ipcc.ch/SPM2feb07.pdf , while an opposing view is at www.co2science.org/scripts/CO2ScienceB2C/Index.jsp . On paper, the geological factors are well expounded by Peter Fookes and Mark Lee in Geology Today (Climate variation - a simple geological perspective: v23, p66-73, 2007), while the IPCC conclusions are summarised and expanded in New Scientist (Climate change: v193, n2590, p6-9, 10 Feb 2007).

statistically smoothed out. Since about 1976, the trend of global warming has been opposite to that of solar activity (Fig. 7). Though solar activity appears to have been a contributory factor in the past, it is clearly not the primary cause of global warming. It is also well known that some temperature variations within the last 700 years have been due to volcanic eruptions that modified the atmosphere by their dust input. But, along with meteorite impacts, volcanoes are not cyclic, and belong in the list of smaller natural factors.

Ice Ages and lesser periods of cooling are not the only signs of climatic change held in the geological record. The stratigraphical record shows an abundance of sedimentary cycles, notably those of the Coal Measures, the Blue Lias, less conspicuous banding within limestones, and a host of others. The causes of these are not all understood, and climatic cycles vie with tectonic cycles as the more plausible for individual sequences. But they do record changes in the Earth's environment that are major and totally natural. The scale and power of these natural changes is rather overlooked in the heated debate on the current climatic shift - which is quite small in comparison with many in the geological record.

There remains the question of how important are "snowball effects", where a small event can trigger a chain of larger events. Computers are good at modelling these chain reactions, but only when the input data is totally sound, and that is not easy in modelling something as complex as the Earth's environment. Mass extinctions lie alongside Ice Ages

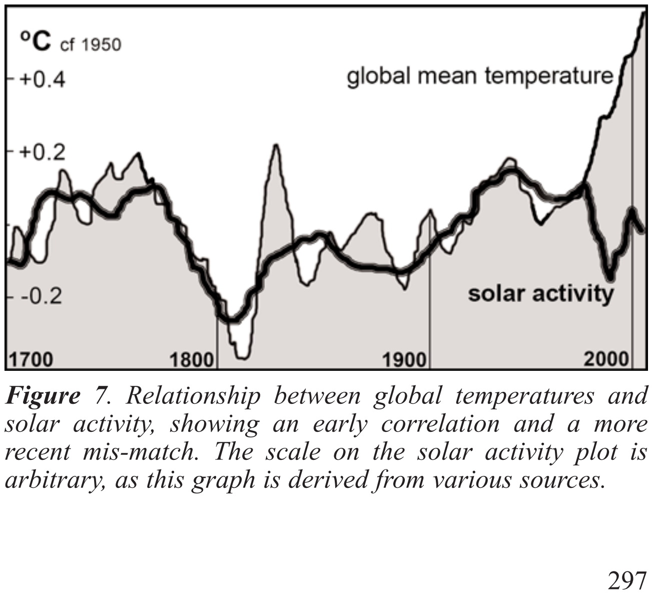

Figure 7. Relationship between global temperatures and solar activity, showing an early correlation and a more recent mis-match. The scale on the solar activity plot is arbitrary, as this graph is derived from various sources.

as examples of the end-result. The trigger event could be the closing of a seaway between oceans, expansion of an icecap on a new mountain range, or a volcanic eruption. Or it could be man's input of a major dose of carbon dioxide. Significantly, man's contribution cannot be overlooked, but neither can the very large number of natural factors.

The way ahead

The geological record does show enormous and global changes in climate, including periods of very significant global warming. We are now in one of those warming phases, and have been for about the last 300 years (since the Little Ice Age) or for about the last 12,000 years (since the Loch Lomond retreat); and we now have an increased effect from the superimposition of the small-scale and large-scale cycles. There is also evidence of accelerated warming over the last 50 years or so, which does appear to correlate with environmental changes induced by mankind. It therefore appears that mankind is contributing to global warming. This is very different from saying that he is causing global warming. And the scale of the contribution remains open to debate.

As pointed out by the US Centre for Atmospheric Research, "no matter how much humanity reduces gas emissions, global warming and sea-level rise will continue for hundreds of years"; this is largely due to the slow response of thermal change in the oceans. So if sea-level rise is threatening a huge swathe of mankind, and is a geologically normal and unstoppable process, would it not be better to take more positive action to mitigate the damaging effects of this, rather than "reducing the carbon footprint" - which cripples industry in developing countries and enforces regulations on people everywhere (with everyone carefully side-stepping the nuclear option, which has to be the future in our resource-challenged world and has minimal carbon impact). The reductions in available space on dry land could be accommodated with ease if the effort that is going into the problem of global warming went into dismantling the religious and nationalistic barriers to population control. There are other direct impacts from global warming, notably on patterns of agriculture. But these are solvable, and there are far greater problems in disease pandemics and in the incessant warfare in Africa, to name but two. By focussing so heavily on global warming, mankind may be missing the point.

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Though this essay has been prepared by the Editor of Mercian Geologist, it is only a personal view, and is not presented as an authoritative editorial; it has been accepted by the Editorial Board as an interesting viewpoint that is a worthwhile contribution to the ongoing debate. Further contributions, debate and criticism will be welcome for the next issue of the journal.

REVIEWS

Fluorite, the Collectors Choice, edited by Jesse Fisher and others 2006. Lithographic LLC: Connecticut. ISBN 0-9715371-9-4, 128 pp. $30.
[*in UK from - Ian Bruce, PO#3967, Yeovil BA20 9AH (ian@crystalclassics.co.uk); Philip Taylor, Egis Lion House, Dyce Avenue, Dyce, Aberdeen AB21 0LQ; Paul Lowe, 3B United Downs Ind. Park, St Day, Redruth TR16 5HY (paul@lowestone.com)*].

This is a beautifully produced book with numerous fine coloured illustrations. It is number nine in an unspecified series. Aimed at the mineral collector it has been compiled by 33 contributors from countries around the world, only one British (Ian Jones, of Cardiff). Some entries were translated from other languages but it is not made clear which they were.

The book opens with one page on the classical banded myrrhine, which resembles Derbyshire's Blue John: a precis of its history is given but nothing is said about the original deposits generally thought to be in eastern Iran. An introductory chapter includes notes on atomic structure, crystallography, colour, commercial uses, fluorescence, luminescence and on the many variations of crystal habit from cubes with or without bevelled edges, through octahedra to highly complex forms some of which are almost spherical!

The main part of the book is divided into entries by continent and country. These are of a very varied standard, some give maps locating fluorite deposits, but most do not. Some outline the geological setting, but regrettably most do not. Instead emphasis is placed on the experiences of collectors. There are ten pages on British fluorites, including one page on Blue John, where the author was unaware of your reviewer's book on *Derbyshire Blue John* (Landmark, Ashbourne). Maps are given of Co. Durham and Cornwall but the Peak District gets short shrift. Other European countries with choice fluorites include Spain, France and Switzerland but are there no fluorites worth recording in the rest of Europe?

Numerous localities in USA, Canada and Mexico are noted in the chapter on the Americas, but the only country listed in South America is Peru. Asian countries include Russia, China, Pakistan and Japan. The Chinese equivalent of Blue John, now to be seen in many tourist shops throughout Europe in the form of carved animals and other ornaments is not mentioned. African fluorites seem to be restricted to Morocco and South Africa. Australia has no mention.

The book concludes with some useful short chapters on cutting facetted gemstones from fluorite, on fluid and gaseous inclusions, and on cleaning crystals. There is a two page list of references. From the attractive appearance of this book on Fluorite I expected a much more comprehensive treatment of *all* countries with fluorite deposits and of the geological setting of those deposits – I was disappointed.

Trevor Ford