CAM QUA

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Global warming: a perspective from earth history

A position paper of the Stratigraphy Commission of
the Geological Society of London

Global climate change is increasingly recognised as the key threat to the continued development - and even survival - of humanity. Here, we give the context obtained from earth history, as the pattern of global environmental change in the past provides an indispensable context to establishing likely trajectories of future climate change. We find that the evidence for human-induced climate change is now persuasive, and the need for direct action compelling.

Ice Age climate

Ice Age climate change has been rapid, pervasive and frequent. For instance, during the last 2.6 million years, the duration of the current Ice Age, there have been 104 major fluctuations between global cold and global warmth. Each of the major fluctuations was itself complex, encompassing 'minor' changes of up to 5 degrees centigrade in average annual temperature. As temperature rose and fell, so did global sea level, by up to 130 metres. These changes did not lead to catastrophic global extinctions of the earth's biota. The extensive animal and plant communities of the past, undisrupted by human development, could adapt to the changes by migrating, or by shrinking or expanding populations. In shrinking animal populations, of course, there is an excess of deaths over births, by starvation or predation. Our current human population, faced with comparable climate change, will have a similar choice, and there is now little room for migration.

Our current interglacial

Human development has coincided with one of the relatively infrequent episodes of prolonged climate stability, of a little over 10,000 years since the end of the last glaciation. This episode is the latest of a series of interglacial phases which, in the last half million years, have occurred at intervals of roughly 100,000 years. It has been commonly thought that we are at the tail-end of this warm climate phase, and that feeling sharpened in the late 1990's when new data from Antarctic ice cores showed that the previous three warm phases each lasted between 6000 and 9000 years. Thus, given a similar trend, the ice-sheets would have returned to cover Europe during the ancient Egyptian or Greek civilizations, and the trend of human history would have been immeasurably different.

This year, though, the longest Antarctic ice-core record yet obtained shows that the warm phase before that, a little less than half a million years ago, lasted some 30,000 years. That long interglacial episode is thought to be the best model for our current warm phase, because of the similarity of the earth's alignment vis-à-vis the sun's rays. On these grounds, therefore, even without human intervention, another 20,000 years of warmth may be expected.

Greenhouse gas records

As regards the greenhouse gases carbon dioxide (CO_2) and methane (CH_4), the link of these to climate is now firm. The ice-cores not only preserve a detailed and reproducible record of global temperature (deduced from isotope ratios); they also contain a record of atmospheric composition, now going back three-quarters of a million years, as bubbles of gas trapped in the ice layers. As temperatures rose and fell, so did the levels of these gases in the atmosphere.

It is also undoubted that levels of CO_2 are now some 30% higher than at any time over the past 750,000 years, (with levels of methane having more than doubled). CO_2 levels are now increasing by nearly 1% a year, and the trend is accelerating. It is also beyond doubt that these increases are due to human activity, particularly the burning of fossil fuels, rather than being due to volcanic activity. Levels of human-sourced emission dwarf anything produced by even the largest recent eruptions (e.g. Krakatoa) and the ice-core record shows that, while records of past massive eruptions are preserved as layers rich in volcanic dust and sulphur dioxide, there are no CO_2 'spikes' of eruptive origin.

Cause and effect?

The ice-core trends of temperature and greenhouse gases match so precisely that there has been room for doubt as to what is cause and what is effect. Thus, could the temperature changes be driving CO_2/methane levels in the atmosphere (by altering patterns of global biomass production and storage) rather than the other way around? If this was true, then the currently increasing levels of CO_2 and methane need not give rise to significant global warming: they would be a consequence, rather than a cause.

The record of greenhouse gas links to climate is further muddied by records of climate change which were not global in extent. It is becoming clear, for instance, that a severe, millennium-long cooling event in the northern hemisphere, which saw an ice-cap grow over northern Scotland some 12,000 years ago, saw warming (by a kind of global see-saw effect) in the southern hemisphere. Another uncertainty of the recent record is that we are already at a temperature high of the current Ice Age, and so, climatically, are heading towards uncharted territory.

One track into this uncharted territory is to model, mathematically, the effects of increasing greenhouse gases on temperature. In these models, the earth and its various parameters need to be simplified, and there also remain considerable uncertainties, such as whether increased water vapour produced during warming will lead to further warming (water vapour being a greenhouse gas) or cooling (if the water vapour condenses to produce light-reflecting clouds). Most current models suggest global warming of between 2 and 6 degrees by the end of this century, to levels unprecedented in earth history over the past few million years.

Lessons from the deep past

An alternative approach is to look for examples in more ancient earth history, of similar phenomena to the present: that is, of sudden, massive outbursts of greenhouse gases into a world that is already warm. At least two have been identified, in the Toarcian epoch of the Jurassic Period, some 180 million years ago, and in the early Eocene Epoch, around 55 million years ago.

In both of these, the influx of greenhouse gases has been demonstrated by changes in the ratios of carbon isotopes within fossils. The isotopes themselves do not say whether mainly CO_2 or methane was involved, but plausible scenarios suggest the involvement of both (say, by deriving CO_2 from extraordinary, geologically rare volcanic outbursts, providing initial warming which in turn destabilized methane which had been stored in permafrost or in ocean floor sediments). Whatever the precise mix of gases, the amount of warming is now well established, again from isotope ratios preserved in fossils. Rapid warming of the order of between 5 and 10° C took place globally, the temperatures declining back to background values over many thousands of years, probably as the excess greenhouse gases were slowly drawn out of the atmosphere by reactions associated with rock weathering.

These geological examples strongly reinforce the modelled scenarios of global warming for later this century. Crucially, such temperature surges show the earth behaving in a non-linear fashion when reacting to environmental stress: that is, it tends to 'flip' from one quasi-stable state to another, and this kind of behaviour is inherently difficult to model or to predict. There will be, the oceanographer Wallace Broecker has said, unpleasant surprises in the greenhouse.

Consequences of climate change

Some of the likely consequences of climate change - shifts in temperature and rainfall that may create dustbowls and famine, and more frequent and violent hurricanes - have been given considerable publicity. While these represent grave problems, it has been argued that it would benefit society more to carry on with economic business as usual, and simply adapt to the new climatic circumstances. We focus here on sea level change, the impact of which is likely to be on such a scale that adaptation cannot be presented as a preferred option.

Sea level change

Sea level has constantly fluctuated in the geological past: its highest recorded level was in the Cretaceous, some 80 million years ago, when CO_2 levels were considerably higher than at present, and ice-caps were virtually absent from the earth. Then, sea level stood at least 200 metres higher than today, with most of the UK being submerged.

The sea level fluctuations of the Ice Age, as continental ice caps waxed and waned, are well known. Thus, 20,000 years ago, at the peak of the last glaciation, sea level stood some 120 metres below its present level, and Stone Age people walked across the floor of the North Sea.

The most recent analogue?

Less well known are the variable sea levels recorded in previous warm phases of the Ice Ages. For instance, in the most recent of these, some 125,000 years ago, sea level reached some 6 m higher than at present. Such a difference is geologically modest, and reflects relatively minor differences in the extent of melting of land ice. We emphasize that it occurred in a world where levels of greenhouse gases, unaffected by humans, were lower than at present.

So how much can sea level rise in a world where, say, the levels of CO_2 are at twice pre-industrial levels and where global temperatures are between 2 and 5 degrees higher? We cannot predict this precisely, but sea level rises of a few to several tens of metres would not be geologically unusual.

Ice sheets today

Even at today's slightly elevated temperatures, with a rise of around half a degree centigrade, mountain glaciers are receding significantly, as also seem to be, locally, the margins of the ice in Greenland and Antarctica. The Greenland icecap is vulnerable, and its loss would mean a sea level rise of some 7 metres. As it creates its own regional climate, its loss may be effectively permanent. In Antarctica, the recent break-up of ice shelves has precipitated increased streaming of ice from much farther inland, which potentially represents the initiation of a phase of much more serious ice-sheet collapse.

This recently observed behaviour has shown clearly that ice-sheets are not relatively inert masses responding sluggishly to temperature change. Rather they are now perceived in much more dynamic terms, showing strong - and potentially dangerous - responses to small changes in external conditions. This would accord with geological evidence indicating past ice-sheet collapses, releasing 'iceberg armadas' and causing sea level rises of several metres in a decade.

Implications

The threat to humanity is clear: such a disappearance of living space (with some 100 million people living within less than 1 metre above present sea level) would represent a virtually impossible burden to a human population that is already struggling to feed itself, and is set to add another three billions to its numbers this century.

We note that it may not be the amount of sea level rise, as its speed, which may be catastrophic for a large section of humanity. The geological record shows that the melting of icecaps does not proceed smoothly, but occurs in fits and starts. Thus, the last retreat of the great ice-sheets included at least three episodes where sea level rose some 5-10 metres within the space of a decade. This is because a modest sea level rise can destabilize the edge of a mass of land ice, causing large parts of it to rapidly slide into the sea.

The consequences of such a sea level rise would be calamitous, comparable (and perhaps including as a consequence) a global war. Unlike a world war, though, civilization cannot get back to normal afterwards, as much of the landscape will have been drowned, effectively forever. We consider the threat to be imminent, the timescale of the global changes seeming likely to include the lifespan of our children.

The central problem

We therefore add our voices to those urging more serious attention, and action, from national and international bodies. The central problem is one of the massive transfer of carbon from beneath the ground into the atmosphere, caused by humanity's enormous demands for energy, and current dependence on fossil fuels to supply by far the greatest part of this energy.

It is hard to convey the sheer scale of this carbon transfer. In numbers, it currently runs at some 6.5 billion tons each year. How can one visualize this? If the Great Pyramid of Khufu were made of diamond, the densest and most compact form of pure carbon, it would weigh some 6.5 million tons. So, globally, our annual carbon transfer, through fossil fuel burning, to the atmosphere is equivalent to one thousand Great Pyramids, all made of diamond. We burn, each year, around a million years worth of accumulated hydrocarbons.

Action

The problem can only be marginally (i.e. ineffectually) addressed by increases in alternative energy and energy efficiency; these should be promoted, but likely savings will be modest, and probably offset by population and economic growth. And, given the huge energy and material demands in the construction of, say, wind farms, the ultimate value of these is debatable. More radical solutions to humanity's dilemma are necessary, and these might include:

- massive underground sequestration of CO_2. This is not yet a proven method on anything like the scale needed, but needs to be pursued with urgency.
- large-scale capture of CO_2 from the air and its conversion into a mineralised form, perhaps as carbonate minerals.
- a large-scale switch to civil nuclear power. This has the benefit of being proven technology and, additionally, has the potential to lie at the heart of future hydrogen-based transport systems. We are acutely aware of the problems and current public unpopularity of this route, and the knock-on effects for, say, nuclear arms proliferation. Nevertheless, the dangers arising from global warming may be orders of magnitude greater than those resulting from an effectively controlled nuclear power generation programme.

We urge serious, and immediate, consideration of these issues. The dangers posed by climate change are no longer merely possible and long-term. They are probable, imminent, and global in scope.

The Stratigraphy Commission of the Geological Society of London.

Dr. Jan Zalasiewicz (Chair), Dr. Tiffany Barry (secretary), Dr. Angela Coe, Dr. David Cantrill, Professor Andy Gale, Dr. Philip Gibbard, Dr. John Gregory, Dr. Mick Oates, Professor Peter Rawson, Dr. Alan Smith.

From The Guardian (EducationGuardian.co.uk/higher/research) of Friday November 26, 2004.

Godwin Laboratory: celebration of 35 years research

A party was held on Friday 15 October 2004 to celebrate the 35 years of working partnership between Professor Sir Nicholas Shackleton and Mike Hall. Since 1969, Nick and Mike have been at the forefront of international research into the geological history of climatic change.

During their time working together, they have developed techniques to measure the stable isotopic composition of minute fossils that lived in the oceans. The isotope ratios of these calcite shells hold clues to past climates, and provide vital information for reconstructing the past, and for helping to make predictions about future climate change. These records have also provided the basis for Nick to develop a much more accurate time scale for the last 30 million years of the Earth's history.

All the technical staff, students, postgraduates and visiting scholars who have worked in the Godwin Laboratory during the 35 years, together with friends and colleagues, were invited. It was a testament to the friendliness and scientific reputation of the laboratory that on the night some 150 people attended the celebration, travelling from all over the UK and from overseas.

Over his career Nick Shackleton has received many accolades from the international scientific community, culminating in his Knighthood in 1998. His collected medals made an impressive display. Nick retired at the end of September but is still carrying out research at the Godwin laboratory as an Emeritus Professor.

The work at the Godwin Laboratory continues to develop with the recent acquisition of two new Mass Spectrometers enabling the isotopic analysis of very small carbonate samples and studies of stable isotopes in water and organic matter.

Mike said "It was good to see so many faces from the past 35 years. It was an excellent reunion for everyone. We were pleased that so many people were able to come and were surprised at the distances some people had travelled to be with us for the celebration".

Further pictures of the evening are available to view at: http://delphi.esc.cam.ac.uk/partypics.html

W(h)ither… the Godwin Institute?

CAMQUA continues to cover the story on the Godwin Institute for Quaternary Research

New Advisory Committee meets.

After over 9 months of waiting to determine the precise form that the Quaternary community's new 'institute' structure would take, an Advisory Committee met on 9 November, to consider the way forward. The changes in the Godwin institute structure, that arose following the retirement of Nick Shackleton, had led to considerable discussions, but now seem to be clear. It was confirmed by the University that the institute should continue to exist, since this was clearly the desire of the Quaternary community, as previously reported in CAMQUA.

Armed with this vote of confidence, a new Advisory Committee was convened by Phil Gibbard (Geography), who was unanimously elected as chair. The committee was drawn from representatives of each of the major groupings of Quaternary workers in the University: Tom Spencer (Geography), Martin Head (Geography), Nick McCave (Earth Sciences), David Pyle (Earth Sciences), Richard Preece (Zoology), Maryline Vautravers (Godwin Lab), Roy Switsur (Godwin Lab), Martin Jones (Archaeology) and Clare Allen (British Antarctic Survey). The wide-ranging discussion touched on the name, structure, membership and future of the organisation.

Concerning **the name**, some difficulties had been raised by the University over the continued use of 'Godwin Institute'. The name Godwin Institute of Quaternary Research was originally proposed and approved by the General Board in 1994. This name has caused confusion in the past between the Godwin Laboratory (now an isotope facility in Earth Sciences) and the umbrella, cross-departmental organisation of the Godwin Institute. The Faculty's apparent unease with the use of the terms 'Institute' or 'Centre', relates to 'the financial implication for the Departments within which they are embedded' of both terms. This view was initially downplayed but later partially confirmed. Nevertheless the importance of continuity, external perception and appropriate status were seen as vital by the Committee, including the point that the organisation was a type of 'virtual institute', the establishment (and presumably continuation) of which was being strongly encouraged by the University. The wide brand-recognition of the GIQR within, and most importantly beyond the University, meant that it was in everyone's interest that any new identity should reflect continuity with the previous structure.

If the name needed to be changed, two names emerged as alternatives:

- *Cambridge Institute of Quaternary Research (CIQR)*, the advantage of which was that although continuing the name 'Institute', it was very close to the existing name, and continued the theme of the GIQR.

-or, *Cambridge Quaternary*. The committee members were enthusiastic for the latter, which they felt fulfilled the criteria laid down by the University, but also provided a modern identity. However, this choice would not maintain the continuity with the GIQR.

Discussion on **the structure** of the institute centred around whom should be involved, communication and the public face of the organisation. The feeling was that the organisation should be only a research structure, with membership open to all Quaternary researchers in the University. Importantly, it was also agreed that individuals and groups from outside the University, such as those from the British Antarctic Survey and Anglia Polytechnic University, could also join as Associate Members.

The difficulties of keeping **members** informed across several departments was discussed at length. It was thought that one person could be appointed in each research group to co-ordinate communication. Also, a bulletin board could be established in addition to the existing GIQR website. Consultation with the Computing Officer, in Geography, Martin Lucas-Smith, said that this would not be effective.

The discussion then focussed on **external matters**. The *Quaternary Discussion Group* and *CAMQUA* newsletter would continue as normal. The possibility of the institute producing an annual report was suggested as an excellent way of publicising the group's activities. The need to undertake joint research, possibly through the establishment of an over-riding research project, like the Stage 3 Project, was agreed by all.

One important idea for re-launching the institute was to hold a one-day discussion meeting, recent successes like the *Stage 3 Symposia* and the *Early/Middle Pleistocene Transition Meeting* held in 2003 are evidence that this could be easily achieved. This idea was enthusiastically welcomed and it was agreed that members of each group should give talks or posters to illustrate their current and recent work, possibly with some invited speakers. Nick McCave agreed to co-ordinate a small organising committee to oversee the running of the meeting.

It was agreed that the Advisory Committee will meet at least once each year.

by *Phil Gibbard*

BAS, EPICA and the Quaternary

An advantage of the planned new institute is that it will allow all of us to see how diverse the Quaternary community in Cambridge is. At the British Antarctic Survey (BAS), we have a small marine and lake sediment team, and we also bring ice cores into the Cambridge scene. For those of you who don't know, BAS is a NERC institute, and it sits out on Madingley Road, just before the motorway!

BAS has been particularly strongly involved in the European Project for Ice Coring in Antarctica (EPICA). This is a consortium of groups from 10 European nations, that aims to drill two cores to bedrock in Antarctica. Unless you have been on Mars (another target for ice coring!), you will be aware that last summer EPICA took ice cores into a new realm by publishing in Nature a 740,000 year record of climate from one of the sites, Dome C. The record of carbon dioxide and methane for the same period is currently being produced and is likely to make another big splash in 2005. The drillers at Dome C reported on 22 December that the drilling operation was stopped because they have reached the target depth of 3270.2 m. This is 5 metres from where we think the true bed is. Because the ice is almost certainly melting slowly at the base, we have stopped at this depth to avoid any danger of contaminating the bed with drilling fluid. It remains to be seen if the extra ice will yield a dateable record, but if it does, we expect it will take us to 900,000 years.

We (the international ice core community) have plans to find a location with even older ice, so we hope we can contribute eventually to at least half of the Quaternary period (depending what definition is chosen!). Meanwhile, at BAS, we are very keen to work with and talk to other experts in Cambridge, so don't hesitate to get in touch.

by *Eric Wolff*, British Antarctic Survey
ewwo@bas.ac.uk

Joint QRA/IQUA Annual Field meeting: Western Ireland, *5-9 April 2005*

Organisers: Pete Coxon and Michael O'Connell
Contact: Pete Coxon

The 2005 QRA Annual Field Meeting will be based in western Ireland. More detailed and updated information may be obtained at: http://www.tcd.ie/Geography/IQUA/Index.htm

The field trip involves visits to The Burren (*karst landscape, landscape evolution, Late-glacial and Holocene vegetation and archaeology*), the limestone lowlands of east County Galway (*karst landscapes and palaeolakes, turloughs, archaeology, Pliocene lignites, and landscape evolution*), the classic Connemara landscape (*landscape evolution, glacial history, nearshore marine sediments -cool water carbonates- and archaeology*) and the mountain scenery of central western Ireland (*glacimarine(?) deltas at Letterfrack and Leenane*) and Clew Bay (*drumlins, ice limits and moraines*).

First Mini Research Conference

Lectures in Palaeoclimate

Presented by the Earth and Biosphere Institute, University of Leeds

Four distinguished palaeoclimatologists have been invited to present their work. Don't miss the opportunity to attend this exciting event in the **Lecture Theatre, School of Geography on Thursday 27th January**. The programme starts at 13:30.

Programme

13:30 Introduction

13:45 Miriam Bar-Matthews
Geological Survey of Israel, Jerusalem, Israel
"Palaeoclimate transitions and the origin of rainfall fronts in the Eastern Mediterranean - NE Sahara Desert"

14:30 Eelco Rohling
Southampton Oceanography Centre, Southampton University
"Unicellular zooplankton fossils, wind-blown dust, and African monsoon variability"

15.15 Refreshments

15:45 David Beerling
Department of Animal and Plant Sciences, University of Sheffield
"Global warming in the early Eocene: a role for non-CO_2 greenhouse gases"

16:30 Michel Crucifix
Hadley Centre for Climate Prediction and Research, Met Office
"Modelling vegetation-climate feedbacks for studying palaeoclimates"

17:15-18:00 Informal discussion with speakers
Refreshments provided.

Diary Dates, Lent Term 2005

January

SPRI Wednesday, January 19, 4.30pm. *"What do sediments on the Pacific margin of Antarctica tell us about development of, and late Quaternary fluctuations in, the West Antarctic and Antarctic Peninsula ice sheets?"* Dr. Rob Larter (British Antarctic Survey)

QDG Friday, Friday 21, 8.30pm. *"Millennial-scale sea level in the last glacial cycle: amplitudes resolved by monte carlo modelling of coral reef sequences, and the fraught question of U-series dating of salient events"* Prof. John Chappell (The Australian National University)

February

SPRI Wednesday, February 2, 4.30pm. *"Seminar title to be confirmed (Himalayan glaciology & climate change)"* Dr. Doug Benn (University of St. Andrews)

SPRI Wednesday, February 16, 4.30pm. *"Periglacial trimlines, palaeonunataks and the dimensions of the last British Ice Sheet"* Prof. Colin Ballantyne (University of St. Andrews)

ARCH Friday, February 18, 1.15pm. *"Long-term landscape history of riparian areas of northern New Mexico over the last 6000 years"* Dr. Charly French (Dept. of Archeology, University of Cambridge)

March

QDG Friday, March 4, 8.30pm. *"Glacial History of the Pindus Mountains, Greece"* Dr. Philip Hughes (University of Manchester)

ARCH Thursday, March 10, 1.15pm. *"The extinction of a Mediterranean shallow lake throughout the Holocene"* Andrea Balbo (Dept. of Archeology, University of Cambridge)

SPRI Wednesday, March 16, 4.30pm *"Seminar title to be confirmed"* Dr. Doug Mair (University of Aberdeen)

ARCH Friday, March 18, 1.15pm. *"Exploring the origins of cultivated broomcorn millet through genetic markers"* Dr. Harriet Hunt (McDonald Institute for Archeological Research, University of Cambridge)

QDG Friday, March 18, 8.30pm. *"Cairngorms — move over Dartmoor"* Dr. Adrian Hall (Fettes College, Edinburgh, Scotland)

QDG talks to be held in West Court, Clare Hall, Hershel Road.
Enquiries contact: M. J. Head, (3)39751, (martin.head@geog.cam.ac.uk)

SPRI seminars to be held in the Scott Polar Research Institute Lecture theatre.
Enquiries contact: Jeff Evans, (3)36570, (jeffrey.evans@spri.cam.ac.uk)

ARCH Talks of the George Pitt-Rivers bioarchaeology laboratory are held in the McDonald Institute lecture room (ground floor). Full program on http://www.arch.cam.ac.uk/pittrivers/GPRtalks.html
Enquiries contact: Rachel Ballantyne, (3)33537, (rmb51@hermes.cam.ac.uk)

Deadlines: Contributions for the next issue of CAMQUA should be submitted before the start of next term.

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