GA Conference 2017, Cardiff

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Speakers' Abstracts

Earth's Climate Evolution - a New Geological Perspective

Geology tells us that Earth's climate operates within a narrow envelope of change driven by (a) plate tectonics (volcanic supply of CO_2 and its extraction from the atmosphere by chemical weathering); (b) orbital and axial variations, controlling incoming solar radiation; and (c) variations in solar output. Superimposed on these are the effects of (d) small regional internal oscillations, like El Niño events, and (e) occasional large volcanic eruptions. Our climate is ultimately driven by the Sun, but climate variability follows the pattern (a)>(b)>(c)>(d), with occasional change from (e). Over the past 2000 years Earth cooled due to (b), with minor wiggles due to (c) and (d), and occasionally (e). The combination of (b), (c) and (e) drove us into the Little Ice Age (LIA) 1350-1850 AD. Orbital and solar conditions indicate that we should still be in the LIA. So why are we not? Geology shows that increasing CO_2 creates warming, raises sea level, and acidifies the ocean. Bearing that in mind, and the decline in (c) since 1990, current warming is most likely due to growing human emissions of greenhouse gases. Hence continuing 'business as usual' will warm us more, raise our sea levels further and acidify our oceans.

Colin Summerhayes, Emeritus Associate, Scott Polar Research Institute, Cambridge University

Escaping Snowball Earth

Did the Earth really suffer the encapsulating climatic catastrophe of a Snowball Earth as some claim? The BBC website shows such a planet as an essentially white ball, but could the earth ever escape from such a highly reflective state? And how strong is the geological evidence that a shift to a completely different climate regime actually happened?

This lecture focuses on the second of two globally distributed ice ages (panglaciations) in the Neoproterozoic Era (around 635 million years before present). It sets up some critical tests of Snowball Earth theory and shows how the succession exposed in Svalbard meets these predictions. Specifically, the ice age started with a long hiatus, carbon dioxide rose to high levels during glaciation, and the glacial deposits themselves were deposited near the end of the glaciation. The ice sheets waxed and waned in the closing phases of the glaciation, which we attributed to orbital (precessional) forcing. The sedimentology and geochemistry of the deposits clearly shows cold, hyper-arid climatic conditions, like modern Antarctica, and that much of the Snowball continents was bare ground – conclusions backed by new models. Today we have an anti-Snowball as ice melts in the Arctic, but a recurrence could be expected following a nuclear war.

Ian Fairchild: Emeritus Professor, University of Birmingham

Early land vegetation and climate

Various aspects of fossil plants (eg. stomata, leaf form, growth rings) have long been considered important tools in studies of past climates. With the possible exception of stomata, such relevant characters are absent from components of early terrestrial vegetation and hence provide little information on climate parameters. However the effects of such vegetation on the atmosphere via changes in carbon dioxide concentration are hypothesised to have had profound influences on global temperatures and hence climate. This lecture will review current evidence for such impacts in Ordovician to Lower Devonian times.

Dianne Edwards; Research Professor, School of Earth and Ocean Sciences, Cardiff University

Devonian plants, forests, atmospheres and climates

The Devonian was a time of profound change in the plant kingdom, from the little plants of the Silurian through to the Carboniferous coal forests. The appearance of major plant groups, including cladoxylopsids, lycopsids, progymnosperms and finally seed plants through the Mid and Late Devonian each cumulatively added capacity for 'carbon capture' and intensification of weathering processes. They may also have played a role in altering hydrological cycles. Increasing understanding of the trees themselves, rare fossil forests and geochemical studies give further opportunity to evaluate the contribution of plants effect on the Earth's Carbon cycle and potential impact on climate systems.

Christopher Berry, Senior Lecturer, Palaeobotany, School of Earth & Ocean Sciences, Cardiff University

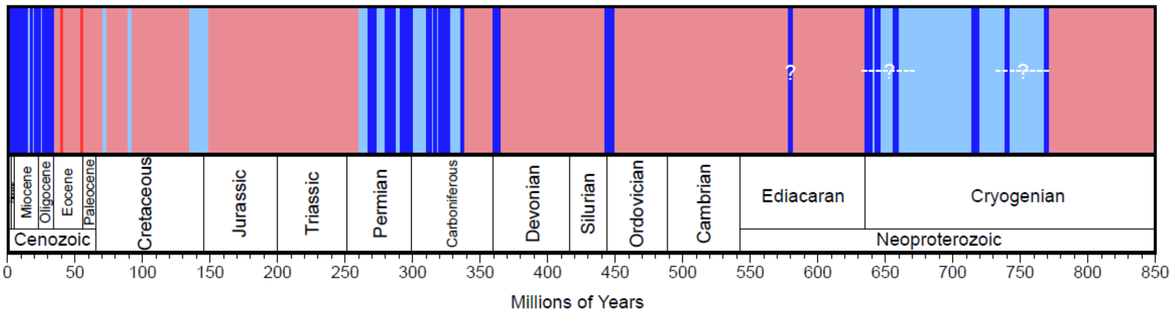
Come visit the jungles of South Wales – the Carboniferous coal-swamps

The South Wales Coalfield has a unique geoheritage of sites showing late Carboniferous (Pennsylvanian) terrestrial deposits with abundant fossil biotas, especially floras. Not only does the area have one of the most complete sequences of Westphalian (upper Bashkirian – lower Moscovian) terrestrial deposits in Euramerica, these deposits can be seen and studied in natural outcrop – an increasingly important factor with the rapid decline in coal mining and consequential loss of artificial exposures. Historically, South Wales saw pioneering studies on plant palaeoecology and biostratigraphy, notably through the work of David Davies and Emily Dix. More recently, South Wales has been at the centre of a series of international collaborative projects looking at the relationship between Palaeozoic tropical vegetation dynamics, and climate, landscape and tectonic changes.

Christopher J. Cleal: Head of Botany, Department of Natural Sciences, Amgueddfa Cymru – National Museum Wales, Cardiff

Environmental impact of extreme climate change at the Permo-Triassic boundary

The past 850 million years of the Earth's climate history can be broadly divided into long intervals of warmer "greenhouse conditions" (red colours in the figure below) and shorter, though still lengthy, cool "icehouse" conditions (light blue colour below) when there is sometimes evidence of continental ice sheets at the poles (dark blue colour). Against the background of these long-term changes are superimposed a number of extreme and short-lived ('freak') climate change events. These include the Palaeocene-Eocene Thermal Maximum, the extreme global warming associated with the end Permian mass extinction and arguably our current phase of man-made climate change.



In this talk we will examine the evidence for severe climatic perturbations around the Permo-Triassic boundary and the impact this had on the Earth's biological and geological systems. In addition to using evidence from China, Russia, Australia and elsewhere we will re-examine our own familiar Permian and Triassic stratigraphy of the UK in the context of abnormal climatic conditions.

[Michael J. Benton, Andrew J. Newell, Impacts of global warming on Permo-Triassic terrestrial ecosystems, Gondwana Research, Volume 25, Issue 4, 2014, Pages 1308-1337, Andrew J. Newell, Rifts, rivers and climate recovery: A new model for the Triassic of England, In Proceedings of the Geologists' Association, 2017, https://doi.org/10.1016/j.pgeola.2017.04.001.]

Andy Newall, British Geological Survey, Wallingford.

The Cretaceous greenhouse climate

The Cretaceous Period is conventionally viewed as representing the 'greenhouse state' of the planet, with equatorial sea-surface temperatures >30˚C and polar sea-surface temperatures >15˚C. The evidence for this interpretation comes from the presence of tropical faunas and floras at high latitudes, with potential quantification supplied by oxygen-isotope data from carbonate sediments and fossils and organic geochemical proxies derived from black shales. A warmer planet implies deeper weathering of oceanic and continental crustal rocks and an accelerated hydrological cycle, and the impact of increased nutrient delivery to the oceans can be seen in the widespread sedimentary record of organic-rich sediments, recording relatively elevated plankton productivity on a global scale. Particularly during so-called hyperthermals – intervals of extreme global high temperatures – were these processes of great importance, leading to large tracts of the ocean becoming deoxygenated, as in the early Aptian (~120 Ma) and during Cenomanian–Turonian boundary time (~94 Ma). These intervals describe Oceanic Anoxic Events during which deoxygenation in parts of the proto-Atlantic became so severe that sulphidic conditions resulted, as in the present-day Black Sea. Elevated carbon dioxide levels in the atmosphere were likely drivers of Cretaceous climate, with copious quantities of this greenhouse gas derived from Large Igneous Provinces.

Hugh C. Jenkyns: Professor of Stratigraphy, Dept of Earth Sciences, Oxford University

Descent into the Icehouse: A Cenozoic perspective on climate change and ice sheet stability

From crocodiles in the Arctic to today's bipolar icehouse world, the Cenozoic Era represents Earth's most recent Greenhouse-Icehouse Transition. New geochemical proxies enable us to better understand the sensitivity of the Earth System to changing levels of carbon dioxide. For example, the impacts of the growth and decay of Earth's continental ice sheets reach far throughout the Earth System. Yet the local records of these changes are constantly rewritten through geological time, so their history must be determined using indirect evidence. What do such geochemical proxy records tell us about ice sheet dynamics? First and foremost, they demonstrate that the cryosphere does not respond linearly to external forcing of Earth's climate system. For example, the establishment of the Antarctic ice sheet at the Eocene-Oligocene Transition (~34Ma) was the rapid culmination of a long-term cooling trend that began several million years earlier, as a threshold in the climate system was passed. Most ice sheet models agree that the climate threshold for melting the Antarctic ice sheet is higher (warmer) than for its inception, due to the cold, elevated nature of its upper surface. The records of the ice sheet growth and decay at the Oligocene-Miocene Boundary (~24 Ma) therefore present something of a geological puzzle, because at first sight they seem to contain little evidence of this hysteresis effect. One possible explanation is that the deglaciation of the Antarctic ice sheet was facilitated by an input of carbon to the ocean-atmosphere system. In addition, recent advances in ice sheet modelling provide a better fit to these proxy records. However, these models have worrying implications for future ice sheet stability.

Carrie Lear, Professor of Earth Science, School of Earth and Ocean Sciences, Cardiff University

Larsen C ice shelf – the day before tomorrow?

Much media attention was focussed recently on the calving of a large iceberg from Larsen C Ice Shelf and whether the event was caused by 'global warming'. Larsen C is the largest remaining ice shelf on the Antarctic Peninsula where, over the past few decades, shelves have been thinning, retreating, and even breaking up completely.

The whole Antarctic continent is fringed by floating ice shelves where the land ice flows into the ocean, and although the break-up of a floating ice shelf does not directly contribute to sea-level rise, ice shelves act as brakes on the glaciers which feed them. Releasing the brake allows these glaciers to flow faster and discharge more ice from land into the ocean – this will add to sea level rise. It is likely that warming oceans beneath the ice shelves, and increasing air temperatures above them are both contributing to the break-up of Antarctic Peninsula ice shelves.

In 2014 and 2015 we went to do some fieldwork on Larsen C, to learn more about how the ice shelf is being affected by surface melt which in some places is leading to ponds of liquid water. We are using our field observations and data acquired by satellites together with numerical models to investigate the history and future outlook for the ice shelf.

I will present the background behind our research and some of our results, including plenty of photos of one of the most beautiful and remote places on Earth to be carrying out fieldwork.

Suzanne Bevan, Swansea University

The climate of the Anthropocene

The Anthropocene, the concept that humans now dominate geological processes, effectively originated with Paul Crutzen, working as part of the Earth System science community, in 2000. Since 2008, this concept has been tested as a potential formal stratigraphic unit distinct from the Holocene, and a considerable array of evidence has been assembled to suggest that it has geological reality, and that the boundary might be most conveniently placed around the mid-20th century. The evidence includes: widespread novel 'mineral' particles, including plastics and fly ash; ‘rocks’ such as concrete and ceramics; chemostratigraphic indicators such as changes to carbon and nitrogen isotopes, persistent organic pollutants and artificial radionuclides; and the biostratigraphical traces of species invasions, extinctions and modifications.

The climate signal is not straightforward. In the last century or so, climate drivers such as carbon dioxide and methane have shown unprecedentedly rapid increases to levels beyond anything known from the Quaternary, and today continue on this sharp upwards trajectory. As a result, global climate is warming and sea level is rising at an accelerating rate. Both have departed from their respective long-term Holocene trends, but neither has yet exceeded maximum Quaternary interglacial levels, although temperature is currently near this limit. It is highly likely that the future Anthropocene world will be marked by warmer-than-Quaternary climates and high sea levels for many millenia, with the scale and rate of change largely depending on greenhouse gas emissions over this century.

Jan Zalasiewicz, Professor of Palaeobiology, School of Geography, Geology and the Environment, University of Leicester and *Colin Summerhayes, Emeritus Associate, Scott Polar Research Institute, Cambridge University*