President's Day 2013 – senior medallists' talks

Wollaston Medal (Kurt Lambeck)

Of Ice and Land, Sea and Strand: Sea Level During Glacial Cycles

One of the classic problems joining many of the geoscience disciplines is the relationship between ice sheets, sea level and the solid Earth during glacial cycles: Geophysical modelling defines the solid Earth's response to changes in surface loads and hence constrains estimates of mantle rheology; geological observations provides constraints on past ice movements and on the sea level response to the changes in the ice loads; geodetic data provides measures of the recent response to past and present ice changes; glaciology provides the observational evidence and theory for ice movements in a changing climate; and the dynamics of the solar system provides one of the driving forces for the growth and decay of ice sheets. It provides therefore not only a scientific challenge but also insights into the working of the climate system of the planet, and a framework for discussing human migrations and coastal archaeological settings. Here, I will endeavour to give an overview of where this science is at: what have we learnt about past ice sheets from geophysical inversions of geological data; what have we learnt about the mantle's response to surface loading on time scales of thousands of years; are realistic palaeo reconstructions possible of the coastal zones; and are there lessons that may be relevant to understanding present sea level change.

Lyell Medal (Paula Reimer)

Calibrating the radiocarbon timescale

Radiocarbon (^{14}C) dating has been the workhorse for establishing a time frame for many late Quaternary records since the method was first reported by Willard Libby and colleagues in 1949. Unlike some radiometric techniques, radiocarbon ages don't have a direct 1-to-1 correspondence with time elapsed due primarily to variations in atmospheric ^{14}C production and ocean circulation. Corrections for these variations were initially accomplished by calibration to ^{14}C measurements made on dendrochronologically dated wood. However, the tree-ring resource is limited by the extent to which subfossil trees have been preserved outside of the ice sheet limits of the Last Glacial Maximum and by the difficulty of piecing together chronologies from these. The desire to push the calibration beyond the limit of tree-ring chronologies has resulted in the use of alternative archives such as U-Th dated corals and stalagmites, foraminifera from marine sediments and terrestrial macrofossils from lake sediments. Except for the terrestrial macrofossils these archives do not directly record atmospheric ^{14}C levels but each contains information which informs the reconstruction of past atmospheric ^{14}C. Stalagmite formation includes a proportion of ancient, ^{14}C-free carbonate from limestone which can vary with hydrological changes. The ocean surface layer where the corals and planktic foraminifera grew has an apparent radiocarbon age of about 400 years on average due to the uptake of atmospheric CO_2 and the upward mixing of water which has been sequestered in the deeper ocean for hundreds or thousands of years. Our knowledge of the extent of past changes in the ocean surface age and the proportion of ^{14}C-free carbon in stalagmites is limited, especially during major oscillations in the climate. To construct a calibration curve back to the limit of radiocarbon dating (ca. 50,000 years before present) we must combine the available records in a statistically valid way while recognizing the different physical processes under which the archives evolved. While every effort needs to be made to develop new terrestrial ^{14}C records, a major challenge for future improvements to radiocarbon calibration is to document ocean surface age changes in key oceanographic regions and, with the involvement of earth system modellers, to further our understanding of ocean and atmospheric responses to climate change.

Murchison Medal (Peter Kokelaar)

Understanding Avalanche Mobility

Catastrophic dense granular flows, including rock avalanches, debris flows and some pyroclastic flows, tend to self-organize in ways that promote runout distance; they can travel hundreds to thousands of metres down slopes as slight as 6°-2°. The issue of their 'excessive travel distance', which implies surprisingly low friction, has long been a problematic feature that has attracted numerous and diverse potential explanations. The flows typically form relatively coarse-grained levees, which restrict lateral spreading, and the kinematics of levee formation is reasonably well understood. An important new finding is that the flows form fine-grained linings in the leveed channel, from the flow head; the flows create their own 'conduit' from the front, persistently maintaining low flow-contact friction and preventing dissipation of pore pressure. The findings emphasize the volume-dependence of channelized flow runout and that slope analysis with anticipation of flow type is most physically relevant in hazards assessment.

William Smith Medal (Martin Jackson)

Origin and Evolution of Allochthonous Salt Sheets

Defying the law of superposition, allochthonous salt sheets overlie younger strata. They extrude as salt glaciers from thrust nappes or from plug-like evaporite diapirs. Extrusion is enhanced by lateral compression resulting from either a topographic slope or orogenic collision. A salt sheet need not be exposed to move forward. Shallowly buried salt sheets can advance by thrusting over the land surface or sea floor. A siliciclastic carapace protects salt from dissolution. Spreading salt sheets can coalesce along sutures, forming salt canopies tens to hundreds of kilometres wide. As they spread, these vast, composite salt bodies can carry kilometer-scale inclusions of non-evaporite rocks for distances of several tens of kilometers. As they are buried, the contents of salt canopies are typically recycled and redistributed by internal creep. Like a deflating air mattress, salt sheets become thinner beneath the thickest parts of overlying strata. Eventually the upper and lower contacts of a thinning salt sheet can join to form a salt weld. Meanwhile allochthonous salt expelled from a deflating zone inflates the salt sheet beneath thinner parts of the overburden. This recycled salt can provide a source for second-generation diapirs rising from the buried canopy.