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VIEWS AND NEWS

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IPY Project PLATES & GATES: Plate tectonics and polar gateways in the Earth system—tectonic control on long-term climate evolution

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The thermohaline ocean circulation is an important component in the global climate system as the ocean currents transport heat and matter around the globe. At large timescales, the global circulation is affected by geodynamic processes which control the motions of the lithospheric plates as well as crustal uplift and subsidence. The plate motions have constantly altered the geometries of the ocean basins and distribution of land masses. In particular, the geometries of so-called oceanic gateways—acting as continental bottlenecks in the exchange of water masses between ocean basins—are key parameters in simulating palaeo-ocean current systems and palaeo-climate scenarios. The reconstruction of the geometries of ocean gateways and basins, therefore, feeds into numerical models studying the tectonic effect on climate changes. The project PLATES & GATES focuses on Cenozoic and Mesozoic times and, in particular, on its transition from climatic greenhouse to icehouse conditions.

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For the reconstruction of the oceanographic conditions at relevant times of climate changes, tectonic-magmatic, geodynamic, sedimentary and biostratigraphic processes are studied in the polar and subpolar regions. Scientists of 18 nations are involved in geophysical surveying techniques and sedimentary sampling at relevant oceanic and terrestrial sites in the Arctic, sub-Arctic, Antarctica and the Southern Ocean in order to address specific objectives such as (1) seismic, magnetic and gravimetric surveying of crust and lithosphere of ocean basin, gateways and their continental margins for constraining past and present plate motions, mantle processes, and vertical crustal motion, (2) reconstructing the distribution and variation of palaeo-current systems in the ocean basins by seismic imaging of sedimentary sequences in combination with analyses of palaeoceanographic proxies for decoding signals of past deep-water circulation patterns, (3) reconstructing the palaeobathymetric geometries of polar ocean gateways for shallow and deep-water passages between basins at particular times, (4) reconstructing the long timescale palaeoclimatic evolution from the greenhouse conditions of the Mesozoic and Early Tertiary to icehouse conditions in the Late Tertiary to Quaternary, and (5) numerical modelling of palaeo-current scenarios at varying gateway and basin geometries with regard to the global carbon cycle, the biological evolution and the development of ice sheets.

In the Arctic, palaeomagnetic, stratigraphic and petrological data from Franz Josef Land, Axel Heiberg Is., Ellesmere Is., the New Siberian Is. and North Greenland are being collected and analysed. Geoscientific studies including bathymetric mapping, seismic and magnetic surveying, sub-bottom profiling and sediment coring are carried out in the Amundsen Basin, on transects across the Alpha-Mendeleev Ridge, over the Lomonosov Ridge and from the North Greenland Shelf. Geological and neotectonic studies are conducted for North and East Greenland, Svalbard, Bear Island, Mohns Ridge, Knipovich Ridge and the Barents Sea. The gateways between the Arctic Ocean and the other world oceans—the Fram Strait, Davis Strait/Baffin Bay with the Canadian archipelago as well as the Bering Strait—are investigated by a wide spectrum of geophysical and geological approaches to understand the timing and palaeo-climatic consequences of water mass exchange (e.g. Jakobsson et al. 2007).

Geophysical and bathymetric surveying as well as geological and biological sampling have been and will further be conducted for critical regions of the Southern Ocean that formed since the break-up of Gondwana. A thorough revision of the break-up processes is performed in parallel with new data acquisition giving special emphasis to the compilation and integration of existing data sets. Uncertainties about the early stages of development of the Drake Passage/Scotia Sea gateway (e.g. Livermore et al. 2007) are resolved by studies of the tectonic and sedimentary evolution of the basins and the origin of bathymetric highs, the structure and history of relevant plate boundaries, and deformation of neighbouring land areas. From geophysical data of the Tasmanian gateway, we expect to better constrain the timing of shallow and deep-water opening between the Indian and Pacific Oceans as well as the motion between East and West Antarctica which is critical to the timing of the uplift of the Transantarctic Mountains and the evolution of the West Antarctic Rift System. This rift may have played a role as an additional Pacific-Atlantic gateway at times when the submarine-based West Antarctic ice sheet did not exist.

As the distribution of global and regional bottom-water currents is restricted by seafloor morphology in general, the dynamics of outstanding oceanic plateaus, ridges and fracture zones as well as the varying morphology along continental margins and rises (e.g. development of sedimentary drift deposits) are an additional object of PLATES & GATES investigations. The Antarctic Circumpolar Current, for instance, is deviated by the elongated and up to three-kilometer-high basement ridges of the Udintsev and Eltanin Fracture Zone systems in the southern Pacific as well as the Kerguelen Plateau in the southern Indian Ocean (Fig. 1).

The generation of highly resolved palaeobathymetric and palaeotopographic grids is a key condition for realistic simulations of palaeo-ocean currents. Within the PLATES & GATES project, Cenozoic and Mesozoic climate reconstructions are performed using a variety of Earth

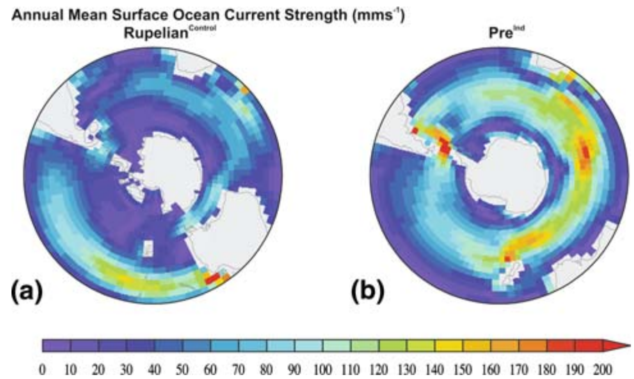

Fig. 1 Prediction of annual mean Antarctic Circumpolar Current (ACC) strength (in mm/s^{-1}) for (**a**) the Rupelian geological stage (Early Oligocene) and (**b**) the pre-industrial era produced by the HadCM3L general circulation model (GCM). The model predicts a weaker ACC during the Early Oligocene even though the Drake Passage and Tasman gateway are specified as open. The ability of GCMs to correctly simulate the oceanographic response associated with the opening of high-latitude gateways such as Drake Passage partly depends on the provision of accurate geological reconstructions of gateway opening histories and information on palaeo-ocean bathymetry in general

system models designed to evaluate the effect of ocean gateways and basins on palaeo-circulation patterns, the global carbon cycle and nature of polar ice-sheet development. These experiments include sensitivity runs incorporating new palaeo-bathymetric reconstructions arising from the new data acquisition described above. The results from these experiments are compared with other model simulations, which include different forcing factors such as atmospheric greenhouse gasses and mountain uplift to determine the relative importance of palaeo-geography on the evolution of polar and global climates over long geological timescales. Further information about PLATES & GATES can be found online at the URL, http://platesgates.geo.su.se, as well as at the website, http://www.international-polar-year.de/Plates-and-Gates.28.0.html.

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