Kimberlite intrusions, kimberlitic ash dispersal, diamond transport and diamond deposition: The potential role of Earth Systems Modelling in diamond exploration.

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Introduction

Our Plate Kinematics model can be used to help predict the locations and orientations of kimberlitic intrusions (using intra-plate palaeostress in relation to geological structure). Our Palaeo-Earth Systems Models can be used to predict transport directions of volcanic ash carrying kimberlitic indicators (by modelling palaeowinds) and potential distribution of alluvial diamonds (by quantifying runoff and sediment flux in successive paleogeographic contexts through modelling rainfall, rainfall intensity, evapotranspiration and vegetation). In marine settings, modelling of potential diamond sand distributions includes predictions based on palaeotidal currents, palaeowind-driven currents and gravitational resedimentation of sands on steep slopes.

Plate Model

The Robertson Plate Kinematics model classifies continental crust into areas which have responded rigidly to intraplate stress throughout the Phanerozoic, and into deformable areas which have suffered extension and/or shortening within that period. The deformable areas play an important role in controlling the way in which far-field stress from global-scale plate motions is transmitted into the rigid plates. The plate model incorporates the changing deformation states in these continental areas and so provides a basis for predicting the direction and timing of intraplate stress within Archaen and Proterozoic crust throughout the Phanerozoic. The plate model is also used as the basis for palaeogeographic mapping from which digital elevation models (DEMs) are constructed. An explanation of the Plate Kinematics model, the palaeogeographic mapping and the Earth Systems Modelling are included in Harris *et al*., (in press).

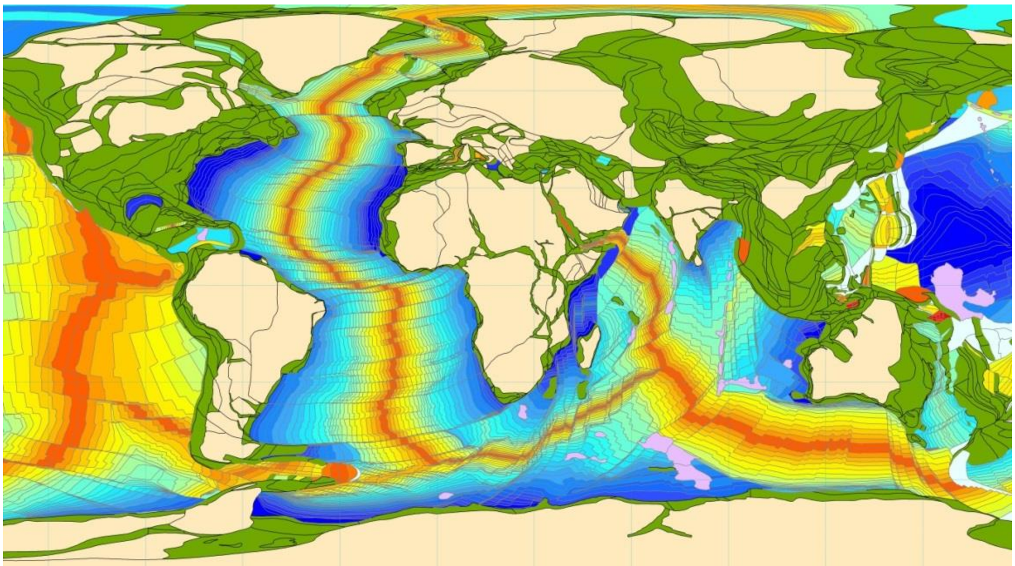

Figure 1: Plates which have shown rigid (pale buff) or deformable (green) behaviour during the Phanerozoic, in relation to oceanic plateau (pink) and oceanic crust age data, which help constrain plate kinematics.

Earth System Models

A series of 18 and Recent Earth System Models have been run, together with a series of sensitivity tests. The ages have been chosen by clients to target time slices of interest for petroleum exploration. The DEMs are coupled with state-of-the-art palaeo-Earth systems models (UK Met Office HadCM3 palaeoclimate model) and an unstructured mesh model to simulate palaeotides (Imperial College, UK, ICOM tide model). The resulting palaeoclimate results fit well with globally distributed geological proxies for palaeoclimatide indicators at these ages. This gives confidence in the palaeogeographies constructed and in the Earth System Model results.

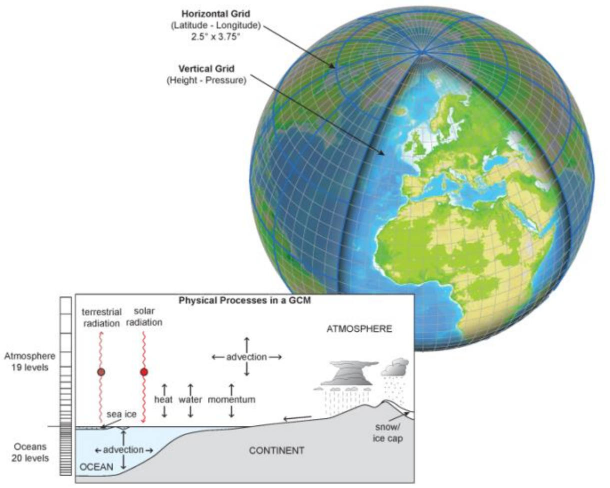

Figure 2: The coupled ocean-atmosphere palaeoclimate model links the physics of oceanic and atmospheric grids.

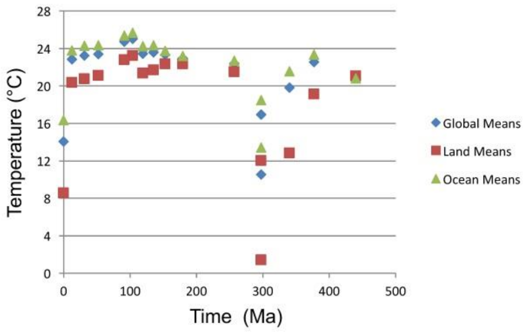

Figure 3: The palaeoclimate results fit well with "hot house" and "ice house" worlds.

These Earth System Models are run on paleogeographic and palaeotopographic DEMs created using an approach which relates topography and bathymetry to plate tectonic context and depositional environments.

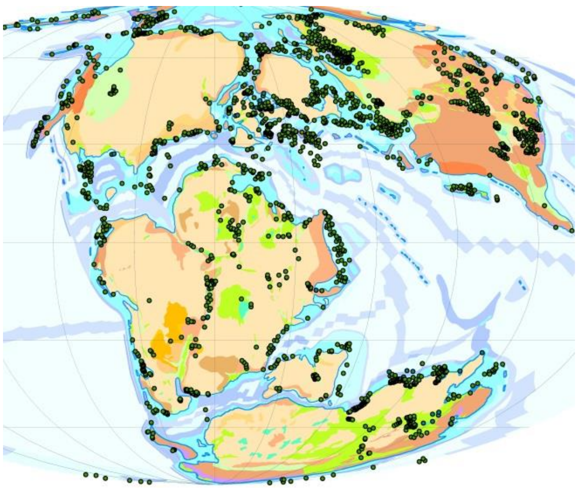

Figure 4: Plate tectonic context polygons and palaeoenvironment control points.

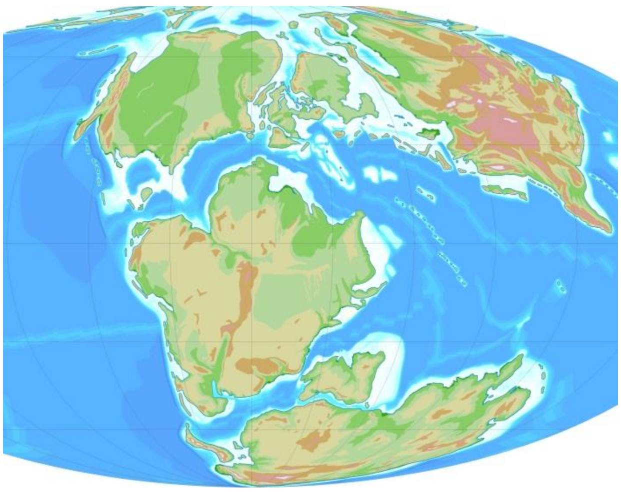

Figure 5: Resulting palaeotopographic and palaeobathymetric digital elevation model.

The palaeogeographies are constrained by legacy data representing over 35 years of petroleum geological studies. The predictions of palaeoclimate and sediment distributions are tested against thousands of control points collated from the public domain and from confidential oil industry exploration wells. This approach provides an understanding of regional palaeogeographic change and palaeoclimatic geohistory that includes drainage basin evolution and the quantification of clastic sediment flux. These models are run on the entire Earth, and for this conference we will present a series of case studies illustrating operation of these Earth System models on a series of time slices.

Over the last 20 years we have used this methodology to help our oil company partners explore for marine oil-prone source facies and reservoir rocks. We believe the methodology could, with minimal re-tuning, also have applications in exploration for diamonds.

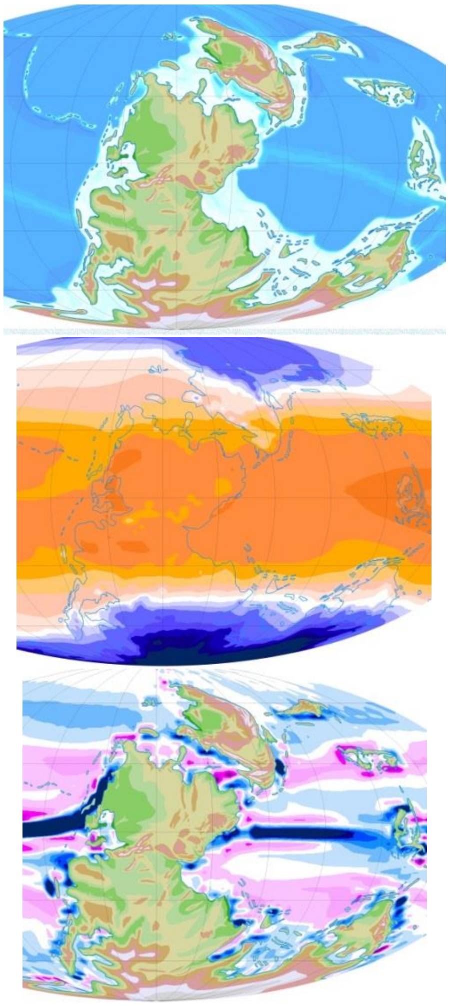

Figure 8: Early Permian palaeogeography, showing surface air temperature (blue: cold) and oceanic upwelling (dark blue) modelled from palaeowind data.

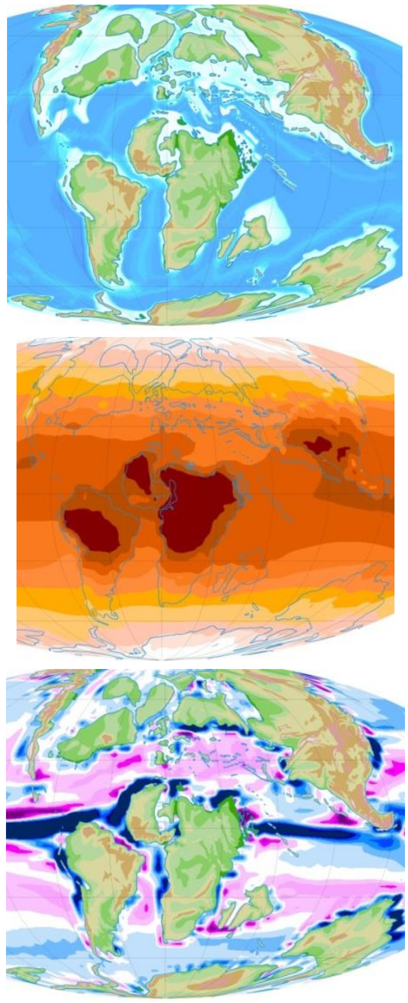

Figure 9: Turonian palaeogeography, showing surface air temperature (red: hot) and oceanic upwelling (dark blue) modelled from palaeowind data.

For example, the palaeowind data, which is compiled on a monthly, seasonal and annual basis, could be used to predict dispersion directions for kimberlitic ash, and hence help track kimberlitic indicators back to undiscovered kimberlite pipes.

Reference

Harris, J., Ashley, A., Otto, S., Valdes, P., Crossley, R., Preston, R., Watson, J., Goodrich, M., and the Merlin+ Project Team (in press). Paleogeography and Paleo-Earth Systems in the Modeling of Marine Paleoproductivity: A Prerequisite for the Prediction of Petroleum Source Rocks, in M. AbuAli and I. Moretti, eds., Petroleum System Case Studies: AAPG Memoir 114, p. 37–60.