Abstract

Petroleum Source Rocks and the Predicative Modelling of Marine Productivity: Palaeogeographic and Palaeo-Earth Systems Controls on Latitudinal Distribution Patterns

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The distribution of source rocks and the lateral variation in source quality are some of the main uncertainties for exploration in frontier basins. To construct a predictive tool designed to address this problem, Plate Wizard reconstructions were used as the basis for global palaeogeographic mapping. Detailed palaeotectonics and palaeoenvironments maps were prepared. These base maps were compiled using a global database of palaeoenvironmental and lithofacies data, the legacy of over 30 years of petroleum geological studies and an equally extensive source rocks database. A novel method relating topography and bathymetry to plate tectonic environments was used in the construction of palaeo digital elevation models (DEMs). The DEMs were 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 database also includes climate proxies that were used to test the veracity of modelling results. In conjunction with the DEMs, palaeo-Earth systems were used to create a new predictive model of organic matter (OM) productivity, dilution and preservation. This model defines source facies depositional space for the selected time slices. The combined approach also provides an understanding of regional palaeogeographic and palaeoclimatic geohistory, drainage basin evolution, and the estimation of clastic sediment flux. Predictive mapping is used here to illustrate the palaeogeographic and in particular the latitudinal distribution patterns of marine OM productivity.

Nutrient supply, and available sunlight moderated by water turbidity and the related depth of light penetration are important factors that control primary productivity in the marine photosynthetic biosphere. Both upwelling and storms are major factors in the supply of nutrients to the photic zone and low light levels are a significant seasonal limit on primary productivity particularly at high latitudes in polar winters.

Upwelling can be derived from the ocean vertical velocity elements of the UK Met Office HadCM3 model output. These results include coastal and dynamic upwelling processes and also include upwelling in the inter-tropical convergence zone that is a prominent feature of the HadCM3 results. Given the importance of surface winds, clear latitudinal patterns are apparent at the present day and for Pangaeic and Mesozoic – Cenozoic break-up palaeogeographies. For each of these, local palaeogeographic controls are additional to the broader latitudinal patterns.

Although individual storms are not modelled in HadCM3 the more generally applicable storminess of the climate system can be derived using the eddy kinetic energy (EKE) elements of the model results. EKE also exhibits strong latitudinal controls where the importance of mid-high latitude winter storms are a dominant feature.

Together upwelling in the near surface layers of the ocean and the storminess of the climate system as nutrient supply mechanisms have been used to create an approximate estimate of OM productivity in the photic zone. However the amount of light received at the Earth's surface is a significant seasonal factor limiting primary productivity in the winter and promoting high rates of OM productivity in the spring – early summer. To account for the seasonal variations in day length and the associated variation in available solar radiation, a simplified approach has been adopted that utilises monthly net solar radiation values.

Application of this additional element of the predictive routine provides moderated OM productivity values and global distribution patterns that retain significant latitudinal and local palaeogeographic controls. These are a starting point for the modelling of OM dilution and preservation that are required for a complete OM predictive tool. Several questions remain concerning the details of the palaeogeographies and the upwelling and storm processes that have been used some of which can be assessed using sensitivity tests or alternative models. There is also an important point concerning species diversity and their evolutionary adaptations in response to low and variable irradiance. This latter point is difficult if not impossible to determine for the deep past and as such a simplified approach seems justified.