

**ESTIMATION OF THERMOGENIC GAS EMISSIONS USING BASIN MODELLING:  
A CASE STUDY FROM THE ORANGE BASIN, SOUTH AFRICA**

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Natural hydrocarbon seepage is a process recognised to occur in varying intensity along most continental shelves. The seafloor and seismic expression of such seepage sites includes gas chimneys as well as surface and buried mud volcanoes (Milkov, 2000), pock marks (Hovland & Judd, 1988) and carbonate mounds (Hovland & Thomsen, 1997).

Major consequences of hydrocarbon seepage include the support of diverse biological communities, the potential to reduce the stability of continental margin sediments and, importantly, the flux of carbon into the hydrosphere and atmosphere (Judd *et al.*, 1997).

The proportion of methane reaching the atmosphere due to natural seepage has until recently been assumed to be insignificant (IPCC, 1990). However, first assessments of the flux of gas from seabed seepages indicate that the geological sources of atmospheric methane may be more significant than is generally acknowledged. Judd *et al.* (1997) reported that estimates of gas seepages on the UK continental shelf can reach values representing 2 to 40% of the total UK methane emission. Despite the vast amount of work already performed on varying aspects of natural gas seepage an integrated study involving detailed mapping of gas escape or sequestration features (mud volcanoes, pockmarks, gas chimneys and bottom simulating reflectors indicative of gas hydrates), their distribution through time, their relationship to the hydrocarbon system as well as a characterisation of gas generation, migration and leakage dynamics through geologic time has as yet not been performed.

Mud volcanoes, pock marks and possibly cold-water corals have been observed in the distal part of the Orange River delta, South Africa (Ben Avraham *et al.*, 2002). In order to assess the possible contribution of thermogenic gas to the atmosphere a 3D modelling study of the southern part of the Orange Basin was undertaken using Petromod software (IES, Germany). Seismic interpretation of a total of 20 seismic lines provided the input data for the model. Within the basin three different source rocks are available for potential hydrocarbon generation. These are an Upper Jurassic-Neocomian lacustrine source rock within local syn-rift graben structures, a Barremian-Lower Aptian marine-transitional source rock which is the source two commercial gas fields in the basin and an uncertain Cenomanian-Turonian marine source rock.

After model calibration to available temperature and vitrinite reflectance data petroleum system evolution and source rock maturity was reconstructed for each time step. For modelling gas migration through the sediment column variations in lithology as well as sediment physical properties are highly relevant and tested extensively in the model runs. Petroleum generation and migration was calculated using PhaseKinetic models (di Primio & Horsfield, 2006) for marine and lacustrine source rock types. This approach allows the correct reconstruction of petroleum generation, phase separation and phase composition during migration. Fluid flow predictions and especially leakage sites were calibrated against gas chimneys observed in the seismics. The timing of possible leakage events, fluid flow direction as well as the volume of hydrocarbons generated and leaking out of the individual model boundaries was calculated for each time-step in the model. The results indicate a close relationship of gas leakage rates to the structural evolution of the basin, whereby leakage rates culminated in the Campanian and dropped sharply following a Maastrichtian to Paleocene erosion and tilting event. Following this episode delta progradation over the shelf break led to a renewed episode of hydrocarbon generation during the Tertiary extending up to the present day. Calculated leakage rates reach maximum values of up to 300 kg/year/km<sup>2</sup>, values which match the ranges reported for actively leaking systems.

In order to address the total emissions from the basin, as well as local variability, we are currently expanding the model to include the bulk of the South African Orange Basin. Sensitivity analysis of the model predictions is currently being performed.

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