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Evidences of early to late fluid migration from an upper Miocene turbiditic channel revealed by 3D seismic coupled to geochemical sampling within seafloor pockmarks, Lower Congo Basin

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Abstract

Using high quality 3D seismic data within the Lower Congo Basin (LCB), we have identified pockmarks that are aligned above the sinuous belt of a buried turbiditic palaeo-channel, 1000 m beneath the seafloor. Geochemical analyses on cores (GC traces), taken in the centre of four of these pockmarks along this channel, show no clear evidence for migrated oil. But, some features of the GC traces, including elevated baselines (UCM > 34 μg/g) and a broad molecular weight range of *n*-alkanes with little odd–even preference, may be interpreted as indicating the presence of thermogenic hydrocarbons in the cores.

Seismic profiles show that these pockmarks developed above two main features representative of pore fluid escape during early compaction: (1) closely spaced normal faults affecting the upper 0–800 ms TWT of the sedimentary column. This highly faulted interval (HFI) appears as a hexagonal network in plane view, which is characteristic of a volumetrical contraction of sediments in response to pore fluid escape. (2) Buried palaeo-pockmarks and their underlying chimneys seem to be rooted at the channel–levee interface. The chimneys developed during early stages of burial and are now connected to the HFI.

This study shows that the buried turbiditic channel now concentrates thermogenic fluids that can migrate through early chimneys and polygonal faults to reach the seafloor within some pockmarks. Using a multidisciplinary approach within the Lower Congo Basin, combining 3D seismic data and geochemical analyses on cores, we trace the fluid history from early compaction expelling pore fluids to later migration of thermogenic hydrocarbons.

Keywords: Pockmarks; Turbiditic channels; Fluid migration; Polygonal faults; Seismic chimneys; Pipes

1. Introduction

Gases of thermal origin in near-surface sediments are believed to have been generated at greater depth and migrated to the surface (Leythaeuser et al., 1982, 2000). Detection of near-surface thermal hydrocarbons could obviously be of economic importance because it offers the possibility of direct geochemical hydrocarbon prospecting and exploration (Wenger and Isaksen, 2002; Abrams, 1992; Horvitz and Ma, 1988; Faber and Stahl, 1984; Horvitz, 1972, 1978). The origin of hydrocarbons in shallow sediments and the applicability of geochemical surface data in petroleum prospecting is still controversial due to difficulties in data interpretation and in the principal understanding of the effects of biodegradation and vertical migration of hydrocarbons from deep source rocks to the surface (Faber et al., 1998; Hunt, 1990; Fuex, 1977).

Due to the low matrix permeability of argillaceous mudstone, fluid flow through the sedimentary column is quite slow and diffusive but it is compensated for by long Ma timescale. However, active gas venting is clearly controlled by subsurface structures such as faults and faulted anticlines (Eichhubl et al., 2000). Evidence of focused fluid flow through the sedimentary column is seen (1) on the surface by pockmarks that are consistently located above faults of a polygonal fault interval (Gay et al., 2004) and (2) in the

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sedimentary column by seismic chimneys that are indicative of deeper reservoirs (Gay et al., 2003; Heggland, 1998). Seeps associated with diapiric features in offshore West Africa are often abundant and are often very large (visibly oil-stained sediments, very high petroleum concentrations), actively migrating, associated with high concentrations of gas with a thermogenic component and sometimes supporting oil slicks on the sea surface (Wenger and Isaksen, 2002). Even when seeps are authenticated, their presence does not prove economic hydrocarbon accumulations at depth, seal failure or gas displacement from reservoirs (Wenger and Isaksen, 2002). In the Lower Congo Basin (LCB), we have identified pockmarks related to a deep buried turbiditic channel (i.e. upper Miocene). Using a multidisciplinary approach, combining 3D seismic data and geochemical analyses on shallow sediments (Fig. 1), we trace the fluid history from early compaction expelling pore fluids to later migration of deep thermogenic hydrocarbons from the upper Miocene turbiditic channel. Although our examples are specific to the LCB, it is hoped that the dynamical model proposed may find applicability in other basins characterized by similar post-rift stratigraphy.

2. Data base, sample selection and analyses

This study was primarily based on 3D seismic datasets from the Lower Congo Basin (LCB) acquired by the TOTAL oil company (Fig. 1). The selected 3D-dataset covers an area of 4150 km^2 with a line spacing of 12.5 m, a CDP distance of 12.5 m and a vertical resolution of 4 ms. The data were loaded on a workstation and interpreted using the SISMAGE software developed by TOTAL. The bathymetric and reflectivity maps were acquired with a Simrad EM12 dual multibeam. Complementary data collected more recently with the Simrad EM300 dual multibeam provide higher vertical and lateral resolution for acquisition in water depth less than 3500 m. Data from the ODP Leg 175 on the West African margin (see Fig. 1 for location) have constrained the stratigraphic record, sedimentation rates and mechanical properties of Pliocene to Recent sediments (Wefer et al., 1998a).

Core locations were chosen on the basis of strong evidence of gas on seismic profiles (seismic chimney above a bottom simulating reflector (BSR) and a free gas zone) and indications of actual seepage processes (i.e. pockmark) on the seafloor identified on 3D seismic data and on reflectivity maps (cores

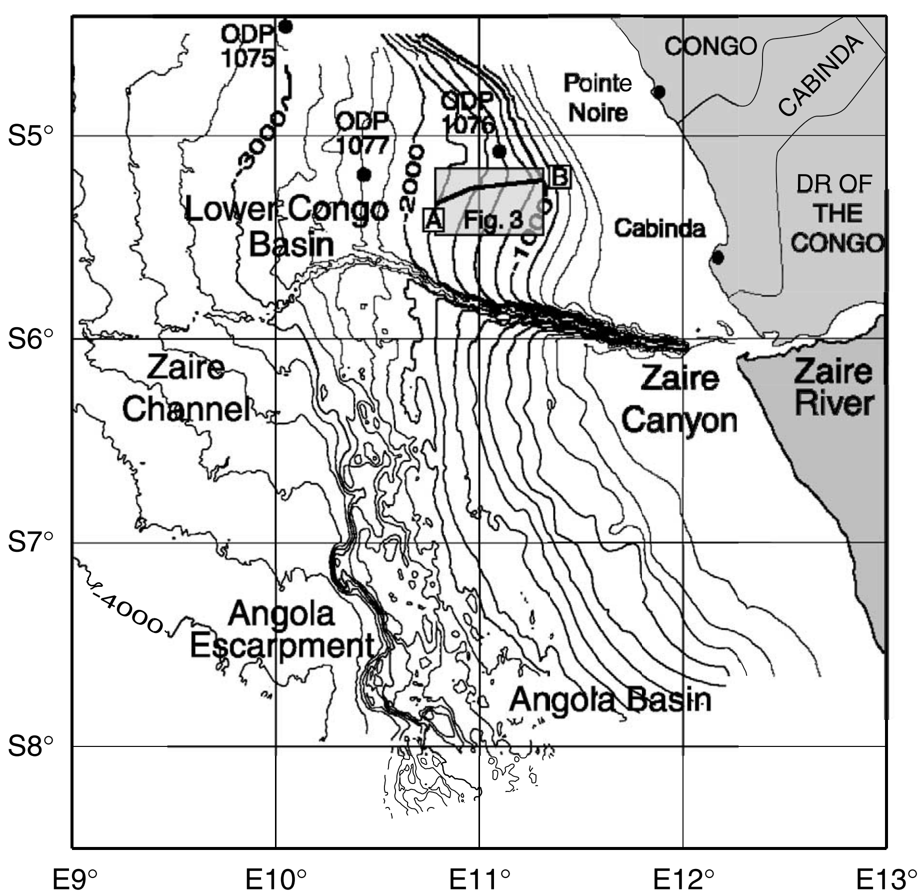

Fig. 1. Bathymetric map of the Congo–Angola Basin issued from the EM-12 multibeam bathymetry acquired during the ZAIANGO project (1998–2000). The study area (grey-shaded rectangle) is located on the north flank of the present day Zaire channel between 1000 and 1800 m water depth. The three sites of the Leg ODP 175 in this zone are reported.