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Seismic imaging of past and present fluid flow from reservoir to surface offshore West Africa

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Seismic data acquired on the continental slope offshore West Africa are widely recognized as being of excellent quality. 3D seismic data from this area allows spectacular insights into the morphology of deepwater turbidite channel systems, and related fluid migration and expulsion features within overlying and encasing strata of Oligocene-Recent age. A time-honored approach for evaluation of frontier exploration acreage is the direct detection and analysis of past and present fluid migration structures, such as seabed- or paleo-pockmarks, gas chimneys, gas hydrates, and more enigmatic pipe-like structures and high-amplitude anomalies in the subsurface. If analyzed and understood correctly, such structures can help calibrate models of fluid migration within the shallow crust, and can thus be used to track the expulsion and migration of hydrocarbons in petroliferous basins through time. This approach has recently seen a significant come back due to advances in 3D seismic quality and visualization tools and here we present some recent findings that highlight the shallow manifestations of the fluid flow systems and their impact on seafloor morphology.

The study area is located in 1-1.5 km water where the Oligocene-Recent succession is some 2.5-3 km thick. Using a high-quality near- and far-stack time migrated 3D seismic survey sampled at 12.5m by 12.5m by 4ms TWT and a dominant wavelength

of the order of 30-50m, we identified several features relevant to geomorphology of the paleo-seabed, fluid escape through the overburden and distribution of potential shallow reservoirs or lateral carrier beds. These features include both recent and paleo-pockmarks, intervals of higher net/gross depositional units, and high amplitude pipe-like seismic anomalies (free gas accumulations or carbonate concretions?).

The analysis showed that fluids escaped from the primary reservoir interval resulting in focused fluid flow in specific areas mainly controlled by syndepositional structural highs, intermediate carrier beds, fault breach and to some degree the distribution of the main reservoir itself. This focused fluid flow has led to formation of numerous pockmarks and amplitude anomalies within the immediate overburden. A major fluid flow event is recorded by an extensive pockmark field along an upper middle Miocene stratigraphic marker. The Plio-Pleistocene succession is characterized by stacks of fossil pockmarks, which pre-date polygonal fault systems along the Pliocene basin centre. Sub-vertical pipes of low-amplitude discontinuous seismic character, which penetrate the overburden to the base of a layer of free gas and gas hydrate, are also observed. Occasionally the surficial layers are entirely breached by the pipe-like structures and in those cases they are overlain by seabed pockmarks, implying that fluids are venting to the surface.

The seismic mapping of the anomalies related to fluid migration offshore West Africa has thus helped identify an interconnected system of fluid storage and leakage mainly controlled by syndepositional elements, faults, lateral carriers and focused pipe-like conduits. Together these structures provide pathways for fluids migrating from the prospective Oligocene succession vertically through the Miocene seals and laterally through carrier beds and through the Plio-Pleistocene mudstone cover to the seabed. The fact that migration is ongoing and that deep fluids are venting to identified locations on the seabed (seabed pockmarks) can be used to calibrate models for primary and secondary migration, storage and leakage of hydrocarbons and can thus be used to de-risk prospects in the examined area.