Research Advances

The Characteristics and Distribution Pattern of Seafloor Sinuous Pockmark Train in the Niger Delta Basin, West Africa

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Objective

The term "pockmark" was introduced by King and MacLean (1970) to describe small "circular" on echo-sounder records in Nova Scotia. Pockmarks are usually described as circular, near circular or elongated depressions, generally 10–400 m in diameter and 30–50 m in deep. Pockmarks are normally regarded to be manifestations of fluids escape through the seabed. Pockmarks are valuable features on the seafloor and are useful in constraining the hydrodynamics of sedimentary basins. Since then pockmarks have been recognized in many areas around the world. They occur predominantly in fine-grained siliciclastic depositional settings, although a few case studies have been reported in carbonate settings. In this paper we illustrate a suite of fluid escape features, discovered during the course of petroleum exploration on the West Africa continental margin (Fig. 1). They are particularly of interest to the oil and gas industry because they could be potential indicators of deeply buried hydrocarbon reservoirs, and fluid flow phenomena in the deep water oilfield are important for the safe and efficient exploration, development and production of hydrocarbons in the area.

Methods

Our study area is a pockmark field located within the Niger Delta Basin on the continental margin offshore Nigeria and the depth of water is 1300–1700 m (Fig. 1). The Niger Delta Basin is one of the most prolific hydrocarbon provinces in the world. It is also considered as one of the largest regressive delta in the world and is a typical passive continental margin basin. A high quality 1220 km² 3D seismic reflection dataset is utilized for this study, to 1300 m water depth. The 3-D seismic survey is time-migrated and of high resolution and good interpretation quality in the shallow section. The volume has a dominant frequency of about 70 Hz in the shallow subsurface interval, generating a resolution of a vertical resolution of approximately 6–7 m in the sallow buried sedimentary section (using a velocity of 1500–1750 m/s for the upper 300 m of strata). The multibeam bathymetry data provide good details on the geomorphology of sea floor. The underlying structures, sedimentary bodies and fluid features could be mapped by the associated seismic data.

Results

A range of pockmarks with various morphology and arrangement types was identified on the seafloor within the study area. The pockmarks have a diameter range of 40–400 m and a depth range of a few meters to about 50 m, respectively. In plan-view, the features display mainly circular, near circular, elliptical and elongated geometries, with a few showing crescent-shaped geometries. In cross-sectional view, the pockmarks display a predominantly V-shaped morphology with a few U-shaped occurrences. The pockmarks occur as isolated features, groups of randomly and systematically distributed features.

In general, pockmarks are seafloor depressions widely believed to form by focused fluid escape. The distribution of pockmarks clearly indicates the path of fluid migration and their seabed organization reflect the geometry and morphology of the reservoir. The pathway of fluid migration includes fault, polygonal fault (a type of non-tectonic fault distributing in deep water fine-grained sediments), mud diapir, gas chimney and buried sediment body boundary. Systematic arrangement pockmarks always attribute to polygonal faults or shallow buried sediment body boundary, such as shallow buried channel depositional boundary. The source of seeping fluid in uncompacted shallow buried channel sediment may include hydrocarbon fluid migrated from deep deposition, pore fluid from shallow buried channel and shallow biogenic gas. Fluid in shallow buried channel can seep to seafloor along the depositional boundary of channel. The possible reason is that the shallow buried turbiditic channel is covered by unconsolidated deep-marine sediment, so the

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depositional boundary of shallow buried channel has weaker yield strength than the surrounding sedimentary strata, and can be used as dominant migration pathway of gas or pore fluid seep to seafloor. New field data suggest that pockmark formation is not only controlled by slow gas hydrate dissolution but also by rapid hydrate formation, the process may be continuous or episodic. Both processes disperse fine-grained sediment into the water column, from where it later settles out or is moved away by currents (bottom current or turbidity current) and form pockmarks.

Pockmarks have been reported worldwide in a wide range of spatial densities, such as random and systematic distributions and linear array. The distribution of pockmarks is indicative of the path of fluid migration. The distribution of pockmarks clearly suggests that fluid seeps are not randomly distributed, but their seabed organization reflects the geometry and morphology of the reservoir and the location of the underlying reservoir where the fluids come from.

In this study, the distribution of seabed pockmark has significant regularity, and different pockmark arrangement modes have been reported. We describe and illustrate a new type of pockmark arrangement, which we have termed them as sinuous linear pockmarks train. The morphology and position of sinuous pockmark trains and underlying shallow buried channel are similar. The existence of shallow buried channel affects the position and distribution of pockmarks.

Conclusions

The distribution of pockmarks clearly indicates that fluid seeps are not randomly distributed, but their seabed organization reflects: (1) the geometry and morphology of the reservoir, (2) the location of the underlying reservoir where the fluids come from. Systematic arrangement of seafloor pockmarks is clues to buried reservoirs, and the inheritance evolution of channel complex can provide insights into reservoir architecture. The research could be crucial in frontier exploration of buried deep-water channel reservoirs and for risk assessment of development activities on top of submarine channels.

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