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Petroleum Systems of the Coastal Kwanza and Benguela Basins, Angola*

Abstract

The Kwanza and Benguela basins of coastal and offshore central Angola (Figure 1) have significant exploration potential but are under explored. The basins are part of the greater Aptian salt basin of West Africa and Brazil that formed during the opening of the South Atlantic. Recent discoveries in deepwater blocks awarded in the early 1990s in the Congo basin, offshore northern Angola, have generated a lot of industry interest. New blocks recently awarded in the Kwanza and Benguela basins will be the next frontier to be drilled. Our paper focuses on the regional geologic framework in this exciting area.

Hydrocarbon Occurences

The Benguela basin is undrilled, but oil accumulations are known in the Kwanza basin in Albian carbonates (Catumbela fm), Tertiary sandstones and the presalt Cuvo fm. Based on analyses of oils from seeps, and petroleum and bitumen extracts from outcrops and wells, there are at least two source rock intervals generating oil in the basins. One is an anoxic lacustrine sequence in the pre-salt section, similar to the Bucomazi source rocks of Cabinda, and the second is a marine carbonate inferred to be the basin facies of Albian shelf carbonates (downdip equivalent of the Tuenza fm of the Kwanza basin or the Pinda of the Lower Congo basin). Both units are penetrated by wells in Block 9 in the southern, offshore Kwanza basin. Basin micrites of Albian age also occur at DSDP Site 364 at the seaward margin of the Benguela basin, where the source richness was much greater than that observed in the wells. Analysis of biomarker data from Site 364 helped constrain the interpretation of the origin of oils found in offshore seeps and wells.

Regional Structural Frameworks

Both basins were affected by pronounced uplift of the continental margin in the Neogene. Uplift and seaward tilting amplified deformation of the salt beyond that observed throughout the Aptian salt basin of West Africa. Depositional loading by clastics shed from the raised areas enhanced rafting of slabs of the post-salt section downdip along the base-of-salt décollement, creating salt ridges, diapirs, and allochthonous sheets in offshore areas. In the southern Kwanza basin, deformation was further modified by buttressing of the mobile salt against a volcanic chain. The chain of seamounts, presumed to be of early to mid Cretaceous age, separates the Kwanza and Benguela basins. Elsewhere, the pattern of salt ridges and diapirs proceeds seaward to where salt nappes appear to have overridden the abyssal plain and presumed oceanic crust of the South Atlantic.

Consideration of Tertiary isopachs shows that sediment rafts that moved progressively seaward on the salt decollement controlled the distribution of sediment. Grabens formed at the updip margin of each raft captured thick sections of clastics in which sandstones and shales as young as Miocene rest directly on presalt sediments. Lateral boundaries between sediment rafts, where extensional, may have provided avenues for basinward transport of sands, allowing bypass of parts of the shelf and upper slope. Other boundaries between rafts had local strike-slip movement, as demonstrated by compressional or transpressional features where adjacent rafts moved at different times or rates. An asphalt-impregnated, overturned fold at Cabo Ledo, along the shoreline in the Kwanza basin, is interpreted to have formed in this manner rather than along a transform fault

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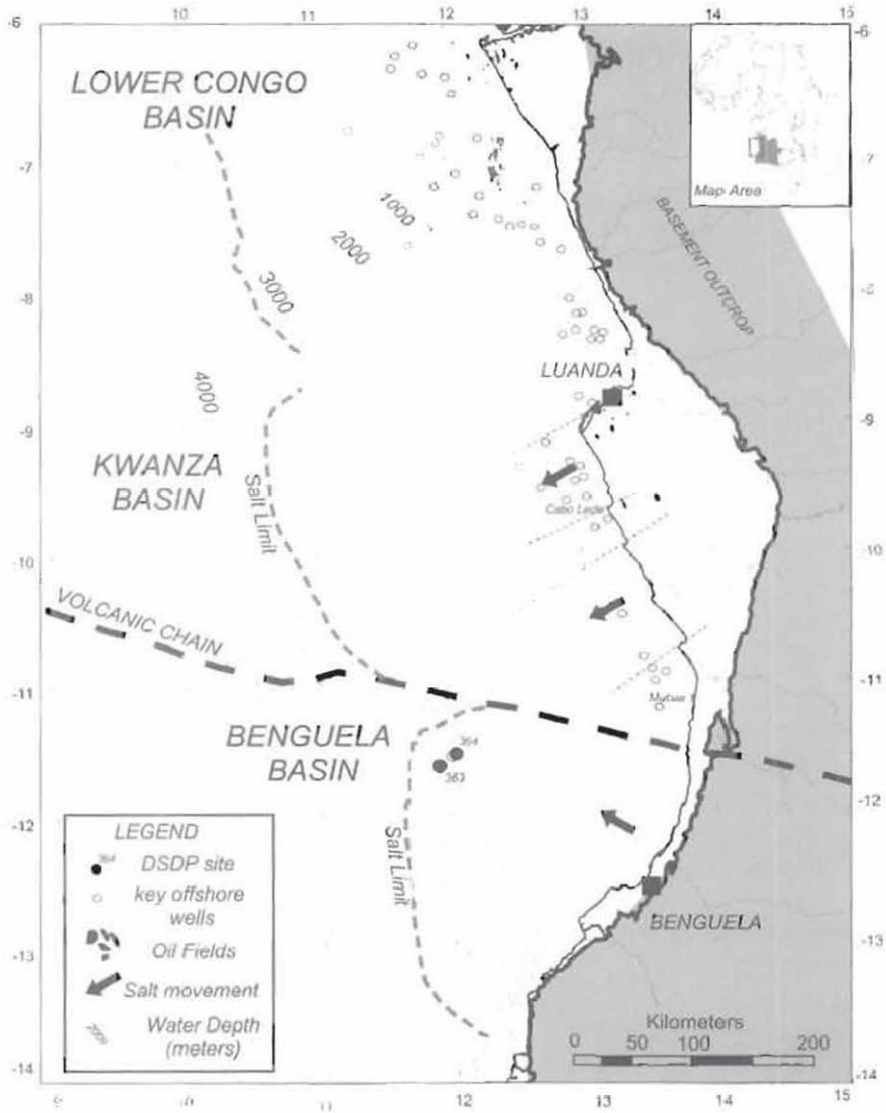

Figure 1: *Location map Kwanza and Benuela Basins, offshore Angola.*

associated with seafloor spreading, as has been previously proposed. Orientation of the lateral boundaries between salt rafts (same direction as the dip of the base of salt décollement) is similar to the orientation of the seafloor transforms, or perpendicular to the continental margin at the time of spreading. Rafting of the postsalt section has transported large volumes of shelf sediments as much as 20 kilometers basinward. Restoration of rafted terrain facilitates paleogeographic mapping of the Albian carbonate facies.

Hydrocarbon Migration

The salt tectonics also affected patterns of petroleum migration. Much of the salt is concentrated in ridges, diapirs or allochthonous bodies, with the remainder being isolated salt prisms trapped as the salt sheet evacuated the area in its basinward movement. In areas of greatest sediment loading, salt welds allowed oil from pre-salt sources to move into younger reservoirs. Numerous seafloor oil seeps occur in downdip areas of the southern Kwanza basin, where salt diapirs are abundant. Vertical movement of the salt, which has carried rocks as old as Campanian up to the seafloor, also provided conduits for oil migration. ⇨

Reservoirs

Tertiary sandstone petrology of the offshore Kwanza and Benguela basins is expected to be different, since the provenance of the sands is different. In the Kwanza basin, as much as two kilometers of uplifted Cretaceous and Paleogene sediments were removed during the Neogene from the onshore and redeposited in deepwater offshore. In the Benguela basin, adjacent basement areas were uplifted as much as three kilometers, creating a steep gradient that facilitated delivery of first-cycle siliciclastics from a mixed granite and metamorphic terrain into the deep basin during the Neogene.

A volcanic chain separating the two basins offshore extends onshore as a series of syenite and carbonatite intrusives. Basalts and minor rhyolites occur where the chain crosses the boundary fault at the edge of the basement outcrop. Locally, a basalt (basanite) dated as Cenomanian fills in karstified Albian carbonates, implying local post-Albian, pre-Cenomanian doming associated with one of the volcanic centers. Volcanics have been observed onshore and in southern Block 9 offshore; however, the linear extent of a chain of seamounts trending WNW for a great distance offshore was only recently recognized through the use of satellite altimetry-derived gravity data. The age of volcanic activity is not well documented.

Streams discharging from the volcanic area should have deposited a mixture of volcanic and intrusive igneous debris locally in the northern part of the Benguela basin. The influence of the Tertiary sandstones on reservoir quality is thought to be localized, because volcanic lithologies or problematic mineralogy are not seen in either DSDP Site 364, 50 kilometers south of the chain or in the Tertiary section penetrated by the Mucua-1 well, 40 kilometers north of the chain.

Traps and Timing

The structural history of the area has generated many styles of traps, most of which are undrilled. Objectives range from presalt to Albian shelf carbonates to Tertiary deepwater fans. Numerous traps with anomalous seismic amplitudes in the Tertiary occur on anticlines and on the flanks of salt structures. Presalt sources have been in the oil window since the early Tertiary. Postsalt sources are modeled to have locally generated and expelled petroleum coincident with late Tertiary sediment loading.

Risks

The principal exploration risks in the deepwater areas of the Kwanza and Benguela basins are petroleum charge and reservoir quality. The efficiency of charging the traps with commercial volumes of oil is uncertain. It is also difficult to predict if the Tertiary sandstones will ultimately yield reserves and flow rates that can support commercial levels of production. Drilling that will follow the current leasing activity in the area should resolve these questions.

Biographical Sketch

Al Danforth is a senior explorationist at Texaco's international exploration department in Bellaire, Texas. His 26-year career in the oil business includes experience in the regional geology of many of the major frontiers and producing basins of the world in the course of pathfinding, new venture evaluation, and acquisition for Texaco, Chevron, and their affiliate, Amoseas Indonesia. This article was prepared and presented jointly by Texaco and Sonangol for the Hedberg Research Symposium on "Petroleum Systems of the South Atlantic Margin," jointly sponsored by AAPG and ABGP in Rio de Janeiro, November 1997. The author especially expresses his thanks to Sonangol for granting permission to present the results of this work to the Houston Geological Society. □