Deepwater Gabon – Is it an Analog for the Deepwater Gulf of Mexico?

James F. Fox, Reading & Bates Development Co.

Paul R. Ashton, Vanco Energy Co.

Introduction

Raft features created by gravity gliding on a salt layer dominate the shelf area offshore West Africa. In the deepwater area downdip of these rafts, a series of compressional features absorb this extension. These salt features have a major impact on sedimentation. Major minibasins form due to thin-skinned extension and linked compression, compared to other salt basins worldwide where minibasins form due to differential loading. These minibasins trap thick sections of basin-floor fans on the upper slope. Continued salt movement allows many depositional lows to later become highs, either as turtle structures or compressional over-printed structures. This yields attractive exploration targets with thick reservoir sections being preserved in structural highs.

Applying the salt tectonic models that are present in West Africa to the subsalt province of the deepwater Gulf of Mexico could yield a dynamic exploration model that will lower risk and uncertainty.

Description of Salt Structural Style

Gravity gliding (raft tectonics) is a well-recognized mechanism of salt movement in offshore West Africa, offshore Brazil, and in the eastern Mediterranean. Salt served as a decollement surface that allowed thin-skinned extensional features to form above the Aptian salt layer in West Africa (Figure 1). Gravity gliding is the translation of fault blocks down a gentle slope. Post breakup of the South Atlantic during the late Aptian, the outer continental margin gradually subsided into the newly formed oceanic basin, and Albian carbonates were deposited on the shelf. This subsidence and sedimentary loading allowed the gravity gliding phenomena to start. Rafts of the newly deposited sediment formed as the margin overextended. The rafts translated downdip and young sediments infilled the expanding depocenters that grew with continued sedimentation. Salt

Paper presented at the AAPG Hedberg Research Conference, "Integration of Geologic Models for Understanding Risk in the Gulf of Mexico," September 20–24, 1998 (Galveston, Texas).

rollers underlie the rafts, and as the salt was squeezed out downdip, listric faults soled out onto the evacuating salt layer, and salt and fault welds formed.

In addition, reactive diapirs formed in the void left behind as the rafts moved downdip. Reactive diapirs form during regional extension, and collapse grabens form over the crest of laterally stretched diapirs. Reactive diapirs use the additional space created by the extension as a weakness zone to rise through sediments. As extension continues, the reactive diapirs collapse, leaving behind inverted basins that are "inverted turtles".

This extension is accommodated downdip by the formation of a downdip fold and thrust belt. Locally, there is also displacement of salt into allochthonous sheets. This linked system forms varying types of salt structures that segment out into provinces:

1. In the north is a zone that has experienced raft tectonics, but has not overextended as much as further seaward. In this area, we see the Albian rafts are separated by reactive diapirs, and long, linear glide faults develop that bound minibasins. The rafts and reactive diapirs all strike from northwest to southeast and the rafts are clearly gliding downdip to the southwest on a gentle base salt slope.
2. Further seaward, there is a change of structural style. The rafts become more broken up, and the reactive diapirs have deflated. The deflation is due to overextension of the margin above the salt decollement surface. Many of the rafts and deflated diapirs still trend northwest southeast, but a large number are beginning to show more of a north-south trend.
3. The next province seaward is typified by a series of long linear compressional features form that are called "compressive toe diapirs". The base of salt dip flattens, and the original salt thickness is greater. In this province, which essentially marks the beginning of the contractional stress regime, the post-salt sequence is folded and the salt rises to form the compressional diapirs. The diapirs exhibit a strong basinward tilt, and have thrust faults on their seaward side. The diapirs are not point sourced, but are long linear walls that trend northwest southeast. Long narrow minibasins form between these compressive salt walls.
4. The next province is dominated by more massive salt. The salt forms swells that have an obvious compressional nature and are therefore labeled "massifs with compressional toes". A very thick salt layer forming swells under a strongly folded post-salt section

characterizes the province. This folding uplifts the section, forming very large anticlines. The folds also exhibit episodic growth that sometimes continues to the present day with uplift and erosion present at the sea floor.

5. Thick salt massifs with no obvious compression, but some uplift due to probable compression and differential loading characterize the zone furthest seaward. Further south, offshore Angola, a similar province is located just shoreward of a volcanic or basement high that was probably emplaced during the Aptian. This area offshore Gabon may be analogous, and some of the bright reflectors near the top of salt may be interbedded volcanics.

Factors influencing the distribution of salt features

Regional mapping shows that there are several main factors that control the location of the rafts, compressional toe features, diapiric salt features and major mini-basins. These are, in order of importance:

1. Basement topography – This includes the type of basement, whether continental, transitional, or oceanic. Also important are major basement faults that have been reactivated or caused differential fault block rotation and subsidence.

2. Changing dips on the base of salt – Basement topography is important, but early synrift sedimentation filled in many of the discontinuities. The base of the salt is the decollement surface that the salt glides upon, and a strong variation in dip occurs where the basement blocks rotated synthetically versus antithetically. Shoreward, the dip is severe and the rafts glide basinward. In the deeper water, the dip on the base of salt is less severe, and the compressional features form on this flat dipping area. This strong change of basement dip is called the “Atlantic Flexure” in northern Gabon and offshore Angola.

3. Original thickness of salt – The combination of the two previous factors controlled the original thickness of the salt. Shoreward there was less initial thickness of salt due to limited subsidence of this part of the margin. Seaward, the basement was subsiding more rapidly, and thicker salt was deposited. The rafts glide on moderate thickness salt, whereas the toe features and salt walls require thick salt.

4. Loading phenomena of major deltas and linked fans - The Gulf of Mexico exhibits a strong relationship between loading and salt movement. The same is true for the West

African margin that offsets the Congo River. The arcuate nature of some of the salt walls away from the Congo River loading indicates that differential loading is playing a part in the mobilization of salt.

5. Convex vs. concave basin margins – This is in regard to the amount of accommodation space downdip of the overextending rafts. The rafts collide on concave margins because they are tangentially gliding toward one another as they move basinward. On a convex margin, the rafts will separate as the glide downdip and away from one another.

6. Width of the initial carbonate bank - Albian carbonates developed on the paleo-shelf and then overextended into deepwater. Rafts could only form where the shelf carbonates could build a sufficient thickness. Rafts do not form in the less cohesive distal shales and marls.

Possible Analogs

Similar linked systems are seen along the West Africa margin, and many structural analogs can be found offshore Congo and Angola in the Lower Congo Basin. The area is also very analogous to the offshore Campos Basin in Brazil. The linked nature of the rafts and compressional features look alike, and their impact on Tertiary sedimentation appears similar.

The interaction of all of these factors could have an impact on models related to salt sheets in the Gulf of Mexico. The study area is most analogous to an area offshore Louisiana in the Mississippi Canyon deepwater region during the early Miocene. The seaward features resemble the Mississippi Fan Fold Belt. The toe thrusts and salt walls could be an example of early salt feeders for the large salt sheets. Detailed analysis of the features offshore Gabon could yield important clues to the subsalt minibasins in the Gulf of Mexico. Also, after initial emplacement of salt sheets, gravity gliding could be the major force that allows secondary features, such as toe thrusts and colliding minibasins, to form.

Other points of the analogy are important to examine as exploration in the deepwater continues:

1. Basement topography and dip - Basement is hard to image on seismic in the Gulf of Mexico, but gravity and magnetics and recently published models indicate a similarity with West Africa. The importance of basement transfer faults in segregating the margin is clear in both basins. With the clear influence of basement faults on the compressional features in West Africa, it is possible that a basement fault model will

have a strong impact on the location of compressional features in the subsalt region of the Gulf of Mexico.

2. Concave margin – The Gulf of Mexico is a concave margin, and like the West African margin, will have space problems downdip for the large amount of thin-skinned extension updip.
3. Loading phenomena – Major deltas and their linked deep sea fans impact the salt structuring in the Gulf of Mexico. Both this loading phenomena and underlying basement lineaments also impacts minibasin types. We see the same pattern emerging in West Africa.

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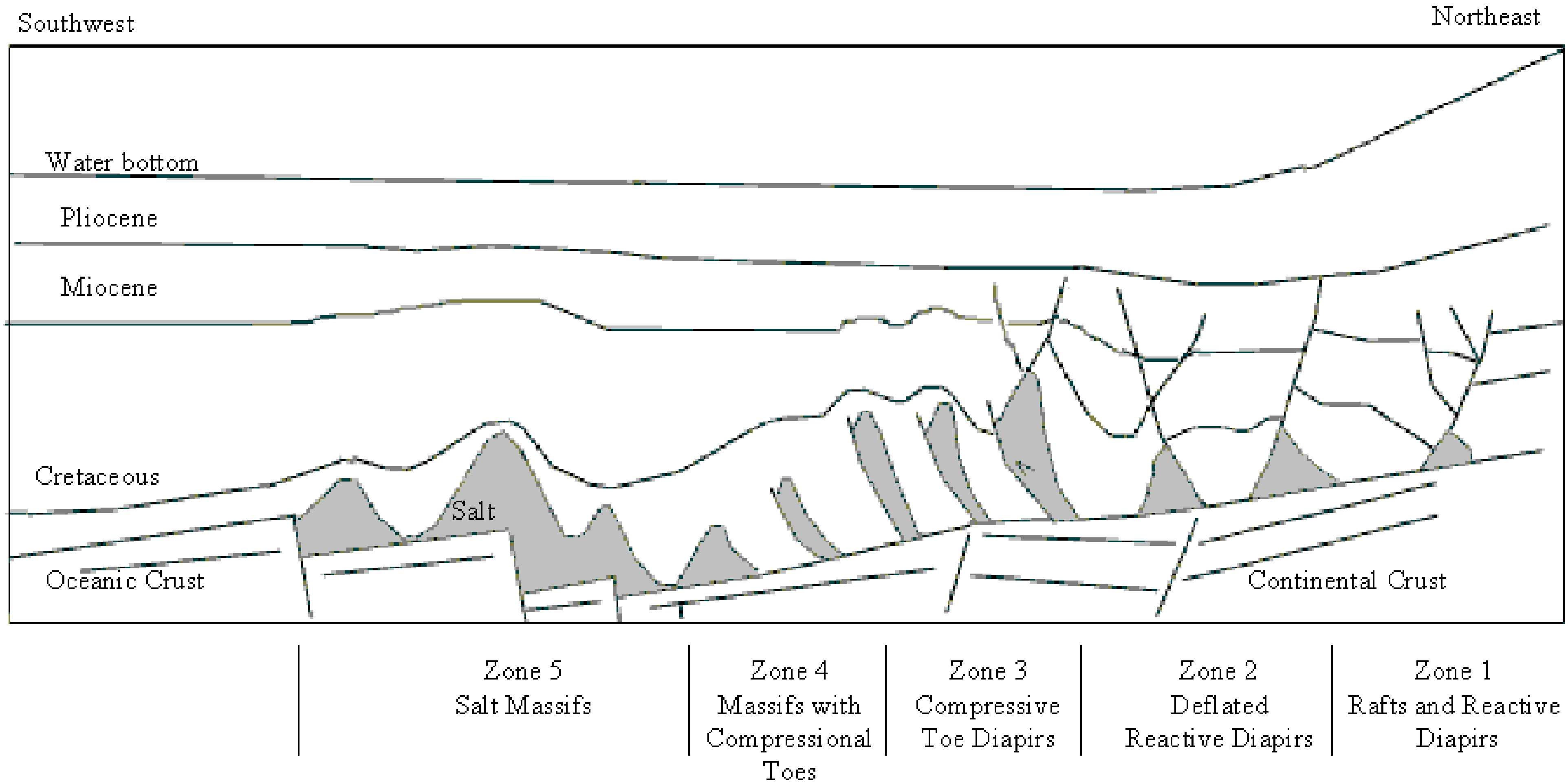

Scale 1” = 10 Miles

Figure 1 Offshore Southern Gabon