SALT CONTROLLED SUB-BASINS IN NORTHERN SANTOS BASIN

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Summary

The interplay between the great amount of Aptian salt and the intense progradation of sediments during Late Cretaceous favored conditions for the formation of sub-basins controlled by salt movement in the Santos basin, in a time of dominant highstand of sea level.

During Late Cretaceous diastrophic tectonism and associated volcanism were intense and the denudated Mountain Range from Rio to Cabo Frio acted as a provenance area for sediments. Thick package of sediments were deposited in such a way that it overcame the worldwide tendency of sea level rise during this time. Proximal facies represented by coarse siliciclastics are widespread in the platform area and distal facies represented by turbidites interlayered with pelagic shales were mainly deposited in sub-basins controlled by salt movement along the slope of the basin.

Late Cretaceous sedimentation rate was so high that the progradation even bypassed the Cabo Frio Fault, a major structural feature which trends NE-SW and separated platform from slope areas mainly during Maastrichtian. Thousands of meters of sediment accumulated in the down thrown side of the fault. From Cenomanian into Maastrichtian sub-basins related to salt movement were formed in the distal area resulting in the deposition of interbeded sand and shale in these sub-basins.

Later movement of salt uplifted previously deposited sedimentary packages during Upper Cretaceous, resulting in partial erosion of the sequences. These reworked sediments were deposited in neighboring sub-basins which are slightly diachronous in time.

Introduction

Santos basin is located along the southern coast of Brazil between the parallels 23 and 28 degrees south and it presents an area of about 275,000 sq. km. up to the bathymetric contour of 2,000 m. It is separated from Campos basin, to the north, by the Cabo Frio High and from Pelotas basin, to the south, by the Florianópolis Plataform (Pereira and Feijó, 1994).

The focus of this study is the northern area of this basin, which presents an area of about 60,000 sq. km., extending itself along the southern area of Rio de Janeiro state.

Main geological features in northern Santos basin include:

1) a hinge line, located about 50 km from the coast and trending in an E/NE-W/SW direction;

2) a regional antithetic fault created by salt evacuation, the Cabo Frio Fault, in the central area (the Cabo Frio Fault Zone, Mohriak *et. al.*, 1995), sub parallel to the hinge line and,

3) the area of sub-basins encased in the salt prone area, southern of the Cabo Frio Fault.

Santos basin evolved in a similar way of adjacent Campos basin, although thermal subsidence was more intense than in Campos basin, having an important control in salt accumulation and post-salt sedimentation and structural effects.

Sedimentation started during Barremian and continued during Aptian in a rift and transitional environment above previously extruded basalt. This section was capped by very thick salt deposition, mainly halite, which had a very important control on Albian to Maastrichtian sedimentation pattern. Upper Cretaceous section is very thick in Santos basin, while Tertiary section is rather thin along the basin, the opposite of Campos basin where Upper Creteceous section is rather thinner and Tertiary is much thicker.

Salt controlled sub-basins occur nowadays in actual water depth above 1,000m. They were studied in an area presenting a width of 90 km and extending themselves along 250 km, giving a total of 22,500 sq. km., in a NE-SW direction. The area of the salt controlled sub-basins received much of the salt remobilized from shallower areas and its movement had a very important control on sedimentation since Early Albian.

The term salt controlled sub-basin is used here as a depositional site from Albian to Maastrichtian presenting less than 500m of salt in the area of the sub-basin, surrounded by salt pillow and domes whose thickness varies between 500m and over 3,000m.

Salt Controlled Sub-basin Formation

Some important factors which control the formation of these sub-basins are:

1)Salt base has a steep dip in the border of the basin, becomes deeper in the central area and becomes gradually shallower in deep water (above actual 2,000m water depth). This profile must have allowed originally a thicker accumulation of Aptian salt in the central area of the basin as can be observed by the Upper Cretaceous sedimentation pattern in the central area of the basin, adjacent to the Cabo Frio Fault. The salt was later remobilized toward deeper waters.

2)In many areas of northern Santos basin Lower Albian sedimentation, just above salt, seems to have been in a very deep environment, being shale prone and practically devoid of microfossils probably due to CCD (carbonate compensation depth).

3)Very intense progradation of coarse siliciclastics from Cenomanian to Maastrichtian, in a time of dominant high stand of sea level, exerting a huge weight above salt, pushing it laterally toward deeper waters.

Salt controlled sub-basins generally decreases in size toward deeper waters while at the same time they become more encased in salt.

Salt Movement Structural Effects on Albian to Maastrichtian Section

In the proximal and central areas of northern Santos basin (up to the bathymetric contour of 1,000 m) most of the growth faults associated to salt generally affect sediments up to Campanian, and only locally they affect sediments as young as Tertiary. Originally deposited salt in these areas were removed to deeper waters, except small salt pillows beneath fault planes. The fault planes terminate in the salt base level.

The Cabo Frio Fault strikes in a NE-SW direction around actual water depth of 1,000m. It has several subsidiary synthetic and antithetic faults, and they affect sediments as young as Miocene. This fault generally separates areas almost devoid of salt pillows and domes to the north from areas with thick and more continuous salt layers, pillows and domes to the south.

North of the Cabo Frio Fault, Lower Albian to Cenomanian section was deposited in highs and adjacent lows, controlled by growth faults. Closer to the Cabo Frio Fault, fault movement had a big control on Upper Cretaceous deposition pattern, whose layers dip very steeply toward the salt base.

South of the Cabo Frio Fault, in areas where salt pillows are present, Lower Albian section was also uplifted, whereas in areas of salt domes, Upper Cretaceous section was partially uplifted and partially broken and pushed away by the salt dome uplift. Further south, toward deeper waters, fault pattern is dominantly located above domes crests, affecting mostly the Tertiary section.

Generally, in areas above 2,000 m water depth, sediments affected by salt movement are rather folded than faulted.

Salt Controlled Sub-basins Filling

In general, the more distal these sub-basins are the younger is the age of the sedimentary infill. In the more proximal sub-basins, sedimentation within the sub-basins started during Early Albian, and adjacent sub-basins toward deeper waters sedimentation started later, during Cenomanian, Campanian or even Maastrichtian. Age of the sedimentary filling are probably synchronous with basin formation, which are generally younger toward the basin.

Facies variation occur along adjacent sub-basins along the strike, some of them are more sand prone while others are more shale prone. This may be related with the pulses of movement of the Cabo Frio Fault, which generally separates dominantly coarse siliciclastics deposited on the platform to the north from dominantly shale prone areas deposited on the slope to the south. Another aspect that may be responsible to facies variation in the sediments that fills these sub-basins is the shape of the sub-basins. Some of them allow better connection with areas source of sediments while other sub-basins evolved in a more isolated way.

In the more proximal sub-basins, whose evolution started earlier and where Albian and Cenomanian comprehends about half of the sub-basin filling, mostly constituted by shale, marls and sandstone turbidites, environment of deposition was very deep what can be estimated by the absence of preserved microfossils even in shale prone sections, probably because these areas were below CCD.

Another important point is that most of the sedimentary filling of these sub-basins occurred during Cenomanian, Campanian and Maastrichtian, a time of worldwide high stand of sea level. However, in northern Santos basin, source of sediments were available from the Mountain Range from Rio to Cabo Frio, which acted as a provenance area, in such a way that it overcame this dominant period of high stand of sea level and coarse siliciclastic sediments were deposited and preserved in the platform area, about 80 km wide.

Subsequent movement of salt from one sub-basin to the adjacent one may have uplifted part of the deposited section within one sub-basin, partially eroded the section top which was then redeposited in the neighboring one. So, Maastrichtian top in one sub-basin may be slightly diachronous in time than the adjacent one.

In adjacent Campos basin, for instance, Upper Cretaceous batial sediments were deposited adjacent to the basin border fault (Rangel *et. al*.., 1987), attesting the affect of the high stand of the sea level in the southern area of Brazil during this time.

Also, tectonic pulses were verified in the basin from Cenomanian to Maastrichtian, by the presence of volcanic rocks such as basalt layers, volcanic cones, etc., within the sedimentary section. These volcanic rocks, which may be more prolific in the platform area, are also present within the sediments that fills some of the sub-basins. In the extreme northern area of Santos basin and in southern Campos basin tectonic events became more important from Early Paleocene into Mid Eocene (Rangel and Barros, 1992). Tertiary section presents less variation in thickness along dip from the border of the basin to actual 2,000 m water depth, indicating small effect of salt movement in the area during this time. But in areas above bathimetric contour of 2,000 m, there are thickness variation in the Tertiary section attesting the effect of salt movement in the deeper areas of northern Santos basin during Tertiary.

Conclusions

Salt controlled sub-basins were formed in northern Santos basin due to the variation in the declivity of the salt base along the basin which allowed a thick accumulation of Aptian salt and the intense progradation of sediments from Cenomanian to Maastrichtian in a time of dominant high stand of sea level. The interplay between these two factors allowed the formation of the salt controlled sub-basins in the region presently under 1,000 m water depth.

These sub-basins generally become smaller in size toward deeper waters and basin filling varies according to the shape of the basins which may have allowed a better connection with source of sediments area or evolved in a more isolated way. Age of sedimentary filling are probably synchronous with basin formation, which are generally younger toward offshore.

These salt-controlled sub-basins present favorable petroleum systems for hydrocarbon exploration.

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