Lower Tertiary Salt-Sediment Interaction in Walker Ridge, Deep Water Gulf of Mexico

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Abstract

The Cascade discovery, operated by BHP Billiton, identified a thick Lower Tertiary, Wilcox equivalent, section and opened a new exploration trend in the historically unsuccessful Walker Ridge, Gulf of Mexico protraction area. Subsequent exploration wells confirmed a prolific hydrocarbon trend within an extensive clastic depositional system. The areally extensive, thick sand section generated questions concerning sediment transport, dispersion, and the interaction with salt during the Lower Tertiary period. Log and core data from Cascade suggest the Lower Tertiary sequence is composed of stacked, amalgamated sheet sands deposited as basin floor fans, with the well located in the mid to distal fan. Salt history reconstruction from the Late Cretaceous through Early Eocene depicts an open system for deposition with little restriction from paleo salt relief. Pre-stack depth migrated seismic isopach maps from Top Cretaceous to Early Eocene demonstrate autochthonous salt movement during the Cretaceous and into the Lower Tertiary. This is also evidenced by an increased number of moderate relief, high frequency salt ridges located proximal and sub parallel to mapped autochthonous salt limits. The generation and progression of Walker Ridge folds began in the Northeast with subsequent evolution trending south, southwest. Isopach maps generated with available data, show local variations over the frontal folds yet subtle variations on a regional scale. Conclusions are that Lower Tertiary clastics were deposited in a relatively unrestricted system with minimal basal salt layer influence. Lower Tertiary Deposition may have perpetuated but did not initiate autochthonous salt movement.

Prior to The BHP Billiton operated Cascade discovery, Miocene exploration targets in Walker Ridge were unsuccessful, with poorly developed reservoirs and no economic hydrocarbon accumulations. The Cascade prospect's original target also proved unsuccessful, but regional information from key industry wells led the partnership to explore for deeper potential. The result was the first discovery in Walker Ridge, which opened a new exploration trend targeting a deep, Lower Tertiary (Wilcox equivalent) interval. Subsequent exploration wells confirmed areally extensive sands and a prolific hydrocarbon system. This generated questions concerning sediment transport, dispersion, and the interaction with salt during the Lower Tertiary period.

Log and core data from Cascade suggest the Lower Tertiary interval was composed of stacked, amalgamated sheet sands deposited in a basin floor fan setting. Deposition of the section occurred over a 15 million year time interval, originating from a north to northwestern source and traveling a tremendous distance basinward. Grain size and stacking facies suggest the Cascade well penetrated the mid to distal fan.

Observed stratigraphic thinning over paleo salt features and terminations mapped at salt ascension zones identified influential salt bodies during Lower Tertiary sediment deposition. The resulting map shows a scattering of discrete, isolated salt structures, as well as low amplitude, high frequency folds and the autochthonous nappe. While paleo salt influenced structural generation, thick sand accumulations indicate deposition was minimally affected. Furthermore, the wide distribution of discrete salt bodies and lack of large, linear geometries, suggests that there were no regional boundaries impeding deposition or creating tortuous, or focused paths in the Walker Ridge area. Deposition occurred through a largely open fairway facilitating the development of a thick, geographically extensive system over a long temporal duration.

Although paleo salt features present at Lower Tertiary time had little regional depositional influence, their distribution and continued-mobilization influenced local deposition. Early salt movement in the Walker Ridge fold belt initiated by up dip extension during the Jurassic, Cretaceous and into the Lower Tertiary generated compressive forces at the down dip salt terminus (Rowan, et al, 2004). This is supported by the presence of an allochthonous nappe extending south and southwestward from autochthonous Louann salt. In addition, low amplitude, high frequency folding of Cretaceous and Lower Tertiary strata is observed on seismic data and isopach maps between the Top Cretaceous and Early Eocene events. These folds form broad arcuate ridges sub-parallel to the mapped limits of the Louann salt nappe. Paleo salt relief at the edge of the Louann nappe may have formed a secondary basinal slope of which Lower Tertiary sediments spilled over onto a deeper basin floor. Thinning and stratigraphic terminations of the Paleocene and Eocene provides further evidence for early salt relief. Discoveries such as Cascade and St. Malo demonstrate such geometries.

Simple structural reconstructions over the St. Malo and Chinook discoveries show the relationship between subtle relief of top Louann salt and the variable thickness of the Cretaceous section. By the top of the Early Eocene, we see the continued influence of Louann salt mobilization driven by compression and resulting in early salt inflation and low amplitude, high frequency folding in the Cretaceous sediments. This created the initial development of discrete structural highs, which later became salt feeders or structural traps. The predominant structural maturation of the modern day Walker Ridge fold belt occurred in the Miocene, facilitated by salt withdrawal in the back basins and sustained salt mobilization from differential loading. While most of the salt evacuated and formed a canopy, some salt was mobilized into the autochthonous nappe. This drove salt inflation at structures such as St. Malo and Chinook and continued until the Louann salt welded out in the back basins. In some instances, such as Chinook, salt evacuation and mobilization of the frontal fold continued well in to the late Miocene. This is evidenced by the presence of a thick Miocene section situated over the thin Lower Tertiary, back basin limb.

From analyzing seismic data, structural and isopach maps and basic structural reconstructions, we conclude that Lower Tertiary clastics, in the Walker Ridge Area, were deposited in a relatively unrestricted system with minimal basal salt layer influence. Autochthonous salt movement was initiated by down dip compression driven by up dip extension in the Jurassic through early Paleocene, while major structural formation of the Walker Ridge fold belt occurred during the Miocene driven by salt withdrawal in the back basins.

References

Rowan, M.G., F.J. Peel, and B.C. Vendeville, 2004, Gravity-driven fold belts on passive margins, *in* K.R. Mclay, ed, Thrust tectonics and hydrocarbon systems: AAPG Memoir 82, p. 157-182.