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Turbidites from Deep Water Campos Basin Visualized on 3D Seismic Attribute Volumes Using Stratigraphic and Structural Concepts

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Abstract

Many oil accumulations in deep water portion of Campos Basin, offshore, Brazil are located in Oligocene/Miocene, sand-rich turbidites that consist of contrasting architectural types.These reservoirs comprise up to 50 m-thick, 1-5 km-wide, and 2-10 km-long lobes displaying compensation stacking patterns. These turbidites have high structural dips and also high variability in spatial distribution and heterogeneities. They show seismic reflections mostly embedded into a single amplitude trough meaning a relative decrease of seismic impedance, which can not be followed or resolved by conventional mapping using either automatic or hand tracking. The geometry and resolution of such reservoirs are fundamental for the positioning of high-cost horizontal and multilateral wells. For these turbidites we need more than conventional concepts of seismic stratal surfaces to visualize their stacking pattern because we can not recognize a single frequency-independent event that can be used as a stratigraphic datum for attribute slicing. Furthermore the simple but good concepts of stratigraphic volume visualization strategies as time windowed, detection and horizon keyed also need tobe enhanced to isolate them because these technologies are based on the values of physical samples and normally the attribute-strenghts into the stacking pattern have subtle or no differences. This paper shows how to use concepts of seismic stratigraphy and structural geology combined with concepts of seismic attribute transparency to visualize and map such turbidites from deep water Campos Basin. A geoadaptive approach of 3D seismic visualization is introduced by using several relative seismic time-stratigraphic windows in agreement with previous geological models and then mapping and detachment of depositional subystems through variable-shifted surfaces from the attribute volume.

INTRODUCTION

3-D seismic data have proven to be a powerful structural risk reducer for oil exploration in Campos Basin. Modern seismic visualization is bringing a similar positive economical impact for exploitation activities of Petrobras in this basin. Such importance is directly related to how the reservoirs will be developed in the deep water portion. Hundreds of horizontal and multilateral wells are planned to be drilled in the next years and they need a high-precised positioning. This is mainly intensified when the targeted accumulations are in thin and heterogeneous with small seismic time-resolution among amalgamated lobes. This economical risk challenges the conventional seismic refletion method as an effective tool for optimum reservoir characterization in this portion of the basin. Every modern 3D seismic visualization techniques has been failed for these targets because they consider separately either stratigraphic concepts or physical-mathematical approaches. Aiming to overcome these limitations we present a geoadaptive visualization in which is considered previous stratigraphic and structural concepts about how deep water turbidites are stacked into different architetural types building depositional subsystems. These concepts are combined with those related to stratal surfaces mapping (Zeng et al, 1998) and interesting voxel concepts in the detection and mapping (Kidd, 1999-a). A geoadaptation of a 3D seismic visualization initially needs structural and stratigraphic models for the deposition of the targets. In the deep water portion of Campos Basin they are unconfined, sand-rich lobes heavily dissected by younger, mud-filled channels, unconfined, sand-rich lobes, trough-confined, sand-rich lobes, and sand-rich channel-fills and splays. These complex systems become the use of simple stratigraphic sequences concepts in a hard task on defining seismic surfaces for their 3D visualization because there is not a frequency-independent that can be used as a reference for all of them. However the interpretation and drawing of continuous bodies from several stratal surfaces got from an uniform seismic reference “build“ several but “invisible” different seismic reference surfaces that are able to isolate meaningful geological subvolumes. This geoadaptive visualization technique is illustrated for a 9km-long turbidite system, but it can be applied to any other depositional system which is displaying in a single seismic event with very small and invisible differences in their attributes.

IMPORTANCE OF THE STRATIGRAPHY AND STRUCTURAL GEOLOGY OF OLIGOCENE/MIOCENE TURBIDITES FROM DEEP WATER CAMPOS BASIN FOR THEIR 3D SEISMIC VISUALIZATION

Oligocene/Miocene, sand-rich turbidites fill intra-slope, wide depressions in the present day deep water (400-2,500 m) Campos Basin, which were developed in response of the eastward tilting of the basin, and the resulting downslope gliding of underlying, Aptian evaporites. Oligocene/Miocene reservoirs are mostly composed of (1) unstratified, medium- to fine-grained sandstones, and (2) amalgamated T_{ab}, T_{abc}, and T_{bc} Bouma beds of fine- to very fine-grained sandstones. Porosities and permeabilities are relatively homogeneous, typically averaging 28-30%, and 1,400-1,5000 mD, respectively.

Four major architectural types of turbidite reservoirs were recognized in the study area (Lopes et al., 1999; Figure 1): (1) unconfined, sand-rich lobes heavily dissected by younger, mud-filled channels, (2) unconfined, sand-rich lobes, (3) trough-confined, sand-rich lobes, and (4) sand-rich channel-fills and splays. Individual lobes comprise up to 50 m-thick, 2-8 km-wide, and 5-12 km-long sandstone bodies, commonly displaying compensation stacking patterns. The four architectural types comprise the lowstand systems tract of four distinct 4th-order sequences, which can be bounded in the study area by unconformities and/or correlative, non-erosive surfaces. These four sequences resulted from falls in relative sea level (and related increase in sediment supply) that punctuated the overall trend of sea level fall from the Middle Eocene to the Recent. The overlapping or coalescing of several lobes form oil-bearing turbidite complexes (up to 100 m-thick) exceeding 3,000 km^2 that are normaly laying down over a condensed section widely recognized in the deep water of Campos Basin – the marker bed blue. Such complexes are being developed by several pairs of injector and producer wells being all of them high-cost horizontal and multi lateral wells that need high-precised spatial positioning.

The understanding of the architectural types is crucial for 3D seismic turbidites visualization because they present high spatial variability in their geometry and thickness. Many times they are embedded in a single seismic reflection trough related to a relative-decrease of seismic impedance, which can not be followed or resolved by conventional mapping using either automatic or hand tracking.

Some concepts for improving the ability of picking data following a single 3D seismic model using stratal slices are hard to be applied for such turbidites because there is not a single frequency-independent seismic event which can be used as a reference for slicing and visualizing the different depositional subsystems. On the other hand the important concepts of seismic attribute-volume visualization such as time windowed, detection and horizon keyed strategies as defined by Kidd (1999, b), fail in isolating many of these turbidites because such technologies are based on visual differentiations of physical sample values and the studied amalgamated sand lobes have same visual level of attribute-strenghts.

Figure 2 shows the architetural types into a common seismic amplitude oppacity cube overlying the structural map of the marker bed blue, a condensed section widely correlated in deep water Campos Basin. We observe that it is not possible to identify individual sand geometries as we need for the mentioned oil field development projects. The conventional amplitude map of reservoir-tops showed in Figure 3 was used to define the occurrences of the types illustrated in Figure 1. We can see that only truncated geometries of those types can be safely drawn as much as they are related to the envelope of the low seismic frequency amplitudes from the complete system and they do not represent good spatial images of neither geometry nor heterogeneities for any single turbidite, as required for the mentioned oil field development style.

Each architetural type should be handled like a small stratigraphic unit on the context of the overall deposition history.

In the next section we will concentrate our attention to the central type 2 turbidites of the Figure 3 (unconfined, sand-rich lobes) mostly accumulated along a rollover syncline. The choice is because this type is perhaps the most difficult to be individualized using seismic attributes in that area and we will show that other types will appear after geoadaptive visualization. This area was isolated from amplitude map and is displayed in Figure 3 - B.

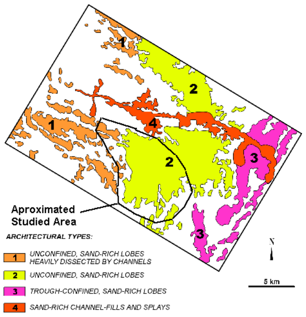


Figure 1- Architeural types of Campos Basin turbidites (after Lopes *et al.*, 1999)

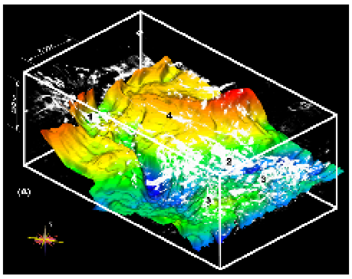


Figure 2- Amplitude opacity cube showing the architetural types. (after Lopes *et al.*, 1999)

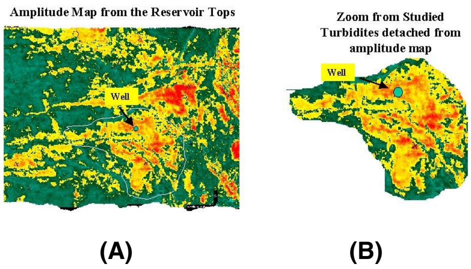


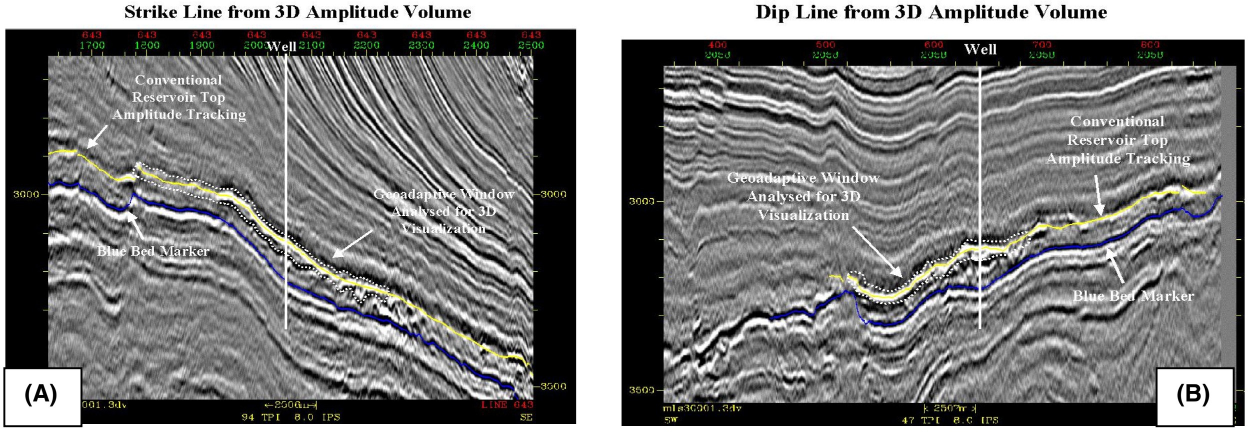
Figure 3- (A) Amplitude map from the sand reservoir top. (B) Study area in detail.

MAPPING 3D SEISMIC ATTRIBUTES USING GEOADAPTATIVE VISUALIZATIONS

The first step of a 3D seismic geoadaptive visualization is the comprehension of the structural and stratigraphic models for the deposition of the seismic target objects. In our example, they are unconfined, sand-rich lobes – type 2 – with geometries defined from seismic amplitude top reservoir mapping. In this step is essential the knowledge about how their geometries are expected to be combined along with the concepts of compensation stacking patterns. For the complete 3D stratigraphic visualization of these turbidites under stratal slicing concepts is necessary more than using a single seismic event considered as a stratigraphic reference. Although no frequency-independent seismic event is present to be used as a single reference for surface slicing for all turbidites, the interpretation and drawing of sandbody continuity by a composition of several stratal surfaces using an uniform seismic datum – the marker bed blue – is possible. This technique removes the structural style imposed to the data until the geological time of the marker deposit and builds several but invisible and different seismic-reference surfaces that are used as limits for each deposition. From them we are able to isolate meaningful geological subvolumes.

Figure 4 A and B, show approximations of 2D adaptive windows in strike and dip lines extracted from the 3D amplitude data. In this example, we use seismic amplitude only for the 3D mapping of marker bed blue. For the adaptive seismic visualization itself we used impedance volume derived from amplitude data inversion that has advantages in time and spatial resolutions compared to amplitude volumes and make possible more precision in the turbidite mapping. We restrict our interpretation to six different subsystems. However with a more detailed analysis it could be extended to at least the double. Each isolated volume has thicknesses that range from 4 to 24 ms retrieved from an adaptive 48 ms window and can be evaluated by using different levels of transparency from the seismic data. Figure 5 shows the example of three adaptive windows displayed over a stratal surface and enhances the most recents of the six interpreted subsystems (A, B and C) detached from the full turbidite system. The subsystem (A) is a water-saturated unconfined lobe that is isolated from the others by their seismic impedances that are subtly different and invisible from the sands which are laying imediately below it. The interpretation is done by the geometries and truncation of lobes.

We can isolate more five subsystems (B to F) going down the section as showed in Figure 6. Following the same process of interpretation and using different levels of transparency, we can observe that the geometry of the dominant architectural type 2, designed from the amplitude map of reservoirs top and showed in part B of Figure 3, is generated by the envelope of the thick and oil-saturated subsystem D overlaying the also oil-saturated subsystems E and F which show continuations of the NW architectural type 1 – unconfined sand-rich lobes heavily dissected by younger, mud-filled channels as showed on the Figure 1. The subsystems A to D were deposited in stacking patterns over the older subsystems E and F. The subsystem F should not be tested by the well pointed in the Figure 6.


Strike Line from 3D Amplitude Volume

Dip Line from 3D Amplitude Volume

Figure 4- (A) – Strike line from 3D amplitude volume showing an approximation of a geoadaptive window for visualization of turbidite systems. (B) Dip line with similar window.

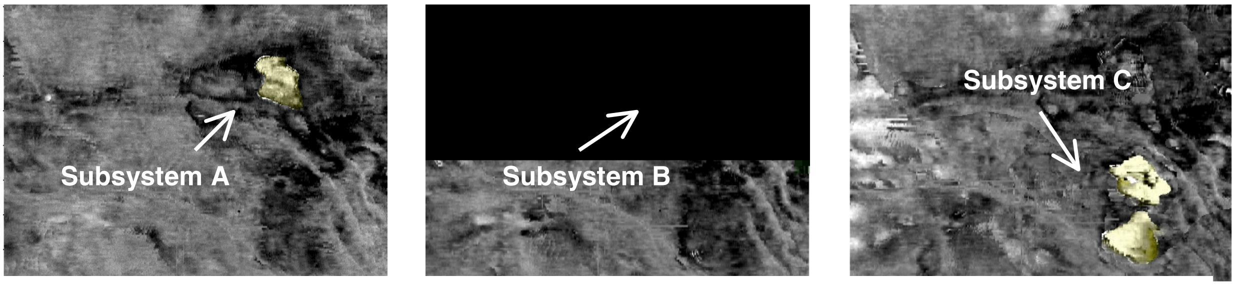


Figure 5- Younger turbidite subsystems A, B and C detached from different and geoadapted 3D seismic impedance windows. Each window has length of about 10 km.

Figure 6- Turbidite subsystems from older F (top left) to younger A (top right) got from seismic impedance geoadaptive windows showed at different steps of transparency. Observe the similarities between full turbidite system envelope geometry (bottom right) and the detached amplitude area from Figure 3, but with differences from higher frequencies for each body definition.

Conclusions

A geoadaptive 3D seismic visualization using stratigraphic and structural concepts combined with several levels of transparency of the data is essential to isolate amalgamated turbidite systems. It is suitable for those sedimentary occurrences which the individual systems can not be mapped by either conventional 2D sections tracking methods or modern techniques of 3D visualization which use only physical approaches of transparency. We use a stratal seismic datum to remove major structural features from our targets and interpret the subsystems using well known models, several geoadapted stratal surfaces and different levels of seismic impedance transparency to isolate and mapping six subsystems, separating oil-saturated, water-saturated and untested sands in a 9 km-long turbidite system from deep water Campos Basin.

REFERENCES

Lopes, M.R.F., Bruhn, C.H.L., Santos, R.A., Corá, C.A.G., Becker, M.R., Alves, R.R.P., and Sarzenski, D.J., 1999, Architecture of Sand-Rich, Turbidite Reservoirs from Deep Water Campos Basin, Brazil, in 1999 AAPG Annual Meeting, Poster Session, San Antonio, Texas.

Kidd, G. , 1999a, Fundamentals of 3D Seismic Volume Visualization:, OTC 11054

Kidd, G. , 1999b, Stratigraphic Volume Visualization – Work Flows and Strategies – Paper submited to 6th International Congress of the Brazilian Geophysical Society – Rio'99.

Zeng, H., Backus,M.M., Barrow, K.T. and Tyler, N., 1998, Stratal Slicing, Part I: Realistic 3-D seismic model. Geophysics , 63, 502-513

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