Generating regional 3D data from historic 2D to enable low-cost regional screening in the Equatorial margin of Brazil.

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Abstract Summary

Exploration is usually performed in a phased approach, regional 2D is initially acquired with very sparse line spacings (20-50 km), this is then followed by a period of densification over specific areas, where 2D is shot on much finer line spacings (5-10 km). After this screening phase, 3D data is acquired on specific areas. This can lead to modern day exploration being overly focused to where only 3D exists.

To maximize the value from the historical 2D library, we took the existing 2D from both the ANP database and TGS data library, totaling over 160,000 line km, to generate a regional 3D dataset in excess of 265,000 km2. To do this we implemented a technology known as 2Dcubed (Whiteside et al, 2013, O'Keefe 2017, Davies 2023).

This involved the matching and merging of several hundred lines of 2D seismic, each with numerous intersections, all from various vintages of acquisition and processing, which is then interpolated using a structurally consistent interpolation to create a single contiguous dataset that is designed for regional screening. In areas where final processed gathers were available, we also generated a series of AVO angle products to further de-risk exploration. This paper will discuss the challenges in creating and processing large volumes of data and the steps associated with generating a 3D volume over a vast area.

Geological overview

The Equatorial Margin of Brazil (EMB) could be on the brink of an oil and gas exploration boom. A string of wildcat discoveries in the adjacent margin (Guyana/Suriname) and on the conjugate margin (Ghana/Ivory Coast) suggest a high probability for similar discoveries in the EMB (Reuber, 2025). The 5th Concession Round of Brazil's Permanent Offer (OPC) contains 47 exploration blocks in the Foz do Amazonas (Amapá sub-basin) and Pará-Maranhão Basins. These blocks have a wide range of play types, mid to late Cretaceous slope fans, stacked channel/levee complexes. The Miocene-Present deposition of sediments from the Amazon River drainage has resulted in the accumulation of thick deltaic deposits. Due to the nature and magnitude of deposition, much of the deltaic cone has been structured in a fold and thrust belt. This deformation has led to the development of additional play types in the area. The thick deltaic sediments, although causing complexities, have insured the emplacement of petroleum system elements necessary for hydrocarbon generation along the margin segment. Notable well results in this area are Petrobras` PAS-11, Pirapema, APS-51A, Harpia and MAS-05 discoveries, plus the BP-02 well, all which encountered oil and/or gas in clastic/carbonate reservoirs ranging from the Late Cretaceous to Miocene, proving at least two functioning petroleum systems offshore. In order to aid exploration activity, use of existing 2D, interpolated to 3D, can yield new insights into under-explored areas within the basin.

Method - data preparation

The first step was to gain access to as much legacy 2D seismic data as practicable, this was a mixture of both pre-stack and post stack data. To improve the similarity of the stack images from different processing vintage, where pre-stack data was available, stacks were re-generated with a consistent mute. QC of over 300 2D lines from 15 different vintages of processing was necessary to understand the data quality, issues and determine what could be used as input to the project. Arbitrary or fence lines were generated to ensure navigation was also consistent.

Most of the datasets data pre-stack time migrated, where depth migrated data was used, we stretched the data back to time with the appropriate velocity. One complication was that one survey had been deghosted and a notional post stack re-ghosting was applied to those data.

Due to the variety of processing vintages, it was not possible to use the existing angle stacks to generate 3D angle stacks due to both the inconsistency of the angle mute used and the variation in velocities used to determine the angles in the original processing. Where processed gathers were available, a consistent set of angle volumes were generated on the 2D data, which would then allow 3D volumes to be created. process can begin, thus the final angle volumes are generated using only a subset of the available data. The lines used in this project are shown in figure 1.

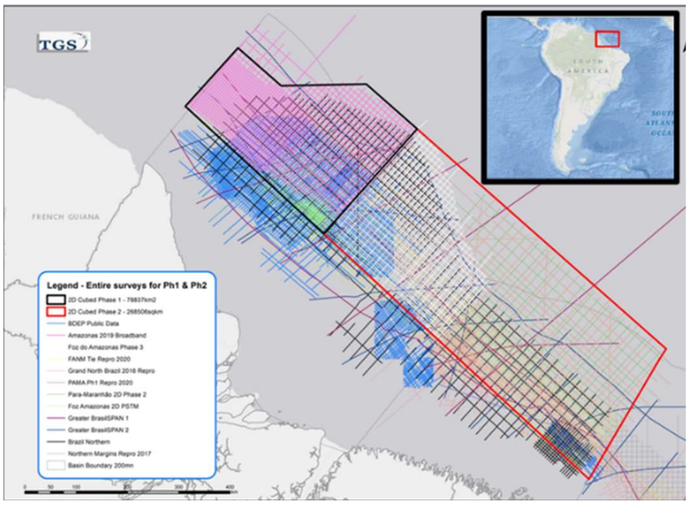

Figure 1 – Map of input data and the output polygon

The data were provisionally matched via a single amplitude scalar, gain function and time shift per survey. The data were then demigrated and matching of both spectral (amplitude and phase) and decay curves was performed. Next, the key step of intersection matching is run on all lines to ensure there are no busts in the data which would result in poor interpolation. A 2D layer model is then generated for each line which is later converted to a 3D model and used as a priori information in the interpolation of the 2D data to a 3D seismic volume, the interpolated data is then imaged with a 3D post stack Kirchhoff migration. The migration velocities came from the existing regional dataset that was recently reprocessed. This was gridded and extrapolated to cover the full area.

Results

In order to extract maximum value from the processing, we needed to overcome the challenge of processing a large area and the geological challenges associated with continental break-up in deep water. In order to meet both these objectives, the data were processed in an iterative manner such that learnings could be incorporated quickly and influence the final products.

The first iteration focused on the north-western side of the output polygon and was limited to an area of ~30,000 km2. This allowed for timely testing whilst still having the challenges of a large area, at this stage only the full stack data was tested. For the second iteration, the area was expanded to 72,000 km2 (black polygon in figure 1), initially there was a focus on the full stack, but once parameters were finalized, the same dip model was used to interpolate the 4 angle stacks. The third and final iteration output the remaining 196,000 km2 (red polygon in figure 1) of data. However, some of the interpolation parameters had to be further refined due to the larger line spacing of the 2D lines along the Eastern edge of the polygon in the deep-water area.The outputs from the first and second iteration were merged to generate a seamless product over the full 268,000 km2.

In addition, where publicly available 3D is present, an additional product was generated where these 3D volumes are inserted into the 2Dcubed data. Inspection of this data validates the appropriateness of the data for regional screening. An example of this is shown in figure 2. Figure 3 compares timeslices of the final 2Dcubed data with underlying 3D inserted in the yellow polygon as demonstration of the validity of the interpolated result.

A final QC is that of the angle products, figure 4 compares the (Far-Near)*Far products from both the 2Dcubed and underlying 3D data. The majority of the events are similar, albeit lower spatial resolution than true 3D, but there are some significant differences in the AVO response due to the AVO fidelity of the original 2D processing, rather than the interpolation scheme we have used.

A by-product of the entire process is that all the individual 2D lines are matched and are output as unified dataset to allow for QC both against historical data and the final 3D volume.

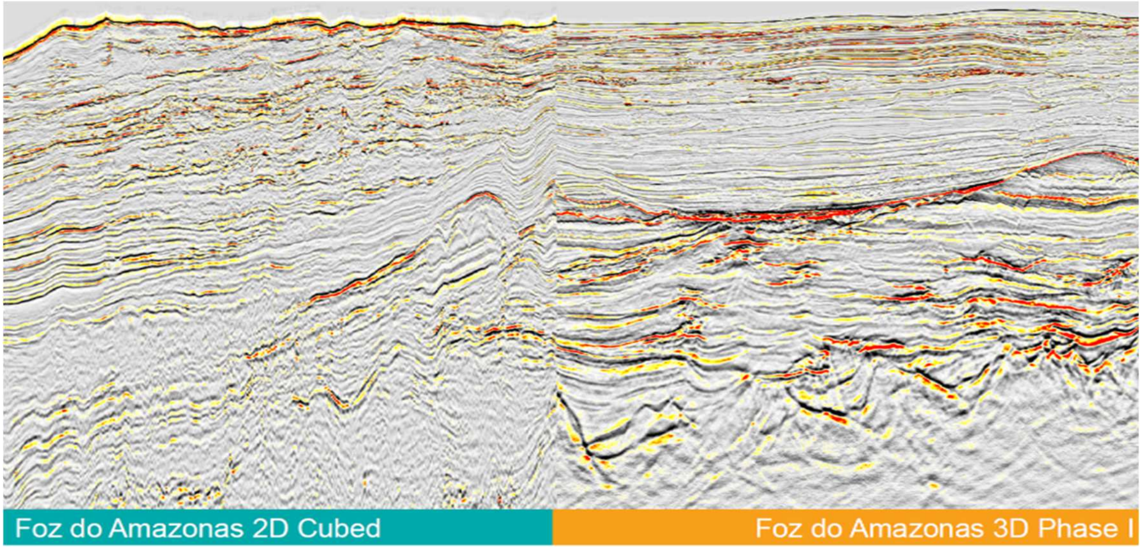

Figure 2 –a butt merge of 2Dcubed (left) and 3D data (right)

Conclusions

The final product yields a 3D cube which is suitable for regional exploration screening and further seismic acquisition survey design studies. The 3D angle stacks, where available, also help reduce exploration risk.

There are some gaps in the data where it was not feasible to accurately interpolate such sparse data, but this does not detract from the advantages that such a dataset offers the user.

The comparison of regional lines at the matching phase showed a significant uplift both in terms of amplitude scales, but also intersection matching. However, the most powerful demonstration of the success of the process is a comparison of a timeslice comparing the original 2D points and the interpolated result which is shown in figure 3.

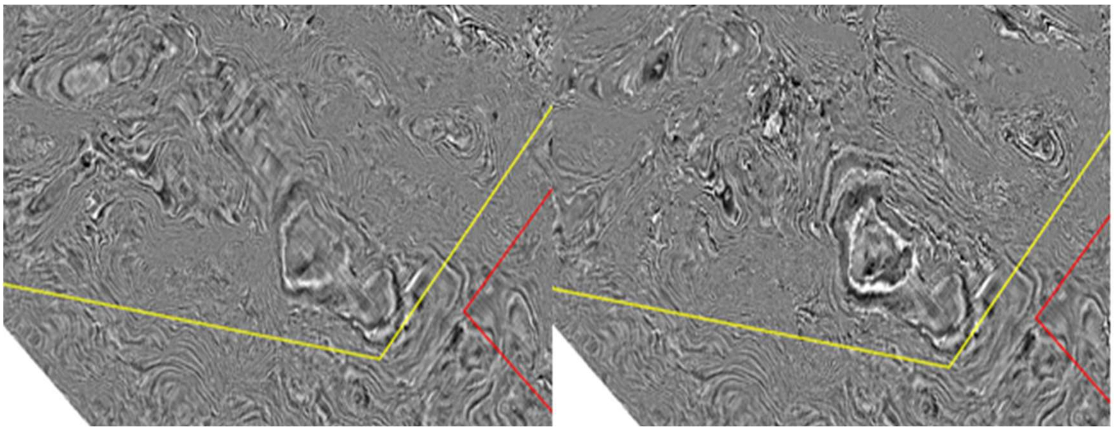

Figure 3 – time slice comparison of 2Dcubed (left) and 3D data (right) within the yellow *polygon*

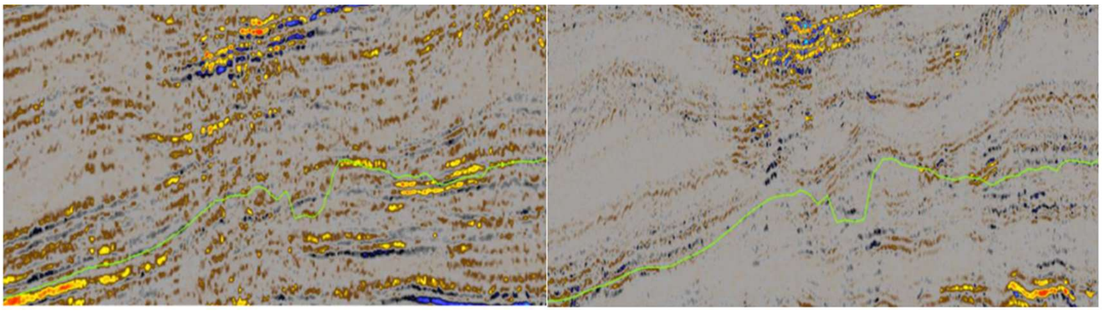

Figure 4 – AVO comparison of 2Dcubed (left) and 3D data (courtesy TGS & Viridien (right)

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