PS 2D Seismic Lines Reprocessing Using Prestack Time Migration: Case Study of the Solimões Basin*

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Abstract

After the discovery of hydrocarbons in the maritime basins, investment in the exploration of hydrocarbons in Brazilian land sedimentary basins was reduced, which has led to a relative lack of information today. In most cases, there is little seismic data coverage, or the data are old and were processed using obsolete techniques. The Solimões Basin is an exception among the Paleozoic basins in terms of coverage and has reasonable line quality. In economic terms, this basin is now producing oil near the Urucú River (discovered in 1986) and gas near the Juruá River (discovered in 1978). This work presents the results of the reprocessing of the 2D seismic lines of the Solimões Basin, to which modern processing techniques were applied to improve the seismic image quality of data acquired in the 1970s and 1980s.

In addition to the economic issues, the poor quality of the seismic data of Brazilian land basins is attributed to a strong presence of magmatism which, without proper treatment, can damage the seismic imaging because of the high speed of wave propagation in these rocks. The central portion of the Solimões Basin contains three sills of diabase with a total thickness of approximately 800 m. Despite the imaging difficulty, these sills played an important historical role in the generation of hydrocarbons.

A Kirchoff algorithm was applied to the prestack time migration. The reprocessing emphasized static correction (first break pick and residuals), parameters applied to recover the amplitudes, deconvolution, noise reduction process, and three-velocity analysis. The results show final sessions with high quality and resolution, and better signal-to-noise ratio below the second door-sill, and deliver relevant benefits to the interpreters.

Introduction

In 2007, Landmark, a Halliburton entity, reprocessed approximately 20 km of 2D seismic lines from the Solimões Basin. The objective was to improve the quality of the seismic signal, primarily below the second door-sill, delivering relevant benefits to the interpreter. This objective was met and the final products were delivered (Silva et al., 2007 and Pelizzon et al., 2007).

On this job, we used the same workflow applied in 2007, but with one more velocity analysis (residual velocity). Three velocity fields were picked; the first was picked using intervals of 2000 m and the second one used intervals of 1000 m. The residual velocity analysis was performed in intervals of 250 m. This methodology provided good results and show a clear improvement in terms of signal recovery.

Study Area

The Solimões Basin is located in the Amazonas state of the northern region of Brazil, between the parallels 2° and 8°S and the meridians 62° and 72°W (Figure 1). It covers a total area of 600 km².

The Solimões Basin is structurally limited to the north and south by the Guyana and Brazilian shields, respectively (Figure 2). It is bounded on the east side by the Purus Arch and on the west by the Iquitos Arch. The High of Carauari divides the basin into two sub-basins (Juruá on the east and Jandiatuba on the west).

Petroliferous System of Solimões Basin

The Paleozoic Solimões Basin includes an important petroliferous system called Jandiatuba-Jurua. The Devonian source rock is mainly represented by the radioactive shale of the Jandiatuba Formation (Eiras, 1999). The reservoir rock consists of eolian and marginal marine Carboniferous sandstones of the Jurua Formation. Its stratigraphy is positioned above and in direct contact with the source rock, which facilitated the migration processes. Traps are primarily represented by reverse faults that resulted from the development of an intraplate zone. An evaporitic rock of the Juruá Formation provides a good seal. Figure 3 presents a stratigraphic chart and Figure 4 shows the scaling of the events.

The Mesozoic magmatism deeply affected the maturation of the source rock and played an important historical role in the generation of hydrocarbons of this basin. From a geological perspective, the presence of the diabase sills was important in the maturation of the organic matter in oil and gas (Bender et al., 2001). There was a close relationship between maturation and geothermal effects. The fluid type present in the reservoirs, if oil or gas, directly depends on the thickness and position of the intrusive body (Figure 5).

2D Seismic Lines Reprocessing

The first processing of the 2D seismic lines of the Solimões Basin was developed by another company using poststack Kirchhoff time migration. This strategy originally met the objectives, which resulted in the discovery of many fields. Worldwide, old seismic data has now been reprocessed using modern methods (Ritchie et al., 2005; Chopra et al., 2004), which has yielded information that can be used to better focus on the target area (reservoir interval). Newer data is also sometimes very difficult to acquire because of high cost, logistical constraints, and time or environmental restrictions. The new processing tools, however, can be used to improve the resolution of the original seismic data. In the Solimões Basin, Landmark reprocessed approximately 20 km of 2D lines using prestack Kirchhoff time migration (Figure 6).

The workflow applied includes noise edit (statistical methods and manual), velocity analysis, refraction static (and residuals), multiples attenuation by radon, and other tools, such as surface consistent deconvolution, amplitude gains, and divergence spherical correction. In this study, one of the most important tools used was the prestack time migration. Figure 7 illustrates the workflow used.

The addition of a residual velocity analysis to the workflow provides a significant improvement when using PSTM. This type of migration positions each reflection at the exact time at which it was generated, based on a velocity model extracted from the seismic data. Consequently, improvements in the quality of the velocity model tend to improve the outcome of migration.

Even with a good model, it is difficult to produce the desired imaging with performed poststack migration because the data was previously stacked using NMO velocity, which provides poor structural control (the NMO correction algorithm is based on the geometry of a perfect layer cake model). Because the Solimões Basin has a complex structural history, it is not easy to interpret the seismic data using a migration based on stacked data.

On this job, a residual velocity analysis was performed after the migration using an interval of 250 m. The velocity field was updated to better characterize the geological model, and the second prestack time migration was performed which resulted in a better subsurface image.

Final Results

When comparing the results of the two seismic processing methods, differences become obvious, as shown in Figure 8. This comparison shows two images; the first image shows migrated poststack data, and the second image shows migrated prestack data. For the second image, a velocity field updated by residual analysis was applied. A better signal-to-noise ratio was obtained for all data. Other improvements include a better image of the door-sills, preservation of the structural components, and better recovery of the amplitude signal. Note that on the old process (poststack migrated), some of the fault zones were hidden by the use of filters or were lost in the migration process.

Conclusions

The reprocessing of old seismic data using modern methods is a valuable tool for improving the quality of the subsurface image. Advantages of reprocessing the data include better focus on the target area, reduced time, and cost savings. In addition, because of current environmental restrictions, new data acquisitions would not be permitted in some areas.

The use of Kirchhoff prestack time migration and velocity field updates using a residual analysis contributed to the production of reliable final sections on this job. The newly reprocessed data of the Solimões Basin preserve the structural components (fault zones) and show a clear improvement in terms of signal recovery.

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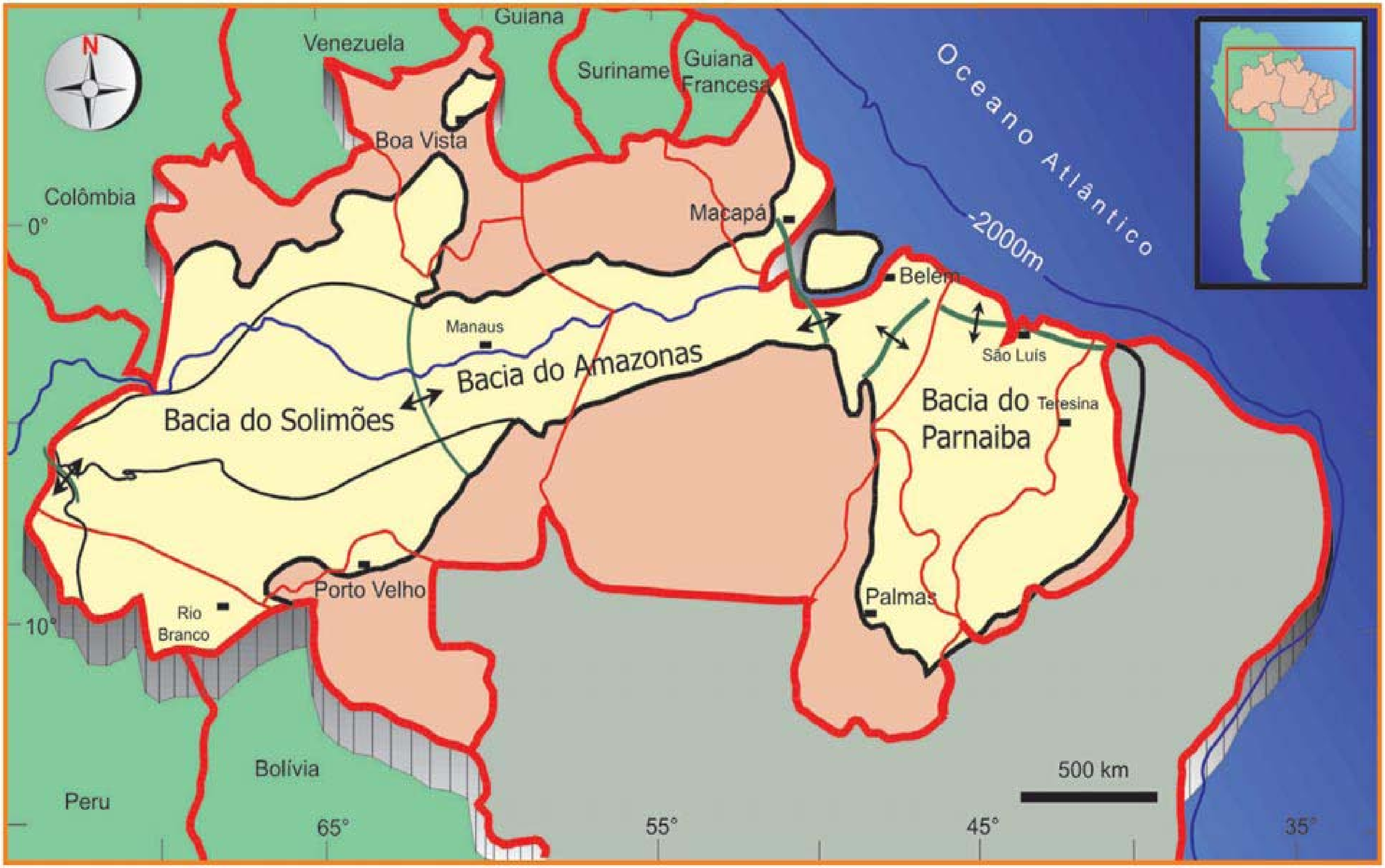

Figure 1. Solimões Basin map (Wanderley Filho et al., 2006).

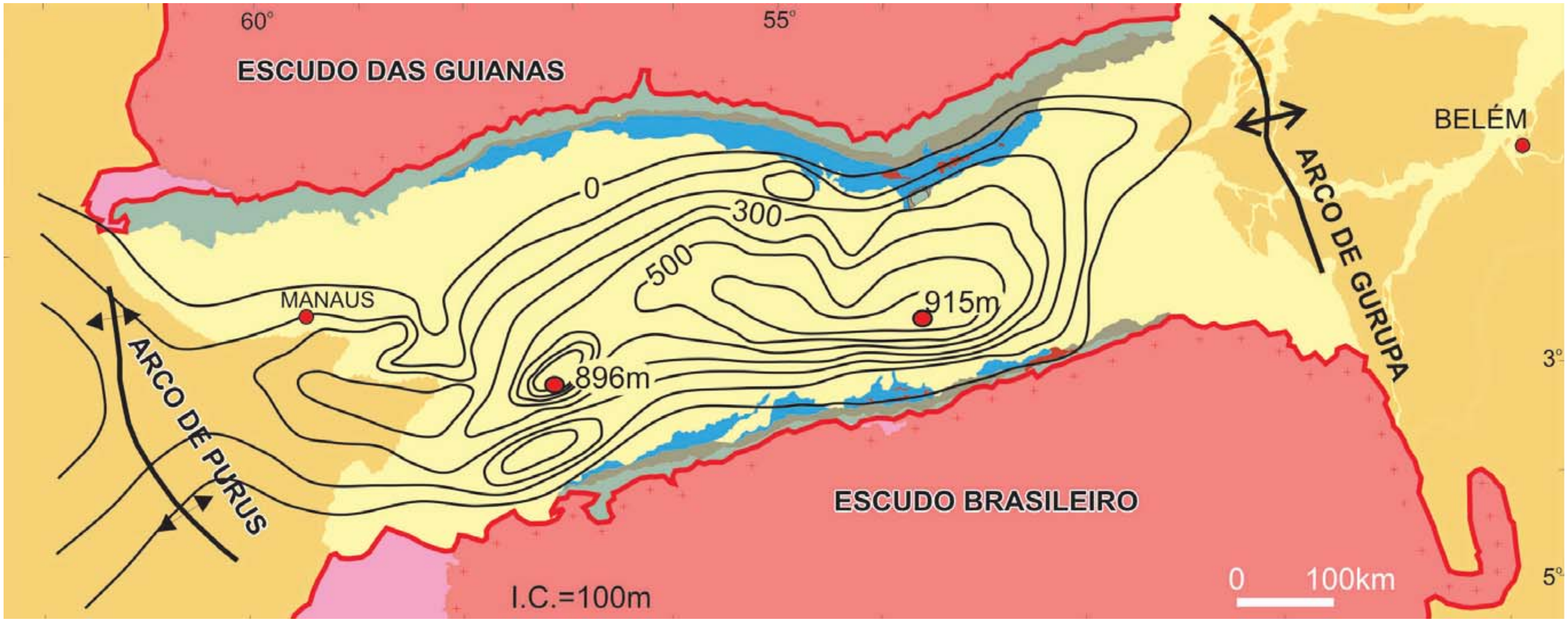

Figure 2. Solimões structural limits on an isolith map of the diabase inside the Permian-Carboniferous sequence (Wanderley Filho et al., 2006).

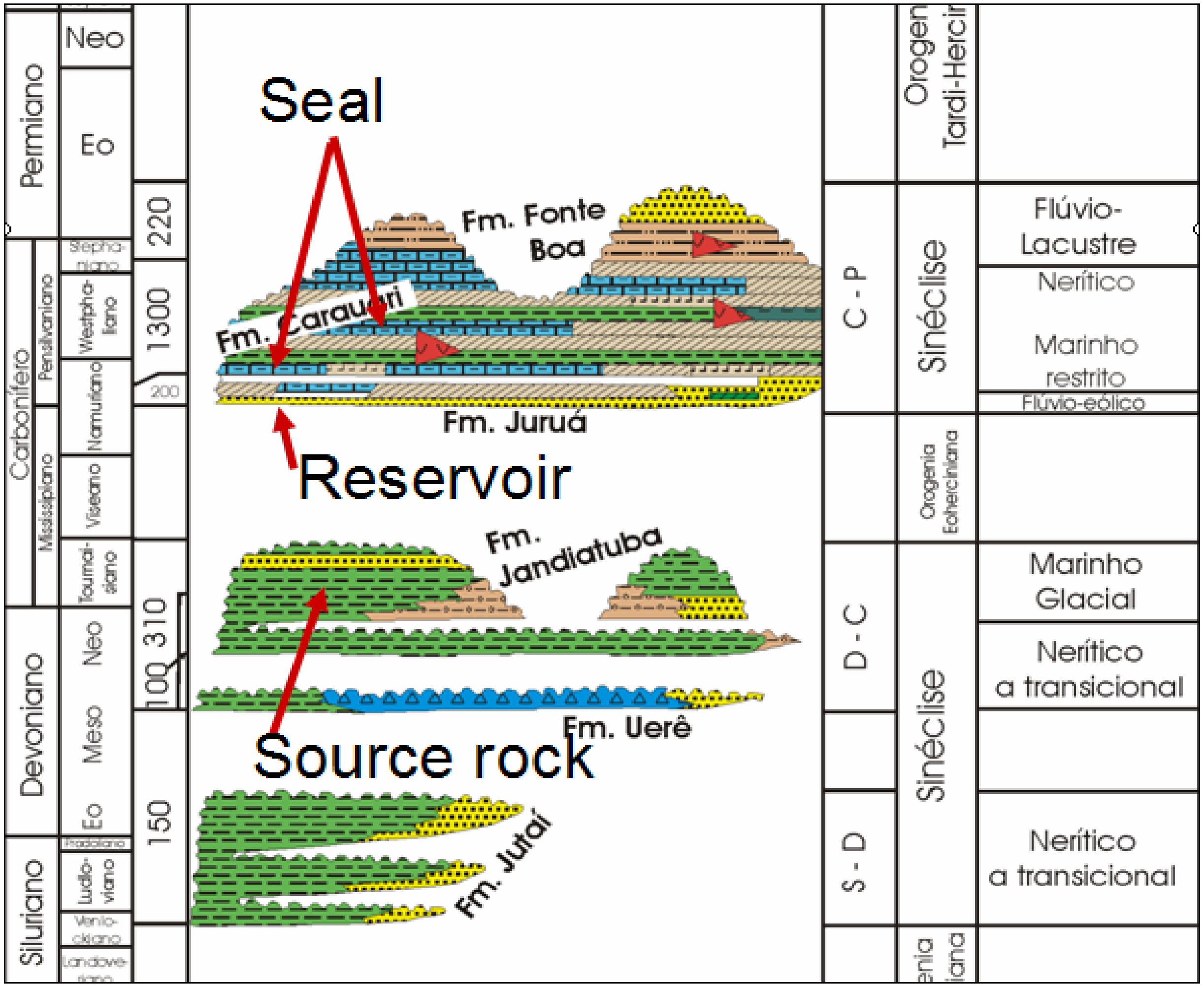

Figure 3. Part of a stratigraphic chart of the Solimões Basin indicating the elements of the petroleum system acting on the area (modified from Milani and Thomaz Filho, 2000).

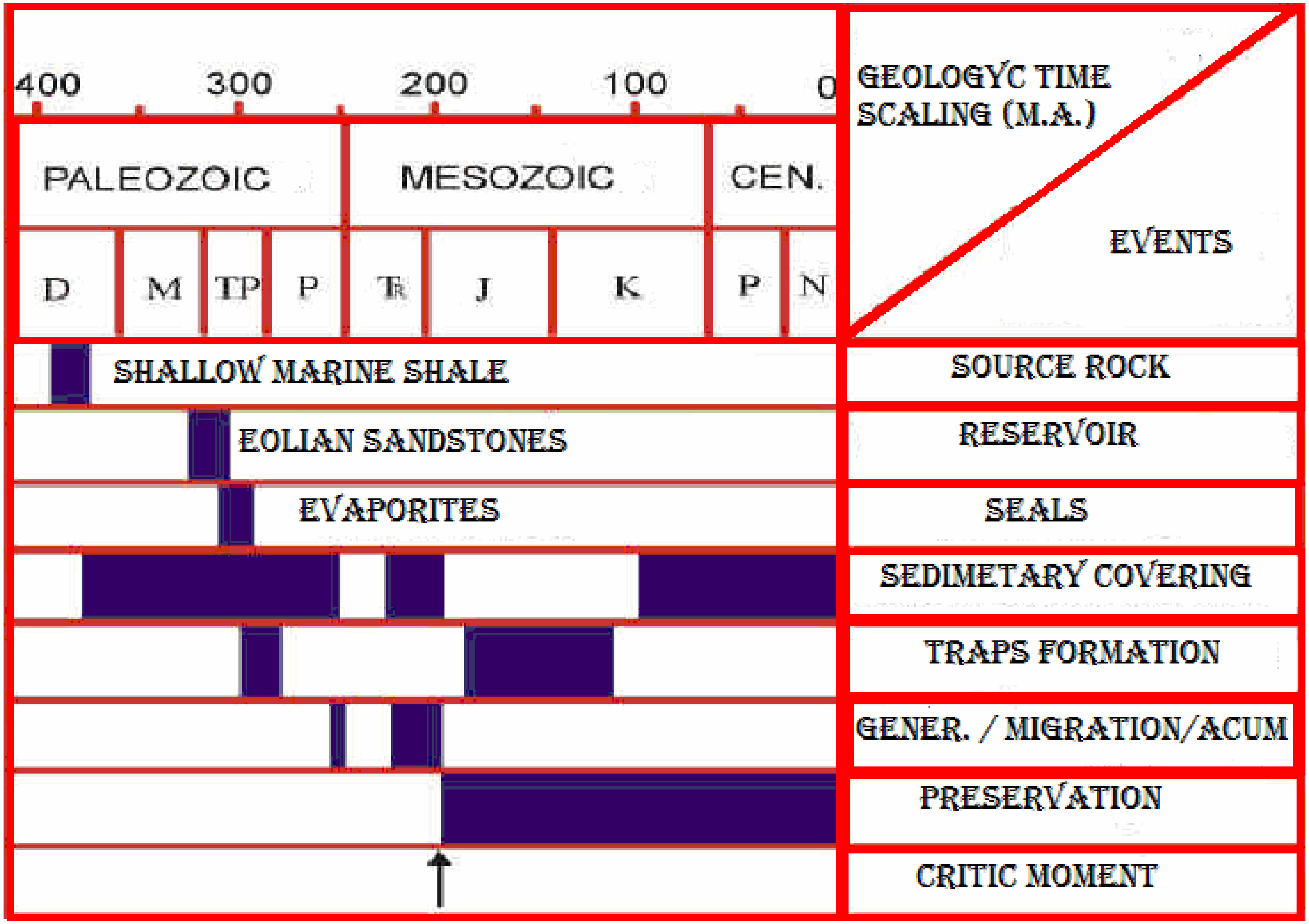

Figure 4. Petroliferous system of the Solimões Basin (Mello et al., 1994).

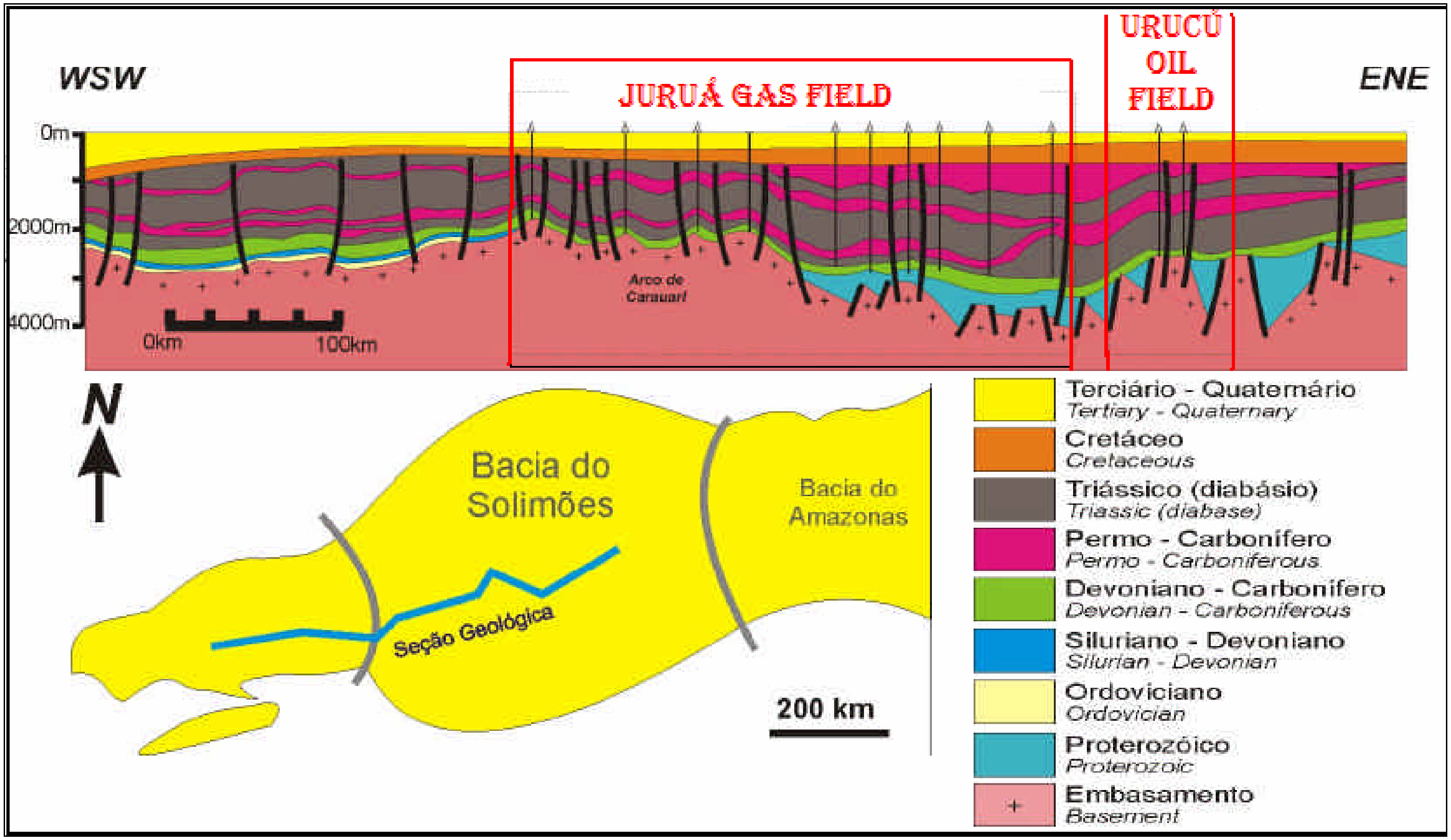

Figure 5. Solimões Basin schematic cross section (modified from Eiras, 1999).

Figure 6. Map view with lines reprocessed by Halliburton in 2007.

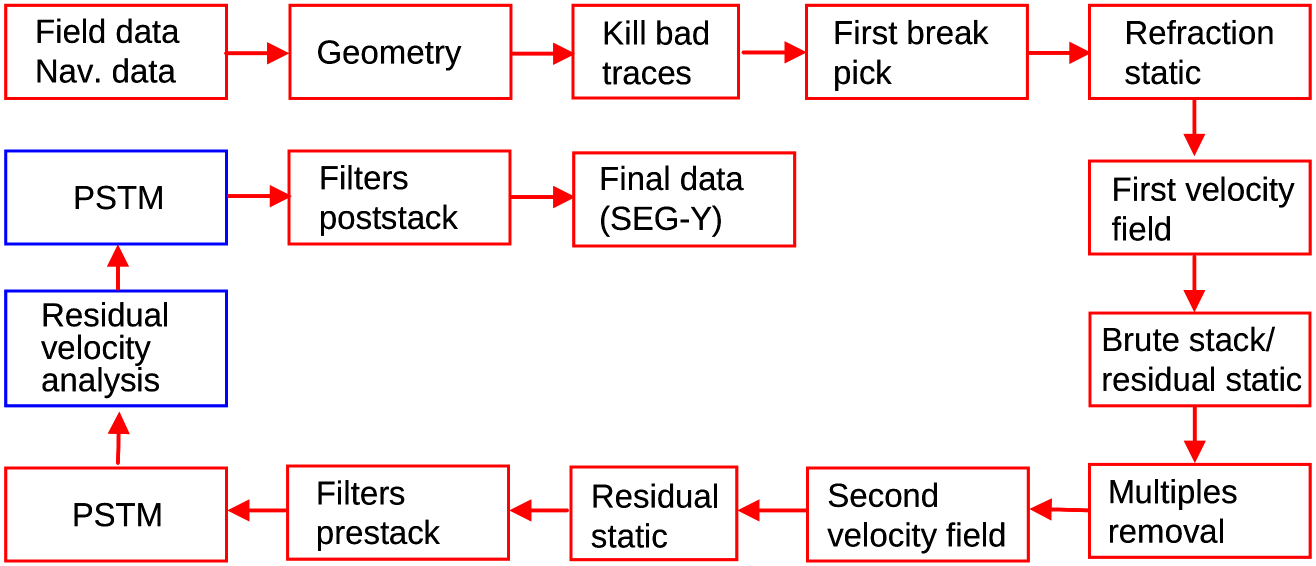

Figure 7. Seismic processing workflow used; the blue boxes indicate the additions to the workflow used in 2007.

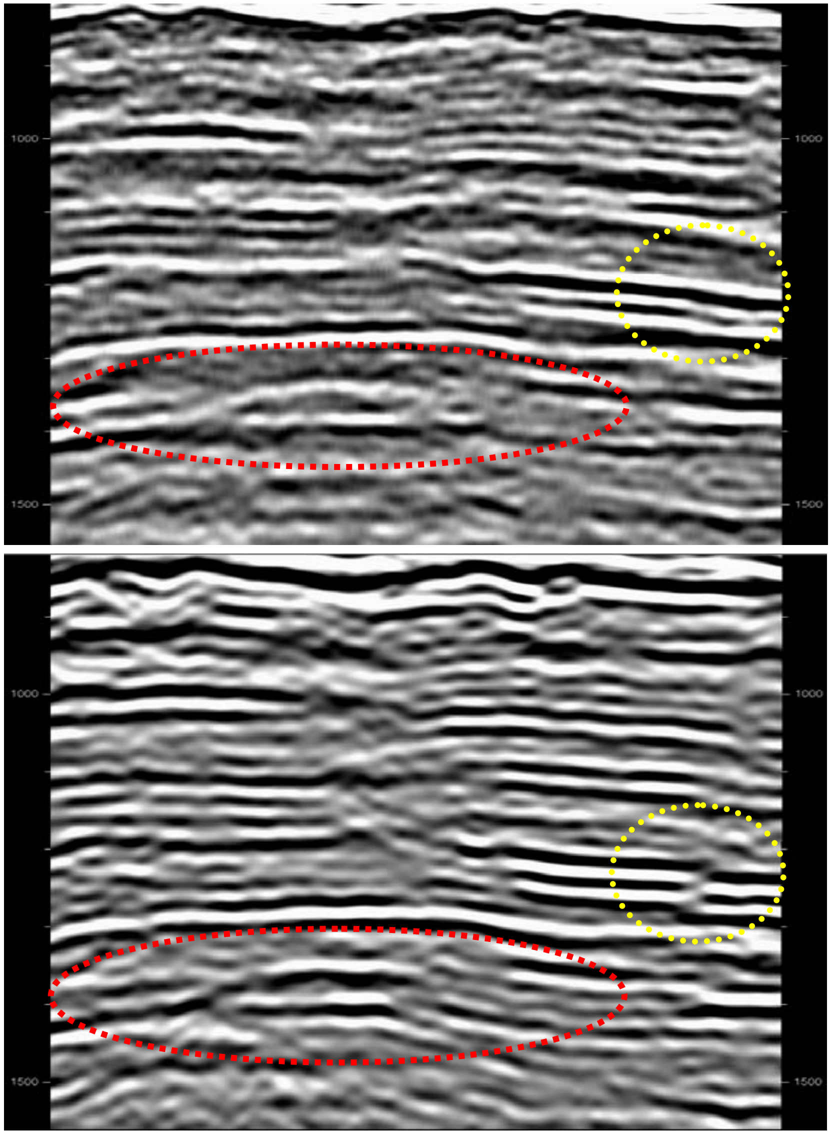

Figure 8. Results of two seismic processing data. The top portion shows the old poststack section and the bottom portion shows the reprocessed prestack version. The newly processed data shows a better signal-to-noise ratio. Note that even up one second, there were great improvements. The red ellipses show the improvements on the reservoir zone. The yellow ellipses show that the faults were better preserved on the second processing.