A 3-D Azimuth-Rich Survey on the sedimentary cover in Santa Catarina island

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Abstract

It is well known that a 3-D survey can provide the best visualization of the subsurface. But the common practice in 3-D GPR is very poor in comparison with the corresponding for the land 3-D seismic. The usual deployment of closed-spaced fixed-offset profiles have limited azimuthal information and restricts processing to post-stack. In this paper we use another field deployment that is richer in azimuth and thus produces a much better image of the subsurface. We compare our methodology with the usual deployment to illustrate the differences in rendered cubes and in time-slices.

Introduction

A 3-D survey potentially provide the best visualization of a sedimentary structure albeit being tricky to perform with a bistatic equipment with just one transmitter, T, and one receiver, R. To deal with this limitation the so-called 3-D GPR surveys are successfully carried out with closed-spaced profiles or with multi-antenna carriers (Birken et al., 2002), sometime with bad results due to mixing of antenna polarization (Kim et al., 2005). Due to logistical issues the latter usually restricted to high frequency surveys. Surveys with closed-spaced fixed-offset profiles are very time consuming to collect and process. The former due to the necessity to accurately record the position and elevation of each individual trace.

A proper choice of an appropriate survey design helps to optimize field time and collection of useful data. Notwithstanding most 3-D GPR surveys have covered an area of a few tens of meters. The usual way of doing that is to deploy antennas in a fixed-offset, FOff, broadside-perpendicular configuration, BPer. This means that the mutual distance between T and R is kept fixed, with parallel antennas, perpendicular to the profile, which cuts them half way.

Field data obtained in close-spaced profiles may be displayed in fence diagrams or 3-D rendered data cubes. A Full-resolution 3D GPR imaging was discussed by Grasmueck et al. (2005). Those authors says that a real 3-D through 2-D parallel lines depends of relation between the source-receiver coupling and wavelength. They suggest that the line spacing should be one-quarter of a wavelength in the ground to provide a meaningful imaging of the sedimentary structures. One sensible way is to keep inline and cross line distance equal (Böniger & Tronicke, 2010). Profiles may cross the survey area through two perpendicular directions adding more azimuthal information to the data (Pessoa & Travassos, 2007; Leucci et al. 2010). Notwithstanding that a quick comparison with land 3-D seismic shows us that the usual 3-D GPR surveys are restricted to a post-stack framework and rather poor in azimuthal information (Cordsen et al., 2000)

This work describes a 3-D survey done on Quaternary marine and alluvial sedimentary soil, in which the azimuthally information does add new information and, at the same time keeping fixed the antenna polarization for all traces.

Fieldwork

The fieldwork was done on the sedimentary cover in Santa Catarina island. The sediments are associated to the most intense event of sea transgression and its subsequent regression. The sediments are unconsolidated deposits of eolian, alluvial, lacustrine and marine sands with less than 5 % of silt and clay.

The GPR acquisition was done in two distinct field strategies: (1) The more usual closed spaced parallel FOff profiles and (2) On a regular square grid on a 12 x 12 m² area. In both cases the antennas were kept on a BPer configuration throughout. The two field strategies are depicted in Figure 1.

We will refer to the first strategy as 2-D and as 2.5-D to the second. The 2.5-D strategy is inspired in the rectangular grid used in land seismic acquisition (Cordsen et al. 2000). The difference in our case is that as we have only one transmitter, T, and one receiver, R, we use a FOff approach. In this we circulate R in relation to a fixed T measuring at each vertex. In that way we end up with four traces for each square of the grid. The great advantage here is that those traces have four different azimuths. Note that field polarization is the same for all traces.

The spatial sampling along the 2-D profiles was a few centimeters, decimated to 0.4 m, equal to the profile spacing. This strategy yields a uniform grid of traces at each 0.4 m along x and y directions. The spatial sampling on the 3-D grid was 0.5 m in both directions. We therefore can assume that both strategies have similar spatial samplings.

We have applied a simple processing flow: a) static correction, b) DEWOW filter c) gain function and d) bandpass filter. We have applied the same processing flow to both data sets.

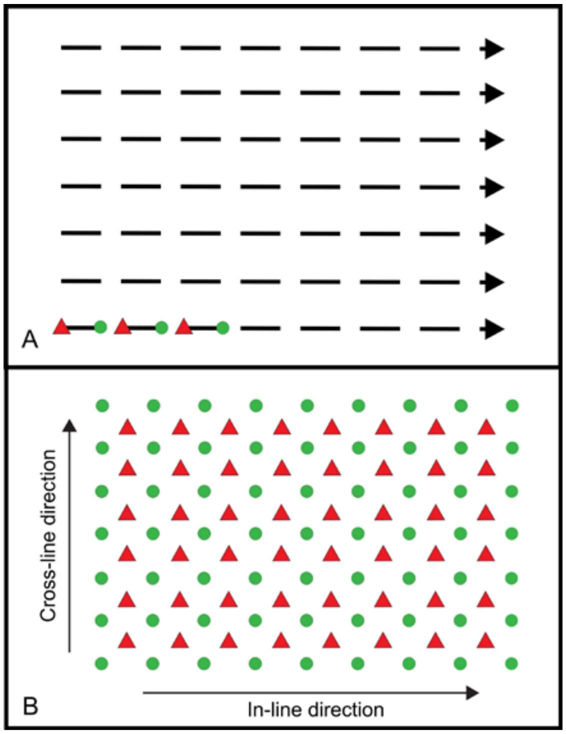

Figure 1. The two field strategies used in the fieldwork. A is the 2-D methodology. We represented only the first few positions of T and R for the lowermost profile. T is represented by a red triangle while R is a green circle. B is the 2.5-D methodology.

Results

The striking difference on the results from the two distinct strategies, 2-D and 2.5-D can be seen comparing Figure 2 and Figure 3. As it can be seen the 3-D cube yields a richer image of the subsurface, not only in respect to the amount of information but also on cleaner and more continuous reflectors. Note the 2-D footprint on the top of the 2-D cube.

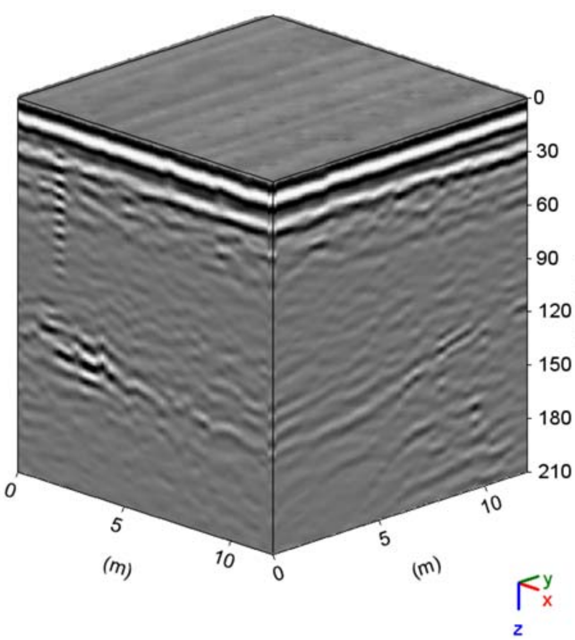

Figure 2. A 3-D rendering of the 2-D field strategy.

Time slices give another way of comparing the two data sets. Let us choose a TWT = 115 ns time slice. At that TWT the reflector seen dipping towards the reader in Figure 2 and Figure 3 cuts the slice along a NW direction. The difference now gets even more dramatic; the reflector trace on the 2-D derived slice appears just as a hint, it can be seen in Figure 4. On the other hand the strike line of the reflector is clearly seen on the 2.5-D derived time slice, as seen in Figure 5.

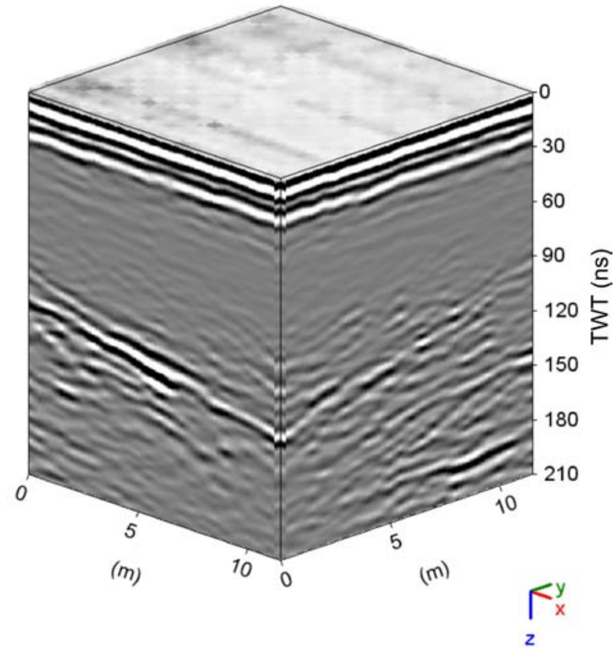

Figure 3. A 3-D cube obtained using the 2.5-D field strategy.

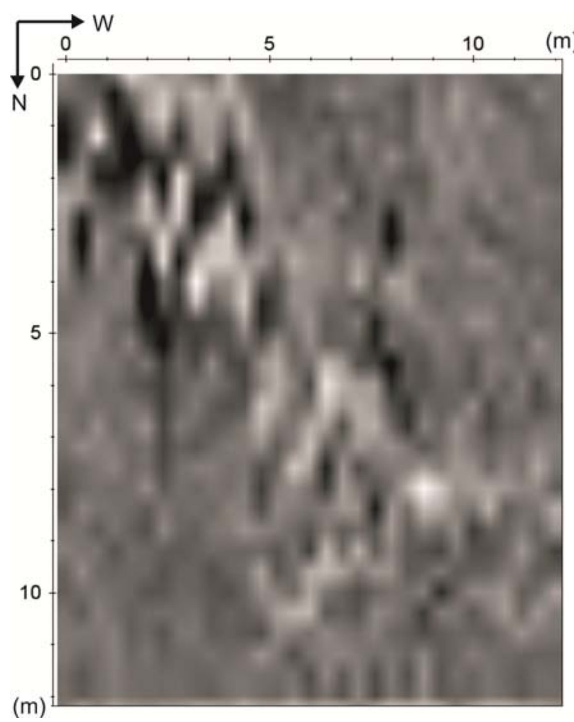

Figure 4. TWT = 115 ns time slice in the 2-D derived rendered cube.

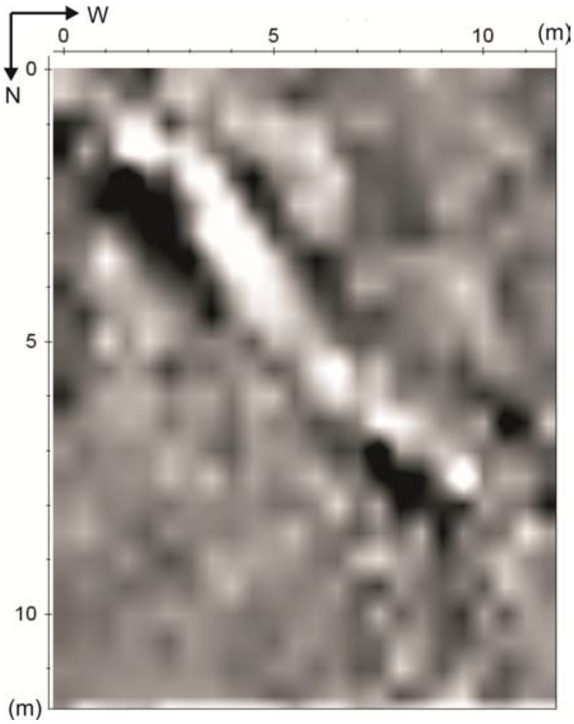

Figure 5. TWT = 115 ns time slice in the 2.5-D derived cube.

Conclusions

Two surveys were made in two distinct field strategies: with closed spaced parallel FOff profiles and on a regular square grid. As both surveys used a FOff approach all processing is restricted to post-stack. The main difference between them is the azimuth information, richer in the square survey. The 2.5-D cube has much better resolution compared with the one rendered with 2-D profiles.

Looking at time-slice for both cubes only corroborate the conclusion obtained through the comparison of the two cubes; the 2.5-D survey provide a much better image of the subsurface than the corresponding 2-D.

Acknowledgments

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