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ENHANCED DEPTH IMAGING IN THE WEST-SARDINIAN OFFSHORE THROUGH IMPROVED 2-D VELOCITY MACRO-MODELS

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Introduction. Complex overburden such as diapiric structures are characterized by strong 3-D seismic velocity variations. Time migration doesn't account for such variations so it is inadequate to image the Base Of Salt (BOS) and subsalt reflections. For such geological conditions, depth imaging by 3-D prestack depth migration techniques is mandatory; moreover, realistic subsalt imaging requires accurate velocity models. The existing standard methodology of salt model-building is based on four steps (Siddiqui et al., 2003; Huang et al., 2009): 1) define the water bottom surface choosing the water velocity which flattens the corresponding event in the Common Image Gathers (CIGs); 2) interpret the Top Of Salt (TOS) on the sediment flood migration image obtained with tomographic inversion; 3) use a constant salt velocity or a dirty salt model for the salt flood migration so that BOS can be interpreted; 4) refine the subsalt velocity model. Gravimetry and magnetics are also used to constrain velocity model (Foss et al., 2008). Anyway, where salt geometry is not clearly identifiable in the seismic migration image, the existing salt velocity model building methodology may not be effective (Wang et al., 2009), overall when there are velocity perturbations due to a mix of salt, sediments and other rock/minerals (Haugen et al., 2008). Further imaging enhancements can be achieved by Reverse Time Migration (RTM) (Baysal et al., 1983) and Tilted Transverse Isotropy (TTI) imaging (Huang et al., 2008).

The accuracy of the velocity model depends essentially by the maximum depth to migrate, by the signal/noise ratio, by velocity contrasts and by cable length: the higher the velocity, the deeper the reflector and the shorter the cable length, the more difficult is to discriminate velocities by analysing curvature of events within the CIGs. An accurate velocity field reconstruction is essential not only to obtain a proper subsurface imaging, but also to reach a detailed characterization of different geological materials. Salt and, in general, all the evaporites have a peculiar seismic signature due to very high velocity as compared to other sedimentary rocks. In September 2010 a new 2-D seismic data acquisition was carried out in the West-Sardinian margin by R/V OGS-Explora (Project West-Sardinia, by OGS, in collaboration with the Universities of Cagliari, Napoli and Trieste).

Some of the acquired seismic data (part of the SO10-04 seismic line: see Fig. 1 for location) were processed in the framework of a master degree thesis with the objec-

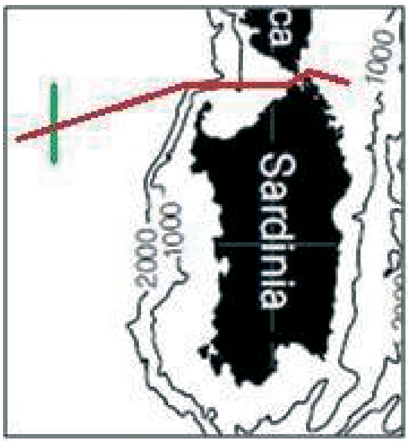


Fig. 1 – Location map of the seismic profiles analysed: SO10-04 (in green) and CROP M2A (in red).

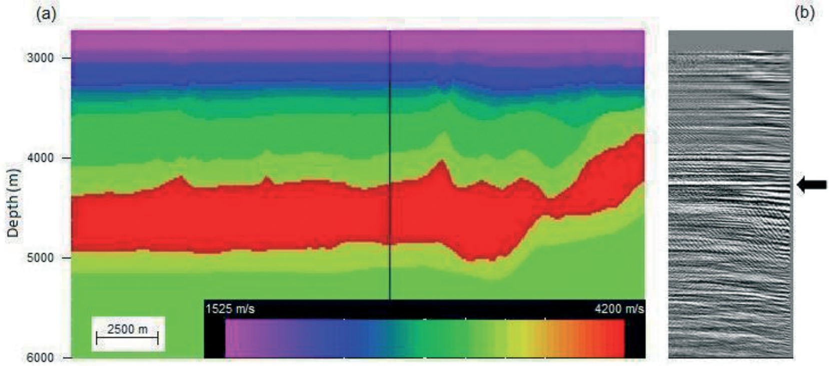
tive to improve the imaging of the pre-Messinian reflectors. Line SO10-04 was shot using a 2x0.0058 m^3 GI-gun and recorded by a 120-channel digital streamer with a maximum offset of 1512.5 m and the near offset of 25 m. The shot and receiver intervals were 25 and 12.5 m, respectively. The record length was 8 s with a sampling rate of 1 ms; the maximum fold was 3000%. The segment of the seismic profile analyzed in this work is located in the Liguro-Provencal Basin, with a water depth of nearly 2700 m. The sedimentary cover (Mauffret et al., 1973) consists of Plio-Quaternary shales overlaying the Messinian evaporite succession. The latter shows three different main seismo-stratigraphic sequences, generally called "Upper Evaporites", "Salt", and "Lower Evaporites"; at the bottom, the sedimentary sequence is closed by the middle and lower Miocene layers. In the study area, several salt bodies in close proximity obscure reflectors deeper than the Plio-Quaternary ones, so that depth imaging techniques are required. Because of great water depth and of cable shortness, velocity model building by means of tomographic inversion and analysis of events in CIGs would lead to an incorrect velocity determination; in fact, the "non-flatness" of an event on CIGs is detactable only if there is an adequate spread length. To overcome such restriction, we analysed the CROP M2A seismic line (Fig. 1), acquired in 1991 with a 0.0804 m^3 airgun array and a 180-channel streamer with 25 m group interval: the near and far offset were 100 m and 4575 m, respectively. The shot interval was 50 m and the maximum fold was 4500%. The dataset was recorded up to 17 s with a sampling rate of 4 ms. The main goal is to build a velocity-depth model down to 6 km on a selected part of M2A profile by CIGs analysis. The velocities thus obtained were used in an iterative depth-migration process to define a velocity-depth model for a selected segment of the novel seismic line.

Methods. The velocity model for line M2A was obtained with a layer-stripping approach. For each interface, a series of Kirchhoff prestack depth migration was carried out, each using a different velocity for the layer. The output from a prestack depth migration step was arranged as CIGs. At selected CIG locations, we analysed the residual curvature of each event. A down- or up-ward curvature of the reflector indicates that the assumed velocity is too high or too low, respectively. The proper velocity is the one that yields the flattest CIG. The main limits of such technique are: 1) errors in determining velocity of shallow layers tend to accumulate in the deeper strata; 2) a specific event can be flat on a selected CIG but cannot be properly corrected on the adjacent ones; 3) the lack of constraints makes different velocity models acceptable (Kosloff et al., 1996).

In addition with the previous flow, we are currently testing a mean of tomographic techniques to better evaluate lateral velocity variations and the sub-salt velocity field. The final aim of the research will be not only the critical comparison of results obtained with different methodologies, but also the combination and integration of algorithms and procedures.

Moreover, the velocity model obtained from the CIGs analysis performed on line M2A was correlated with the novel SO10-04 profile: while the velocity field can be assumed similar along the two lines, the depth and the shape of the horizons are obviously different. To obtain the correct geometries, we applied an iterative depth-migration process until a pre-defined convergence between consecutive velocity models was achieved.

Results and discussion. Fig. 2a shows the calculated velocity-depth model for the selected segment of the CROP profile while in Fig. 2b an example of CIG (location 6100) is shown. The deeper flattened event corresponds to the top of the Salt layer and is indicated by the black arrow. Below that, subsalt events are difficult to interpret and it is hard to assign a velocity based on the curvature analysis of CIGs. Therefore, velocities of the Salt, Lower Evaporites and middle Miocene sequences are set with approximate values obtained from geophysical literature (see e.g. Finetti et al., 2005). Note that events inside Salt layer, migrated with an assumed 4200 m/s velocity, show a downward curvature at large offset, which means that the applied velocity is too high: nonetheless, a lower velocity for the entire layer is not plausible. Further difficulties in curvature analysis are due to the aperture parameter in Kirchhoff migration: an overly large aperture width, comparable to the far offset (5000 m), makes deep random noise creep into the high SNR shallow part of the record. Nonetheless, such a large aperture is required to evaluate the flatness of the events within the CIGs.



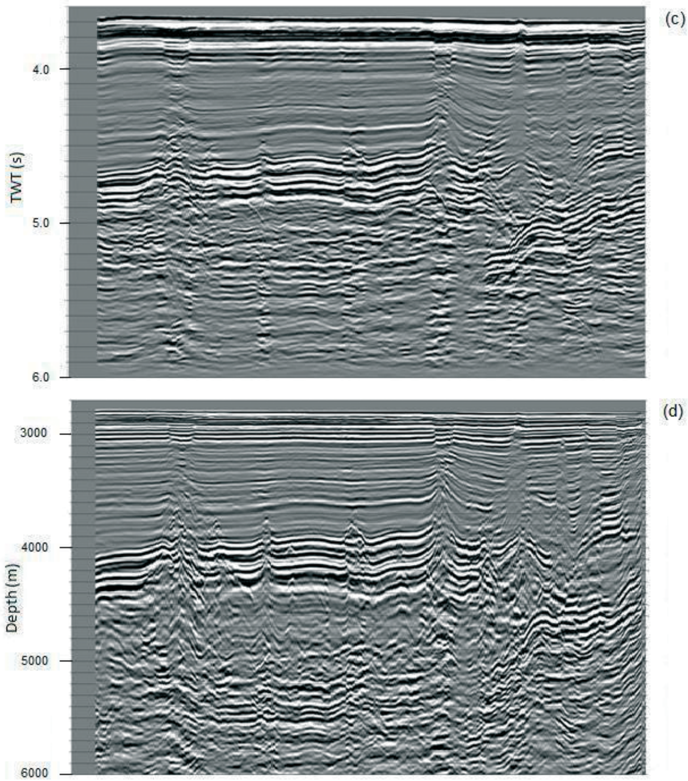


Fig. 2 – (a) Calculated velocity-depth field for the examined segment of the M2A line. The vertical line in (a) indicates the location of the CIG 6100 in (b). (c) Time migration of the M2A segment using a velocity field directly obtained by semblance analysis. (d) The corresponding prestack depth migration image using the velocity (a).

Fig. 2c shows the poststack time migration image using velocities from semblance analysis. Fig. 2d shows the prestack depth migration image using the velocity-depth model of Fig. 2a and an aperture width of 1500 m. The refined model produces apparent improvements: the amplitude, both above and below the Salt layer, is properly restored, even if continuity and shape of reflectors inside the Salt layer and in the subsalt region remain difficult to interpret.

Fig. 3a shows a depth image of line SO10-04 obtained with the velocity field of Fig. 2a. Fig. 3b shows the corresponding time image produced by the velocity field obtained from semblance analysis. Imaging of the sedimentary sequence above the top of the Upper Evaporites doesn't exhibit remarkable differences in the two images. The depth image gives evidence of the lateral displacement of the salt dome location respect to the acquisition line and allows a better interpretation of events inside and below the salt region. The top of the dome is better imaged by time migration.

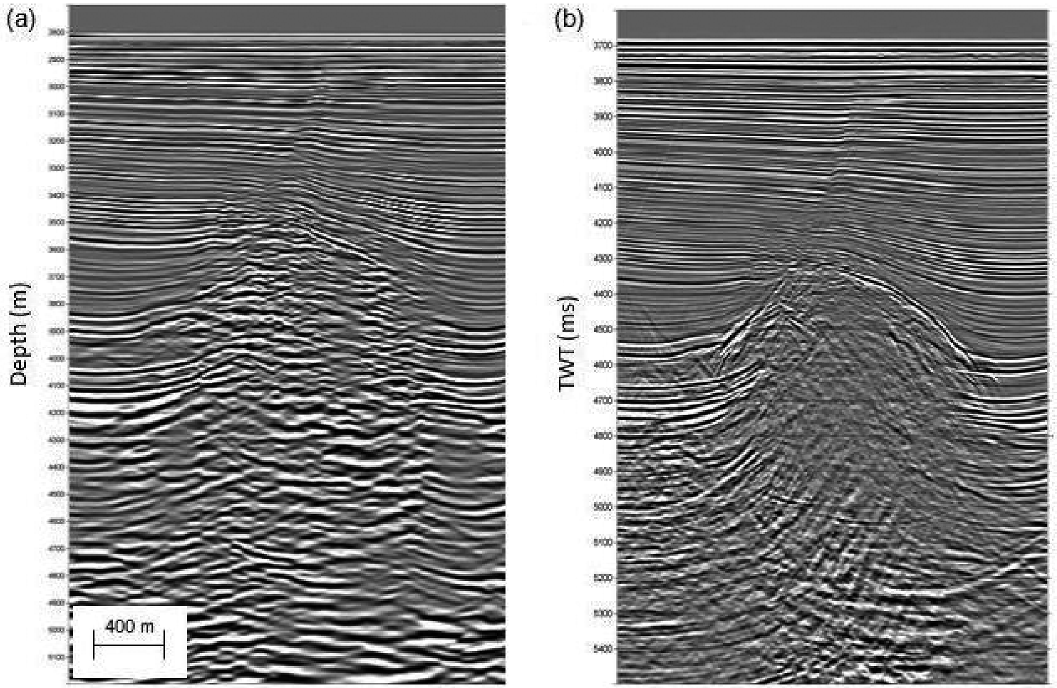


Fig. 3 – (a) Prestack depth migration image for a segment of the SO10-04 seismic line. Velocity field was obtained after an iterative depth-migration process using the same velocities as in Fig. 2a. (b) The corresponding time migrated section using a velocity field obtained from semblance analysis.

Conclusions. The Liguro-Provencal Basin is a complex area where the occurrence of multiple salt bodies, the presence of both layered evaporites and mobile salt, the absence of well data to constrain models and 3-D effects on 2-D sesmic data, make harder the interpretation of salt geometry in migrated seismic images and therefore velocity-depth model building. Interpretation of reflectors beneath salt bodies in such complex areas is difficult because of migration swings, 3-D behavior of diapiric structures, the occurrence of several structures in close proximity that perturbs signal propagation in depth, internal salt reflections ignored in the model building that can lead to the degradation of the subsalt events (Ji et al., 2010). For the SO10-04 seismic profile, the velocity analysis is also limited by the short spread used for the acquisition, which prevents an effective curvature analysis of the CIGs. Velocities derived from the long-offset M2A profile allowed an improved depth imaging of the novel seismic data; further improvements are expected with the application of tomography on this CROP line.

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References

Baysal E., Kosloff D.D. and Sherwood J.W.C.; 1983: Reverse Time Migration. Geophysics, 48, 1514-1524.

Finetti I., Forlin E. and Pipan M.; 2005: CROP Seismic Data Acquisition, Processing and Interpretative Reprocessing. In: CROP PROJECT: Deep Seismic Exploration of the Central Mediterranean and Italy. Elsevier, ISBN 0-444-50693-4.

Foss S., Rhodes M., Dalstrøm B., Gram C. and Welbon A.; 2008: Geologically constrained seismic imaging-Workflow. Geophysics, 73, 313-319.

Haugen J.H., Arntsen B. and Mispel J.; 2008: Modeling of "dirty salt". SEG Las Vegas 2008 Annual Meeting.

Huang T., Xu S., Wang J., Ionescu G. and Richardson M.; 2008: The benefit of TTI tomography for dual azimuth data in Gulf of Mexico. SEG Expanded Abstracts, 27, 222-226.

Huang Y., Lin D., Bai B. and Ricardez C.; 2009: Pre-salt Depth Imaging of Santos Basin, Brazil. SEG Expanded Abstracts, 28, 2869-2873.
Ji S., Huang T., Fu K., Li Z. and CGGVeritas; 2010: Dirty Salt Velocity Inversion: the Road to a clearer Subsalt Image. SEG Denver 2010 Annual Meeting.
Kosloff D., Sherwood J., Koren Z., Machet E. and Falkovitz Y.; 1996: Velocity and depth interface determination by tomography of depth migrated gathers. Geophysics, 61, 1511-1523.
Mauffret A., Fail J.P., Montadert L., Sancho J. and Winnock E.; 1973: Northwestern Mediterranean sedimentary basin from seismic reflection profile. Bull. Am. Assoc. Pet. Geol., 57, 2245-2262.
Siddiqui K., Clark S., Epili, D., Chazalnoel N. and Anderson L.; 2003: Velocity model building methodology and PSDM in deep water Gulf of Mexico: A case history. SEG Expanded Abstracts, 22, 442-445.
Wang B., Mason C., Yoon K., Ji J., Cai J., TGS-NOPEC, Suh S.Y. and KIGAM; 2009: Complex-salt model building using combination of interactive beam migration and localized RTM. SEG Houston 2009 International Exposition and Annual Meeting.

Fig. 1 – Multichannel seismic profile collected in 2009 across the Gulf of Trieste.