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Inversion Structures in a Foreland Area - Seismic Examples from the Adriatic Sea - Italy

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SUMMARY

The Adriatic represents a foreland area surrounded by three distinct fold-and-thrust belts: the Apennines to the west, the Southern Alps to the north, and the Dinarides to the east. A NW-SE-trending compressional ridge (Mid-Adriatic Ridge) extending from more than 100 km affects the middle zone of the Adriatic foreland. The interpretation of recently reprocessed seismic data from the Italian sector of the Adriatic offshore reveals that most of the thrust-related folds belonging to the Mid-Adriatic Ridge are positive inversion structures. On seismic, they typically appear as asymmetric inversion anticlines developed by the Neogene reverse reactivation of inherited Mesozoic graben and half-graben basin-bounding normal faults. Some of these structures are undrilled and they may potentially be attractive carbonate targets.

Introduction

Inversion structures have a significant potential for hydrocarbon exploration being important hydrocarbon plays in both mature and under-explored areas (e.g. Charlton, 2004). The identification of inversion structures in foreland fold-and-thrust belts is valuable for the hydrocarbon prospectivity of these regions because the positive inversion tectonic processes control the petroleum system elements from the initial extension up through the later compressional deformation (Cooper & Warren 2010). By interpreting recently reprocessed seismic reflection data from the Italian sector of the Adriatic offshore (Fig. 1A) this study documents geometries and styles of some interesting positive inversion structures belonging to the deformed sector of the Adriatic foreland and developed during the Plio-Quaternary compressional-transpressional tectonic event. The results of this study contribute to understanding the regional tectonic setting of the folded and compressed Central Adriatic, whose nature is still largely debated.

Method and Theory

The Italian sector of the Adriatic is a long-established hydrocarbon province that recorded in the past a successful exploration history with two main proved plays represented by the biogenic gas in the shallow Pliocene-Pleistocene sequence and light-to-heavy oil and gas discoveries in the Cretaceous-Miocene carbonates. The Adriatic represents a common foreland shared among the Apennines, the Southern Alps and the Dinaric fold-and-thrust belts. Normal faults connected to both rifting phases (Permian-Triassic and Jurassic) and to the syn-orogenic foreland flexure (Neogene) affected this area. In the Central Adriatic, compressive-transpressive deformation developed a NW-SE trending ridge that transects the entire foreland (i.e., the Mid-Adriatic Ridge). The Mid-Adriatic ridge (Fig. 1A) is considered a compressive foreland deformation zone (Argnani and Gamberi, 1995) either related to the NE-verging Apennine (Scrocca, 2006) or SW-verging Dinaric (Finetti and Del Ben, 2005) thrust fronts, or as an inversion-dominated intraplate foreland deformation area (Scisciani, 2009; Scisciani and Calamita, 2009). In the mid-2011 Spectrum has completed the reprocessing of 8,200 km of regional vintage 2D seismic data in the Italian sector of the Adriatic that were acquired by the Italian government between the 1960s and 1970s. Spectrum's reprocessing old data has been a spectacular success with tremendous improvements being made in the imaging (Peace et al., 2012). The reprocessed 2D digital seismic reflection profiles were uploaded into a Kingdom project along with the available exploration well log information. The spectacularly improved seismic imagery brings out the details of structures nicely allowing a better reconstruction of their geometry. The digital seismic interpretation revealed that most of the compressional structures involving the carbonate sequence are thrust-related inversion anticlines that developed by the transpressional reactivation of pre-existing Permian-Triassic normal faults. Such structures, affecting the Triassic-Miocene carbonate succession and the Permian pre-carbonate sequence, present typical features of positive inversion tectonics. They appear as asymmetric harpoon-shaped anticlines facing toward the footwall and riding over high-angle blind thrust faults (Fig. 1B-C). The positive basin inversion process involved both symmetric graben-like and asymmetric half-graben type Permian-Triassic/Jurassic basins. The geometrical characteristics of this inversion structures are consistent with deep-rooted basement-involved deformation.

Conclusions

The seismic expression of positive inversion tectonics structures within a deformed foreland area are illustrated in this study by examining structures from the Italian sector of the Adriatic offshore. The inversion structures here presented are consistent with an intraplate foreland deformation, in which the contractional deformation that triggered the positive reactivation of the inherited Mesozoic normal faults is most likely to be connected as a far field foreland deformation transmitted from the surrounding fold-and-thrust belts (i.e., Apennines, Dinarides, and Southern Alps, Fig. 1A). Within this context, the deep hydrocarbon potential of the Adriatic Sea needs to be further revaluated deserving renewed exploration efforts in this hydrocarbon province by taking into account that positive inversion is the dominant tectonic process for the relatively deep-seated structures.

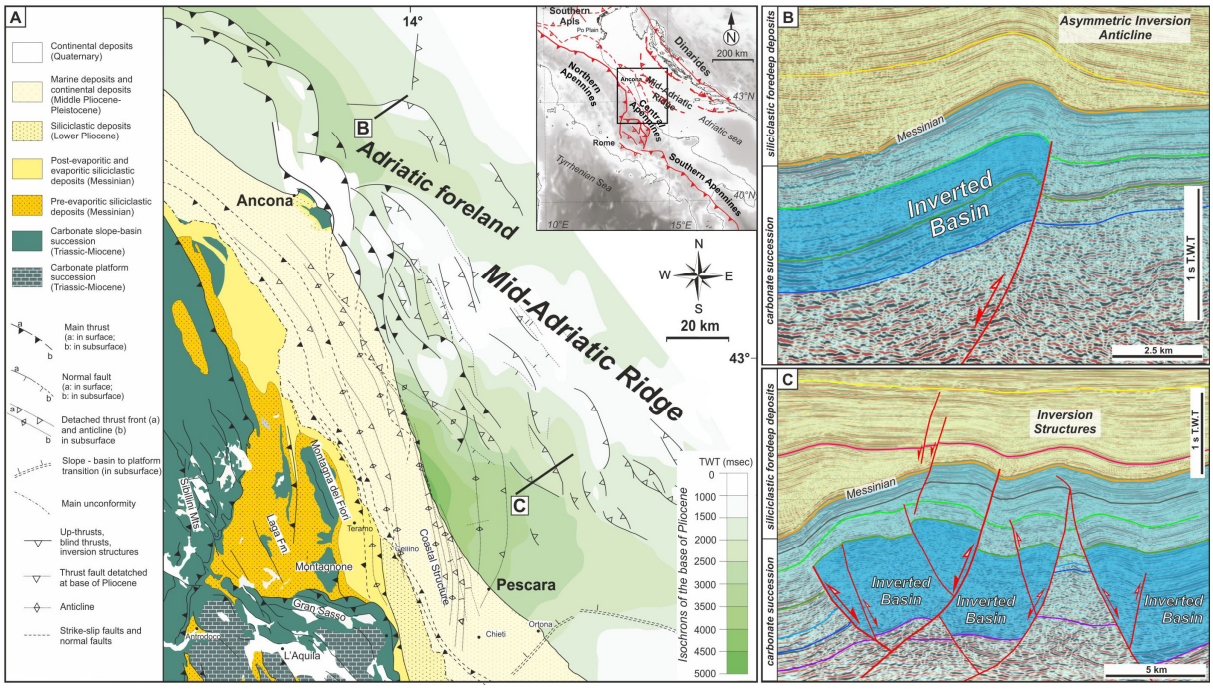

Figure 1 *A) Simplified structural-geological map of the outer Central Apennines and of the deformed sector of the Adriatic foreland in the Adriatic offshore; B and C) Seismic expression of the thrust-related positive inversion structures developed by reactivating both graben and half-graben basin-bounding Permian-Triassic/Jurassic basins. They are likely related to the intraplate compressional deformation affecting the middle zone of the Adriatic foreland (i.e., the Mid-Adriatic Ridge).*

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References

Argnani, A. and Gamberi, F. [1995] Stili strutturali al fronte della catena appenninica nell'Adriatico centro-settentrionale. *Studi Geologici Camerti*, **1**, 19-27.

Charlton, T.R. [2004] The petroleum potential of inversion anticlines in the Banda Arc. *American Association of Petroleum Geologists Bulletin*, **88**, 565-585.

Cooper, M.A. and Warren, M.J. [2010] The geometric characteristics, genesis and petroleum significance of inversion structures. In: Law, R.D., Butler, R.W.H., Holdsworth, R.E., Krabbendam, M. and Strachan, R.A. (Eds) *Continental Tectonics and Mountain Building: The Legacy of Peach and Horne*. Geological Society of London, Special Publications, **335**, 827-846.

Finetti, I.R. and Del Ben, A. [2005] Crustal tectono-stratigraphic setting of the Adriatic Sea from new crop seismic data. In: Finetti, I. (Ed.), *CROP Project, Deep Seismic Exploration of the Central Mediterranean Region and Italy*. Elsevier, 519-548.

Peace, D., Brown, D., Zappaterra, E., Spoors, R., Scaife, G., Rowlands, D. and Sewell, D. [2012] The Italian Adriatic Sea: Bringing new life to an established region. *The Leading Edge*, **31**,802-809, doi: 10.1190/tle31070802.1.

Scisciani, V. [2009] Styles of positive inversion tectonics in the Central Apennines and in the Adriatic foreland: Implications for the evolution of the Apennine chain (Italy). *Journal of Structural Geology*, **31**, 1276-1294, doi: 10.1016/j.jsg.2009.02.004.

Scisciani, V. and Calamita, F. [2009] Active intraplate deformation within Adria: Examples from the Adriatic region. *Tectonophysics*, **476**, 57-72, doi: 10.1016/j.tecto.2008.10.030.

Scrocca, D. [2006] Thrust front segmentation induced by differential slab retreat in the Apennines (Italy). *Terra Nova*, **18**, 154-161 doi: 10.1111/j.1365–3121.2006.00675.x.