Seismic Characterization of the First 3D Surveys Offshore Cyprus and Lebanon*

Øystein Lie[1] and Mark Trayfoot[1]

Search and Discovery Article #10194 (2009)
Posted May 22, 2009

*Adapted from oral presentation at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2008

[1]Petroleum Geo-Services, Oslo, Norway (mailto:oystein.lie@pgs.com)

Abstract

The first 3D seismic data in the deep water offshore Cyprus and Lebanon have been acquired, processed and interpreted. Pre-stack time migration was applied and the 3D data sets have high signal to noise-ratio and very high reflectivity at both shallow and deep levels. Despite the lack of exploration well data, a consistent chronostratigraphic framework has been built across Cyprus and Lebanon and implications for prospectivity assessed. Several petroleum systems were identified, and potential prospect types include four-way dip closure structures and stratigraphic traps. Direct hydrocarbon indicators, including amplitude and frequency anomalies, are associated with many of the identified prospects. Amplitude maps have been extracted on offset stacks, and a good correlation between amplitude anomalies and the closures was found. The recent 3D seismic is considered to reduce the exploration risk in this unexplored frontier area.

Introduction

The offshore areas of Cyprus and Lebanon in the eastern Mediterranean Sea are currently unexplored with respect to hydrocarbon resources. The first 3D seismic surveys were acquired to obtain an improved understanding of the geological structures and the petroleum potential in these frontier deep water areas. The regional tectono-stratigraphic framework of the area is influenced by the relative movements of three adjacent continental tectonic plates; the African plate to the south, the Arabian plate to the east, and the Anatolian sub-plate to the north. The Levantine Basin, containing up to 10km of Mesozoic-Cenozoic sediments, is situated on the northeast edge of the African plate. The basin is bounded to the north by the Latakia Ridge (LR), part of the Cyprus deformation zone (Hall et al., 2005), to the west by the Eratosthenes Seamount (ES) and to the south by the Nile Delta Cone (NDC) (Figure 1).

Two areas considered highly prospective were selected for acquisition of the 3D seismic data. The surveys were acquired late 2006/early 2007 and cover approximately 1550km² (Phase 1 to the south) and 1350km² (Phase 2 to the north) (Figure 1). Phase 1 covers the central part of the Levantine Basin. Phase 2 covers the northern part of the basin, the Latakia Ridge, and several other large Syrian- and Cyprus-Arc deformation folds. The pre-stack time migrated 3D seismic data sets have a high signal to noise-ratio and a very high reflectivity at both shallow and deeper levels. Although no exploration wells have yet been drilled offshore Cyprus and Lebanon, valuable information can be extracted from some excellent geological exposures and data from seven Lebanese onshore exploration wells (Walley, 1998). Analogues can also be drawn from the proven hydrocarbon producing provinces of the Nile Delta, North Sinai, Gaza and Israel.

Seismic Interpretation and Hydrocarbon Plays

Nine key regional horizons have been interpreted to evaluate the prospectivity of the area. By tying the key reflectors from Cyprus in the west to Lebanon in the east a consistent chronostratigraphy was established. The following horizons were interpreted; Seabed, Intra Pliocene, Base Pliocene, Base Messinian Evaporite, Upper Miocene, Mid Miocene, Base Miocene, Eocene Unconformity and Senonian Unconformity (Figure 2).

The area contains a number of potential hydrocarbon plays and a variety of structural and stratigraphic trapping styles exist. The Upper Miocene Messinian Evaporite Formation which forms a regional cap rock in the eastern Mediterranean Sea is well developed, and intra-formational seals could also be present within the Cretaceous and Tertiary sequences. Source rock intervals proven onshore Lebanon within the Jurassic, Cretaceous and Paleogene (Beydoun, 1988) are postulated to continue offshore and vertical hydrocarbon migration can be expected along numerous fault planes. Multiple clastic and carbonate horizons in the Jurassic, Lower and Upper Cretaceous, Paleogene and Neogene represent potential reservoir intervals.

Prospect Types

Seismic interpretation has delineated large, four-way dip closure structures, and stratigraphic traps. The large four-way dip closure structures in the Phase 1 survey area trend NNE-SSW, parallel to the structural trends observed onshore Lebanon, whereas large transpressional structures further north in the Phase 2 survey trend NE-SW (Figure 3). One such structure, the Latakia Ridge, exhibits a complex structural evolution whereby normal extensional faults were subsequently reactivated during later compressional tectonic phases. The largest sub-salt structural closure in the Levantine Basin is approximately 200km², and depth conversion using interval velocities indicates that the vertical relief is in the order of 200m to 350m.

Potential stratigraphic traps include Miocene(?) onlap and pinchout, deepwater turbidite fans, incised channels and Late-Cretaceous(?) carbonate build-ups. The carbonate build-ups could have excellent porosities and permeabilities and would represent a new play type for deep water exploration where reservoir deliverability is a key aspect of prospect economics.

Prospect Evaluation and Direct Hydrocarbon Indicators

Possible direct hydrocarbon indicators (DHI's) have been observed at multiple levels within the prospects. These include flat spots, bright spots, low frequency anomalies, gas chimneys and seabed pock marks. The DHI's indicate an active petroleum system and help de-risk the prospects. Figure 4 shows bright spots, flat spots and gas chimneys within an anticline structural closure, amplitude anomalies within a Miocene(?) stratigraphic pinchout trap and Late-Cretaceous(?) carbonate build-ups.

To interrogate the sub-salt prospects, a series of RMS amplitude maps were extracted along the Base Messinian Evaporite horizon. High amplitude values were observed in the structural closures in the eastern part of the survey area (Figure 5). To further investigate these anomalies, amplitudes were also extracted from near and far offset stack cubes. A good conformance of high amplitudes with the highs was identified, particularly on the far offset cube (Figure 5). These high amplitude areas potentially represent areas where the reservoir is hydrocarbon-filled.

Conclusions

Recent high quality 3D pre-stack time migrated seismic data has illuminated several attractive large sub-salt four-way dip closures and new stratigraphic plays offshore Cyprus and Lebanon. Numerous DHI's associated with the prospects indicate several active petroleum systems and reduce the exploration risk in this frontier region.

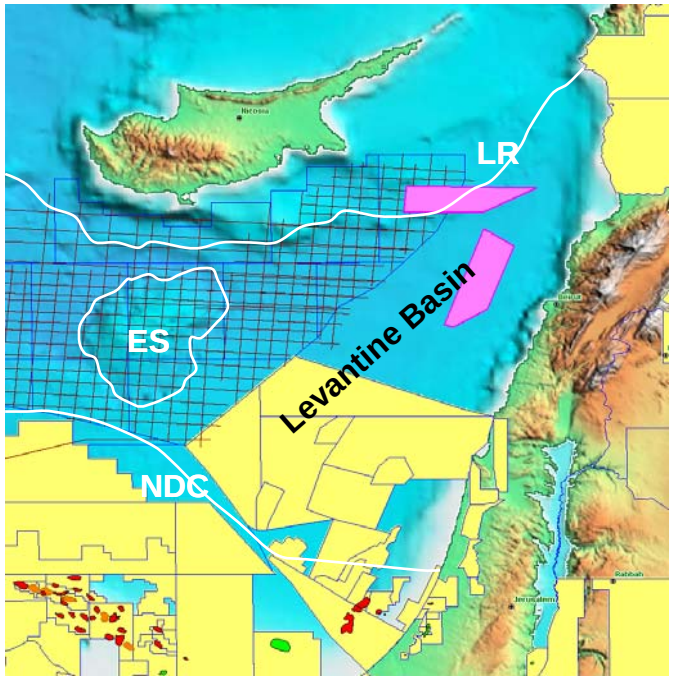

Figure 1. A map of the eastern Mediterranean area with the two 3D surveys offshore Cyprus and Lebanon highlighted in pink.

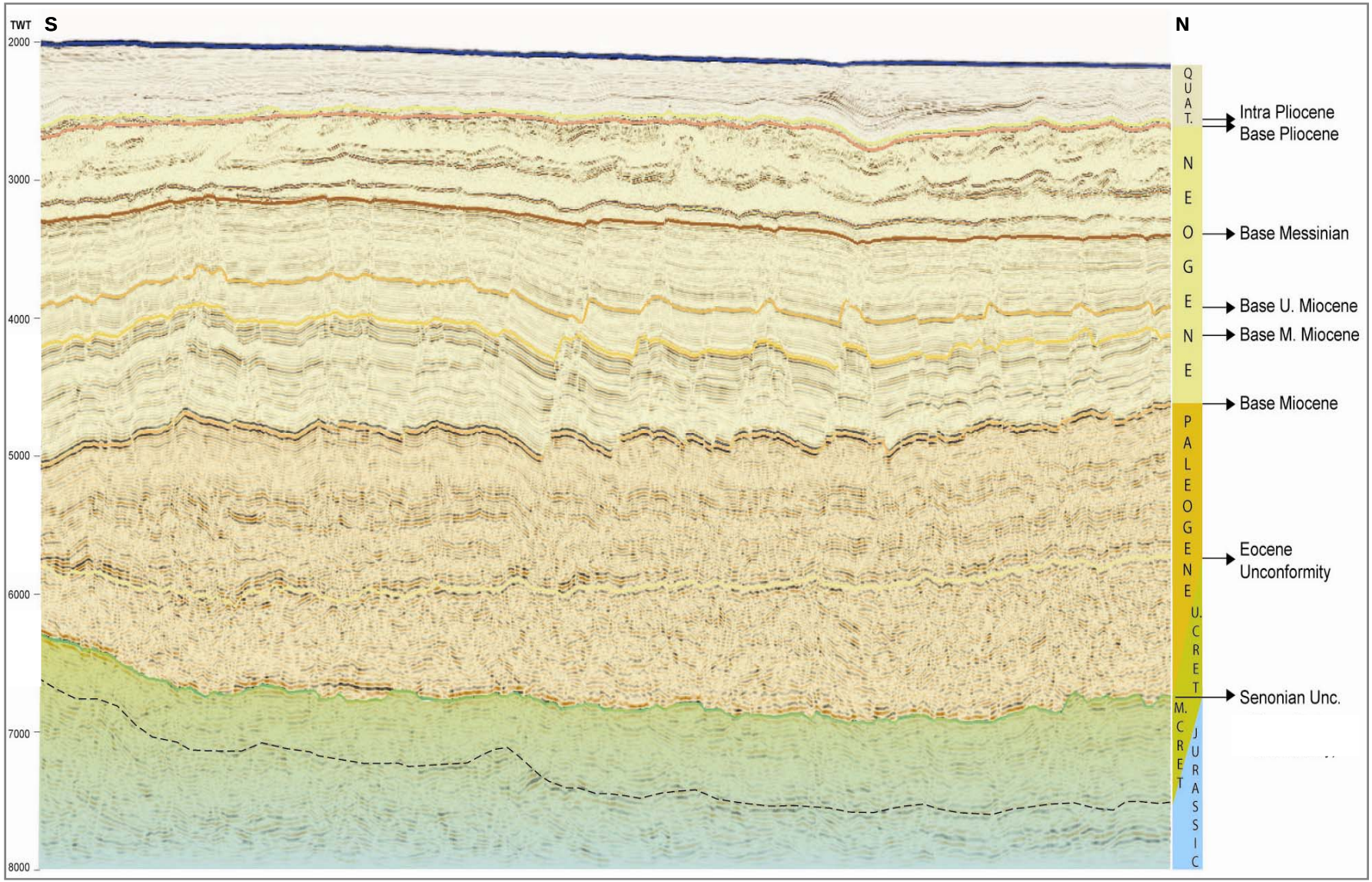

Figure 2. A 3D inline showing the key reflectors interpreted in the Levantine Basin, with the chronostratigraphy to the right.

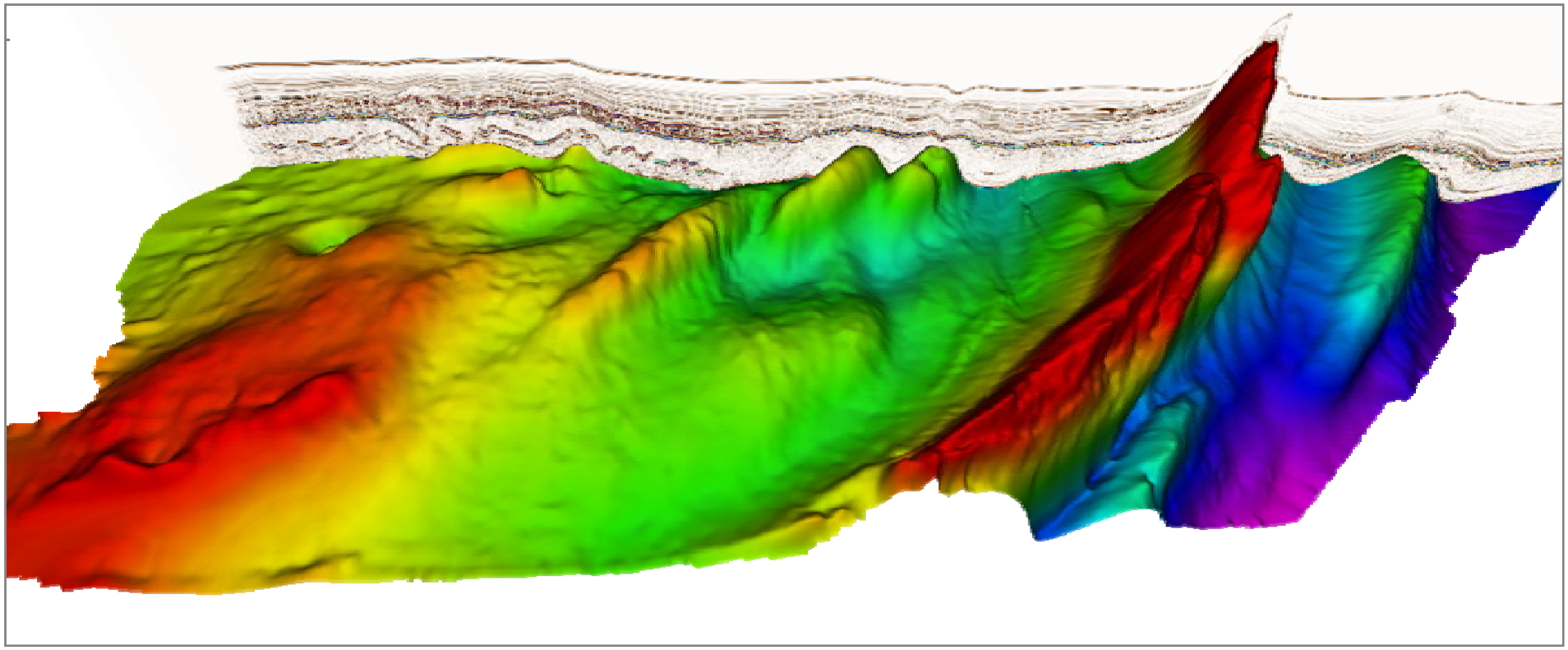

Figure 3. Large four-way dip structural closures and the Latakia Ridge in the Phase 2 survey, defined by the Base Messinian Evaporite horizon.

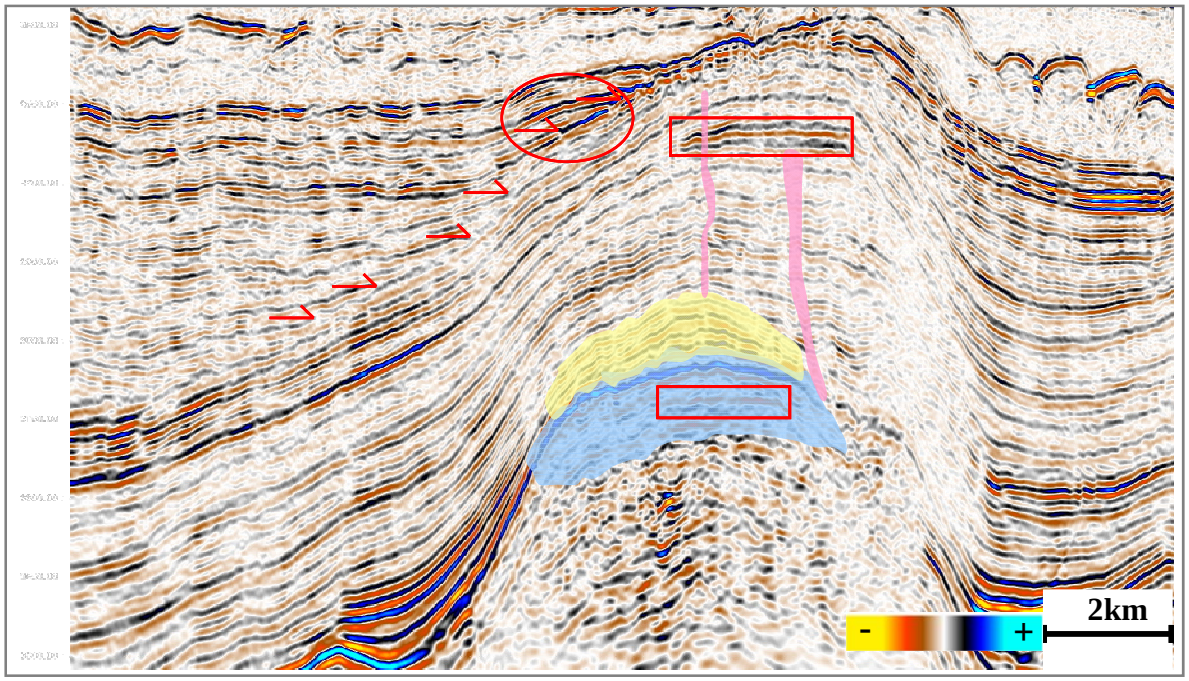

Figure 4. Potential DHI’s including flat spots, amplitude anomalies and gas chimneys.

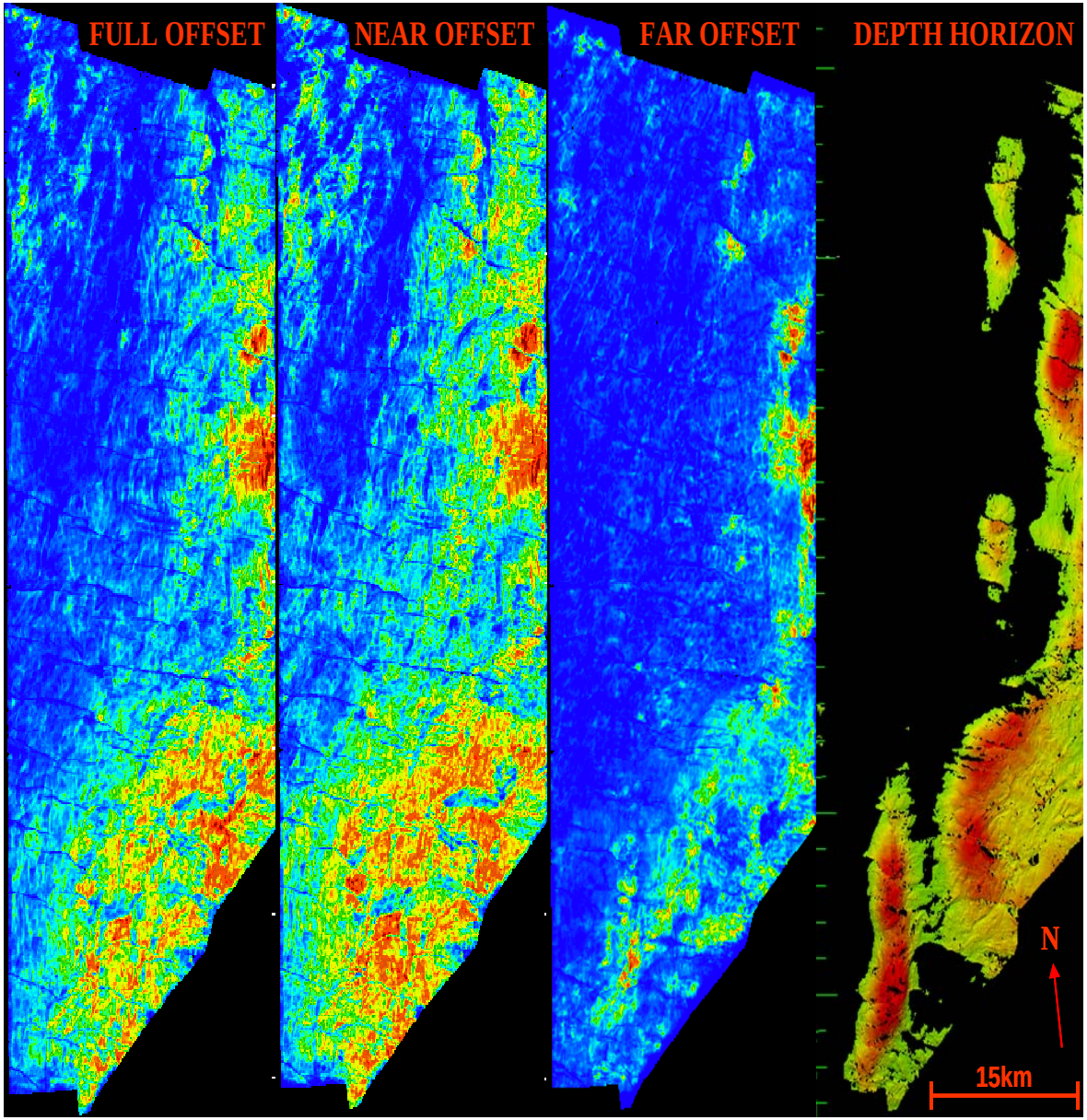

Figure 5. RMS amplitude maps extracted along the Base Messinian Evaporite horizon, with the corresponding depth map showing the highs to the right.

Acknowledgements

The authors would like to thank Wissam Zahabi representing the Lebanese Ministry, Solon Kassinis and Stelios Nicolaides of the Cyprus Ministry of Commerce, Industry and Tourism, and PGS Geophysical for permission to publish this work. Additionally we would like to acknowledge the contribution of our many colleagues, particularly Cecilie Skiple, Tim Bird and Caroline Lowrey.

References

Beydoun, Z.R., 1988, The Middle East: Regional geology and petroleum resources, Scientific Press, UK, 292 p.

Hall, J., T.J. Calon, A.E. Aksu, and S.R. Meade, 2005, Structural evolution of the Latakia Ridge and the Cyprus Basin at the front of the Cyprus Arc, Eastern Mediterranean Sea, Marine Geology, 221, p. 261-297.

Walley, C.D., 1998, Some outstanding issues in the geology of Lebanon and their importance in the tectonic evolution of the Levantine region, Tectonophysics, 329, p. 37-62.