The Messinian Salinity Crisis (MSC) Signature, Offshore Western Greece*

V. Kosmidou[1], G. Makrodimitras[1], and N. Papatheodorou[1]

Search and Discovery Article #30537 (2017)**
Posted December 26, 2017

*Adapted from extended abstract based on oral presentation given at AAPG International Conference and Exhibition, London, England, October 15-18, 2017

[1]Hellenic Hydrocarbon Resources Management S.A. (HHRM S.A.), Athens, Greece (v.kosmidou@greekhydrocarbons.gr)

Abstract

The current Mediterranean Sea is the remnant of a Mesozoic basin (NeoTethys), almost totally consumed because of long-term plate convergence between Africa and Eurasia. Among other consequences, this convergence created a fold and thrust belt (The Hellenic Fold and Thrust Belt) in the southern part of the Adriatic Sea, including the Ionian Islands area, described by a number of geotectonic zones. This area is mature, with 13 wells drilled and one offshore oil discovery in Katakolon. The major petroleum system of the Ionian zone is proven in Katakolon and has Jurassic "Posidonia" and Cretaceous "Vigla" shales as source rocks, with migration into the Cretaceous to Eocene carbonates/sands and the Miocene sands. The sands with provenance from continental Greece have excellent reservoir quality while evaporites and Plio-Pleistocene mudstone deposits serve as a seal. The trap is of anticlinal type formed by the uplift of the Pindos zone thrust. The pre-Apulian Zone (Paxos) is made up of Triassic to Miocene deposits – mainly neritic and hemipelagic, which stand, due to shortening and Triassic evaporite detachment zone, below the Ionian zone. Work on source rocks from wells and the presence of seeps occurring along western Greece, onshore and offshore, point to an active Mid-Mesozoic hydrocarbon system, and a possible Tertiary one due to organic rich mudstones of late Oligocene to Early-Mid Miocene turbidites. Recent MC marine seismic data indicate west of Corfu, from 40°N to 38°N, the presence of an important Late Miocene morphological feature with N-S direction. It represents an elongated channel of the central pre-Apulian zone, which was progressively inundated from the south after the Messinian Salinity Crisis (MSC). This process was concomitant with the deposition of sediments from the erosion of mainland coming from the east and suggests the presence of flows with crossed directions that can bear potential play types in a deep turbidite environment, buried today below 3 to 4 thousand meters of clastic sediments. Due to the lack of a well network, extend of the MSC peak and of the subsequent Pliocene reflooding remain unknown. However, in the generally admitted time interval between 5.9 and 5.4 Ma, preexisting reefal constructions (highs) suffered subaerial erosion or lack of sedimentation. These variations were the result of sea-level fall at the onset of the MSC, tectonic uplift and influence of cooling.

Introduction

The aim of this study is to focus on the signature of the Messinian Salinity Crisis (MSC) in the northern part of the Ionian Sea and its role in the petroleum system of the area. The results of this study indicate the presence of a new petroleum play of Miocene age and highlight the role of

MSC deposits as a possible seal for the Cretaceous-Tertiary plays. Despite the extensive research regarding the effect of the MSC in the deeper parts of the Mediterranean Sea, little is known about the MSC and its associated Messinian Erosional Surface (MES) in the shallower parts of the basin that were exposed to subaerial erosion. The studied area includes the Ionian, Pre-Apulian and Apulian Zone and is bounded to the north by the Borsh-Kharhiqit fault, to the south by the Kefalonia Transform Fault, to the east by the middle Ionian thrust and to the west by the Apulian Escarpment.

The study mainly relied on the detailed seismic interpretation of the available seismic data set. Seismic horizons, as well as detailed sequence stratigraphic surfaces, were interpreted. The results were used as input data to the model built to simulate the paleo-bathymetry changes since Early Paleogene. Paleowater depth values were used from the available literature (Bache et al., 2012; Gargani et al., 2007). Along with the seismic data, well data (Table 1) were used to identify the stratigraphic evolution of the MSC deposits from Cretaceous to Quaternary. Finally, analogues were an integral part of this study for a better insight into the transitional setting from the platform to the basin, since no well constraint existed from the legacy data of the Greek state.

The activity of the Liassic faults that bounded the deep basin created large platform-margin failures (megabreccias) along with bioclastic grainstones. Sporadically, huge carbonate clasts from the platform supply the slope area. Seismic data indicate the presence of a “platform to basin” system suggesting a shallow water environment to the west, while to the east, deep basins created by the downthrown movement of large fault blocks and filled with deep-water sediments. This system is equivalent to the Middle Jurassic to Eocene carbonate platform located in Gargano Promontory and other sites in offshore Italy. To the east, up to Late Cretaceous, similar deep-water carbonates were deposited and from Paleocene onwards they were incorporated into the Ionian thrust.

Seismic characters of low amplitude chaotic and transparent reflections to the west and high amplitude subparallel reflections to the east have been interpreted as an Oligocene to Miocene play. Reef facies, identified to the eastern side of the platform, were subjected to extensive erosion due to weather conditions and the geometry of the platform. In this system, carbonate turbidites from the shelf alternate with clastic sediments (flysch) supplied from the thrusting. Moreover, tilting of the Apulian Platform due to the activity of the Cephalonia Transform Fault (CTF) and the arching of the platform due to the obduction of the thrusts has been inferred from the seismic data.

The deep parts of the basin were more proximal to the Ionian thrust and were filled with siliciclastic sediments. On the carbonate platform itself, only a thin layer can be identified on seismic, suggesting that lack of carbonate sedimentation prevailed on the platform. The MES is the seismo-stratigraphic horizon associated with the rapid sea level drop and is identified not only in the offshore area but also in onshore outcrops and all studied well cores. It is a fluvial subaerial erosional surface to most of its extent as it is indicated by the seismic data and the simulation output. The simulations ran during this project aim to map the area in order to distinguish where the MES was subaerial, thus to simulate how the paleo-bathymetry was during Messinian. At that time, Apulian Platform was an elongated island.

Discussion

Seismic data suggested that during the Messinian two distinct plays existed in the area of research. A carbonate play of fringing reefs and back reef facies to the west (Figure 1c) and a clastic play with mainly fluvial and transitional fluvial-marine environments representing the foredeep fill with flysch deposits (Figure1b). In the slope of the Apulian Platform, the erosion of the steep flanks produced talus breccias and conglomerates. In the more basinal parts, marls and clays (flysch) were redeposited during the Messinian. During this time interval, several unconformities and erosional surfaces are identified in the seismic data, corresponding to sea level changes or hiatuses of sedimentation. Messinian sediments were later eroded by severe weather conditions during the Zanclean flood.

Meanwhile, in the Ionian Zone (Figure 2) transgressive marine sediments were deposited in a piggyback basin together with fluvio-lacustrine deposits. Tortonian and Lower Pliocene sediments in nearby outcrops indicate paleo-bathymetry depths of more than 1000m, typical of the marly limestones of Trubi that are overlaid above the conglomerates deposited during the Zanclean flood. As stated by Hinsbergen et al. (2006), adding the amount of sediments deposited during this time span suggests that the shallowing was initially accompanied by subsidence and from 4.5 Ma onwards by uplift.

Results

The Messinian Salinity Crisis seems to have drastically stopped the development of the Miocene reefs since the area of research has been exposed to subaerial erosion. The concurrent uplift of the eastern side of the Ionian Basin due to the progression of the Ionian Thrust further intensified the effect of the MSC since it provided more extreme conditions for the development and rejuvenation of extensive fluvial drainage systems. Interpretation has revealed later erosion surfaces of less significance; not dated yet. Simulation results conducted as part of this study further support the theory that most of the area of research at different times during the MSC was exposed to subaerial erosion with subsequent development of erosive channels and slumps.

The present petroleum system suggests a source rock related to organic-rich and black shales of Mesozoic. The main reservoirs are the Jurassic and Cretaceous carbonate rocks (deep-water carbonates, platform and reef deposits) together with the calciturbidites that were eroded and transferred to the basin. Finally, the Messinian deposits may act as a seal along with the Tertiary flysch deposits and the Triassic evaporites. Allochthonous (Messinian?) evaporites that were deposited in the southern part of the basin in the Plio-Pleistocene series also act as a seal. The post-Messinian deposits reach a thickness ranging from 1km at the fringes of the platform to more than 1.5km at the deeper parts of the basin. Faults that bound the basin between the platform and the thrust, as well as the extensive faulting system on the swell, enhance the migration process. The effect of the rapid pressure change during the MSC has not been examined yet in the area of research.

Conclusions

As a conclusion, a hybrid clastic-carbonate play of Messinian has been identified similar to the Oligocene-Miocene play. The shift of the coast to the east due to the MSC led to the subaerial exposure of the Apulia Carbonate Platform and the development of a lagoonal-tidal environment. Meanwhile, at the margins, fringing reefs and a shallow shelf and reefal margin developed. To the east, the subaerial Messinian topography was characterised by clastic sedimentation in fluvial and lacustrine environments.

References Cited

Bache, F., S.M. Popescu, M. Rabineau, C. Gorini, J.P. Suc, G. Clauzon, J.L. Olivet, J.L. Rubino, M.C. Melinte-Dobrinescu, F. Estrada, L. Londeix, R. Armijo, B. Meyer, L. Jolivet, G. Jouannic, E. Leroux, D. Aslanian, A.T.D. Reis, L. Mocochain, N. Dumurdžanov, L. Zagorchev, V. Lesić, D. Tomić, N. Namik Çağatay, J.P. Brun, D. Sokoutis, L. Csato, G. Ucarkus, and Z. Çakir, 2012, A two-step process for the reflooding of the Mediterranean Basin after the Messinian Salinity Crisis: Basin Research, v. 24, p. 125-153.

Bosellini, F.R., A. Russo, and A. Vescogni, 2001, Messinian reef-building assemblages of the Salento Peninsula (southern Italy): palaeobathymetric and palaeoclimatic significance: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 175, no. 1-4, p. 7–26, doi:10.1016/s0031-0182(01)00383-2.

Gargani, J., and C. Rigollet, 2007, Mediterranean Sea level variations during the Messinian salinity crisis: Geophysical Research Letters, v. 34, no. 10, doi: 10.1029/2007gl029885.

Hinsbergen, D.J.J.V., D.G.V.D. Meer, W.J. Zachariasse, and J.E. Meulenkamp, 2005, Deformation of western Greece during Neogene clockwise rotation and collision with Apulia: International Journal of Earth Sciences, v. 95, no. 3, p. 463–490, doi:10.1007/s00531-005-0047-5.

Kamberis, E., C. Ioakim, S. Tsaila Monopolis, F. Manelis, and S. Sotiropoulos, 1998, Geological and paleogeographic evolution of Western Greece, during the Neogene - Quaternary period in the geodynamic setting of Hellenic Arc: Rom. J. Stratigraphy, v.78, p.63-73.

Manzi, V., S. Lugli, M. Roveri, B.C. Schreiber, and R. Gennari, 2010, The Messinian "Calcare di Base" (Sicily, Italy) revisited: Geological Society of America Bulletin, v. 123, no. 1-2, p. 347–370, doi:10.1130/b30262.1.

Monopolis, D., and A. Bruneton, 1982, Ionian sea (Western Greece): Its structural outline deduced from drilling and geophysical data: Tectonophysics, v. 83, no. 3-4, p. 227–242, doi: 10.1016/0040-1951(82)90020-8.

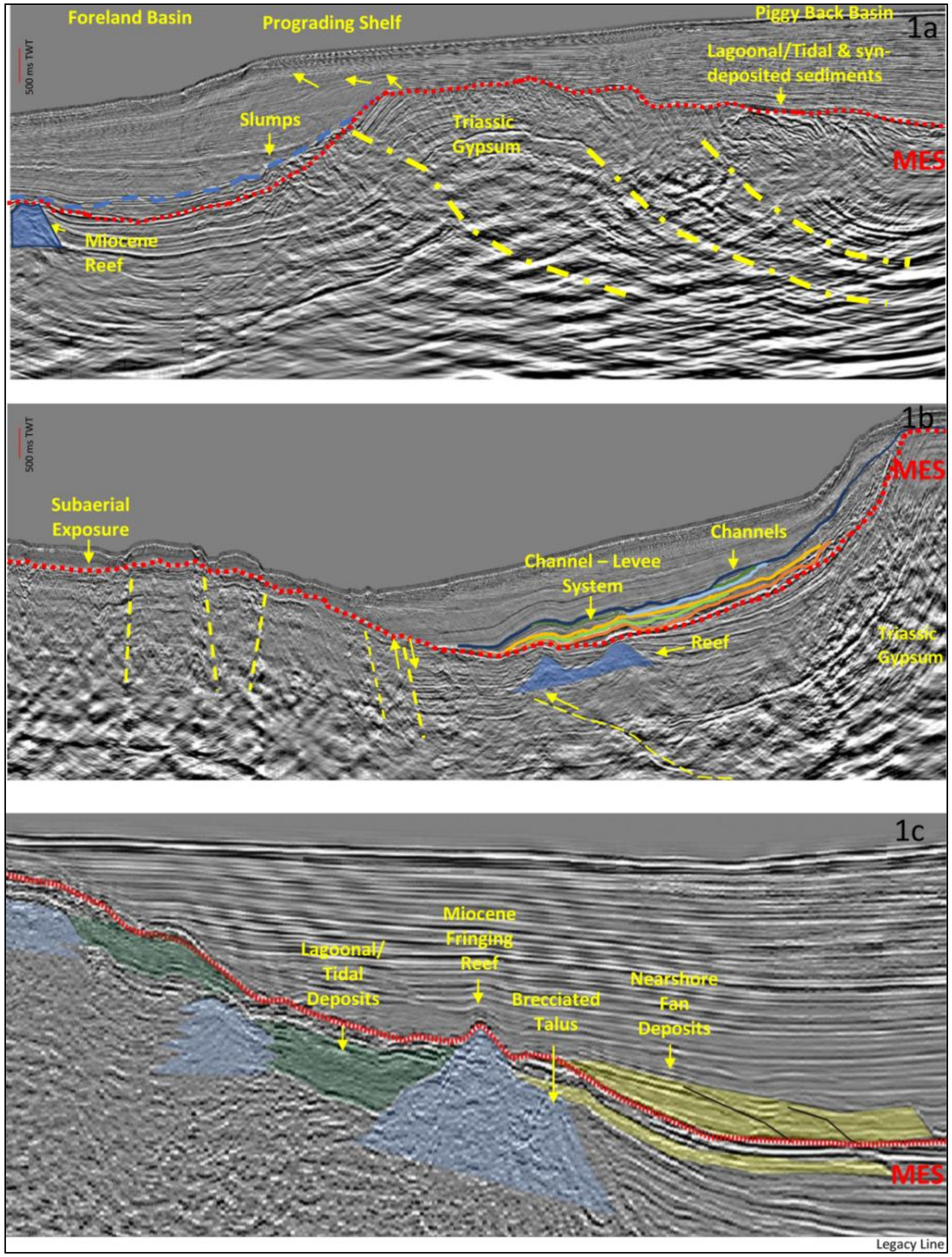

Figure 1. Interpreted SW-NE Seismic Lines. Seismic Line 1a is located on the Ionian Zone; seismic line 1b features the Pre – Apulian Zone and the Apulian Platform and seismic line 1c focuses on the marginal facies of the Apulian Platform.

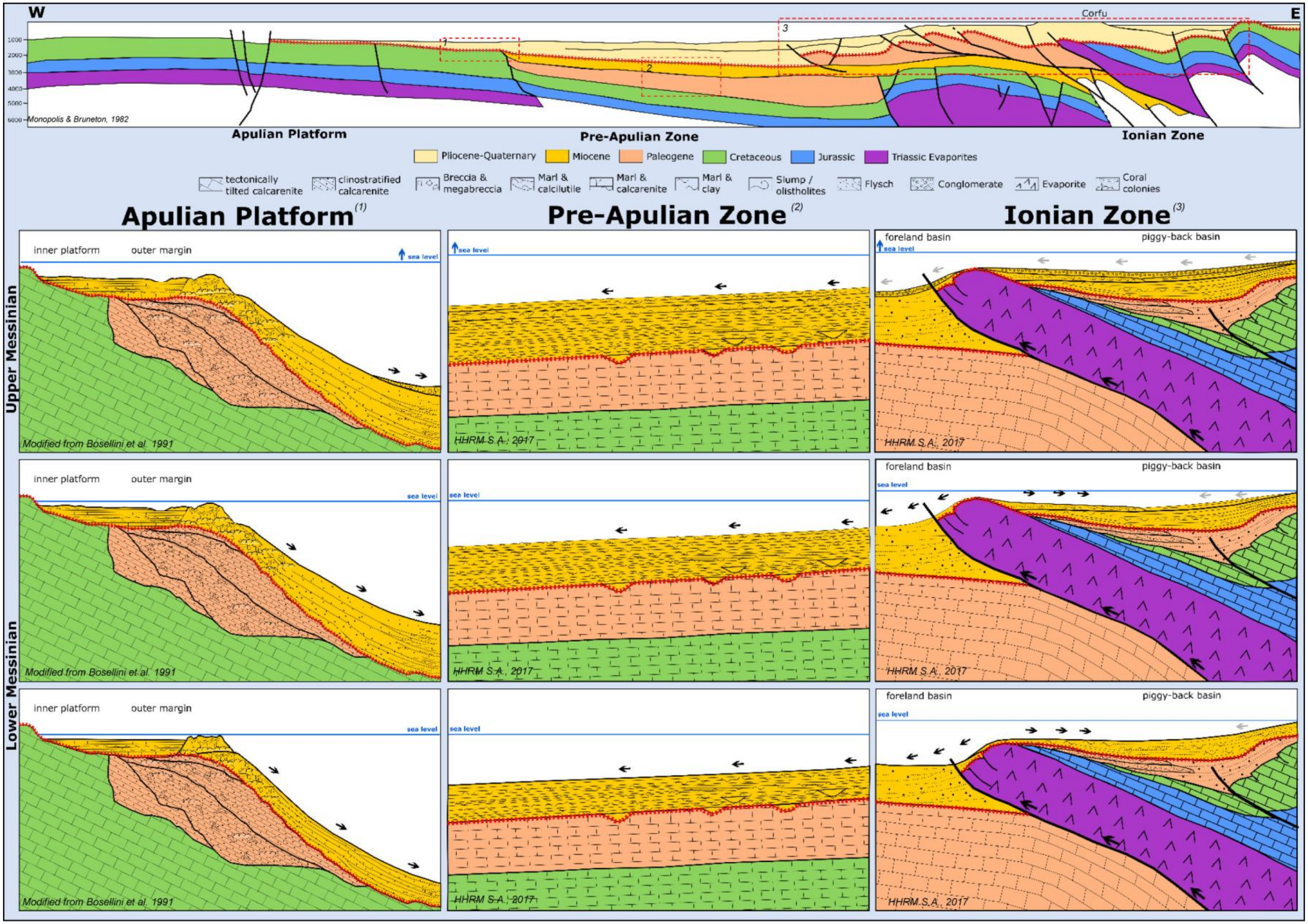

Figure 2. Messinian Depositional Environments in the Apulian Platform, Pre-Apulian Zone and Ionian Zone.

	Apulian Platform	Pre-Apulian Basin	Ionian Zone
Upper Messinian	*Rignano Formation:* Conglomerates, talus breccia ↓ **Nearshore fan deposits (gravity flows?) & Ephermal ponds and sump related to deep drainage channel** (Bosellini *et al.,* 1999, 2002, Casolari *et al.,* 2000)	Marls and clays (Kamberis *et al.,* 1998, M). Locally redeposited gypsum ↓ **Redeposited sediments (flysch) due to thrust activity** (Casolari *et al.,* 2000, Bosellini *et al.*, 2002)	Basal conglomerates and breccias ↓ **Sediment gravity flows** (Kamberis *et al.,* 1998)
Lower Messinian	*Tripoli Formation:* Migrating dunes or sand waves (near shore?), diatomites (lake?), Aturia Level, thin pelagic unit ↓ **Basal continental interval** *Calcare di Base:* wave ripples and small to medium scale sand waves. Peritidal lime/dolostones with inter-supratidal structures (e.g. stromatolites), desiccation cracks and mini-tepee ↓ **Lagoon/Tidal deposits** *Novaglie Formation*: ↓ **Fringing Reef** *Adrano Calcarenite:* ↓ **Shallow shelf and reefal margin** (Bosellini *et al.,* 1999, 2002, Casolari *et al.*, 2000)		Transgressive marine sediments (marls, sandstones and marly limestones) fill the piggy back basin. Due to thrust activity: syn-deposited olistholites, slumps (wavy erosional surfaces) ↓ **Lagoonal/tidal & Syn-deposited sediments** (Kamberis *et al.,* 1998)
Wells	**Rospo Mare-1:** Anhydrites (seal to proposed reservoir model).	**Aquilla-1:** Silty marls, siltstone and anhydrite layers (Colombacci Formation) and marls with layers of gypsum (Gessoso Solfifera Formation).	**East Ericoussa-1:** Calcareous micromicaceous, siltstone deposits with high traces of shell fragments and microfossils.
		Sparviero-1: Marl with argillaceous intercalations and anhydrite.	**Yannades-1:** Oligo-Miocene clastics with Langhian-Burdigalian series intercalated with evaporites.
	Merlo-1: Marls (Gessoso Solfifera Formation-seal).	**Rovesti-1:** Fossiliferous marls with clay intercalations.	**Parga-1:** Deepwater deposits with pelagic protozoa. Claystone-locally silty interbedded with sandstone.
		Falco-1: Siltstones.	

Table 1. Messinian sedimentary environments in Apulian Platform, Pre-Apulian Basin and Ionian Zone.