New and Emerging Plays in the Eastern Mediterranean

23-25 February 2011

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Wednesday 23 February

Session One: Regional Tectonics, Reservoirs and Prospectivity

Keynote Speaker: Tectonic Development of the Eastern Mediterranean Basin

A. Robertson[1], T. Kinnaird[2], G. McCay[1], O. Parlak[3]

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Despite being considered as one of the last frontiers for hydrocarbon exploration the geological development of the E Mediterranean is quite well known from land and sea. The E Mediterranean basin represents the last vestiges of a Mesozoic oceanic basin generally known as the Southern Neotethys. The Southern Neotethys rifted from Gondwana during the Late Permian-Mid Triassic, followed by continental break-up and initial sea-floor spreading during Late Triassic. There is no convincing evidence for the existence of Permian oceanic crust in contrast to some reconstructions. The seafloor between Cyprus, the Levant margin and North Africa is likely to be largely underlain by a broad continent-ocean transition zone with oceanic crust developed only north of the Eratosthenes Seamount. Spreading is likely to have been pulsed rather than continuous since the ocean remained relatively narrow (~1000 km). Passive margins conditions persisted during the Jurassic until the Late Cretaceous. Northward intra-oceanic subduction initiated during the Late Cretaceous and ophiolites formed in the Southern Neotethys (e.g. Troodos & Hatay ophiolites). Northward subduction also generated arc magmatism along the northern, active continental margin in eastern Turkey. Ophiolites were emplaced onto the Arabian margin in the east in response to the collision of the subduction trench with the Arabian passive margin during latest Cretaceous. Remaining oceanic crust subducted northwards during the Cenozoic, suturing the ocean during the Early Miocene in eastern Turkey. The Eastern Mediterranean Sea area remained as an oceanic remnant that was mainly consumed by subduction south of Cyprus during Neogene time. At ~3 Ma the Eratosthenes Seamount collided with the Cyprus trench, initiating strike-slip and tectonic escape along the 'Cyprus arc' and rapid uplift of the island. In contrast, the geological development of the southern passive margin of the Eastern Mediterranean remains less well known if only because much of the relevant data are not in the public domain.

Syrian Arc Tectonics and Implications for Petroleum Prospectivity in the Eastern Mediterranean

Sebastian Lüning, Hesham Maksoud, *RWE Dea, Überseering 40, 22297 Hamburg, Germany*

The Syrian Arc is an intraplate orogen in the Eastern Mediterranean region that formed during the late Cretaceous to Miocene by inversion of a late Triassic – early Jurassic half-graben system (Abd El-Motaal and Kusky, 2003; Ayyad and Darwish, 1996; Chaimov et al., 1993; Druckman et al., 1995; Moustafa and Khalil, 1990; Shahar, 1994). The northern branch of the deformational belt is represented by the Palmyrides fold and thrust belt in Syria which is offset from the southern branch in the Negev and Sinai by the Neogene Dead Sea Transform Fault. Syrian Arc anticlines also occur in the offshore areas of the Negev and Sinai. The inversion system continues westwards in the subsurface into the Egyptian Western Desert (El Sisi et al., 2002) and the NE Libyan Jebel Akhdar (Röhlich, 1990).

The compressional stress originated from the subduction of the African-Arabian Plate beneath the Eurasian Plate. Onshore, the plate boundary is located in the Bitlis-Zagros suture zone in Iran and Turkey. The suture continues westwards offshore as a pronounced oceanic fault system and subduction zone (Dolson et al., 2001). The collisional stress propagated along existing fault systems into the intraplate area where it resulted in transpressional inversion of the early Mesozoic half-graben systems.

Syrian Arc inversion commenced around the Cenomanian, coinciding with the start of African-Arabian and Eurasian plate collision and the initial closure of the Neotethys (Bosworth et al., 1999; Gardosh and Druckman, 2006; Lüning et al., 1998). Inversion activity continued in series of intensity pulses until the early Miocene when the last oceanic lithosphere between the Arabian and Eurasian plates was finally consumed (Okay et al., 2010). This resulted in a significant weakening of compressional stress in the collisional zone and hence also in the intraplate area. While in the Palmyride fold and thrust belt inversion was most intense during the Miocene (Chaimov et al., 1992), Late Cretaceous deformation seems to have dominated in the Negev and Sinai parts of the Syrian Arc. In NW Sinai mid Miocene uplift closed off the northern end of the Gulf of Suez, separating it from the Mediterranean as evidenced by faunal assemblage compositions (Dolson et al., 2001). Notably, this final phase of 'Syrian Arc' tectonics interacted with Gulf of Suez and Gulf of Aqaba rifting of the Gulf of Suez Basins (Keeley & Massoud 1998).

A great number of small and some medium-sized gas fields as well as some small oil fields have been discovered in the Palmyrides fold and thrust belt. The reservoirs are predominantly Triassic with Permo-Triassic and Carboniferous shales representing the main source rocks. In contrast, exploration results in the Syrian Arc onshore Negev and Sinai have been disappointing, despite the drilling of many exploration wells. In the Negev, only a few small oil and gas fields were found (Pierce, 2004). The only onshore field in Sinai is the small Rafah South (Sadot) gas field at the Israeli border. Oil shows were recorded in wells Nakhl-1 and Abu Hamth-1 in central Sinai (Ayyad and Darwish, 1996; El Ayouty, 1990). Reservoirs in both the Negev and Sinai are mainly of Jurassic and Cretaceous age. In the near offshore of Israel, a few million barrels of oil have been discovered in Jurassic carbonates in the Yam-2 and Yam Yafo-1 fields. The traps are defined by Syrian Arc anticlines. On the Sinai side, the Mango-1 well tested 10,000 bo/d plus gas from a number of thin Albian/Aptian turbidite sands. Nevertheless, the field turned out to be too small to justify development (Peck, 2008; Peck and Horscroft, 2005).

In 2009 the giant Tamar gas field was discovered in the deepwater off Israel. The gas is reservoired in Lower Miocene submarine fan sandstones and trapped in a late-stage Syrian Arc anticline. The smaller Dalit offshore gas field, discovered only a few months later, further raised the prospectivity of this play. The fields share some similarities with the giant Raven Field cluster in the offshore Nile Delta. The Raven Field Cluster is trapped in a large anticlinorium that has been growing throughout the Tertiary (Peck and Horscroft, 2005; Whaley, 2008). Like in the Syrian Arc, the deformational stress may have originated from the African-Arabian and Eurasian plate collision and been transferred by the Qattara and related faults into the Raven area.

The Syrian Arc inversion system continues westwards in the subsurface into the Egyptian Western Desert where a large number of oil and gas fields have been discovered. Syrian-arc related structures form the bulk of the productive traps in this region (Ayyad and Darwish, 1996; Dolson et al., 2001). This also includes the giant Abu Gharadiq Field (Dolson et al., 2001).

Prediction of the Late Cretaceous to Recent Drainage and Turbidite Systems of NE Africa

Duncan Macgregor, *Surestream Petroleum and MacGeology Ltd*

Prediction of clastic sediment supply through time to the northeastern part of the African plate margin relies on the reconstruction of past drainage systems and on an assessment of the impact of past climates and uplift-related topographies. An approach is presented here, integrating lines of evidence for past sedimentation rates and volumes (calculated from regional sections and isopach maps), seismic facies (progradational patterns), denudation (AFTA), topographies (erosional patterns imposed on peneplanation surfaces, abandoned canyons) and past climates (various lithological indicators and models). It is necessary to take a very wide regional approach in view of the interplay of northern African drainage systems with those that now drain to the western and eastern margins of the continent.

The current Nile river system demonstrates climatic and topographic controls, with 80% of current sediment originating from the seasonally wet Ethiopian rift shoulders. This pattern is however only indicative of the current unusual dry conditions affecting the region and during wetter phases, clearly more sediment derived from the Red Sea rift shoulders and from the Nubian and Darfur swells : this ‘wet phase’ sediment was undoubtedly more sand prone. While the course of the drainage system since its probable initiation in early Oligocene, may have changed, particularly within Egypt, evidence from sedimentation rates and denudation indicators suggest the origin and outlet of the river have remained in much the same locations, at least for the Blue Nile (the White Nile may be a more recent capture from the Congo system). The Oligocene to Recent sediment volumes in the Nile cone are not consistent with published histories of the river that do not include Sudanese and Ethiopian connections until relatively Recent times. Sedimentation rate changes and seismic facies indicators suggest the prodelta sediment thick may have periodically switched between the Herodotus and Levantine Basins with distal reservoirs likely to extent well beyond Egyptian waters.

Relationships can be demonstrated Africa wide between sedimentation rates , large rivers draining wet and high regions and the occurrence of commercial turbidite reservoirs. These fit with observations in the Nile prodelta and allow other North African drainage systems, including those active only during wet phases (e.g the Sahabi and Ashdod systems), to be analysed in a similar manner.

Stratigraphic Architecture of the Upper Barremian-Lower Coniacian Levant Platform along the Syrian Arc Fold Belt (Sinai-Jordan)

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The offshore Levant Basin meets to the south/southeast the continental slopes of the African and Arabian plates, with the Syrian Arc intraplate fold-thrust belt in between. The Syrian Arc extends from central Sinai through Israel to central Syria (including basin and swell structures east of the Dead Sea-rift in Jordan). Its basin history commenced with the Triassic opening of the Neo-Tethys and continued to the Early Cretaceous rifting, as evidenced by cyclical igneous activity at the Levant margin (Segev et al., 2009) and by rift-related depositional patterns at northern Sinai (Bachmann et al., 2010). While extensional activities decreased in Albian/Cenomanian times, the first imprints of Syrian Arc inversion -and thus the change to a compressional regime- are evidenced in early Turonian times (Kuss, et al., 2000) and culminated with several tectonic pulses until the early Miocene.

The upper Barremian – lower Coniacian succession of the Levant Platform was subdivided into seven platform stages, comprising up to 35 3rd-order sequences. Variations in sequence architecture are correlated with different platform geometries of the successive platform stages, starting with an initial ramp (late Barremian–mid Albian), followed by a distally steepened ramp (mid Albian–mid Cenomanian), a shallow platform with intra-platform basins (Mid Cenomanian–late Turonian) that terminated after platform drowning (early Coniacian) and deep water (chalk)sediments above. Significant emergences at the lower/upper Aptian boundary (?global) and during the lower mid Turonian (local?) correlate with similar events on the Arabian Plate. Carbon crisis during OAE 1a, MCE 1 and OAE2 are recorded from the Levant Platform, however, did not affect the platform evolution sustainably.

In northern Sinai we infer an extensional tectonic regime from the identification of syn-tectonic growth faults, starting in the Early Cretaceous and continuing until the late Aptian. Thickness and facies variations of the Lower Cretaceous sequence indicate that this rifting event led to a step-like margin with fault-controlled deposition on elongated siliciclastically influenced ramps. Decreasing tectonic activity during late Aptian-mid Albian led to a homoclinal ramp that is characterized by a braod delta system in North Sinai. Retrogradational patterns prevail in the systems tracts of the distally steepened ramp above that is followed by a flat-topped Cenomanian-Turonian platform. The latter is characterized by several 100m thick accumulations of carbonate rocks, occurring all over the area of the Syrian Arc Fold Belt.

Vertical facies variations within the biostratigraphically subdivided units reflect large scale stacking patterns that are clearly attributed to 3rd order sea level variations. Their particular importance as a major controlling factor of deposition on the Levant Platform is indicated by predominantly synchronous cyclicities and concordant distribution patterns of the microbenthos within individual sequences. The impact of changes in platform architecture as a result of global paleoceanographic events is recorded in different regions.

Predicting the Spatial and Temporal Distribution of Tertiary Reservoir Facies within the Eastern Mediterranean: A Regional Sequence Stratigraphic Approach

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The control of relative sea-level fluctuations on large-scale changes in lithofacies and stratigraphic architecture is well established, forming the basis for the use of sequence stratigraphy in hydrocarbon exploration. In 2001 we demonstrated the veracity of a sequence stratigraphic model for the Arabian Plate identifying 63 major Maximum Flooding Surfaces (MFS) and Sequence Boundaries (SB). Ongoing work, incorporating all sedimentary basins, now demonstrates the occurrence of 118 biostratigraphically constrained sequences that are global in nature and observed independent of tectonics or sediment supply. The application of this model to frontier basins can provide important insights into the occurrence of important petroleum system elements.

The Eastern Mediterranean is relatively under-explored and yet considerable reserves have already been discovered within the Tertiary deep water successions of both offshore Egypt and Israel. Whereas these discoveries confirm the presence of a working petroleum system, they raise many questions regarding the distribution and chronostratigraphy of the reservoir facies encountered within these two regions.

Using publically available well, outcrop and seismic data, we review the spatial and temporal relationships between Palaeogene and Neogene deepwater sandstone units observed within the Nile Delta and Levantine basins within the context of a global sequence stratigraphic model. Such sandstone bodies are considered closely related to periods of eustatic sea-level fall, amplified by more localised tectonic events. Inferences on play potential and petroleum prospectivity will be discussed.

Keynote Speaker: Mesozoic Petroleum Source Rocks in the Central Mediterranean Region

Hugh C.Jenkyns, *Department of Earth Sciences, University of Oxford*

The central Mediterranean area, constituted by Mesozoic sediments deposited on the Tethyan continental margin, exposes numerous outcrops of organic-rich shales. Both palaeoceanography and palaeogeography played a role in their formation. Fault-bounded basinal areas situated between Bahamian-type carbonate platforms developed in several areas during the latest Triassic–earliest Jurassic and during the Late Jurassic: the key factor that controlled the relative enrichment in organic matter in such areas appears to have been relative restriction and stratification of the watermass. Where subsidence was particularly rapid, hundreds of metres or more of black shale and limestone were able to accumulate. Significant source-rock intervals were also formed when the Tethyan continental margin was affected by major Oceanic Anoxic Events (OAEs), namely those of the early Toarcian, early Aptian and Cenomanian–Turonian boundary. Organic-rich sediments were developed in deep pelagic basins, submarine plateaus and, locally, on carbonate platforms. The least organic-rich units are those of the early Toarcian (typically <5 wt %TOC), followed by those of the early Aptian (typically < 15 wt% %TOC), with highest values (locally > 30%) characteristic of the Cenomanian–Turonian OAE. However, many of these sequences are relatively thin, being typically developed on the metre scale. OAEs are currently interpreted as productivity-driven phenomena, ultimately forced by extreme atmospheric and sea-surface temperatures, and are of global reach. In certain geographically restricted peri-mediterranean basinal areas affected by OAEs, organic biomarkers and inorganic proxys indicate that conditions locally became euxinic (sulphidic), greatly enhancing preservation of organic matter. Such effects were particularly important during the Cenomanian–Turonian OAE, rendering this a particularly significant source-rock interval in the region.

Wednesday 23 February

Session Two: New and Emerging Plays Offshore Egypt

Keynote Speaker: Understanding Crustal Structure and the Early Opening History of the Eastern Mediterranean Basin, Offshore Northern Egypt and the Levant

Tim Bevan, *c/o BP Egypt Exploration, P.O. Box 2409, Cairo, Egypt*

Consistent with the varied opinions concerning the plate-tectonic history of the eastern Mediterranean basin (EMB), the crustal structure of this portion of the Neo-Tethyan system has been the subject of much debate. Prior to this study, the position of the ocean-continent boundary, as well as the depth and thickness of the continental and oceanic portions of the basin were all poorly constrained. In order to better define these issues, BP Egypt undertook a major regional study integrating regional gravity data with deep 2D seismic reflection and refraction profiling. The results of this recent work provide the basis of this presentation.

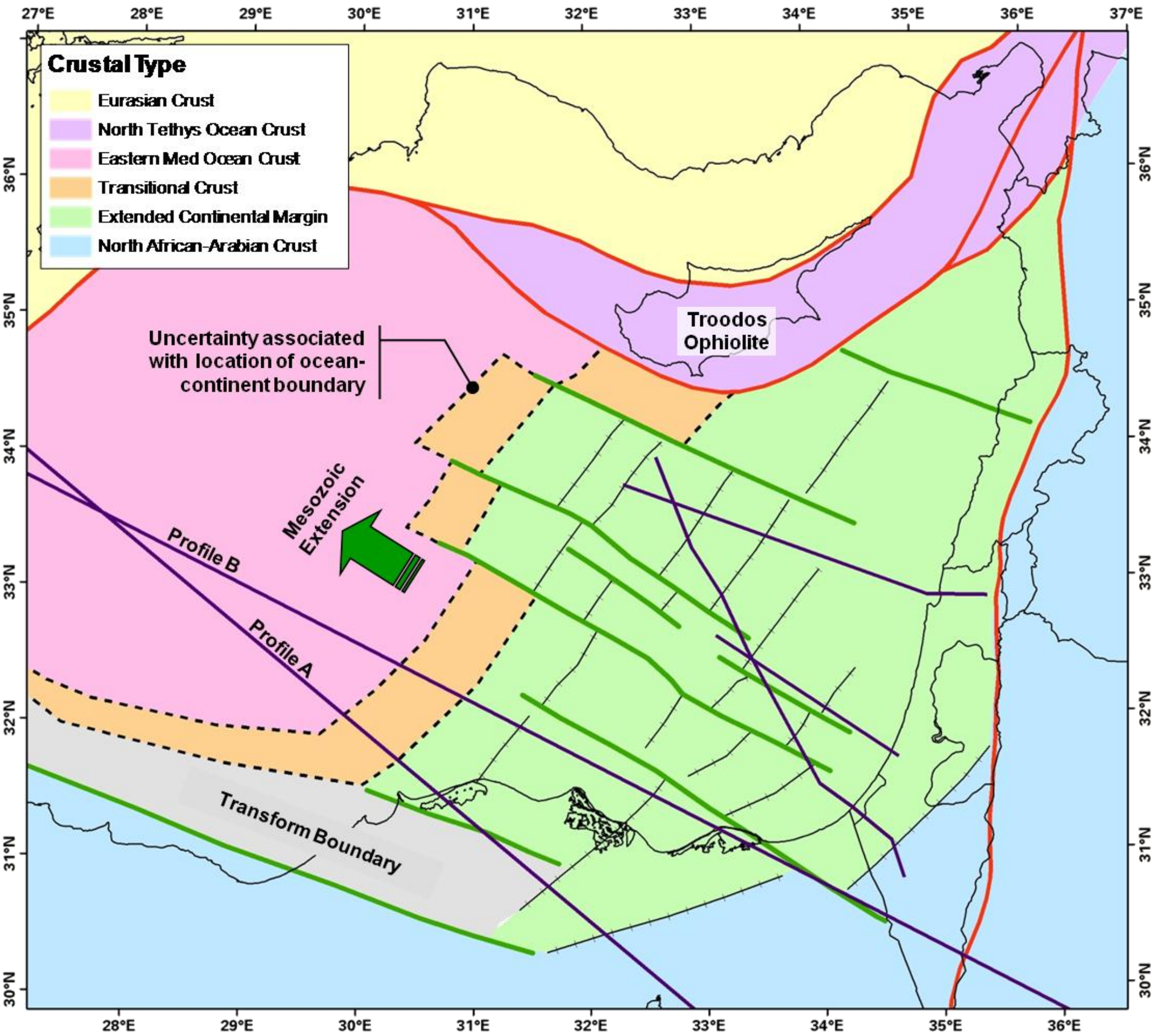

Figure 1: Preferred model for crustal distribution in the offshore eastern Mediterranean basin

Two crustal-scale cross sections were constructed across the EMB using a combination of proprietary and public domain information. The locations of these profiles are shown on Figure 1. Recent regional tele-seismic studies have estimated the depth to the Moho within the area of the larger Mediterranean region (Marone et al. 2003) and were used to constrain the western portions of both profiles. Al-Demagh et al. (2005) have published similar data for the larger Arabian plate, thereby constraining Moho depth and crustal thickness at the eastern terminations of our profiles. The western terminations of both profiles are constrained by projecting the profile data from Bohnhoff et al. (2001) while the depth and thickness of the oceanic plate beneath the Mediterranean Ridge and deep Herodotus Basin are constrained by the data of Makris & Yegorova (2006).

Based on observations from the regional gravity data combined with onshore fault trends, and regional arguments for plate tectonic reconstructions, we concur with Meshref (1990) & Garfunkel (1998; 2004) in proposing an opening direction that was strongly oblique to the present-day continental margin of northern Egypt (Figure 1). This is consistent with structural observations along the Levant Margin and offshore North Sinai (Garfunkel 2004; Farris et al. 2004); but is in contrast to a number of other authors that suggest rifting occurred N-S, at a high-angle to the present-day coastline (Stampfli et al. 2002; Robertson 1998).

Evidence presented by Walley (1998) agrees with a proposed ENE-WSW opening direction and suggests that the present-day coast of the Levant is underlain by a NNE-SSW-trending extensional margin of Late Triassic-Early Jurassic age. In our preferred scenario for initial development and rifting of the EMB, the southern margin of the basin develops as a left-lateral ocean-continent transform boundary separating oceanic crust of the southern Tethys from mildly-extended continental crust of the northern Egypt. Potential analogs for such a transform margin have been documented along the Equatorial Guinean continental margin, where oceanic fracture zones intersect the coastline at an oblique angle (Wilson et al. 2003).

From Neoproterozoic to Early Cenozoic: Exploring the Potential of Older and Deeper Hydrocarbon Plays Across North Africa and the Middle East

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As the traditional exploration plays in the main productive basins of North Africa and the Middle East become more ‘mature’, attention is increasingly focusing on more challenging, older and deeper plays in the main producing basins and on high-risk, but more conventional, plays in under-explored frontier areas. This shift brings with it a range of technical and commercial challenges that must be addressed, if exploration in the region is to remain an attractive proposition. Exploration in North Africa and the Middle East has traditionally focused on the prolific Mesozoic- and Cenozoic-sourced petroleum systems of the Nile Delta, the Sirte Basin, the Pelagian Shelf, and the Arabian Plate and on the Palaeozoic-sourced petroleum systems of the Berkine, Ghadames, Illizi, Ahnet and Murzuq basins, the Central Arabian Basin, the Qatar Arch and the Rub Al Khali Basin. Together these form one of the most prolific petroleum provinces in the world and, as a consequence, there has been little commercial incentive to invest in exploring more challenging and riskier plays in these areas. However, as the need to find new reserves becomes imperative, attempts are increasingly being made to test new play concepts and to extend already proven plays into new areas. Key recent developments in this regard include the recognition of the hydrocarbon potential of the Neoproterozoic to Early Cambrian (‘Infracambrian’) sedimentary section lying below the traditionally explored Palaeozoic succession in many basins in North Africa. In some areas, particularly the Berkine Basin in Algeria, the Nile Delta in Egypt and the Rub Al Khali Basin in Saudi Arabia, attention is also increasingly being focused on developing deeper gas plays, both in new areas and beneath existing producing fields. The technical challenges associated with these deeper gas plays are immense and include difficult seismic imaging of deep prospects, low porosity and permeability, high temperature and pressure and a critical need to identify ‘sweet spots’ where either locally preserved primary reservoir characteristics or secondary enhancement of reservoir quality through palaeo-weathering and/or fracturing allow commercial rates of gas production to be achieved. Despite these challenges, it is clear that the future for exploration in many of the more mature basins of North Africa and the Middle East will increasingly lie in evaluating such older and more deeply-buried plays.

Shelf-To-Basin Floor Architecture of the Rosetta Turbidite System (Western Nile Delta, Egypt)

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Most recent delta-fed turbidite systems are classically connected to one mature canyon that deeply incises the continental shelf and slope (examples from the Amazon fan, the Zaire fan, the Indus fan and the Danube fan, among others). In these cases, process of sediment-pathway migration generally occurs at the base of the slope, through channel avulsions. The Mississippi and Bengal fans are two other cases where migration of the main pathways delivering particles to the basin was documented directly on the upper part of the continental slope.

Using a large dataset, including multibeam bathymetry, backscatter imagery, 2D and 3D seismic-reflexion data, available over the whole the Rosetta turbidite system (western Nile deep-sea fan), from the shelf to the basin, numerous sedimentary bodies have been discriminated and characterized along the depositional profile and replaced within a relative chronological framework to build an architectural model of the system.

The main architectural elements identified on the present-day seafloor and in the Plio-Quaternary sedimentary pile are canyons, mass-transport deposits (MTDs), turbidite channels and turbidite lobes. Eleven diachronous submarine canyons were identified on the outer shelf in an area 55-kilometer wide. Numerous MTDs of various sizes were also identified at the shelf break. The location of both canyons and MTDs is frequently correlated. On the continental slope, channel-levee systems developed from the mouth of the canyons to the deep part of the basin. The Rosetta system appears as a rapid point-source migrating system driven by large-scale slope failures and sea-level variations. During falling stages of sea level, sediment transfer is constrained and channelized by headwall scars at the shelf break, resulting in the construction of small channels indenting the top of mass-transport deposits and depositing ponded lobes in topographic lows. As the sea level drops, a short submarine canyon progressively build and the turbidite system progrades toward the basin floor. Sea-level lowstands favour the development of wide shelf-margin deltas feeding and prograding over the canyon head that rapidly evolve in an unconfined meandering channel-levees system. These channel-levees systems are affected by avulsion processes at slope gradient changes (mainly controlled by salt-tectonic), by crevasse splays, and they deposit wide distal-lobe complexes at their mouth, at the base of the continental slope or in the basin.

This architectural evolution of the western Nile deep-sea fan might be used as a predictive analog for gas reservoirs for the Miocene-Pliocene formations of the Nile margin and, more generally, for any other unconfined delta-fed turbidite systems.

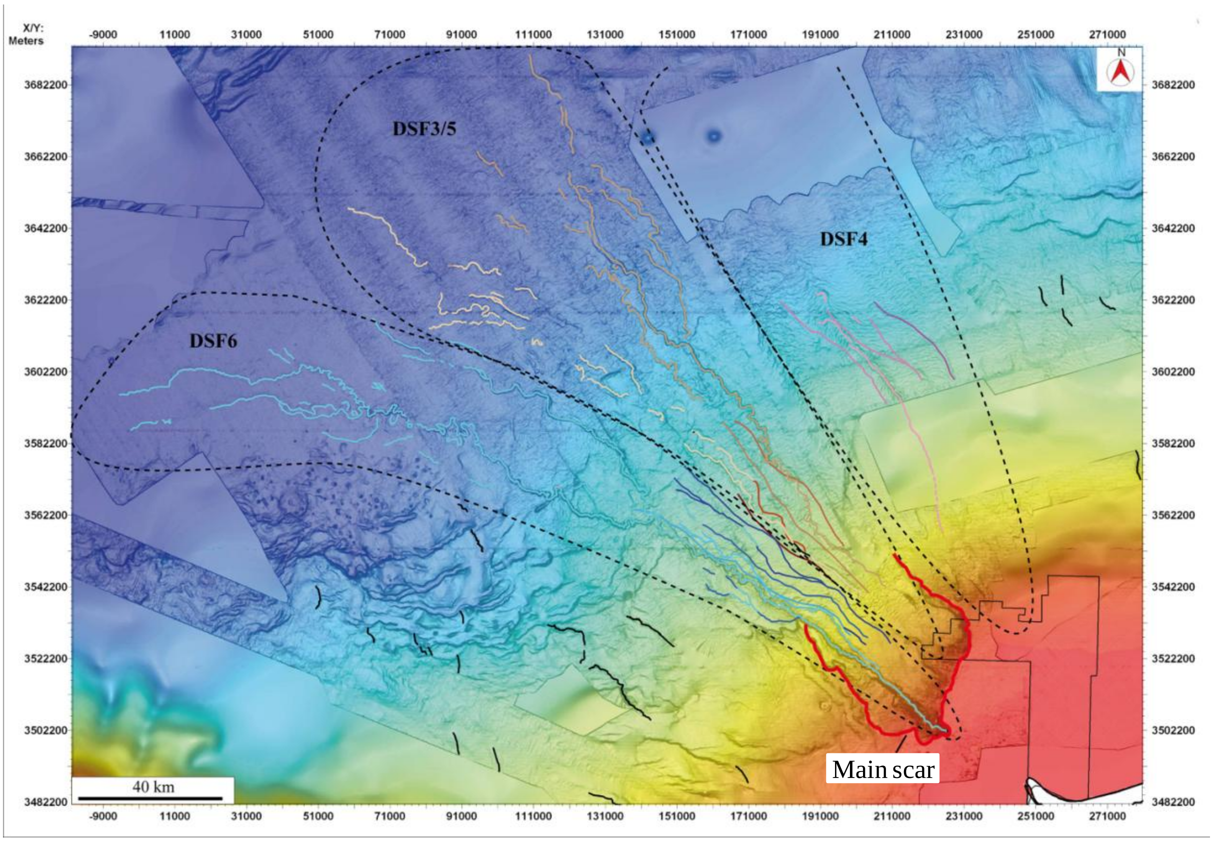

Figure 1: shaded bathymetric map of the western province of the Nile deep-sea fan revealing the distribution of the main channel-levee systems during the Plio-Quaternary. Some channels are still visible on the present-day seafloor. The dark dashed lines underline the extension of channels-levees-lobes complex.

Deepwater Play Types, Matruh and Herodotus Basins, NW Egypt

Gabor Tari[1], Peter Krois[1], Hussein Hussein[2], Bernhard Novotny[2], Robert Kohazy[1], Kathy Hannke[3]

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The onshore Western Desert Basin system of Egypt is regarded as a classical petroleum province. Some 600 exploratory tests in this large region have discovered about 1.5 BBO of oil and 10 TCF of gas. However, the offshore continuation of this prolific basin in the Eastern Mediterranean has been somewhat neglected by the industry until recently. The reason for this is the dominantly deepwater character of the margin as opposed to the Nile Delta region to the east.

Structurally, the north-facing passive margin of NW Egypt is the result of the opening of the Neo-Tethys basin during mid-Jurassic to early Cretaceous times. Specifically, the evolution of Jurassic rift basins onshore continued into the Neocomian/Barremian, but by Aptian time syn-rift extension ceased in the Western Desert basin system. The post-rift period saw a short-lived compressional reactivation of normal faults during the early Senonian. Specifically, shortening and uplift associated with the regional Syrian Arc deformation started in the Santonian and continued into the Paleocene/Eocene.

On a sub-regional scale, the Matruh Trough is prominent structural feature, trending almost perpendicular to the coastline in the Obaiyed Offshore area. This aborted Jurassic syn-rift basin has a NNE-SSW trend evident on seismic and potential field data onshore and offshore. The Matruh Trough is responsible for the formation of a major Cretaceous shale detachment system which is nested in the overlying Matruh Canyon. Numerous deepwater play types have been identified in the southeastern part of the Obaiyed Offshore block area and most of these plays are related to the shale décollement within the Matruh Canyon. The footwalls of the growth faults provide fault-controlled 3-way closures very similar to the well-known rafts in the Lower Congo Basin in West Africa. Within the rafts, the targets are located at several stratigraphic levels. As updip extension transitions to downdip shortening, some imbrications can be found in the ultra-deepwater part of the Matruh Basin. Some complex toe-thrust features abruptly terminate against the Messinian unconformity and salt, defining a sub-unconformity trap.

Another important play type in the deepwater offshore Matruh Basin is related to a prominent syn-rift hinge zone. A large prospect representing this play type has been mapped on recently acquired 3D seismic data and, if the play concept is confirmed by a discovery, it could serve as a play opener in this segment of the Eastern Mediterranean.

An additional, very significant set of play types in the broader Herodotus Basin of NW Egypt is related to the Messinian salt. These play types have very important succesful analogs in the East Mediterranean including those drilled in the offshore Levant (e.g. Tamar and Dalit). The Messinian play types have not been fully evaluated due to the insufficient seismic coverage in the ultra-deepwater areas. The subsalt prospectivity, however, is seen as an important upside in the broader area.

The offshore Matruh and Herodotus Basins of NW Egypt represent an unexplored region of the Eastern Mediterranean, with no deepwater wells drilled along the margin, as of October 2010.

Pre-Messinain Exploration Opportunities, Offshore Nile Delta, Egypt

Nazim Abdullayev, Jeff Reinprecht, Jennifer Villinski, *BP Egypt Exploration*

The offshore Nile Delta consists of a number of successfully proven play fairways. To date, fields have been found in systems ranging from incised valleys, shelf edge deltas and, more recently, slope channel systems.

The slope channel fairway has been dominated by discoveries in the Plio-Pleistocene However, recent exploration success in older pre-Messinian slope systems have generated additional bid round activity across the offshore Nile Delta. Wells targeting middle and lower Miocene intervals have successfully proven the existence of this slope channel fairway at the Raven and Taurus locations. Also, recent exploration drilling in the East Nile Delta has added Oligocene potential at the Satis prospect.

An understanding of basin controls on source presence and distribution, sediment deposition, and structural timing are essential to determine areas of focus for future exploration in the offshore Nile Delta. Geochemical analysis suggests that the hydrocarbons found in the pre-Messinian are predominantly land derived plant material indicating gas versus oil potential. The scale of the slope channel fairway as imaged on seismic suggests a substantial Tertiary Delta delivery system supplying up to 8 kilometers of mid-Miocene through Oligocene clastics into the basin. Tectonic events in the late Cretaceous through Messinian (and beyond) are instrumental in developing the basin architecture and trapping elements. Regional analysis and integration of these elements should provide areas of exploration potential and focus.

‘Water-Way’ to Gas Identification in Raven

James Saxton, *BP Egypt Business Unit, West Nile Delta Team*

There are several examples of turbiditic gas fields across the WND with asymmetric gas columns: where a higher GWC in the south is driven by a hydrodynamic aquifer. The cause of this is generally considered to be the rapid burial and dewatering of the overburden into the reservoir of interest. In the Pliocene, this asymmetry is clearly defined by classic seismic direct hydrocarbon indicators (DHI’s), including flatspots, bright spots and well developed class 3 AVO signatures. In documented examples of Pliocene Fields in the WND, seismic flatspots have been penetrated and the MDT data acquired clearly demonstrates a deeper saturated gas column in the north compared to the south.

In contrast, at a depth of 4km and with a seismic resolution of 30m, the same robust seismic DHI’s are not observed in the Miocene aged Raven field. MDT data from the 3 well appraisal campaign on Raven revealed a GDT in the north of the field that is 28m deeper than the logged GWC in the south, also indicating an asymmetric gas column. The magnitude of the asymmetry is yet unknown as the northern GWC remains unpenetrated. However, observations from the high quality near-offset multi-azimuth (MAZ) seismic dataset does reveal a prominent seismic dimming of amplitudes onto the crest of structure. This observation is consistent with the response of a gas charged reservoir, as predicted from fluid substitution modelling of the appraisal wells. This near-offset effect is enhanced by the relative contrast of the strong class 1 water response, which dims dramatically in offset in both the north and south of the field, to the response of the gas leg, which brightens in offset (class 2P). When mapped spatially, this far-offset response of the gas reservoir reveals striking channelized geometries (where rock properties permit!). Taken together, these seismic observations suggest a most likely northern gas column of 400m.

These amplitude and AVO attributes have not only been used to optimise development well locations at Raven, but have obvious predictive implications for new exploration and appraisal opportunities in gas reservoirs across the Nile Delta. However, ‘one size should not be assumed to fit all’ as there are other proved examples in the WND where the gas response on seismic is very different. The assertion of a ‘DHI floor’ is clearly challenged and where the rock properties and geology permit, we are in ‘should-see’ territory. The obvious challenge moving forward is to ensure calibration of the observed seismic response in order to use it predicatively.

Multiple Pulses of Syrian Arc Uplift in the Early Palaeogene – New High Resolution Data from the Galala Mountains, Egypt

Stefan Höntzsch, Christian Scheibner, Jochen Kuss, *Dept. of Geosciences, University Bremen, PO Box 330440, Bremen, Germany*

The Galala Mountains (Eastern Desert, Egypt) represent an Early Maastrichtian to Eocene isolated carbonate platform at the southern margin of the Levant Basin. Formation and evolution of the Galala platform are strongly connected to the activity along the Wadi Araba Fault (WAF), which demonstrates a SW branch of the Syrian Arc-Fold Belt. In the Early Eocene, a major phase of tectonic uplift has been documented along the Syrian Arc, yielding to the reactivation of Cretaceous fault systems. However, high resolution outcrop data which will help to characterize the timing and the sedimentary expression of this uplift are still rare.

In this study, we present new data from the Galala Mountains, based on eight sections along an N-S platform-to-basin transect. Rocks of the shallow-marine platform interior in the North are dominated by fossiliferous limestones and fossil-barren dolostones. Deeper-marine slope deposits in the South are dominated by hemipelagic marls with intercalated limestones and sandstones, which frequently contain inner platform biota (e.g. larger benthic foraminifera, green algae). Characteristic fabrics of limestones and sandstones at the slope are interpreted as mass flow deposits (turbidites, debris flows). In the uppermost Paleocene, Scheibner et al. (2003) describe the first occurrence of quartz-barren mass flow deposits, which refer to sea-level fluctuations and platform progradation prior to the tectonic reactivation of the Syria Arc. During the Lower Eocene, quartz-rich sandstones and limestones accumulate in distinct intervals throughout the studied slope sections. We document four phases of increased quartz-rich mass flow deposition (Fig. 1; NP10 – NP14a). Besides the overall high amount of quartz in the studied deposits, thin section analyses indicate a deepening upward at the slope throughout the Early Eocene, whereas quartz-barren inner platform deposits indicate a shallowing during the same time interval. This oppositional evolution is related to the massive uplift of shallow-marine inner platform environments between NP10 and NP14a (Fig. 1). The dominance of siliciclastic material at the southern slope and the coeval pure carbonate deposition at the shallow-marine inner platform suggest the onset of a tectonically-controlled palaeogeographic barrier between both environments, which cause the erosion and southward transport of Mesozoic and Palaeozoic siliciclastics.

Platform evolution of the Galala Mountains has been described since the Late Cretaceous (Kuss et al., 2000). Regional platform stages point to variations in the tectonic regime and eustatic sea level. Scheibner et al. (2003) discriminates five regional platform stages (stage A - E) from the Maastrichtian emergence of the platform system (stage A) to latest Paleocene prior to the PETM (stage E). Scheibner and Speijer (2008) introduced a sixth platform stage F that was redefine during the ongoing studies; furthermore, we introduce two additional platform stages, which describe the evolution of the Galala platform until the uppermost Lower Eocene.

In the earliest Eocene (stage F, NP9b – NP11), the first occurrence of isolated sandstone beds at the slope reflects a reactivation of a Cretaceous fault system, yielding to the tectonic uplift of Mesozoic and Palaeozoic siliciclastics. As a consequence, the Paleocene platform with pure carbonate deposition shifted to a mixed carbonate-siliciclastic system during stage F. The subsequent platform stage G (NP11 – NP14a) is characterized by a deepening trend at the slope, resulting in the retrogradation of the platform. The increasing deposition of quartz-rich sandstones at the slope reflects the enhanced erosion of Mesozoic and Palaeozoic deposits. In contrast to the deepening trend at the slope, the deposition of cyclic tidalites reflects a coeval shallowing and the temporarily subaerial exposure of the platform. This oppositional trend is related to the continuing uplift along the Syrian Arc-Fold-Belt in stage G. Platform stage H (NP14a - ?) demonstrates the termination of Syrian Arc uplift and the recovery from a mixed siliciclastic-carbonate deposition to pure carbonate deposition.

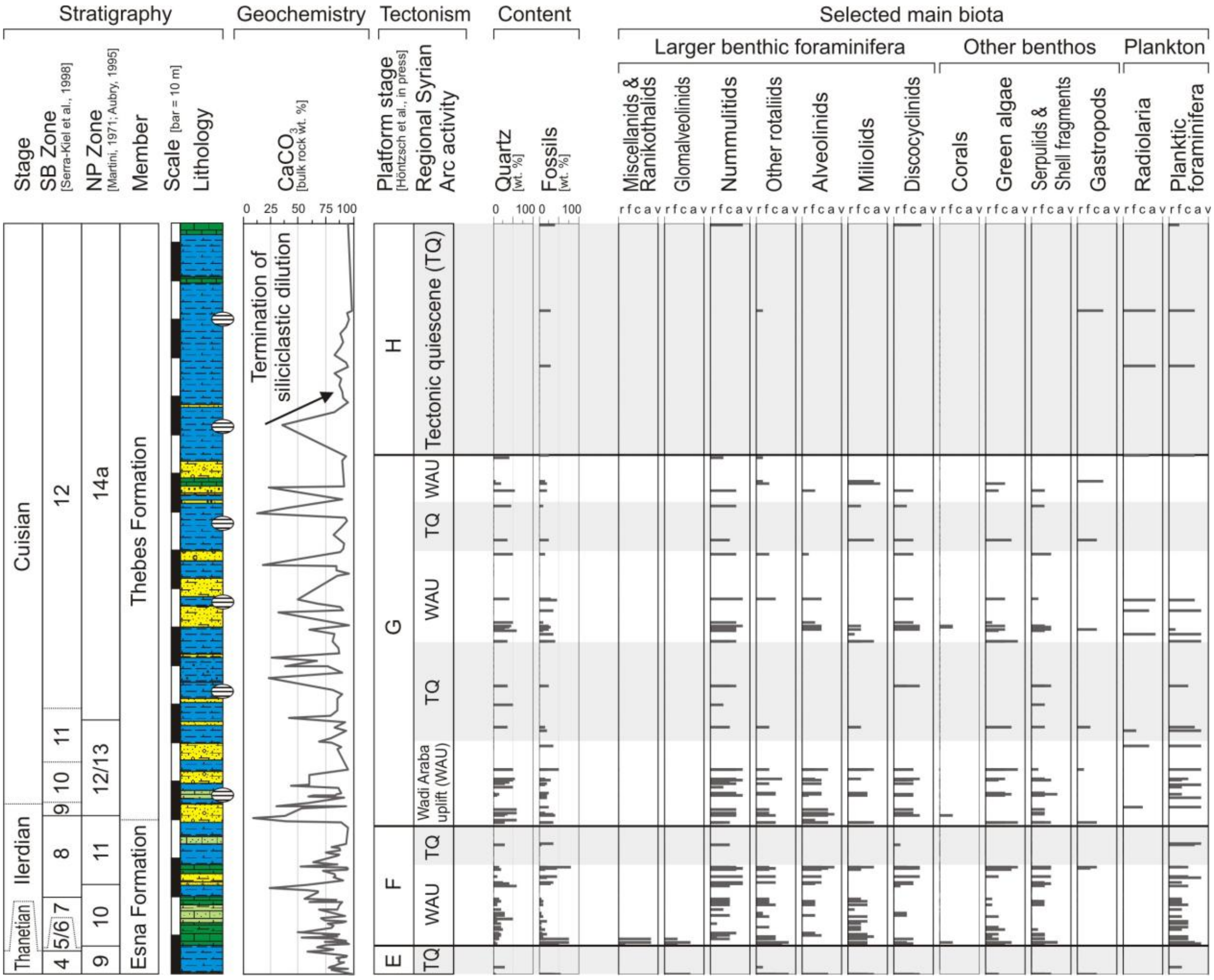

Fig. 1 - Integrated tectonical and microfacial comparison of slope section 4a from the latest Paleocene to uppermost Early Eocene. Platform stages are adapted from Höntzsch et al. (in press) and Scheibner and Speijer (2008). Grey shaded intervals indicate times of tectonic quiescence (TQ); white intervals represent tectonic uplift along the WAF. The chart on the right hand site is based on thin section analyses of limestone and sandstone turbidites and includes %-values of the quartz and fossil content, as well as the semi-quantitative abundance of selected main biota (r...rare, f...few, c...common, a...abundant, v...very abundant).

Thursday 24 February

Session Three: Libya, Tunisia and Malta

Keynote Speaker: Cretaceous or Permo-Triassic Opening of S Tethys in the Ionian Sea? Support from Crustal Structure and Subsidence Analysis of the Offshore Sirt Basin, Libya.

Bevan, T.G[1]. , Roberts[2], A.M. & Kusznir, N.J.[3], Mohn, G.T.[4]

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[2]*Badley Geoscience, Hundleby, UK.*
[3]*University of Liverpool, UK.*
[4]*Université de Strasbourg, France.*

A lack of definitive magnetic anomalies in the Eastern Mediterranean has led to wide debate on the timing of rifting and spreading in the Southern Tethys Ocean; sea floor spreading is generally thought to be of either Permo-Triassic or Cretaceous age. Each model has distinct implications on the development of the passive margin along the N African coast and on the hydrocarbon potential and plays in the offshore areas.

Regional seismic interpretations, observations on new offshore 3D data, and well penetrations, have led to the development of new 3D-gravity inversion crustal models and subsidence analysis in the offshore Sirt Basin. The offshore Sirt data reveals crustal-scale tilted fault blocks buried below a substantial (up to 6 km) post-rift passive marine-onlap section. Reverse thermal subsidence backstripping of the offshore Sirt has found that high beta factors (>3) are required to restore Cretaceous shallow-water markers (carbonates, erosion surfaces) to sea-level. Stretching of this magnitude is more indicative of continental separation. This modelling suggests that the oceanic crustal fragment of Southern Tethys in the Ionian Sea is therefore Cretaceous in age, rather than Permo-Triassic. Initial rifting in the Early Cretaceous, at the same time as the development of the onshore Sirt rift, was followed by rapid subsidence at the onset of sea floor spreading in the Mid Cretaceous. This is consistent with the presence of Mid-Cretaceous pillow-basalts and shallow-water carbonates, overlain by Late Cretaceous pelagic carbonates, found outcropping on the Cyrene Sea-mount, offshore Cyrenaica.

The crustal structure and subsidence models in the onshore Sirt Basin, in contrast to the offshore, suggest that this part of the basin formed through lower beta factors (1.5), which are more typical of intra-continental rifting. We propose therefore, that the onshore Sirt rift is a V-shaped basin that propagated southwards from the offshore spreading centre, rather than being a northward-propagation of intra-continental rifting from the Central African rifts.

A new tectonic model and plate reconstruction synthesis have been devised to illustrate the development of the Sirt Basin and S Tethys in the Eastern Mediterranean.

Exploration Potential of the Offshore Sirt Basin, Libya

A. V. Belopolsky [1], J. Alexander[1], H. Ali[2], C. Atteck[1], T. Bevan[1], M. Bourne[1], T. Dunn[2], T. Green[1], **J. Iliffe[1]**, T. Lapinski[2], H. Leach[1], C. Leighton[1], J. Omma[1], J. Pace[1], A. Poole[1], M. Shann[2], T. G. Sabato[1], C. Simmons[1], R. Woodfine[1], A. Fraser[3]

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[2]*BP Exploration, Tripoli, Libya*
[3]*Imperial College, London, U.K.*

The onshore Sirt basin in Libya is one of most prolific in the world with discovered reserves of 43 billion BOE (USGS). The offshore extension of the basin remains largely unexplored. Recent licensing, seismic acquisition and exploration drilling are bringing to light the new data that open up potential exploration plays in the offshore.

The majority of the fields onshore Sirt are charged from the Upper Cretaceous marine source rocks deposited during flooding events (the exception is the Sarir area where deeper lacustrine source rocks are locally present). The traps are formed by a series of high basement blocks created by the Aptian rifting. The reservoirs are largely locally-sourced Cretaceous basal sandstones and shallow water carbonates from Upper Cretaceous to Eocene age.

Initially, exploration concepts applied to the offshore followed the same onshore Sirt play concepts. Previous exploration efforts were mainly confined to the costal shallow water areas without much success. The recent significant gas and condensate discovery by Amerada Hess well 54/01 (Arous Al-Bahar) in the south-western corner of the basin confirmed the presence of a source rock and a working petroleum system offshore. The reported Eocene carbonate reservoir (IHS) is likely to be in shallow water facies similar to those found onshore. The A1-NC202 discovery well drilled by Repsol in shallow water on the eastern flank of the basin was also reported to have a oil discovery in Eocene carbonates (IHS).

Recent seismic data across the deep water part of the basin has been able to significantly improve the imaging underneath the Messinian evaporites and show that while some of the onshore play concepts still apply, the geological history and sedimentary fill of the offshore basin may be different. Several large gravity highs are clearly present in the deep water. They correspond to several large highs or “ridges” of uncertain age seen on seismic data. The highs are separated by troughs, some of which contain syn-rift growth strata implying deposition contemporaneous with extension. The Upper Cretaceous and lower Tertiary section appears to be thin and condensed in comparison with the thick carbonate sequences present onshore Sirt. Imminent exploration wells will provide necessary calibration for the seismically-defined concepts.

Implications of NW Libya – Tunisia Outcrop Geology to the Offshore Tectono-Stratigraphy and Petroleum Potential of Libya

Mark Shann[1], Todd Lapinski[1] Ali M Sbeta[2]

[1]BP Exploration Libya, Noufleen, Tripoli,

[2]Al-Fateh University, Tripoli, Libya

The outcrop geology of NW Libya and Tunisia reveals much about the basin evolution that underpins the offshore petroleum potential of the explored Tripolitania Basin and the frontier relatively-undrilled Sirte Basin continuation into deep water. Very well studied outcrops along the Libya Jebel Nafusah escarpment document the Mesozoic shelfal hinterland and provenance for reservoir systems; while excellent surface exposures across Tunisia reveal their Mesozoic basinal equivalents that have been uplifted by the Atlas Mountain orogeny from the Oligocene onwards.

Much of this work comes from ESSL (Earth Science Society of Libya), sponsored field trips to Jebel Nafusah and Tunisia. They provide a good example of how academic institutions, state oil companies (NOC, ETAP) and IOC's can collaborate to improve the understanding of the key elements which impact the search for oil & gas in Libya.

This work will show how these outcrops fit into a tectono-sequence (or megasequence) framework and how key parts of the observed outcrop stratigraphy: source, reservoir and seal relate to the ongoing exploration effort offshore Libya. Three key tectonic events, as revealed from outcrop, are linked to offshore well and seismic observations and some key questions posed in terms of impact on petroleum potential and future issues for research.

(1) Significance of two Cretaceous unconformities (? Aptian) to the enhancement of Cretaceous carbonate reservoir quality in offshore areas.

(2) Demise of the Eocene nummulite play fairway, its extent and link to tectonics

(3) Impact of the Miocene eastwards thrust displacement from the Tunisian Atlas to the Calabrian Arc.

The Malta Platform: Controls on Sedimentation and Petroleum Plays

Peter A. Gatt, *Malta Council for Science and Technology, Villa Bighi, Kalkara, Malta*

The development of carbonate reservoirs at the regional scale is controlled by tectonics and changing environmental conditions.

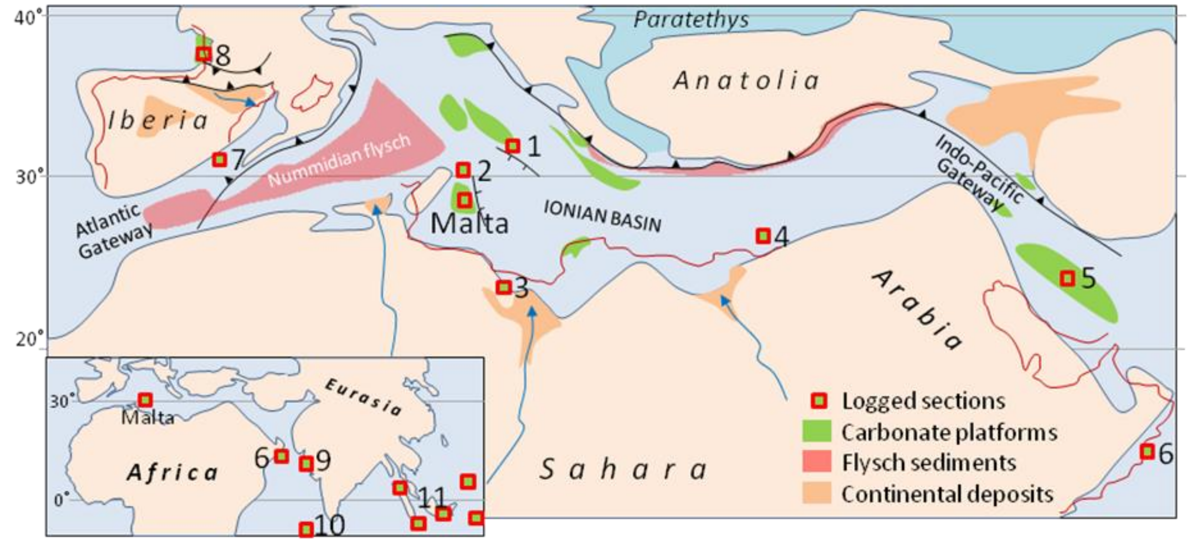
Many carbonate reservoirs of the Eastern Mediterranean are the remnants of partly subducted or dissected carbonate platforms that developed throughout the Tethys during the Mesozoic. By the mid-Cenozoic, the western Tethys had developed two distinct basins: 1.The western basin that was overwhelmed by siliciclastics from African fluvial systems which deposited sandstones, clays and the Numidian flysch and, 2.The eastern basin, where carbonate platforms continued to aggrade along subsiding continental shelves rimming the Ionian crust.

An erosional hiatus (Mazara-Gulf of Hammamet High) that extended from northern Tunisia to western Sicily had separated the two basins. The Malta Platform developed on the African crust since the Mesozoic with its eastern and western margins constrained by the Ionian crust and the Mazara-Gulf of Hammamet High, respectively. Carbonate sedimentation was controlled by two mechanisms:

1. Tectonics: (a) Triassic continental breakup produced several E-W trending grabens filled with shales (e.g. Streppenosa Fm) that charged the surrounding carbonates; (b) passive margin extension created N-S trending troughs that partly dissect the Malta Platform, e.g. Melita Graben (Cretaceous) and Valletta Graben (mid-Cenozoic), later filled with pelagic carbonate; (c) Cenozoic continental convergence created an emergent forebulge between Tunisia and western Sicily. The collapse of this landbridge around the mid-Neogene resulted in the incursion of clay over the Malta and Hyblean platforms, terminating carbonate platform ecosystems;

2. Climate: Greenhouse conditions from the Cretaceous to Eocene and low nutrient supply during highstands of sea-level stimulated carbonate platform aggradation. The thin beds of evaporites within a thick dolomite succession suggest occasional emergence during arid conditions. Falling sea-level during the Eocene is associated with depsotion of Nummulites that formed prograding clinoforms. Global cooling that began by the early Oligocene resulted in the expansion of the Antarctic ice-sheet and the oscillation of the Inter-tropical convergence zone (ITCZ) to the north of the equator. When the ITCZ was over north Africa, greater nutrient supply to the semi-enclosed western Tethys caused a shift to heterozoan carbonate ecosystems throughout the western Tethys (Fig. 1), whereas semi-arid continental conditions resulted in oligotrophic periods when photozoan carbonate biota (coral and large benthic foraminifera) could flourish.

The development of the Malta Platform as an isolated carbonate platform surrounded by basinal domains accumulating source rock shales, e.g. Fahdene and Bahloul Formations, points to a number of Cretaceous and Eocene petroleum plays along the depositional and faulted margins of the Malta Platform.



40°
30°
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Paratethys
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IONIAN BASIN
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Carbonate platforms
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Figure 1

Tectono-Stratigraphic Evolution of the Central Pelagian Basin (Mediterranean Sea): The Melita-Medina Graben (Malta Offshore Area 4)

L. Lipparini[1], D. Scrocca[2], P. Carugno[1], C. Cavallini[1]

[1]*Malta Oil Ltd (MOL-MOG)*
[2]*Istituto di Geologia Ambientale e Geoingegneria (IGAF-CNR), Roma*

Malta Oil Ltd (MOL holds an open exploration license over Malta Area 4, 130 km south of Malta Island, abutting to the south the established and undisputed international boundary with the Libyan waters (fig. 1.)

The area, where no wells have been drilled to date, shows, from an exploration point of view, important analogies with the surrounding, well known, off-shore Tunisia and northern Libyan petroleum provinces: in fact, sources, reservoirs and seals, similar in age and characteristics to those known in Tunisia and Libya, appear to have been likely developed also in the study area (see Lipparini *et alli*, first break, vol.27, February 2009).

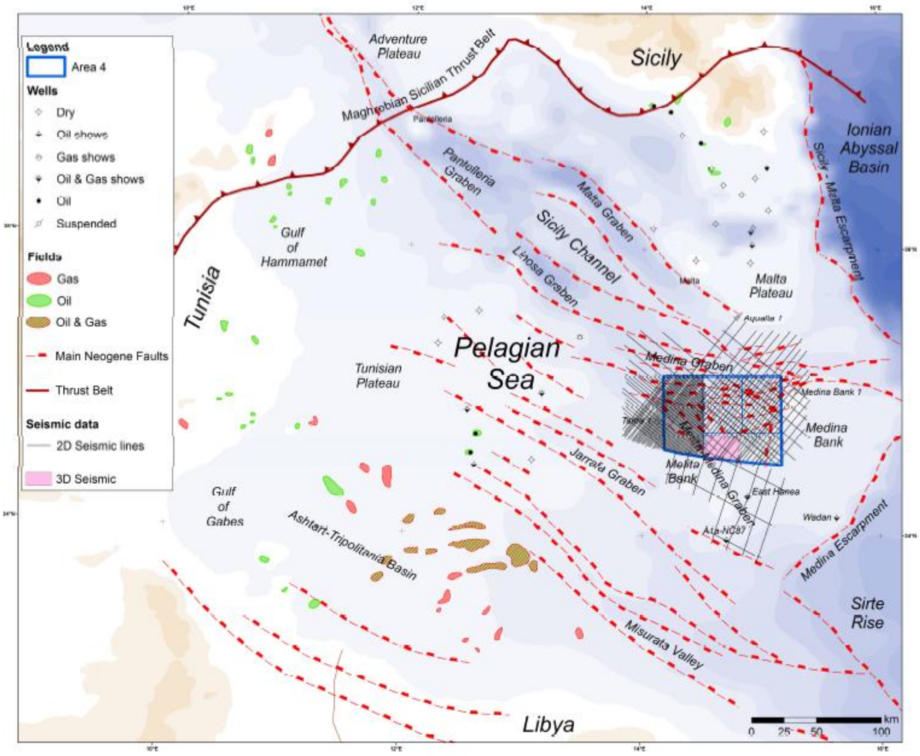

Fig 1 – Pelagian domain base map (including Maltese Area 4, in blue) – Main Neogene structural features, HC occurrences & Seismic-Well Dataset are shown.

Regionally, a "persistent" meso-cenozoic shallow water carbonate platform, surrounded by more basinal domains, is well known in the Malta area. This depositional domain extended south-ward also into our area of interest, where shallow marine carbonates characterise the Cretaceous interval in part of the area, as documented by exisiting wells.

However, available wells and seismic evidences show that the continuity of the Cretaceous carbonate platform was locally interrupted by the development of fault-controlled grabens (well developed also in the basinal domain), such as the Melita-Medina Graben, which represent a main feature of interest in the studied area, also from an Exploration point of view (fig. 2).

More recent technical efforts have been in-fact focused to better frame, both regionally and in details, the existing geological models and to better define the tectono-evolution of the area, with a particular attention at the grabens development and its implications.

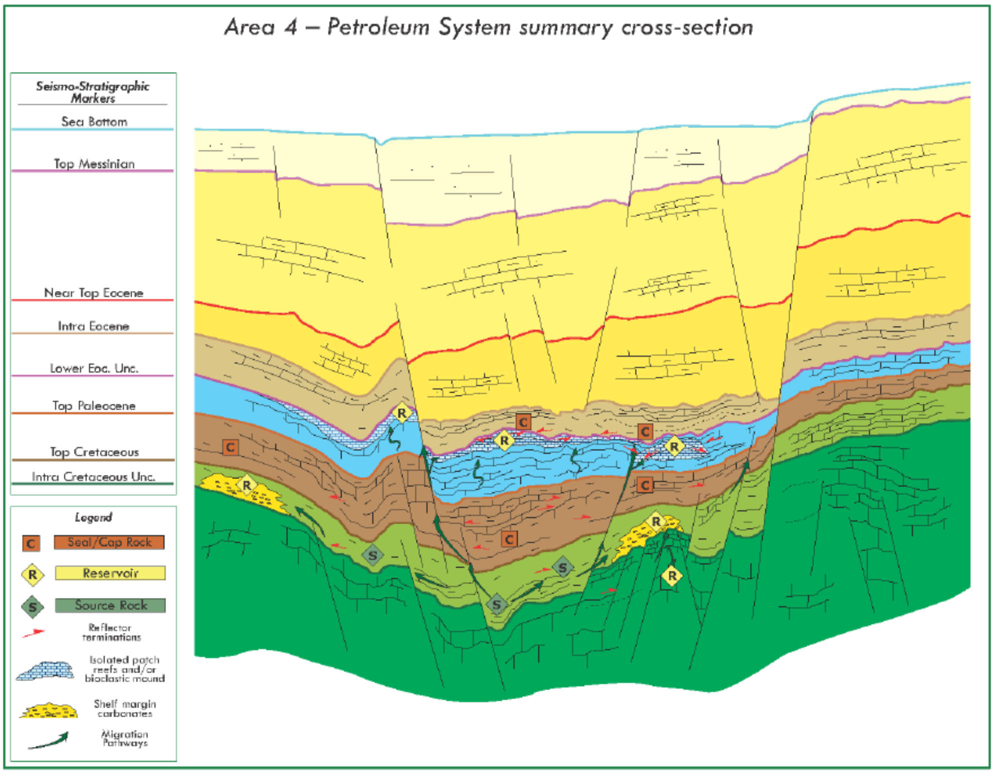

Fig 2 – Area 4 – Petroleum system summary cross-section (after Lipparini *et alli*, first break, vol.27, February 2009.

Seismic data clearly show that the growth of some of these grabens, although partly reactivated by following tectonic events, may be related to Cretaceous rifting episodes, well documented in the entire Pelagian domain (Argnani and Torelli, 2001; Guiraud, 1998); based on the available data a conceptual model was developed which take into account the control exerted by the Cretaceous faulting on source rocks and reservoirs deposition and on traps development.

From an exploration standpoint, the ongoing technical effort is dedicated to understand and mature the deeper Cretaceous Play in the Area, through the following main steps: 1) 630 km of 2D regional seismic lines over the "Libyan side" of the area have been purchased and interpreted; 2) a depth re-processing (PreSDM) of the existing 3D dataset (on Block 7-Area 4), has been carried out; 3) available information on 6 relevant wells in the area, also from the "Libyan side", have been collected, analyses and critically reviewed; 4) the reference wells have been tied to the seismic.

Following the above steps, the existing interpretation has been verified, refined and extended to the south, and key information, such as source distribution, have been extracted from the reference wells to the whole area.

The objective of this note is to share some of the results obtained, with a particular attention to the geological evolution of the Cretaceous Grabens and associated features, in particular to the Melita-Medina graben. The understanding of the graben evolution is in-fact a key factor to increase the possibility to predict the facies distribution and hence to make a more robust exploration assessment of the area

Keynote Speaker: Palaeogeographic Evolution of Tunisia and Associated Petroleum Systems as a Witnesses to the History of the "Vanished Tethys Ocean".

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The major geodynamic events and the global sea level fluctuations that accompanied the opening and the closure of the Tethys Ocean are well expressed within the sedimentary record of Tunisia (Mesozoic rifting and Pyrenean-Alpine orogenies).

To illustrate these events, several palaeogeographic maps showing lithofacies and depositional environments distribution have been established on the basis of diverse datasets including surface and subsurface information. This regional study clearly indicates that the development of the relatively thick organic-rich facies of the Tunisian stratigraphic column are generally associated with the major transgressive events that have been recorded within the Tehyan ocean; while the development of the shallow carbonate and siliciclastic reservoir facies are associated either with the regressive pulses and/or to the tectonic uplifts. When associated together these facies (Source, Reservoir and Seal) constitute interesting petroleum systems. Some of them are known and well documented.

The aim of the presentation is to give an overview on: (1) the sedimentary and palaeogeographic evolution and changes that affected Tunisia (Atlasic and Cratonic domains), through time (Palaeozoic, Mesozoic and Cenozoic), using selected key paleogeographic maps and regional lithostratigraphic cross-sections calibrated by petroleum wells, (2) the characteristics of the Petroleum Systems of Tunisia on the basis of significant geochemical updated datasets.

The Palaeozoic Petroleum System

This system is well known in subsurface and is sourced from the Silurian and/or the Devonian organic-rich facies. In Ghadames basin, the Early Silurian Tannezuft formation (Hot shales) as well as the Middle-Late Devonian Aouinet Ouenine formation, constitute the main source rocks with high TOC contents (up to 17%) and good to excellent petroleum potential (up to 40 kg HC/t of rock). Oil to source rock correlation studies show these 2 formations are the main sources of the oil produced in El Borma, Ech Chouech, Oued Zar fields; however, towards the North in the Chotts area, the source rock is represented by the Late Silurian-Early Devonian Fegaguira formation, characterised also by high TOC values and good petroleum potential and proved to be the source of the oils produced in this basin (Sabria, Franig fields).

Reservoirs consist in sandstones and fractured quartzites of Ordovician, Silurian Acacus formation, Devonian Ouan Kasa and Tadrart formations and Triassic Kirchaou formation. Intra-formational shales within the Palaeozoic constitute seals. Most prospective areas are located within both sides of Telemzanz-Bounemcha arch (Southern Tunisia), the Ghadames basin to the South and the Chotts basin to the North.

The Cretaceous Petroleum System

The Albian-Vraconian lower Fahdene and the Late Cenomanian-Early Turonian Bahloul formations constitute the main source rocks of this system. They exhibit fair to high TOC contents (up to 4% and 14% respectively) and good to excellent petroleum potential (up to 74 and 100 kg of HC/t of rock respectively). Based mainly on biomarker parameters and carbon isotope compositions these 2 formations are shown to be the sources of several oils produced in Tunisia mainly in Sfax area (Bahloul formation) and in Douleb- Semmama area and the Gulf of Hammamet (Lower Fahdene formation). The main reservoir are represented by intra-Cretaceous sandstones (M'Cherga, Meloussi, Sidi Aich formations) and essentially shallow marine carbonates (Serj, Bireno, Douleb, Abiod formations), the Miocene carbonate and the Middle Miocene coastal marine sandstones (Birsa formation). Intermediate seals are provided by several shaly formations such as El Haria, Souar, Aleg. Most prospective area is located within the Central platform and its extension offshore in the Pelagian basin.

The Tertiary Petroleum System

This system relies on the Eocene Bou Dabbous source rock which exhibits high TOC values (up to 4%) and good to excellent petroleum potential (up to 10 kg of HC/t of rock). Geochemical correlation studies demonstrate this formation constitute the main source of the oils produced in the Gulf of Gabes (Ashtart, Salambo, Cercina…). Reservoir levels are included within the Eocene inner to middle ramp nummilitic limestones of El Garia and Reneiche formations. The deep marine Bou Dabbous carbonates which encompass a much larger area of Northern Tunisia, when fractured, constitute also proven reservoir. Seals are provided by the shaly Souar formation. The most attractive play is along the NW-SE nummulitic belt located in the eastern part of the Central Platform and extending into the Pelagian Basin offshore Tunisia and Lybia.

Many other petroleum systems, either proven (Jurassic, Numidian flysh...) but yet of limited extension or potential (Ordovician, Permian...) and which are still understudied will be also presented.

Thursday 24 February

Session Four: “Northern” Margin (Italy, Turkey and Cyprus

Keynote Speaker: Geological Framework and Hydrocarbon Prospectivity Offshore Cyprus

Solon Kassinis, *Director, Energy Service, Ministry of Commerce, Industry and Tourism, Andrea Araouzou 13-15, 1421 Nicosia, Republic of Cyprus*

Offshore Cyprus is a deep-water frontier area. It is bounded to the north by the Alpine fold and thrust belt with the Cyprus Arc at its southern boundary, to the east by the Levantine Basin and its Levant margin, to the south by the Egyptian and Lybian margins and to the west by the Herodotus Basin and the fold and thrust belt of the Mediterranean Ridge. The seabed depth horizon ranges from 300 m below sea level on the Cyprus Arc, closed to the island of Cyprus to more than 3,000 m in the deeper part of the Herodotus basin.

The delimitation of the Exclusive Economic Zone (EEZ) of Cyprus has been already agreed and signed with the Arab Republic of Egypt and Lebanon. Negotiations for the delimitation of the EEZ of Cyprus with Israel and Syria are under way. Part of the EEZ, that is located south of the island of Cyprus and covers an area of 51,000 km2, has been divided into 13 Explorations Blocks. The Government of the Republic of Cyprus held its 1st Licensing Round in 2007 and one Hydrocarbon Exploration License has been granted to Noble Energy International Ltd for Block 12.

The main structural units inside that area are:
(a) Levantine and Herodotus Basins, formed by rifting and spreading from the Triassic to Lower Cretaceous. Their total thickness attains 12 to 15 km. They are filled in by deep-water sediments.
(b) Eratosthenes Continental Block (ECB), a block detached from Arabia. Its sedimentary cover is essentially made of shallow-water to slope carbonate deposits with the thickness of about 5 km.
(c) West Eratosthenes sub-basin and High. This Miocene basin is open to the west on a major High (or anticlinorium) with a SSW-NNE orientation.
(d) Cyprus Arc, formed in the Late Cretaceous and reactivated in the Neogene.

Two major regional events, related to sediment deposits, have important consequences for the prospectivity of the area: (a) the Nile Delta and its Deep Sea Fan development from the Oligocene to Present time, especially important west of the ECB in the Herodotus Basin, and (b) the Messinian Salinity Crisis with deposition of thick evaporites in the basins. They constitute a regional seal in the Offshore Cyprus and their deformation resulted in the formation of numerous structures of interest to exploration.

The assessment of the hydrocarbon prospectivity Offshore Cyprus relies on the existence of active hydrocarbon systems like gas discoveries in the vicinity of Egypt and Israel in the very thick Levantine and Herodotus Basins. Also is based on the interpretation of the 19,036 line-km of 2D seismic data that cover part of the Exclusive Economic Zone of Cyprus, the 3D seismic survey of 659 km2 (north of the Levantine Basin) and the regional geological background.

The 2D seismic profiles, made possible the definition of fourteen plays and many leads on the basis of closed surfaces only. Some of them correspond to major structural features and display a closed surface of several hundred km2. Thus, based on these data, Offshore Cyprus shows great potential for hydrocarbon exploration.

The Interpretation Report which assesses the hydrocarbon prospectivity Offshore Cyprus, especially the inventory of plays and leads, is available for purchasing from the Energy Service of the Ministry of Commerce, Industry and Tourism of the Republic of Cyprus, while the available seismic data package by Petroleum Geo-Services (PGS).

New Insights Into the Stratigraphic-Structural Setting of the Outermost Calabrian Accretionary Wedge (NW Ionian Sea) Based on Recently-Migrated Reflection Data.

Vera Valenti, *Dipartimento di Geologia e Geodesia, Università di Palermo*

External Calabrian Arc (hereinafter ECA) is a SE-verging accretionary wedge developed above the convergent plate boundary between Africa and European plates, related to the subduction of the Ionian plate beneath the Calabrian plate: sediments have been scraped off the subducting Ionian plate and piled up along thrust faults opposite of the European region.

Although regional geophysical studies conducted in the past 20 years suggest constraints on the internal structure of the ECA (e.g. CATALANO & SULLI, 2006), few, if any, of these studies discussed in detail its thin frontal portion, i.e. the transition of the ECA with the Ionian abyssal plain. We believe that this is the reason why a major questions remain unanswered: 1) are the Messinian evaporirtes composed of salt so that they behave as a weak décollément level? 2) how the occurring Messinian evaporites influence the tectonic style and geometry of the wedge?

Till now seismic character of the Messinian evaporites in terms of reflectivity patterns and deformational structures have not yet been convincingly related to its stratigraphic layering and its rheology. That is because the rough seabed topography (otherwise known as the “cobblestone topography”, HERSEY, 1965) at the ECA southernmost front and the occurrence, at depth, of diffraction hyperbolae coming from the Messinian evaporitic sequence have strongly hampered the study of the outermost ECA internal structure.

The afore-mentioned questions are addressed here through a recently-migrated set of existing multichannel seismic reflection profiles from the NW Ionian Sea, around the front of the wedge (Fig. 1). A new detailed seismostratigraphic analysis allows us to better define the seismic stratigraphy of the Messinian evaporite deposits and to analyze the role played by Messinian evaporites in controlling the tectonic style of the thin frontal portion of the wedge.

Dataset

To constrain better the main features of the thin frontal part of the ECA, we use post-stack time- migrated multichannel seismic profiles of the CROP (CROsta Profonda) Project (Fig. 1). Application of migration techniques to the CROP dataset focused on imaging, in detail, the shallow subsurface in the 1.0–2.0 s ⁄TWT range. We focused on the velocity distribution with depth, by utilizing the results of the Expanding Spread Profile (ESP) data supplied by De Voogd et al. (1992). The result was an improvement of the data quality and enhancement of the signal-to-noise ratio of the data.

Seismic Interpretation

The seismostratigraphic analysis of the seismic profiles calibrated with the refraction data (DE VOOGD *et al.*, 1992) suggest a general bipartition of the Messinian unit in the outer ECA, consisting of a transparent subunit at the bottom and a layered subunit at the top.
Wave-like deformation and salt-based compressional structures characterize the folded but overall unfaulted lower subunit, suggesting ductile deformation of this subunit, submitted to diffuse flow. Thrusting and brittle deformation characterize the overlying subunit which contains faults soling out at its base.

Both the difference in seismic facies and the difference in deformational style allow a better definition of the unit’s stratigraphic layering, which consists of the reflection-free and plastic Messinian salt layer below and the alternation of marls and gypsum above.

Locally, the two Messinian subunits are not well-imaged and a chaotic facies occurs. Here, a different deformational style is evidenced by the occurrence of a series of double-verging imbricated thrust sheets of the whole Messinian unit

At the south-easternmost border of the study area (Fig. 1), the Messinian unit shows two superposed imbricated packages; the upper one, with a chaotic facies and a thickness smaller than the lower one, appears markedly detached from the underlying one. Due to both the laterally discontinuous occurrence and the reduced thickness of Messinian upper package, we interpret the upper body as the result of large gravitational glide tectonics over Messinian deposits. This large-scale instability of the area, since the Late Messinian, could be due to a progressive increase in the wedge slope steepness, consequent to the thickening of a sub-critically tapered wedge. However, it could be hypothesized that the salt tectonics have also played a role in the emplacement of the chaotic succession. In this case, the gravity-gliding tectonics might well reduce the top of the taper, contributing to lowering the taper value detected for the ECA.

Concluding remarks

Post-stack time migration of Ionian CROP seismic data provides new and interesting constraints for structures and processes characterizing the outermost ECA.

- A more detailed stratigraphy framework of Messinian evaporite deposits than previously known, consisting generally of gypsum and marls overlying salt, is given. The "upper" evaporite layer shows evidence of brittle deformation while the "lower" evaporite layer acted as a globally ductile layer, also through the development of salt-cored thrusting structures.

- Lateral variation in composition and thickness of Messinian evaporite deposits reflects a change in style of compressional structures, with the development of double-verging thrust faults offsetting the whole Messinian sequence.
- A gravitational glide tectonics characterized the outermost ECA since Late Messinian, due to both the salt occurrence and a wedge slope too steep to support a skinny evaporite-based top layer (a near-surface "olistostrome").

- Migration of data permitted also to map more carefully the ECA leading edge that advances substantially farther to the south than shown on previously reconstructions (see e.g. CATALANO *et al.,* 2001; FINETTI, 2005).

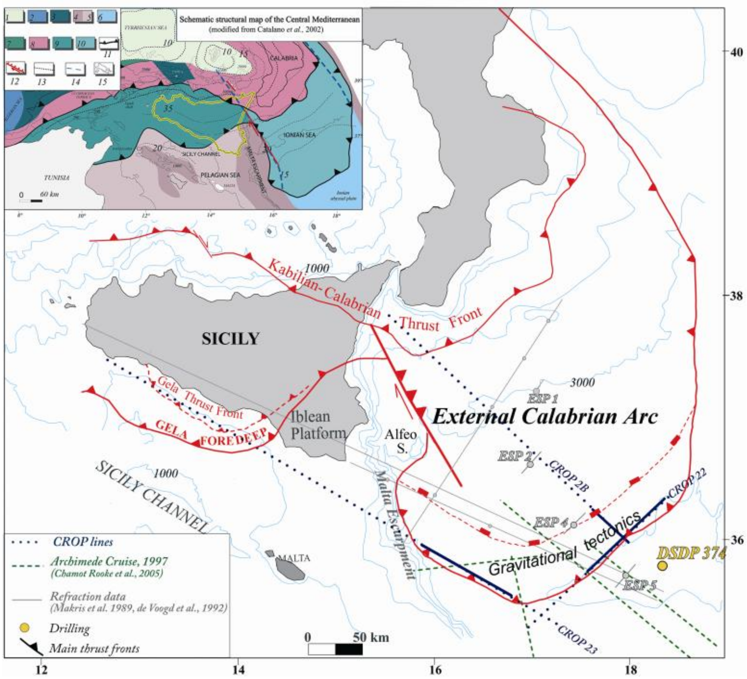

Fig. 1. Bathymetric map of the study area (modified from CATALANO et al., 2006) with the location of the grid of the interpreted (CROP) multichannel seismic profiles (bold segments). Main structural features based on present and previously published (CHAMOT-ROOKE et al., 2005) works are displayed. Inset shows a schematic structural map of the study and surrounding area. The numbers in the legend are: 1) Tyrrhenian deep basin; 2) Algerian basin; 3) Thinned Sardinia and Kabilian continental crust; 4) African continental thinned

crust; 5) African continental crust; 6) Ionian oceanic basin; 7) Sardinia units; 8) Kabilian-Calabrian units; 9) Sicilian-Maghrebian units; 10) Ionian accretionary wedge; 11) Thrust fronts; 12) Transtensional fault; 13) Moho isobaths in km; 14) Hypothetical Ionian crust boundary; 15) Bathymetry.

Biogenic Gas in the Plio-Pleistocene Terrigenous Unit: A New Foredeep to Explore (Sicily Channel, Italy)

Valter Gatti, Roberto Ruspi, **Paolo Storer,** *Eni E & P Division, San Donato Milanese (Italy)*

The Gela foredeep, located off the Agrigento coast in the Sicily Channel, represents one of the most interesting areas for gas research in Italy. This Plio-Pleistocene basin develops outside the front sector of the Appenine-Maghrebian thrust belt, known as the Gela nappe (Fig. 1). In the past many exploration campaigns were carried out in this portion of the Sicilian offshore aimed at oil research in the Mesozoic carbonates of the Hyblean foreland. The Perla and Prezioso oil discoveries in 1976 and 1982 are the most important results of the activity carried out in this first exploration cycle.

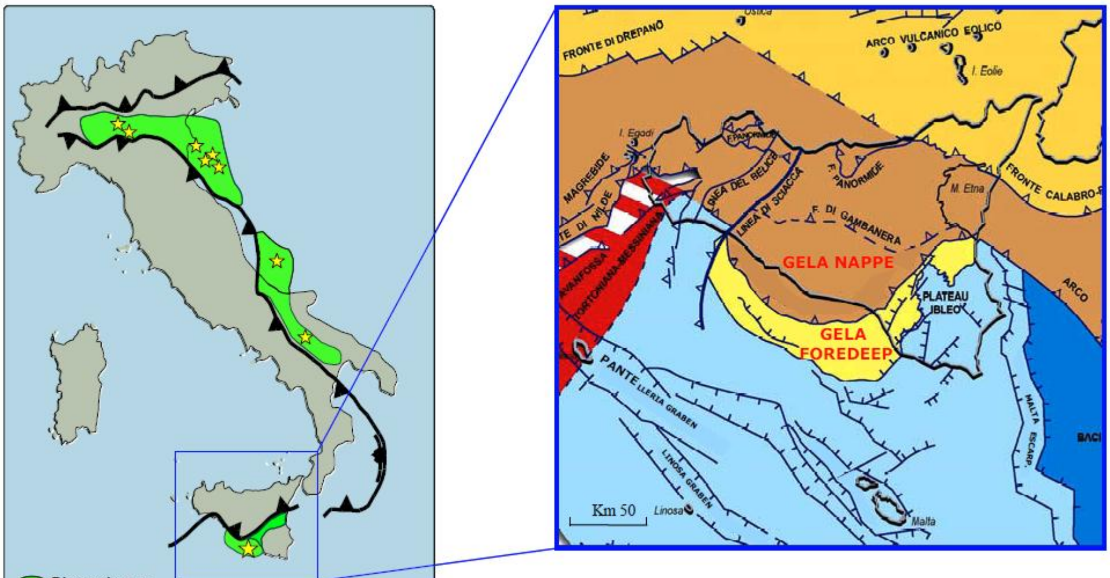

Fig. 1 – Gela foredeep

A series of interesting acoustic impedance anomalies has been highlighted since 1995 in the Plio-Pleistocene clastic series. Furthermore the wells drilled in the past at the basin margins, encountered gas shows of a certain interest in the terrigenous Pleistocene sequence. These HC indications suggested to carry out special studies finalized to evaluate the potential of this almost unexplored basin.

The new G&G studies issued a positive evaluation of the basin for exploration purposes. The Plio-Pleistocene sedimentation began in lower and middle Pliocene with 60-100 meters of marine Marls and shales deposited over the foreland. At the middle-upper Pliocene boundary, a remarkable deformation phase resulted in the tilting of large portions of the foreland and in the general passage to slope and foredeep deeper marine environments. The foredeep basin fill, represented by a wedge of sediments 2000-2500 meters thick in the depocenters, is made of upper Pliocene-lower Pleistocene turbidites.

The area with the higher exploration potential has been delimited within two exploration blocks, namely G.R13.AG and G.R14.AG, where Eni E&P is operator with the participation of Edison S.p.A (ENI E&P 60%, Edison S.p.A. 40%). The blocks have been awarded in 1999, and are now within the third exploration period. In this area the sea bottom is in the range of 100-700 m depth. The drilling of the first commitment well Panda 1 in 2002 led to the first significant discovery of biogenic gas in the Hyblean foredeep and represents the starting point of a new exploration cycle. This well confirmed the presence of a typical multilayered reservoir composed of intercalations of shales and thin-bedded highly porous unconsolidated sands. In 2003 well Panda West 1 was drilled with success on a nearby structure. The production potential of the play was tested in wells Panda 1 and Panda West 1, where tests gave a production rate of about 200.000 Scm/day.

In 2004 the acquisition of a new 3D seismic volume was completed over an area of about 800 Sqkm, in order to cover a large portion of the foredeep area with homogenous and high resolution data, with the aim of detecting gas accumulations by using the most up to date technologies. The new data and studies allowed the definition of a number of prospects with interesting acoustic impedance anomalies and with positive A.V.O. effect in the Plio- Quaternary foredeep sediments. This phase of data analysis was followed by the drilling of well Argo1, which led to the discovery of the Argo gas field in 2006 (Fig. 2). In 2008 well Cassiopea 1 dir, drilled about 6 km W of Argo1, confirmed the presence of another gas field, with a potential of about 160 m of net pay, while a few months later well Argo 2 was positively drilled on a deeper pool of the Argo field.

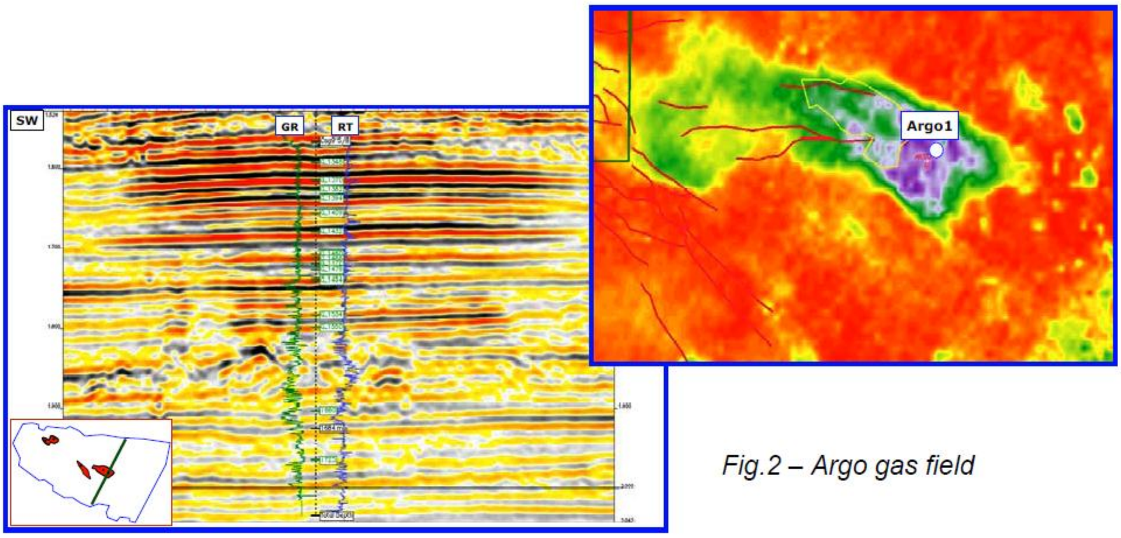

Fig.2 – Argo gas field

So far, the main target of the foredeep exploration is represented by biogenic gas accumulations in the Plio-Pleistocene turbidite reservoirs with structural, mixed and stratigraphic traps. The gas quality is high, pure methane dry gas has been produced by tests (99.7% CH_4). Petrophysical analyses show very good reservoir characteristics for the sand layers intercalated to shales, with porosity in the range of 30-40 P.U. MDT measurements on wells confirm an overpressure condition of the reservoir, probably due to the under-consolidation of sediments. The source rock is represented by the shale layers interbedded with the porous reservoir layers. Shale beds have good values of T.O.C and H.I.

The HC potential of the Pleistocene sequence within the exploration acreage has been estimated at about 20 Bcm of biogenic gas (HIIP) considering prospects with low/medium risk assessment. A number of economically sustainable prospects have been ranked and scheduled for drilling for the next year's activity, while exploitation activity has been planned with the application of two development leases and the definition of an integrated development plan.

The link between the onshore and offshore Sicilian fold and thrust belts: tectono-stratigraphic evolution and implications for hydrocarbon exploration

C. Caldarelli[1], D. Smith[1], C. Turrini[2]

[1]Northern Petroleum Plc,
[2]Claudio Turrini Geological Consulting

Northern Petroleum (UK) Ltd and its partner Shell Italia E & P S.p.A. are currently engaged in exploration for hydrocarbons in a large area of relatively deep water offshore western Sicily. Geologically, the area under study contains the easterly extension of the Atlas thrust belt of northern Africa (Morocco, Algeria and Tunisia) which links to the north-east with the onshore Sicilian thrust belt continuing to the Apennine mountain chain forming the spine of the Italian mainland. This major compressional zone was caused by the northward collision of the African tectonic plate with the Eurasian plate, which influenced this area from Oligocene age until present day.

The structural style within the thrust belt is complex, as suggested by exploration studies within the Atlas, onshore Sicily and the southern Apennines. However, working hydrocarbon systems have been proven in each of these. To date, just one well, Ermione-1 (Agip/Deutche Shell, 1989), has been drilled in the offshore thrust belt, while the foredeep and foreland have been explored in the 1980’s with one significant developed discovery, the Nilde field.

Paleomagnetic data from previous studies indicate that sequences within the northern portion of the Sicilian thrust belt were originally trending N-S to NNE-SSW, approximately in lateral continuity with similar paleogeographical domains occurring in northern Tunisia. The rotation vectors are related to the opening of the Tyrrhenian Sea and the retreat of the subducting Ionian plate. Rotation in north-western Sicily is in the order of 60-90 degrees clockwise, whilst rotations have not been documented in Tunisia and only minor clockwise rotations likely affected the offshore thrust belt (15-30 degrees predicted). It is suggested that the uplift of the Sicilian fold and thrust belt is largely the result of significant clockwise rotation with increasing amount of shortening towards eastern Sicily (increasing depth of the substratum is confirmed by seismic sections). The variation in shortening was accommodated by lateral ramps with dextral strike slip displacement.

Published geological studies carried out in western Sicily (northern Trapanese Domain, inverted Tortonian-Messinian foredeep) conclude that the observed inversion tectonics is anomalous as faults were not reactivated with an opposite sense of slip. The model proposed in the published literature involves inversion of the deep seated structures through fault rotation and reactivated structural highs forming anticlines with local expulsion of faulted blocks through large pop up structures. It is suggested here that this model has significant limitations due to the considerable fault rotation and pressure solution needed in order to explain the loss of volume at the core of the anticlines.

The model proposed in this work is largely controlled by shortcut faults uplifting narrow and elongated horst blocks. Such evolution is validated by structural analogues such as the inversion of the Windermere High in the Canadian Rockies. A similar tectonic evolution is expected for the deformed Tortonian-Messinian offshore foredeep.

A system of NE-SW oriented inverted faults in the offshore Tortonian-Messinian foredeep (exemplified by Nilde) likely initiated in the Late Triassic - Lias as extensional faults which were subsequently inverted during the Oligo-Miocene compression, as also observed in western Sicily. In the latter region this system was characterised by an alignment of paleohighs which are still visible in some areas (i.e. M. Kumeta, M.

Busambra-M.Grande alignment) and intraplatform basins where anoxic facies with hydrocarbon potential developed. An example is provided by the Marineo basin drilled by Agip, which showed presence of bitumen.

A preliminary analysis of seeps combined with the structural-tectonic setting in which they occur suggests that intraplatform basins like the Marineo extended to westernmost Sicily and likely into the offshore. This hypothesis has been recently endorsed by new geochemical analyses which indicate a similar carbonate source rock for all the bitumen seeps in Western Sicily.

The Cenomanian-Turonian black shales outcropping in NE Sicily, regarded as a unit equivalent to the Bahoul Fm. in North Africa, have the highest source rock potential (TOC above 20%, HI up to 640, early oil maturity window).

Our studies suggest these sequences likely formed within slope facies of the Panormide Platform domain and were emplaced on the Argille Scagliose Fm. by large back thrusts rather than being “exotic blocks”. The possible presence of similar sequences in the offshore Sicilian thrust belt has been inferred from regional paleogeographical reconstructions, indicating the likely presence of nappes of equivalent U. Cretaceous slope domains overlain by Pre-Panormide type sequences. The latter units with thickness of about 4km overlain by syn and post orogenic deposits may have provided sufficient burial for hydrocarbon generation.

The interpretation of seismic data in the offshore Sicilian thrust belt has highlighted a complex interference of several tectonic events. The major compressional phase likely occurred in the Oligocene-Early Miocene and was characterised by NNE-NE to SSW-SW maximum compressional stress.

Extensional tectonics postdates the previous event and occurred before the formation of the Messinian unconformity; the orientation of faults is variable being characterized by W-E trending faults progressively rotating to NNW-SSE in the northern portions of the offshore thrust belt. Deformation patterns in the most shallow sequences outline a maximum compressive stress oriented NNW-SSE to NW-SE in the Plio-Pleistocene in a strike slip to compressive regime. This is in agreement with what observed in North-Western Sicily.

In this presentation we will present comparative examples of seismic lines recently acquired in the offshore Sicilian thrust belt together with stratigraphical correlations, examples of predicted stratigraphy and other data and information from the available literature which has been reviewed.

Association between Messinian Drainage System and Tectonic Evolution in the Northern Apennines (Italy)

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The Northern Apennines (Italy) offer an excellent opportunity to constrain the temporal and spatial relationships between drainage network formation and tectonic activity. The Apenninic system is characterized by a drainage network with transverse rivers, flowing north-eastwards into the Adriatic sea, that cross the anticlinal ridges and the foothills and show in many portions a lack of structural control (Alvarez, 1999). The rivers often maintain their courses cutting gorges several hundred meters deep, some of which pass through the axial culminations and the highest topography of the anticlines. Many authors have suggested that deformation in the Northern Apennines took place below sea level during the late Miocene/middle Pliocene and that the fold belt emerged above sea level only in the Pliocene–Pleistocene (Bally et al., 1986; Cencetti, 1988; Castellarin and Stewart, 1989; Casabianca et al., 1995). A consequence of this interpretation is that the drainage network developed under subaerial conditions after the stage of submarine deformation, therefore the antecedence mechanism cannot be invoked to explain the transverse drainage. In addition, the young age of the chain and the lack of any evidence for a flat-lying blanket of sedimentary rocks covering the Apennines indicate that the rivers could not have been superposed on the underlying structures. These observations point out two important questions concerning the relationship between drainage network development and tectonic evolution of the Northern Apennines: (1) why do rivers cut across structures given that the deformation is thought to have taken place below the sea level? (2) why do rivers cut the axial and topographic culmination of folds? Using a combination of field data, seismic lines and well data we show that the main deformation phase took place during the Messinian when the area, affected by the Messinian sea level drop, emerged and evolved from marine to continental conditions. The results highlight that during the Messinian emergence a drainage network developed contemporaneously with the thrust front advancement. The present-day river system, which is dominated by transverse rivers that cut straight across the tectonic grain, is located in older Messinian palaeo-valleys and re-incise the easily erodible marly-clay sediments filling the palaeo-channel.

Pre-Evaporite Jurassic Succession: A New Play in the Apulian Platform

Alfredo Pugliese, **Valeria Scola,** *Eni E & P Division, San Donato Milanese (Italy)*

Southern Italy geological setting is described by a thrust belt-foredeep-foreland system (fig. 1) where several petroleum systems have developed resulting in significant hydrocarbon accumulations in each structural domain. Although in the last 60 years the area underwent an intense and successful exploration and production activity both onshore and offshore, HC exploration potential is still envisaged related either to proven, emerging and unproven plays (Bertello *et al*., 2010).

In Southern Italy the Apulian Platform, mainly constituted of Mesozoic-Tertiary shallow water carbonates, represents an important exploration target in all structural setting. It has been involved in the Southern Apennine chain, where it bears Italy largest oil and gas accumulation (Val d'Agri field) and it represents the substratum of the Bradanic Foredeep Plio-Pleistocene terrigenous turbidite sequence.

HC occurrences in the highlighted area (fig.1) are related to several petroleum systems, associated to two main Italy tectono-stratigraphic settings (fig.2):

Fig.1 Structural sketch

- Biogenic gas in terrigenous Plio-Pleistocene foredeep wedges. In such setting shale layers interbedded in turbidite succession constitute both the source and seal.

- Oil and thermogenic gas in Mesozoic carbonate substratum. Two source rocks are well known and proven (Albian-Cenomanian and Late Triassic/Early Jurassic). The Cretaceous source deposited in transtentional intra-platform basins, the older one formed during the anoxic stage that occurred before the spreading of Jurassic basins. The sourced reservoirs are found both in coeval platform units and in younger overlying carbonate reservoirs.

In the Bradanic Foredeep area, many plays have been successfully proven related to the Plio-Pleistocene and Cretaceous petroleum systems. Many gas fields were discovered and set in production, starting from the Fifty's, from the turbiditic sands (e.g. Candela field). In addition, the sourced reservoirs are, in this area, also the Apulian Platform carbonates, where mixed gas is found (e.g. Grottole-Ferrandina field). Oil accumulation in the uppermost section of the Apulian Platform gave also rise to significant production (Pisticci field) in the past.

In such a mature area high attention was put by explorationists in detecting hints of new plays occurrence: the presence in some seismic sections of an intra carbonatic sequence strong reflector suggested the possible presence of an intermediate seal. This idea lead to drill the well Elce 1 targeted to investigate the platform much deeper than all the surrounding wells. Below the Apulian Platform Cretaceous section, the well drilled approx 2000m of evaporite unit. This unit, never encountered before, is constituted of interlayered anhydrites and thin carbonate leyers of Neocomian/Malm age. The well ended in a dolomite/limestone sequence of Oxfordian age with some oil shows (fig. 3).

Such a thick evaporite unit constitutes a previously undetected seal and provides the basis for a new play in the region: Jurassic Apulian Platform reservoir, sealed by thick Upper Jurassic evaporites, sourced by Late Triassic/Early Jurassic anoxic deposits.

Several uncertainty and critical elements affect this new challenging play, but some important favourable data must be also considered. Concerning the seal, the evaporite regional extension is unknown. In spite of the large number of wells drilled onshore in the area surrounding Elce 1 well, a wide sector of the Apulian Platform is still untested with respect to the Neocomian/Jurassic section. On the other hand, interpretation of gravity data processed with the innovative Gravity Gradient Tensor technique suggests the possible presence of evaporite deposits in an elongated intraplatform basin that extends both onshore and offshore.

Source rock distribution and efficiency is a critical issue. All the oil accumulation related to the Late Triassic/Early Jurassic source rocks in Southern Italy are found along the Apulian margin, no oil accumulation associated to this source is found within the Apulian long time lasting shallow platform domain. The presence of late Triassic/Early Jurassic anoxic intra-platform basins in such domain has been for a long time hypothesized. A proof of their effective presence comes from Elce 1 oil shows. This oil display a geochemical characterization that correlate very well with the oil related to Triassic/Early Jurassic source rocks found in Central Italy (Rospo Mare, Miglianico, Ombrina oil fields).

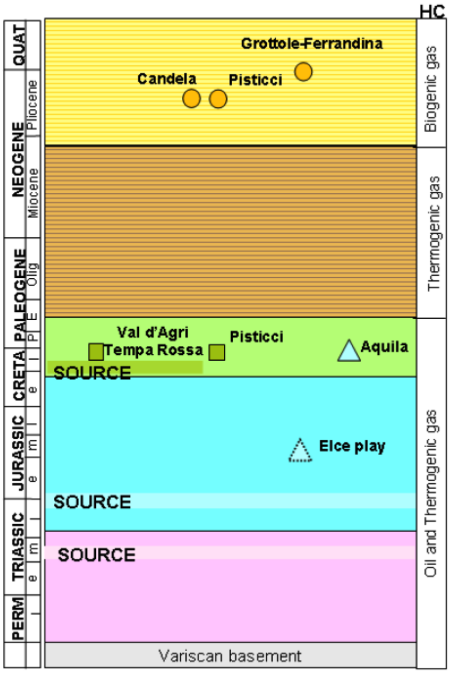

Fig.2. Main HC fields located in the area of interest are displayed with respect to Italy petroleum systems scheme: symbols position is related to main reservoir age, symbol shape and colour refers to hydrocarbon source, background colour to tectono-stratigraphic setting.
(Modified after Bertello et al. 2010)

A further risk is related to reservoir quality; carbonate platform units may display low permeability values if not affected by intense fracturing which is common to occur in thrust belts (Italy largest oil and gas Val d' Agri field) rather than in foreland domain. Nevertheless both paleokarst events and dolomitization could have occured in this area improving the reservoir quality.

Finally Elce play could be compared with the Late Jurassic succession already explored in the Middle East. This play is proven, for example, in the Kuwait region, where is defined by the vertical superposition of a mostly anhydritic seal (Gotnia Fm.) above a complex stack of shallow water carbonate rocks belonging to the Oxfordian Naymah Fm. (Yousif & Nouman,1997).

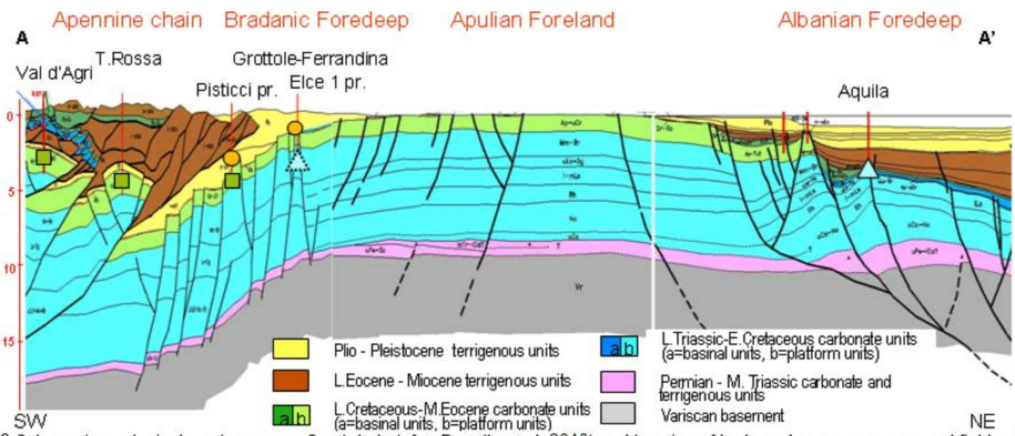

Fig.3 Schematic geological section across South Italy (after Bertello et al. 2010) and location of hydrocarbon occurrences and fields with respect to petroleum systems.

Hydrocarbon Systems of the Adriatic Basin: New Opportunities in a Mature Area

Alberto Riva, Raffaele Di Cuia, Mara Marian, *G.E.Plan Consulting s.r.l., via Borgo dei Leoni 132, 44121 Ferrara, Italy*

The Adriatic basin is an elongated area that lies between the eastern cost of Italy and the coasts of Slovenia, Croatia, Montenegro and Albania. This offshore basin is more than 820 km long and 80 km to 220 km wide. The water depth ranges from few meters to more than 1100m (figure 1).

The basin is bounded to both sides by thrust belts, to the west by the Apennine thrust belt and its foreland and to the east by the Dinarides thrust-belt and it has a long geological story that extends from early Triassic to Pleistocene.
In geological terms the Adriatic basin represents today the foredeep of both the Apennine and Dinarides thrust belts.

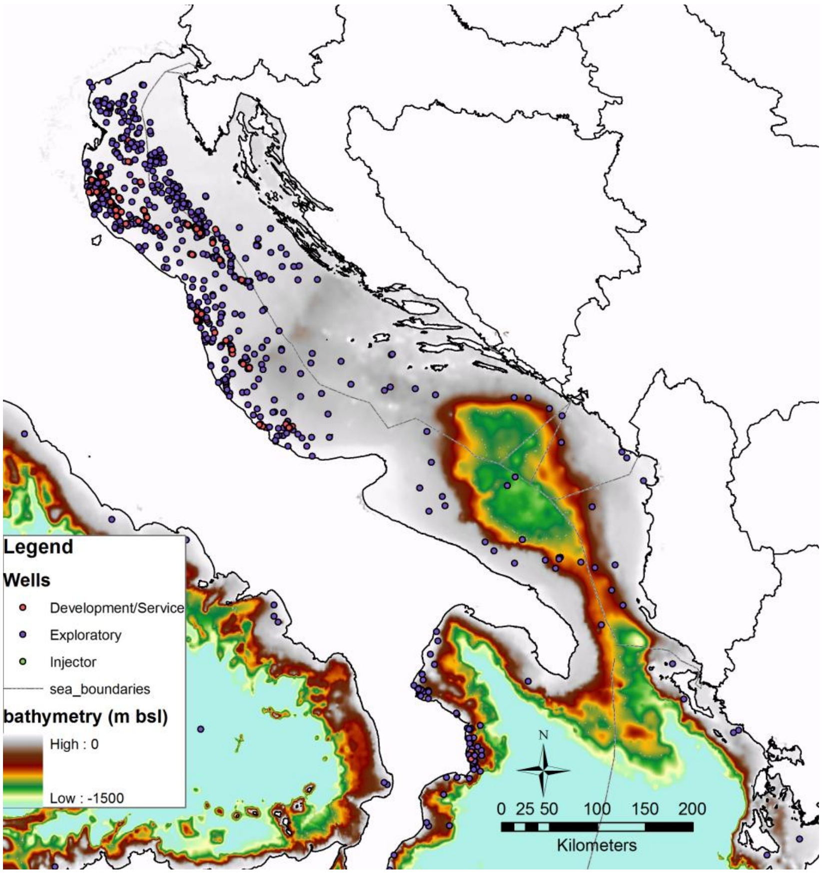

Figure 1 – Bathymetry of the Adriatic sea and location of the wells drilled in the basin

The Adriatic basin has been explored for hydrocarbons since the late 50's with a major period of high drilling activities between 1968-1972 and an increasing drilling activity from 1978 to 1992 (88 wells but only 7 NFW). The exploration activity has been concentrated in the northern and central part of the basin and mainly on the Italian side. Between 1960 to 2006 more than 1500 wells were drilled in this basin but only 150 were drilled outside the Italian waters. This exploration activity lead to the discovery of more than 90 gas fields (90% on the Italian side) and only 8 oil fields. The gas discoveries and production are mainly concentrated on the northern part of the basin (85%), while the oil discoveries are only in the southern and central part of the basin.

The two main proved plays are represented by the biogenic gas in the Pliocene-Pleistocene sequence and by the oil and gas in the Cretaceous to Miocene carbonates.

The Pliocene-Pleistocene play type is characterized by a sequence with the presence of clastic turidites deposited mainly along the long axis of the Plio-Plestocene foredeep of Northern and Central Appenines. The clastic turbidites are represented by a complex alternation of shale and sandstone with highly variable thickness according to their relative position with respect to the sediment source. The reservoir is made of the sandy part of the turbiditic sequence while the finer portion and the background basinal deposition represent a very effective seal. The source rock is within the same turbiditic sequence and could generate biogenic gas because of the characteristics of temperature and subsidence of the basin. The traps are represented by the most external structure of the Apennine thrust belt that involved also the younger part of the Pliocene-Pleistocene sequence or by stratigraphic produced by the 3D distribution of the turbiditic flows on the Pliocene-Pleistocene foredeep basin floor.

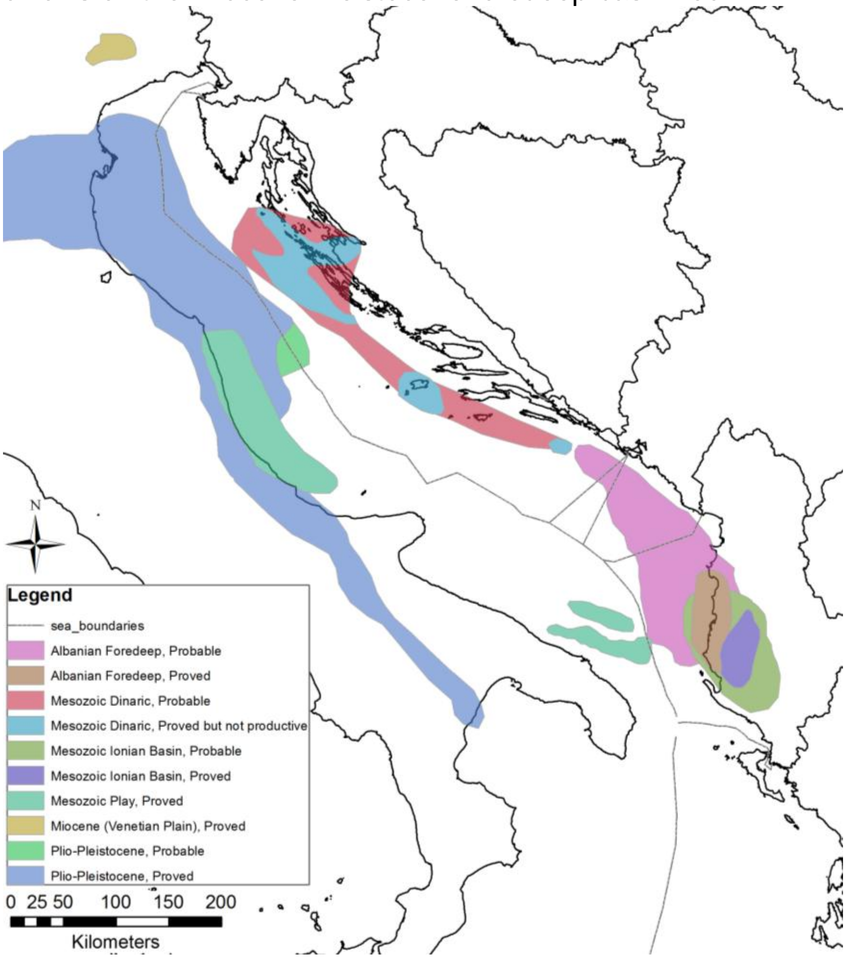

Figure 2 – Distribution of the main proved and probable plays in the Adriatic basin

The Cretaceous to Miocene play type is mainly characterized by heavy to light oils generated by lower Cretaceous intra-platform sequences deposited in anoxic conditions or by lower Triassic carbonate sequences with high organic content. The reservoir is represented by the Upper Cretaceous fractured carbonates (low matrix properties) or by the Eocene and Upper Cretaceous karstified limestone underneath the main Miocene unconformity. The seal is represented by the fine-grained clastic sequence belonging to the lower part of the Pliocene sequence. The hydrocarbon accumulations are mainly trapped in horst-type structures or partially inverted blocks.
A recent revision of the existing available data has highlighted the presence of a new partially proved play represented by the deep Ladinian-Carnian siliciclastic sequence (see Lastovo 1 well) sourced by hydrocarbons generated in the Triassic limestone sequence with mixed sabkha and anhydrite facies (see Vlasta 1 well). If confirmed this new play may open new exploration opportunities related to structural highs at Triassic levels in the eastern part of the basin.

Investigating Seabed Seepage of Hydrocarbons on the Calabrian Accretionary Prism Offshore Southern Italy

Daniel Praeg[1*], Silvia Ceramicola[1], Daniella Accettella[1], Ann Andersen[2], Roberto Barbieri[3], Andrea Cova[1], Stephanie Dupré[4], Francois Harmegnies[4], Dierk Hebbeln[5], Jean Mascle[6], Catherine Pierre[7], Vikram Unnithan[8], Nigel Wardell[1]

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The submarine extension of the Calabrian accretionary prism offshore southern Italy is being investigated by OGS and partners in order to characterize seabed seepage features in relation to tectonic activity over time. These investigations have taken place in the context of EC-funded projects, making use of regional multibeam coverage that facilitated the discovery of mud volcanoes (MVs) in 2005, plus detailed studies of two MV sites using seismic profiles, cores and ROV seabed observations. Here we summarise evidence of a late Pliocene to Quaternary history of tectonically-driven mud volcanism and ongoing hydrocarbon seepage. Multibeam data reveal the seabed tectonic features of the Calabrian Arc across water depths of 1000-4000 m: the inner forearc basins (Spartivento-Crotone), a central thrust-fold belt and an outer area of cobblestone topography developed above Messinian evaporites. Integration of swath bathymetry with backscatter data reveals at least 32 sites of mud volcanism, as sub-circular to elongate high backscatter patches of varying morphology (e.g. cones, calderas, domes, pies, scarps). Most lie on the inner to central accretionary prism, landward of a major escarpment, c. 500 m in relief, known to have experienced post-Messinian (out of sequence) thrusting. Seismic profiles across two sites (Madonna dello Ionio and Pythagoras MVs, respectively in the Spartivento forearc basin and on the central thrust-fold belt) show that both are underlain by subsurface extrusive edifices >1 km thick that interfinger with the upper of two main Plio-Quaternary units, above an unconformable reflection that descends into subsidence basins beneath the mud volcanoes. The boundary between the two units can be correlated to the regional mid-Pliocene (3-3.5 Ma) unconformity of southern Italy, suggested to record a regional tectonic reorganization of the accretionary system. Mud breccias from both sites contain clasts from multiple stratigraphic levels as old as Late Cretaceous. These observations support a model in which mid-Pliocene tectonic activity within the inner to central accretionary prism triggered the rise of fluids from depth, to form near-surface mud chambers that have driven mud extrusion and subsidence over at least 3 Ma. Radiocarbon dates from marine sediments overlying mud breccias in gravity cores provide evidence of extrusive activity since the last glacial maximum (>20 ka). Seabed investigations using Remotely Operated Vehicles (ROVs) provide evidence of ongoing seepage of methane from both the Madonna and Pythagoras MVs. At the Madonna, hydrocarbon seepage is associated with geothermal anomalies, localized outflows of warm mud and chemosynthetic ecosystems. Ongoing investigations are aimed at understanding how many other seepage sites on the Calabrian Arc are currently active, whether gas hydrates are present, and what types and quantities of hydrocarbons and other fluids are being released into the water column.

The Adriatic Sea a Good Time to Revisit This Prolific Region of Europe

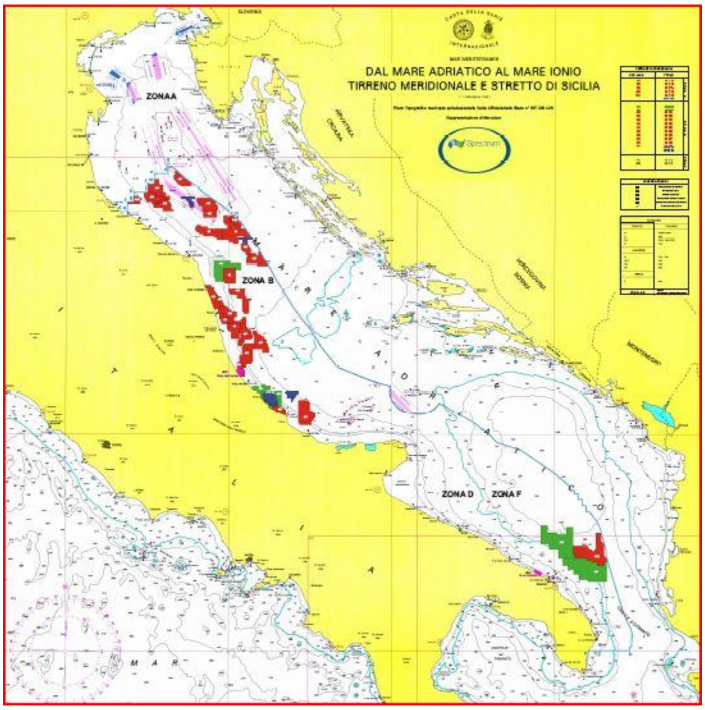
Dave Peace[1], Mike Johnson[2]

[1]*EastMedCo*
[2]*SpectrumGeo*

Italy has been one of the most active and pioneering countries in Europe for exploration for Oil and Gas since around 1950. Go back about 20-30 years and it would be fair to say that the offshore Adriatic Sea was a very active exploration region, particularly in Zone A of the Italian side in the north of the Adriatic region. In 1987 there were some 332 exploration permits in effect, but by 2007 this had shrunk to only 90, in similar vein in 1987 there were 19 offshore exploration wells drilled which had dwindled to just the one in 2007, with a similar decline in production wells in the same period from 41 in 1987 to 12 in 2007*

Also over the last decade the main focus of exploration has largely changed from the shallower very successful Pliocene gas plays to the deeper Mesozoic oil plays.
In 1994 peak gas production was at a level of 20.6 billion Sm3 or 751 bcf of which about 75% was from offshore Italy with 53% of that coming from Zone A. Current demand for gas is around 70+ billion Sm3/year and forecast to rise to around 95 billion Sm3 this year…so Italy faces a huge shortfall in gas supply which has been augmented by huge imports of gas typically from North Africa.

However if you look at the current map of licences offshore Italy in the Adriatic you see that outside of Zone A about 70-80% of the area is open and not licenced

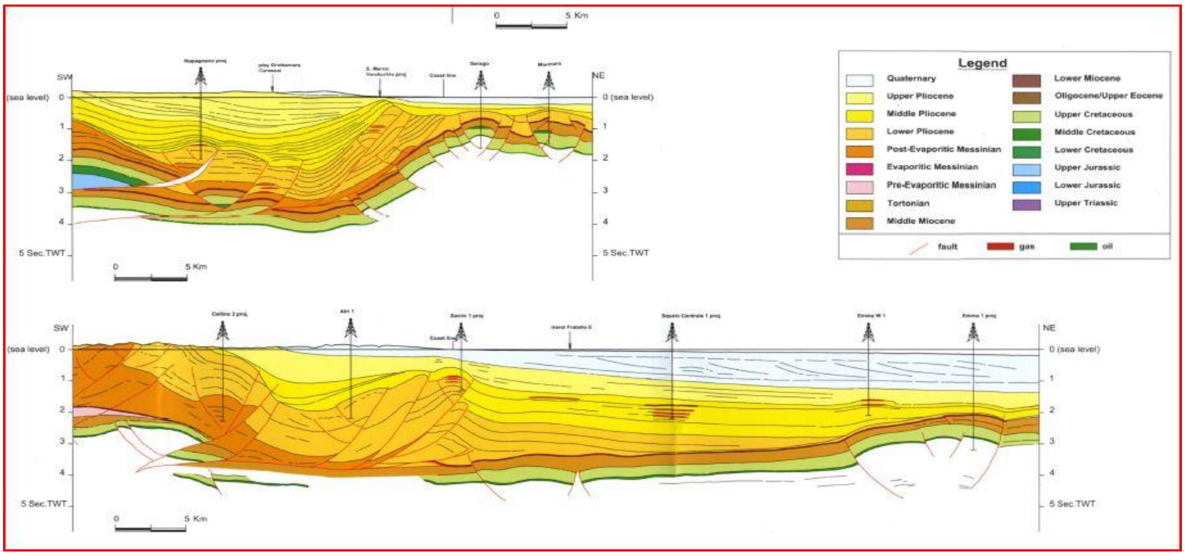


Map showing current licences offshore Adriatic (not Zone A)

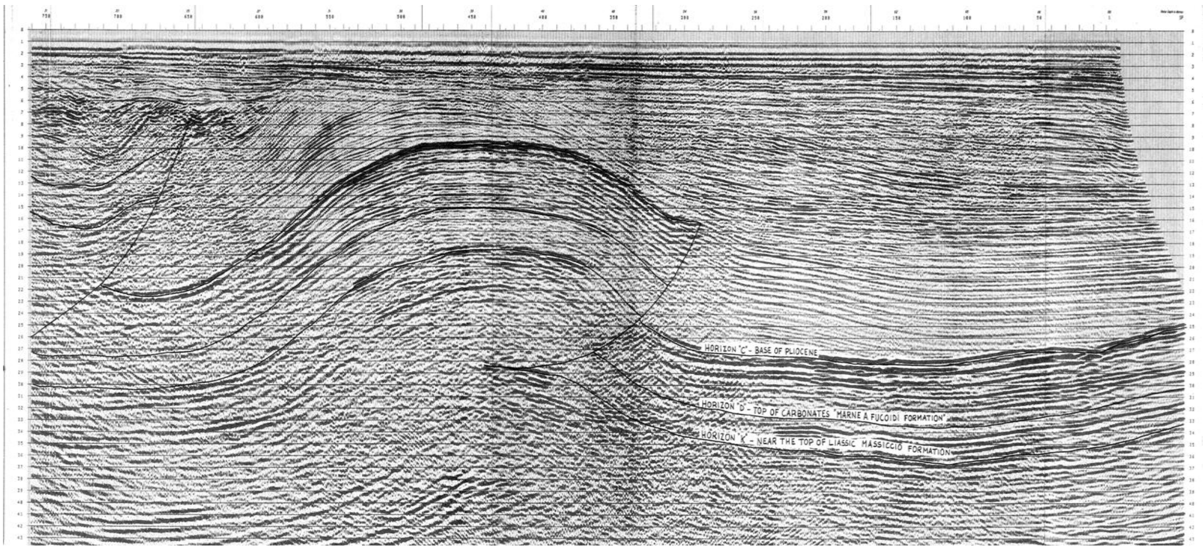
Italy has a very high demand for gas itself which is increasing year by year, and a significant pipeline infrastructure. It is close to the huge European market as well and fiscal terms and conditions for new exploration are among some of the best in the world. Many plays have been proven within Pliocene to Miocene, water depths are shallow and hence development & production costs are low as well…so it should be all to play for and we would reasonably expect a high level of exploration activity in the region.

So what has happened ?......why has exploration declined so much, and is this a good time to maybe revisit the area ?

The geological cross sections below show typical W-E structure in the northern part of the Adriatic which is heavily influenced by the West to East thrusting of the Apennine over-thrust belt. This over thrust dramatically influences the offshore structure of the region, allowing numerous play types to be found in the region from 4 way anti-clinal dip closures at several levels, structural-stratigraphic plays around the highs and more subtle stratigraphic plays often with associated amplitude anomalies. Some of the more recent discoveries such as Barbara, Anna Maria, Andreina have been in this latter play type and are multi TCF sized fields.



Seismic data quality is generally very good and detailed interpretation is possible from 2D and 3D data, similarly amplitude anomalies are frequently seen on seismic data, and are very diagnostic of significant gas presence.



This presentation will outline the regional geology and structure of the Adriatic Sea, show examples of past discoveries, discuss the various play types that are present and proven in the Adriatic and suggest some reasons why now could be a good time to be going back to the region.

The Tectono-Sedimentary Evolution of the Darende and Hekimhan Basins, Central Eastern Turkey

Matthew G. Booth[1], Alastair H. F. Robertson[1], Ulvi Can Ünlügenç[2], John E. Dixon[1], Stephen Vincent[3].

[1]*University of Edinburgh*
[2]*Çukurova University, Turkey*
[3]*Cambridge Arctic Shelf Program (CASP)*

Many of the Central Anatolian Basins have previously been explored for hydrocarbons, for example, the Tuzgölü Basin, Central Anatolia. Here, we focus on the Darende and Hekimhan Basins in the Malatya Region of central eastern Anatolia (Fig. 1). We demonstrate the importance of these basins for an understanding of the regional geological development during the Cretaceous to Eocene closure of Neotethys.

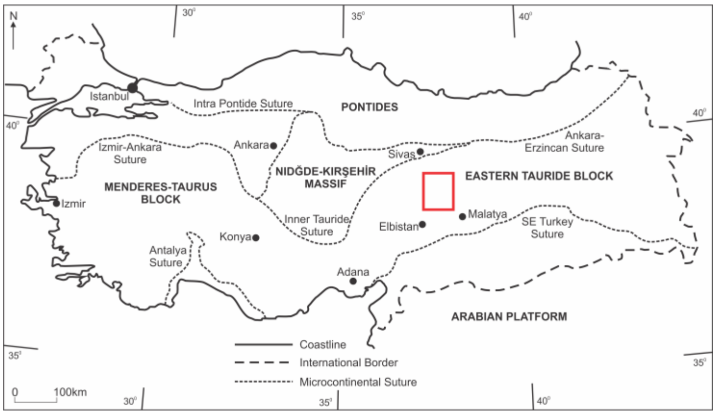


Figure 1 - Palaeogeographic map of Turkey showing the main suture zones. Red box indicates the study area. Modified from Clark & Robertson 2005.

The Darende Basin and the adjacent Hekimhan Basin developed as part of the northern margin of the Tauride microcontinent during the collision and suturing of Neotethys (Fig. 2). The basins both exhibit a Jurassic to Upper Cretaceous regional carbonate platform 'basement' overlain by a dismembered ophiolite that was emplaced southwards onto the Mesozoic Tauride carbonate platform during latest Cretaceous time. Sedimentation on the emplaced ophiolites in both basins began later, during the Maastrichtian, triggered by a basin-wide transgression coupled with tectonic extension and subsidence. Ophiolite-derived clastic sediments accumulated in basin depocentres and palaeovalleys, followed by Maastrichtian-aged, rudist-rich patch reefs. In the Darende Basin microbial carbonates accumulated on the basin margins and on palaeotopographic highs. Deposition in the Darende Basin then halted. In contrast, similar Maastrichtian sediments in the Hekimhan Basin are overlain by subaqueous within plate-type alkaline basaltic-trachytic lavas and associated volcaniclastic sediments of latest Cretaceous age (~1000 m thick). The volcanic rocks are intruded by alkaline syenite bodies that locally display orbicular structures, contact metamorphism, hydrothermal alteration and mineralisation. The igneous activity was followed by the deposition of pelagic to hemipelagic marls, shallow marine-limestones and dolomites all of latest Cretaceous age. An important regression ensued, associated with an unconformity and a sedimentary hiatus during the Paleocene in both the Darende and Hekimhan Basins. Sedimentation resumed in the both basins during the Early Eocene. The basins then filled with variable sedimentary facies including conglomerate, sandstone, marl and

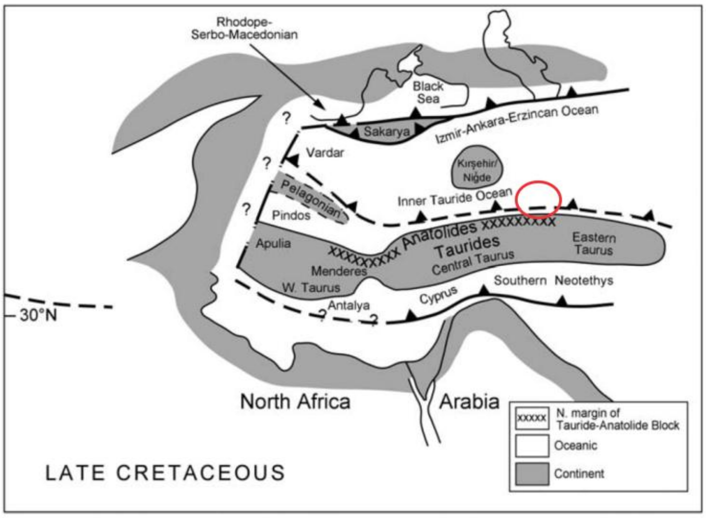


Figure 2 - Plate tectonic sketch of the Eastern Mediterranean region during the Late Cretaceous. Red circle highlights the approximate location of the study area. After Robertson *et al* 2009.

shallow marine nummulitic limestone and widespread but localised basaltic eruptions which record successive deepening, shallowing and finally emergence of both basins during the Late Eocene. In contrast to the Darende Basin, in the Hekimhan Basin several hundred metres of Lower Eocene evaporites accumulated in localised depocentres, followed by fluvial, overbank-type clastics and thin lacustrine limestones, together with Middle Eocene andesitic- rhyolitic volcanics. The Oligocene is represented by post-collisional red braided-fluvial deposits that are only exposed in the Hekimhan Basin. A marine transgression occurred in both basins probably during the Miocene resulting in the deposition of faunally diverse, shallow-marine, limestones (<10m thick). Pliocene subaerial basalts (~1000m thick) and Pliocene-Recent continental deposits complete the sequence.

The following tectonically and eustatically controlled stages of basin development are inferred: 1) Late Cretaceous extension initiated basin development (after ophiolite emplacement), possibly related to immediate isostatic compensation and on-going slab-pull during northward subduction of remaining Neotethyan oceanic crust. The eruption of the within-plate lavas and the intrusion of alkaline syenite bodies in the Hekimhan Basin reflect this extensional setting; 2) The emergence of the Darende and Hekimhan Basins in the latest Cretaceous was possibly controlled by regional flexural uplift as the down-going plate approached the subduction zone to the north (and was possibly also influenced by sea-level change); 3) Early Eocene flexural subsidence was probably caused by regional crustal loading that accompanied progressive collision of the Tauride microcontinent with Eurasia (“soft collision”). This caused the Darende and Hekimhan Basins to subside and allowed sedimentation to resume, coupled with a significant eustatic sea level rise; 4) Mid-Late Eocene “hard collision” resulted in progressive restriction of the basins, regional uplift and subaerial exposure; 5) Suture tightening and compression, probably during the Miocene, resulted in reactivation of pre-existing extensional faults and terminated marine sedimentation. Both basins were affected by predominantly sinistral strike-slip faulting during the Plio-Quaternary westward tectonic escape of Anatolia.

Both basins are relatively undeformed internally, although they were affected by post-Mid-Eocene to Miocene, post-collisional suture tightening and subsequent Neotectonic strike-slip. This unexpected preservation is attributed to their location within a “strain shadow” to the east of a microcontinent, the Nidğe-Kırşehir Massif, which acted as a regional-scale indenter between Eurasia to the north and the Taurides to the south.

Friday 25 February

Session Five: New Technological Advances and Seismic Imaging

Keynote Speaker: Systematic geophysical mapping of the deep Eastern Mediterranean Sea Basins and Margins

Jean Mascle[1], Nicolas Chamot-Rooke[2], Laurent Camera[1], Laetitia Brosolo[3], Benoit Loubrieu[4]

[1]*Geoazur, Villefranche sur Mer, France*
[2]*ENS Géologie, Paris, France*
[3]*CNRS-INSU-DT,La Seyne sur Mer, France*
[4]*Ifremer-Geosciences Marine, Plouzané, France*

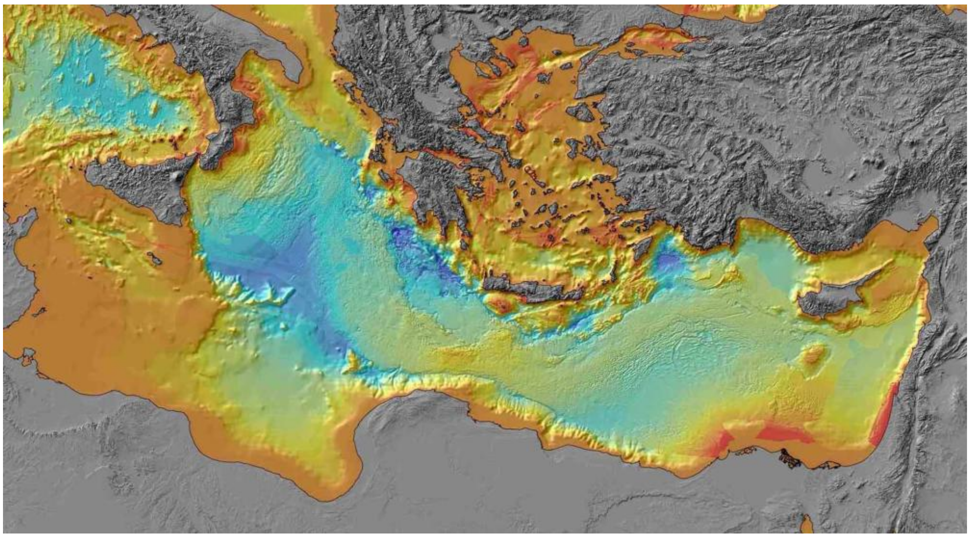
During the past 12 years several French academic Institutions have conducted systematic swath bathymetric and backscatter mapping surveys over most of the Eastern Mediterranean deep basins and surrounding active and passive continental margins.

Depending of the areas these data have allowed producing morphological maps, at various DTM (from 1 to 500 meters grids) for regional and local studies.

This data set perfectly illustrates most of the various active geological processes, which are directly operating, and thus imprinted, on the sea floor. Recent to active tectonics, salt and gravity tectonic, slope sedimentary by-passing, slides and instabilities, brines lakes, fluid seepages, mud volcanism, gas chimneys are particularly well identified on the sea bed and can thus been mapped in detail.

During most of these academic surveys 6 channels seismic reflection profiles were also recorded providing the possibility to evaluate the geological structural background often up to 2 seconds TWT. Locally, particularly across some segments of the Libyan and Egyptian continental margins and across wide areas of the Mediterranean Ridge, 96 and 360 channels MCS seismic lines were also obtained, and in some cases (Peloponnese) former MCS data were reprocessed.

We present and discuss the main results derived from these data, which can be helpful to better evaluate new oil and gas emerging plays as well as better assessing geo-hazards in the deep Eastern Mediterranean offshore.



Shaded bathymetry of the Eastern Mediterranean Sea (DTM at 500m)
(After Brosolo and Mascle 2007)

Dual-Sensor Technology to Improve the Geological Understanding of the Eastern Mediterranean

Øystein Lie, Per Helge Semb, *Petroleum Geo-Services*

The Eastern Mediterranean is known for its complexity with variations in water depth, tectonic lineaments, salt thickness and basin thickness that result in a variety of geophysical challenges. The thick Messinian salt layer in the Levantine Basin absorbs the seismic energy causing problems in achieving the deep penetration needed to see the underlying prospective intervals. The Herodotus Basin has a complex overburden with varying salt thickness that affects the imaging of the deeper Cretaceous/Jurassic rotated fault blocks. In offshore Tunisia, Libya and Egypt there are shallow and deep targets and the imaging of these requires both high and low frequencies.

Conventional acquisition setups have traditionally been a compromise between shallow and deep targets. A shallow streamer tow obtained high frequencies and good shallow resolution whereas a deep streamer tow obtained lower frequencies and deeper penetration. In both cases the seismic resolution is limited due to the receiver ghost. By introducing a dual-sensor streamer the need to compromise has been overcome. The dual-sensor streamer measures both the pressure wavefield, using hydrophones and the vertical component of the particle velocity using co-located motion sensors. Combining the data from the two sensors separates the wavefield into its' up- and down-going components. By considering only the up-going wavefield the effect of the ghost reflections from the sea surface is removed, which results in improved bandwidth at both low and high frequencies.

2D dual-sensor streamer seismic data examples repeating existing conventional seismic data from Tunisia, Libya, Egypt, Cyprus and Lebanon have provided revolutionary images and enabled an improved geological understanding of existing and new targets. Compared to conventional seismic data the dual-sensor data gives a significant uplift in the data quality; the signal-to-noise ratio is higher and the frequency content is richer for both low and high frequencies giving improved resolution and penetration (Figure 1).

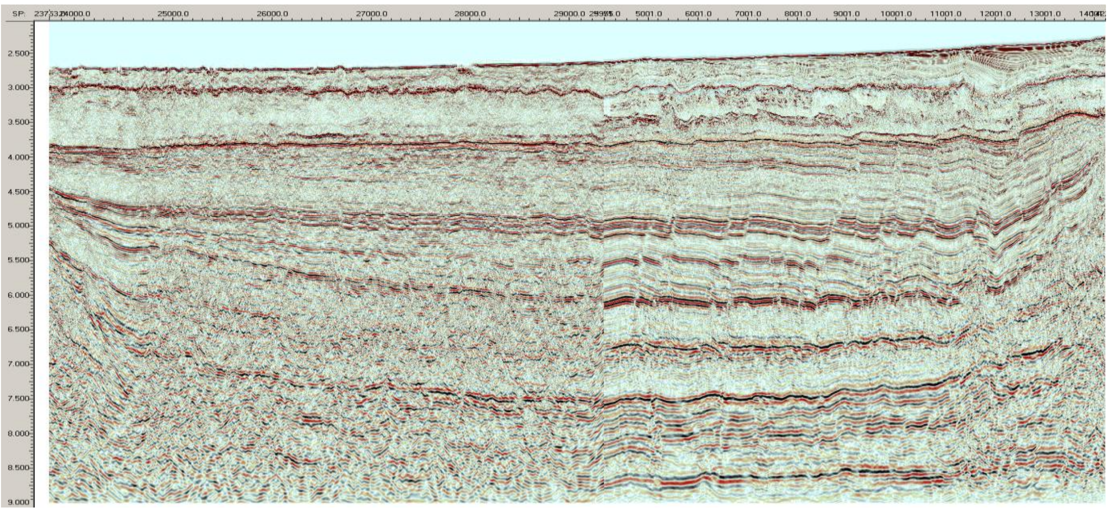


Figure 1: Data example from the Levantine Basin, conventional 2D data (left) dual-sensor 2D data (right)

In areas where the conventional streamer data was lacking penetration the dual-sensor data reveals continuous seismic signal which supplies important information about new sub-salt targets and is reducing the exploration risk.

Modern Geophysical Techniques – Key for Deepwater of North-West Egypt

Linda Kirchberger[1], Roman Spitzer[1], Sandor Bezdan[1], Bernhard Novotny[2]

[1]*OMV Exploration & Production, Vienna, Austria*
[2]*OMV Egypt, Cairo, Egypt*

The offshore basins of NW Egypt represent an underexplored region of the eastern Mediterranean Basin. The Matruh Trough, located west of the Nile Delta province and north of the Western Desert, is mostly covered by the Obaiyed offshore block. This area is considered as a prospective undrilled deepwater block downdip from numerous gas and oil fields of the Western Desert petroleum province. The acreage extends across a relatively narrow shelf into deepwater comprising complex geology, therefore it requires a combination of state-of-the-art seismic data acquisition, processing and interpretation with special attention to (a) seismic multiple attenuation, (b) depth imaging and (c) seismic attribute analysis.

True-azimuth prediction of multiple seismic reflections allow modeling and subtracting multiples without relying on pre-processing such as extrapolation to zero-offset and shot interpolation. Especially, problems arising from extremely rugged seafloor can be solved efficiently.

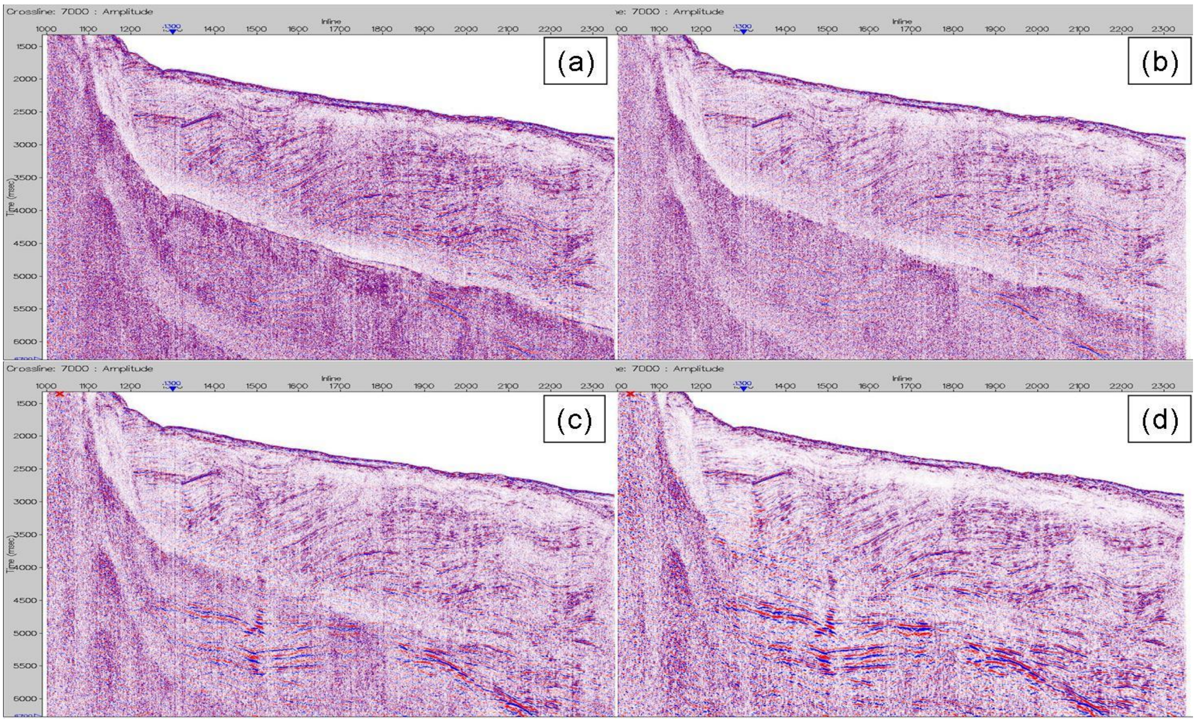


Figure 1: This figure shows the results of consecutive processing steps such as (a) noise attenuation, (b) 3D General Surface Multiple Prediction, (c) Radon demultiple and denoise, and (d) Azimuth-Moveout regularisation.

Secondly, pre-stack depth migration has been performed resulting in superior images due to the high lateral and vertical velocity variations associated with complex geology of the area. This imaging route leads the way for potential target-oriented migrations along specified exploration or development targets. The fault definition also improves remarkably through depth imaging.

Finally, supervised neural networks have been used to highlight potential gas chimneys. Attributes such as verticality, low signal-to-noise ratio, chaotic dips of the seismic events, amplitude wash-out, and frequency anomalies are used in a neural network to emphasis gas chimneys. The results obtained from chimney attributes have been validated following a robust in-house approach.

This comprehensive geophysical approach yields a high-quality seismic product for detailed interpretation.

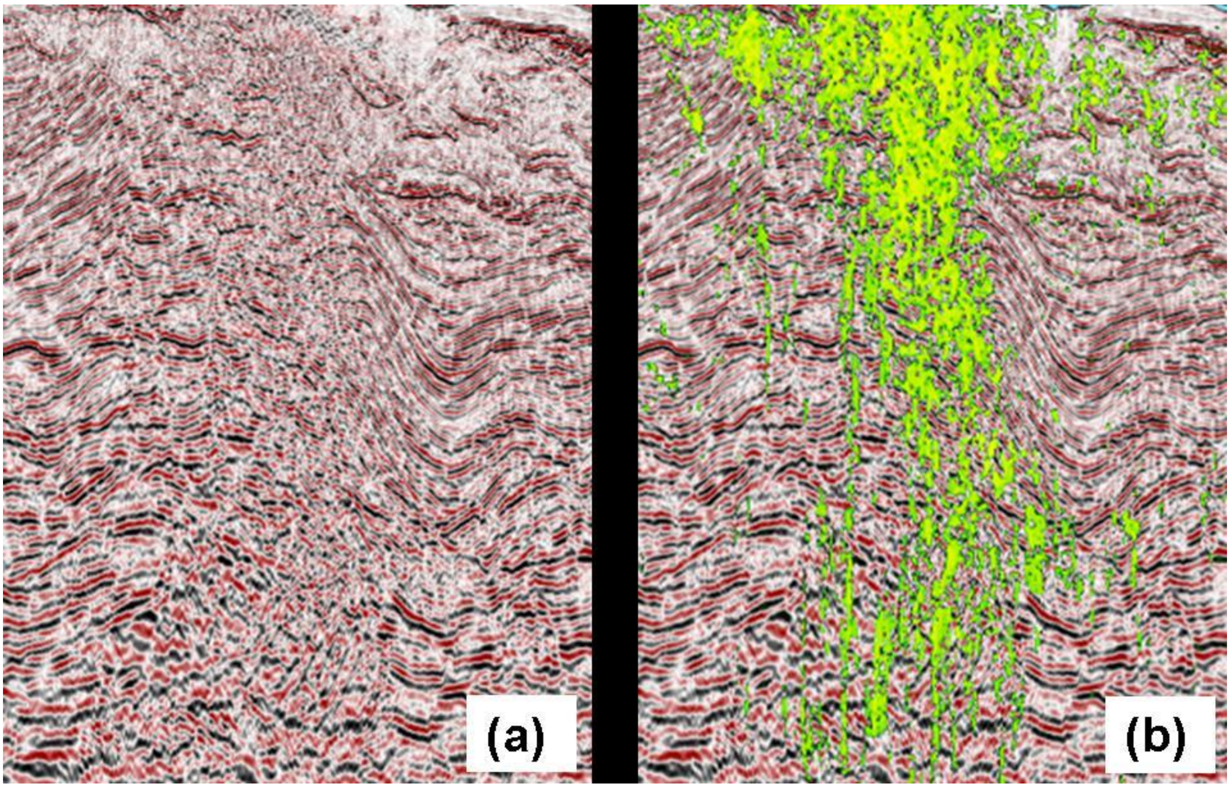


Figure 2: This shows a seismic section (a) without and (b) with highlighted gas chimneys.

An Integrated Approach to Imaging the Levantine Basin and Eastern Mediterranean

Theodore Stieglitz, Richard Spoors, David Peace, Mike Johnson, *Spectrum Geo*

An integrated approach described here explains how complex imaging extracts geologic value from vintage multi-client data acquired over the Levantine basin in the Eastern Mediterranean Sea. Although seismic data may be processed independently of any geology, superior imaging results from understanding the interaction between the seismic experiment on the sub-surface lithology. This paper demonstrates the application of specific geologic friendly workflows, which extend the use and life of vintage data as an exploration tool in this newly proven basin (Peace and Johnson, 2011).

Introduction

The dataset consists of 12,303 km subset of a vintage 2D multi-client program covering the offshore areas of Cyprus, Israel, Lebanon and Syria (Figure 1). This survey was acquired during 2000 and was originally processed during 2000 and 2001 using a time migration processing workflow based upon (at the time) best in class technology. The data was later re-processed with refined techniques and taken to depth in 2006/2007.

The regional geology consists of a fairly uniform layer of sediment overlying Messinian salt, below which there is a deep sedimentary section extending through the Cretaceous and Jurassic. The regional geologic understanding diverges from this simple scenario over the Eratosthenes Seamount. To the west of the Seamount is the Herodotus basin where the Messinian salt is substantially thicker and the shallow sediments are very complex and occasionally chaotic. In comparison, little salt remains to the North of the Larnaca Thrust Zone and in-shore towards the South East (in the Israeli sector).

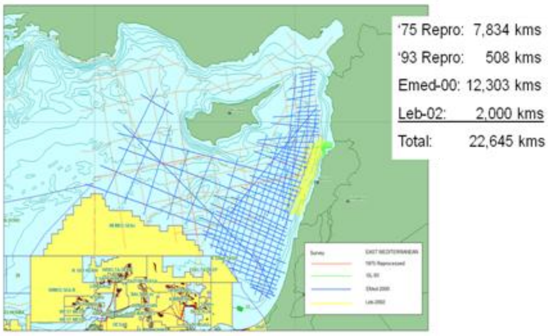


Figure 1: Entire Eastern Mediterranean multi-client program.

Imaging Implications

The complex nature of the geologic structure in the Eastern Mediterranean and the presence of salt and carbonates make seismic imaging and model building difficult. Care must be taken to remove non-primary coherent energy which may occlude the ability to resolve velocity perturbations based upon residual curvature analysis. Tests reveal that substantial imaging improvements can be achieved using a geologic friendly depth imaging workflow, predicated upon relative amplitude preserving data preparation. New technology standards such as surface related multiple elimination (SRME) have been incorporated into the re-processing workflow for addressing the near and mid-cable water bottom multiple followed by radon for minimizing any residual far offset water bottom and inter-bed multiples.

Geologically Driven Model Building

Geologic driven model building of complex structures involves imaging in stages. In describing this process, Bednar (2009) correctly draws the analogy between imaging and model building as conjugate pairs where the definition of velocity is implicitly tied to the operator used to analyze the seismic reflection data.

In order to back-project seismic data into the Earth, we need to understand the medium through which energy is reflected from the source to receivers at the surface. Although beyond the scope of this paper, this method for determining rock properties can be summarized as an inversion process. In our case, the key property we are interested in resolving for generating an image is the velocity of the rock matrix through which the recorded seismic wavefield passed.

There is a long history of mathematics for modeling the propagation of seismic wavefields through the Earth. Time and depth migration operators come in a wide array of permutations pending the theory used to model the seismic data. Under simple acoustic assumptions, time migration operators are based upon smoothly varying rms velocities whereas depth imaging requires the use of interval velocities which may impart significant detail in geologic structure. Fortunately linear relationships may be assumed for relating rms and interval velocities such that the geologic information generated in time may then be used as a guide for the depth imaging workflow.

In building the smoothly varying rms velocity field it is important to take care to capture lateral base-line variations in regional background geologic trends such that several iterations of 1-D manual velocity analysis may be required. The geologically derived model building flow proposed here is favored over automated solutions based purely upon grid based imaging. Model building predicated purely upon gridded velocity models may fail at impedance boundaries such as faults, erosional surfaces, or even sequence boundaries which may constrain matrix fluids and significantly alter rock properties. Although not a requirement in this project with the exception of imparting salt, horizons may be used to isolate local pressure regimes where localized grid based solutions are more stable for resolving fine grained perturbations in lithology.

In our staged model building approach we leverage the value of each successively complex migration algorithm to extract the most value from imaging. As we improve the operator accuracy so does our ability to resolve finer features of the sediment structure. Initial focus is placed on estimating a simple background trend based upon vertical variations in velocity structure as a function of lateral position. Our understanding of the geology is tied to our understanding of the imaging as we transition from Kirchhoff pre-stack time to Kirchhoff pre-stack depth. Although not explored in imaging this dataset, further enhancement of the depth model might be improved by incorporating anisotropy estimates in calculating the Kirchhoff PSDM travel-time operators. Comparisons between Kirchhoff pre-stack time and depth are shown in Figures 2 and 3.

As salt was present in the data, the sediment model was further refined by an involved model building flow consisting of picking a top Messinian salt horizon, imaging the salt flood model, picking a base salt and extrapolating a sub-salt sediment trend. The final salt model was built using a one-way based wave equation migration for addressing complex multi-valued wave propagation through and beneath the salt.

Imaging Exceptions

The chosen imaging approach presented here was based upon generalized client expectations of the multi-client program. These assumptions did not apply well to the data within the Eratnosthenes Seamount. While it may have been possible to build a more accurate velocity model in this area, analysis of the data showed that this would have been at considerable expense to the program requirements. It was acknowledged that the assumptions underpinning our methodology broke down in this geologic area; a simple extension was opted by inserting a thick, high velocity layer beneath the Seamount. Although far from ideal, the stack results were a significant improvement over the original imaging. It is likely that substantial “out of plane” effects are coming into play, placing severe limitations on the extent to which this area can be imaged using 2D data.

Conclusions

An integrated approach has been demonstrated for resolving complex imaging problems present in the Eastern Mediterranean. Using a geologically driven imaging workflow, a high quality imaging product has been generated in a very difficult structural regime. The imaging products generated from the vintage multi-client dataset have been successfully used to add value towards understanding the exploration potential of the Eastern Mediterranean Levantine Basin

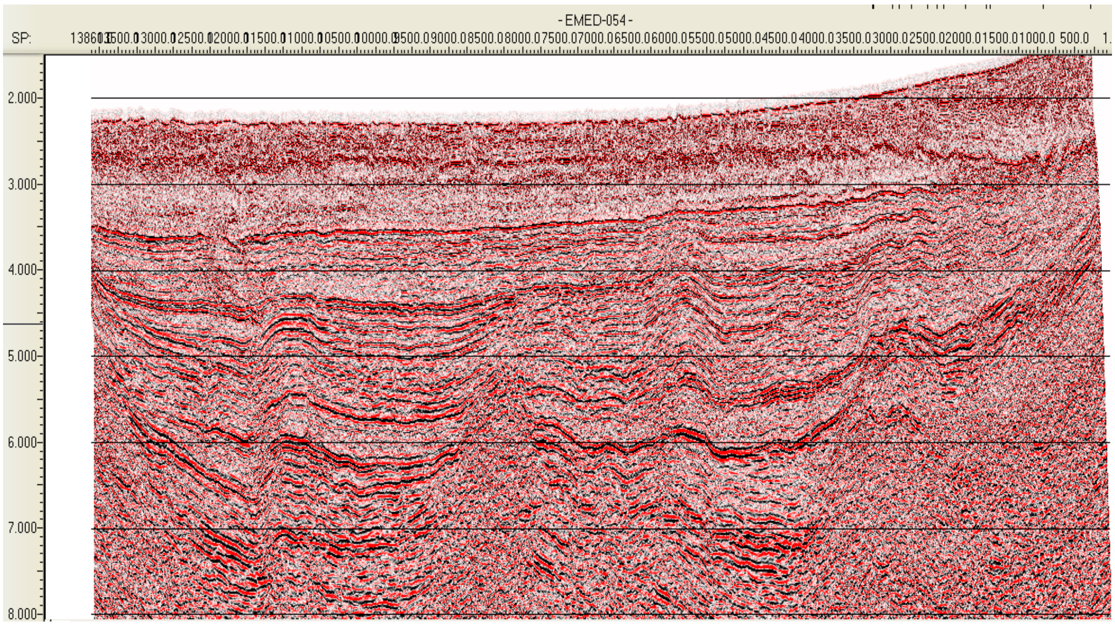


Figure 2: Kirchhoff Pre-stack Time Migration

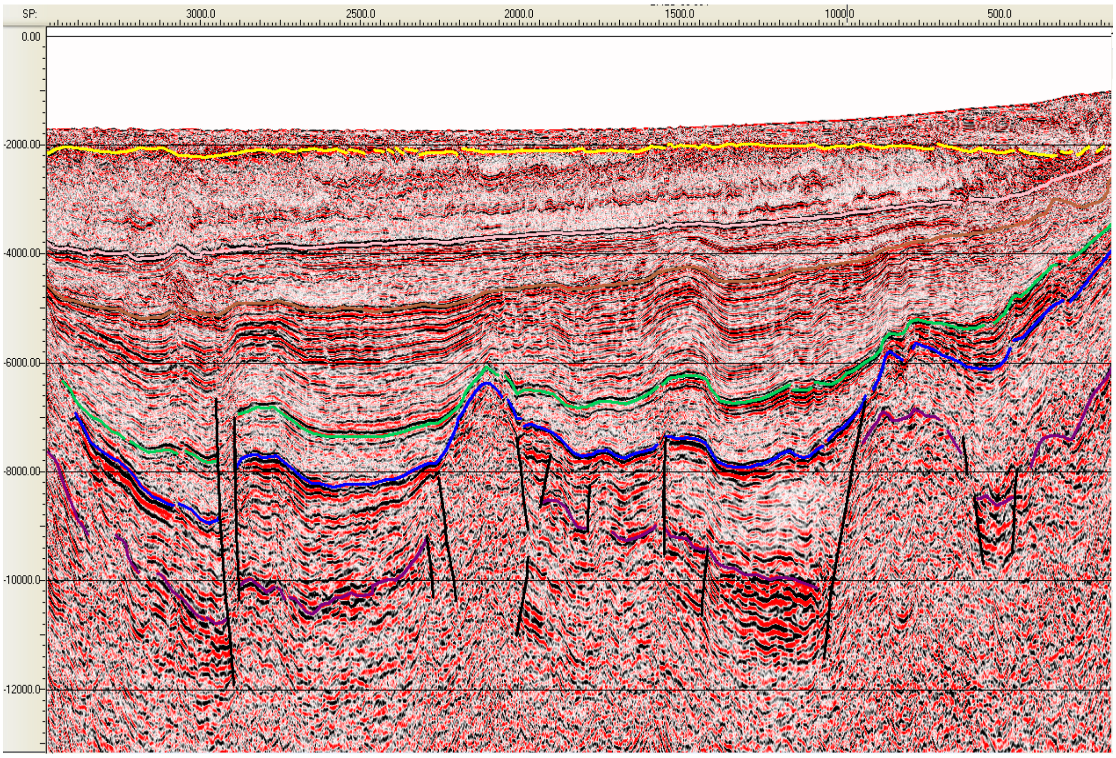


Figure 3: Kirchhoff Pre-stack Depth Migration with interpretation

Seismic Interpretation and Attribute Analysis of Pre-Salt (Tertiary) Successions in the Eastern Mediterranean (With Focus on the Levantine and Herodotus Basins)

Cecilie Skiple[1], Rune Sakariassen[1], Caroline Lowrey[1], Fernando Cerda[1], Thore Sortemos[2]

[1]*PGS Reservoir*
[2]*Bayern Gas*

In the Eastern Mediterranean the Messinian Salinity Crisis produced a regionally extensive salt deposit that remains a laterally persistent cover today. There has been interest in the hydrocarbon potential of the region since the early 21st century and this was encouraged by discoveries in sub Messinian (sub salt) reservoirs in the deepwater Levantine Basin (the Tamar and Dalit wells). The need of our industry to more clearly understand the area and the reservoir intervals was also stimulated by License rounds in Cyprus and potential 1st License round in Lebanon.

We have been acquiring seismic data and enabling investigation of the petroleum potential of the Eastern Mediterranean area for several years, most recently with a high quality (dual-sensor streamer seismic) regional 2D survey. We matched this to existing 3D, and substantial volumes of 2D, seismic, to create one MegaProject (>25000 sq kms). Our earlier interpretation defined a framework of regionally recognisable horizons and identified several potential reservoirs and large attractive traps. These reservoirs are predominantly located beneath the Messinian salt sequence and many uncertainties remain regarding the sediments; their lithology, the nature of the depositional system(s), provenance area(s) and transport direction(s). By combining our previous work with the extended seismic coverage of the MegaProject, investigation of analogues and the application and integration of reservoir characterization we will provide possible answers to these challenging questions. Using the dual streamer technology, advanced processing and AVO analysis we can define at least 7 possible targets with potential hydrocarbon prospectivity. Several of these are identified as possible Class III gas sands.

This presentation will focus on the primary interval of interest; pre-Messinian (pre-salt) sediments (particularly the Miocene) to illustrate that combining state of the art seismic, regional data and interpretation and advanced attribute analysis provides a powerful force for delineating the potential hydrocarbon system over this challenging area.

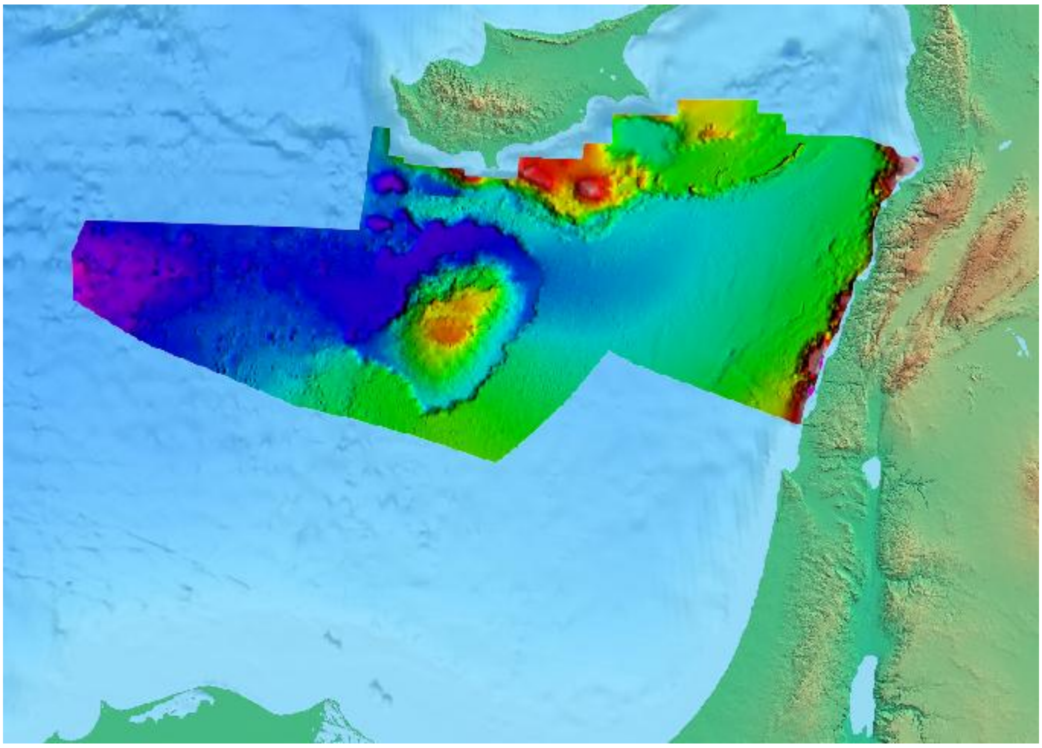


Fig.1 Gridded Seabed, Eastern Mediterranean

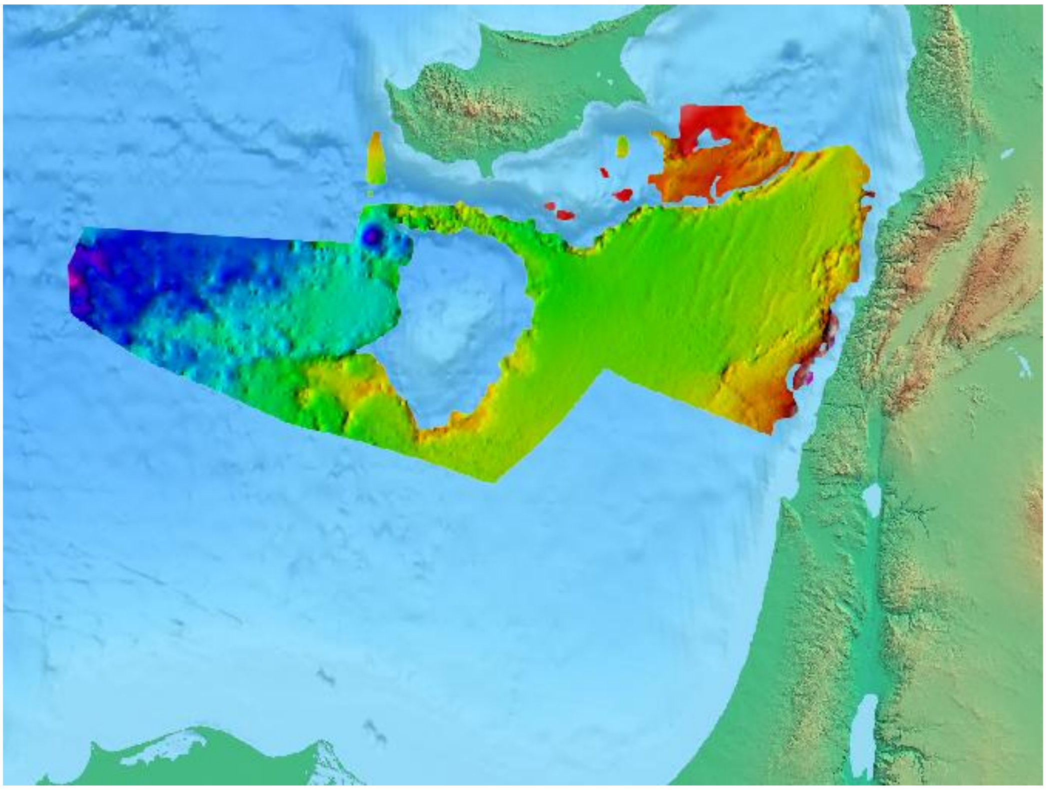


Fig.2 Gridded Base Salt (Messinian), Eastern Mediterranean

Friday 25 February

Session Six: Greater Levant (Israel, Lebanon and Syria)

Keynote Speaker: Petroleum Prospects of Lebanon: An Overview

Fadi H. Nader, *IFP Energies Nouvelles, 1-4 Av. Bois-Préau, 92852 Rueil-Malmaison Cedex, France*

This contribution presents an updated comprehensive review of the petroleum prospects of Lebanon, based on the tectono-stratigraphic sequence, correlation with nearby countries, and results of recent offshore seismic survey. A generalized model illustrating the potential petroleum system(s) in Lebanon is proposed disclosing data about Paleozoic, Mesozoic and Cenozoic prospects. Major lithological rock units are described, and their aspects with respect to hydrocarbon prospects are assessed (source rocks, reservoirs, cap-rocks). Offshore prospects will be highlighted through the discussion of seismic profiles (courtesy of Per Helge Semb, PGS). Here, the focus will be chiefly on the Oligo-Miocene rock units, underlying the Messinian salts.

The presented conceptual petroleum model incorporates onshore and offshore, as well as margin potential prospects.

- Onshore plays:

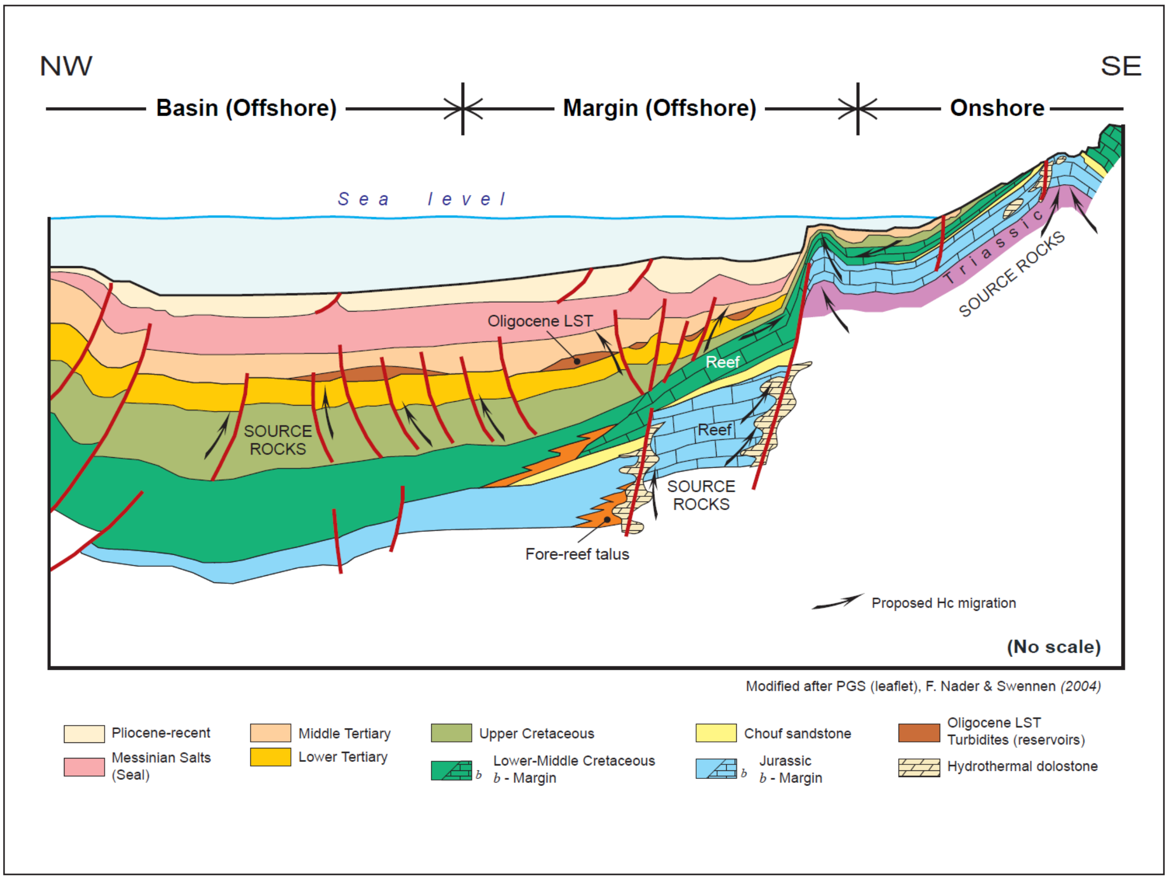
The Qartaba Structure (or similar structures), situated in northern Mount Lebanon should only target Triassic (or pre-Jurassic) prospects. The structure may have a maximum length of 75km and a width ranging between 10 and 25km. It also provides optimal locations for exploration wells reaching the Carboniferous.

- Margin plays:

Triassic, Jurassic, Cretaceous, and Oligo-Miocene reservoirs would be separated by the evaporites, volcanics, clays and marls, as well as the Messinian salts, which acts as a heat conductor and may save the underlying source rocks from overcooking. Fracture-related and fluid-flow diagenesis (e.g. hydrothermal dolomitisation) may enhance the reservoir properties and vertical connectivity of the Mesozoic plays. Local reef platfrom structures of Miocene age could provide attractive targets if capped by the Messinian salts.

- Offshore plays:

Turbidites of Oligocene and Miocene ages (sub- Messinian salt) offshore Lebanon, within the southern Levant Basin, are believed to provide adequate reservoirs whether confined to canyons or spread as sheets and lobes basinward. Several underlying Mesozoic formations could provide suitable source rocks. Potential reservoirs (where favorable structures are observed on seismic sections) are generally well sealed with the overlying Messinian salts.



A proposed, schematic petroleum system model for Lebanon, with possible plays offshore (basin), in the continental margin, and onshore. Potential source rocks, reservoirs and seals are also indicated.

Keynote Speaker: Stratigraphic and Structural Framework of Gas Discoveries in the Late Tertiary Section Offshore Israel

Michael Gardosh, *Oil and Gas Unit, Israel Ministry of Infrastructures, 234 Jaffa St, Jerusalem, Israel*

During the last decade 13 TCF of gas were discovered in the Late Tertiary section of the Levantine Basin offshore Israel (a). High ratio of drilling success and growing demand for gas in the local market promotes an intensive exploration campaign that will include in 2010-2011 the shooting of about 3000 km2 of 3D seismics and the drilling of 4 exploration wells. Geophysical and geologic data acquired in the past ten years shed light on the young tectonic evolution of the Levantine Basin and its hydrocarbon potential.

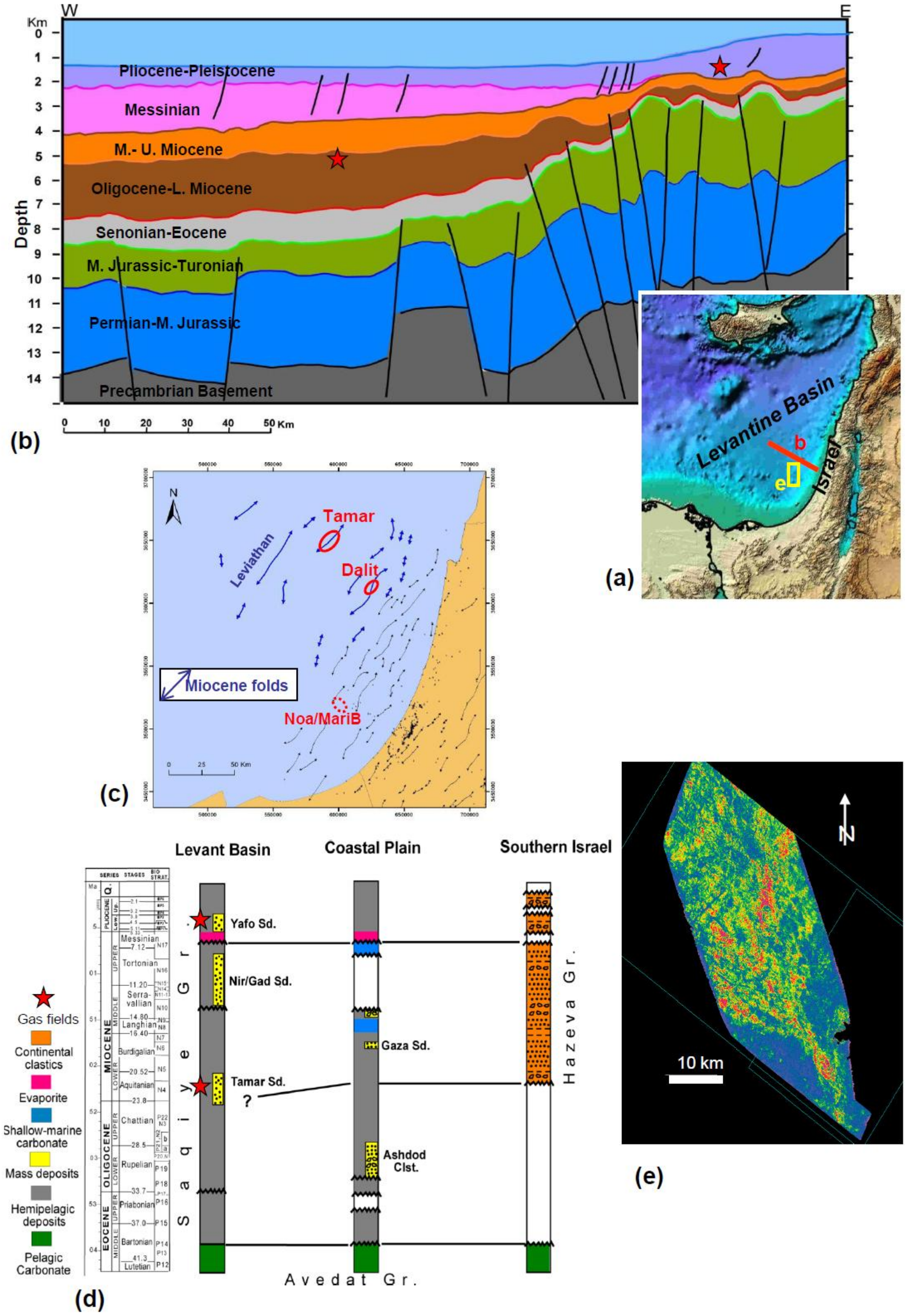
The Late Tertiary section is composed of a 2-6 km thick, mud-dominated siliciclastic units of Oligocene to Plio-Pleistocene age (b,d). The deposition of these rock units coincide with three regional tectonic events: closure of the Southern Tethys Ocean, reactivation of the Mesozoic, passive continental margin and initiation of the Dead Sea Transform. The Levant region was affected during this time by contractional deformation and vertical motions that resulted with creation of accommodation west of the present-day, Mediterranean coastline (b). A series of compressional structures known as the 'Syrian Arc' folds were formed throughout the onshore and offshore area (c). The inner part of the Levant was largely exposed and was affected by cycles of subareal erosion and deposition (d). Extensive drainage system transported coarse-grained Oligo-Miocene deposits from the shelf into the basin through several submarine canyons that were deeply incised into the Levant slope. Desiccation of the Mediterranean Sea during the uppermost Miocene resulted with accumulation of the 1-2 km thick Messinian Evaporite (b). Subsequent rise of sea-level was followed by renewed clastic transport and basinward progradation of a Plio-Pleistocene sedimentary wedge (b).

Exploration activity in the Late Tertiary section of the Levantine Basin resulted so far with the discovery of six gas fields in two types of plays. An Oligo-Miocene play was tested by the Tamar-1 and Dalit-1 wells (c) drilled during 2008-2009 in the northern part of the basin, 50-90 km offshore. The two wells penetrated a 100-150 m thick, highly-porous, gas bearing sand layer below the Messinian Evaporite (b). The Tamar Sands (d) were deposited in a series of submarine, turbidite fans of Chatian to Aquitanian age that accumulated at the base of the Levant slope. A large slope fan of this type is imaged by amplitude extraction maps in the mouth of the Afiq Canyon, at the southern part of the basin (e). In both Tamar and Dalit fields gas is trapped within large, folds that were formed during the Late Miocene in a late stage of the Syrian Arc contractional deformation. The Tamar Sands appear to be widely distributed in the Levantine Basin and are possibly found in other structure such as the Leviathan block SW of Tamar (c).

A second, early Pliocene play was tested by Noa-1, MariB-1 and several other wells drilled during 1999-2000 in the southern part of the basin, 30 km offshore (c). These wells penetrated gas bearing, turbidite sands at the base of the Yafo Formation, above the Messinian Evaporite (b, d). The lower Pliocene Yafo Sands were deposited in slope and basin-floor fans at the mouth of the Afiq and el-Arish Canyons. Part of the Yafo sand layer was remobilized, resulting with the formation of several hundred meters thick, mounded sand complexes (see in second abstract).

Reservoir rocks are found within the Late Tertiary section in other stratigraphic intervals (c). Thick sandstone and conglomerate beds of lower Oligocene and upper Miocene age were penetrated by wells near the present-day coastline (Ashdod Clastics and Gad Sands); and are likely present also in the deeper part of the

Levantine Basin. Gas discoveries and a variety of reservoirs rocks and structural and stratigraphic traps highlight the potential of an emerging hydrocarbon province in the eastern Mediterranean Sea.



The Regional Structure, Some Play Styles and the Exploration Potential of the Eastern Mediterranean & Levantine Basin Area

Dave Peace[1], Mike Johnson[2]

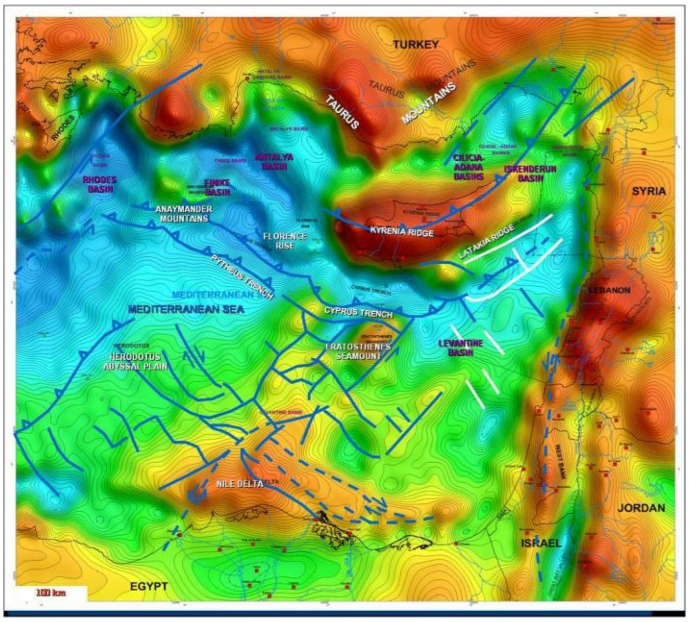
[1]*EastMedCo*
[2]*SpectrumGeo*

Until recently, the Levantine basin located in the greater Eastern Mediterranean could be described as your archetypal "Underexplored Basin Region", with the only significant activity in the basin being located offshore Israel & Gaza where several post salt Pliocene gas fields have been discovered. This is quite surprising considering the area is located close to European markets.

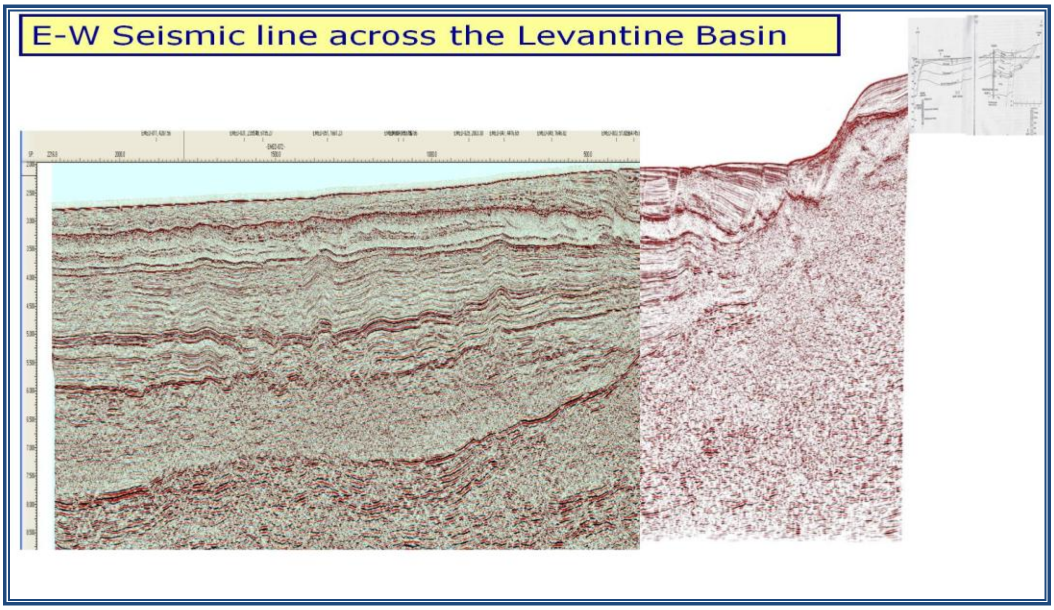
However recent drilling in 2009 by Noble in the deep water sub salt area of the southern Levantine basin has resulted in the discovery of 2 new gas fields Tamar and Dalit with more than 8tcf mean reserves. In addition there is some compelling evidence to suggest that a deeper light oil play exists as well in the basin. This first new success proves the potential of the region, with significant implications for the whole Levantine basin region.

As a result of these recent new discoveries, interest in the region has increased with the prospect of new licence rounds in offshore Cyprus, Lebanon and Syria likely in the next couple of years.

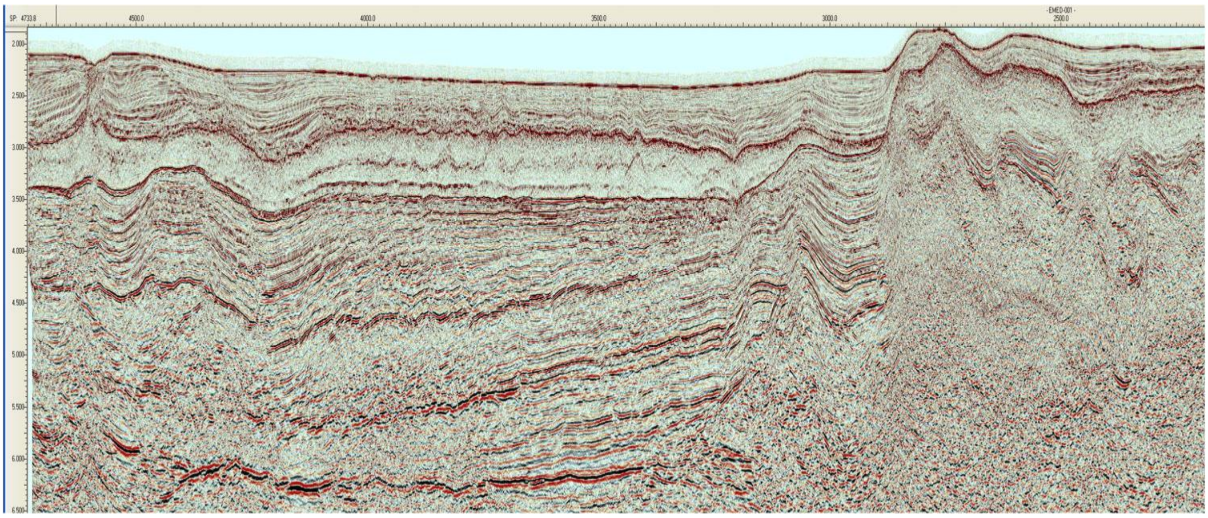
We would like to show you more about the basin, its linkages to the major structures surrounding it from the Nile Delta to Southern Turkey, the stratigraphy as currently known in the basin and some of the play types both proven and speculative that we have identified over many years of working the area.



The simple gravity map above shows the location of the Levantine basin in relation to the Nile delta on its SW side and the Larnaca-Latakia ridge systems to the north which mark the southern extent of the Anatolian plate where it collides with the African plate.
While the seismic section below illustrates the dramatic change from onshore Carbonates to offshore sediments and prospectivity.



While the recent discoveries at Tamar and Dalit are in Lower Miocene turbidite sands, there are a wide variety of play types contained within the basin from Post Messinian down to Jurrasic and maybe even deeper. The strike line below through the central part of the basin shows a number of very interesting leads.



This talk will show some regional lines to illustrate the braod structure of the East Med put this important discovery into context for offshore Israel, show what it implies for the local geological section and hydrocarbon potential of the basin, and then illustrate the wider potential of the now proven play around the Levantine basin and greater East Mediterranean Region.

Origin of Lower Pliocene Remobilized Deepwater Mounded Deposits, Yafo Formation, Levantine Basin, Southeastern Mediterranean Sea

Andrew Fuhrmann[1], Paul Weimer[1], Renaud Bouroullec[1], **Michael Gardosh[2]**, Henry Pettingill[3], Andrew Hurst[4]

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[4]*Department of Geology, University of Aberdeen, Scotland UK*

A series of wells drilled in the southeastern Mediterranean Sea offshore Israel (Fig. 1), penetrated thick sand layer at the base of the Plio-Pleistocene Yafo Formation. The Yafo Sand Member was deposited in submarine turbidite fans and lobes at the mouth of the Afiq and el-Arish canyons (Fig. 1), during the rise of the Mediterranean that followed the Messinian salinity event. Part of the Yafo sand layer was later remobilized, resulting with the formation of large mounded complexes.The Andromeda-1 dry hole that was drilled into one of these mounds (Fig. 2), penetrated 400 m thick section of very fine to fine-grained quartz sand with some interbedded claystone (Fig. 3). A 3D seismic volume that covers the Andromeda area and one well log suite were used for a detailedstudy of the morphology, structure and evolution of this unusual feature.

The Andromeda Mound Complex (Figs. 2, 4) is composed of fifteen individual or small groups of mounds [A-O]. All of the mounds are confined to the lower Pliocene Yafo Sand Member stratigraphic interval. The fifteen large, high net-to-gross mounds are separated into three distinct groups, based on both their internal and external seismic farcies. The Group 1 mounds [A-H] (Fig. 2) are structurally the simplest and most easily interpreted. The thickening of the Yafo Sand Member is typically the result of a single thrust fault or box fold. The mounds of Group 2 [I-J] (Fig. 2) are larger and more structurally complex than those in Group 1. They contain numerous faults and also have an element of growth-related sediments (Fig. 4). The Group 3 mounds [K-O] (Fig. 2) are the most difficult to interpret. The internal structure and stratigraphy of the mounds classified in this group have extremely low to high amplitudes but discontinuous seismic reflections. No definitive internal structural or stratigraphic interpretation was possible for the Group 3 mounds.

Our model for the genesis of the Andromeda Mound Complex is based on the combined effects of several factors: (a) the formation of pre-Messinian pockmarks, (b) more extensive up-dip initial Messinian Evaporite deposition, (c) the deposition of the turbidite sands of the Yafo Sand Member above the low gradient top Messinian surface, (d) lower Pliocene Syrian Arc uplift, which created conduits for undersaturated, low-salinity fluid migration into the Messinian Evaporites, (e) variable rates of evaporite dissolution within the study area, (f) mass-movement of individual block of the Yafo Sand Member along the basal detachment surface into collapse features associated with evaporite dissolution, (g) and continued Syrian Arc uplift and Messinian Evaporite dissolution resulting in the inversion of the mounded portions of the Yafo Sand Member and overlying sediments.

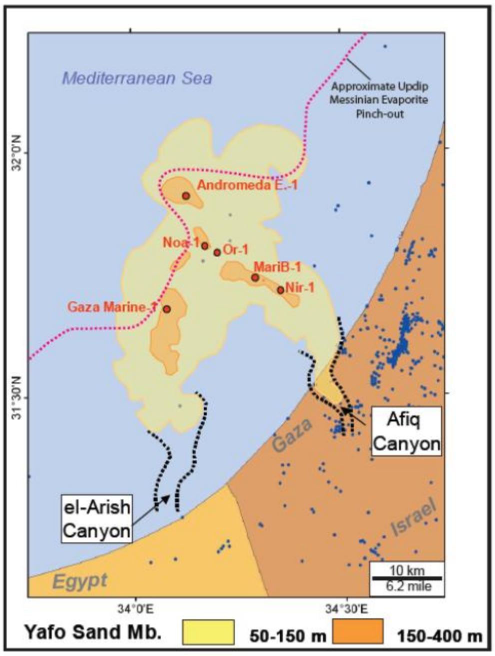

Fig. 1

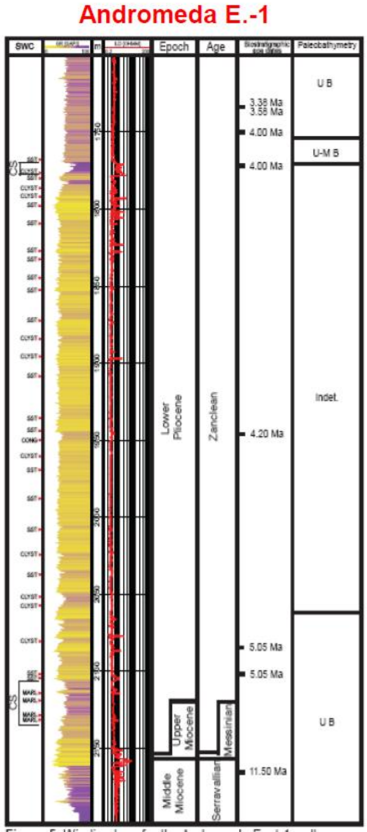

Fig. 3

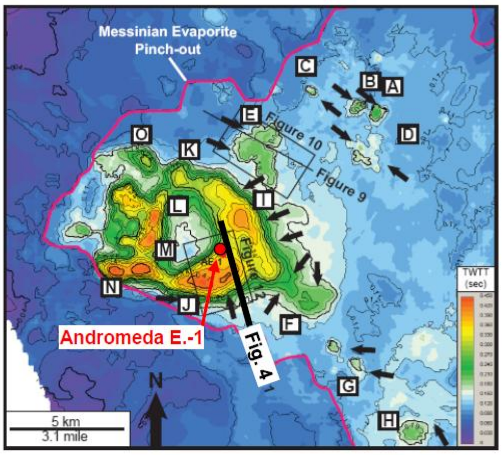

Fig. 2

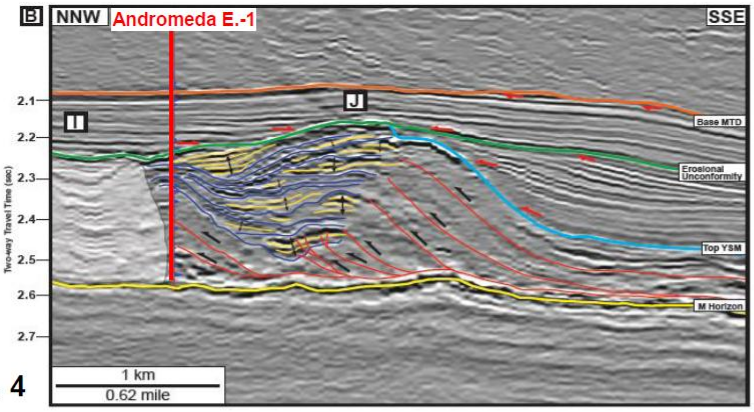

Fig. 4

Messinian Erosional Surface around the Levantine Basin.

Mocochain Ludovic[1/2], Clauzon Georges[3], Robinet Jérémy[2], Blanpied Christian[3], Suc Jean-Pierre[2], Rubino Jean-Loup[3],Gorini Christian[2], Al Abdalla Abdulkarim [5], Azki Fawaz [5]

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[3]*C.E.R.E.G.E. (UMR 6635), Université Paul Cézanne, Europôle de l'Arbois, BP 80, 13545 Aix-en-Provence Cedex 04, France*
[4]*TOTAL, TG/ISS, CSTJF, Avenue Laribeau, 64018 Pau Cedex, France.*
[5]*University of Tishreen, Lattakia, Syria.*

Recent studies in three areas in the Eastern Mediterranean region, especially in the basins of Hatay (Turkey), Lattakie (Syria), and Psematismenos (Cyprus) basins confirm the presence of the Messinian Erosional Surface which separates the uppermost Miocene deposits from the Pliocene ones clearly inbedded within the latters.

Chronologically, three main sedimentary and morphological features characterize this unconformity.

The first cartography of this unconformity and a systematic effort in chronostratigraphy in the Rhône Valley established that it is related to a fluvial erosion responsible for the presence of the now well-known Messinian fluvial canyons in relation with the peak of the Messinian Salinity Crisis. Similar canyons have now been identified in many places in Eastern Mediterranean region, truncating all the pre-existing rocks with the peculiar fluvial erosional pattern.

On the edges of the canyons, the Messinian Erosional Surface impacts the previously deposited Messinian marginal evaporites which date from the first step of the Messinian Salinity Crisis. Products of this erosion are often locally preserved along the canyons edges and made of breccias with blocks of variable size of gypsum and other pre-Messinian rocks. They deposited during debris flows events along the edges of the canyon walls, the only part visible in outcrops.

The Pliocene marine reflooding of the Mediterranean Basin resulted in large scale Gilbert type fan delta complexes infilling the Messinian canyons with a prograding sedimentary process. The most spectacular one developed in the Nahr El Khabir Valley in northern Syria.

The recent identification of these three components in three basins of the Eastern Mediterranean region fit very well with the generally accepted scenario of the Messinian Salinity Crisis in the Western Mediterranean (Clauzon *et al*., 1996; CIESM, 2008).

Preliminary observations suggest that the scenario can be validated and applied also in the Antalya and Adana basins in southern Turkey.

This model consists in a two distinct steps of the Messinian Salinity Crisis: 1- circum-Mediterranean deposition of marginal evaporite between 5.96 and 5.6 Ma in suspended basins, and 2- the downcutting of the Messinian fluvial canyons between 5.6 and 5.32Ma ending with the Pliocene marine reflooding.

Structural Development of the Latakia Ridge and Adjacent Basins Based on Recent Long-Offset Seismic Aquisition Offshore Syria

S. A. Bowman, **S. R. Toothill**, *CGGVeritas*

The Lataika Ridge is a major NNE-SSW trending structural lineament forming the eastern extent of the Cyprean Arc which delinieates the plate boundary between the African and Eurasian plates offshore Syria within the Eastern Mediterranean. It is by far the most important structural lineament offshore Syria. It seperates the Levantine Basin above the African plate to the SE from the Cyprean and Latakia 'piggy-back' basins above the Eurasian plate to the NW. The Iskenderun Basin can also be observed offshore Syria further to the NW above the Eurasian plate although its eastern boundary with the Latakia Basin is poorly defined and somewhat ambiguous. The Latakia Ridge has a complex tectonic history involving each type of plate boundary, Divergent, Convergent and Transform, during its structural development

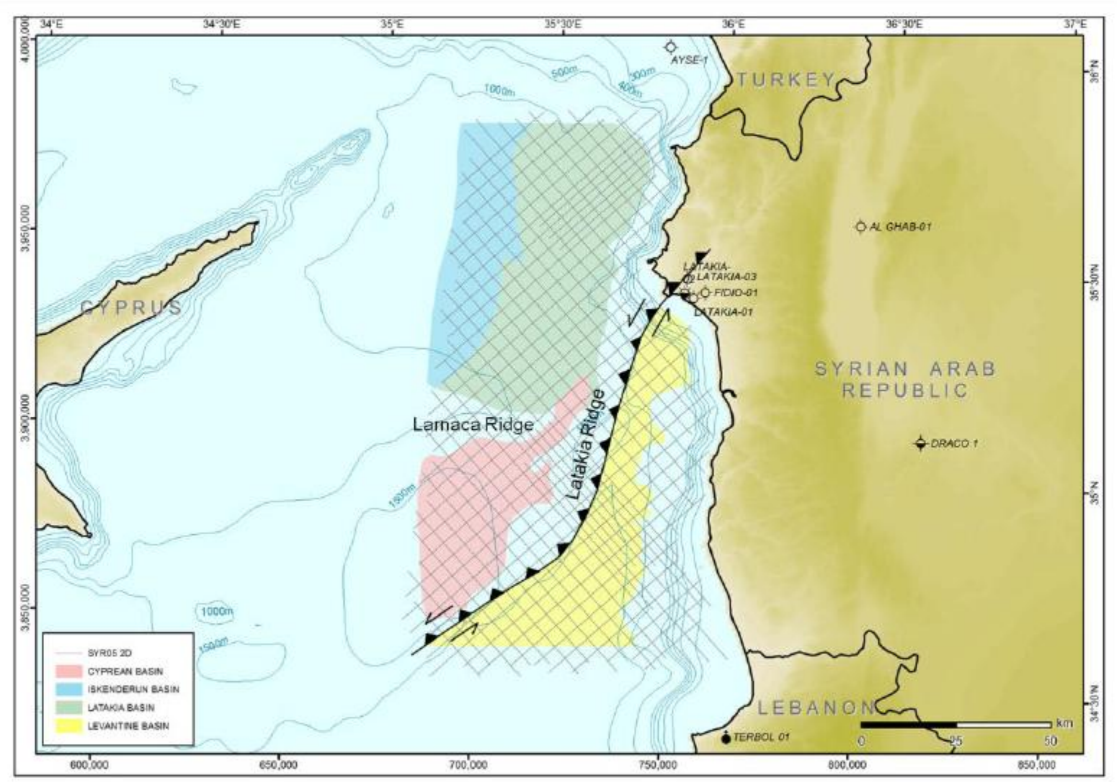

Figure 1: Location map showing the seismic data coverage and basins offshore Syria

Although the Latakia Ridge was not formed until the late Cretaceous its history can be dated back to the initial rifting of the Neo-Tethys during the late Triassic to early Jurassic (Robertson 2007). Early rifting was was controlled by NE and NNE trending listric extensional faults transversely bounded by orthogonal NW trending right-lateral transform faults (El-Motaal and Kusky, 2003). Neo-Tethyan rifting is interpreted to have continued through to the early Cretaceous punctuated by a period of quiescence and passive margin development during the mid Triassic to late Jurassic (Robertson, 2007). The final Neo-Tethyan rifting stage during the late Jurassic to early Cretaceous is marked by a period of sharply accelerated rifting associated with either rift-related or plume-related volcanism (walley, 2001; Sawaf et al., 2001; Robertson, 2007) which can be observed offshore Syria withing the Levantine Basin.

During the early and mid Cretaceous the rifted Neo-Tethyan half-grabens were largely infilled and were transgressed during the Cenomanian with deposition of marine marls, carbonates and chalk across the Latakia Ridge. Severla prominent seismic markers have been interpreted across CGGVeritas's long-offset 2D seismic data offshore Syria including in the mid Cretaceous (Cenomanian) and top Eocene horizons. An isopach map generated between these two horizons shows that there was relatively uniform deposition during this time across the Latakia Ridge with some thinning and onlap onto tilted Neo-Tethyan fault blocks. This is a key observation because it indicates that the Latakia Ridge was not a prominent structural feature during this time.

The tectonic setting of the eastern Mediterranean changed from and extensional regime to a compressional regime during the late Cretaceous due to the closure of the Neo-Tethys and the coincident collision of the African and Eurasian plates. The principle stress direction during the closure of the Neo-Tethys is interpreted to have been oriented NNW-SSE roughly parallel to the previous principal stress direction during the opening of the Neo-Tethys (El-Motaal and Kusky 2003). This resulted in the re-activation of earlier extensional faults under compression as the Eurasian plate was thrusted up over the African plate. Thrusting initiated within older sediments and propagated up through the mid Cretaceous to Eocene layers with clear examples of fault-propagation folds observable along the Latakia Ridge.

There has been up to 3 km or more of displacement as a result of uplift and thrusting. The intensity of the thrusting and deformation along the Latakia Ridge increases to the NNE towards the Dead Sea Transform. The Latakia Ridge continues onshore into northern Syria where the Baër-Bassit ophiolite is exposed along the coast. It represents a portion of the Neo-Tethyan oceanic crust which was thrust up onto the Latakia Ridge during the Maastrictian. There are close similarities between the Baër-Bassit ophiolite and those of Cyprus, Hatay and Oman indicating that they belong to the same geotectonic structure (Parrot, 1980). Given the regional occurrences of ophiolites within the Eastern Mediterranean there are likely further examples of ophiolites along the offshore Latakia Ridge although these are indistinguishable on the 2D seismic data.

A compressional regime is thought to have continued through to the late Miocene (Hall et al., 2005), albeit less intense. Following a reorganisation of plate movements during the late Miocene to early Pliocene the Latakia Ridge changed from a collisional zone to a sinstral strike-slip zone characterized by positive flower structures which have lead to further uplift along the Latakia Ridge which continues to this day.

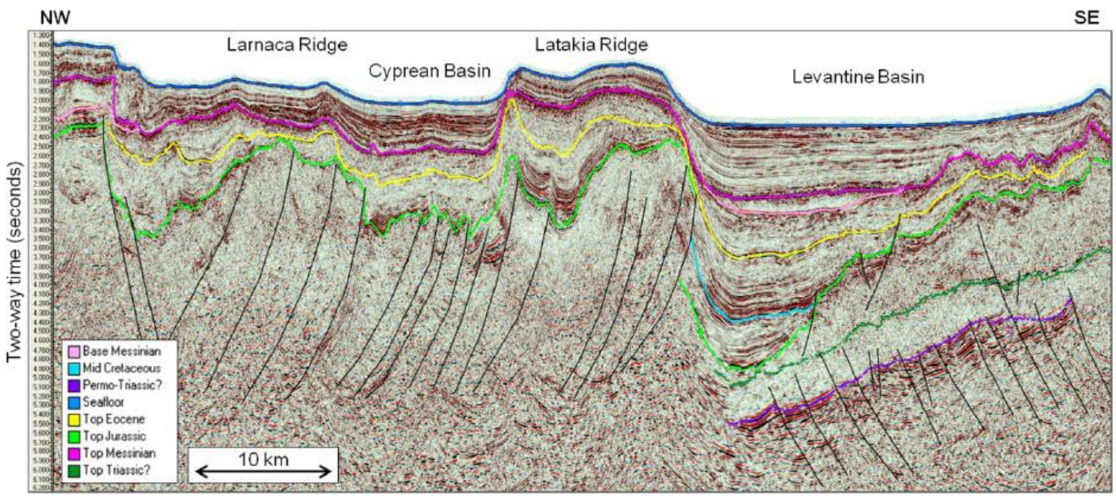

Figure 2: Seismic section across the Latakia Ridge and adjacent Levantine and Cyprean Basins.

Karstogenesis in Messinian Evaporites

Ludovic Mocochain [1, 2], Georges Clauzon [3], Jérémy Robinet, Christian Blanpied [3], Jean-Pierre Suc[2], Jean-Loup Rubino[3], Christian Gorini[2], Abdulkarim Al Abdalla[5], Fawaz Azki[5]

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[5]*University of Tishreen, Lattakia, Syria*

Several Basins in the Mediterranean realm contain evaporitic series dating from the early phase of the Messinian salinity crisis. These series are well documented in the Sorbas and the Vera basins in southern Spain, as well as in the Altanissetta basin in Italy. In the eastern Mediterranean region these series have also been deposited in the basins of Hatay in souothern Turkey, Lattakie in northern Syria, and in several sub basins in Cyprus, among them the Psematismenos sub basin features will be highlighted.

The morphologic and sedimentary study of the evaporate series lead to identify karstic features that are fossilised by Pliocene aged shale. These new observations in this part of the Mediterranean extend to the east of the presence of such morphologies.

The generalised presence of such karstic features around the Mediterranean basin thus corroborate the fact that the general lowering of the sea level occurring during the second phase of the salinity crisis between 5.6 and 5.32 Ma is reflected by a morphologic response, i.e. the formation of karstic conduits. This then support the generalisation of the two phase model presented in the western Mediterranean by Clauzon et al., 1996.

Poster Presentation Abstracts

(in Alphabetical order)

Project "CoCoCo" – Incipient Continent-Continent Collision between the Eratosthenes Seamount and the Anatolian Plate

Axel Ehrhardt[1], Christian Hübscher[2], Maria S. Merian cruises MSM14/2 & 14/3 Scientific Parties

[1]*BGR Hannover*
[1]*Institute of Geophysics – University of Hamburg*

In early 2010 two marine geophysical surveys took place in the subduction-collision zone south of Cyprus in the areas of the Eratosthenes Seamount and Hecateus Ridge. The second survey included also an amphibian experiment crossing the Anatolian Plate from Cyprus to Turkey.

The analysis and interpretation of the data will be realized in the project "Continent-Continent Collision (CoCoCo)". This project strives for a quantitative understanding of earth processes related to incipient continent-continent collision, exemplified on the instance of Cyprus and the Eratosthenes Seamount (ESM) in the eastern Mediterranean where collision was initiated in the early Pleistocene. The 3D-geometry of the down thrusted crustal block of the seamount will be examined mainly by the analysis of the dense 2D multi-channel seismic data set incorporating the refraction (wide angle), gravity, magnetic, magneto-telluric and high resolution multi-channel seismic data. The 2D-geometry of the uplifted and overriding Cyprus-Anatolian Plate will be unraveled by the analysis of wide-angle reflection / refraction seismic profiles. High-resolution reflection seismics, echosounder and multi-beam data represent the key for the in-depth understanding of the impact of the structural shortening on the stratigraphy, salt tectonics, slope stability and fluid migration of the interjacent sedimentary succession.

The data acquisition for this project was carried out aboard the German research vessel *Maria S. Merian* from January to April 2010 in two subsequent surveys. The first survey was focused on the acquisition of a dense and regular 2D reflection seismic data set across the Eratosthenes Seamount and the western Levante Basin. We used a streamer with 3900m active length and two G-Gun arrays as source with a total volume of 3100 in^3. A total of 4200 km of 2D lines were acquired with 5 nautical miles line spacing in a regular pattern covering the Eratosthenes Seamount area the on to the western Levantine Basin and the continental slope of Cyprus. In addition two wide angle seismic lines and one marine magnetotelluric line were acquired as well as gravity, magnetic and hydroacoustic data.

The second survey focused on the Eratosthenes Seamount, the trench between the Seamount and Cyprus as well as on the Hecateus Ridge. High resolution reflection seismic lines were acquired together with hydroacoustic data and gravity and magnetic data. Four wide angle reflection / refraction seismic lines with up to 30 Ocean Bottom Seismometer (OBS) and a source volume of 6000 in^3 were crossing the transition from the Eratosthenes Seamount to the Hecateus Ridge and Cyprus as well as from Hecataeus Ridge to the Levantine Basin.

In our presentation we will present first results based on multi-beam and reflection seismic data. According to our findings, the continent-continent collision caused compressional regime results in the flexure of the Eratosthenes Seamount, uplift of Cyprus and Turkey and accordingly an increased tilt of the facing slopes. The collision reactivated Mesozoic fault lineaments in the Levantine Basin like the Baltim-Hecataeus-Line and created the Hecataeus Rise. Shortening in the non-consolidated Messinian to Holocene sediment succession between the seamount and Cyprus results in faulting, folding and compressional salt diapirism. The increase in pore pressure causes fluid migration and mud volcanism. Slope tilt and earth-quakes trigger mass wasting (slumping). All of these processes shape the seafloor morphology and interact with the bottom current circulation, which is reflected by sediment drift deposition, sediment remobilisation and erosion, which facilitates again mass wasting.

Deep Rooted Fault Systems in the Levante Basin / Eastern Mediterranean

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New geophysical data shed light on the basement morphology and related deep rooted fault systems in the Levant Basin / Eastern Mediterranean. Residual gravity anomaly maps and the derived morphostructure of the crystalline basement indicate that the Levante Basin consists of two different domains. The northern basement domain is limited to the north by the Cyprus Arc and it is characterized by a generally smooth basement topography. Onshore, this domain corresponds to the Galilee-Libanon block. The southern domain is dominated by NE-SW Tstriking horst-graben structures dissected by NW-SE trending faults and it correlates onshore with the Judea-Samaria (south) block. No evidence for sea-floor spreading has been found.

Both domains are divided by a fault line striking between Mount Carmel and southern Cyprus. The presence of the Carmel-Cyprus fault and two different crustal blocks north and south of it is further corroborated by the distribution of earthquake hypocenters and upper mantle velocity anomalies. The internal deformation pattern of Messinian evaporites suggests that this fault was active during the Messinian. The residual bathymetry of the Levante Basin further points towards active sea-floor deformation along a NE-SW striking fault which has been called “Damietta-Latakia Line” by other authors.

We further discuss the presence and activity of deep rooted faults in the Levant Basin. This topic gained increasing attraction because all reported Plio-Pleistocene gas and gas condensate discoveries as well as observed water-bottom oil seeps are, as other authors stated, proximal to deep-seated, near vertical paleo-faults that extend through the entire stratigraphic column, inclusive of the Messinian salt. It has been assumed that these near-vertical faults represent conduits for rising hydrocarbon.

However, the interpretation of near-vertical faults in the subsalt domain is ambiguous. Owing to the strong seismic velocity contrast between the salt and its overburden small scale thickness variation of the Messinian salt cause imaging artefacts like velocity pull-downs which are than erroneously interpreted as faults. We discuss this problem by means of model-based prestack-depth migrated seismic data and ray-tracing. E.g., reflection disruptions beneath pop-up structures in the Messinian evaporites of the central basin have been previously interpreted as deep-seated faults. Our results show that some of these features represent artefacts and no faults. In contrast to these findings we found that the geometry of salt rollers beneath the eastern basin margin is not only controlled by thin-skinned tectonics but also by deep rooted faults beneath.

Geophysical Signature of Seepage Activity at an Exceptional Site of Brine, Gas and Mud Expulsions in the Deep Waters off North-Western Egypt

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The Nile Deep Sea Fan hosts numerous active fluid escape structures associated with large gas emitting mud volcanoes, authigenic carbonates, pockmarks and briny mud volcanoes. During the MEDECO2 expedition (HERMES Program), some of these seeps were investigated with the research vessel *Pourquoi pas?*. Subbottom profilers and water column imageries were acquired with a CHIRP (1,8-5,3 kHz) and an EA600 echosounders (38 kHz), respectively. Near bottom geophysical investigations were conducted with the use of the *Victor* ROV (Remotely Operated Vehicle). *Victor* was equipped with 1) a Reson 7125 multibeam system operated at 400 kHz for high-resolution bathymetry and backscatter seafloor imagery and 2) an OTUS camera for long range optical black and white imaging. We present here, in the view of the seepage activity, the geophysical characterization of a large mud volcano caldera complex called Menes located in the Western Nile Province. Extending by 3000 m water depths with a diameter of ~8 km, the Menes Caldera contains several active mud volcanoes. Chephren and Cheops mud volcanoes located in the south and roughly in the centre of the caldera, respectively, are the most spectacular (Fig. 1).

The Chephren structure is composed of two craters of 250 to 300 m in diameter each (Fig. 2). The northern crater is filled up with muddy brine sediments. Within this brine lake, salinity reaches high values (120 to 145 psu). Gas analysis in the water column revealed high methane concentrations, 0.4 to 5.6 mmol/l. The temperatures within the lake indicate uniform values with depth, reaching ~60°C. In contrast, the southern crater is relatively cold with thermal gradients similar to background values. This crater 10 to 20 metres deep corresponds to a former brine lake that is at present inactive in terms of brine seepage. Running outflows emitted from the northern brine lake are visible all around the mud volcano with the most recent activity located at the northern side. The seepage activity there corresponds to highly unstable seafloor environment. The fauna is mostly restricted within the close periphery of the brine lake. The small and narrow subcircular plateaus that composed the upper part of the crater attract many crabs and polychaete tubeworms. Within the brine lake, the less unstable areas appear to be characterized by dense accumulation of white filaments that correspond to sulfur associated with arcobater, sulphide oxidizing bacteria.

Cheops mud volcano, similarly to Chephren, exhibits high salinity values and methane concentrations (respectively 210 to 240 psu and 2.4 to 3.7 mmol/l). Cheops mud volcano, with an average diameter of ~250m, is composed of a brine lake surrounded by an almost continuous depression ring, covered in some places with recent outflows. This latter probably corresponds to a former edge of the lake. As previously suspected, the inner domain of this mud volcano correlates with an almost flat top where numerous muddy brine pools, decimetre to metre in scale and covered by whitish filaments, were observed at the surface of the lake. An average temperature of ~43°C was recorded from the surface of the lake down to 440m through a very unconsolidated material. The uniformity of the temperature profile with depth clearly supports the occurrence of first order active convection within a mud/brine/fluid conduit.

The newly acquired geophysical dataset and high-resolution seabed photographic images brought more details, in particular, in the seabed morphology and spatial distribution of the seepage activity. The seepage activity is not restricted to the major mud volcanoes. The entire caldera is disturbed by fluids associated in depth with numerous faults and fractures and at the seabed with brine-related features. Acoustic anomalies were detected in the water column using the 38 kHz echosounder of the R/V *Pourquoi pas?*. An echo contiguous to the seafloor was recorded up to 600 m above the seafloor at the south-western border of the Menes. This acoustic anomaly is interpreted as a gas flare associated with a listric fault in relation with salt tectonics.

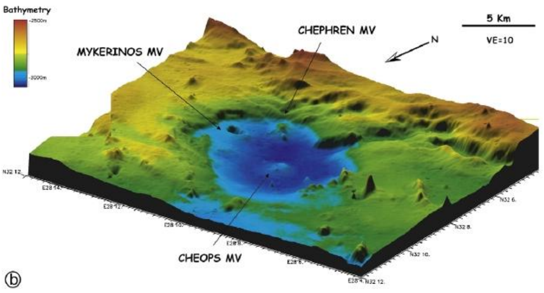

Fig. 1. 3D bathymetry block of the Menes caldera and surroundings (NAUTINIL multibeam Simrad EM12 data). VE stands for vertical exaggeration.

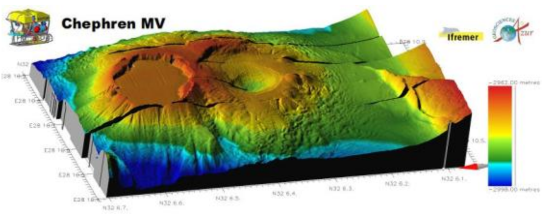

Fig. 2. High-resolution bathymetry (1m pixel grid) map of the Chephren mud volcano acquired in 2007 as part of the MEDECO2 cruise with a Reson 7125 multibeam system mounted on the *Victor* ROV and operated at 400 kHz.

Offshore and Onshore Evolution of the Nile during the Messinian Salinity Crisis

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The Mediterranean Basin has not always been connected to the Atlantic Ocean. During the Messinian salinity crisis (MSC), the Mediterranean Sea became progressively isolated by a complex combination of tectonic and glacio-eustatic processes. The amplitude and number of large water level fluctuations, dependent on hydrologic flux, in the isolated Mediterranean is still controversial, despite numerous geological investigations. A dramatic sea-level fall occurred during part of the crisis and deep erosion has been observed on the Mediterranean margins as well as on the continent. This resulted in several incised valleys of Messinian age around the Mediterranean. A record of this event can be observed on the Egyptian margin. Onshore and offshore seismic refraction profiles along the Nile basin have shown the presence of at least two Miocene erosional unconformities (Rouchy and Saint-Martin, 1992). Pre-Messinian facies are represented by pelitic sediments of the deep sea or outer shelf that ends abruptly in Messinian fluvio-deltaic series and evaporites (Ghisetti & Vezzani, 1983). A fairly pronounced emersion followed, accompanied by phenomena such as gravity gliding and spreading, gravity instability and failure, sub-aerial erosion and deposition of evaporites. The end of the Messinian and the passage to the Pliocene was marked by basal sand deposits lying on this erosional surface. The sandy terrains are progressively followed by Pliocene open-sea clays. The offshore seismic profiles show that during the Messinian a 1km thick terrigenous supply filled a deep sector of the Mediterranean basin in front of the Nile delta. Because there is no evidence of tectonic activity during this period, the deposition of a large amount of sand is hypothesized to have been caused by morphologic rejuvenation of the landmass due to the Messinian Salinity Crisis and sea level drop. Reconstruction of the Messinian palaeodrainage indicates that the Nile was entrenched as far as 1200 km inland (Gargani & Rigollet, 2007). Beneath the modern delta the thalwegs of the ancient Messinian river valley lies as much as 2500 m below the present sea level. Here, we show that the erosion and the large sea-level fall generated a significant uplift along the Nile River delta valley, due to isostatic rebound. Quantitative results suggest that the uplift of the Egyptian margin and the Nile valley flanks may have triggered an enclosed environment during the Messinian salinity crisis (MSC). We estimated a mean rate of regressive erosion of -2.5 m/y along the River Nile during the MSC and of 1.25 and 0.4 m/y for the smaller rivers. The water discharge of the River Nile necessary to trigger this erosion rate was at least 5 to 25 times greater than the water discharge of smaller rivers. Furthermore, the observation of 3 – 5 erosional surfaces in the Nile delta (Eastern Basin) provides new elements for understanding the dynamics of the MSC. Our model demonstrates that several short-lived mean water level fluctuations within the Mediterranean, may explain the presence of discontinuous river profiles at ~500 m and ~1500 m found in the Western Basin, as well as the existence

Mapping Crustal Thickness and Oceanic Lithosphere Distribution in the Eastern Mediterranean using Gravity Inversion

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Oceanic and continental lithosphere distribution within the eastern Mediterranean is not well understood. Gravity inversion, incorporating a lithosphere thermal gravity anomaly correction, has been used to map the crustal thickness and lithosphere thinning factor for the eastern Mediterranean from which the distribution of oceanic and continental crust and the ocean-continent transition location determined. Data used in the gravity inversion are bathymetry, free-air gravity and sediment thickness data from Smith and Sandwell (1997), Sandwell and Smith (2009) and Laske and Masters (1997) respectively. Gravity inversion results are dependent on the age of oceanic lithosphere and continental breakup due to the inclusion of the lithosphere thermal gravity correction; however, these ages are uncertain for the eastern Mediterranean. Gravity inversion sensitivities to break-up ages of 225Ma (late Triassic) and 100Ma (early Cretaceous) have been examined.

Gravity inversion results show the eastern Mediterranean basin regions to exhibit thinner crustal thicknesses and higher thinning factors with respect to the surrounding area. Crustal thicknesses range between 5 and 10km for the Ionian Sea and the Herodotus Basin of the eastern Mediterranean consistent with these basins being underlain by oceanic or highly thinned continental crust. Predicted Moho depths from the gravity inversion are in accordance with published Ionian Sea ESP results (Voogd et al, 1992) and suggests that the gravity inversion reference Moho depth increases to the north, which we attribute to subduction dynamic subsidence. Calibration of gravity inversion Moho against ESP results show a trade-off between break-up age and reference Moho depth; a Cretaceous age ocean requires a larger Moho reference depth than a Triassic age ocean.

The relationship between the Cretaceous North African rift system (Benue Trough, Chad, CASZ and Sudan basins) and the eastern Mediterranean basins has been examined, however continuity between this southern Cretaceous rift system and the eastern Mediterranean basins is not seen in the lithosphere thinning factor maps from gravity inversion. If the Ionian Sea is of Cretaceous age then it is more likely linked to Cretaceous rifting and sea-floor spreading to its north and north-west.

Interaction between Salt Tectonics and Deep-Seated Tectonics: Examples from Eastern Mediterranean Sea

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During Messinian times (Latest Miocene) the Eastern Mediterranean region has undergone a strong desiccation event, which has led to the deposition of thick evaporite sequences in bathymetric depressions (Hsü *et al*., 1977; Sage & Letouzey, 1990). At the same period, and in response to a general northward convergence of the African plate with respect to the Anatolian/Aegean micro plate, the Eastern Mediterranean basins were still affected by active shortening and thrusting along the Hellenic and Cyprus Arcs and within their associated accretionary prisms. Thus thick piles of Messinian evaporite were deposited along the northern and southern sides of the two accretionary prisms, the Mediterranean Ridge and the Florence Rise, which acted as structural highs (Sage et Letouzey, 1990). The presence of this ductile and weak layers triggered later on gravity-driven deformations within the Plio-Quaternary (PQ) cover. Systematic geophysical surveys conducted in the area (Prismed II in 1998, Fanil in 2000, Medisis in 2002 and Simed/Medor in 2004) allowed a to complete a nearly full sea floor mapping of the Egyptian continental margin (Nile deep fan), of the Mediterranean Ridge, the Florence Rise and of the Hellenic trenches and surrounding features. Analysis of this huge morpho-bathymetric data set stresses the crucial play of shallow salt tectonics on the shaping of the seafloor deformational pattern of the Eastern Mediterranean convergent domains. We present and discuss structural and experimental analyses, which help to better understand the interactions between deep-seated and shallower gravity tectonics in the Eastern Mediterranean Sea.

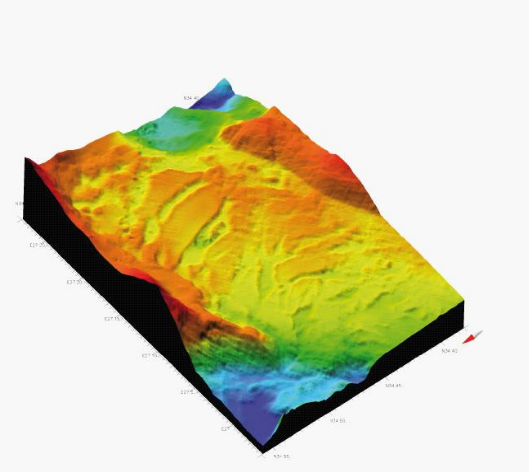

Figure 1. Example of sediment rafts gliding above salt towards the Pliny trench.

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