For a **Diver**   Every day is **Ocean Day**

ION Basin SPAN Seismic Data in the Mediterranean

CROP Repro – 4,700 km
acquired 80s-90s
4.5-6 km offsets
17-20s record

MS Repro –17,000 km
acquired '70s-'80s
2.4 km offsets
10-12s record, dynamite source

LibyaSPAN – ION acquired
2014 – 7040 km
10 km offsets
18s record, WiBand processing

LibyaRepro –38,000 km
acquired 2005
8.5 km offsets
10s record, WiBand re-processing
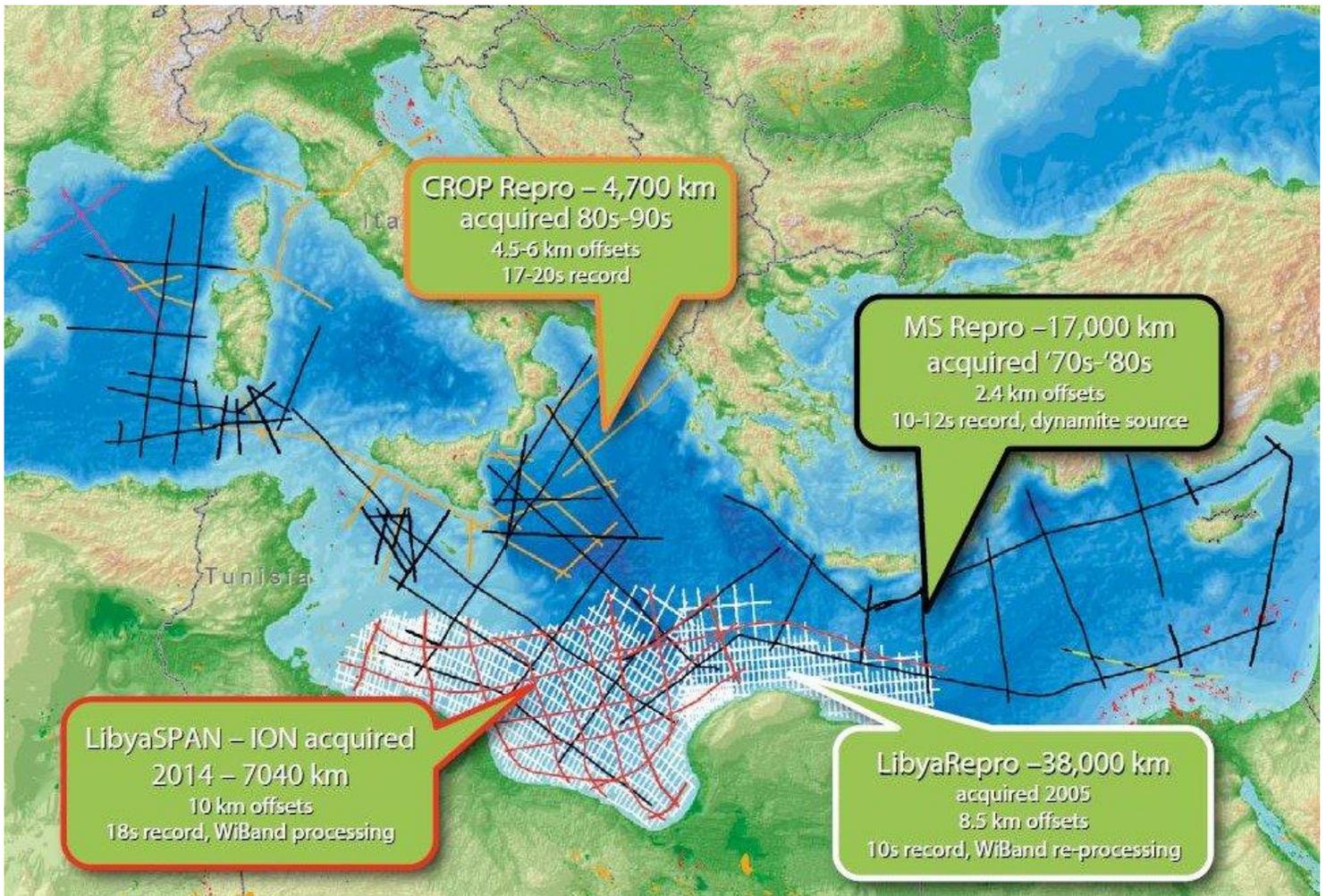
Survey locations in the Mediterranean. Image source: ION. Exploration in the Mediterranean Sea has experienced **significant renewed interest** over the last decade, with exciting, **play-opening discoveries in Israel, Egypt and Libya**. **ION** has taken an **innovative approach** in order to **rapidly** and **cost-effectively** develop an integrated dataset to aid understanding of the **whole Mediterranean**, which can be used as the framework for future exploration programmes and to challenge existing basin models. The dataset consists of **newly acquired BasinSPAN**™ data and reprocessed data from both industry and academic sources. These surveys have been

IN PARTNERSHIP WITH

processed concurrently to provide a **consistent velocity model** across the Mediterranean and generate a fully integrated **geological** and **geophysical interpretation** using **seismic**, **well**, **gravity** and **magnetic data**. ION has created a **unique dataset** in the region to support the next phase of exploration, with licence rounds expected in the near future.

Seismic Section from the Mediterranean. Data source: ION.

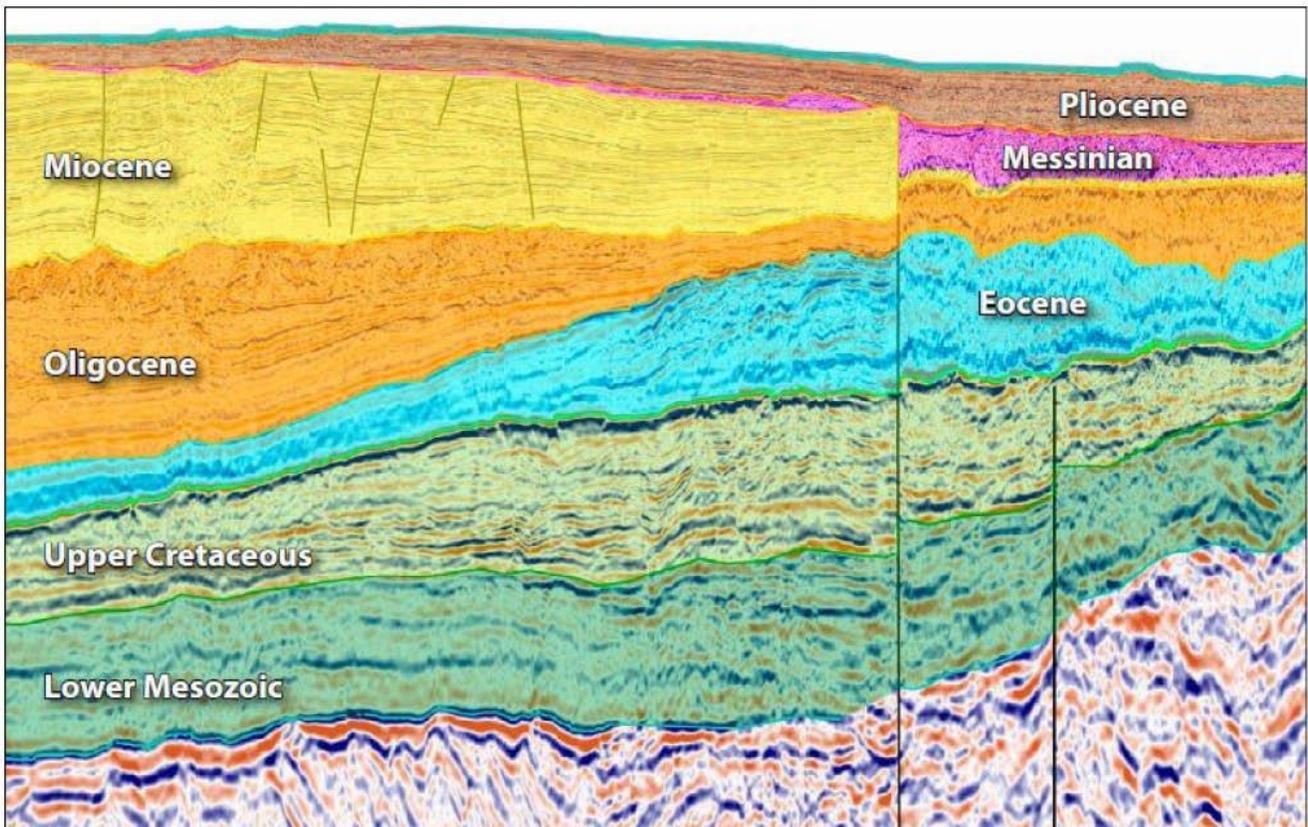**An Integrated Geological & Geophysical Interpretation of the Mediterranean**

Figure 1: Interpreted section of seismic outlined in black on foldout line (above). Image source: ION. The offshore Mediterranean basins are the focus of **renewed interest** since the 2008 discovery in **Libya**, the **Tamar** and **Leviathan** discoveries in **Israel**, and the recent **Zohr** discovery in **Egyptian waters**. **ION's** regional Mediterranean programme demonstrates the utility and exploration value of a **fully integrated seismic dataset and velocity model across the entire basin**. Interpretation of these data provides the context to correlate known discoveries into those new and complex underexplored areas.

Regional Geology of the Mediterranean Basin

The present-day configuration of the Mediterranean Basin is dominated by the Cenozoic collision of Africa and Eurasia, creating compressional and back-arc extensional tectonic settings. The current tectonic elements and basins have overprinted pre-existing Tethyan margins that stretch from Algeria to the Eastern Mediterranean and extend to the Arabian Peninsula. The **variability** in **basin types** and ages provide **significant**

hydrocarbonpotential for a wide variety of play types, with **source rocks** of Palaeozoic to Cenozoic age.

The Mediterranean contains several **well-known plays**: biogenic Pliocene gas offshore Nile Delta; salt-generated structural plays of the Sabratha Basin; and the Po Valley/Adriatic Sea gas play. There are also areas where commercial discoveries have been elusive and areas which have yet to be explored with the potential for new play types.

Exploration & Discoveries in Offshore Libya

*Figure 2: Example line in Cyrenaica area from reprocessed Libya dataset highlighting areas of improved imaging and features of interest. Image source: ION.*Offshore Libya has attracted exploration interest for some time. The prolific petroleum systems of Libya have generated **proven oil discoveries** of about 130 Bbo, the majority of this onshore. The offshore extensions of these petroleum systems are largely unexplored. The success of the 2005 EPSA IV licence round highlighted industry interest in the area and the subsequent **play-opening Arous Al-Bahar gas discovery** in the offshore **Sirt Basin** in 2008 **confirmed** the **continuity** of
the **onshore Cretaceous carbonate play** into the Sirt Basin. The potential of Eocene marls and limestone reservoirs lying unconformably on the Cenomanian and Turonian carbonate blocks remains poorly understood. Discoveries continue to be made in the more
developed **Sabratha Basin**,but **several structures and deeper targets remain undrilled**.
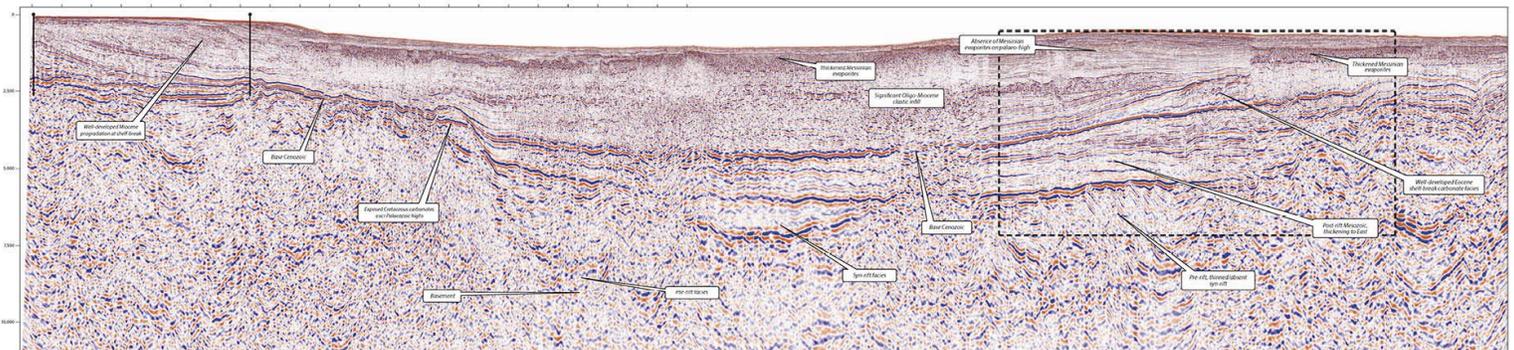
Given the **proven offshore extension** of the enormous reserves onshore Libya, creating an integrated depth-migrated seismic dataset and basin framework interpretation provides the basis for **future exploration**. The regional framework **LibyaSPAN™** data are infilled with 39,000 km of modern reprocessed 2D data. The processing
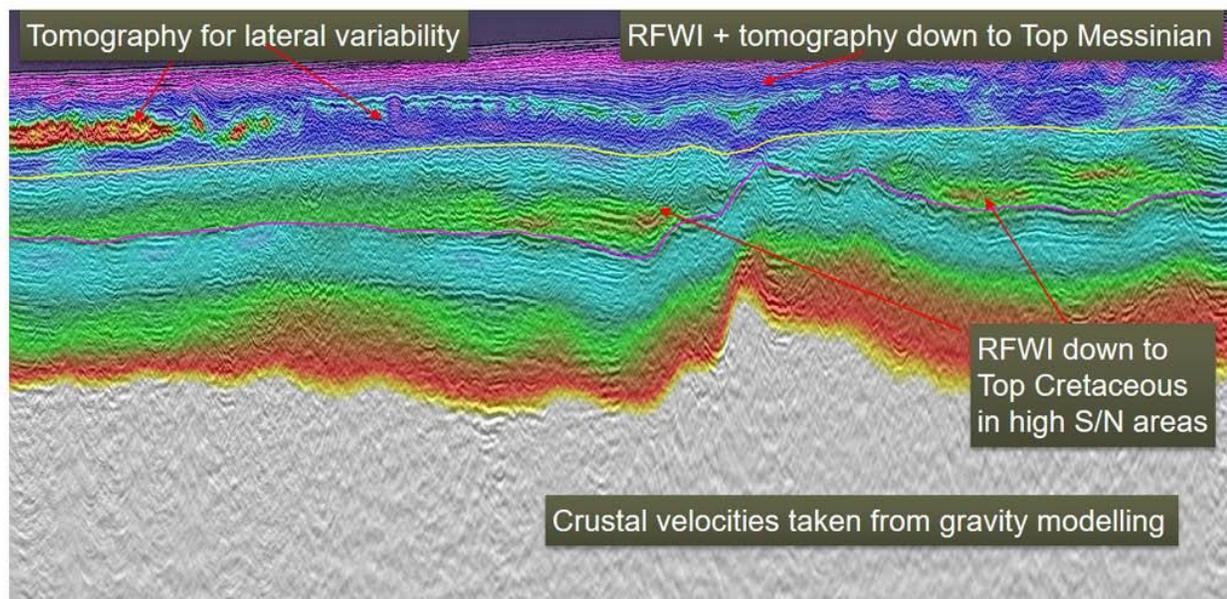
and imaging of these datasets are fully integrated and **calibrated** using **gravity**, **magnetic**, and **well controldata**. The **improved imaging** provides a database to identify **new prospects** and plays in the **Sirt** and **Cyrenaica Ridge** areas as well as the eastern margin of the basin. These data create the framework to develop a **new understanding** of the entire offshore system from crust to sediment in a basin-scale context and are vital to understanding the **petroleumpotential** of the offshore Libyan margin. (**See Figures 2 and 3**.)

Exploration & Gas Discoveries in the Nile Delta

*Figure 3: Example of improvement in imaging with modern processing offshore Libya. Image source: ION.*The **Nile**
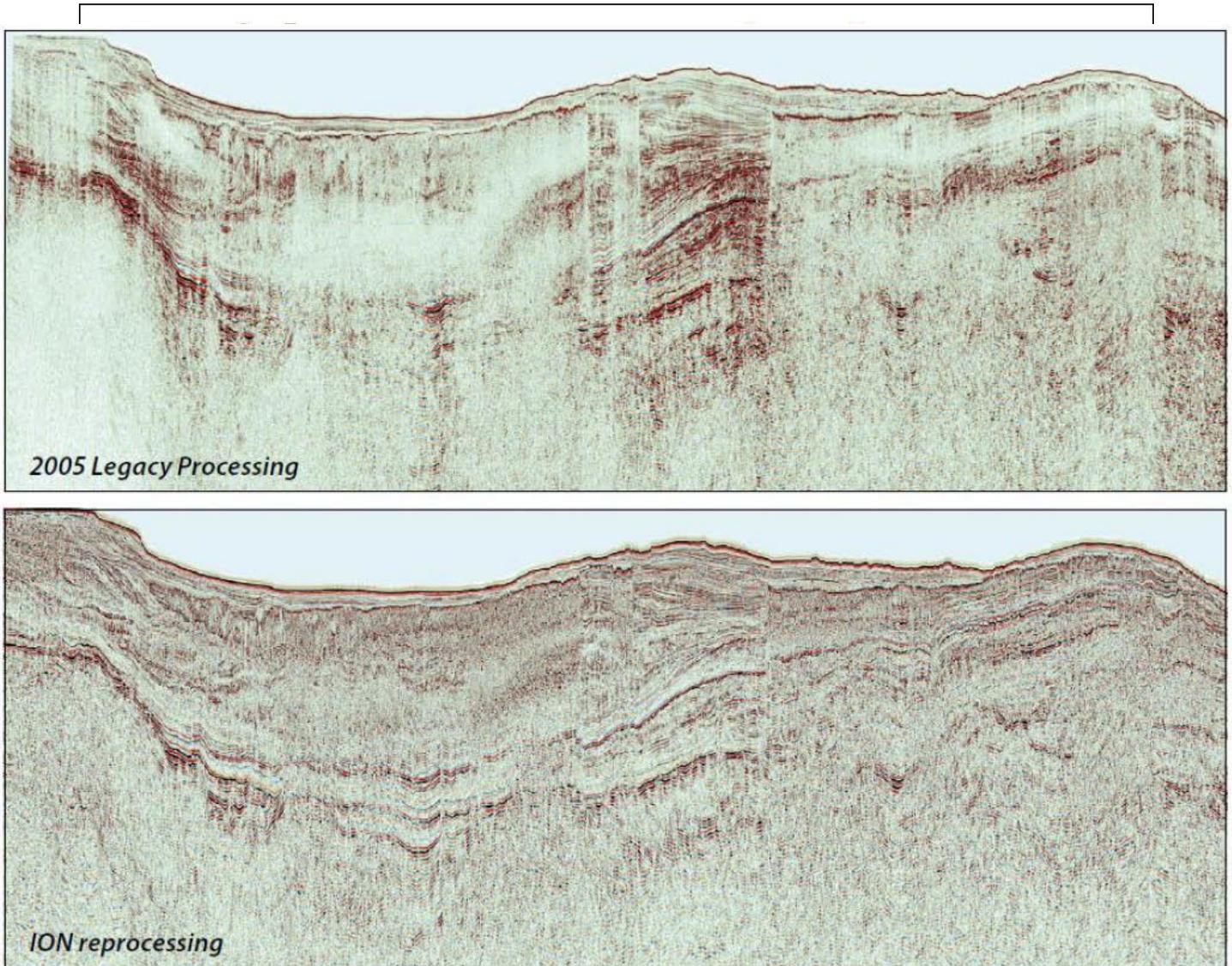
Delta region has undergone several phases of exploration, but is dominated by Plio-Pleistocene **gas discoveries** in stratigraphic and structural traps. Exploration of deeper Miocene and Oligocene strata has had varying success and has been slower to develop. However, even with the extensive dataset across the area, fundamental questions regarding deeper stratigraphy and structure still remain. Development of new exploration plays in deeper water and older stratigraphy requires a **better understanding** of the underlying basement

architecture and stratigraphy. **ION**, in **collaboration** with the **Egyptian Natural Gas Holding Company** (**EGAS**), acquired a deep, long-offset line across the central and western parts of the Nile Delta, imaged to 40 km depth. One of the critical observations from these new data is the **>12 km thickness** of sediment to the west of the Delta.

The **Nile Delta 2D** line was processed using **ION's WiBand™** broadband processing solution, which provides **deghosting** that enhances the bandwidth of the data by **recovering low-frequency** components of the data and performing multiple suppression prior to waveform inversion. **High resolution** non-parametric inversion (**GMO Tomography**) incorporating anisotropy combined with the use of full waveform inversion created the **detailed velocity mode**l in the complex strata below the Messinian salt (**Figure 4**). Interpretation of crustal events (basement and Moho) using the new migration velocities calibrated with potential field data were combined to **create high quality depth imaging**. The integration of these data (potential field, refraction and PSDM) support the interpretation, addressing questions of crustal structure and the nature of the basin development. **Recent discoveries** and the presence of thick sediment lend support to **source rock maturity** continuing beyond the areas previously predicted.

Central and Western Mediterranean Exploration

*Figure 4: Nile DeltaSPAN velocity model highlighting the modern techniques used to maximise the accuracy of the velocity model and improve the quality of the deeper imaging. Image source: ION.*Exploration successes in the offshore Ionian, southern Adriatic, and Sicilian Channel occurred predominantly from the 1970s to the 1980s. Oil discoveries within the Apulian platform were made in the 1990s and gas discoveries were made in the Gela foredeep of the Pelagian Basin beginning in the early 2000s. Despite intensive onshore and shallow water exploration, there remains **significant underexplored offshore potential**, including searching for known plays along strike and new play types.

Both the **North African** and **Southern Eurasian** margins developed as carbonate-dominated platforms on the margins of the **Tethyan Ocean**. The complex Mesozoic palaeogeographies (**shallow water platforms and intervening deep water euxinic basins**) were controlled by extensional phases and later inversion. **Proven hydrocarbon**plays in structural traps in the up-dip platform carbonates are thought to be sourced from basinal organic-rich mudstones.

Middle Eocene Alpine orogenic events across the margin resulted in the Apennine fold belt having an eastward migrating subduction system and the development of foreland and back-arc basins. The east–west trending Maghrebian thrust belt of North Africa, the Calabrian Arc and connected north–south trending Italian Apennines show significant variability in the width and deformation style along its strike. Progressively younger foreland fold-thrust belt settings characterise the compressional system and are **important** to **hydrocarbon generation** and **accumulations sourced** from either **terrigenous flysch** or **mature pre-Alpine Mesozoic strata**.
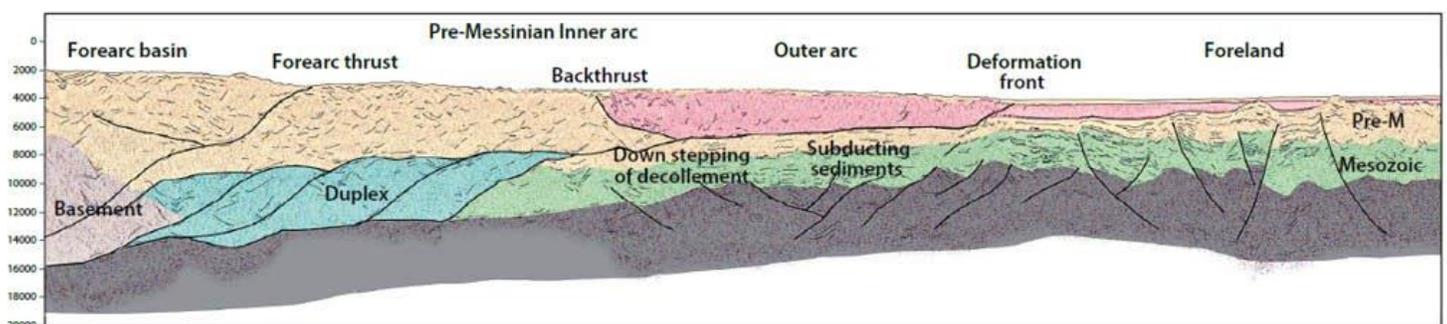
A New Look at New Seismic

*Figure 5: Geoseismic section (PSDM) of the Calabrian Arc from Sicily to the Ionian Abyssal Plain demonstrating the complex structure of the Arc with deformation younging towards the south-east. Thick deformed and undeformed Messinian evaporites dominate the Outer Arc and foreland. Improved sub-salt imaging provides uplift of the sediments and structures below. Image source: ION.*Reprocessing of **two legacy datasets**, MS (acquired 1970–82) and CROP (acquired 1988–95), using I**ON's BasinSPAN™** processing workflow, has been integrated into the **interpretation** and **regional velocity model**. These data span the complex and varied domains of the central and western Mediterranean basins, providing a **new look at the petroleum systems and multiple play types**.

Identified analogue plays on the **Apulian Platform**include karsted carbonate reservoirs and shelf-edge carbonate deposits. Fractured carbonate reservoirs in sub-thrust plays sealed by flysch are another attractive candidate. The **Calabrian Arc** remains virtually untested with only nearshore fields in the **Cretone Basin** and academic wells which only penetrated the top of the **Messinian evaporitic** section in the deep basin. Inverted extensional structures in the thick Mesozoic and Cenozoic strata underlying relatively **undeformed Messinian evaporites** are compelling, but are located in ultra-deep water (**Figure 5**).

More mature and shallow water areas, such as the **Pelagian Basin** offshore **Sicily**, **Malta**and **Tunisia**, contain multiple play types and multiple source rock intervals that are working in Sicily and Libya/Tunisia. These plays are likely to be present in the **Maltese offshore**, but exploration efforts are hampered by **boundary disputes** and **paucity of data**. A younger Oligocene rift basin with a thick post-rift section in **offshore West Sardinia** may also contain an **active petroleum system**. Multiple plays in the pre-, syn- and post-rift sections are possible, with several source and reservoir intervals that could be sealed by **Messinian evaporites** or **Pliocene shales**. Interpretation of this **contiguous dataset** across the complex inverted margin of the **Maghrebian** in the **Sicily Channel** to the **Balearic** creates a new correlation framework between these diverse basins.

Cost-Effective Exploration in the Mediterranean

Exploration teams constantly strive to understand the basin framework in order to high-grade areas that align with company strategy and identify proven and **future successful hydrocarbon plays**. The complexities of the **Mediterranean Basin** architecture and the variety of play types highlight the **importance** of understanding the regional tectonic and stratigraphic framework to **fully assess** the remaining potential in the region. Using a **fully integrated** Mediterranean **seismic dataset** that crosses **multiple country boundaries**, tying mature areas (**Sabratha Basin**) with less explored areas in **Libya**, **Malta**and **Italy**, makes this interpretation and model **refinement possible**.

Given the current **low price environment**, it is critical for companies to **acquire high quality information** in a cost-effective manner. Combining new acquisition with reprocessed legacy data and modern integration techniques, **ION** has created a dataset that can be used to understand the **future hydrocarbon potential in the Mediterranean**.

Reference:

- *Hallet, D., and Clark-Lowes, D., Petroleum Geology of Libya, Elsevier, Amsterdam, Netherlands, 2016.*

For additional reading see The WFCRC Document Gallery for articles about:

- Public Service Announcements (PSA)
- Coral Alert Network (CAN)
- Emergency Reporting Reports (ERR)
- Call to Action (CTA)
- Marine Protected Areas (MPA)
- Marine Life Alert (MLA)
- Seismic and Oil Production Threats
- Natural Science Reports (NSR)
- Oil Spill Alerts (OSA)
- And other miscellaneous documents