NEOS
GEOSOLUTIONS

LEBANON
neoBASIN Program

Over 6,000 square kilometers of airborne acquired, multi-physics data providing basement-to-surface insights of Lebanon's underexplored onshore and the transition zone along the Mediterranean coastline.

neos

GEOSOLUTIONS

NEOS GeoSolutions helps E&P operators all over the world gain new insights into the subsurface. Using a methodology called Multi-Measurement Interpretation (MMI), NEOS integrates newly acquired airborne geophysical data with existing seismic, well, and geologic information. The result is highly constrained subsurface images that reveal new insights from the basement to the surface, allowing geoscientists to optimize decisions about where to explore, lease, and drill in both conventional and unconventional hydrocarbon basins.

Lebanon neoBASIN™ Program

NEOS has completed a geophysical airborne survey designed to map the regional prospectivity of 6,000 square kilometers of onshore northern Lebanon and the transition zone (TZ) along the Mediterranean coastline by integrating legacy well and seismic data with newly acquired airborne geophysical datasets. The results are promising, with oil seeps indicative of an active hydrocarbon system, several intriguing play types, and resistivity anomalies aligning with structural highs and fault-bounded reservoir intervals.

Lebanon neoBASIN
webpage

OIL & GAS IN LEBANON

Lebanon has not been known historically as a center for hydrocarbon exploration and development. But that may be about to change. The country's small number of wells (and discoveries) and limited oil & gas production from neighboring countries have constrained the interest of the International Oil Companies (IOCs). However, recent offshore discoveries in the Eastern Mediterranean (EastMed) have all increased the amount of exploration activity in the broader area, albeit primarily offshore. In response, the Ministry of Energy and Water (MoEW) and the Lebanon Petroleum Administration (LPA) have begun to draft the necessary laws and regulations to open up Lebanon's petroleum sector.

OFFSHORE SUMMARY

Rising interest in the EastMed regions comes as significant natural gas fields have recently been discovered, most of them in the Levant Basin. The largest offshore discovery within the Levant Basin to date is the Leviathan field – located approximately 80 miles off the coast to the south and situated in water that is more than 5,000 feet deep – which is estimated to hold 22 Trillion Cubic Feet (Tcf) in recoverable resources.

The Lebanese government completed a pre-qualification bid for exploration in the country's territorial waters in April 2013.

Gas in the eastern Mediterranean

Offshore Discoveries

---> Tamar

---> Leviathan

---> Tanin

---> Aphroditite (in Cyprus waters)

ONSHORE SUMMARY

Development of onshore oil resources in Lebanon began in 1947 but was discontinued in 1967 due to civil war. With the recent upswing in exploration activity in the EastMed, geoscientists are now curious about the broader implications of the region's hydrocarbon systems, including the prospectivity of Lebanon's onshore basins. More data is needed, as currently there exists only sparse legacy well data in the onshore region.

Existing onshore production in the Eastern Mediterranean:

---> Meged (Occupied Territory)

---> Deir Ezzor (Syria)

---> Qamishli (Syria)

---> Palmyra (Syria)
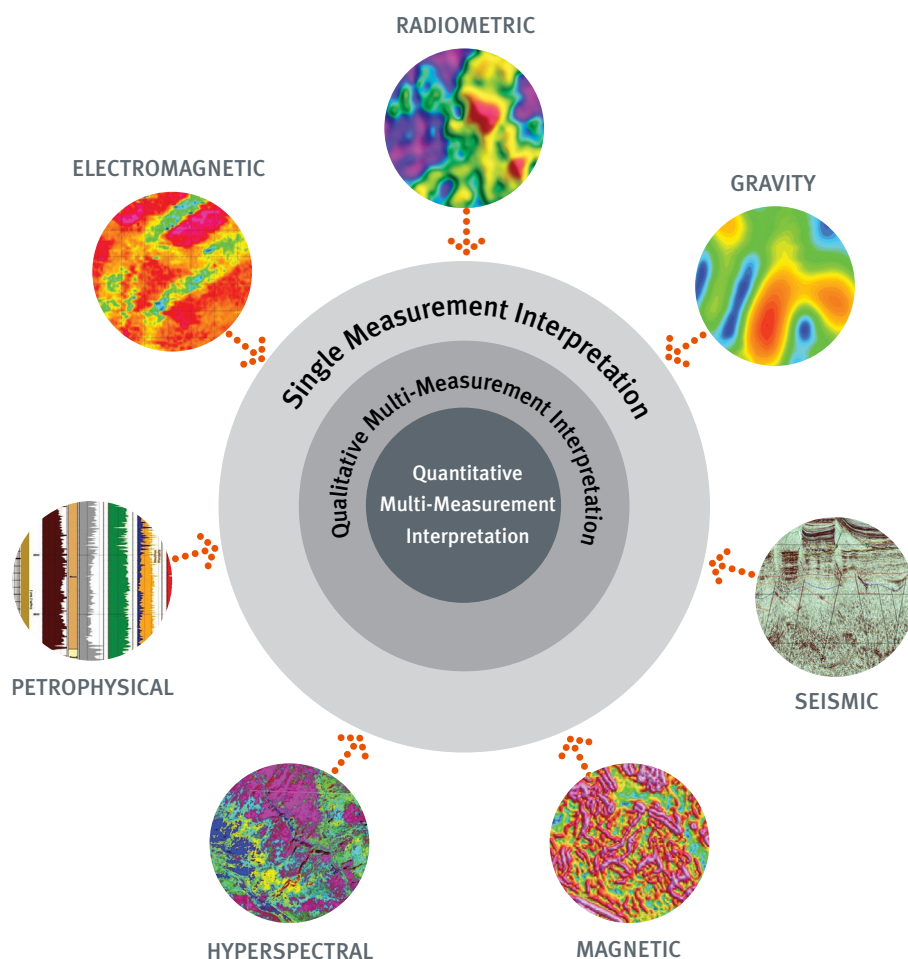
---> Sinai (Egypt)

ONSHORE LEBANON

Lebanon is a country of challenging topography. Terrain and geo-politics complicate ground-based seismic acquisition.
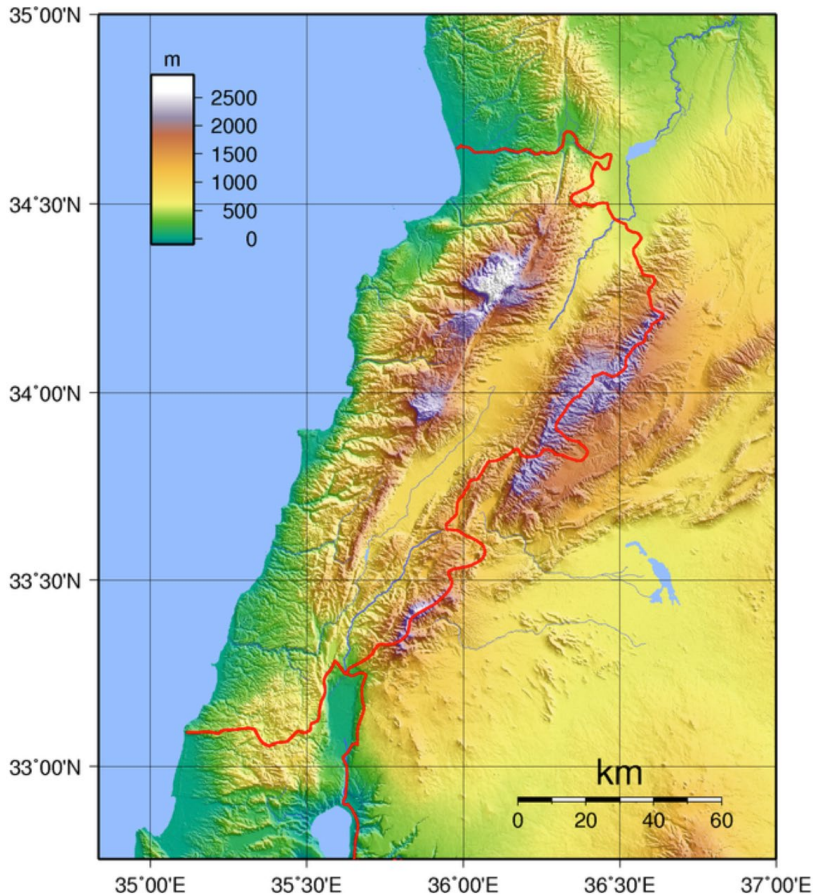
MULTI-MEASUREMENT INTERPRETATION

AIRBORNE-ACQUIRED MULTI-PHYSICS MEASUREMENTS AND INTERPRETATION METHODOLOGY

Seismic and non-seismic measurements interpreted simultaneously.

VALUE IN THE MMI APPROACH

Simultaneously interpreting all measurements, while incorporating the latest techniques in data mining, geostatistics, and predictive analytics produces results that reveal powerful basement-to-surface insights into regional prospectivity and well productivity for operators across the globe.

The benefits of MMI include:

⟶ Low-touch acquisition – Cost effectively acquire multi-physics datasets over broad areas using low-touch airborne methods;

⟶ Basement-to-surface insights – Learn how variations in basin architecture affect deposition, maturation, migration and trapping systems;

⟶ Holistic petroleum system understanding – Discover the interrelationships among the region's onshore and offshore hydrocarbon systems.

LEBANON neoBASIN PROGRAM

Over 6000 sqkm of airborne acquired multi-measurement data providing basement-to-surface insights along Lebanon's Mediterranean coastline and underexplored onshore region.

KEY TECHNOLOGIES:

- MAGNETIC
- PASSIVE SOURCE EM & MT
- RADIOMETRIC *(onshore only)*
- GRAVITY
- HYPERSPECTRAL *(onshore only)*
- PREDICTIVE ANALYTICS

LEBANON neoBASIN PROGRAM OBJECTIVES

····> Identify deep basement architecture and composition;

····> Map key structural and stratigraphic horizons;

····> Map basement-to-surface fault systems and fracture networks;

····> Highlight regional potential exploration targets and highgrade acreage.

PROGRAM OVERVIEW

NEOS geoscientists have worked with the program's underwriters to identify the relationships among key geologic features that extend into the survey area from offshore structures and from Syria's onshore petroleum systems, as well as to efficiently highgrade acreage across the survey area in order to support future leasing, drilling, and G&G investment decisions.
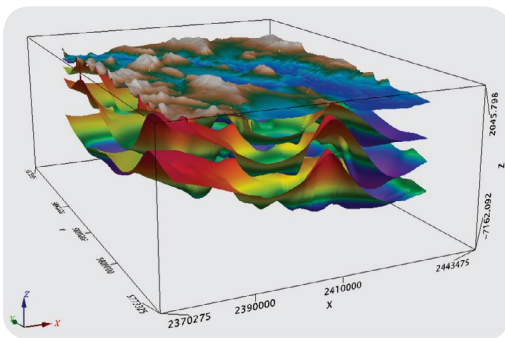
DATA NOW AVAILABLE

Lebanon neoBASIN
narrated slideshow

LEBANON neoBASIN PROGRAM

LEBANON neoBASIN KEY MEASUREMENTS

NEOS tailors sensor packages, acquisition geometries, and data processing and interpretation methodologies to both the unique characteristics of the basin being studied and the technical objectives of its clients. In the case of the Lebanon neoBASIN program, the following measurements provide insights in some of the areas noted:

- **Magnetic:** helps identify fault zones, detect crystalline intrusions and support structural and stratigraphic mapping;
- **Electromagnetic:** provides insights into both lateral and vertical resistivity variations throughout the geologic column;
- **Radiometric:** halo indicator of increased thermal maturity and TOC, and the presence of micro-seeps at the surface (onshore only);
- **Gravity:** delineates depth-to-basement and variations in the thickness of the sediment package across the basin;
- **Hyperspectral:** enables subtle, surface-penetrating lineaments to be identified (and potentially traced to depth via other measurements), and detects both indirect and direct hydrocarbon indicators (DHIs) such as oil seeps (onshore only);
- **Predictive Analytics:** use advanced geostatistical and neural networking techniques to highgrade acreage.

3-D basement-to-surface model of key horizons, developed by infilling among a dozen 2-D cross sections using Grav-Mag data.

(Neuquén Basin, Argentina)
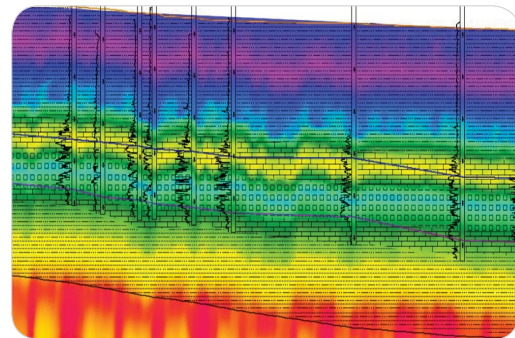
*Example cross-section of airborne-acquired EM data.*

(Appalachian Basin, USA)

PROGRAM DELIVERABLES & INSIGHTS

In addition to being provided with all of the raw and processed datasets associated with these newly acquired geophysical measurements, licensees of the Lebanon neoBASIN data library will receive:

- Maps of naturally occurring, surface-based oil seeps and indirect hydrocarbon indicators (onshore only);
- Maps of basement topography and key structural and stratigraphic horizons;
- Basement-to-surface maps highlighting local faults (including the Dead Sea fault north extension) lineaments, and intrusives;
- 2-D cross-sections and regional 3-D structural models of the subsurface, including geologic trends that can be extrapolated into the survey area from Syria or recent discoveries that have been made offshore in the eastern Mediterranean;
- Maps of key reservoir intervals of interest, including isopach, burial depth, and depth-to-basement maps of these horizons;
- Regional resistivity voxels along with resistivity cross-sections and depth slices in areas of heightened geologic interest;
- Regional highgraded acreage maps depicting the most (and least) prospective areas for leasing, drilling, and/or further G&G study and investment.
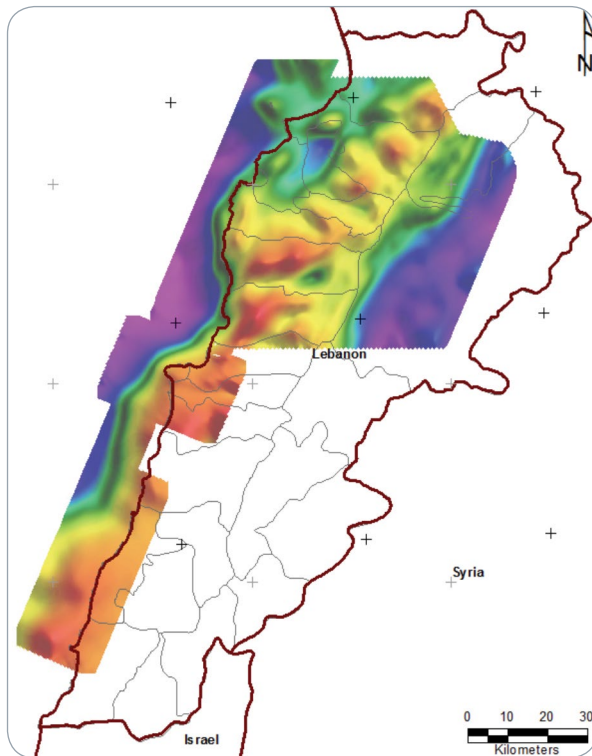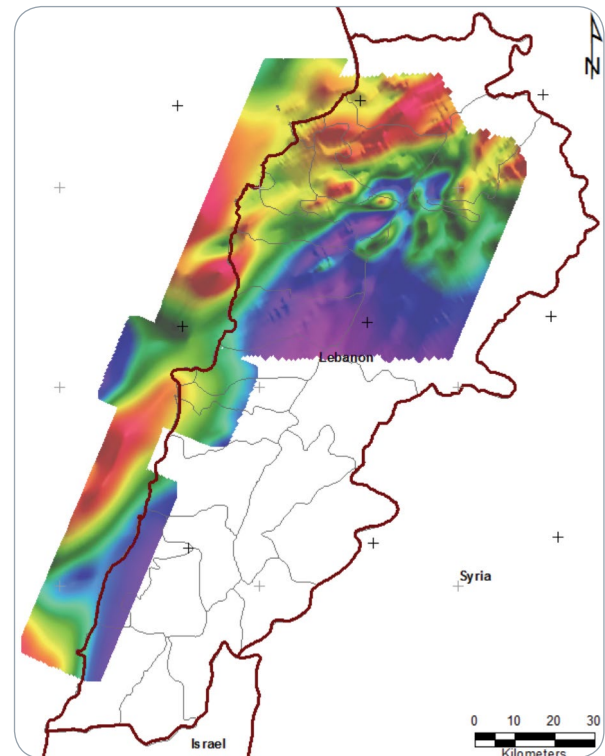
Gravity

Magnetic

GRAVITY AND MAGNETIC DATA

Complete Bouguer Gravity (CBG, left) and Residual Magnetic Intensity (RMI, right) are used to provide a view into basin architecture. Moving west to east, the gravity data show the crustal transition boundary along the Eastern Mediterranean coastline, the Lebanon Mountains (warm colors) and the Bekaa Valley depo-center (cool colors). The magnetic data highlight similar north-south trending geologic features, although less can be said at this stage about what implications the magnetic data might have for the region's hydrocarbon prospectivity.

Referencing the gravity image (left), the clearly defined boundary between the western Bekaa depo-center and the uplift associated with the Lebanon Mountains is a structural archetype that NEOS has seen associated with hydrocarbon trapping in other known oil & gas provinces around the world.

EXAMPLE INTERPRETIVE PRODUCTS
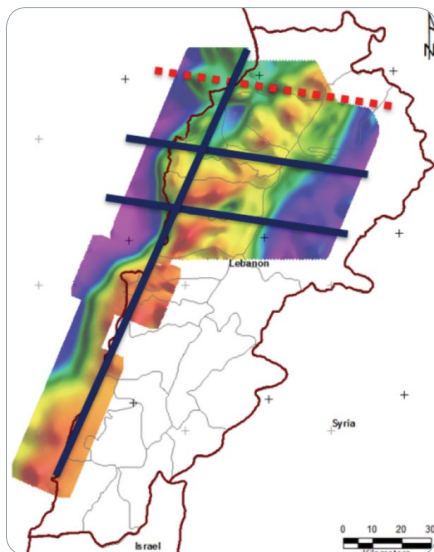

2-D AND 3-D MODELING

NEOS has generated four 2-D cross-sections in the locations shown (left) by the black and red lines. Airborne Grav-Mag data, seismic, well and outcrop information are all analyzed simultaneously to develop a constrained 2-D profile (such as the one shown below) that highlights the thickness and burial depth of major geologic horizons.

This information provides key insights into the potential for individual horizons to generate hydrocarbons and may provide some indication – along with other G&G information – as to whether the generated hydrocarbons are more likely to be gas-prone or liquids-rich.
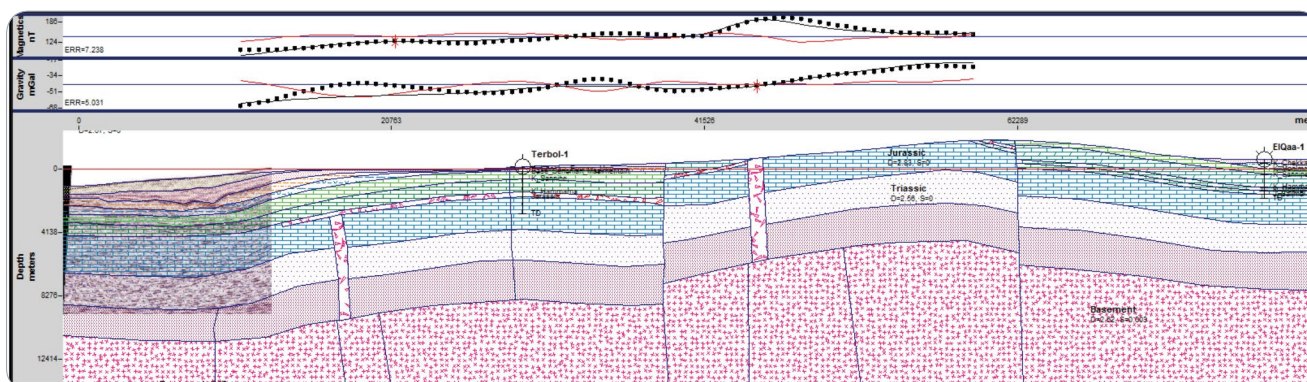
The 2-D cross-section above has been developed using actual data from Lebanon in the northern-most portion of the survey area (red cross-hashed line in the upper image). It highlights the thicknesses and burial depths of the geologic horizons of primary exploration interest – the Jurassic (blue) and the deeper Triassic (white with red dots). Non-commercial wells were drilled into the Jurassic horizon near this section. The deeper Triassic interval is considered to be potentially prospective in the region, but this horizon's burial depth in the northern portion of the AOI suggests it may be too deep for economic development. Preliminary modeling work in areas farther south suggest that similarly thick Triassic intervals may exist, albeit at shallower (and therefore more commercially viable) burial depths.
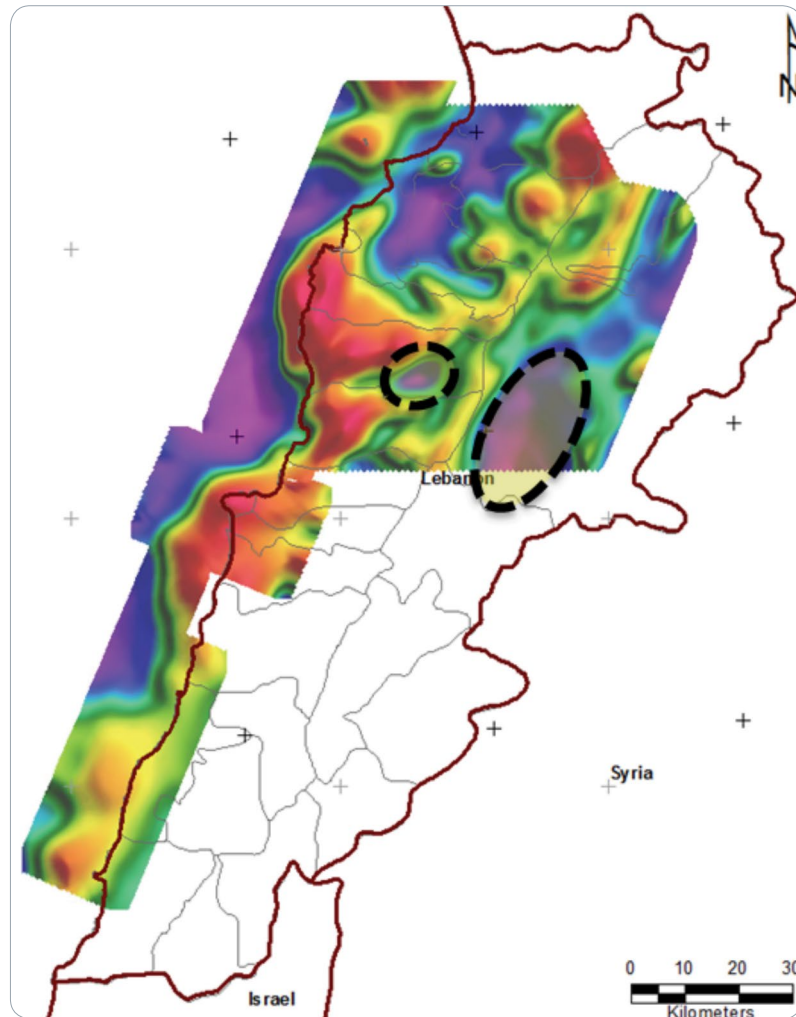
EVIDENCE OF SEDIMENTARY DEPO-CENTERS

Several intriguing areas, two of which are highlighted above on this CBG image, have been identified on the First Look interpretation. This filtered (60 km high-pass) image has removed the low frequency (deeply penetrating) gravity data in order to isolate shallower portions of the sedimentary section that are of most interest to explorationists.

In these two areas, Triassic interval that is nearly 2,000 meters thick appears to be present. Moreover, the early modeling work suggests that the burial depth in these areas ranges from 1,500-2,500 meters deep which would be much more advantageous to commercial development if TOC-rich source rocks (and trapping mechanisms) are present in the area.

EXAMPLE INTERPRETIVE PRODUCTS
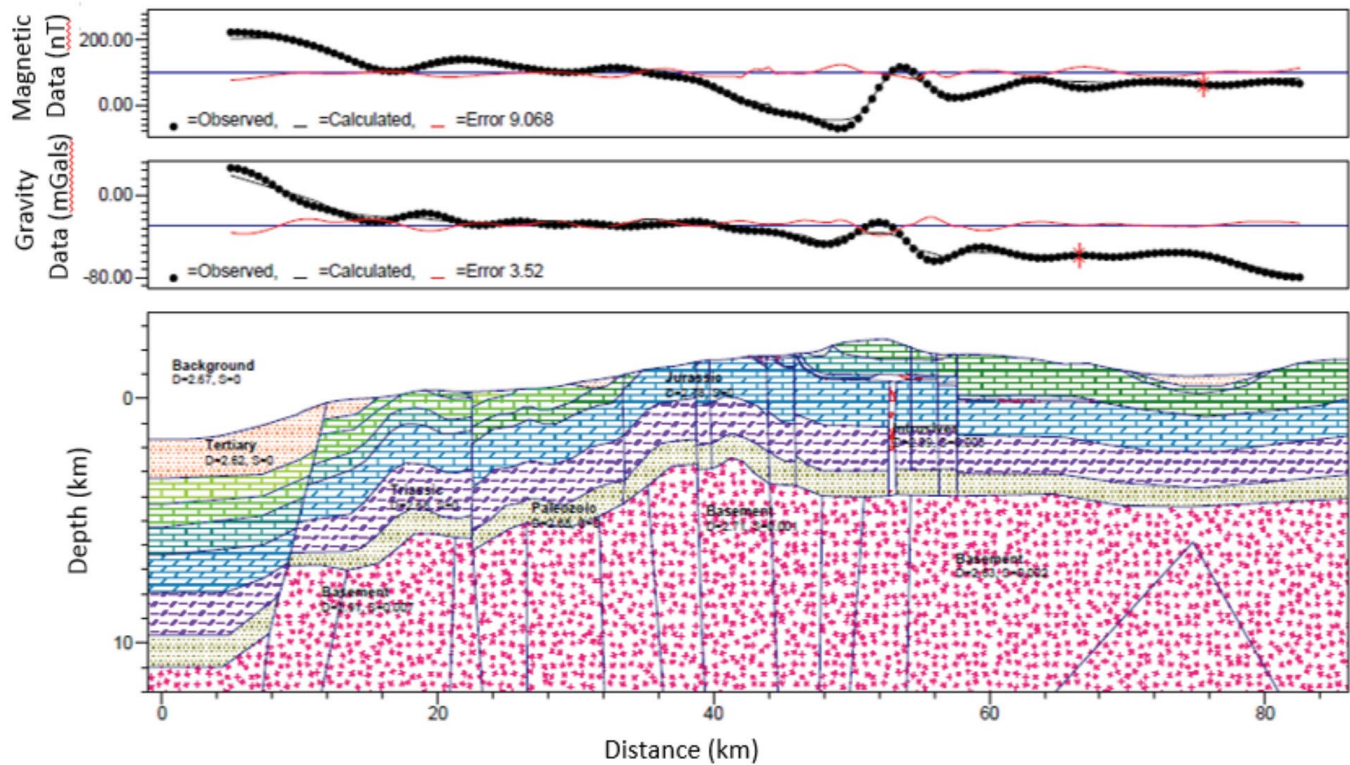
2-D CROSS-SECTION

About 30 km to the south of the cross-section shared on page 9, are some interesting features. NEOS interpreters have been intrigued throughout the project by the potential for a Triassic hydrocarbon system, and this Second Look section shows a Triassic interval nearly 2 km thick and roughly 2 km below the surface at its shallowest point. Perhaps even more intriguing, the Triassic is doming up in a classic anticlinal structure, with several large bounding faults on either side. This feature is quite large, and extends over a fairly sizeable distance in a north-south direction paralleling the Lebanon Mountains.

Mineral Alteration Zones

4,400 2,200 0 4,400 Meters

Legend
- Clays
- Iron Oxides
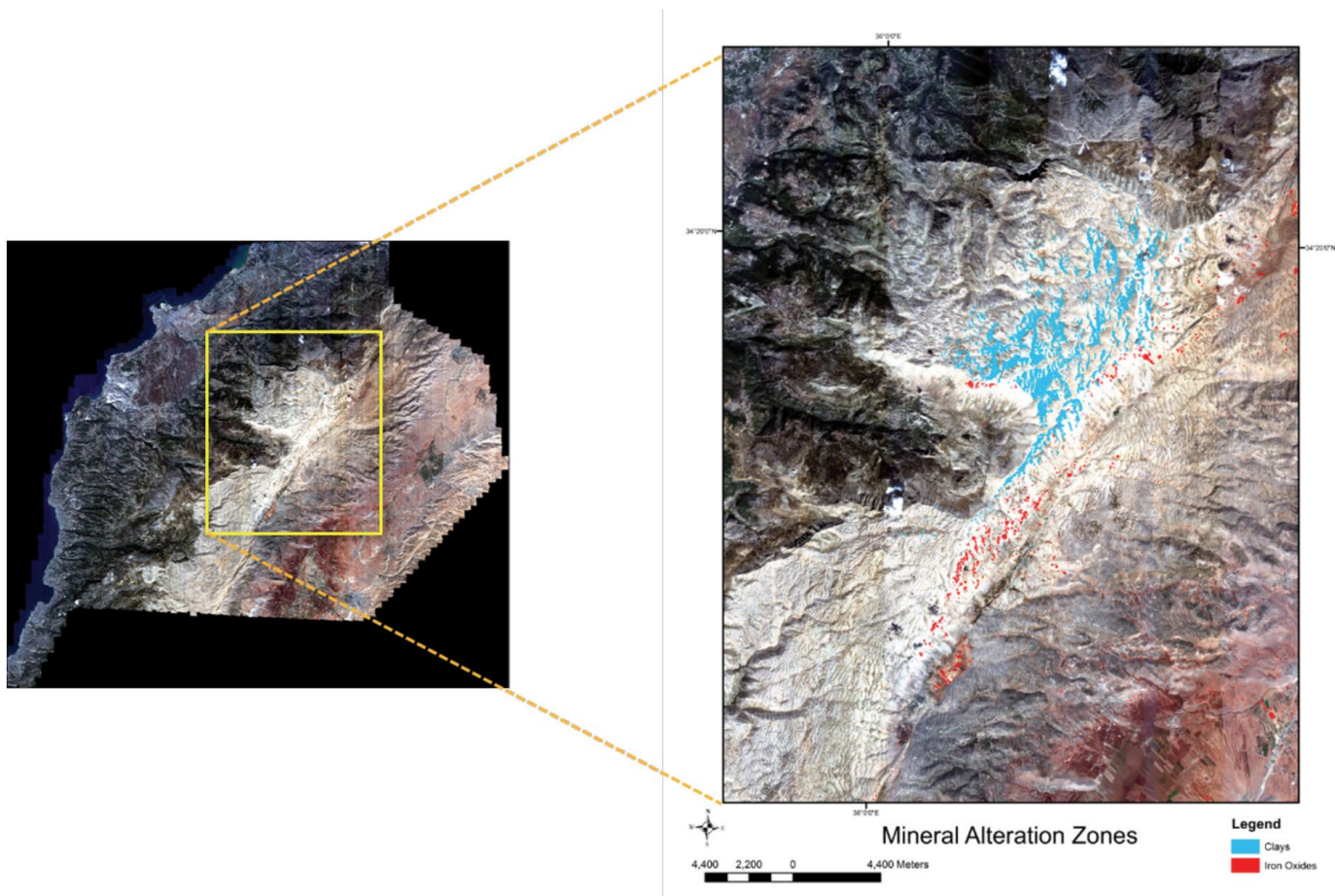
INDIRECT HYDROCARBON INDICATORS (IHIs) VIA HYPERSPECTRAL IMAGING

Preliminary classification analysis of the hyperspectral data mosaic (left image) is complete. NEOS personnel analyzed the data in order to be able to map the lithology of outrcrops, identify DHIs such as oil seeps and, as shown on the right image, to detect mineral alteration zones (IHIs) that are often caused by hydrocarbon leakage from the sub-surface along faults and bedding planes over the course of geologic time.

A First Look interpretation indicates that IHIs similar to those NEOS has mapped in other known oil & gas provinces are indeed present along the western margin of the Bekaa depo-center. Given that IHIs are present at all, and further that they are located in an area where the subsurface intervals under the Bekaa Valley are being uplifted by the Lebanon Mountains, is an encouraging early sign about the region's hydrocarbon potential.

EXAMPLE INTERPRETIVE PRODUCTS

Spectra 1
Spectra 2
Known Shows
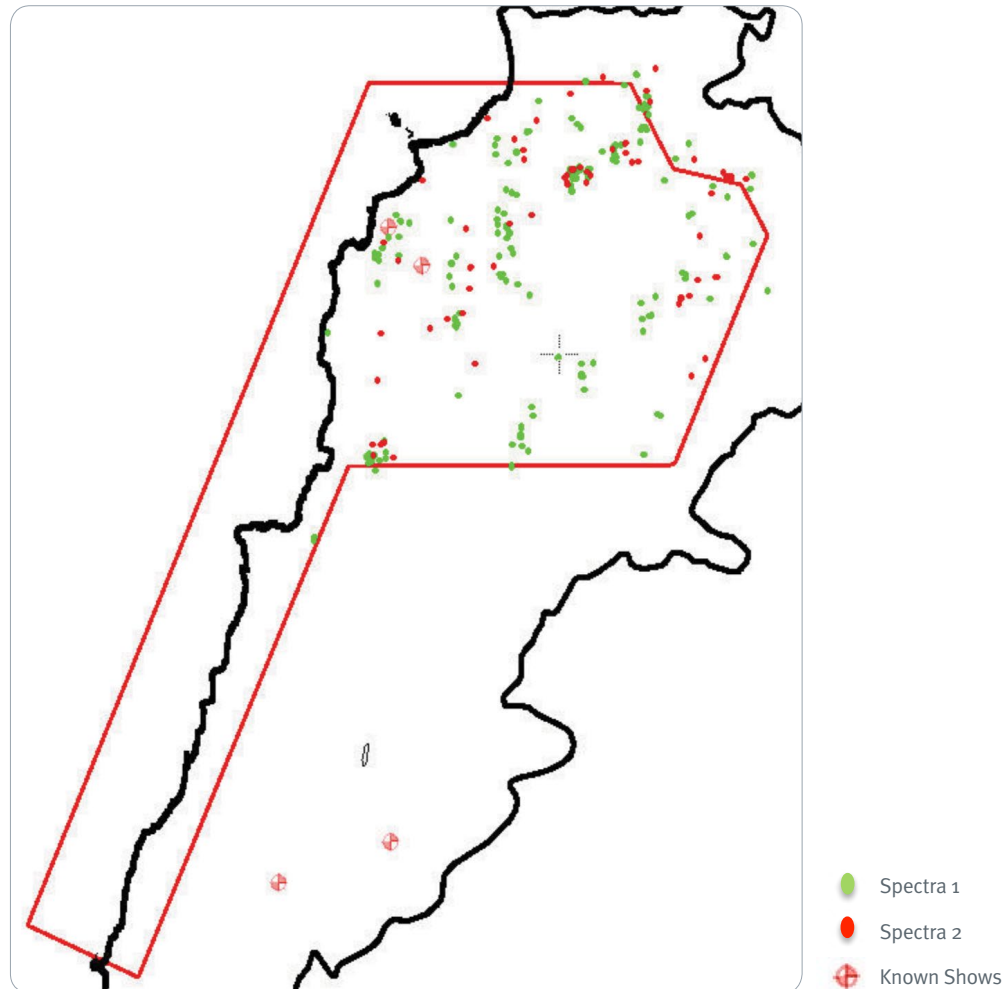
HYPERSPECTRAL IMAGING SHOWS OIL SEEPS

The presence of direct hydrocarbon indicators (DHIs) or oil seeps in an area inspires confidence in having an active hydrocarbon system. In the case of Lebanon, in this Second Look interpretation, we see oil seeps throughout a large part of the northern onshore AOI.

Hyperspectral imaging was used to look for oil on the surface that might share similar spectral signatures to oil seeps we have seen in other known hydrocarbon systems. NEOS has detected seeps sharing these spectral signatures in Lebanon.

The number of seeps and their broad distribution throughout the project area are very encouraging indeed.

Amanda Jane
NEOS GeoSolutions
Lebanon Program Manager
+1 202 569 9905
lebanon@neosgeo.com

Karine Zeinni
Petroserv
Sales & Project Engineer
+961 3 864 151
karine.zeinni@petroserv.com.lb