The use of satellite images to identify sea surface oil slicks is a technique that can directly reduce exploration risk in undrilled basins as natural oil seeps demonstrate a working petroleum system. This technique is used in frontier areas where a lack of well data precludes confident identification of source rock distribution, or where there is uncertainty in modeling source rock maturity.

Oil slicks are visible in satellite images because oil on the sea surface reduces the wave amplitude relative to the surrounding sea surface. As a consequence, more sunlight reflects off of the slick in the same direction away from the satellite compared to the surrounding, rougher, sea which backscatters more radiation in the direction of the satellite. To a satellite the oil slick appears darker and the surrounding sea surface appears brighter.

**Technique**

The process is significantly influenced by wind conditions; in zero wind the smoothness of the sea surface and the oil slick are similar so the slick is not visible (figure 1). Stronger winds help the slick to be differentiated but dissipate oils quickly (figure 2).

A presence of persistent surface slicks can be indicative of a working subsurface hydrocarbon system, mature for oil generation. However, it is important to separate anthropogenic pollution and natural seeps. Multiple slicks in close proximity to one another reduce the likelihood that the slick is a one-off anthropogenic pollution event. It is also important to look at a large number of satellite images taken over a period of time to have a better chance of observing re-occurring but episodic seeps, and as such repeating slicks are a good indication of a natural oil seep - rather than anthropogenic pollution.

**Methodology**

For optimum results this technique requires a high volume of satellite images. For this reason the Landsat satellite image archive provides an ideal resource; images have been collected into the archive for over 40 years, often with over 250 satellite images available for a single location. For this study over 1000 satellite images were available for analysis, with over 100 containing suitable weather characteristics for slick identification. The location and origin of any slicks have been logged in a GIS project for future comparison.
The following workflow has been followed to complete the sea surface slicks study:
1. Tile(s) to be included in area study identified.
2. (each tile contains ~250 200 km x 200 km images)
3. Initial assessment “firstlook” quality images downloaded and examined.
4. Scenes with suitable characteristics for slick identification downloaded.
5. RGB colour bands merged, contrast/brightness balanced.
6. Images loaded in GIS project.
7. Surface slicks identified and captured into shapefile database.
8. Slick origin and areal extent captured.
9. ERSI ArcMap and ESRI ArcReader GIS projects published.

**Innovation**

An innovation discussed here is to compare the slick pattern to basin structure by evaluation of seismic that reveals the underlying geology. Slicks closely correlated with regional structural trends are more likely to be natural hydrocarbon seeps. This study utilizes a large sample size of satellite images examined and conlates this data with interpretation of seismic from Spectrum’s regional data library.

Over 150 sea surface slicks were collected in the study area. This large volume of input data allows for the identification of 3 trends in the data collected:

- **Trend 1:** A linear trend extending from the Balearic Islands towards Marseille.
- **Trend 2:** A clustering of slicks approximately 50km north of Mallorca
- **Trend 3:** Clustering of slicks in the approximately location of the change in bathymetry between shallow and deep waters, (shelf edge) offshore Barcelona

**Figure 4:** Distribution of sea surface slicks in the Western Mediterranean (red) including trends identified (blue), and the Messinian halite canopy.
Cross-correlation of sea surface slicks and 2D seismic

The strongest trend identified in the slicks analysis was trend 1. In each 2D line example the slick-trend correlated closely with the up-dip thinning and breakup of the regionally extensive Messinian halite canopy (figures 4 and 5). The breakup is often with associated growth faulting to the surface, with the highest frequency of slicks coinciding with the most significant faulting (point A, figures 4 and 5). Down-dip to the east, where the Messinian halite is thicker, there are significantly fewer slicks. We interpret this absence of slicks in the east of the study to be as important as the strong correlation of slicks at the edge of the halite. The focus of slicks corresponding to the growth faults at the western margin of the salt canopy indicates that up-dip migration pathways exist to allow for the passage of oil past the edge of the halite, escaping to the seafloor wherever the halite cannot provide an effective seal. We suggest that this is strong evidence for the presence of a working oil generative petroleum system located beneath the halite. A hydrocarbon system is proven on the shallow water shelf to south-west, where the Casablanca field is reported to comprise Mesozoic carbonates charged by overlying lower Miocene source rocks (Salas and Permanyer, 2003; Varela et al., 2005). The Miocene beneath the salt canopy is the most likely source for the natural oil seeps in slick trend 1.

Figure 5: Spectrum’s NW-SE dip line SPBAL-16 (“A” correlates with “A” in figure 4)

Mesozoic Source Evidence

Not all sea surface slicks appear to be closely related to the presence / instability of Messinian halites. Clustering of slicks around trend 2 is also prominent from the analysis. This area is south east of the halite canopy, and curiously the Miocene appears too shallow to be mature for hydrocarbon generation suggesting a deeper source is active here. A deeper, syn-rift package is visible on the seismic from this area adjacent to the clear structural feature at point B (figures 4 and 6), suggesting the source of the sea surface slicks here is oil from the Mesozoic migrating against this structure.

Figure 6: Spectrum seismic line MEDS 4C. An eroded anticline onto which a potential Mesozoic source rock onlaps.

Mesozoic Source at Shelf Edge

The third slick-trend identified lies adjacent to the basins shelf-margin (figure 4). The close proximity of this trend to the city of Barcelona means that an association with anthropogenic sources cannot be ruled out. However, the location of the slicks also relates to deep, incised canyons visible in seafloor bathymetry and seismic lines (figure 7). The reason for the association of slicks with the shelf edge here is less clear. It is probable that the modern shelf edge is associated with older basin bounding faults which are providing a conduit from deep, oil generative Mesozoic source into the cover section (Esestime et. al. 2013).
Reference:

Salas, R. and Permanyer A. 2003 Evidence of hydrocarbon generation in the Mas d’Ascla marls formation (Upper Jurassic, Iberian Chain) and its relationship to the Amposta oil field of the Tarragona Basin. Boletín Geológico y Minero, 114, 75-86.


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This study refers to data available from the U.S. geological survey.

Conclusion
Natural oil slicks provide strong evidence for a working hydrocarbon system in the Balearic Basin. Source rocks of Miocene age have long been described in shallow water, but now can be extended further into the basin. Slick-trends 2 and 3 also suggest the presence of a regionally extensive oil prone Mesozoic source rock in the deep water. This is an exciting development for hydrocarbon prospectively in this area, de-risking a both source presence and maturity in an under explored and largely unlicensed basin.

About Spectrum
Spectrum provides innovative Multi-Client seismic surveys and high-quality seismic imaging services to the global oil and gas industry from offices in the UK, Norway, USA, Egypt, Australia, Indonesia and Singapore. Spectrum designs, acquires and processes seismic data to deliver high quality solutions through its dedicated and experienced workforce.

Spectrum holds one of the world’s largest libraries of Multi-Client 2D marine seismic data. The company’s strategy focuses on both the major, established hydrocarbon-producing regions of the world as well as key frontier areas identified by our experienced team of geoscientists. The Spectrum library of Multi-Client data contains projects from many of the foremost oil producing regions of the world. These include new acquisition, reprocessing and interpretation reports.

References

Salas, R. and Permanyer A. 2003 Evidence of hydrocarbon generation in the Mas d’Ascla marls formation (Upper Jurassic, Iberian Chain) and its relationship to the Amposta oil field of the Tarragona Basin. Boletín Geológico y Minero, 114, 75-86.