creating a clearer picture

Phillip Hargreaves, Spectrum GEO, UK, explores the process of examining source rock presence in frontier offshore basins using satellite imagery and seismic cross sections.

Those who have ever traced a hydrocarbon source rock interval across a long regional seismic line will have likely experienced the challenge in tracking a deeply buried source rock.

The source rock interval of a hydrocarbon play concept can be a difficult sedimentary element to resolve using seismic imaging. For a source rock to be sufficiently matured it is likely to be quite deep in the section, sometimes much deeper than the reservoir and trap components. Energy returned from these deeper intervals is generally lower, so the clarity of the seismic image can be less defined. Also, seismic survey design and image processing is often tuned to maximise imaging at reservoir level to better define prospects rather than source rocks. Historically, the short cable lengths of most 1980 - 1990 seismic campaigns significantly reduced the imaging power at source rock interval depths. In a mature basin, with reasonably distributed well control at source interval depth, it is possible to be more confident of source rock interpretation. Understanding the presence, distribution and maturity of a source rock in frontier basins with little well control is risky; there is a big difference between 'mapping the source rock interval' and 'proving the presence of a mature hydrocarbon source.'

Technological principle

Clusters of persistent sea surface slicks (those that occur in the same place over many different dates) can be direct hydrocarbon indicators; their presence is indicative of a working subsurface hydrocarbon system. This concept has been proven in many areas around the world, including the Mexican Gulf of Mexico. The observation of sea surface slicks by Mexican fishermen in the 1970s led to the discovery of one of the world's largest oilfields: Cantarell. Today, satellite imagery can be used to identify sea surface slicks and survey basin sized areas quickly, significantly reducing the uncertainties associated with source rock mapping.

Figure 1. *Landsat 8 image showing a Sea surface slick detected offshore Croatia. Slicks are persistently observed in this location. (Satellite imagery courtesy of the US Geological Survey).*

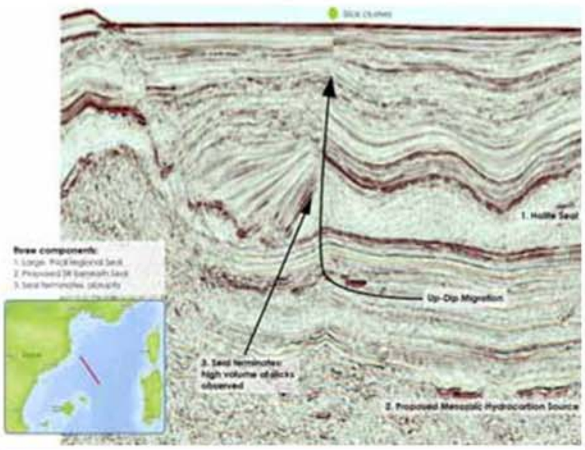

Figure 2. *Seismic cross section beneath a strong cluster of sea surface slicks in the Western Mediterranean.*

Figure 3. *Halite seal in the Western Mediterranean.*

Recent growth in the availability of satellite imagery data has been remarkable – some satellite providers are now capable of delivering an image of any part of the world each day. The principle of satellite imaging takes advantage of the difference in surface texture between a natural sea surface and an oil slick floating on top of the sea. In suitable conditions the sea surface is slightly rougher than the oil slick; sunlight reflects off the slick in a different direction than the sea and this is captured by the satellite image (Figure 1).

However, the technique is weather dependant: if the sea is too rough then any oil floating in the sea is dispersed too quickly to form a large slick. On calm days, the sea surface will have a smooth texture similar to an oil slick making detection difficult.

There is also the problem of pollution: the observation of a single slick in an area with frequent passing vessel activity could be the result of pollution rather than naturally occurring oil seeps. Differentiation between the two is important, but their appearance is similar. By comparing many images over the same location from different dates, it is possible to identify locations where surface oils appear regularly, reducing the likelihood of false identification of an anthropogenic oil source.

The value of the sea surface slicks can only be confirmed when these locations are correlated with seismic cross sections. If they are found to be in association with major geologic events such as faults or shallow gas/fluid features, the likelihood of these slicks being the result of a naturally occurring hydrocarbon system are significantly increased. In a frontier basin this may be the first confident sign of an oil source.

Spectrum has deployed this technique in many frontier basins with geological characteristics, which in turn has allowed the company to spot shared common geologic traits that the technique illuminates.

Seal termination and sea surface slicks

Sea surface slick trends can reveal as much about a source rock as they do about basin wide seals. In Figure 2, from the Western Mediterranean, several strong clusters of slicks can be seen above a large fault that reaches from the sea floor to mark the edge of a thick regional halite sea. The distribution of the slicks and the seal reveal information about where the oil is coming from. The oils are migrating through the section using the fault to reach the seafloor. There is an absence of slicks on the ocean above the area covered by the regional seal, so it can be inferred that the oil source is located beneath the seal and is migrating updip against the bottom of the seal until its termination, where the sea surface slicks can be seen (Figure 3). This inference has important consequences for the prospectivity of the basin – any prospects located under the seal are likely to be charged with oil.

This trait is repeated in other basins too. In the Irish Porcupine basin, Spectrum collaborated with Airbus Defence and Space to collect slick locations and found that the underlying trend of slick clusters was the eastern pinch out of a regional shale. Below this shale, in the centre of the basin, a source rock similar to that of the conjugate Jeanne d'Arc Basin (offshore Canada) is thought to be located but as yet goes unproven. Evidence of oil slicks at the edge of this shale again point to the presence of oils beneath the seal, but as the slicks can only be seen on the eastern edge, it suggests that oils migrating from the centre of the basin are migrating

VIDEOTEC
VIDEO SECURITY PRODUCTS
Made in Italy since 1986

MAXIMUS MMX
EX-PROOF CAMERAS

With the **MAXIMUS MMX** cameras, a new world of cost-effective video surveillance solutions for onshore, offshore, marine, heavy industrial or hazardous environments.

www.videotec.com
info@videotec.com

ATEX IECEx c UL us LISTED EAC Ex

preferentially eastwards. Clearly this is good for the operators on the eastern side of the basin, but it could also point towards a contributing reason behind the dry well drilled in 2017 at the Dromberg Prospect on the Western side of the basin.

Basins without regional seals

A second trait that has been regularly encountered in Spectrum's studies is a correlation between slick clusters and the edges of sedimentary basins. In Croatia, the Cretaceous shelf edge marks the edge of a deeper Mesozoic sedimentary basin that runs the length of the Croatian Adriatic. The shelf edge does not form a straight line or gently sweeping curve but a sinuous boundary that revealed itself as seismic interpretations in the basin were completed. It was not until the shelf edge was mapped against the sea surface slick distributions that a correlation was revealed – many slicks were located close to the shelf edge in either point or linear clusters (Figure 1). When examined closely, some linear clusters were found to imitate the shape of a minor fault leading to the seafloor from the edge of the shelf. Elsewhere point clusters were found above the shelf, often with bright amplitude events observed in the seismic close to the seafloor. This evidence suggests that hydrocarbons are migrating from the centre of the basin towards the shelf edge where they are finding their way to the surface along minor faults. Hydrocarbon prospects are often found in association with the edges of carbonate shelves and in Croatia this is thought to be one of the key plays that explorers will follow. Slicks were found in correlation with the shelf edge from the south to the north of Croatia indicating that an oil prone source rock is present across the central Adriatic and this play could be viable across the province.

The distribution of some sea surface slicks offshore Somalia were also hard to interpret before examining detailed seismic interpretations. It was not until maps of the deeper syn-rift grabens were overlain against them, was a strong correlation between the two noticed – slicks were found almost exclusively at the edges of Jurassic syn-rift grabens (Figure 4), corroborating basin modelling studies that predict that these deeper Jurassic sediments are oil prone. Several syn-rift grabens are mapped across the Somalia offshore, each around half of the size of Lake Malawi.

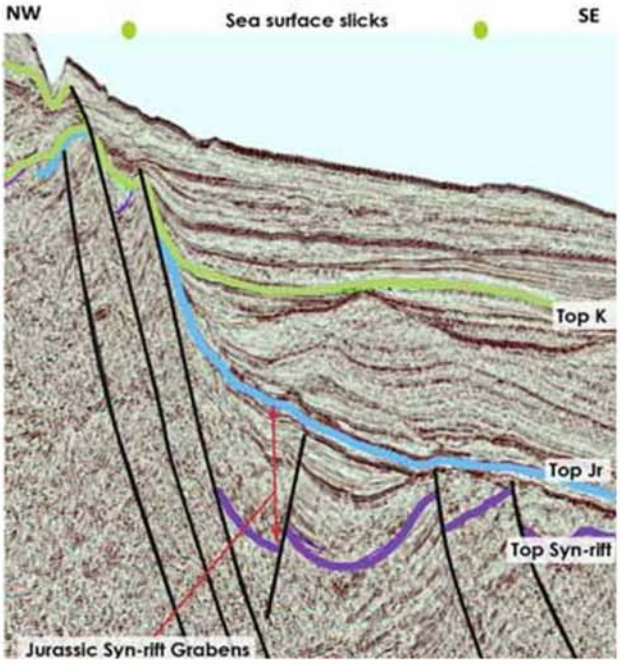

Figure 4. *Syn-rift graben offshore Somalia.*

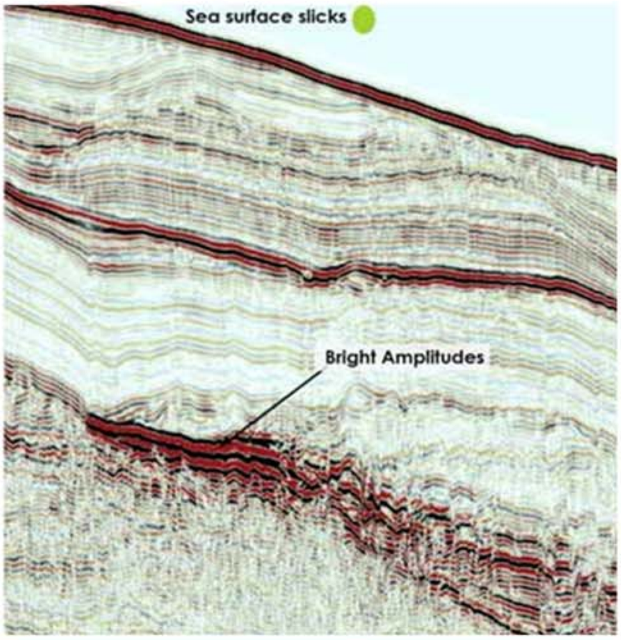

Figure 5. *Bright amplitudes conforming to structure thought to be a Cretaceous basin floor fan.*

Correlation with leads

Bright amplitudes events observed in seismic sections can be (but are not always) indicative of a hydrocarbon-filled reservoirs. In Figure 5, also from Somalia, the bright amplitudes conforming to structure are interpreted to be a large Cretaceous basin floor fan located in deep water. An isolated slick cluster is found to be located above the downdip closure of the lead, suggesting that oil is spilling over the edge of the structure and escaping to the seafloor and eventually the surface of the sea, increasing the confidence that the lead is charged with oil.

Conclusions

Proving the existence of a functioning hydrocarbon source rock in frontier basins is risky. Without well control, identification of a source interval is difficult; extrapolation over large distances even more so. Satellite imagery allows an opportunity to make direct observations of hydrocarbons on the sea surface. When combined with seismic cross sections a picture can be built of where these hydrocarbons have originated from, how they are migrating through the section, the effectiveness of seals and even to help diagnose prospects. It has been found that, where oil is present in a basin, slicks are often found in correlation with basin edges, particularly where basin bounding faults are present. Cluster patterns may be found around a point focus or may have a linear pattern, especially if associated with faulting. The combined picture leads to a reduction in the risks associated with the presence of a hydrocarbon source rock.