Remote Sensing – The Rise of the Virtual Geologist

Over the years remote sensing has developed from an obscure and expensive experiment to an essential and cost effective tool in the search for hydrocarbons, particularly in remote and inaccessible parts of the world. We talk to Infoterra, one of the leading exponents of this complex and fascinating discipline.

Jane Whaley

Ever since man first sent a camera into space in 1960, we have been mesmerized by this very different and spectacular view of the earth. Very soon it was realised that satellite imagery could afford us some unique insights into the earth's surface and what lay beneath. Oil companies rapidly saw the value of the technology, many of them setting up their own satellite imaging departments with dedicated hardware and software. Eventually, however, they found it more cost effective to divest themselves of these and turn to specialist companies for remote sensing acquisition and interpretation services.

Developing into a worldwide tool

"The first commercial Earth observation satellite was launched in 1972 amid great excitement in the oil industry. This initial enthusiasm started to wane as doubts over the value of satellite imagery set in, probably partly as a reaction to the original over-hyping of the tool," explains Dr. Anthony Denniss, Technical Director of Infoterra Ltd.

"The usefulness of satellite imagery then was constrained by the limitations of a single satellite and the relatively simple level of the technology at the time. As the number of satellites increased and the range of spectral bands gathered improved, together with better spatial resolution, the true effectiveness of satellite imagery to the oil industry as a way of looking at prospective areas became apparent, and the market rapidly opened up."

The acquisition of satellite imagery generates vast quantities of data which initially had to be stored on huge dedicated computers. This also contributed to the initial loss of faith in the technology. With the rapid increase in computing power over the last decade, together with the concurrent decrease in the physical size of computers, processing large volumes of satellite imagery has become more feasible, so much so that a great deal of the image processing can now be done on a laptop computer.

Dr. John Diggens explains the advantages of satellite imagery for structural interpretation.

Anthony considers that a major advancement in recent years has been the reduction in the purchase cost of satellite data. "In the 1990's LandSat data at what we now consider to be low resolution cost approx $3,000 per scene; we can now download this same data free. Most other satellite systems are commercially owned but even their rates have dropped as a result of competition".

"In addition, there are now extensive archives of data, so that you can obtain data only 6 months old for half the price of up to date data. It is also possible to order coverage on demand, but obviously you pay a premium for that. The 'open skies' policy means that we can now explore almost the entire world remotely," says Anthony Denniss.

Range of data available

"The range of uses for remote sensing in the oil and gas industry increases all the time" adds Paul Murphy, Business Development Manager at Infoterra Ltd. "To enhance our interpretations we use a variety of datasets from different sources and with different resolutions and footprints: the smaller the footprint, the more detailed the dataset and the larger the file size. As we were able to acquire higher resolution images, we could look at smaller areas in greater detail,

What is Remote Sensing?

Remote sensing can be defined as the science of deriving information about the Earth's land and water areas from images and digital data acquired at a distance, either through airborne sensors or from sensors carried on satellites. The latter includes collecting data in both the visible and non-visible portions of the electromagnetic spectrum. Applications associated with satellite imagery are most commonly used for the oil and gas industry.

Optical satellite imagery is defined by two major criteria, the resolution and the band or colour content. The resolution of a satellite is defined as the size of the smallest individual component or pixel from which the image is constituted, so that if a satellite's resolution is stated as '5 metres', this means that each pixel in the imagery is 5m by 5m in size. Current commercial satellites provide data at resolutions ranging from 0.6m to several kms for weather type satellites.

The colour content is defined by the number of 'bands' of data that are available within the imagery provided. Each band of data is acquired separately and filtered so that only the information for a defined portion of the electromagnetic spectrum is recorded. An image consisting of the visible red, green and blue bands of data (RGB), for example, represents a natural colour image when combined. Most satellites acquire their imagery in four or more "bands", many of which are outside the visible colour spectrum and it is this characteristic that allows data which is not normally visible to the human eye to be used in an interpretation of the components of the earth's surface.

All satellite imagery is recorded as distinct areas, known as scenes, at a predefined size. This is usually defined as the square area of the satellite's swath width, which is the distance on the earth that the satellite scans in a single pass. For example, if the swath width of a satellite is 60 km, then a scene will usually be delivered as a 60 km x 60 km image. Combining 2 or more scenes together is referred to as mosaicking.

This image shows an area of the UAE using Landsat & multispectral bands 3, 2, 1 as Red, Green, Blue, giving a true colour image.

The same area of the UAE visualised using Landsat & multispectral bands 4, 5, 3 as Red, Green, Blue. This gives a false colour image, which is good for highlighting vegetation, seen in red.

Using Landsat & multispectral bands 7, 4, 2 as Red, Green, Blue gives a false colour image, which is good for highlighting lithology in arid areas. This images shows that the coastal plain includes dune sand (yellow), gypsum and/or sabkha (turquoise blue), and cultivated areas (vivid green). The mountainous area to the east is mainly composed of a thick carbonate sequence (browny-green to pale yellow).

3D visualisation using satellite imagery is very valuable when undertaking landcover and elevation analysis for pipeline route planning.

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Geological and structural interpretation from Satellite Imagery.

which opened up new applications for the technology, such as pipeline route investigations and facilities monitoring. The different resolutions equate to a scale range of 1:2,000 to 1:500,000."

The US series of Landsat satellites has been providing high quality multi-spectral data for many years and can now offer a worldwide database of scenes with a spatial resolution down to 15m. Further detail can be interpreted using ASTER data, which provides higher spectral resolution in 14 different wavelengths of the electromagnetic spectrum.

"These satellites use light reflected from the earth, which obviously is a problem in areas where the sun is frequently obscured by cloud cover, such as the Nigerian coast," explains John Diggens, Senior Geological and Environmental Consultant with Infoterra Ltd., "but in these cases we can enhance our understanding through Synthetic Aperture Radar (SAR) data, which penetrates cloud, fog and haze."

A further recent advancement of great help to the geologist has been the development of stereoscopic data using the SPOT, ASTER, IKONOS or QuickBird satellites, which produces very detailed terrain mapping information from space. It takes 2D info and puts it into 3D context, ideal for the geologist.

John describes how this can be used. "Our first step after geo-referencing the various images is to make a digital elevation model (DEM) or a digital terrain model (DTM) of the area. We can then drape the different interpretations and images onto this to give a full 3D view of the area. By using anaglyphs - images displayed in different hues, usually red and green - and stereo instrumentation or glasses, the eye can distinguish features in the imagery in 3D. We also run our interpretations through software which can create a 'fly through', to give our client an idea of what the area looks like on the ground. This is particularly useful in poorly explored areas.

Sophisticated imagery and multiple uses

"We have 15 geoscientists in the Oil, Gas and Minerals Exploration division," explains John Diggens. "We undertake investigations throughout the range of exploration work, from regional evaluation through to licence and prospect evaluation and environmental modelling. Satellite imagery is an invaluable tool for mapping in remote areas or difficult terrain, particularly in the initial stages of analysing and developing a prospect, where

Largest in Europe

Infoterra was established 25 years ago as part of the Royal Aircraft Establishment, based in Farnborough, Hampshire. It was privatised in 1991 as the National Remote Sensing Centre and in 2001 the company changed the name to Infoterra and became part of EADS, Europe's largest aerospace company. EADS covers the whole range of the aerospace business, including building and launching Earth observation and telecommunications satellites whereas Infoterra Ltd., based in Leicester and Farnborough, concentrates on creating applications and offering interpretation and consultancy services.

The interpretation of remotely sensed data for use in the hydrocarbon and mineral extraction industry has always been a key business for Infoterra. The interpretations are used for geological, environmental and logistical applications at both exploration and development stages. Practical uses of satellite interpretation in the hydrocarbon industry include geological and structural mapping, the recording of offshore oil seepage, seismic quality studies, pipeline and infrastructure planning, geohazard mapping and hydrology.

Dr. John Diggens, Senior Geological and Environmental Consultant and Paul Murphy, Business Development Manager at Infoterra Ltd (left).

detailed field geology is not an option. For the client this is a very cost effective way of assessing the economic risk of an area."

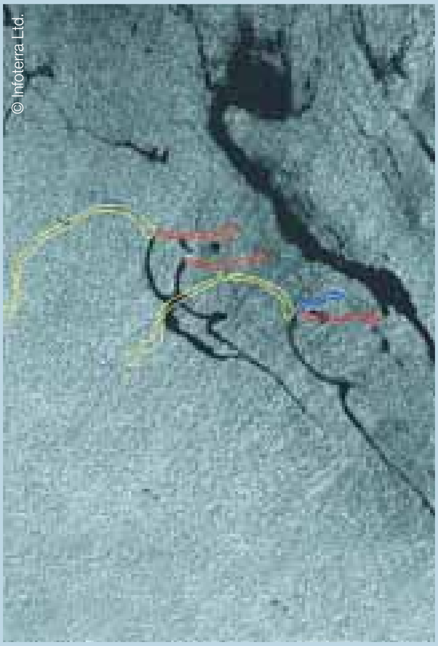
John goes on to discuss how the geoscientists tune the images and manipulate spectral bands to look for the spectral responses of different features and land cover types. "By using both 'true' and 'false' colour images we can map a wide range of features. The 'true' colour bands show features, which are visible to the human eye, and we use this to aid in the interpretation of geological structure, easily identifying faults, dips, anticlines and synclines. 'False' colour images use wavelengths collected outside the range of human visibility, so that, for instance, near infrared is useful for studying vegetation. Short wave infrared highlights different rock types and is used for geological and mineral mapping. It has now become so sophisticated that with the latest developments in satellite sensor technology it is possible to identify, for example, not just clay, but subtle compositional variations such as kaolinite and illite."

Environmental baseline studies and risk assessments, a prerequisite for many new exploration licences, is a sphere which is making increasing use of remote sensing. Through archived images it is possible to picture an area before hydrocarbon exploration, which can then be monitored during exploration and production activity and the imagery can ensure that sites are restored to their original condition if necessary. As John says "the thermal bands in use now can even pick out warm currents, indicating pollution by production water, as well as identify oil slicks, which could indicate potentially prospective oil seeps, or maybe just ships emptying their bilges."

All the interpretation is undertaken on-screen in a GIS environment, so that the results are easy to combine with other datasets.

Turning into Virtual Geologists

John Diggens brings his extensive field experience to bear when looking at images and can often imagine himself walking along the outcrop. He says that, for him, interpreting satellite imagery is "like being on a field trip every day. In any field situation it is important to stand back first to look at the whole thing before going in close to the outcrop. Therefore - with the latest high resolution data - we are able to get a lot closer to the rock face. It is now possible to undertake detailed fracture analysis and follow individual beds. I used to be a geologist – now I'm a virtual geologist!"



Example of remote sensing used to identify oil seepage in the Caspian Sea. Interpretations from earlier scenes (in colour) show how the seeps have moved over time.

Anthony Denniss considers that "remote sensing is an industry that will continue to develop, with, for example, new satellites such as TerraSar-X , due to be launched in Q4 2006. This will enable the collection of synthetic aperture radar (SAR) data at an incredible 1m resolution.

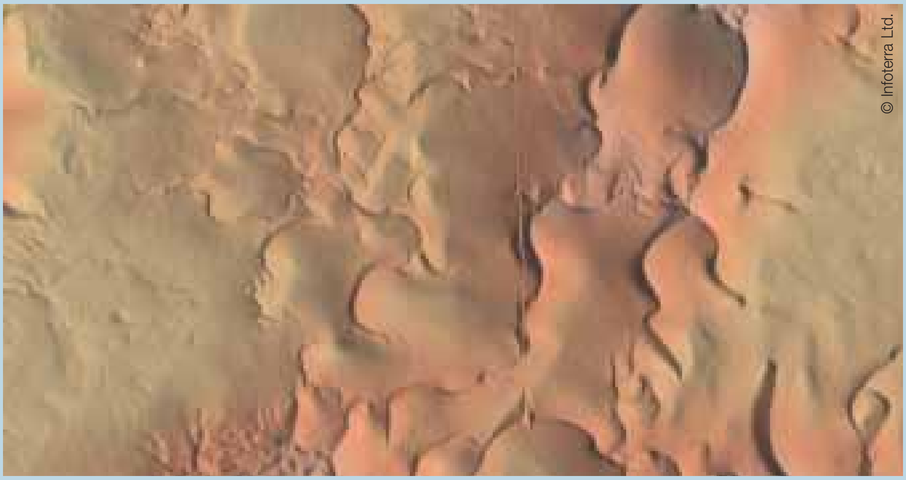
"The most important aspect of remote sensing to the hydrocarbon industry is that it ensures a company can effectively target field resources. As the technology develops even further, it will open up more and more applications and become even more important to the industry," concludes Anthony Denniss.

Seismic Route Planning

An interesting recent extension of the use of remote sensing in the oil and gas industry is in the planning of seismic survey routes in areas of difficult terrain, particularly in desert regions. Infoterra have been working with WesternGeco to investigate the quality of seismic acquired in the Algerian desert, using ASTER imagery and digital terrain modelling to ascertain the types of terrain through which the survey passed. Information from this ground-truthing exercise can be used to help plan more cost effective surveys in future, avoiding the need to reshoot poor quality data by predicting likely areas of poor seismic returns.

Vibroseis trucks can operate easily on gentle slopes, and can be used with care on slopes between 10° and 15°. Slopes steeper than 15°, however are not feasible. Infoterra mapped the survey area using relief shaded optical imagery and digital terrain modelling, colour coded to show slope information, clearly identifying the most suitable route to avoid the steeper slopes. The mapping also distinguished different dune types, with the more stable star shaped dunes clearly differentiated from the softer rounded dunes.

Gypsum and sabkha give poor seismic returns and remote sensing images can be used to identify these areas, highlighted through colour coding, again making it easy to plan a route which would avoiding the shooting of poor quality or unusable seismic data.



Lidar Digital Elevation Model from the Sahara Desert.