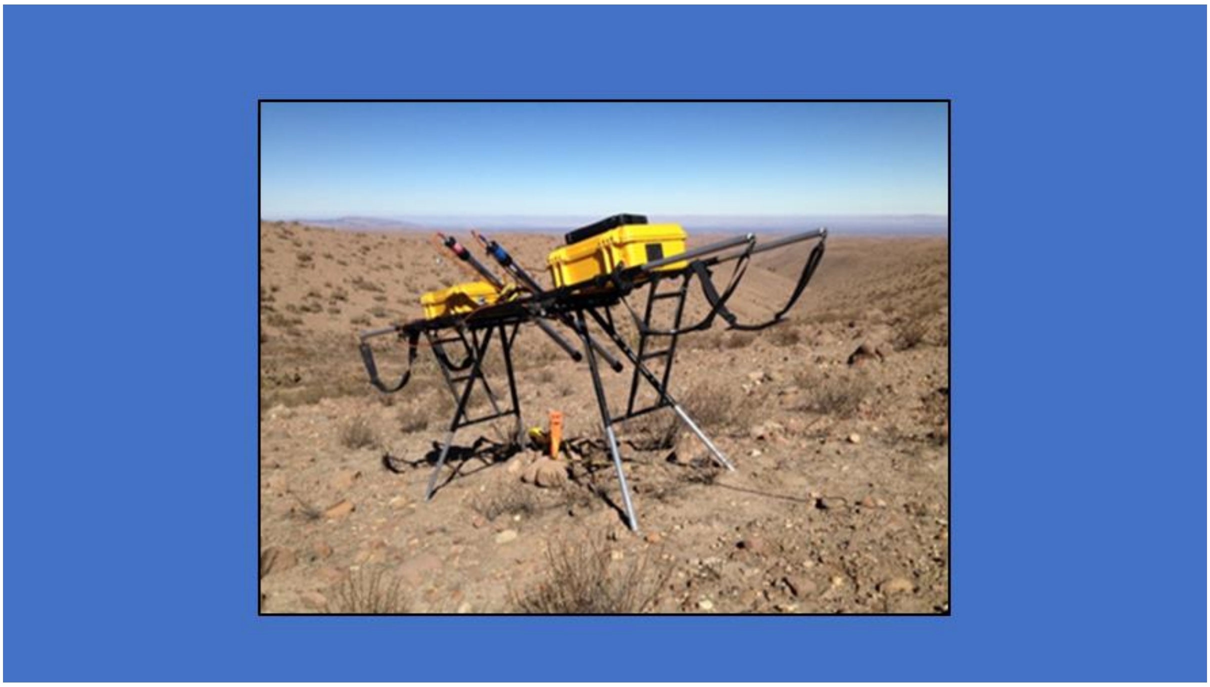
FROM RADAR to ADR: ILLUMINATING THE SUBSURFACE



It ain't no seismic survey, and it ain't no drilling rig, but you might be surprised what it can find…

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Paetoro and Adrok are jointly presenting a poster at PETEX next week, on how the application of ADR technology (atomic dielectric resonance) has been applied with a hydrocarbon context in the onshore UK Weald Basin. There, we hope to share more about this incipient but maturing technology.

The back-story of how it got to that point, is an interesting one, worth sharing as a prelude.

HOW DID IT HAPPEN?

The ability of radar signals to see the subsurface was first recognised in 1910 and application of the technology led to estimates of glacier depth in the late 1920's – but it was not until the military became involved in developing the technology that commercial ground penetrating radar (GPR) applications first started evolving, becoming available in the 1970's.

In the early eighties there were a lot of military and space agency led experiments in synthetic aperture radars (SAR) – the technology of moving a radar sensor over an area from an aircraft or spacecraft, sending directed radar pulses and using the echoes to make high resolution images. In 1981 the European space agency experimented with this using a Canadian aircraft over beach dunes in the Ythan estuary Scotland. It achieved imaging of groundwater surfaces – still in the near surface, but much deeper than was expected.

The same year, the first Shuttle Imaging Radar experiment took place (SIR-A) and was able to detect ancient river channel systems in the subsurface in Egypt. In 1984 a repeat experiment from the Shuttle (SIR-B) tried narrowing the beam angle over a shallow water test area in the North Sea. The UK Ministry of Defence (MOD) flew under the shuttle in real time acquiring simultaneous infrared imagery. The experiment found that narrow beams achieved much deeper penetration.

RADAR subsurface potential first recognised ~1910

RADAR Applied to measure glacial ice thickness 1920's

Military starts to become interested in sub-surface RADAR applications

Advent of commercial ground penetrating radar (GPR) in 1970's for shallow subsurface applications

1981 – European Space Agency uses a Canadian aircraft over estuary dunes in Scotland and sees groundwater surfaces deeper than anticipated

Early eighties - military & space agency air & space-borne experiments flying radar to detect subsurface – synthetic aperture radar (SAR)

1981 Space shuttle in SAR experiments detects ancient river channels in Egyptian subsurface

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1984 Space shuttle & MOD confirm improved depth penetration from narrow SAR beams used in shallow North Sea

80's & 90's developments in beamed laser and LIDAR technologies

90's Increased awareness of potential to do the same, at radio and microwave frequencies, at deep penetrating lower freq. than GPR

1994 Adrok founded by C. Stove, expert with experience in these SAR experiments and GPR

ADR - use of pulsed narrow coherent multi-spectral radio and microwave beams to penetrate deeper and resonate subsurface materials

First patents issued in 1999 and many more since, with ongoing development and application of tool in various subsurface applications

This led to the development of narrow coherent (mathematically relatable) beams to penetrate and illuminate the subsurface. The coherency helps to reduce dispersion – the loss of energy to the surroundings. The simultaneous development of lasers and LIDAR technologies helped the development of similar microwave and radio-wave frequency multi-spectral beams. It's this kind of technology that recently has led to the European Space Agency's Mars Express discovery of a sub-glacial lake at the Martian South pole, a mile beneath the surface.

RELATIVE PERMITTIVITY/DIELECTRIC CONSTANT

The dielectric constant controls any material's response to the electromagnetic beams sent to it. It can be thought of in three ways – it's related to absorption – it's the ability of a material to store and release electromagnetic energy, and first arose as a term from the study of capacitors. It's also the ability of a material to restrict the flow of free charges and it's the amount of polarisation a material shows in an applied electric field. It influences the travel time of energy through materials. Clearly rocks are mixtures of minerals and fluid filled pores, so that gives an added dimension of complexity on top of the already complex physics of atomic level responses.

We don't need to know all that. What we need to know is that for water it's about 80 to 81, for hydrocarbons it's between 1 and 2, and for most minerals it's between 2 and 10. Hence if we can measure this parameter – we should be able to see porous rocks – of use to hydrogeology and geothermal exploration, and we should be able to distinguish pores filled with hydrocarbons. That is good.

The overlaps of values for various minerals means that to distinguish lithology and mineral responses can be trickier, but calibration at historical well sites and lab calibrated spectroscopy helps there, so that the technology has already been used helpfully in mining contexts. It is however important to remember that we are observing the changes in rock response related to their total dielectric character. That means we won't see every geological change, just those with a significant dielectric contrast.

THE NOW - ADROK

Colin Stove – founder and chairman of Adrok Ltd., was involved in those early experiments in Scotland, and with the MOD's shuttle-synchronised experiments over the North Sea, as well as in pioneering ground penetrating radar. That long and varied experience in related fields allowed him to recognise the subsurface potential that was emerging. He instigated Adrok in the early 90's, with the first patents occurring in 1999, and many more since. Adrok has used a variety of methods to take the signal deeper, such that now recording is routinely taken to depths of 3 km.

Adrok has grown into a significant Edinburgh based operation. It developed and continues to develop the subsurface application with its scanner (pictured) using two synchronised coherent, pulsed multi-spectral beams. The beams work in phase and have two components – a long wavelength standing wave that carries the energy deep, and shorter resonant waves within it that enhance vertical resolution. When these beams encounter a material, the material is "excited" and undergoes a resonant energy response at atomic level. The timing and nature of this response is dictated by the dielectric constant and is transmitted and picked up by the receivers, to be measured in terms of energy, frequency, and phase relationships.

The greater depth penetration, higher depth resolution, and lower frequencies used, set ADR apart from other electromagnetic techniques. Noise and non-uniqueness of complex porous rock signatures always pose a challenge, so it's no easy answer to all subsurface problems, but there are ways of mitigating those issues. The processing is involved, though not unlike seismic in nature. That said progress is steady, and workflows are being continually enhanced and improved.

PETEX 2018

So that's a bit of the background. At PETEX we hope to show you more of the detail and stir your imaginations as to possible applications. These exist in virtually any science which involves the subsurface, from archaeology to hydrogeology; minerals to hydrocarbons; and geothermal to waste disposal. The thing which will make this already eye-catching tool better, is practice. Be it mineral, geothermal, or hydrocarbon E&P, the things it is achieving already are worth understanding better and improving.

Over the past twelve months, as part of an independent review, Paetoro has applied several new elements to the analysis workflows, and they seem helpful. We invite you to our PETEX poster to investigate whether this technology can help you.