Dr Colin Stove, Adrok Group Limited

# **Sensing** the Future

## Exploring the environment with less disruption

**The field of remote sensing is broad and has a variety of applications, from environmental monitoring to military imaging, and use by civilian businesses.**

A very wide part of the electro-magnetic spectrum is available to remote sensing scientists, giving access to information on scales from the 'cosmic' down to the 'micro'. The study of the earth's sub-surface, however, has generally been left to low technology techniques such as seismic or physical coring of areas of interest.

Both seismic and borehole cutting are potentially environmentally disruptive, requiring the use of percussive forces for seismic and road infrastructure for bringing drilling rigs onto a site of interest for cutting cores. For delicate sites in need of preservation, such as archaeologically important areas, or as part of the built environment, physically damaging technologies are less than ideal for investigating such areas.

There is therefore a need for a less disruptive method of exploration.

### A new, careful niche

For water, minerals, oil and gas this means a technology whereby sites can be dismissed without the need for expensive and time consuming techniques, and only places with a higher probability of successful recovery can be focused on, while places of archaeological and architectural importance need to be explored without damage.

This is one of the niches that a new scanner fits into – giving sub-surface geological information without the need for infrastructure support, or causing any environmental disruption. The small form factor of the equipment means that it can be easily manned portably, and can also be mounted on many sorts of land vehicles, aircraft and ships.

### Top technology

The newly developed scanning device represents a passion for innovation, which has grown up around the use of the Atomic Dielectric Resonance (ADR) technology in a manner that presents a new way of looking at planet earth, from the small to the large. >

ADR uses novel resonance properties of radio waves from X-band and C-band radar, having been developed using knowledge gained from the aerospace, remote sensing and imaging industries. Data is collected, after which this recorded information is then subjected to specialist analysis using unique software.

In classic Electro Magnetic (EM) theory, the EM properties of the mediums of propagation – air, water, soil, rock and biological materials, for example – there are three key variables which are usually studied:

- Dielectric permittivity ($\varepsilon$)
- Magnetic permeability ($\mu$)
- Electric conductivity ($\sigma$)

The mathematical and statistical methods of ADR analysis produce synthetic relationships which can then be used to compute very precise values of $\varepsilon$, $\mu$ and $\sigma$.

## The story behind the technology

The most up to date iteration of the equipment has been built to exacting standards and builds on previous versions that have shown utility in various sectors of industry and research.

The technology has been developed over several decades through its use to solve problems in a multitude of situations. Some of the earliest work where the specialist ADR, and its ground penetrating radar forerunner, showed its prowess was in the fields of archaeology and civil engineering.

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The clarity and much greater depth of penetration that is achievable for archaeological work led to the appearance of the technology on a BBC television science programme, Tomorrow's World, in 1990.

A project was undertaken to probe an area in the city of York in the UK, which was undergoing renovation. The earlier version of the scanner was able to give images at a depth of ten metres, and was also able to correctly identify walls and graves for the team of archaeologists studying the area.

Many other uses of the technology in the field of archaeology have been undertaken, but this is not the only field of endeavour where the capabilities of the equipment have proven their versatility.

## Widespread applications

Civil engineering often has the requirement to gauge the nature of the ground that construction projects are taking place on. In this case I have been involved in many projects where archaeology and civil engineering worked in tandem.

In 1993, at the behest of English Heritage, London Underground Limited I took scans to provide information on the construction techniques used on the world's first shield driven tunnel – Sir Marc Brunel's 1,200 feet (366m) long tunnel beneath the river Thames.

Using specialist antennae and the propriety WARR (Wide Angle Reflection and Refraction) technique an accurate structural analysis of the twin brick arch structure was provided from inside the tunnel. Furthermore, the plots of the riverbed derived from the scans, taken looking up through the tunnel towards the river, showed good correlation with the work of Sir Arthur Skempton who had studied the riverbed in detail from above.

In other work for London Underground we traced a source of water that had caused a leak in a tunnel. On this occasion the scanning was from the surface looking down towards the tunnel.

From 1992 to 1997 a £1.1 million project was undertaken to conserve the historically valuable Laigh Milton Viaduct over the river Irvine in Scotland – this is believed to be the world's oldest viaduct for a public railway, dating from 1811. To enable the project to proceed, a radar survey was undertaken to determine the nature and position of the rock surface under each pier.

This information was used to enable contractors to produce 'design and build' bids and included the finding of a timber platform at 2m depth below one of the piers. The platform was later found as indicated.

The survey allowed the contract to be carried out on time and on budget and the whole project received a Saltire Society award for "skill in preserving a structure on the verge of collapse."

One of the more unusual applications for the scanner was when we used it to try to prove a long standing Highland legend. During the building of the West Highland Railway in the Eighties, it was alleged that a horse and a cart loaded with rubble for filling the inside of piers had fallen into one of the Glenfinnan viaduct piers, now known to millions of people worldwide as the Harry Potter viaduct from the films featuring the eponymous character.

Although many people knew of the story there was no documentary evidence to support the claims. In an effort to confirm or refute the story a survey using cameras inserted into the piers was therefore carried out in 1987. The walls were found to be 4 feet thick concrete, but the cameras showed that the massive concrete piers were actually hollow and not filled with rubble, so there was no evidence that a horse and cart would have been used.

Some years later more detective work by Sir Roland Paxton MBE led to information coming to light that the accident might have occurred at the Loch-nan-Uamh viaduct, slightly further west on the line. In 2001, after finding that the piers of this viaduct were filled with rubble and

*Figure 1. Radar image of the remains of the horse and cart*

therefore inaccessible to cameras, ADR radar scanning was undertaken through concrete walls up to 9 feet thick.

This work made the discovery of the remains of a horse and cart in a vertical position lying against the east wall of the structure of the 'king pier' (Figure 1). (RCAHMS Broadsheet 10 The Mallaig Railway. Edinburgh 2002; R Paxton and J Shipway, Civil Engineering Heritage Scotland Highland and Islands. Thomas Telford Ltd, London, 2007. 184-188).

Both of the previous projects were generously supported by The Hon Sir William McAlpine, and through Sir Robert McAlpine Ltd.

## Investigating water

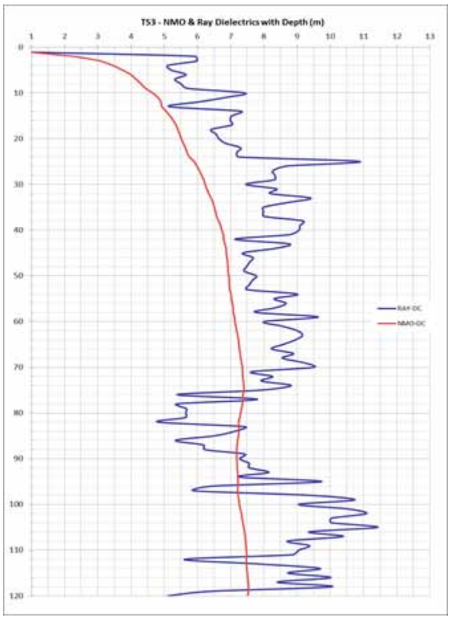
From the previous brief description of a little of the work that has been carried out using our novel techniques, the alert reader will have realised that among various possible uses for ADR that finding water is possible.

Indeed, I am interested in looking for aquifers, both natural and those forming due to the workings of man below ground. In virtually all areas of the world, fresh water supplies are under increasing pressure.

Even in the UK, which is well known for its rainfall, there is a constant need to find new sources of water and to check on the health of existing supplies below ground. Using the information returns giving an indication of the dielectric properties of the strata we are able to predict areas of high water content.

This led to a project with Scottish Water to test out methodologies for the accurate identification of even small aquifers (Figure 2).

*Figure 2. An example of virtual bore dielectrics from a project looking at aquifers*




A corollary of the work on natural freshwater aquifers is that places similar to the UK which have had hundreds of years of mining, of mainly coal in the UK, have large areas of underground water where old mine works have become inundated.

These old works have engendered interest in ways of using these features as a resource.

One of the ways of using these as a useful resource is for extracting geothermal energy – the deeper the mine the greater the temperature difference with the surface. In Britain some of the cities sit atop, or close to old mine works, making them prime candidates for using the geothermal energy held in the flooded mines for domestic and/or industrial use.

"we are working on methods for extracting geothermal energy, locating the mine works and gauging the relative water temperature"

We are working on methods for both locating the mine works and gauging the relative temperature of the water. To this end, collaboration is underway between scientists at the University of Glasgow's department of Engineering, a venture funded by the UK Technology Strategy Board.

## Health and biology

In other collaborations with university and health service partners, we have explored new ways of examining biological specimens, thus, moving from macro to micro scale experiments.

With our interest in tackling very difficult problems we made ourselves available for the study of sporadic Creutzfeldt-Jakob disease (sCJD) and its infectious relation, variant CJD (vCJD). Using known samples of the aforementioned diseases and other neurological conditions, a database of information gleaned from ADR analysis was built up.

Due to the nature of these diseases the sample sizes were small in number, but from this database algorithms were derived indicating that differences between the disease groups could be detected. To extend the work, blood from sCJD patients and vCJD infected individuals was tested against samples taken from normal donors and neurological control patients in two separate studies.

The first study was essentially a training exercise to evaluate whether the discrimination was reliable and used some 'blind test' samples among known samples. Results from the first study showed that more information was required to enable the expert systems to function at the required level of statistical significance.

The identities of all samples were given and the results fed into the algorithms to enhance the specificity of the results. For the second study a small number of blinded samples were put through the testing regime and the results analysed. Again, these consisted of normal and disease controls as well as samples from sCJD and vCJD patients. >

With the increased reliability derived from including all the data from the first study into the algorithms, the unknown samples were identified with 100% accuracy. This work shows the potential utility of the technology in solving problems in the field of medicine and biology. (Timothy J Fagge, G Robin Barclay, G Colin Stove, Gordon Stove, Michael J Robinson, Mark W Head, James W Ironside and Marc L Turner. Application of Atomic Dielectric Resonance Spectroscopy for the screening of blood samples from patients with clinical variant and sporadic CJD. Journal of Translational Medicine 2007, 5:41).

## Minerals, oil and gas

When surveying for minerals, oil and gas, companies will more often than not employ the staple methods of seismic and physical sampling, such as drilling. In recent years we have undertaken work with industry partners to explore different areas of the planet in an environmentally friendly way, seeking to make the technology available on a global scale.

Field surveys using ADR can be carried out in a much shorter timescale than conventional methods, and the results are made available after processing.

This utilises a technique whereby the information from the field surveys is captured, usually with several sites of interest being scanned in a single day. Processing of the field data is the more time consuming aspect of the procedure.

If, however, one considers that for a virtual bore of greater than 1,000m depth the time to completely analyse the results might be two weeks, this compares very favourably with other techniques. The output from the processing gives information in a lithological form showing Energy Log, Dielectrics and Energy ADR. An example is shown in Figure 3. >

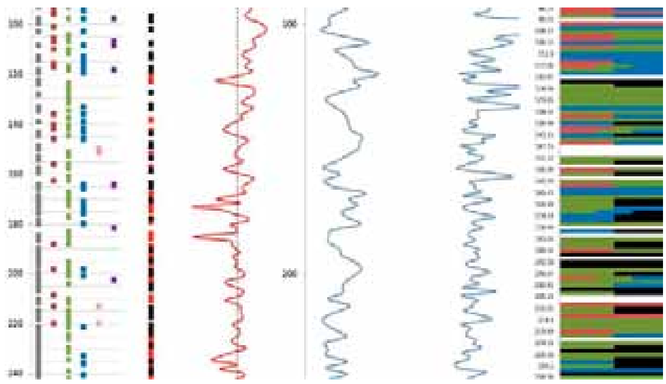


*Figure 3. Part of a lithological log from a field survey*

We have been fortunate to gain the support of Teck, Canada's largest mineral and mining resource company, a company committed to responsible resource development. This relationship has allowed us to continue to develop our systems at all levels of the business.

## "by scanning a variety of minerals and rock types using an ADR chamber, a database can be built of the features displayed"

Among the very useful things that this collaboration has produced is access to stores of mineral samples. By scanning samples of a variety of minerals and rock types using a purpose built ADR chamber, we can build up a database of the features that the different samples display when illuminated with the ADR beam. The database can then be used to try and match unknown samples with known information held in the database.

The ultimate goal is to be able to use the information from the laboratory-based chamber to match to data gathered from field scanning. ■

*Author*

*Dr Colin Stove*

*From 1975, after a successful academic career in the Geography Department at the University of Aberdeen, Dr Colin Stove led Remote Sensing research at the Macaulay Institute for Soil Research. There he pioneered expert systems in remote sensing using radar imaging, photogrammetry and shallow ground geophysics from air, ground and space platforms.*

*In 1983 Dr Stove was headhunted to lead technology development and transfer, for a private company set up to service the UK government and other commercial organisations who were interested in the company's exciting new radar research. Dr Stove held the role of Scientific Director and Chairman of the Board of the company, assisting in developing international business and operations. After five years of growth the company was subsequently sold to a large multinational defence company.*

*In 1988, he set up a new Ground Penetrating Radar business where he worked on new technology developments for non destructive inspection services used on different sites and materials. Following the trade sale of this business in 1994 to a drilling company with international operations, Dr Stove was afforded the time to set up his own science business, which allowed him to develop his ideas of Atomic Dielectric Resonance (ADR).*

*In 1999, after many in-house experiments and while continuing to carry out special investigative services for a variety of clients, Dr Stove applied for patents for his ADR apparatus and techniques. The patent application was successful and can be seen in US Patent 6,864,826.*

*Dr Stove was Vice Chairman of the Association of Consulting Scientists (ACS) and Chairman of its Membership and Promotions Committee from 1994 to 2008. He was also a National Committee Member of the Ultrasonic and Acoustic Transducer Special Interest Group, as well as being Trustee and Director of Soutra Archaeo-Medicine Trust. Dr Stove is currently a member of the Remote Sensing and Photogrammetry Society.*

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