Impact of curiosity-driven research on oil production through *Problem awareness*

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Much effort is applied to the process of *Technology Transfer*, whereby research is commercialised, but it appears that much less attention is given to its counterpoint and possible precursor, *Problem Transfer*. This paper describes one example of how curiosity driven research, performed in the ambience of problem awareness, by chance, had considerable impact on oil production technology. Although it happened by chance it points to the need for greater dissemination of possibly soluble problems.

A major, but relatively little known, problem of the oil industry is the cost of coproducing water with oil, including that injected into the reservoir to increase oil production. A second and also expensive problem is precipitation of mineral "scale" in the well and near-wellbore region, reducing production flow. For example, in offshore wells sulfate present in injected seawater reacts with barium in the formation water precipitating barium sulfate. The problem is ameliorated by addition to the injected water of just the right amount of a relatively expensive scale inhibitor compound.

While setting up a new stable isotope laboratory in an oil company lab and seeking materials to test, a set of water samples was analysed. This produced two surprises. Isotopic analyses of samples from a well in which chemical compositions indicated presence of injected seawater (sulfate) allowed that contribution to be quantified from a cross plot of H and O isotopes. However, the isotopes (which characterise the whole water) showed that the seawater amount had been under-estimated by a factor of two! Excitingly, those wells with no seawater contribution formed a never previously seen anti-correlation of H and O isotopes, which proved to be mixtures of underlying aquifer brine and residual water in the oil zone, with very different chemical compositions. This was significant because estimates of oil reserves involved use of the resistivity of oil zone water, until then believed to be the same as that of the underlying aquifer. Subsequently, we developed a method to analyse oil zone water by extracting it from produced, “dry” oil. The Ph.D. student involved in developing the method formed an SME to undertake this service commercially as soon as he got his degree.

Thus, curiosity-driven research, serendipity and problem awareness delivered great economic impact and indicates the need for a better managed process of *Problem transfer*.

Calibration of Raman spectroscopy to determine water contents in lunar silicate glasses

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Recent lunar sample analyses and remote sensing data suggest that the Moon is probably not as dry as initially thought (e.g. [1-2]). The presence or absence of water in the Moon’s interior has potentially dramatic consequences for the chemical and physical properties of lunar rocks and melts during lunar evolution. It is thus critical that techniques that are able to determine the water content of lunar soils directly on the lunar surface are developed for use during future lunar lander missions. In addition, in order to establish how water influences lunar melt properties, we need to be able to measure accurately the water content of lunar melts/glasses in experiments.

Raman spectroscopy can be used to quantify reliably the water content of both silicate glasses and minerals. Raman analyses are quick, non destructive and do not require any sample preparation, contrary to more classical techniques like FTIR, SIMS or Karl-Fischer titration. Thus we are calibrating the Raman technique to quantitatively measure water content in lunar glasses. Using a piston cylinder apparatus we synthesised a range of lunar glass compositions (as identified by Apollo missions), doped with different amounts of water (0-6wt%). We confirmed that the water content is homogeneous in our standards by imaging the water content by Fourier Transform Infrared spectroscopy, and determined the absolute water content by Karl Fischer titration. We analysed the samples by Raman and found that the ratio between the water peak area at high frequency and the silicate network peak areas at low frequency, calculated according to [3] is proportional to the water content. Above 0.4wt% water the accuracy is comparable with FTIR.

We are also determining the Raman detection limits for water, using a miniaturised Raman instrument previously designed for the ExoMars mission (e.g. [4]). We are testing this instrument in an in-house vacuum chamber to simulate the extremely low pressure conditions on the lunar surface.

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