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Innovative 3D and 4D geological interpretation, modelling and visualisation techniques for subsurface characterisation of complex industrial sites – examples in the UK nuclear industry

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Industrial sites are typically complex, with numerous plants within their (often) relatively small footprint. The 'cramped' nature of these sites means that the geological characterisation that is essential to the development of environmental safety cases may be hampered by a lack of access to exposures, if they exist at all. Due to access limitations and potential for ground vibration affecting key plants, geophysical data are typically limited to those gathered from lower resolution surveys (e.g. electrical resistivity tomography) rather than those gathered from more informative vibroseis seismic reflection surveys. Thus, whilst many industrial sites may possess numerous intrusive boreholes (Sellafield, perhaps the UK's most complex industrial site, has over 3000), there is a lack of ties to either high resolution geophysical data, or important regional lithostratigraphic data provided by exposure of key sequences. This poses a conundrum: the hydrogeological 3D and 4D numerical models required to show the predicted migration paths of potential contamination within the subsurface require the best geological understanding possible, yet without high resolution geophysical data or geological exposure within the sites themselves geological interpretation is often restricted to attempting to correlate between boreholes that may be tens to hundreds of metres apart and only a few metres deep, which one could assume may not provide a good geological understanding.

In this paper, using examples from the nuclear industry, we describe how the use of outcrop analogues and innovative GIS-based, 3D/4D geological interpretation, characterisation, modelling and visualisation techniques goes some way to addressing these issues. Regional outcrops of Triassic sandstone and unconsolidated Quaternary sequences are ideal analogues for unexposed sequences underlying key nuclear sites in West Cumbria (UK), providing important sedimentological (and depositional), lithostratigraphic and structural information. Detailed examination of these alongside numerous borehole logs and existing and new low-resolution geophysical data has allowed the creation of 3D geological interpretations and models, enabling the construction of 3D and 4D hydrogeological and contaminant transport models that are essential to environmental safety cases.

Staying within the nuclear industry, geological characterisation issues may become even more prevalent in the UK's search for a location to build a geological disposal facility (GDF) for the disposal of its higher resolution radioactive waste. Here intrusive investigations would typically involve the drilling of boreholes, yet intrusion needs to be kept to a minimum. However, we show how innovative laser-based digital data gathering techniques which are currently being employed in the development of 3D structural models of crystalline rocks, are likely to be vital to the geological characterisation of the deep subsurface at potential UK locations for a GDF whilst keeping intrusion to a minimum.