OR/17/042 Methodology

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Conceptual geological models

Geological understanding of any area is underpinned principally by the quality, type and quantity of geological data that is available. Within many flat, low-lying coastal areas such as Ince Marshes, natural exposures of the geology are often limited. Geologists therefore rely upon borehole records (where available), non-invasive techniques (e.g. geophysics), site investigation records and observed changes in soil texture and composition to infer the underlying geology. An alternative approach is the Conceptual Geological Model (Figure 2.1) which utilises a semi-iterative approach routinely employed by geologists to build a hierarchical level of observational, interpretational and contextual knowledge and resolve a specific geological problem (Eyles, 1983[1]; Evans, 2003[2]; Rose, 2010[3]; Booth *et al*., 2015[4]). This approach is very similar to a 'conceptual ground (or site) model', which is a conceptual tool employed by civil engineers and hydrogeologists to support decision-making and ground investigation. However, within this context, the Conceptual Geological Model adopts a systems approach to explain the range of 'geological products' (e.g. sediments, structures, landforms and volumes) that may be anticipated relative to the known (and assumed) geological history of a site or area. In other words, by understanding the 'geological drivers' and how these have evolved in time and space, it is possible to predict many of the 'geological processes' that operated within the landscape and, in-turn, the 'geological products' that may be present (i.e. the properties and characteristics of the geological record). Ultimately, this process relies upon one (or ideally two for increased confidence) components of the workflow to be understood to infer to the third.

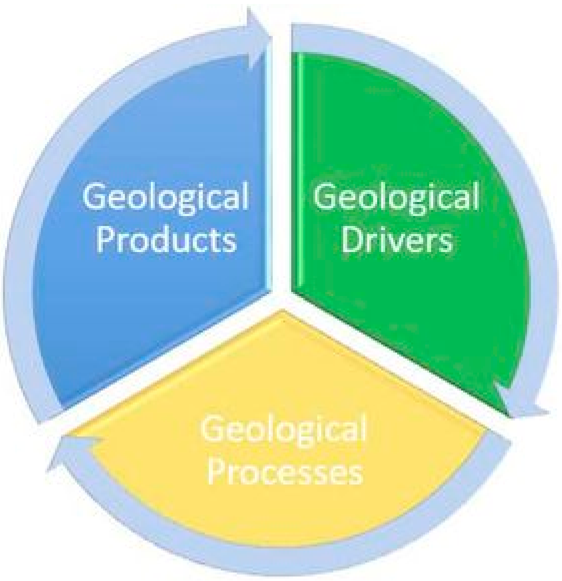

Figure 2.1 A workflow for the conceptual 'systems' geological approach. Effectively, by taking two known components it is possible to predict the third unknown component.

Understanding the drivers and processes of landscape evolution and, in-turn, how they have evolved in time and space, is crucial for developing a robust conceptual geological model that outlines the range of properties that may be present within the shallow sub-surface. The range of geological drivers and processes that have operated within the landscape since the youngest bedrock units were deposited may have changed due to natural changes in geography, climate and tectonic stress regime. However, going back in geological time, our ability to visualise and interpret the geological record going back in geological time typically declines. This reflects the reduced resolution and preservation of the geological record with age; a reduced ability to qualify (and quantify) rates of change; and finally, a more limited understanding of the geological context compared to modern day.

In terms of the study area and northern part of the Cheshire Basin, the youngest bedrock geology encompasses Triassic-age sandstones and mudstones, overlain unconformably by superficial deposits of variable thickness and composition. The absence of rocks or sediments of intervening age (c.200 Ma) means that evidence for the area's geological history during this time is sparse and this limits the direct observations and inferences that can be made. Nevertheless, by analogy with the wider geological evolution of NW England and the East Irish Sea Basin, it is possible to make assumptions about the broader geological history of the study area, which can inform this study.

This report focusses on geological processes that have acted on bedrock, and the resulting Quaternary sediments, from the Late Devensian (27 ka) onwards. However, processes pre-dating this time will have had a significant impact on the local Permo-Triassic bedrock (Sherwood Sandstone Group). These processes have influenced the generation and character of fractures and joints within the Sherwood Sandstone, and the development and evolution of cements through post-depositional diagenetic processes. Further details are in Strong *et al*. (1994)[5] and Milodowski *et al*. (1999)[6] (and references therein), which are summarised below.

Strong *et al*. (1994)[5] describe the petrology and diagenesis of the Permo-Triassic strata near Sellafield in Cumbria' approximately 125 km to the north of the Cheshire Energy Research Field Site. They note that the diagenesis of the St Bees Sandstone (laterally equivalent to the Sherwood Sandstone Group in Cheshire) is characterised by non-ferroan dolomite, quartz, ferroan and non-ferroan calcite and late illite. Analysis indicates that porosity is secondary, following the influence of modern groundwater action, but also the early removal of evaporate cements allowed for the preservation of early-stage porous fabrics.

Milodowski *et al.,* (in Plant *et al*., 1999[7]) conducted a study of the diagenetic history and processes relevant to sandstone-hosted mineralisation in the Sherwood Sandstone Group in the Cheshire Basin and Wirral Peninsular. They proposed a diagenetic paragenesis for the group and related this to the burial history of the Cheshire Basin. They identify eight main phases of diagenesis, ranging from shallow diagenesis/pedogenesis immediately following deposition, to telodiagenetic alteration influenced by modern near-surface groundwaters.

Measuring uncertainty

Measuring *uncertainty* or the *likehood of occurrence* is a fundamental component of communicating geospatial data. Within the context of this report, uncertainty is used to communicate the likehood that a particular geological feature will be present beneath the Ince Marshes study area. Various methodologies have been published that communicate levels of uncertainty although these are principally quantitative (e.g. Kandlikar *et al*., 2005[8]; Patt and Dessai, 2005[9]; Ellingwood and Kinali, 2009[10]; Mastrandrea *et al*., 2010[11]). However, for the purpose of this study, a qualitative approach to uncertainty is employed and the terminology outlined below in Table 2.1.

Table 2.1 Communicating levels of uncertainty/likelihood of occurrence.

Term	**Likelihood of Occurrence**
Virtually certain	Virtually certain to occur other than in exceptional circumstances.
Very likely	Much more likely to occur than not.
Likely	More likely to occur than not.
About as likely as not	May or may not occur.
Unlikely	More unlikely to occur than likely to occur.
Very unlikely	Much more unlikely to occur that likely to occur.
Exceptionally unlikely	Unlikely to occur other than in exceptional circumstances.

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