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The stratigraphy of the Middle Chalk (Upper Cretaceous) succession at Mundford, Norfolk, UK

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ABSTRACT

Four continuously cored boreholes and 82 observation shafts were drilled over an area of *c.* 45 km^2 at Mundford, Norfolk in 1966–67 as part of a geological and geotechnical investigation of for a large (2.4 km diameter) proton accelerator and attendant experimental target areas that was to be commissioned by the Committé Européan pour Recherche Nucleaire (CERN). The site is a low-relief area underlain by Middle Chalk and the oldest part of the Upper Chalk in a region where the stratigraphy of the Chalk was poorly known prior to the investigation. The shafts enabled the unweathered succession to be examined in detail, both vertically and laterally, and proved numerous lithological marker beds, mostly flint bands and marl seams. Some were restricted to the site area; others remained unchanged over a much larger area. Penecontemporaneous erosion channels in the Middle Chalk that probably resulted from minor tectonic activity locally cut out some of the marker beds. The Mundford succession falls within the northern part of the Transitional Chalk Province. A few of the marker beds, notably the thicker marl seams, have been correlated with marker beds in the Southern and Northern Provinces. Some of the on-site names for marker beds were used to illustrate the geological succession and structure in the geotechnical report on the proposed site. As a result, the site subsequently became the *de facto* standard for the Middle Chalk stratigraphy of the region. A description of the full succession is included here for the first time.

1. Introduction

In 1964 the CERN invited the fourteen participating member countries to propose sites for a 300 GeV proton synchrotron which would have been ten times larger than the next largest research facility of its type in the world. The principal requirements were that the site should be large enough to accommodate a 2.4 km diameter accelerator ring, a possible future second ring that would allow 600 GeV collisions, and beam lines up to 4.5 km long that would terminate in 250 m × 1000 m experimental areas. The site should have a low topographical relief to minimise construction costs, should be uninhabited or sparsely populated, should be underlain by relatively uniform rocks whose geotechnical properties were well documented, and should be aseismic for all practical purposes. In 1965 the Institute of Geological Sciences (IGS) was asked by the Science Research Council to suggest possible sites for the facility. The site selected by IGS, and subsequently investigated and submitted to CERN as the UK proposal in competition with sites in 10 other countries, was an almost drift-free, largely afforested area of low relief (<20 m over an area of 5 km × 9 km) on the Middle Chalk between Mundford and Brandon, Norfolk (Fig. 1). Reconnaissance surveys by C.R. Bristow, E.R. Shephard Thorn and R.G. Thurrell showed that the chosen site was underlain by lithologically uniform Chalk overlain in part by a veneer of drift deposits, mostly Cover Sand. Four continuously cored boreholes were drilled to confirm the full thickness and lithology of the Chalk beneath the centre of the site, to provide samples for analysis, and to allow seasonal variations in the level of the water-table to be monitored.

The principal engineering requirement was that the site should be underlain by material whose geotechnical properties were such that there would be minimal differential settlements beneath the heavily loaded accelerator ring, the more lightly loaded beam tunnels, and the heavily loaded laboratory areas which included the radiation-shielded target areas (Ward et al., 1968). In geological terms this meant that the area must be drift free, or contain only thin patches of drift that could be relatively easily removed, and be underlain by a thick layer of relatively uniform rock of sufficient strength to meet the loading requirements.

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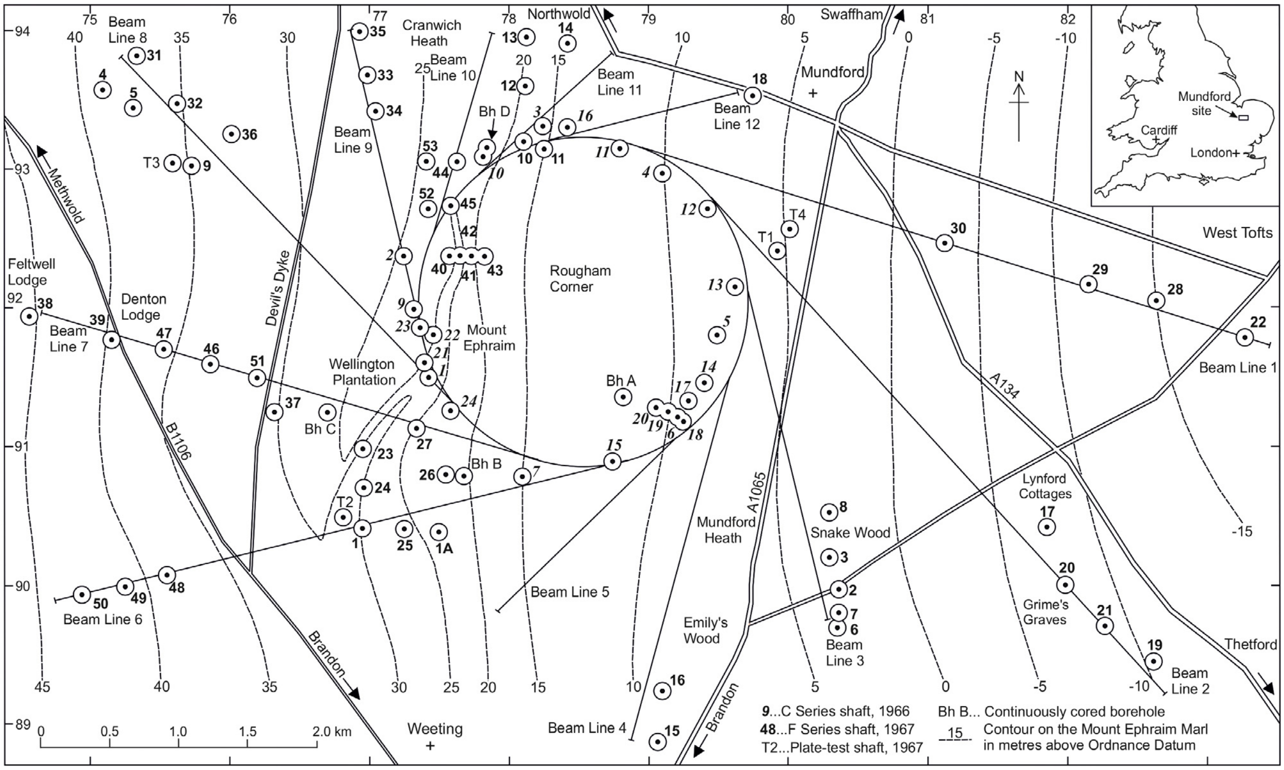

Fig. 1. The proposed 300 GeV proton accelerator site at Mundford, Norfolk showing the positions of the accelerator ring and beam lines, cored boreholes A–C, inspection shafts C1–C24 (1966) and F1–F54 (1967), and Plate Test Shafts T1–T4 (1967) (after Gallois in Anon, 1967, Figs. 3 and 5).

Additional criteria were that the site should have a very low seismic risk to avoid possible damage to the delicate magnetic and vacuum equipment, and that the ring and beam tunnels could be constructed above the highest predicted level of the water table. In this part of East Anglia, Cretaceous rocks rest with marked unconformity on a thick succession of folded Silurian and Devonian mudstones that have remained stable since the end of the Caledonian orogeny.

The four cored boreholes all had poor core recoveries in highly fractured chalks with Rock Quality Designations (RQD) almost all <40% in the top 25 m, the layer of most interest to the investigation. The large area of the site combined with the stringent engineering requirements meant that conventional site-investigation methods based on cored boreholes would have been both unsuccessful and prohibitively costly. Dr W.H. Ward of the Building Research Establishment (BRE), the organisation responsible for the engineering feasibility study, therefore suggested that the stratigraphy and weathering profiles beneath the site could be recorded *in situ* by a geologist in 0.76 m diameter shafts. He did not propose that he or any of his engineers would enter the shafts. A total of 88 shafts (Fig. 2) ranging from 10 to 29 m deep were dug using a bucket-piling auger. This method of investigation proved to be cost effective. Shafts were dug to a depth of 14 m, including the time taken to insert casing to prevent the collapse of the surface layers, within one hour. Deeper shafts which involved the use of an extended kelly bar were dug to over 20 m depth in 2–3 h. The method also proved to be geologically effective for several reasons. First, the shafts had the stratigraphical advantage that they provided a circumferential section of *c.* 2.4 m for examination, and spoil material from a bedding plane area of about 0.45 m^2. This enabled the lateral distribution of widely spaced flints and laterally impersistent marl wisps to be determined with confidence. Second, once a 0.1–0.2 m thick layer of puddled chalk had been plucked from the shaft wall using the modern equivalent of a Neolithic flint miner's deer-horn pick, the lithological and textural details of the Chalk were clearly visible in the unweathered surfaces. Third, the use of a miner's lamp provided an even, well-lit surface that was independent of the weather or seasonal conditions. Fourth, the shafts were left open for over a year to enable them to be re-examined as more detailed lithostratigraphic data became available from the later shafts. Some of those that were dug at times when the water table was high were subsequently deepened and accessed using a rope ladder. The principal disadvantages were first, that the vibration of the auger bucket and the scraping action of the cutting blade meant that few of the larger fossils (ammonites, echinoids and inoceramid bivalves) survived. The smaller fossils, principally brachiopods, survived in large numbers at some levels. Secondly, a limited amount of time could be spent in the confined space of the shafts in atmospheres that were prone to a build up of carbon dioxide at times when atmospheric pressure was falling. This simple but effective method of examining strata *in situ* was banned as unsafe by the Factories Inspectorate when it was drawn to their attention shortly after completion of the site investigation.

A detailed knowledge of the lateral and vertical variations in the stratigraphical succession was a key part of the site investigation given that the presence of any folds, faults or marked lithological variations would have meant that the engineering requirements with respect to differential subsidence could not be met. The preliminary geological results were described by the author (in Wilson, 1967) and the final geological and engineering requirements, tests and results were published in the UK submission to the CERN (Anon, 1967). The geological results have not previously been described except in an abbreviated form in the latter account, parts of which were included in a summary of the geotechnical results (Ward et al., 1968).

The site lies in an area of low relief where the former Chalk escarpment was eroded by a west to east moving Anglian ice sheet that impinged on the escarpment at a high angle (Gallois, 1999). As