The Palaeogeography of the British Zechstein

D.B. Smit

ABSTRACT

Information from bores and surface outcrops indicates that the Zechstein Sea probably formed following flooding of a large sub-sea level inland drainage basin. The floor of this basin was partly of bare rock, and partly covered with desert breccias, aeolian sands and playa-type deposits, including evaporites. The small amount of redistribution of the aeolian sands suggest that flooding of the basin to considerable depths was rapid. Due to basin floor relief, a few islands remained after the flooding, and other, lower, eminences divided the newly-formed sea into several sub-basins.

Because of the considerable initial depth, there is no conventional basal conglomerate and the first marine deposit, the thin Sapropelic Marl Slate, was remarkably uniform and extensive, despite the basin-floor relief. The Marl Slate is the clastic member of the first of four major sedimentation cycles, each of which, in England, has a carbonate, sulphate and chloride phase. The carbonate phases of cycles 1 to 3 are well known from many surface outcrops, and the distribution of reefs, stromatolites and other depth indicators shows that the early basin floor relief dominated sedimentation patterns until the end of cycle 2. Evaporite deposition during later parts of these cycles was probably relatively rapid.

Virtual elimination of basin-floor relief at the end of cycle 2 ensured that subsequent sedimentation was relatively slow, and that carbonate and evaporite deposits were more uniform than formerly. Space for their accumulation was probably provided mainly by subsidence.

The paper will be concerned mainly with tracing the course of sedimentation patterns in the various cycles, and with the contemporary geography northern Britain.

Information from many surface exposures a boreholes indicates that northeast England imme ately prior to the Zechstein transgression form part of a great eastward-sloping arid penepla lower parts of which were floored with aeoli sands, whilst topographically higher parts consist either of bare rock pediment or were covered wi thin piedmont breccias. The peneplain probab extended for fifteen to thirty miles to the west the present margin of the Zechstein sedimen beyond which lay a more varied landscape feat ing a number of subsiding troughs in which thi continental sediments were accumulating. Lit facies patterns and thickness trends in the succe ing marine strata, where present, suggest that t higher (western) part of the northeastern penepl formed a persistent land barrier throughout L Permian time, separating the Zechstein pro from an extensive sea stretching from northw England, to northeast Ireland. This sea, for whi the name *Bakevellia sea* is proposed, was probab fed from a channel lying to the west of Scotla although temporary restricted links with t Zechstein sea cannot entirely be ruled out.

The limited redistribution of aeolian sar (which have yielded no evidence of contempor cementation or fixation) suggests to the writer tl the initial Zechstein transgression may have be extremely rapid, a circumstance most eas accounted for if the Zechstein came into existen

1. Institute of Geological Sciences, Ring Road Halton, Leeds L 8TQ, England. This paper will be published in full in 1970 in Proceedings of the Yorkshire Geological Society.

following flooding of a large sub-sea-level inland drainage basin. That inland drainage areas did occur in parts of the basin is attested by the presence of evaporites and playa-type deposits in north Germany. Flooding of such a basin might take only weeks or months, and could be brought about by the breaching of the basin rim following a relative sea level rise. There is some evidence of other rapid and marked sea level fluctuations at several stages during the ensuing Late Permian, a glacioeustatic mechanism appearing the most likely cause.

The major peneplain of northeast England was divided by a broad tract of slightly elevated land—the Cleveland axis—stretching across most of north Yorkshire. Similar slightly elevated land lay across Nottinghamshire and Lincolnshire. These two tracts appear to have subsided less rapidly than most remaining parts of the English Zechstein basin. By contrast, a broad embayment—the Ripon gulf—immediately south of the Cleveland axis appears to have subsided in cycles 1 to 3 rather more rapidly than most parts of the shelf province, and a broad partly estuarine embayment—the Nottingham bight—persisted until the beginning of Cycle 3 in the area north of Nottingham. Elsewhere, uneven westwards thinning and onlap displayed by some of the higher beds appear to be due to the progressive burial of a number of topographic highs rather than to differential rates of subsidence.

As in Holland and north Germany, four main evaporite cycles may be distinguished in the Zechstein marine sequence of northeast England.

1. *English Zechstein Cycle 1* (EZ1). This cycle is incomplete, and consists of a basal sapropel, a carbonate member and a sulphate member. The limits of the initial transgression, as suggested by the western margin of the sapropelic Marl Slate, lay some distance east of the maximum westerly limit of the ensuing carbonate member, thus showing that relative sea level changes continued after the initial flooding. In County Durham the Marl Slate covers seif dunes up to 200 feet high, and was therefore in places deposited in more than 200 feet of water. No conventional basal conglomerate is present.

   Succeeding carbonates comprise three main depth-related facies:

   a. A standard marine facies, consisting of evenly-bedded, sparingly fosiliferous micritic dolomite, probably deposited under water of some depth.
   b. Shoal facies, consisting of calcarenite sand-grade granular or oolite dolomite enclosing many bryozoan-bivalve-stromatolite patch reefs. This facies is thought to have been deposited on a broad shallow shelf or platform.
   c. A varied marginal or coastal facies, now preserved mainly in north Nottinghamshire, and containing three sub-facies, viz
      (1) a sandy facies consisting of calcarenitic oolite with up to 50 percent detrital non-carbonate sand and with a few coquinas and pebbly horizons,
      (2) a pebbly (? beach) facies consisting of interbedded conglomerates, breccias, sandstones and shelly oolites, and
      (3) an estuarine facies (the Permian Lower Marl) of grey argillaceous plant-rich *Lingula*-bearing carbonate, deposited mainly in a broad shallow bight in south Yorkshire and north Nottinghamshire.

   In County Durham, most of the early Cycle 1 carbonates are of standard marine facies, but widespread submarine slumping about half way through the carbonate phase deposition was accompanied or followed by a marked relative sea level fall and the growth of a major barrier reef and its lagoonal and basin equivalents.

   In Yorkshire, basinward migration of shoal and marginal facies over carbonates of standard facies suggests that here too there was a widespread fall in sea level, shifting the coastline several miles to the east and leading to the establishment of extensive supratidal flats. With continuing subsidence in basin areas, and perhaps to the east of the suspected but unproved basin-rim barrier reef, thick deposits of displacement anhydrite (EZ1A) were built up in central and east Yorkshire. In Durham, the thick Hartlepool Anhydrite of this age was deposited mainly east of the barrier reef, and overlies a thin but persistent bed of algal nodules and colleniform stromatolites.

   No chlorides are known in the first cycle of the English Zechstein, and it seems likely that a renewed influx of sea water initiated the second cycle before completion of the first cycle and before the original basin was filled.

2. *Cycle 2* (EZ2). The second cycle was more complete than the first, and its deposits in most

parts of the basin were considerably thicker. As before, a number of depth-related facies may be distinguished in the carbonate (EZ2Ca) phase, the shoreline of which (following re-transgression of the basin margin) seems to have lain in most places near the most westerly position of the EZ1 coast. Three carbonate facies are identified:

a. A basin facies, consisting of evenly laminated carbonate and thought to have been deposited under fairly deep water well away from the basin margin.
b. A shoal facies of sparingly fossiliferous oolitic dolomite which in Durham is seen to intertongue with and subsequently to overlie the basin facies. Unresolved difficulties of correlation forbid firm identification of this facies in near-crop areas of Yorkshire, but its supposed equivalent is characteristically coarsely cross-laminated and appears to represent a subaqueous dune complex similar to that now found on parts of the Great Bahama Bank.
c. An evenly-bedded oolitic or granular dolomite marginal facies, known only in Nottinghamshire and south Yorkshire, in which (according to locality) are water-lain and aeolian sandy variants and local pebbly horizons. Basinward thickening between stratigraphic markers at the top and bottom of the marginal carbonates yields clear evidence of continuing subsidence during this phase.

In basin parts of north and east Yorkshire, the second cycle carbonates were succeeded by thick, partly laminated evaporites in which several sub-cycles have been recognized. In northeast Durham these evaporites are known only from residues exposed in a narrow coastal belt. In south Durham and much of Yorkshire it seems likely (subject to the previously-mentioned difficulty of correlation) that at this time the marine margin retreated far to the east; and thick sands, silts and clays were laid down on an extensive barren prograding coastal plain favourable locally to the formation of diagenetic evaporites. Relative sea level oscillations from time to time led to marine incursions and the formation of some primary evaporites and carbonates at the seaward margin of this plain, whilst aeolian sands and continental breccias formed locally towards the inland margin.

Despite continuing subsidence, the evidence suggests that by the end of Cycle 2 the initial basin was virtually filled, that the sediment surface was at or above sea level, and that original basin-floor relief had ceased to exercise a decisive influence on sedimentation. Deposits of succeeding cycles are therefore more uniform and extensive than those of cycles 1 and 2 and were necessarily accommodated in space made available by subsidence and/or eustatic changes. Continued activity of the preexisting positive and negative areas is nevertheless clearly recognizable in the thickness trends of the deposits of cycles 3 and 4.

3. *Cycle 3*(EZ3). Over most of northeast England the basal member of this cycle—the Upper Magnesian Limestone (EZ3Ca)—is a remarkably uniform shallow-water carbonate whose thickness increases evenly and progressively basinwards to a maximum of over 200 feet from a known shoreline in south Yorkshire and north Nottinghamshire. Field evidence suggests that the initial transgression was quiet, in keeping with the remarkably low relief of the depositional surface, and with little onlap. In the extreme east, an initial deposit of grey marine clays was laid down in some depth of water, but oolites and oncolites were developed locally in marginal areas and intertidal deposition seems to have been general. Sabhka-type algal deposits are common at and near the top of the Upper Magnesian Limestone, deposition of which seems to have ended abruptly without clear evidence of a marked salinity rise.

The carbonate was succeeded by the widespread Billingham Main Anhydrite, the lower part of which, over wide areas, has the nodular structure characteristic of supratidal (diagenetic) sulphates. Upper parts of the deposit are generally bedded. It seems that the rate of deposition lagged behind that of subsidence and that later parts of the bed were true chemical precipitates. The anhydrite is overlain by a thick deposit of halite which appears to have accumulated so rapidly that the sediment surface again approached sea level. Potash salts were deposited with halite at the end of this phase in northeast Yorkshire. Their texture and distribution suggest deposition in shallow residual pools, possibly partly as primary precipitates but more likely, in the author's opinion, by diagenetic formation within the sediment following the drying-up of these pools. The cycle ends with a thin regressive halite.

4. *The Carnallitic Marl.* Deposits of the third and fourth cycles of the Zechstein are separated by an extensive red clay member known in England as the Carnallitic Marl and in Germany as the Roter Salzton. This is conventionally regarded in Germany as the pelite phase of Cycle 1, but is considered by the author as a deposit in its own right, laid down in a shallow but extensive non-marine playa and therefore genetically unrelated to succeeding marine beds. Locally it includes thin salt beds, and ranges from 20 to 80 feet in thickness.
5. *Cycle 4* (EZ4). The deposits of this cycle, like those of Cycle 3, are relatively thin but are nevertheless uniform and extensive. Carbonate, sulphate and chloride phases are all developed. The carbonate is generally 3 to 12 inches thick and grades into both the underlying Carnallitic Marl and the overlying sulphate. It has yielded no marine fossils and may not be a true marine deposit. The succeeding Upper Anhydrite, however, is a consistently layered, highly uniform extensive deposit, and appears to be a true chemical precipitate from open (though not necessarily deep) saline water. Innumerable courses of halite and anhydrite crystals, pseudomorphing upright gypsum twins, occur through the bed and are similar to those found near the margins of parts of the modern Persian Gulf.

   The Upper Anhydrite is succeeded by up to 150 feet of Upper Halite, the lower part of which contains thin anhydrite laminae and is almost clay-free, whilst the upper part contains little anhydrite but is intimately associated with up to 50 per cent of red interstitial clay. Potash salts are locally found near the junction between the upper and lower parts of the halite in some eastern areas. The relationship of the halite to the clay in the upper part of the Upper Halite suggests that much of the halite grew within a clay matrix, but despite this, the bed has a clearly-defined and consistent top. It is overlain by a thin but very extensive red mudstone the base of which marks the end of Cycle 4.

   A thin sulphate bed–The Top Anhydrite–a short distance above the base of the red mudstones, is found on land only in parts of north-east Yorkshire, and is overlain by thin salt in parts of the North Sea. This sequence may represent a thin, partial, basin-centre fifth cycle.