The English Zechstein and related topics—introduction

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This volume is the printed record of EZ 82, a workshop on the results of recent research on strata of the English Zechstein and related topics. The workshop comprised a six-day field study meeting on Permian rocks at outcrop in north-east England and a three-day indoor discussion meeting in the Department of Geology at the University of Nottingham. Twenty-one research and review papers were presented at this meeting. Most of these were written up for this volume which has been further supplemented by the inclusion of papers submitted by two Polish workers who were unable to attend the workshop.

The field meeting commenced with visits to the classic exposures of Upper Permian reef-margin and slope carbonate rocks in County Durham and adjoining areas and continued to exposures of nearshore and shelf carbonates and continental sediments in Yorkshire, Derbyshire and Nottinghamshire. A guide to the exposures visited, which also included background information on their stratigraphical, environmental and palaeogeographical significance, was prepared for the participants; copies of this guide may be obtained from The Secretary, Department of Geology, The University of Nottingham, Nottingham NG7 2RD (1986 price £3.50 including postage).

The pattern of the workshop was based on that of a highly successful meeting of Zechstein workers in Poland in 1978 (Depowski *et al.* 1981) at which the growing school of Polish workers, amongst others, presented their research results to an international audience with research interests in the Upper Permian. About the same time, the discovery, possible sourcing potential, plus exploitation of hydrocarbons in Zechstein strata in Poland, Denmark, Germany, The Netherlands, England and the southern North Sea had stimulated Fuchtbauer & Peryt (1980) to put together a collection of papers dealing primarily with Zechstein carbonate rocks (*Contr. Sedim.* **9,** 1980). A steady trickle of papers on many aspects of the nature and evolution of Permian strata in Europe, together with the processes that shaped them, was also appearing in other journals, providing further evidence of increased interest in these sometimes enigmatic rocks. The EZ 82 workshop brought together both Zechstein workers from many parts of Europe plus researchers who were working on similar carbonate-evaporite basins from the USA to the USSR, a combination which created a lively discussion meeting.

In a volume dealing with so many diverse aspects by many authors we claim no unifying theme than that of relevance to the Zechstein. We have divided the papers herein on a geographical basis, with papers 2–11 dealing primarily with topics within the United Kingdom, papers 12–15 within Germany and papers 16–21 within Poland with the final contribution, paper 22, describing Upper Permian sediments from the Urals. Within each geographical section the papers are presented, as far as is possible, in stratigraphical order.

The first section, United Kingdom papers, commences with revision of nomenclature for the Upper Permian strata in eastern England (Smith, Harwood, Pattison and Pettigrew). This revision has been thought necessary for some time, particularly as strata in different Zechstein cycles had similar, or confusing, nomenclature in different areas of eastern England. The EZ 82 workshop provided the impetus to produce a revised nomenclature, which is detailed here and includes definitions and type localities.

The remaining papers in the United Kingdom section are mostly concerned with carbonate strata at, or near, outcrop within eastern England. One exception is the paper by Turner and Magaritz, who have carried out detailed mineralogical, chemical and stable isotope analyses on one core from the Marl Slate, taken just offshore of County Durham. They detail a close correlation between lithological and geochemical parameters, including stable isotope values. Sapropelic units, at the base of sub-cycles within the Marl Slate, are characterized by high contents of iron, quartz silt and organic carbon with strongly negative oxygen isotope values. Turner and Magaritz conclude these are indicative of freshwater influxes which promoted productivity, water stratification and regional anoxic conditions, thus forming the base of each sub-cycle. They also conclude that the increase in base metals (notably copper and zinc) away from the sapropelic units indicates these metals to be more associated with the marine conditions re-established in the upper parts of each sub-cycle.

Schweitzer presents an excellent systematic review of all the species of higher plants that have been described from the Zechstein strata of England and Germany and includes one new

species. This flora is characterized by conifers which had reached a surprisingly advanced stage of polygenetic development and resemble some Recent conifers much more closely than Lower Permian flora. Conifer woods display distinct growth rings indicating rhythmic climatic changes, perhaps on an annual cycle. Schweitzer demonstrates that the Zechstein transgression was a significant turning point in floral evolution in northern Europe and that floral development was uniform in both German and English areas of the Zechstein basin. The most abundant plant remains have been discovered in the Marl Slate and the equivalent Kupferschiefer.

Well preserved specimens of the conodont *Merrillina divergens*, separated and described by Swift, have been recovered from English Zechstein Cycle 1 carbonate rocks (EZ1 Ca) in north-east England. Swift reports a uniform collection from each locality which can be assigned to just six elements. This low diversity is typical of Zechstein Cycle 1 (Z1) strata throughout England, Germany and Poland and the recognition of a symmetry transition between the elements is one factor used to conclude that these elements are the apparatus of a single species. Swift surmises that the dominance of a single species reflects difficult living conditions in a wholly, or partially, enclosed basin with fluctuations in sea-level and salinities.

The upper member, the Sprotbrough Member, of the Zechstein Cycle 1 carbonate, the Cadeby Formation (EZ1b Ca—the former Upper Subdivision of the Lower Magnesian Limestone) contains evidence of a former ooid shoal complex which was present over most of its outcrop area. Kaldi describes large-scale cross-stratified bedforms within this complex, including hummocky cross-stratification, fan-shaped bedding, convex-upwards cross-stratification and contemporaneous erosion surfaces. He presents data on palaeocurrent styles and azimuths and concludes that the predominant current direction was from the north-east, but that periodic storms produced spillover lobes orientated towards the north-west. Kaldi adds that although sandwave topography must have controlled local currents by channelling or refracting flows, the exact manner in which the sandwaves originated could not be determined.

Diagenesis within the Cadeby Formation (EZ1 Ca) is the subject of two papers. In the first, Harwood distinguishes the timing of different diagenetic events from penecontemporaneous through burial diagenesis to those events associated with uplift of the formation during the Cenozoic. She includes evidence that shows early, penecontemporaneous events to be facies-restricted whereas later events were more pervasive. These later events, during early burial, were dominated by dolomitization and subsequent partial replacement by evaporites. Harwood concludes that three major dolomite types are present within the Cadeby Formation and that these formed in penecontemporaneous hypersaline lagoons, from reflux of hypersaline fluids after initial deposition and cementation and from mixed water circulation in some nearshore areas. She documents several near-surface events, including anhydrite to gypsum transformation with later gypsum dissolution, leaching of the carbonates and dedolomitization. Kaldi concentrates his paper on the upper, Sprotbrough Member of the Cadeby Formation. He defines five types of dolomite within this member, penecontemporaneous supratidal dolomite, primary dolomite precipitates within semi-restricted lagoons, early and late dolomite cements within the ooid shoal facies and local dolomite cements within open shelf carbonates and a later pervasive, replacive, coarsely crystalline dolomite, the result of mixing of fresh and marine waters. Harwood and Kaldi thus differ as to the cause of the replacive dolomitization phase, but unite in that this was the major diagenetic event within the Cadeby Formation. Kaldi also documents the formation of evaporites both within supratidal sediments and as a later replacive phase. He concludes that porosity evolution was dependent both on the nature of the primary sediments and on their diagenetic history. Together the papers present a good introduction to the complex diagenetic history of these sediments.

In a different approach to the Cadeby Formation, Harwood and Smith describe mineralization occurrences throughout the formation at outcrop. They demonstrate that the majority of mineralized localities cluster within four geographical areas. An underlying structural control is envisaged as a channelway for mineralizing fluids in three of these areas; in the fourth, mineralization appears to be the result of upwards leakage of formation fluids. Minerals present include lead, zinc and copper sulphides with barite and minor fluorite; occurrences are in vugs and breccias of sedimentary origin with extremely rare examples of vein mineralization.

An extensive thin bed, the Trow Point Bed, at the top of the Zechstein Cycle 1 carbonate (EZ1 Ca) in north-east England forms the subject of Smith's paper. This bed is present on the lower part of the basin margin slope and is continuous over an uneven surface, resulting from a submarine slide, with a local relief of up to 15 m. The bed contains oncoids, peloids, algal laminations and columnar stromatolites and is similar, and is in a

comparable stratigraphic position, to deposits described from Germany, Poland and the southern North Sea. Smith concludes that the similarities of these occurrences suggest that, although both German and Polish equivalents are considerably thicker, they are possible correlatives. He further surmises that the Trow Point Bed accumulated in water depths of 25–100 m in oxic conditions and may have been much more extensive than is apparent at outcrop today.

Evidence for present-day dissolution of gypsum from both Zechstein Cycle 1 and Cycle 2 evaporites in North Yorkshire is given by Cooper. The timing of the subsidence resulting from this dissolution within the last few hundred years has been documented from newspaper articles, unpublished notebooks and previous published papers; subsidence during Pleistocene glaciations is evidenced by Late Devensian and Flandrian lacustrine deposits over some tens of square kilometres. Cooper demonstrates the linearity of many of the subsidence hollows, which he concludes is due to a subsurface joint-controlled cave and fissure system where active dissolution is taking, or has taken, place. He also demonstrates that the eastern limit of the subsidence-prone belt is marked by the transition of the secondary gypsum to anhydrite with depth; the western limit is where the gypsum, or its residue, crops out. Cooper's paper is the last in the United Kingdom section of this volume and makes a valuable contribution to this aspect of the Zechstein strata.

The remaining sections of the volume contain papers on the Zechstein elsewhere in northern Europe, plus one paper on the carbonate-evaporite deposits of the Urals. The German papers are contributed by two authors, Paul and Richter-Bernburg. In the first of his two papers, Paul considers the effects of a basin and schwellen topography, inherited from the Variscan regime, on sedimentation within the lower Zechstein cycles in Germany. He shows that although the basinal Kupferschiefer facies are similar throughout the Zechstein, different facies, including red shales and fossiliferous dolomitized carbonates, are present around the basin rim and on schwellen within the basin. In the Zechstein Cycles 1 and 2 carbonates (Z1 and Z2 Ca) reefs and other biogenic sediments dominate the basin margins and biogenic sediments were also abundant on the schwellen (or palaeohighs). Paul further describes how evaporite deposition in both cycles was much greater on the palaeohighs and the basin rims, increasing the relief between palaeohigh and basin floor with consequent sediment instability.

In a second paper Paul describes the stratigraphy of the Lower Werra Cycle Carbonate (Z1 Ca) in West Germany. This paper was submitted after the EZ 82 workshop and is a direct consequence of the field excursions before the oral presentations. In visits to exposures in Yorkshire, Paul was shown the Hampole Discontinuity, first described by Smith (1968). This seemed similar to some German exposures and, on return to his native country, Paul carried out preliminary fieldwork resulting in documentation, here, of the 'Solhops Discontinuity'. Paul concludes this to be equivalent to the Hampole Discontinuity in eastern England. Furthermore, he takes it to represent an extensive regression of the Zechstein Sea, leading to subaerial exposure of marginal areas of the Zechstein basin. This paper is included in this volume both because it resulted from the workshop itself and because of its implications on basin-wide changes in sea-level.

Richter-Bernburg's two papers concentrate on the evaporites within the Zechstein sequence. The author has worked with Zechstein material for many years and has probably seen more Zechstein sediments, both at outcrop and in core, than any other researcher in this field. In the first of two papers he discusses some of the problems of anhydrite sedimentation in Zechstein Cycles 1 and 2 (Z1A and Z2A). He documents five subcycles in the Werraanhydrit (Z1A) throughout Germany which are correlatable with similar evaporites within the southern North Sea. Laminites near the base of the Basalanhydrit (Z2A) can be traced throughout the German Zechstein basin, although higher within the sequence they are abruptly replaced by flaser, or more nodular, anhydrite. This change takes place at a lower position near the basin margins, a factor Richter-Bernburg suggests may indicate an alteration in the depositional environment in those areas. Richter-Bernburg also introduces three new descriptive terms for use in study of evaporite sequences in his paper.

One correlation of Zechstein cycles between Germany, Denmark and England is presented in Richter-Bernburg's second paper. Using criteria including similarities in distribution, thickness and lithology of the evaporites, along with a change in colour, he suggests that the strata of the Don and Aislaby Groups of eastern England are equivalent in age to those of the Werra Cycle in Germany and that those of the Teesside Group are correlatives of the German Stassfurt sequence. This correlation is at variance with that of both Smith *et al.* (1974) and Taylor (1980) and provoked active discussion when it was presented; short discussion contributions are included after the paper.

Although two of the Polish authors were able

to attend the EZ 82 workshop, others found it impossible to do so. We have included two additional papers in this section from these authors both because the authors had originally hoped to present these in Nottingham and because of their relevance to Zechstein research. The first of these papers is by Oszczepalski, and is one of a series of three papers on the Copper Shale in the area of the Foresudetic Monocline in south-western Poland. Oszczepalski, working with a series of cores, has used microfacies analysis combined with geochemical studies to define three major facies within the Copper Shale; a deep shelf facies, a shallow shelf facies and a nearshore facies. Shorewards the Copper Shale is replaced by carbonate and/or terrigenous sediments. A great deal of detailed research has been compiled in this paper as Oszczepalski combines both inorganic and organic geochemical results with personal core descriptions in his analysis.

In contrast, in his two papers, both presented at Nottingham, Tomaszewski concentrates on the base metal enrichment of the Copper Shale. In the first of his papers, he comments on the genesis and structure of the polymetallic ores in the area of the Foresudetic Monocline. Also working with shallow cores, he has produced detailed maps showing the distribution of the types of ore, the different mineral zones and the lead content within the area, together with cross-sections showing the vertical distribution of the mineralization. In the second paper, on the sedimentary environments of the lowest Zechstein sediments, Tomaszewski presents data from samples from underground galleries in the Lubin copper mine, which have been analysed for their metal content and mineralogical components. With additional data from the mine's geological service, he has constructed isopach maps for the Border Dolomite and Copper Shale and also shows the amount of mineralization in the underlying white sandstones. Taken together, Tomaszewski's papers present a wealth of hitherto unpublished data on the extent of mineralization in the Lubin area of the Foresudetic Monocline and discuss some of the current ideas on its genesis.

Peryt contributes a discussion on the chronostratigraphical and lithostratigraphical correlations of the Zechstein Limestone (PZ1 Ca) throughout Poland, which unfortunately he was unable to present personally in Nottingham. He recognizes three sub-cycles within this carbonate, each representing progressive shallowing upwards. In areas around the basin margin the upper parts of these subcycles contain evidence of subaerial exposure. Peryt uses these exposure surfaces as chronostratigraphic markers which he traces across the carbonate platform sediments and throughout many of the slope and basin deposits. He comments that throughout some areas of Poland, in Germany and in England there is only one exposure surface recognized (the 'Solhops Discontinuity' in Germany and the Hampole Discontinuity in eastern England) but is unable to determine whether this coincides with the boundaries between his first and second sub-cycles, or between the second and third, or whether one of these sub-cycles is not developed in the other areas of the Zechstein basin.

The macrofauna present in the first three Zechstein cycles in Poland is summarized by Karwowski and Klapcinski. They distinguish four biozones with characteristic faunal assemblages, which typify palaeogeographical areas within the Zechstein carbonates. Preservation of the macrofauna is variable, in part dependent on the host rock and its diagenetic history. Fauna discussed include bryozoans, brachiopods and bivalves with gastropods, cephalopods and echinoderms being poorly represented. The authors include a faunal list showing stratigraphic occurrence.

In a separate paper, Klapcinski describes the Leine Anhydrite (PZ3A) within Poland. He recognizes three lithostratigraphic units within the anhydrite, principally based on its textural characteristics. The spherulitic structure of units within the anhydrite is described, with examples shown in the text. This texture is recognizable throughout much of the Leine Anhydrite in Poland. Klapcinski concludes that the presence of this spherulitic texture in the anhydrite may provide a useful and extensive marker unit within the Zechstein basin.

The final paper in this volume deals with a carbonate-evaporite succession outside the Zechstein basin, but of a similar age. Chuvashov presents a brief description of sediments from the Kungurian basin of the Urals, concentrating on the carbonates present. He compares these to similar sediments within the Zechstein basin and also provides a stratigraphic summary which helps to depict the evolution of the Kungurian basin.

In compiling this volume we have rejected some manuscripts initially presented at the EZ82 workshop, in addition to including three papers not orally presented at the meeting. We have tried to include as many of the foreign papers as is practicable as little research in this field is published in English; perhaps the references included will encourage some readers to consult the German, Polish and Russian literature. We realize that this represents a very small contribution to research over the whole Zechstein basin and that there are many areas of relevant research that are

not included. Perhaps the greatest omissions are the areas of East Germany, Denmark, the northern Netherlands and the southern North Sea. We also realize that many questions remain unanswered and that many of the papers included in this volume perhaps raise more questions than they answer. We are very conscious of the problems yet to solve and of whole fields that have been largely ignored in research. We hope that this book will go some way towards stimulating interest, and hence further research, on Zechstein strata throughout the basin.

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