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Intra-Zechstein sulphate platform clinothems: a clinoform framework applied to carbonate-evaporite cyclothems

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Here we describe 3D seismic stratigraphic architecture, potential facies and depositional model of a poorly known clinothem body: a progradational-aggradational sulphate/carbonate platform within the cyclothemic Zechstein Group. The study area is located on the United Kingdom Continental Shelf (UKCS) in Quadrants 35-38 and 41-43. The uppermost Permian Zechstein Group was deposited in supra-regional intracontinental sag depressions (e.g., Southern Permian Basin). Intermittent connections to the Arctic seawater allowed the accumulation of up to 1.5–2.0 km of cyclical evaporites and carbonates in the basin depocentres over a period of about 5 myr. Most commonly, four laterally-extensive cyclothems (Z1-Z4) are identified regionally within the Zechstein succession, each characterized by the vertical stacking of carbonate, anhydrite and halite facies.

In the study area, a large "build-up" is observed in the lower Zechstein, covering a total area of 2,284 sq.km. This is bounded on its margins by seismically-defined clinoforms, with maximum thicknesses of 0.12 two-way-time seconds (= c. 240-330 m). This rigid, near-tabular unit is clearly distinguished from the overlying deformed upper Zechstein evaporites. In map-view, a series of embayments and promontories are observed at the build-up margins. Borehole data and comparisons with nearby discoveries (e.g. Crosgan) suggest this build-up to represent a Z1-Z2 sulphate/carbonate platform. The thickest portion (up to 200 m) of the Z1–Z2 clinothems is composed of Z1 Werraanhydrit (anhydrite). The Z2 Hauptdolomit–Basalanhydrit stratigraphy (carbonate-anyhdrite) forms a younger, narrow clinothem fringing the rollover position of the Top Werraanhydrit clinoform. The Stassfurt Halite passively infills the inherited basinal depocentres, being thickest on top of the Z1–Z2 clinothem bottomsets. Above it, a new, but relatively minor, progradational cycle of Z3 Plattendolomit clinothems was deposited. The top of the Z3 carbonate–sulphate platform is affected by a pervasive 'rugosity', which could be representative of regionally-extensive karstification.

The stratigraphy and seismic geomorphology of the Z1–lower Z2, and then again in the lower Z3 cycle, indicate that carbonate- and anhydrite-prone clinothems were deposited in thicker, basin-margin-attached wedges, thinning abruptly basinwards into a stratigraphic equivalent ('bottomset') comprising deeper-water facies. The Z1–Z3 marginal carbonate–sulphate clinothems prograded from the margins of the Southern Permian Basin in towards its central depocentre, marking the progressive lateral filling of the deep-water (c. 200–300 m) Zechstein Basin.

The interaction between repeated seawater influxes and tectonic subsidence caused the strongly cyclical, multi-scale sedimentation patterns typical of the Zechstein Group. Over long timescales (i.e., 0.1-1.0 Myr), the Z1–Z4 Zechstein cyclothems reflect an initial marine transgression, followed by the gradual long-term desiccation of the basin. Over shorter timescales, repeated minor influx–evaporation cycles caused deposition of stacked gypsum layers, which coalesced to form the thick Werraanhydrit platforms. Each subsequent short-term evaporation and brine concentration event formed a layer of marginal selenitic gypsum over pre-existing highs and of thinner basinal gypsum over deeper depocentres. The accumulation of numerous time-equivalent shallow- and deeper-water gypsum layers formed the thick topset-foreset and the thin bottomset portion of the Werraanhydrit clinothem, respectively. Gypsum subsequently converted to anhydrite during late diagenesis.