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Strontium distribution and celestite occurrence in Zechstein (Upper Permian) anhydrites of West Poland

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ABSTRACT

The previous study showed that the Zechstein (Upper Permian) anhydrites have about 0.2% strontium with a remarkably small sample scatter. Our study of three lower Zechstein anhydrite units (Lower Anhydrite, Upper Anhydrite and Basal Anhydrite) from West Poland indicate that although often the Sr content is 0.1–0.2%, there are common deviations. In particular, a considerable part (28%) of the studied samples is characterized by lower values ($<0.1\%$), and on the other hand ca. 15% of samples are Sr-enriched, and in those samples celestite was recorded. Particular anhydrite levels differ especially in the frequency of samples showing great Sr content. The greatest variation was found in the Lower Anhydrite. This agrees well with the conclusion derived from the sedimentological studies indicating that there was the greatest differentiation of depositional environments during the deposition of the Lower Anhydrite. The Sr content is a good indicator of brine concentration during the gypsum precipitation and it seems that the subsequent gypsum–anhydrite transformation itself does not affect the strontium distribution. The histograms of Sr content in the Basal Anhydrite indicate a slightly higher brine concentration than it was during the Lower Anhydrite deposition, and the latter in turn was higher than brine concentration during the Upper Anhydrite sedimentation. Celestite veins are clearly diagenetic in origin. The form of celestite occurrence and the increased strontium content (1% or more) indicate an additional source of ions that occurred outside the anhydrite series. In the case of the Lower Anhydrite, the supposed additional source of Sr was related to aragonite-to-calcite transition and squeezing of $CaCl_2$ brines from reefs into anhydrite series due to increased pressure. For the Basal Anhydrite this source could be related to brines derived from the Older Halite deposits.

1. Introduction

The strontium distribution in sedimentary sulfate is controlled by the paleogeography and paleosalinity of the evaporitic environments (Rosell et al., 1998) and thus strontium concentrations have been used as a paleosalinity and/or paleoenvironmental indicators (Butler, 1973; Kushnir, 1982; Dean, 1978). The average strontium content of anhydrite in the absence of celestite is about 0.2% (Braitsch, 1971) and in comparison with the Sr content of the solution (Braitsch, 1971, p. 148) an enrichment occurs in the solid phase.

The previous study showed that the Werra Anhydrite has about 0.2% strontium with a remarkably small scatter (Jung and Knitzschke, 1960; Herrmann in Jung and Knitzschke, 1961; Gottesmann, 1964; Lorenc, 1975; Pasieczna, 1987; Peryt, 1990; Peryt et al., 1998, 2005) although notable exceptions exist: Ważny (1967) reported the contents of 0.5–0.6% from two boreholes in the Wrocław region (SW Poland), and Orti Cabo et al. (1988) and Garlicki et al. (1991) published results indicating much lower strontium contents (for example, averaging 127 ppm for the Lower Anhydrite of the Piła IG1 borehole, West Poland, located in the basin centre – Garlicki et al., 1991). Those differences may be related, at least in part, to various analytical methods applied. In turn, the Basal Anhydrite shows a considerably greater scatter in the strontium values (Herrmann, 1961; Herrmann in Jung and Knitzschke, 1961) with an increase in the Sr content from the bottom to the top (Braitsch, 1971, p. 208, Table 29).

Most of the strontium is diadochically included in anhydrite and only in the samples richest in strontium (with 0.3–0.4% Sr or more) the occurrence of this element is not isomorphic as indicated by earlier founds of free celestite (Füchtbauer and Goldschmidt, 1956; Braitsch, 1971).

The aim of this paper is to consider what processes have led to the Sr enrichment in three lower Zechstein anhydrite units (Lower Anhydrite, Upper Anhydrite and Basal Anhydrite–Table 1).

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Table 1
Stratigraphic position of the studied Zechstein anhydrite units (in bold).

	Fourth cyclothem, Aller (PZ4)		
Zechstein	Third cyclothem, Leine (PZ3)	Younger Halite and Younger Potash	Na3+K3
		Main Anhydrite	A3
		Platy Dolomite	Ca3
		Grey Salt Clay	T3
	Second cyclothem, Stassfurt (PZ2)	Older Halite and Older Potash	Na2+K2
		Basal Anhydrite	**A2**
		Main Dolomite	Ca2
	First cyclothem, Werra (PZ1)	**Upper Anhydrite**	**A1g**
		Oldest Halite	Na1
		Lower Anhydrite	**A1d**
		Zechstein Limestone	Ca1
		Kupferschiefer	T1

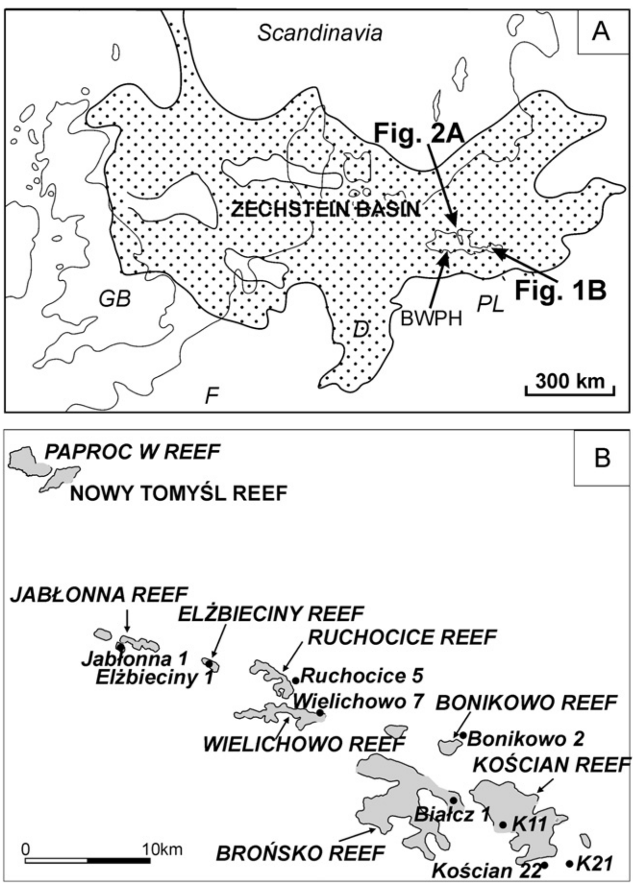

Fig. 1. Location of studied boreholes. A – Zechstein Basin and B – area of occurrence of Zechstein Limestone reefs in the central part of BWPH, Brandenburg-Wolsztyn-Pogorzela High.

2. Geological setting

The Late Permian Polish Zechstein Basin is a part of the Southern Permian Basin initiated in Late Carboniferous (Fig. 1A). Several depressions separated by fault-bounded ridges are present within the Variscan orogen and its foredeep. One of such ridges is the Wolsztyn Ridge, a part of the larger structure called Brandenburg–Wolsztyn–Pogorzela High (Figs. 1B, 2A; Kiersnowski et al., 2010), which separated the Zielona Góra Basin from the Variscan Foreland. In the Foreland and the Zielona Góra Basin, playa lake, aeolian and wadi deposits up to 1000 m thick accumulated during Early Permian (Rotliegend) times, whereas Rotliegend deposits are absent in the Wolsztyn Ridge or are replaced by coeval volcanic rocks (Kiersnowski et al., 1995).

Deposition in the Polish Zechstein Basin commenced with flooding of the continental Rotliegend basin. As a result of Zechstein Limestone deposition, a carbonate platform formed in the marginal parts of the basin as well as on pre-Zechstein highs in the central part of the Wolsztyn Ridge where in most cases reef bodies developed (Fig. 2B; Dyjaczynski et al., 2001; Kiersnowski et al., 2010). The thickness of the reef complex reaches 90.5 m, and there is a characteristic sharp decrease in the thickness at the reef margins to a few metres.

The deposition of the Zechstein Limestone resulted in a distinct enlargement of the inherited relief. This relief was levelled by the deposition of the PZ1 evaporites making the upper surface of the PZ1 (Werra) deposits roughly planar (Dyjaczynski et al., 2001, Figs. 2 and 3) because evaporite deposits are thin (ca. 25–40 m) in the reef zone and much thicker (total thickness >100 m) outside the reef zone (Fig. 2B).

The subsequent depositional and burial history of the Wolsztyn Ridge was the same as of the entire Fore-Sudetic Monocline that constituted a part of the Polish Basin. During Late Permian and Mesozoic times, continual subsidence took place with periods of accelerated subsidence during the late Permian-Early Triassic, Early Jurassic, Late Jurassic and Late Cretaceous, and then the Polish Basin became tectonically inverted (see Scheck-Wenderoth et al., 2008, with references). At the end of Jurassic the Zechstein Limestone deposits were at the depth of ca. 3.5 km (Karnkowski, 1999, Fig. 29), and the present base of the Zechstein Limestone is lying at the depth of 2.1–2.5 km. The PZ1 deposits (100–300 m) are covered by the younger Zechstein cycles: PZ2 (Stassfurt) (100 to >400 m), PZ3 (Leine) (100–200 m) and PZ4 (<100 m), and then by Mesozoic and thin Cenozoic deposits.

3. Materials and methods

We have selected 30 boreholes from the area of the Wolsztyn High in which the sulfate horizons: A1d (Lower Anhydrite), A1g (Upper Anhydrite) and A2 (Basal Anhydrite) (Figs. 1B, 2A; Tables 1 and 2), were cored either partly or (very rarely) entirely, for petrographical and geochemical examination. Most of the cores were slabbed. The main lithology is anhydrite, and the anhydrite classification used in this paper is the one applied to the study of Zechstein anhydrites (see Richter-Bernburg, 1985, for a review). Three principal lithological types of the Zechstein anhydrites are distinguished in core description: nodular, massive, and stratified rocks (see a detailed description and interpretation in Peryt, 1994) (Fig. 3).