Possible vertebrate coprolites from the Upper Cretaceous (Coniacian) of the Sudetes Mountains (southern Poland)

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Abstract: Possible coprolites from the Upper Cretaceous (Coniacian) of Waliszów Stary in the Sudetes Mountains (southern Poland) are described for the first time. They are relatively small, irregular in outline, and preserved as goethite, limonite, siderite and hematite. Although it is difficult to identify the producer of these coprolites, they were most probably formed by some fish.

Key Words: Coprolites; Cretaceous; Coniacian; vertebrates, Poland; Sudetes Mountains.

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Résumé : ***Possibles coprolithes de vertébrés provenant du Crétacé supérieur (Coniacien) des Sudètes (Pologne méridionale).-*** Nous décrivons pour la première fois des coprolithes du Coniacien (Crétacé supérieur) de Waliszów Stary dans les Sudètes (Pologne méridionale). Ils sont relativement petits, de forme irrégulière, et conservés en goethite, limonite, sidérite et/ou en hématite. Bien que le producteur de ces coprolithes soit difficile à identifier clairement, il est très vraisemblable qu'ils furent produits par un poisson.

Mots-clefs : Coprolithes ; Crétacé supérieur ; Coniacien ; vertébrés ; Pologne ; Sudètes.

1. Introduction

Bromalites encompass all fossilized remains of material sourced from the digestive tract of organisms and include coprolites, cololites, gastrolites and enterospires (HUNT, 1992; BRACHANIEC *et al.,* 2015). Regurgitalites and coprolites are perhaps the most common bromalites (CALVO, 1994; CHIN and GILL, 1996; SEILACHER *et al.*, 2001; WINGS, 2007; CERDA, 2008; REGENMORTER *et al.*, 2008; CODORNIÚ *et al.*, 2009; SALAMON *et al.*, 2012, 2014; OWOCKI *et al.*, 2013; BAJDEK *et al.*, 2014; PESQUERO *et al.*, 2014; ZATOŃ *et al.*, 2015; BRACHANIEC *et al.*, 2015). Bromalites constitute an important source of palaeobiological information (HOLLOCHER *et al.*, 2001; POINAR, 2011; DENTZIEN-DIAS *et al.*, 2012; BRACHANIEC *et al.*, 2015). Bromalites from the Mesozoic strata of Poland have been the subject of rare descriptions (SALAMON *et al.*, 2012, 2014; BRACHANIEC *et al.*, 2015). In this paper we describe coprolites from the Upper Cretaceous (Coniacian) of the Sudetes Mountains (southern Poland).

2. Study area

Field work was carried out in the Stary Waliszów district in October 2015 (50°18'37.14"; 16°42'13.05"; TRZĘSIOK *et al.*, 2014) (Fig. 1.A). This area is in the middle of the Sudetic Block, part of the larger Bohemian Massif (ŻELAŹNIEWICZ *et al.*, 2011). Upper Cenomanian - upper Coniacian sedimentary deposits, up to about 1200 m thick, are exposed (NIEDŹWIEDZKI and SALAMON, 2005) and consist of siliciclastic and carbonate rocks. Siderite concretions occur in some sandstone beds.

Coprolites were found in the western part of Stary Waliszów. A section 9 m thick consists of sandstone with siderite concretions in several beds (basal 3.5 m), overlying mudstone and muddy sandstone (4.5 m thick), and uppermost sandstone (1 m) with a concretion-bearing layer (details in TRZĘSIOK *et al.*, 2014). The coprolites reported here were found in muddy sandstone at the top of the outcrop (Fig. 1.B). The age of the succession, determined from the presence of inoceramid *Volviceramus involutus* (SOWERBY), is middle Coniacian (RADWAŃSKI, 1966).

3. Materials and methods

Sixteen specimens were collected and transported to the Faculty of Earth Sciences, University of Silesia, Sosnowiec. Thin sections were prepared for mineralogical/geochemical analysis from samples mounted in epoxy.

BSE and SE imaging was performed with the aid of a Philips XL30 ESEM/TMP scanning electron microscope equipped with an EDS (EDAX type Sapphire) detector at the Faculty of Earth Sciences, University of Silesia. XRD analyses were conducted on light-mineral, powdered samples using a PANalytical X'Pert Pro MPD diffractometer powered by a Philips PW3040/60 X-ray generator and fitted with a 1D silicon strip detector (X'Celerator). The measurements were

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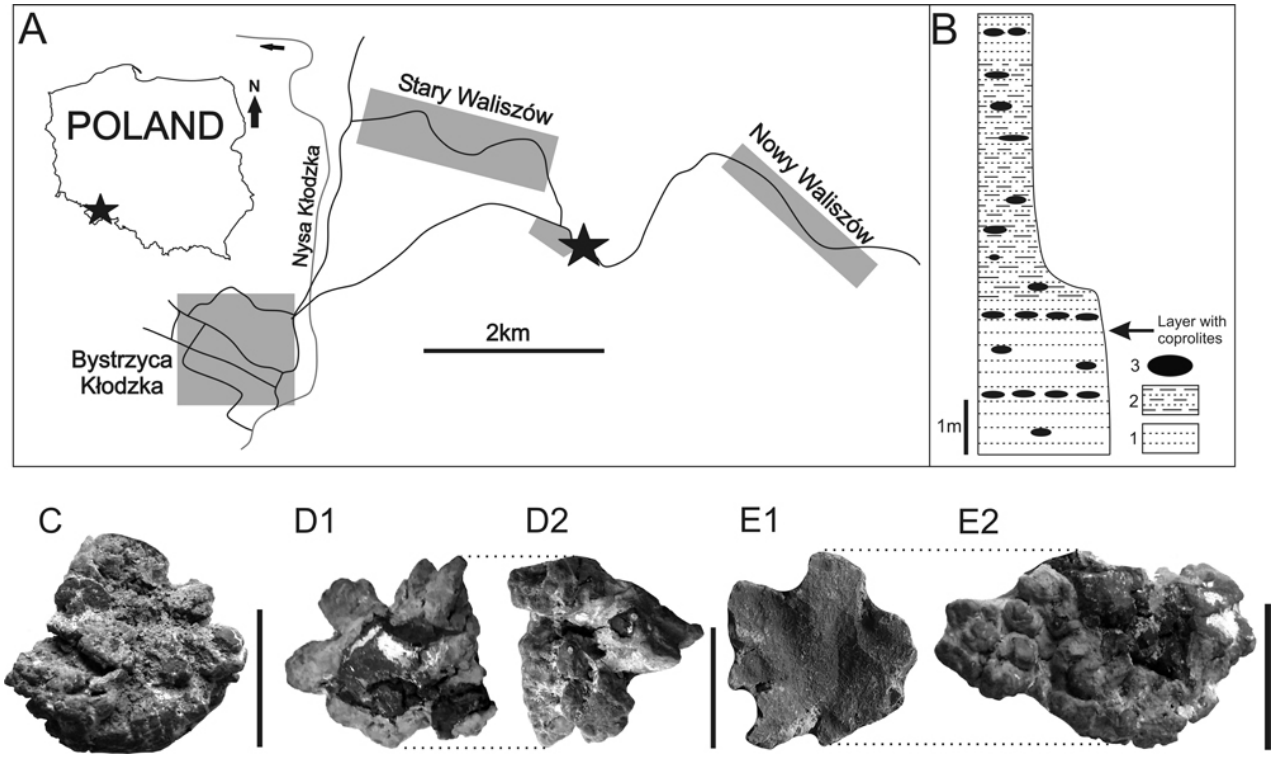

Figure 1: A. Map of Poland and detail of Stary Waliszów district (after TRZĘSIOK *et al.*, 2014). B. Investigated section. 1 - sandstone, 2- mudstone and muddy sandstone, 3 - siderite concretions (taken from TRZĘSIOK *et al.*, 2014). **C-E.** Coprolites from Stary Waliszów, Sudetes Mountains, southern Poland. Scale bar equals 1 cm.

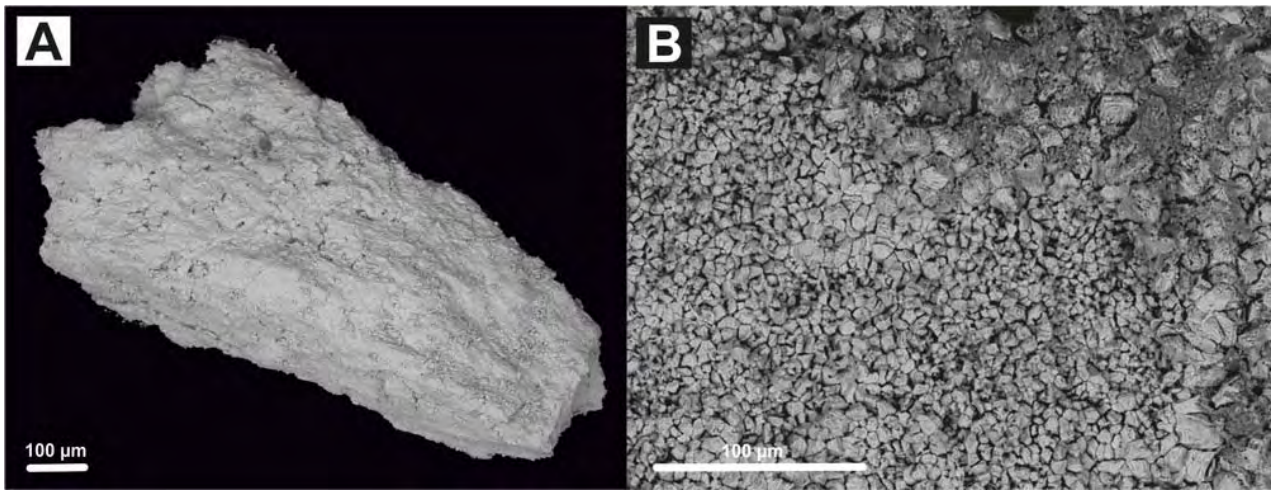

Figure 2: BSE images of the studied coprolites. **A.** Internal fragment of coprolite composed of siderite. **B.** Outermost part of coprolite with Fe-rich hydroxide pseudomorphs (goethite and limonite).

performed using the Cu Kα-radiation with a wavelength of 0.1542 nm, an acceleration voltage of 45 kV and a current of 30 mA, and with 0.01θ step sizes between the angles of 2.5° and 65° 2θ and a 300 s measurement time per step. The collected data were processed using HighScore+ software and the ICSD database. All XRD analyses were performed at the Faculty of Earth Sciences, University of Silesia.

The microscopic observations were carried out at the Faculty of Earth Sciences, University of Silesia, using an Olympus BX-51 microscope.

4. Results

The coprolites examined are relatively small (up to 3 cm longand irregular) (Fig. 1.C-E). Delicate ridges, folds and striations on the surface are aligned parallel or oblique to the long axis. A polygonal pattern of cracks is also present.

Thin sections reveal an internal mineralogical zonation. The outermost part, up to 400 µm thick, is composed of numerous, crystals of Fe-rich hydroxides (goethite and limonite: Fig.2.B), up to 10-15 µm in size. The internal part is

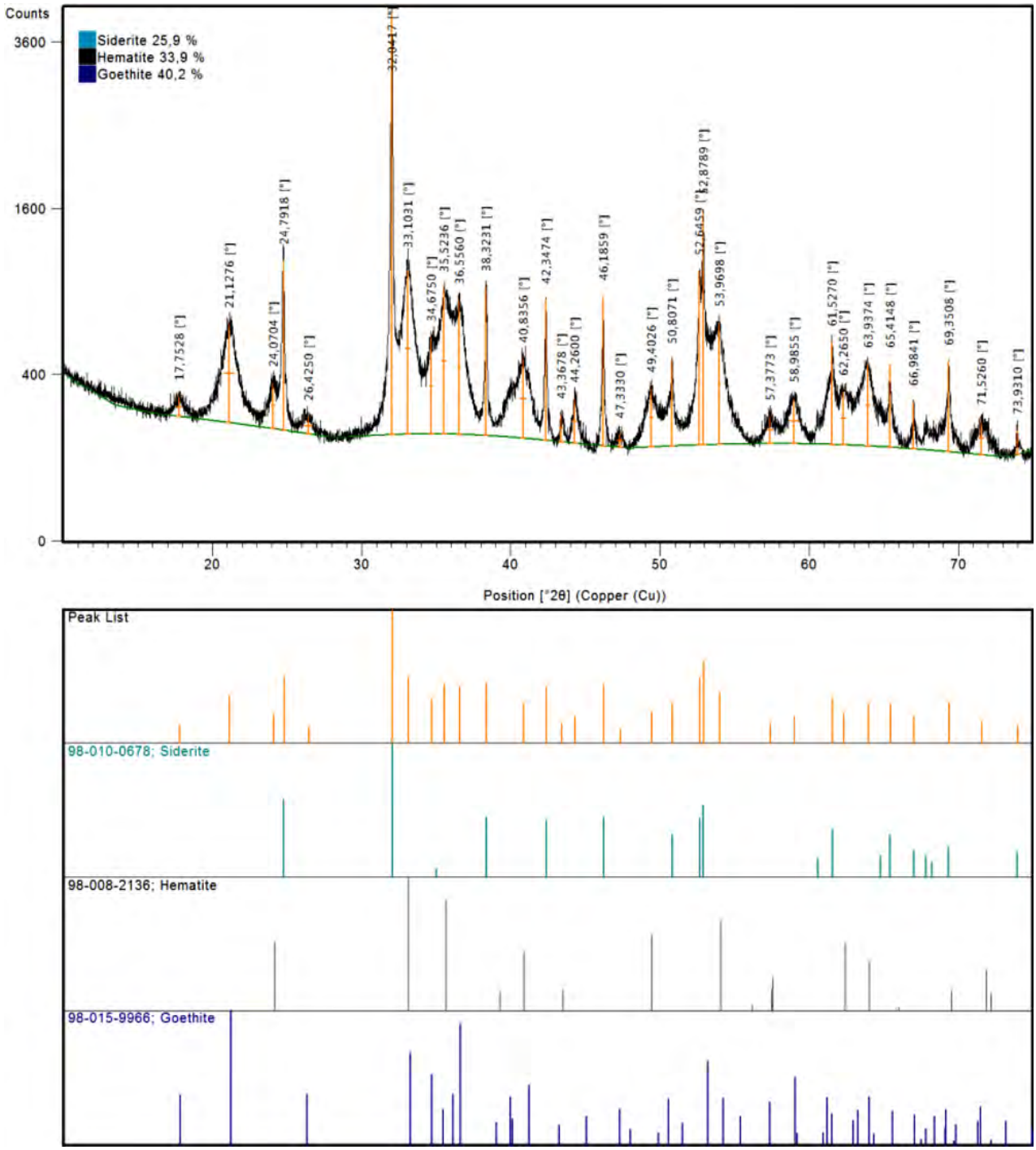

Figure 3: X-ray diffraction pattern of coprolite from Stary Waliszów, southern Poland.

mostly composed of massive siderite and hematite (Fig. 2.A). In a few places limonite forms a "rind" around a siderite and/or hematite core, in particular around the cracks (Fig. 2.A). A few grains up to 2-3 µm of iron sulphide (pyrite) are present (Fig. 2.B). Micro-XRD analyses showed that the main body is composed of goethite (40 wt %), siderite (34 wt %) and hematite (26 wt %) (Fig. 3). Fe-oxyhydroxide phases (goethite and hematite) display broader peaks than siderite due to weathering. Phosphates (*e.g.*, apatite) or silicates including quartz were not found in the coprolite. In some parts of the coprolite, empty pores and rare fossil inclusions are present (Fig. 4).

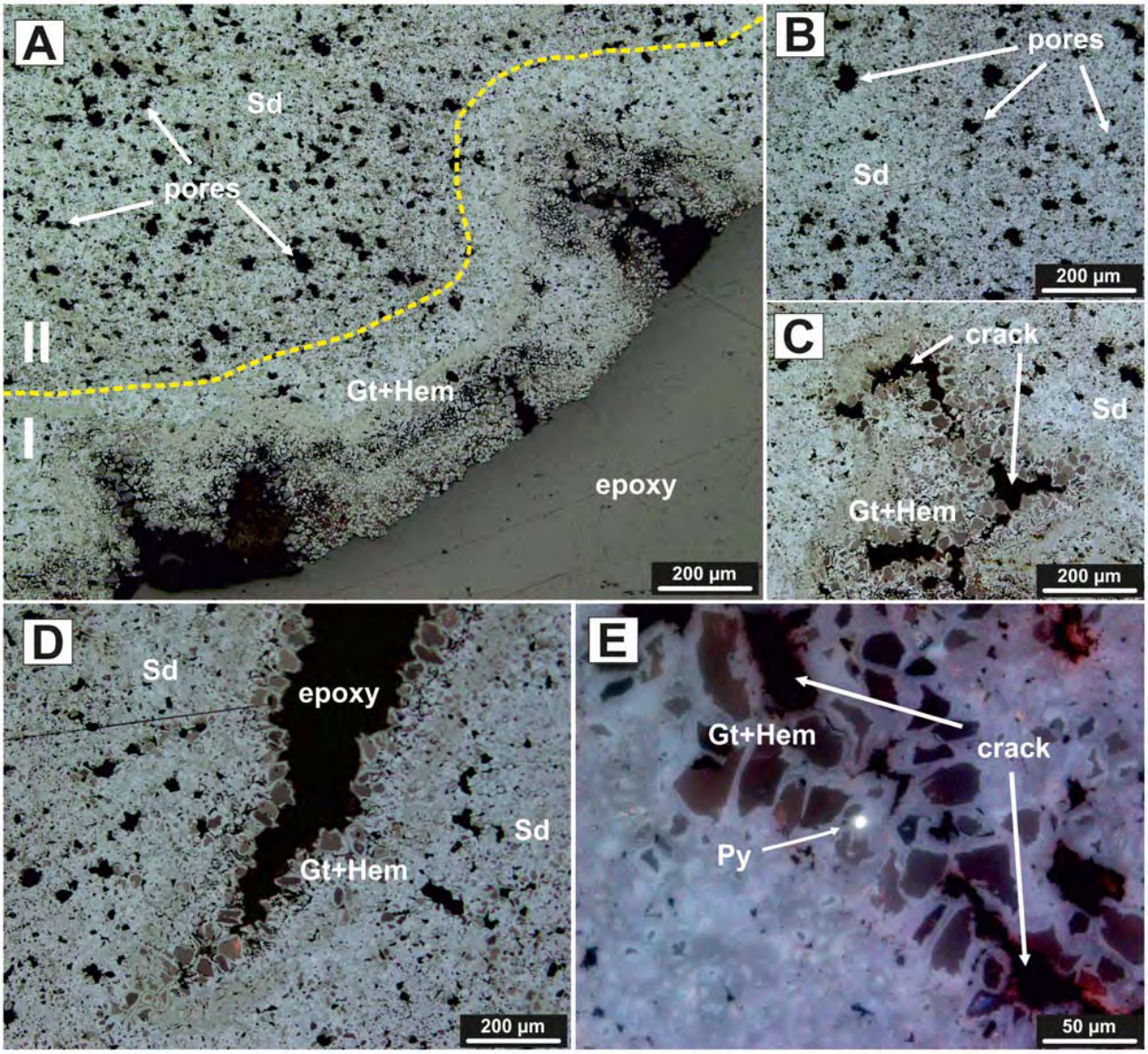

Figure 4: Photomicrographs of textural features of siderite-rich coprolite from Stary Waliszów, Sudetes Mountains, southern Poland. **A.** Contact between the outermost (I), more oxidised part and the internal (II) zone, composed of siderite. **B.** Numerous pores in the siderite-bearing part. **C-D.** Numerous goethite and limonite pseudomorphs after siderite around cracks. **E.** Rare occurrence of relict primary pyrite. Abbreviations: Gt- goethite, Lm- limonite, Sd- siderite, Py- pyrite.

5. Discussion

Coprolites from Stary Waliszów differ from associated concretions in shape, size, internal texture and specific mineralogical composition. According to Trzęsiok *et al.* (2014) concretions from this locality are relatively large and are commonly spherical or discoidal in outline, and display smooth surfaces. Internally, they reveal a much more complex multilayered texture, and are mostly composed of goethite and siderite with high admixture of kaolinite (12 wt %) and quartz (9 wt %).

Coprolites are usually preserved as phosphates with some admixtures of quartz and/or calcite (*e.g.*, Zatoń *et al.*, 2015, and papers cited therein; Brachaniec *et al.*, 2015). They typically contain remains of fauna and flora, evidence of the producer's diet. In the Stary Waliszów coprolites, phosphates have been replaced by limonite and goethite as a result of oxidation. Rare indeterminate inclusions of skeletal debris were also observed. Similar coprolites of the same mineralogy and morphology were described by Broughton *et al.* (1978) from the Upper Cretaceous of Canada (*op. cit.*: Pl. 43, figs. 1, 10, 13-14 & 17-18; Pl. 44, fig. 7). Both Polish and Canadian coprolites display numerous surficial cracks. According to Broughton *et al.* (1978) and Zangerl and Richardson (1963) such structures might have been associated with faecal degassing in anaerobic conditions. It is difficult to identify the producer of the coprolites. No vertebrates have been documented so

far at this locality. However, the coprolites were most probably produced by fish, like a bichir, sturgeon, garpike, bowfin or lungfish that were very common in the Late Cretaceous (*e.g.*, WILLIAMS, 1972; CHIN, 2002).

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