Data Article

Palynological and X-ray fluorescence (XRF) data of Carnian (Late Triassic) formations from western Hungary

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Abstract

The data presented in this article are related to the research article "Palynology and weathering proxies reveal climatic fluctuations during the Carnian Pluvial Episode (CPE) (Late Triassic) from marine successions in the Transdanubian Range (western Hungary)" (Baranyi et al., 2019). Palynological and palynofacies counts and mineralogical data are presented that build the core for the palaeoenvironmental and palaeoclimatic interpretation discussed in the original research article. Other component of this data article is the description of the applied laboratory and analytical techniques. We also supply microscopic images of the identified pollen and spores and a list of all identified palynomorphs.

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1. Data

This article describes the palynological and mineralogical data of Carnian formations (Late Triassic) from the Transdanubian Range (western Hungary). The palynological content includes the raw palynological and palynofacies counts from the 83 studied samples (Supplementary S1eS3). The article contains the list of all identified palynomorphs (Supplementary S4) and Figs. 1–3 document the most significant spore-pollen and aquatic palynomorph types. Mineralogical data and the calculated weathering indices are shown in Supplementary S6. In addition, the article presents the applied palynofacies terminology (Table 1) and the literature compilation that was used in the palaeoecological interpretation of the spore-pollen assemblages. (Table 2).

2. Experimental design, materials and methods

2.1. Materials

Palynology and mineralogical analysis are performed on the same samples as in [2,3]. For palynological and palynofacies analysis 83 samples were taken from three boreholes in the Transdanubian Range (western Hungary). In the Balaton Highland-Bakony Mountains area two borehole sections were studied. The Veszprém–1 (V–1 borehole; N 47°112, E 17°906) was drilled in the Aranyos Valley in Veszprém and the Mencshely–1 (Met–1 borehole, N 46°955, E 17°720) is located ~2 km NE to the village Mencshely. The Zs–14 borehole (N 47° 559, E 18 708) was drilled in the SE foreland of the Gerecse Mountains in the Zsambék Basin, ~25 km NW to Budapest.

2.1.1. Palynomorphs from the Veszprém Marl Formation

See Figs 1–3

2.2. Methods

2.2.1. Palynological sampling and laboratory techniques

The preparation procedures include standard palynological processing techniques [4]. Approximately 10 g of sediment were crushed and spiked with a known quantity of Lycopodium spores (one tablet/12077 spores) to allow for calculation of palynomorph concentrations followed by acid
treatment with HCl (10%), concentrated HF and heavy liquid separation (ZnCl₂, density 2.9 g/cm³). The samples were left in hot concentrated HF (65 °C) in a water bath for two days in order to dissolve the silicate fraction. After washing, the organic residues were sieved to isolate the 250-15 μm size fractions. After the heavy liquid separation, several samples from the Zsámbék-14 borehole were further treated with 10% sodium hypochlorite for 12 hours in order to decrease the high amount of AOM [5]. Unfortunately, the bleaching procedure was not successful and the amount of AOM did not decrease. Slides

Fig. 1. Aquatic palynomorphs from the Veszprém Formation, with the indication of sample code, sample code refers to the depth in meters; Met refers to samples from borehole Mencshely-1, V from Veszprém-1. Scale 10 μm. 1. Micrhystridium sp. 2. Baltisphaeridium sp. V-1/578; 2. Scolecodont V-1/532; 4. Tasmanites sp. Met-1/122.9; 5. Cymatosphaera sp. V-1/343; 6. Foraminiferal test lining Met-1/150; 7. Foraminiferal test lining V-1/485; 8. Botryococcus braunii Met-1/81; 9. Leiofusa sp. V-1/349; 10. Heibergella sp. Met-1/325; 11. Dinocyst indet. Met-1/122.9; 12. Veryhachium sp. Met-1/69.8.
Fig. 2. Spores from the Veszprém Formation and Csákberény Formation, with the indication of sample code and slide number, sample code refers to the depth in meters; Met refers to samples from borehole Mencshely-1, V-1 from Veszprém-1, Zs from Zsámóbek-14. Scale 10 μm. 1. Lycopodiacidites kuepperi V-1 334.6/1; 2. Camarazonosporites rudis V-1 343/2; 3. Gibeosporites
were glued with Entellan, an epoxy resin based mounting medium. The organic residues are curated at the Department of Geosciences, University of Oslo, Norway. Slides were observed with a standard trinocular Zeiss No. 328883 type microscope connected to an AxioCam ERC5s camera and Zen 2011 software. The organic residues and palynological slides are curated at the Department of Geosciences, University of Oslo. In each sample ~300 terrestrial palynomorphs (spores and pollen) were counted. After scanning two complete slides the remaining slides were scanned to check for additional taxa. Tables of raw palynomorph counts are available in the supplementary files (S1eS3). The abundance of undetermined palynomorphs, aquatics and *Lycopodium* grains was documented during the quantitative palynological analysis but they were excluded from the palynomorph sum. Pollen diagrams displaying the relative abundance of the palynomorphs was created in Tilia/TiliaGraph computer program. Stratigraphically constrained palynomorph assemblages were determined by cluster analysis (CONISS) built in the Tilia program. The pollen diagrams display only the counted taxa; specimens found after counting and aquatics were excluded from the cluster analysis.

Palynofacies analysis was performed on all samples. The different types of organic matter components are distinguished based on the terminology of Oboh-Ikuenobe & de Villiers [6] (see Table 1). In each sample approximately 300 sedimentary organic particles (SOM) were counted (Supplementary S1eS3).

### 2.2.2. Ecological signal of the palynomorphs and the SEG method

The ecological interpretation of the dispersed palynomorphs is based on the hygrophytic/xerophytic ratio introduced of Visscher & Van der Zwan ([7]) and the sporomorph ecogroup (SEG) method of Abbink et al. [8]. For details see the original research article Baranyi et al. [1]. The ecological affinity of each spore & pollen type is summarized in Table 2.

#### 2.2.3. Data analysis

Principal component analysis (PCA) was used to reveal the ecological relationship between the dispersed sporomorph types and the presumed parent plants [10]. The PCA routine finds the eigenvalues and eigenvectors in a variance-covariance matrix of the data set. The eigenvalue gives the measure of the variance accounted for by the corresponding components (eigenvector), which is also displayed as the percentages of variance accounted for by each of these components [10]. The principal components are illustrated graphically on two axes as a scatter plot of the data points and variables [10]. The component loadings or species scores on each axis describe the contribution of each of the original variables (e.g., species, taxa) to these environmental trends [11]. Component scores, i.e., sample scores are derived from the component loadings and the original data, so that the highest and lowest scores indicate samples containing the most influential taxa for that axis [11]. When plotted against depth or time, variations in sample score can reveal trends of the ecological/environmental factors represented by the component (axes) in the PCA. The PCA diagram was plotted with PAST.

#### 2.2.4. X-ray fluorescence measurements

Major element analysis was performed by a Philips PW 2404 X-ray fluorescence spectrometer (XRF) with 4 kW Rh-anode, LiF200, PE002-C GE, 111-C, PX-1 analyser crystals, 27/37 mm collimator configuration, scintillator duplex detector at the Department of Earth and Environmental Sciences, University of Pannonia (Veszprém, Hungary). A mass of 1.6 g of selected bulk rock samples (powdered to an average grain size of ~10 μm) was weighed and mixed with 0.4 g of H₂BO₃. The mixture was homogenized using ethanol of analytical purity and pressed under 3000 kg to produce tablets which were measured directly. Total loss on ignition (LOI) was gravimetrically measured after a two-step
heating at 105 °C and at 1000 °C, each for 2 hours. The experimental standard deviation ranges 3–6% for each major element measured, but it does 9–10% for Na₂O.

2.2.5. Weathering indices

The weathering indices were calculated for 108 samples (Supplementary S6). The alpha-indices (α_i) measure the ratio between the concentration of a mobile element and the concentration of an immobile element with similar magmatic compatibility from the same sediment samples [12] (Supplementary S6).

These elemental ratios are then compared to that in the upper continental crust (UCC [13]). Gaillardet et al. ([12]) used six highly mobile alkali and alkaline earth major elements (Ca, Mg, Sr, Na, K, Ba) as proxies but Ca, Mg and Sr, are usually enriched in the carbonate rocks relative to the UCC and to the average shale. As the investigated rock samples are enriched in clastic material, only Na, K and Ba are selected to calculate α-indices in the present work. As the weathering study targets only the silicate fraction of the rocks, determination of silicate bound fraction of these elements causes hampered analytical procedure and significantly increased chance of a misinterpretation. To avoid effects of element dilution by carbonate compounds and to minimize uncertainties related to the determination of the reference values (i.e. upper continental crust, UCC) and to compositional heterogeneity in lithology of the source area, each mobile element is normalized to the immobile, weathering resistant element aluminium [14]. For each studied mobile element (E) the normalized value is calculated as:

\[ \alpha_{iE} = \frac{[Al/E]_{\text{sample}}}{[Al/E]_{\text{UCC}}} \]

The applied weathering index calculations are the following:

### Table 1
Summary of palynofacies terminology. The terminology is used from Oboh-Ikuenobe and de Villiers ([6]).

| Sedimentary organic particles (SOM) | Description |
|-----------------------------------|-------------|
| Amorphous organic matter (AOM)    | Structureless, irregularly shaped, fluffy yellowish-brown to black masses that can be derived from the degradation of terrestrial or marine organic matter. |
| Charcoal/black debris             | Totally opaque particles with variable shape and size. They are derived from highly oxidised wood or other plant debris. |
| Plant tissues (Structured translucent plant debris) | Structured transparent particles with yellow-green to brown colour. They may be derived from degraded plant tissues or wood. They are of various shape and size including lath-shaped and equidimensional particles. |
| Cuticles                          | Epidermal cells of higher plants' leaves and stems, often pale yellow to pale brown in colour. They typically possess rounded or polygonally-shaped cells. |
| Wood fragments                    | Structured lath-shaped or usually blocky particles, varying from pale yellow to brown in colour, often with cellular structure. |
| Resin                             | Translucent, colourless or yellow to red, globular particles, angular fragments or bubbly masses, produced by higher land plants. |
| Spores                            | Male reproductive organs of bryophytes and pteridophytes |
| Pollen grains                     | Male reproductive organs of the seed plants |
| Freshwater algae                  | *Botryococcus, Schizosporis* |
| Marine palynomorphs               | Dinocysts, acritarchs, prasinophytes, scolecodonts and chitinous inner linings of the foraminifera |

**Fig. 3.** Pollen grains from the Veszprém Formation and Csákberény Formation, with the indication of sample code and slide number, sample code refers to the depth in meters; scale 10 μm, Met refers to samples from borehole Mencshely-I, V-1 from Veszprém-I, Zs from Zsámckéh-14. 1. Alisporites aequalis Met-1 122.9/1; 2. Ovalipollis ovalis V-1 343/2; 3. Luminisporites acutus V-1 343/1, 4. Lueckisporites singhii V-1 573/1; 5. Staurasaccites quadrifidus V-1 343/2; 6. Infernopolletites salcutus Met-1 101.4/1; 7. Cycadopites sp. V-1 493/1; 8. Lagenellula martini Met-1 299.5/1; 9. Aulisporites astigmatas V-1 335/1; 10. Striatosaccites quadriquatus V-1 325/1; 11. Triadispora crassa V-1 1573/1; 12. Equisetosporites chilleanus V-1 506/1; 13. a) Enzonalasporites vignei b) Enzonalasporites tenus Met-1 252/1; 14. Patinasporites densus V-1 343/2; 15. Patinasporites explanatus V-1 343/2; 16. Cycadopites sp. V-1 493/2; 17. Partitisporites tenebrosus Met-1 122.9/1; 18. Partitisporites malajvkiniae Met-1 81/2; 19. Partitisporites tenebrosus V-1 491–492/1; 20. Duplicisporites mancus Met-1 122.9/1; 21. Duplicisporites granulatus Met-1 122.9/1; 22. Duplicisporites continuus Met-1 252/1; 23. Duplicisporites continuus V-1 491–492/1; 24. Camerosporites secatus V-1 335/1; 25. Partitisporites tenebrosus tetrad V-1 343/2.
| Taxa                                    | Botanical affinity | Ecology       | SEGs         |
|-----------------------------------------|--------------------|---------------|--------------|
| Anapiculatisporites telephorus         | lycopsid           | hygrophyte    | wet lowland  |
| Aratrisporites spp.                     | lycopsid           | hygrophyte    | coastal      |
| Camarazonosporites rudis               | lycopsid           | hygrophyte    | river        |
| Calamospora tener                      | Equisetales        | hygrophyte    | river        |
| Baculatisporites sp.                   | Filiciopsida       | hygrophyte    | wet lowland  |
| Conbaculatisporites mesozoicus         | Dipteridaceae      | hygrophyte    | river        |
| Concavisporites toralis                | Matoniacae         | hygrophyte    | wet lowland  |
| Converrucosporites tumulosus           | Dicksoniacae       | hygrophyte    | wet lowland  |
| Cyclogranisporites sp.                 | Osmundiacae        | hygrophyte    | river        |
| Deltaidospora sp.                      | Filicales          | hygrophyte    | dry lowland  |
| Dictyophyllidites harrissii            | Filicales          | hygrophyte    | dry lowland  |
| Gibeosporites lativerrucosus           | Filiciopsida       | hygrophyte    | wet lowland  |
| Gordonispora fossulata                 | Bryophyte          | hygrophyte    | river        |
| Kraeuselisporites cooksonae            | Lycopsid           | hygrophyte    | coastal      |
| Leschiepisporis aduncus                | Marrattiales       | hygrophyte    | dry lowland  |
| Lycopodiactites kuepperi              | Lycopsid           | hygrophyte    | river        |
| Nyelastrichtia taylorii                | Osmondaceae        | hygrophyte    | wet lowland  |
| Olomaconvisporites lunzensis           | Filicales          | hygrophyte    | dry lowland  |
| Porcellispora longdonensis             | Liverwort          | hygrophyte    | river        |
| Reticulatisporites dolomiticus         | Fern, lycopsid     | hygrophyte    | coastal      |
| Striatella seebergensis                | Filiciopsida       | hygrophyte    | coastal      |
| Toidisporites spp.                     | Osmondaceae        | hygrophyte    | river        |
| Uvaeosporites gadensis                 | Selaginellales     | hygrophyte    | river        |
| Verrucosporites morulac                | Filicales          | hygrophyte    | wet lowland  |
| Zebrasporites sp.                      | Filicales          | hygrophyte    | wet lowland  |
| Alisporites spp.                       | Seed fern          | hygrophyte?   | dry lowland  |
| Brachysaccus neomundanus               | Conifer            | Xerophyte     | dry lowland? |
| Ellipsovetalisperites plicatus         | Conifer            | Xerophyte     | hinterland   |
| Infernollenientes spp.                 | Conifer            | Xerophyte     | hinterland   |
| Lueckisporites singhii                 | Majonicaceae       | Xerophyte     | hinterland   |
| Lunatisporites acutus                  | Voltziaceae        | Xerophyte     | hinterland   |
| Microachydites doubingeri              | Podocarpaceae      | Xerophyte     | hinterland   |
| Minutusaccus crenulatus                | Voltziaceae        | Xerophyte     | hinterland   |
| Ovalipollis spp.                       | Voltziaceae        | Xerophyte     | hinterland   |
| Partiletes sp.                         | Conifer            | Xerophyte     | hinterland   |
| Pityosporites/Protodiploxypinus        | Conifer/seed fern  | Xerophyte     | hinterland   |
| Platysaccus queensland                 | Podocarpaceae      | Xerophyte     | coastal      |
| Stauroacacies quadrifidus              | Unknown            | Xerophyte?    | hinterland   |
| Striatobobettes aytygii                | Seed fern          | Xerophyte     | hinterland   |
| Sukatisporites krauselii               | Conifer?           | Xerophyte     | hinterland   |
| Triadispora spp.                       | Voltziaceae        | Xerophyte     | hinterland   |
| Enzonolasporites spp.                  | Majonicaceae       | Xerophyte     | hinterland   |
| Patninaspores spp.                     | Majonicaceae       | Xerophyte     | hinterland   |
| Pseudozonolasporites summus            | Majonicaceae       | Xerophyte     | hinterland   |
| Vallaspores ignaci                     | Majonicaceae       | Xerophyte     | hinterland   |
| Camerospores secatus                   | Cheirolepidiaceae  | Xerophyte     | hinterland   |
| Duplicisporites spp.                   | Cheirolepidiaceae  | Xerophyte     | hinterland   |
| Partiticsporites spp.                  | Cheirolepidiaceae  | Xerophyte     | hinterland   |
| Praecirculina granifera                | Cheirolepidiaceae  | Xerophyte     | hinterland   |
| Laricidites sp.                        | Araucariaceae      | Xerophyte     | coastal      |
| Aulisporites astigmatus                | Bennettiales       | Hygrophyte    | dry lowland  |
| Brodispora striata                     | ?                  | Hygrophyte    | NA           |
| Cycadopites sp.                        | Cycadales          | Hygrophyte    | dry lowland  |
| Equisetospores chinleana               | Gnetales           | Xerophyte     | dry lowland  |
| Lagenella martini                      | ?                  | ?             | NA           |
| Retisulcites sp.                       | ?                  | ?             | NA           |
The concentration of each element and the calculated $\alpha_i$ values are available in the Supplementary S6.

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Transparency document

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Appendix A. Supplementary data

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