JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT
Jb. Geol. B.-A. | ISSN 0016–7800 | Band **139** | Heft 4 | S. 505–521 | Wien, Dezember 1996

Biostratigraphy and Lithofacies Pattern of the Gresten Formation (Dogger) in South Moravia (Czech Republic), with Emphasis on Reworked Triassic Material

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Czech Republic
Moravia
Jurassic
Gresten Formation
Biostratigraphy
Lithofacies
Reworking

Contents

Biostratigraphie und Lithofazies der Gresten-Formation (Dogger) in Südmähren (Tschechische Republik) mit besonderer Berücksichtigung von wiederaufgearbeitetem triassischem Material

Zusammenfassung

Bohrkerne aus 10 Bohrungen durch die Gresten-Formation (Dogger, Autochthones Mesozoikum) im SE-Teil des öhmischen Massivs (Tschechische Republik) wurden sedimentologisch und biostratigraphisch untersucht. Die bisherige widersprüchliche stratigraphische Einstufung gleicher Abfolgen in Mähren machte eine gründliche Untersuchung der Mikrofazies und des Fossilgehaltes dieser Formation nötig, um ihre Stratigraphie und Genese zu klären.

Die allgemeine lithofazielle Entwicklung der Gresten-Formation ist gekennzeichnet durch eine zweimalige Abfolge eines grobklastischen, arenitisch dominierten Abschnittes, dem ein feinklastischer, lutitisch dominierter Abschnitt folgt. Extra-Klasten von Biomikriten und Spongien-Tonsteinen sind Merkmale dieser Formation, worin im wesentlichen fünf mikrotexturelle Typen erkannt wurden.

Mikropaläontologische Analysen wurden mit Hilfe von SEM und Dünnschliffen durchgeführt. Durch palynologische Vergleiche konnte für den palynologisch produktiven Abschnitt der Gresten-Formation ein spätes Bajocian-Alter festgelegt werden. Darüberhinaus ist eine Umlagerung von Trias-Material hervorzuheben.

Abstract

Cores from ten borehole sections through the Gresten Formation (Dogger, Autochthonous Mesozoic) in the southeastern part of the Bohemian Massif (Czech Republic) were sedimentologically and biostratigraphically investigated. The previous controversial stratigraphic assessments of corresponding intervals in Moravia necessitated a profound study of the microfacial and fossil content of the formation to determine its development and its stratigraphy.

The general lithofacies development of the formation is characterized by a repetition of a coarse clastic unit (arenaceous dominated) preceding a fine clastic unit (lutaceous dominated). Extraclasts of biomicrites and sponge claystones feature the formation. Within the formation five principal microtextural types could be recognized.

Micropaleontological analyses were carried out by means of S.E.M. and thin section methods. Based on palynological correlation a Late Bajocian age could be assessed for the palynologically productive intervals of the Gresten Formation. The integrated results of the present study document redeposition of Triassic material in the formation.

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1. Introduction

Already in the 1970s sandstones and claystones of the Gresten Formation were drilled at several localities in South Moravia (Text-Fig. 1).

At first the deposits were designated as “the basal Jurassic clastics“, or the Diváky Beds, without any reliable biostratigraphical data (ELIÁŠ, 1974, 1981). On the basis of the ammonite and microfossil content a similar lithofacies development in adjacent Lower Austria (Gresten Formation) was inferred to fall within the Lias–Dogger interval (BRIX et al., 1977). Evaluation of the scarce ammonite fauna in several cores supported this time span of deposition also for the Diváky Beds (VAŠÍCEK, 1977, pers. comm.).

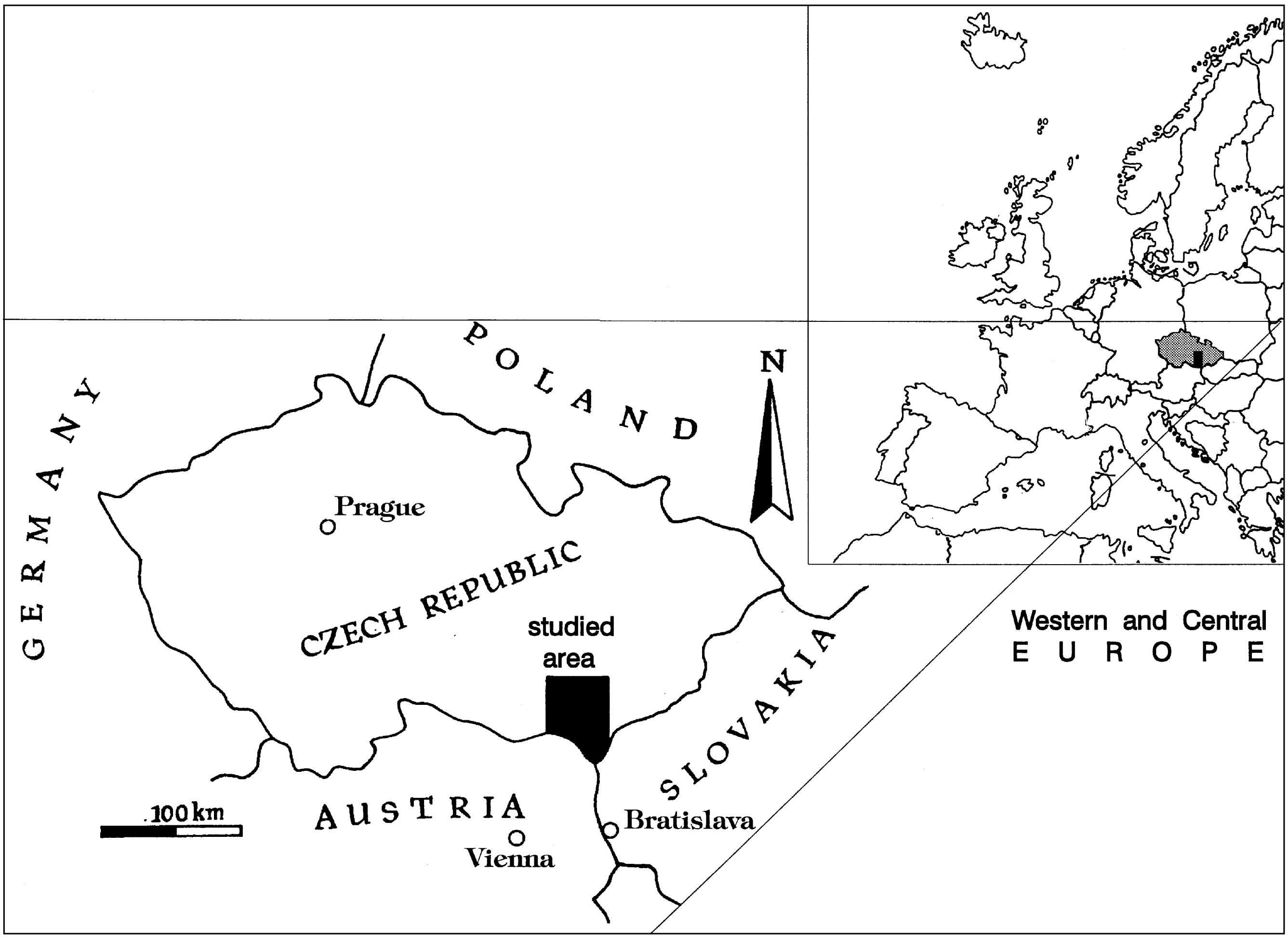
In contrast, later biostratigraphical analyses established an Early Carboniferous age for “the basal Jurassic clastics” in some borehole profiles (ŘEHOR & ŘEHOROVÁ, 1978; VALTEROVÁ, 1980, pers. comm.). Consequently the Diváky Beds designation was abandoned and substituted for the Gresten claystones and sandstones based on lithofacies correlation with borehole profiles in Lower Austria (BRIX et al., 1977; ADÁMEK, 1986).

Regarding the more precise biostratigraphy, the only indisputable results were obtained by means of palynostratigraphical analyses carried out at the Klobouky 2 borehole (included in the present study), and three boreholes in the Uhřice area. It concluded a Late Bajocian–Middle Bathonian age for the formation (DIMTER, ÖMV Vienna, 1991, pers. comm.).

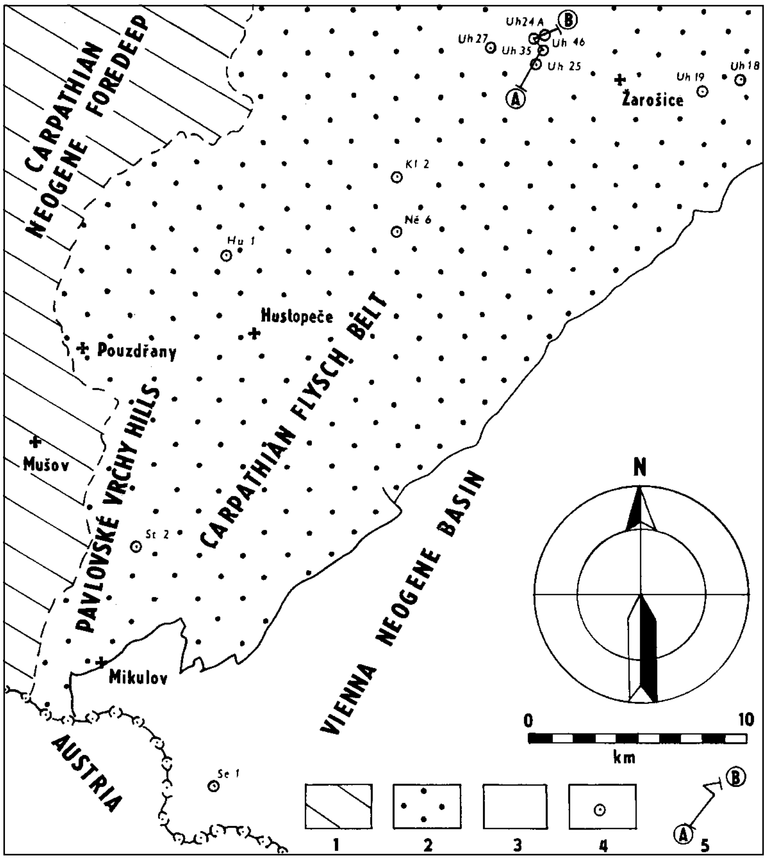
The present study focusses on precise biostratigraphic correlation of the Gresten Formation in Moravia and its microtextural characteristics, in order 1) to give an account of its facies development and 2) to verify previous stratigraphic assessments. The lithofacies classification in ten boreholes was established by the first author; the integrated biostratigraphical evaluation of seven cores involves foraminifera studies (ŘEHÁNEK and SALAJ) and palynological analysis (LEEREVELD and VERREUSSEL).

2. Geological and Palaeo-Environmental Framework

The Gresten Formation in South Moravia is considered to represent the earliest Mesozoic lithostratigraphic unit within the autochthonous sedimentary cover on the southeastern slope of the Bohemian Massif; the Mesozoic succession is overlain by sediments of the Carpathian Neogene Foredeep and the Outer Flysch Belt (ŠPICKA, 1976; Text.-Fig. 2). The regional extension of the Dogger sediments is confined to the Pavlov and Waschberg Blocks; they reach an extreme thickness of approximately 2000 m in the Waschberg Block, close to its interior fault zone (BRIX et al., 1977; JIŘÍČEK, 1990). The Gresten Formation covers Late Cadonian crystalline units, Brunovistulicum (DUDEK, 1980), or Devonian and Carboniferous deposits (ADÁMEK et al., 1980). The formation is transgressively overstepped by a succession of Callovian dolomitic conglomerates and sandstones, and shallow marine

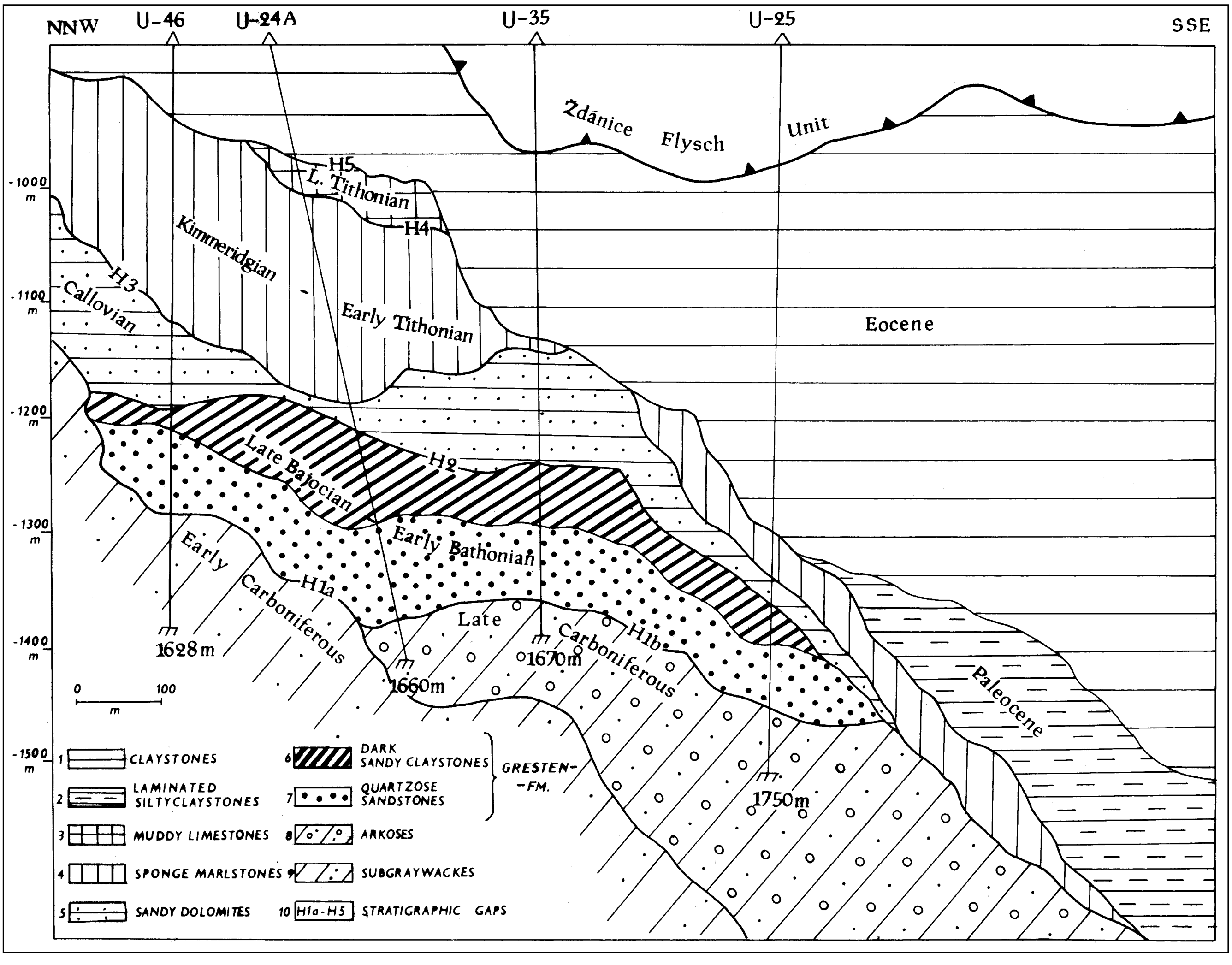


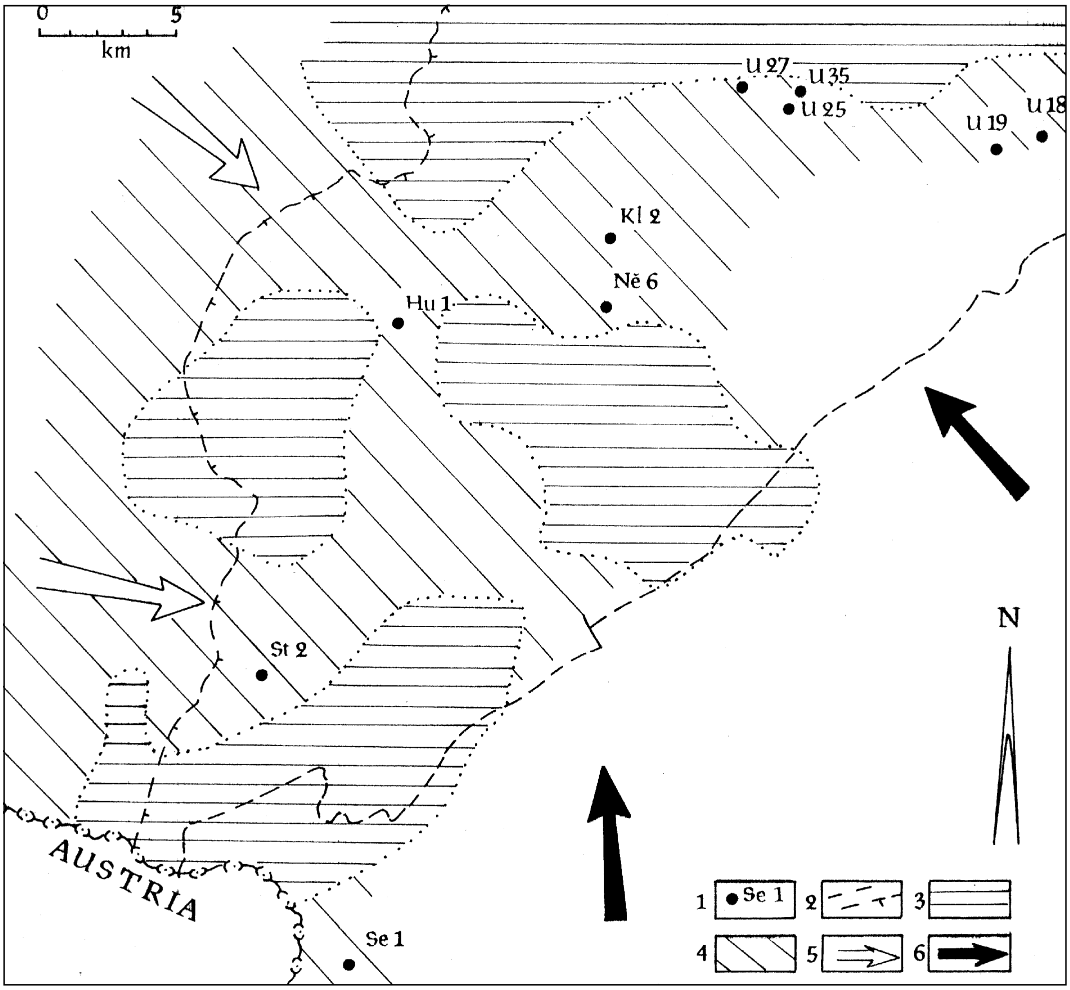
Text-Fig. 1.
Location map of studied area in South Moravia (black area).



Text-Fig. 2. ◀◀◀
Schematic geological sketch of the area showing the locations of studied borehole profiles (after: ŠPICKA, 1976).
1 = Carpathian deposits of the Neogene Carpathian Foredeep; 2 = Ždánice and Pouzdřany Flysch Units (Upper Cretaceous-Lower Miocene); 3 = Badenian, Sarmatian and Pannonian deposits of the Vienna Neogene Basin; 4 = Location of the studied boreholes; Se-1 = Sedlec 1; St-2 = Strachotín 2; Hu-1 = Hustopeče 1; Ně-6 = Němčičky 6; Kl-2 = Klobouky 2; U-18 = Uhřice 18; U-19 = Uhřice 19; U-25 = Uhřice 25; U-27 = Uhřice 27; U-35 = Uhřice 35.

Text-Fig. 3. ▼▼▼
Geological section running across the marginal deposition area of the Gresten Formation in the Uhřice region.
Interpretation of the three-dimensional seismic profiles (J. BERKA, Moravian Oil Company), logging and sedimentology of drill cores studied (J. ŘEHÁNEK).
1 = Uhřice Member of the Nesvačilka Fm; 2 = Telnice Member of the Tešany Fm; 3 = Ernstbrunn Limestones; 4 = Mikulov Marlstones; 5 = Nikolčice Beds; 6,7 = Gresten Fm (6 = upper lutaceous horizon; 7 = upper arenaceous horizon); 8 = indefinite lithostratigraphic unit representing the Late Carboniferous arkoses; 9 = Culm facies; 10 = erosion surfaces referring to particular stratigraphic gaps: H1a-H1b = uncertain time span; H2 = Middle Bathonian–Early Callovian; H3 = ?Oxfordian–Early Kimmeridgian; H4 = middle Tithonian; H5 = latest Tithonian–Late Cretaceous.





Text-Fig. 4.
Palaeogeographic sketch showing distribution of the Gresten Fm in S Moravia.
1 = borehole locality (see also Text-Fig. 2); 2 = limits of the Ždánice Flysch Unit; 3 = absence of Gresten Fm due to bar-development in the Bajocian–Bathonian ("island zones") or erosion effects in connection with H2 stratigraphic gap (Middle Bathonian–Early Callovian); 4 = undistinguished lithofacies development of the Gresten Fm; 5 = principal transport direction of the sandy and pebbly components during deposition of the arenaceous horizons (A1, A2); 6 = marine transgression referring to deposition of the lutaceous horizons (L1, L2).

pelite-carbonate platform deposits of Malm age. Locally the Gresten Formation is roofed by autochthonous Paleogene sediments.

The sandy lithofacies of the Gresten Formation is inferred to represent continental parts of deltaic systems, evidenced by fossil soils, paralic coal seams and palynological associations from Austrian and Moravian boreholes (BRIX et al., 1977; JIŘÍČEK, 1990). New data of borehole profiles from the Uhřice region (N and NE part of the depositional area of the Gresten Formation) revealed estuarine sandstones incorporating thin layers of intraformational conglomerates. Various textural and structural features reflect deposition in an active hydrodynamic environment with local effects of bioturbation. In the Uhrice region, estuarine conditions developed on the terrace relief of the Carboniferous basement (Text-Fig. 3).

In S Moravia mineralogy and geometry of Dogger sandy bodies indicate river transport of clastic components derived from the southeastern slopes of the Bohemian Massif (to the west and northwest). Transport of clastics from "sland zones" within the depositional area appears to be minor (compare Text.-Fig. 4).

Clayey lithofacies with infrequent ammonite relics and poor foraminifer assemblages are indicative of a palaeoenvironment of sheltered anoxic bays with migrating sandy ridges and low barriers. During the Dogger a transgression is supposed to proceed south- and southeastward (Text-Fig. 4).

3. Material and Methods

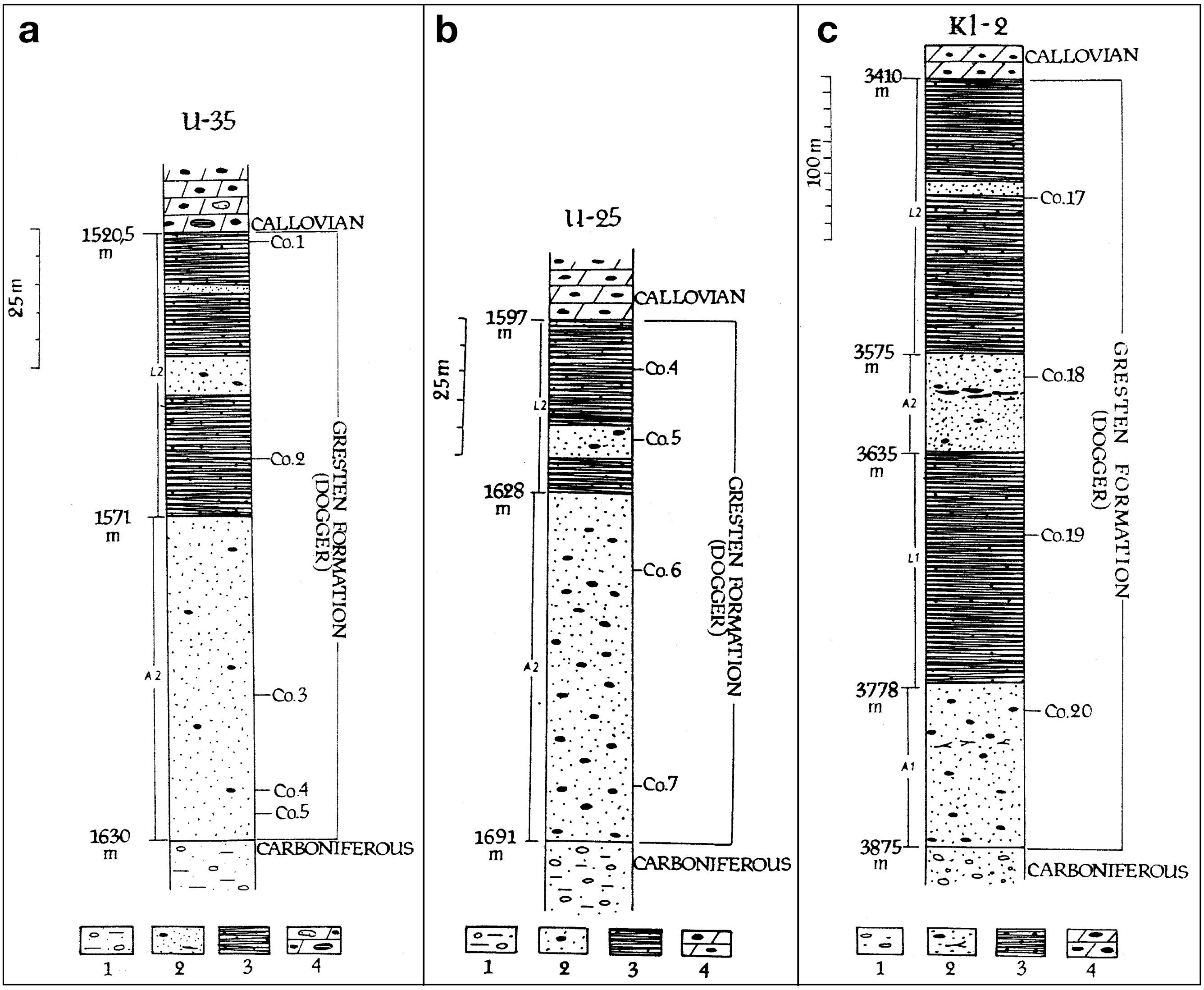
The sedimentological investigation for the Gresten Formation in Moravia was carried out on cores from ten boreholes (their locations are indicated in Text-Fig. 2): Hustopeče 1 (Hu-1), Klobouky 2 (Kl-2; Text-Fig. 5c), Nemčičky 6 (Ne-6), Sedlec 1 (Se-1), Strachotín 2 (St-2), Uhřice 18 (U-18), Uhřice 19 (U-19), Uhřice 25 (U-25; Text-Fig. 5b), Uhřice 27 (U-27) and Uhrice 35 (U-35; Text-Fig. 5a). Apart from a comparative sedimentological study of the cores, numerous samples were analysed by means of thin section microscopy.

The micropaleontological investigation comprised a selection of 54 typical conclusive thin-sections of ten cores from seven boreholes: Se-1, core 24 at 4758.5 m and 4761.0 m; St-2, core 14 at 3044.3 m and 3046.7 m; U-18, core 8 at 2918.1 m, 2918.7 m and 2918.9 m; U-19, core 6 within the interval from 2932.50 m to 2934.55 m.

The thin-sections were examined for approximately 15 cm² each. The semi-quantitative analysis was carried out using a Meopta lightmicroscope. The thin-section slides are stored at the Petrography Department of the Geological-Chemical Centre, the Moravian Oil Company Hodonín, Czech Republic.

The palynological investigation involved the following samples: Ně-6, core 9 at 2914.5 m; Se-1, core 24 at 4759.1 m; St-2, core 13 at 3010.5 m; U-18, core 8 at 2919.55 m; U-19, core 6 at 2934.95 m; U-25, core 4 at 1608.7 m; U-35, core 2 at 1563.65 m.

The samples were processed according to standard palynological procedures (HCl to remove the carbonates, HF to remove the silicates, heavy liquid separation with ZnBr, and sieving over a 25 μm sieve). If the amount of residue allowed, two preparation-slides per sample were prepared using glycerine-jelly as a mounting medium. The semi-quantitative analysis was carried out with a Leitz



Text-Fig. 5.
Synoptical profiles Uhřice 35, Uhřice 25 and Klobouky 2.

a) Uhřice 35 borehole profile.
1 = Late Carboniferous sandstones with pebbly admixtures; 2–3 = Gresten Fm; 2 = unsorted sandstones with different pebbly admixture (upper arenaceous horizon, A2); 3 = black and dark-gray claystones with different silty and sandy portion (upper lutaceous horizon, L2); 4 = Callovian dolomites with polymict pebbly components.

b) Uhřice 25 borehole profile.
1 = Late Carboniferous sandstones with pebbly admixtures; 2–3 = Gresten Fm; 2 = unsorted sandstones with different pebbly admixture (upper arenaceous horizon, A2); 3 = black and dark-gray claystones with different silty and sandy portion (upper lutaceous horizon, L2); 4 = Callovian dolomites with polymict pebbly components and blocks of sandstones and claystones derived from the Gresten Fm.

c) Klobouky 2 borehole profile.
1 = Early Carboniferous sandstones and conglomerates of Culm facies; 2–3 = Gresten Fm; 2 = light gray and brown-gray partly silicified conglomerates with rare carbonized plant detritus, upwards light-grey sandstones, black and dark-grey micaceous siltstones containing laminae of plant debris and small pyrite nodules (lower and upper arenaceous horizons respectively, A1 and A2); 3 = dark silty and sandy claystones (lower and upper lutaceous horizons respectively, L1 and L2); 4 = Callovian dolomitic sandstones and sandy dolomites; Co = depth position of drill core.

ransmitted light-microscope. The palynological preparation slides are stored at the Laboratory of Palaeobotany and Palynology, Utrecht, The Netherlands.

4. Lithofacies

The Gresten Formation in Moravia represents: (1) units of light-grey, fine to medium grained sandstones with plant debris and/or thin coal lenses, and (2) dark-grey to black, thin bedded, silty and sandy claystones with small pyrite nodules. The complete Dogger sequence is characterized by two alternations of arenaceous-lutaceous horizons, being determined as a complex of lower quartzose arenites (A1)-lower lutites (L1), upper quartzose arenites (A2)-upper lutites (L2). A typical example is developed in the Klobouky 2 borehole (Text-Fig. 5c): the lithological boundary L1–A2 is defined at 3.635 m. However, in the majority of the studied profiles the lithological development is irregular and incomplete due to strong local differences in depositional environments, including secondary erosion effects represented by stratigraphic gap H2 (Text-Figs. 3, 5).

In thin section microscopy studies two principal microtextural types of the Dogger deposits can be recognized, viz. (1) non-calcareous to slightly calcareous claystones with variable amounts of silty and fine-grained sandy terrigenous admixtures (Plate I/1–2), and (2) silty fine-grained sandstones with high amounts of quartz clasts and coal detritus admixture (Plate I/5). A scarce and local lithofacies development consists of black slightly biofragmental calcareous claystones with thin intercalations of blue-grey sandy biofragmental limestones (Pl. I/4).

Rare fragments of redeposited material (extraclasts) are observed in several boreholes. In St-2 extraclasts occur within the dark-grey siltstones and fine-grained sandstones of the Gresten Formation (at 3043–3048 m) as 10–15 cm large rounded blocks of rusty-brown slightly calcareous sponge claystones (Pl. I/3). In Se-1 (at 4758–4761 m) extraclasts represent the pebbly admixture of sponge-radiolarian muddy limestones (biomicrites) within the clastic sediments of the Gresten Formation (Pl. I/6). In U-18 (at 2918.10 m, 2918.70 m, and 2918.90 m) redeposited biofragmental-biogenic components appear within the calcareous claystones (Pl. I/2).

5. Micropaleontology

The present micropaleontological study documents only elements diagnostic for the Triassic rather than the Jurassic. Relevant foraminiferal data for stratigraphic correlation of Triassic elements have been reported by e.g. RESCH (1979), SALAJ (1969, 1976), SALAJ et al. (1983) and LOEBLICH & TAPPAN (1988).

Results of the microfacies and semi-quantitative micropaleontological analysis of the selected samples and a stratigraphic interpretation of the foraminiferal content are given below:

Se-1 (core 24, at 4758.5 m)
Biomicrite with slight admixture of terrigenous silty quartz.
- Microfaunal content: specimens of *Auloconus* sp. (rare) and unidentifiable species of thin-walled *Nodosaria*; relics of calcified radiolarians, sponge monaxons and "filaments" are present.
- Stratigraphic evaluation: representatives of *Auloconus* are diagnostic for the Norian–Rhaetian. Most probably they are reworked specimens from the Upper Triassic sponge-radiolarian limestones into the clastics of the Gresten Formation.

Se-1 (core 24, at 4761.0 m)
Unsorted clayey sandstone with fine-pebbly admixture.
- Microfaunal content: radiolarians (scarce), shell debris of lamellibranchs and a specimen of *Ammodiscus* sp..
- Stratigraphic evaluation: based on the microfaunal content no stratigraphic conclusion can be drawn for the interval. The presence of radiolarians and conclusively allothigenic foraminiferal relics, in combination with small micrite-limestone fragments in the shallow marine clastic deposits of the Gresten Formation suggest redeposition from older (? Triassic) sediments.

St-2 (core 14, at 3044.3 m)
Slightly calcareous spongy claystone with fine biofragmental admixture (Pl. 1/3).
- Microfaunal content: rare pyritized tests of *Trochammina* cf. *jaunensis* BROENIMAN et PAGE (Pl. II/8), *Gaudryina* sp. (Pl. II/2), *Epistomina* sp., sponge monaxons (common), debris of thin-walled lamellibranchs, corroded aptychi, and fragments of bryozoans.
- Stratigraphic evaluation: *T.* cf. *jaunensis* is indicative for the Norian–Rhaetian. Most probably specimens from the Upper Triassic sponge-radiolarian limestones form the clastics into the Gresten Formation.

St-2 (core 14, at 3046.7 m)
Fine-grained clayey sandstone with carbonized plant remains (Pl. 1/5).
- Microfaunal content: pyritized specimen of *Tetrataxis* sp. (rare).
- Stratigraphic evaluation: based on the microfaunal content no exact stratigraphic conclusion can be drawn for the interval. The rock sample represents sandy lithofacies of the Gresten Formation with the redeposited Triassic foraminifers.

U-18 (core 8, at 2918.10 m, 2918.70 m, and 2918.90 m)
Calcareous claystones with biofragmental-biogenic admixtures (Pl. 1/2).
- Microfaunal content: small gastropods (scarce), echinoderm segments, bryozoan and pelecypod debris, representatives of the calcareous dinoflagellate cyst *Cadosina* WANNER (Obliquipithonelloideae KEUPP) (Pl. II/9) and foraminifera: *Ammobaculites* sp., *Ammodiscus* sp. (Pl. II/4), *Angulodiscus friedli* (KRISTAN et TOLLMANN) (Pl. II/7), *A. pokornyi* SALAJ (Pl. II/5), *A.* sp., *Involutina* sp. (Pl. II/6), *Dentalina* sp., *Nodosaria* sp., *Tetrataxis* cf. *inflata* KRISTAN.
- Stratigraphic evaluation: the presence of *A. friedli*, *A. pokornyi*, *A.* sp. and *T.* cf. *inflata* is indicative for the Norian–Rhaetian. Most probably specimens of the species are reworked from Upper Triassic biogenic deposits into the clastic sediments of the Gresten Formation.

U-19 (core 6, at 2932.50 m, 2932.60 m, 2933.10 m, 2933.20 m 2933.50 m, 2933.60 m, 2934.05 m, and 2934.55 m)
Slightly biofragmental calcareous claystones with thin intercalations of sandy biomicrorudites (Pl. I/4). Thin-section analysis for the interval allowed distinction of facies into two types: (1) biofragmental calcareous claystones and (2) thin limestone intercalations (sandy biomicrorudites; Pl. I/4).
- Microfaunal content of the claystones: damaged tests of foraminifers (*Ammobaculites* sp., *Auloconus* sp., *Dentalina* sp., *Gaudryina* sp., *Lenticulina* sp., *Nodosaria* sp., *Quinqueloculina* sp.) in addition to pyritized small gastropods.
- Microfaunal content of the limestone intercalations: relics of thick-walled pelecypod shells, debris of brachiopods and green algae, sea-urchin spines, echinoderm segments, worm tubes, pyritized foraminifers: Tetrataxidae (Pl. II/3), *Lenticulina* (*Astacolus*) sp. (Pl. II/1) and *Planiinvoluta* sp.
- Stratigraphic evaluation: representatives of *Auloconus* and *Planiinvoluta* are indicative for the Norian–Rhaetian (e.g. LOEBLICH & TAPPAN, 1988). Most probably these representatives are reworked from Upper Triassic biogenic deposits into the clastic sediments of the Gresten Formation.

6. Palynology

Relevant palynostratigraphic data on the middle Jurassic have been reported by e.g. FENTON & FISHER (1978), FENTON et al. (1980), WOOLLAM & RIDING (1983), RIDING et al.

(1991) and RIDING & THOMAS (1992) from the British Isles, and by e.g. PRAUSS (1989) and FEIST-BURKHARDT & WILLE (1992) from Germany. Ranges of dinoflagellate cysts, reported in these studies, have been calibrated against ammonite biostratigraphy. In respect of the present study the work of FEIST-BURKHARDT & WILLE (1992) forms an important contribution for stratigraphic correlation with successions in an adjacent area, the Swabian Alb (southwest Germany).

A compilation of stratigraphically important Triassic sporomorphs has been presented by W.A. BRUGMAN (1983). For the Norian however, reliable palynostratigraphic information (i.e. calibrated against ammonites or directly correlated with other stratigraphically diagnostic fossils), has so far not become available.

All studied samples consist of palynodebris of fragments of wood, plant cuticles and plant tissue. In general, the identifiable palynological associations are not well diversified and composed of badly preserved palynomorphs. Dinoflagellate cysts and sporomorphs form the principal constituents of the assemblages, whereas acritarchs and acid-resistant tests of foraminifera occur in low frequencies. For dinoflagellate cyst taxonomy is referred to LENTIN & WILLIAMS (1993).

Results of the semi-quantitative palynological analysis and the stratigraphic interpretation of the studied samples are given below (FO = first occurrence):

N-6 borehole (core 9, 2914.5 m)

- Palynological characteristics: within the palynological assemblage sporomorphs and dinoflagellate cysts are the dominant constituents; tests of foraminifera are common, whereas spiny acritarchs and scolecodonts are rare. Within the sporomorph assemblage, alate bisaccoid pollen grains, *Callialasporites dampieri, Cerebropollenites* spp. and *Corollina* spp. are most frequent; *Enzonalasporites vigens, Ovalipollis pseudoalatus*, representatives of *Protohaploxipinus* (Plate IV/1) and *Lunatisporites* (Plate IV/3) are rare. The dinoflagellate cyst assemblage consists of: *Acanthaulax crispa* (frequent), *Ctenidodinium ornatum* (frequent), *Dissiliodinium* spp., *D. erymnoteichos*, *Durotrigia filapicata*, *Gonyaulacysta pectinigera, Kallosphaeridium hypornatum, Korystocysta gochtii/kettonensis*, *Lithodinia* spp., *L. valensii* (frequent), *Nannoceratopsis* spp. (common), *N. pellucida, Pareodinia ceratophora scopaeus* and *Sentusidinium* spp..
- Stratigraphic evaluation: based on the aspect of the dinoflagellate cyst assemblage and the concurrent presence of *A. crispa* (range: Bajocian; however PRAUSS [1989] reported it exclusively from the uppermost Bajocian), *L. valensii* (range: uppermost Lower Bajocian to Lower Bathonian) and *K. gochtii* (FO in the Upper Bajocian) the sample correlates with the Upper Bajocian. The frequent presence of representatives of *Protohaploxipinus* and *Lunatisporites* is characteristic for Permian to Middle Triassic assemblages (although they are also present in the Upper Triassic), whereas *Enzonalasporites vigens* and *Ovalipollis pseudoalatus* are characteristic for the Middle and Upper Triassic. Consequently, these sporomorph types are considered to be reworked.

U-25 borehole (core 4, 1608.7 m)

- Palynological characteristics: within the relatively poor palynological assemblage (composed of badly preserved palynomorphs), dinoflagellate cyst remains and sporomorphs are the dominant constituents; tests of foraminifera are common, whereas tasmanitids are scarce. Within the sporomorph assemblage, alate bisaccoid pollen grains are most abundant. The dinoflagellate cyst assemblage consists of: *Acanthaulax crispa*, *Cribroperidinium* spp., *Ctenidodinium ornatum*, *Lithodinia valensii*, *Nannoceratopsis* spp., *Pareodinia ceratophora* and *Rhynchodiniopsis*? *regalis*.
- Stratigraphic evaluation: based on the aspect of the dinoflagellate cyst assemblage and the concurrent presence of *A. crispa* (range: Bajocian; however PRAUSS [1989] reported it exclusively from the uppermost Bajocian), *L. valensii* (range: uppermost Lower Bajocian to Lower Bathonian) and *R.*? *regalis* (range: Upper Bajocian–Bathonian) the sample correlates with the Upper Bajocian.

U-35 borehole (core 2, 1563.65 m)

- Palynological characteristics: within the relatively poor palynological assemblage (composed of badly preserved palynomorphs) dinoflagellate cyst remains and sporomorphs are the dominant constituents; tests of foraminifera are common. Within the sporomorph assemblage, alete bisaccoid pollen grains, *Callialasporites dampieri* and *Cerebropollenites* spp. are most abundant. The dinoflagellate cyst assemblage consists of: *Acanthaulax crispa*, *Ctenidodinium ornatum*, *Gongylodinium hocneratum, Gonyaulacysta pectinigera, Korystocysta gochtii/kettonensis*, *Lithodinia valensii*, *Nannoceratopsis* spp., *Pareodinia ceratophora, P. stegasta, Orobodinium*? sp. and *Sentusidinium* spp.
- Stratigraphic evaluation: based on the concurrent presence of *A. crispa* (range: Bajocian; however PRAUSS [1989] reported it exclusively from the uppermost Bajocian), *Gongylodinium hocneratum* (range: Upper Bajocian–Bathonian) and *L. valensii* (range: uppermost Lower Bajocian–Lower Bathonian) the sample correlates with the Upper Bajocian.

Se-1 borehole (core 24, 4759.1 m)

- Palynological characteristics: palynomorphs are extremely badly preserved and scarce. Only some specimens of *Cerebropollenites* spp. could be identified. *Cerebropollenites* spp. is a characteristic constituent of Jurassic and Early Cretaceous sediments in an area principally encompassing the northern hemisphere (compare e.g. COUPER, 1958; DÖRHÖFER, 1979; HOCHULI & KELTS, 1980; BATTEN & LI, 1987; THUSU et al., 1988).
- Stratigraphic evaluation: the documented abundant presence of *Cerebropollenites* spp. in the present study in correlative intervals in Moravia does not disagree with the probable Jurassic origin of the sample.

St-2 borehole (core 13, 3010.5 m)

- Palynological characteristics: within the palynological assemblage sporomorphs and dinoflagellate cysts are the dominant constituents; tests of foraminifera are common, whereas spiny acritarchs are rare. Within the sporomorph assemblage, alate bisaccoid pollen grains and *Cerebropollenites* spp. are dominant; *Araucariacites* spp., *Callialasporites dampieri, Corollina* spp. and *Deltoidospora* spp. are common; *Densosporites* spp., *Endosporites papillatus, Pilosisporites* spp. and *Triadispora crassa* (Plate IV/4) are rare. The dinoflagellate cyst assemblage consists of: *Acanthaulax crispa, Aldorfia dictyota* ssp. *dictyota, Atopodinium polygonalis, Ctenidodinium cornigera, C. ornatum* (common), *Dissiliodinium erymnoteichos*, *Durotrigia filapicata* (frequent), *Kallosphaeridium* spp., *K. hypornatum, Lithodinia valensii* (common), *Nannoceratopsis pellucida* (common), *Pareodinia ceratophora, Rhynchodiniopsis cladophora, Scriniodinium acroferum* and *Sirmiodiniopsis orbis*.
- Stratigraphic evaluation: based on the aspect of the dinoflagellate cyst assemblage and the concurrent presence of *A. crispa* (range: Bajocian; however PRAUSS

[1989] reported it exclusively from the uppermost Bajocian), *L. valensii* (range: uppermost Lower Bajocian to Lower Bathonian) and *K. gochtii, D. filapicata, A. polygonalis* and *S. orbis* (FOs in the Upper Bajocian) the samples correlate with the Upper Bajocian. Note that the FO of *Aldorfia dictyota* ssp. *dictyota* is correlated with the Bajocian, conform PRAUSS (1989), who reported *A. dictyota* (as *Aldorfia* cf. *aldorfensis*) from the lower Bajocian Humphriesianum ammonite zone of northwest Germany. Most authors take the base of *Aldorfia dictyota* ssp. *dictyota* to coincide with the basal Callovian. Frequent presence of *Endosporites* (Plate VI/2) is characteristic for Permian and Triassic assemblages, whereas *Triadispora crassa* is characteristic for the Middle and Upper Triassic. Consequently, these sporomorphs are considered to be reworked.

U-18 borehole (core 8, 2919.55 m)
– No identifiable palynolomorphs were encountered. Consequently, no stratigraphic assessment could be accomplished.

U-19 borehole (core 6, 2934.95 m)
– Palynological characteristics: within the relatively poor palynological assemblage (composed of badly preserved palynomorphs) dinoflagellate cyst remains and sporomorphs are the dominant constituents; tests of foraminifera are frequent. Within the sporomorph assemblage, alate bisaccoid pollen grains are most abundant, whereas *Callialasporites dampieri* and *Cerebropollenites* spp. are present. The dinoflagellate cyst assemblage consists of: *Ctenidodinium ornatum*, *Lithodinia valensii* and *Pareodinia ceratophora*.
– Stratigraphic evaluation: based on the presence of *L. valensii* the sample correlates with the uppermost Lower Bajocian–Lower Bathonian.

7. Discussion

The present study confirms previous stratigraphic correlations of the Gresten Formation in South Moravia with the Lias–Dogger (BRIX et al., 1977; VAŠÍČEK, 1977, pers. comm.). Palynological information however, already provided a more precise correlation, viz. with the Upper Bajocian–middle Bathonian (DIMTER, ÖMV Vienna, 1991, pers. comm.). In the present study a higher resolution is obtained for the stratigraphic approximation of certain intervals of the formation: Upper Bajocian.

The Gresten Formation forms the basal part of a relatively continuous Jurassic sedimentary cover in South Moravia. Their age and nature strongly suggest these successive Jurassic deposits to reflect the global Middle-Late Jurassic sea level rise (compare HAQ et al., 1987). Accordingly, the Gresten Formation represents the first signs of the Jurassic transgression in South Moravia, coinciding with the 2nd order Bajocian global highstand (indicated as supercycle LZA-2 in HAQ et al., 1987). Moreover, the characteristic succession of two main lithofacies units recognized in the Gresten Formation of South Moravia, viz. a couple consisting of a coarser clastic unit preceding a finer clastic unit, may be considered to represent fluctuating sedimentary conditions in response to 3rd order oscillations of the sea level in a littoral to continental paleoenvironment. In South Moravia a maximum of two couples has been documented, which perfectly match the mid-Bajocian–earliest Bathonian global cycles 2.1 and 2.2 in supercycle LZA-2 of HAQ et al. (1987). Apparently during the Dogger in South Moravia a basin was created in which good conditions prevailed for the global 2nd and 3rd order sea level fluctuations to be relatively continuously and well expressed in the successive deposits.

The presented detailed lithofacies analysis and micropaleontological study document redeposited carbonate material in the Gresten Formation. The microfauna corresponds to the *Angulodiscus friedli-Angulodiscus pokornyi* Zone recognized in the Late Norian–Early Rhaetian of the West Carpathians (SALAJ, 1976; SALAJ et al., 1983). Remarkably, none of the Late Rhaetian representatives featuring the Triasina hantkeni Zone were encountered. The palynological contamination involves typical Middle-Upper Triassic elements, as well as typical Lower-Middle Triassic elements. No Rhaetian markers were encountered (calibrated Norian palynological information is scarce), however, to support the lithofacies and micropaleontological data. This might be due to the carbonate facies which generally represents unfavourable conditions for palynomorph preservation. In contrast, the exclusive occurrence of older Triassic palynological elements indicates the presence of underlying deposits which are not developed in carbonate facies.

Results of an extensive study to the Triassic paleogeography in Central Europe, carried out by geologists of the Moravian Oil Company, will be published elsewhere in the near future. The preliminary results indicate that the inferred Triassic developments which formed the Middle Jurassic autochthonous basement in Moravia, originate from lagoon-type depositional paleoenvironments representing a vast depression zone. This zone extended in a NE–SW direction from the Polish synclinorium to the southeastern margins of the Bohemian Massif; it continued in Lower Austria where it changed its direction to the Great Hungarian Lowlands region (JIŘÍČEK, personal communication). Such paleogeographic features have not been assumed within previous fundamental evaluations of the South Moravian Mesozoic basement yet (e.g. MÍSAŘ et al., 1983; SUK et al., 1984).

The recorded Early Carboniferous age for the Gresten Formation sediments (ŘEHOR & ŘEHOROVÁ, 1978; VALTEROVÁ, 1980, pers. comm.) might also be based on reworked material. This would imply that at least Carboniferous and Triassic sediments were redeposited into the Dogger Gresten Formation, after the Early Kimmerian orogenetic phase in South Moravia.

8. Conclusions

① The palynologically productive intervals of the Gresten Formation in South Moravia correlate with the middle Bajocian–middle Bathonian; when more precise correlation is possible, the horizons correspond to the Upper Bajocian.

② The Gresten Formation is considered to represent the first sign of the Jurassic transgression in South Moravia, coinciding with the mid-Bajocian–earliest Bathonian global cycles 2.1 and 2.2 in supercycle LZA-2 of HAQ et al. (1987). Apparently, the lithological differences within the formation are the expression of 3rd order global sea level fluctuations.

③ After the Early Kimmerian orogenetic phase a basin was created in the area of South Moravia. Successively sediments of the uplifted margins were eroded and redeposited in the new basin. Within the deltaic to coastal plain deposits of the Dogger Gresten Formation in South Moravia reworked calcareous microfauna and extraclasts indicate redeposition from Norian–Early

Rhaetian carbonate deposits exclusively. In contrast, the reworked sporomorph content suggests redeposition from older Triassic non-carbonate deposits. Furthermore, erosion of the Palaeozoic basement in south Moravia may have resulted in reworking of Early Carboniferous sediments in the Dogger clastic series.

④ The biostratigraphical and sedimentological results presented in this paper contribute to a better understanding of the Triassic paleogeography in Moravia and its relation to adjacent regions: the nowadays completely eroded Triassic sediments in Moravia were originally deposited in a vast depression zone, which extended in a NE–SW direction from the Polish synclinorium to the southeastern margins of the Bohemian Massif; it continued in Lower Austria where it changed direction to the Great Hungarian Lowlands region.

Acknowledgements

The authors are most grateful to the Moravian Oil Company (Hodonin) for the permission to publish this study. J.J. van Tongeren is gratefully acknowledged for the palynological processing of the samples. We are indebted to Dr. R. Jirícek (Moravian Oil Company) for his valuable comments on the paleogeography of the study area. We are grateful to Dr. W. Schnabel (Geological Survey of Austria) for his review and support in bringing the publication of our manuscript to fruition.

This is "Netherlands Research School of Sedimentary Geology – NSG" publication No. 970121.

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Manuskript bei der Schriftleitung eingelangt am 22. Oktober 1996

Plate 1

Fig. 1: Claystone with silty and fine-grained sandy terrigenous admixtures and rare pyritized foraminifers.
Magn. × 47.
Klobouky 2 borehole (core 19, 3696–3700 m, sample B-2).

Fig. 2: Slightly calcareous claystone with insignificant silty terrigenous admixtures and scarce relics of foraminifers, calcareous dinoflagellate cysts, debris of pelecypods and brachiopods.
Magn. × 67.
Uhřice 18 borehole (core 8, 2918–2922 m, sample 927/84).

Fig. 3: Slightly calcareous sponge claystone (extraclast).
Magn. × 67.
Strachotín 2 borehole (core 14, 3043–3048 m, sample 5792).

Fig. 4: Sandy biofragmental muddy limestone (biomicrorudite) with section through oyster shell.
Magn. × 47.
Uhřice 19 borehole (core 6, 2932–2935 m, sample 818–4 G).

Fig. 5: Silty fine-grained sandstone with coal detritus.
Magn. × 67.
Strachotín 2 borehole (core 14, 3043–3048 m, sample 5794).

Fig. 6: Sponge-radiolarian muddy limestone (biomicrite) with pyritized foraminifers (extraclast).
Magn. × 57.
Sedlec 1 borehole (core 24, 4758–4761 m, sample 1404/2).

Photos by J. ŘEHÁNEK.

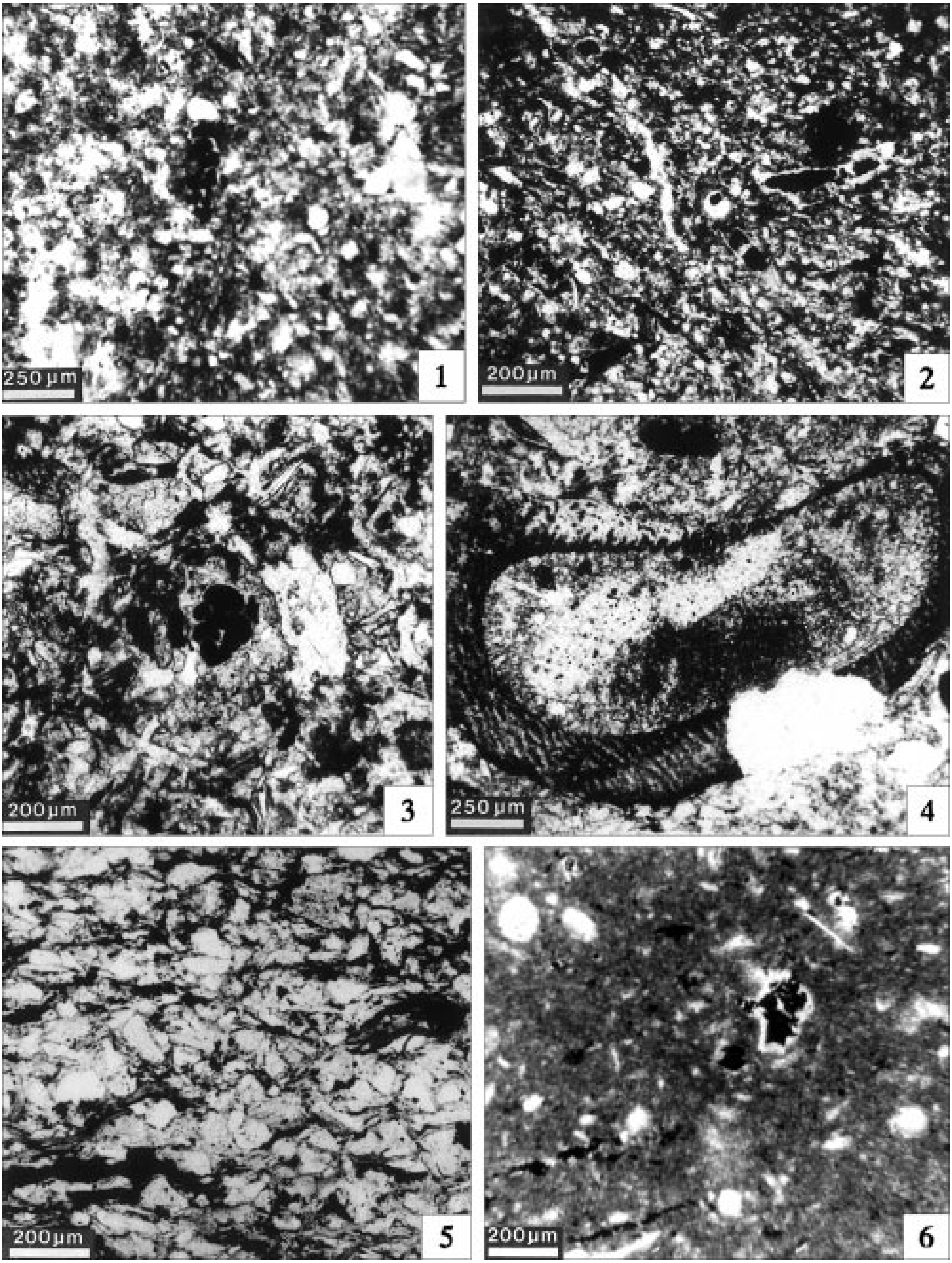
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Plate 2

Fig. 1: Representative of *Lenticulina* (*Astacolus*) DE MONTFORT, 1808.
Magn. × 70.
Uhřice 19 borehole (core 6, 2933.1 m, sample 818/84).

Fig. 2: Representative of *Gaudryina* D'ORBIGNY in DE LA SAGRA, 1839.
Magn. × 200.
Strachotín 2 borehole (core 14, 3044.3 m, sample 5792).

Fig. 3: Representative of Tetrataxidae GALLOWAY, 1933.
Magn. × 200.
Uhřice 19 borehole (core 6, 2933.1 m, sample 818–4 G).

Fig. 4: Representative of *Ammodiscus* REUSS, 1862.
Magn. × 256.
Uhřice 18 borehole (core 8, 2918.1 m, sample 927/84).

Fig. 5: Representative of *Angulodiscus pokornyi* SALAJ, 1967.
Magn. × 175.
Uhřice 18 borehole (core 8, 2918.1 m, sample 927/84).

Fig. 6: Representative of *Involutina* TERQUEM, 1862.
Magn. × 230.
Uhřice 18 borehole (core 8, 2918.15 m, sample 928/84).

Fig. 7: *Angulodiscus friedli* (KRISTAN et TOLLMANN, 1962).
Magn. × 150.
Uhřice 18 borehole (core 8, 2918.1 m, sample 927/84).

Fig. 8: *Trochammina* cf. *jaunensis* BROENIMANN et PAGE, 1966.
Magn. × 150.
Strachotín 2 borehole (core 14, 3044.3 m, sample 5792).

Fig. 9: Representative of *Cadosina* WANNER, 1940 (Obliquipithonelloideae KEUPP, 1987).
Magn. × 510.
Uhřice 18 borehole (core 8, 2918.1 m, sample 927/84).

Photos 1–6, 9 by J. ŘEHÁNEK, 7–8 by J. SALAJ.

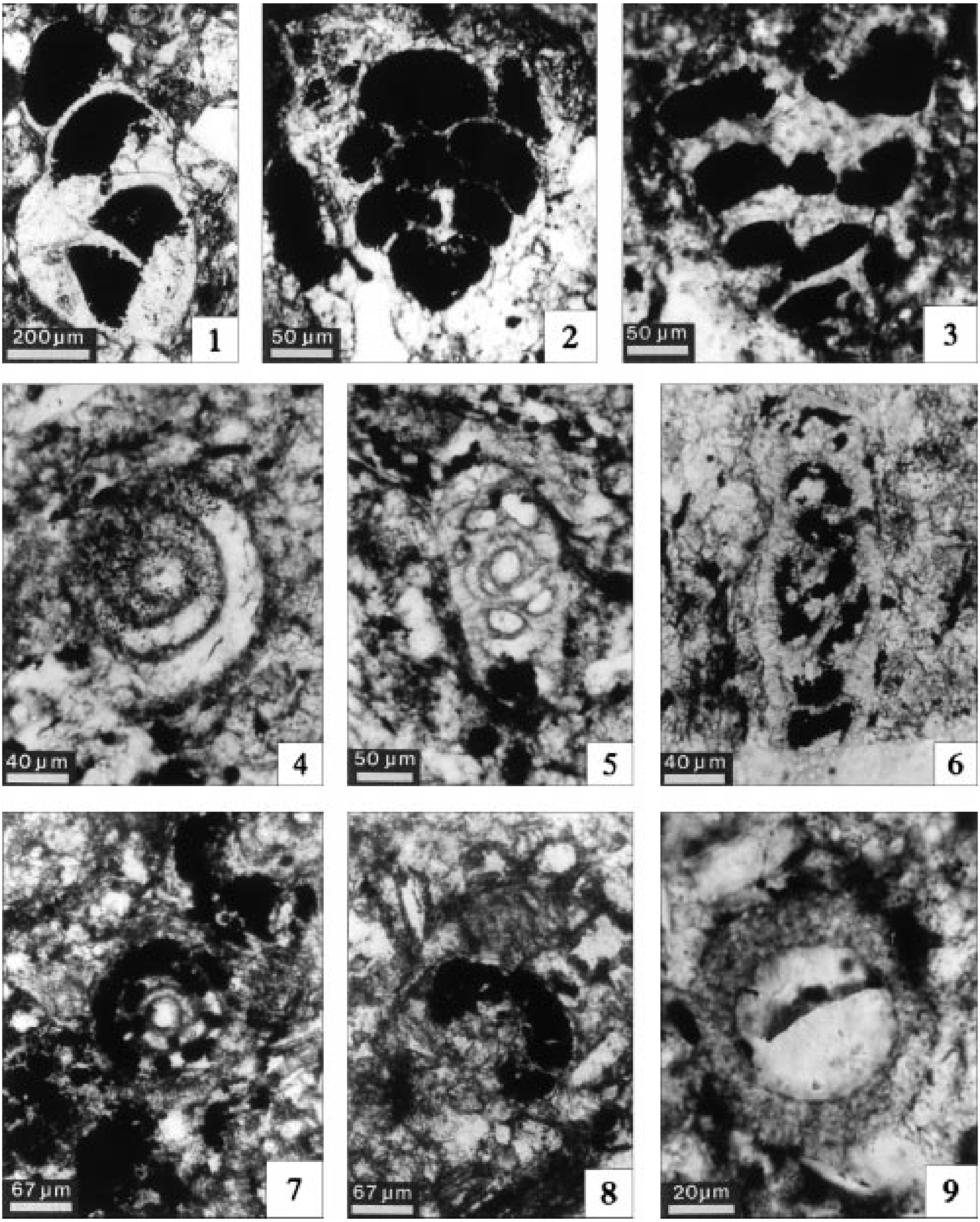
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Plate 3

Fig. 1: *Ctenidodinium ornatum*.
Slide K1/92 (2).
EF coordinates D39; length approx. 60 µm.

Fig. 2: *Lithodinia valensii*.
Slide K1/92 (2).
EF coordinates O41/2; length approx. 80 µm.

Fig. 3: *Durotrigia filapicata*.
Slide G2/92 (1).
EF coordinates Q42/1; length approx. 70 µm.

Fig. 4: *Nannoceratopsis spiculata*.
Slide K1/92 (1).
EF coordinates E42; length approx. 60 µm.

Fig. 5: *Acanthaulax crispa*.
Slide K1/92 (2).
EF coordinates O39/2; length approx. 65 µm.

Fig. 6: *Acanthaulax crispa*.
Slide K3/92 (2).
EF coordinates Q34; interior antapical view; length approx. 60 µm.

Photos by R.M.C.H. Verreussel.

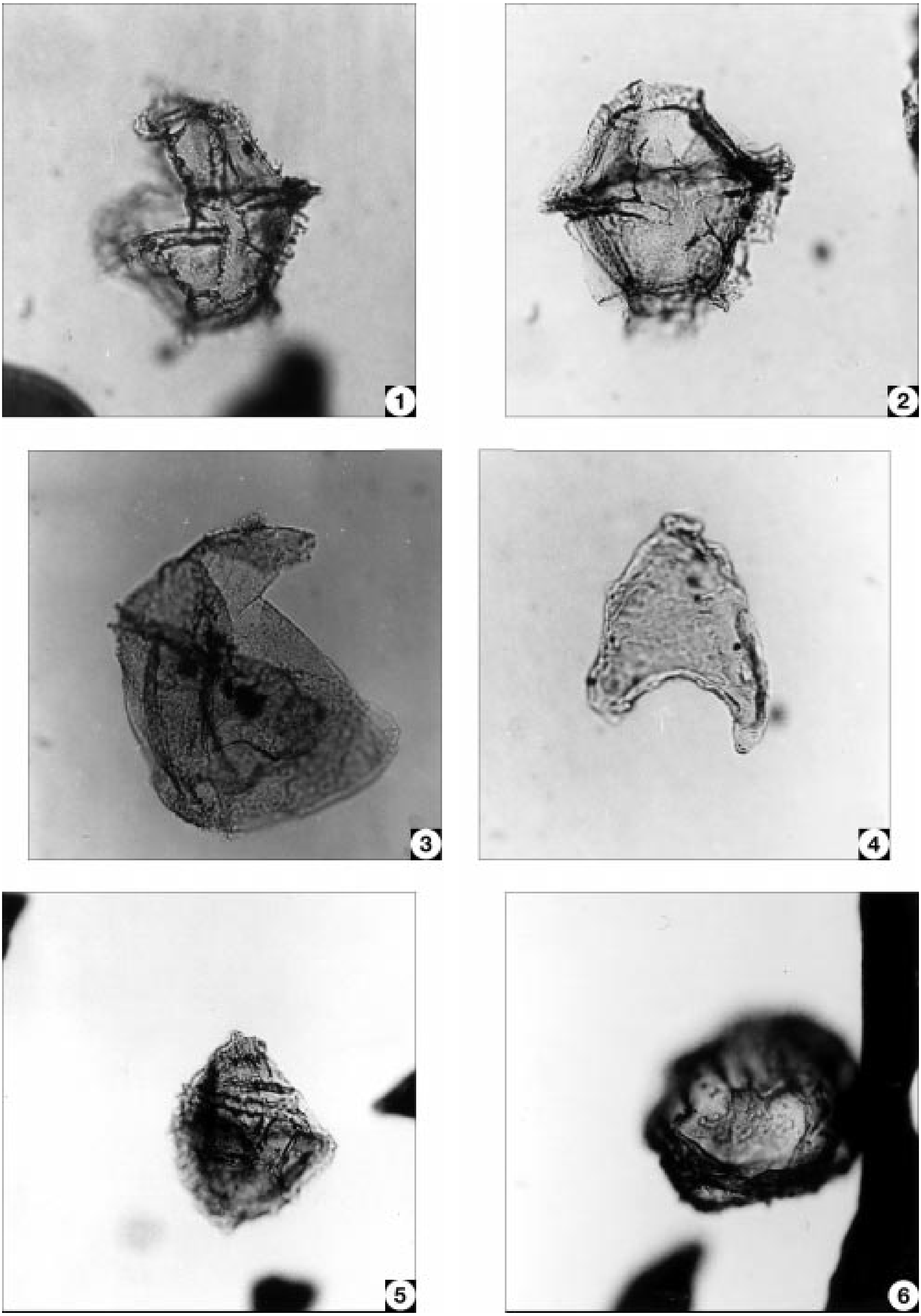
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Plate 4

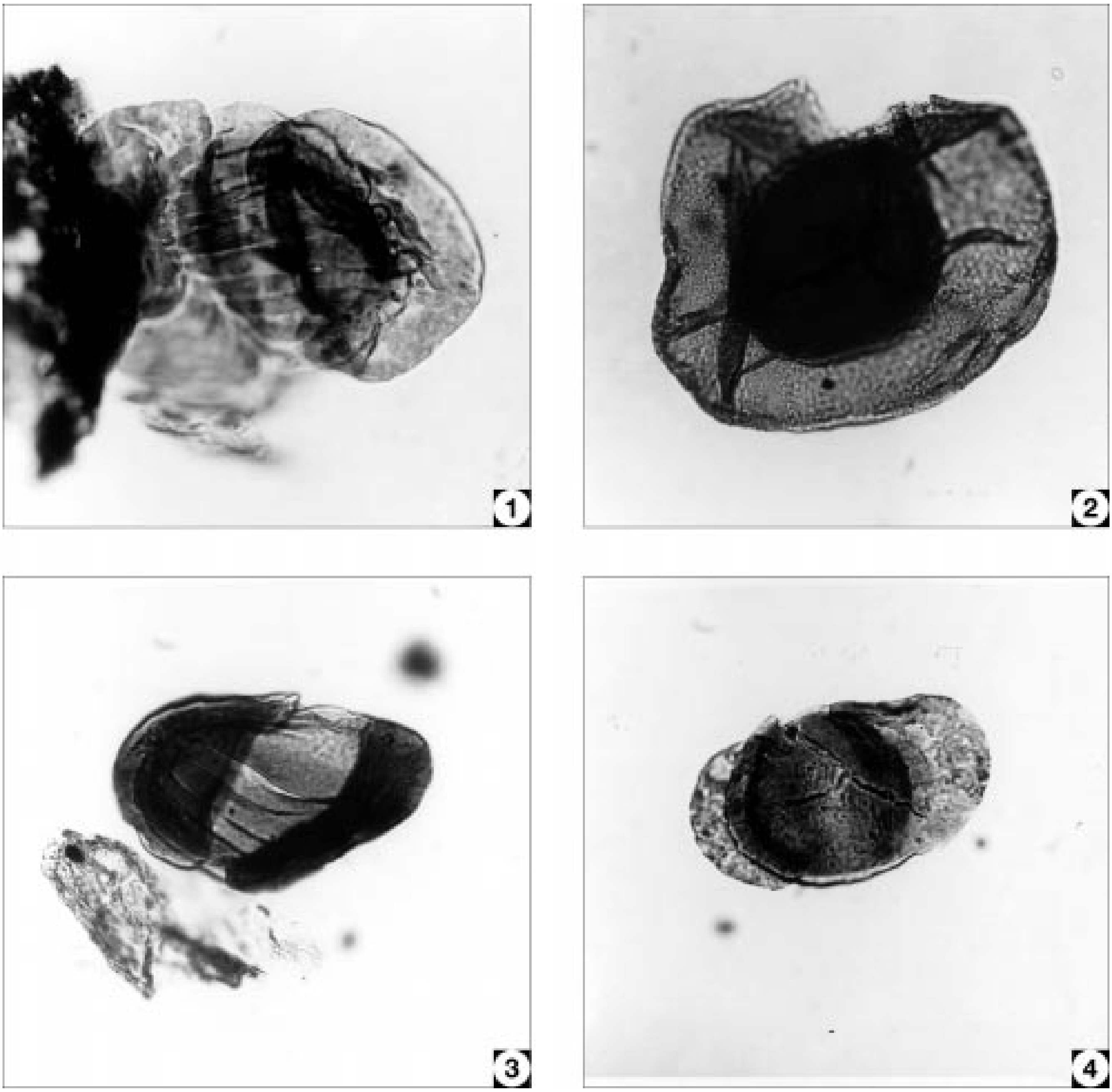
Fig. 1: *Protohaploxipinus* sp.
Slide K1/92 (2).
EF coordinates V42; length approx. 65 μm.

Fig. 2: *Endosporites* sp.
Slide G2/92 (1).
EF coordinates E31/3; length approx. 65 μm.

Fig. 3: *Lunatisporites* sp.
Slide K1/92 (2).
EF coordinates F27; length approx. 50 μm.

Fig. 4: *Triadispora crassa*.
Slide G2/92 (1).
EF coordinates U35; length approx. 50 μm.

Photos by R.M.C.H. Verreussel.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