Dinosaur nesting ground from the Early Jurassic fluvial deposits, Holy Cross Mountains (Poland)

Grzegorz PIENKOWSKI


Two different kinds of rounded structures (spherical and ellipsoid ones), filled by clayey-ferruginous sediment, occur in the fine-grained sandstone of a crevasse splay origin (meandering river environment) in the Early Hettangian Zagaje Formation, in the locality called Soltyków, nearby little town of Odrowąż, central Poland. The structures are interpreted as dinosaur eggs, precisely as the "post-egg structures". They are strongly altered by diagenetic processes and no obvious eggshell structure is preserved. However, faint embryo remains found inside one of the ellipsoid structures and characteristic circular clutch of the spherical structures, allows conclusion that the structures represent dinosaur eggs. This conclusion is supported by other evidences, such as regular size and shape of the structures and joint occurrence with numerous dinosaur footprints. While the circular clutch laid in a shallow depression represents an in situ nest, the smaller, ellipsoid eggs were probably transported a short distance by the current associated with a flood event. The circular clutch of unhatched egg structures most probably represents a nest of earliest sauropods; their footprints and trackways have been found nearby. The smaller ellipsoid egg structures are difficult to classify, they may represent either basal omithisian or theropod eggs. This is the first find of dinosaur egg structures in Poland and the second known Lower Jurassic dinosaur nesting ground world-wide. It may also stimulate discussion on diagenetically altered dinosaur eggs.

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Key words: dinosaur nest, earliest sauropods, egg structures, taphonomy, diagenetic alteration, embryonic remains, Lower Hettangian.

INTRODUCTION

The structures presented in this paper are interpreted as strongly altered dinosaur eggs. No eggshell ultrastructure is preserved but taphonomical, sedimentological and petrological evidence point to their egg origin. Dinosaur eggs and nests older than Cretaceous are relatively rare world-wide (K. Hirsch, 1994). Lower Jurassic egg clutch have been described from South Africa (J. W. Kitchling, 1979; F. E. Grine, J. W. Kitchling, 1987). Jurassic eggs occur also in Portugal (A. F. de Lapparent, G. Zbyszewski, 1957; P. Dantas, 1991). Fairly rich Upper Jurassic material has been described from localities in Colorado and Utah (USA) (K. Hirsch, 1994). The Polish find is important because it would be only second known Lower Jurassic nesting ground world-wide (K. Carpenter, K. Alf, 1994).

GEOLOGICAL AND STRATIGRAPHICAL BACKGROUND

In the Early Jurassic time the terrigenous, continental, deltaic, nearshore and marine deposition was taking place in a large epeiric basin along the Teisseyre-Tornquist Line in Europe (Fig. 1). Early Jurassic sedimentation commenced with continental, fluvial and lacustrine deposition, which is represented by the Zagaje Formation (G. Pienkowski, 1983, 1991; G. Pienkowski, G. Gierlifksi, 1987). These deposits are known both from the shallow boreholes and outcrops. Soltyków represents one of the classical outcrops of the lower part of the Zagaje Formation (Figs. 2, 3; Pl. I, Fig. 1). The outcrop reveals deposits of a meandering river plain, with laterally accreting channels, flood plain/lacustrine deposits and numerous crevasse splays (Figs. 2, 3a; Pl. I, Fig. 1). The Early
Liassic age of these deposits is confirmed by the floral remains (E. Wcislo-Luraniec, 1991b) as well as by the sequence stratigraphy correlation (G. Piekowski, 1991, 1997). It is a lower part of the type 2 Hettangian sequence corresponding to the initial phase of the planorbis- liassic transgressive system tract (TST), which initiated backstepping of sedimentary package (a "pre-trangressive" part of the TST below the transgressive surface; G. Piekowski, 1991, 1997). Besides detailed sedimentological studies, palaeobotanical (E. Wcislo-Luraniec, 1991a, b) and entomological studies (P. Wegierek, V. V. Zherikhin, 1997) were carried out.

**SEDIMENTOLOGY, PALAEOECOLOGY AND PALAEOICHNOLOGY**

The structures occur in the lower part of the outcrop, at the boundary of two sandstone layers separated by a subordinate bounding surface with little amount of muddy substance on it (Pl. I, Fig. 2). The sandstone layers show considerable lateral extension, and tabular and trough cross-bedding of different scale, with fan-like pattern of the current directions (Pl. I, Fig. 2). The sandstone layers are separated by the mudstone layers with numerous plant roots (paleosol levels) (Fig. 2; Pl. II, Fig. 4). The sandstones represent typical wackestones, rich in muddy matrix. In places they are highly ferruginous (high content of iron hydroxides). Drifted flora remains (mostly horsetails and conifers) are very abundant. The plant fossils in the Sołytków section are abundant and well preserved, but not very diverse (G. Pielikowski, G. Gierlinski, 1987). The lower part of the flood plain was dominated by a horsetail vegetation (Hirmeriella (E. Wcislo-Luraniec, 1991a, b)). Floristic assemblage includes mainly thermophilous taxa indicating a warm and humid climate (E. Wcislo-Luraniec, 1991a, b). Numerous dinosaur footprints have been found since 1987 (G. Piekowski, G. Gierlinski, 1987; G. Gierlinski, 1994, 1995). Dessication mud cracks occur in several levels. In places, bivalve resting tracks (Lockeia = Pelecypodichnus) are common (Pl. III, Fig. 4). Also insect burrows (Spongeliomorpha sp.) and arthropod burrows (Scyenia sp.) are fairly abundant. Interesting finds of fossil beetles (P. Wegierek, V.V. Zherikhin, 1997) are worth mentioning in this context. This part of the section is interpreted as crevasse splay deposits formed by floods on the flood plain (Fig. 2).

Crevasse splay deposits in the lower part of the outcrop yielded most of the dinosaur footprints known from this locality (G. Piekowski, G. Gierlinski, 1987; G. Gierlinski, 1994, 1995). The footprints ichnocoenosis comprise: large theropods footprints Kayentapus soltykovenis (left by Dilophosaurus — Pl. II, Fig. 1), small theropod footprint, basal ornithischian footprints represented by Anomoepus sp. (Pl. II, Fig. 2) and, most interestingly, sauropod footprints (Parabrottopodus sp.) — Pl. II, Fig. 3. The present author found one isolated and relatively small pes footprint, but recently the whole trackway has been described (G. Gierlinski, G. Sawicki 1998). The footprints point to the presence of diversified and numerous dinosaur fauna, although no dinosaur bones have yet been found.

**DESCRIPTION OF THE STRUCTURES**

There are two separate kinds of the structures: larger, spherical, slightly flattened and smaller, ellipsoid ones (Pl. II). All the structures are clearly pre-depositional, i.e. they existed before deposition of the host sediment. It is proved by the style of arrangement of cross-bedding lamina around the structures (Fig. 4; Pl. III, Fig. 3).

**SPHERICAL STRUCTURES**

The structures show uniformity in their shape and size and form a half-rim (Pl. I, Fig. 2; Pl. III, Figs. 1, 2 structures A–D). The rim is not fully preserved, because the rest of the layer is missing. However, assuming its diameter, another 2 oval objects lack to form a complete rim. Two of the structures seem to occur in a pair (B with C). One structure (E) occurs separately. Structures are slightly flattened, the longer axis reaches 10 cm, shorter is about 8 cm. The structures are filled with detrital clayey-ferruginous material, which represents a mixture of illite and iron hydroxides (Fig. 5). In places one may observe little amount of silty-sandy filling with rare small, detrital plant fragments. The outer surfaces of the structures are covered with numerous irregular, about 1.5 mm thick plates ("chips") built of clay minerals, sometimes mixed with thin lamina composed of iron hydroxides. Similar chip-like plates are scattered randomly on the surface of the layer, but they are clearly concentrated along the surfaces of the oval and ellipsoid structures (Pl. III, Fig. 1).
The structures are scattered within the sandstone layer with no clear orientation (Pl. III, Figs. 1, 2 — structures a–j). The fill is similar to the fill of the oval structures (detrital muddy-ferruginous substance). In some objects one may observe more sandy material (object j). Most of the structures are placed obliquely in the sediment, with various inclination angle. Objects e and j lie nearly horizontally. The objects are about 8 cm long and 4 cm wide. In places where a more sandy infilling occurs, one can find invertebrate burrows (Pl. III, Fig. 4). Object i shows some tiny structures inside (Pl. III, Fig. 5). They are straight, flattened, cylindrical structures built of darker matter. To find more information about these objects they were examined under the scanning electron microscope (SEM). The following results were obtained:

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1. The cylindrical structures show internal fibrolamellar texture (Figs. 6, 7). The lamellae are 5–10 μ wide and in places show a branching pattern. Lamellae are built of chalcedony (Fig. 8), but in places some encased, small fragments with high calcium content are preserved (Fig. 9).

2. The structures are covered by globular iron hydroxides cover (Fig. 7).

**INTERPRETATION**

At first glance, the structures under question look like large ferruginous nodules — it is a very natural supposition, because such nodules are common in fluvial/lacustrine sediments deposited in warm, humid climate. But first of all they are only partly ferruginous — in other parts they are built chiefly of clay minerals and fine quartz grains. They also show rather laminated than concentric structure. Moreover, ferruginous nodules (in this setting they were formerly siderite, subsequently “limonitic” = goethite + lepidocrocite) usually represent diageneric structures, while objects under questions were present in its shape before sedimentation of the host rock (see Fig. 4; Pl. III, Figs. 1–3). So, could they have been mud clasts? First problem is that they would have been unusually big mud clasts — usually, the maximum grain size in this locality is up to 3 cm. Moreover, those “mud clasts” would have been astonishingly regularly in their size and shape — to make the thing more complicated, they would have occurred in two “bimodal” classes, i.e. in two distinct, separate groups characterised by different size and shape, which is rather unlikely for the mud clasts. At last, some of those structures must have been arranged (by a current!) in a form of a regular rim. Needless to say, such possibilities are much less than remote — they are practically impossible. In some of the structures one can find a very high concentration of iron minerals, but this would be the only similarity with ferruginous nodules. Ferruginous content has nothing to do with the origin of the structures — they were something else, concretions inside or around them developed much later (compare with R. Cousin et al., 1994; p. 68, fig. 5.13).

On a “negative” way of reasoning (i.e. eliminating what it can not be), one has to exclude their inorganic origin. If we agree that biological factor must have been responsible for such a regularity in shape and arrangement, we have to ponder what kind of organic structures they might represent. There are few possibilities, such as plant fragments (most likely seeds or fructifications), animal coprolites or stomach stones. As far as concerns floral remains from Sołytków, their stage of preservation is excellent, and coal is common in those terrains. Hence, the most possible explanation is the organic content of the structures. But even we can not identify these structures have a very high concentration of iron minerals, but this would be the only similarity with ferruginous nodules. Ferruginous content has nothing to do with the origin of the structures — they were something else, concretions inside or around them developed much later (compare with R. Cousin et al., 1994; p. 68, fig. 5.13).

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Dinosaur nesting ground from Early Jurassic fluvial plain area in the earliest Jurassic times.

![Fig. 4. Cross-section of the nest showing the cross-bedding in the sediment covering the egg structures. Note the concordant arrangement of the cross lamine, proving that the structures were present before the deposition of the host sediment.](image)

Przekrój gniazda ukazujący osad pokrywający struktury jajowe. Widoczne zgodne ułożenie lamina warstwowania przekątnego, co dowodzi, że struktury kuliste były obecne przed sedymentacją osady otaczającej je od góry.

of such an interpretation comes from the "positive" facts, indicating what it can be:

1. **Regular shape and rim-like arrangement.** As mentioned before, the structures represent two kinds: spherical and ellipsoid ones. Particularly, the spherical structures are very suggestive. The similarity to sauropod nests and eggs described by many authors (J. W. Kitchling, 1979; F. E. Grine, J. W. Kitchling, 1987; J. J. Moratalla, J. E. Powell, 1994; L. M. Chiappe et al., 1998) is striking. Spherical eggs are also attributed to hadrosaurs but they did not exist in the Lower Jurassic time. It is important that the structures form part of a rim in a shallow depression (Pl. III, Fig. 3) and they seem to occur in pairs (Pl. III, Figs. 1, 2). J. W. Kitchling (1979) and F. E. Grine and J. W. Kitchling (1987) described a clutch of six spherical eggs from South Africa. Basing on preserved embryo remains, the authors attributed those eggs to prosauropods. J. J. Moratalla and J. E. Powell (1994) stated that sauropods laid eggs in circular clutches, parallel rows, or arcs. Sauropods could also dig shallow nests with the forefeet, possibly with the enlarged ungual phalanx of digit I (J. J. Moratalla, J. E. Powell, 1994). Likelihood, that the structures occur in pairs, is also consistent with the way on which the dinosaur eggs were laid — it is connected probably with their twin oviducts.

2. **Association with sauropod footprints.** A well preserved, probably juvenile sauropod pes print (*Parabrontopodus* sp., Pl. II, Fig. 3) has been found by the present author in the same place. G. Gierliński and G. Sawicki (1998) described a whole sauropod trackway just about 60 m apart, in the same complex of strata. Those unique finds point to the fact, that fairly large sauropods were common in the Soltyków fluvial plain area in the earliest Jurassic times.

3. **Chip-like, platy fragments around the structures (Pl. III, Figs. 1, 3).** They are strongly altered and under the SEM (Fig. 10) it is visible that they are built of clay minerals (illite, smectite) and iron hydroxide and oxide. They show laminar structure but little more can be said about them. In places, one can find poorly preserved, parallel or slightly radial tiny canals, which are approximately perpendicular to the plate’s surface (Fig. 10). The "chip-like" structures might be tentatively interpreted as diagenetically altered fragments of eggshells, but such a supposition is highly hypothetical.

![Fig. 5. Elements present in the infilling of the egg structures (EDS). Typical picture of illite mixed with iron hydroxides/oxides and some silica](image)
Fig. 6. Fragment of the inner ultrastructure of the dark substance taken from the cylindrical structures shown in Pl. III, Fig. 5. Note fibrolamellar ultrastructure. In the EDS (marked) presence of pure silica was indicated.

Fig. 7. Fragment of the inner and outer ultrastructure of the dark substance taken from the cylindrical structures shown in Pl. III, Fig. 5. Note fibrolamellar ultrastructure. In the EDS, one point shows typical siliceous composition, while in the other place one can find remnants of the encased substance rich in calcium (see Figs. 8 and 9). The outer ultrastructure is globular — the globules are built of iron hydroxides/oxides, which gives the structures their dark colour.

4. Flattened, cylindrical objects with fibrolamellar ultrastructure. The infilling of the structure i comprises several elongated, cylindrical, strongly flattened, dark objects (Pl. III, Fig 5). Similar structures have been illustrated by S. G. Lucas (1994, p. 193, fig. 13.11) in the cross-section of a hypsilophodontid egg showing some of the bones of the embryonic dinosaur. Under the SEM those objects show fibrolamellar ultrastructure with lamellae built of chalcedony. However, there are some remnants of the primary matter encased within the chalcedony framework. This matter is very rich in calcium (traces of phosphorus are also present) and was obviously sealed in silicified fibrolamellar structure. In the Sołtyków outcrop, calcium is generally absent — it was totally removed due to the low pH conditions during sedimentation and particularly at the burial stage. Fibrolamellar pattern of the objects in question is not a coincidence and it needs explanation. I tentatively identify the collection of long, narrow structures as ossified embryonic skeletal elements, which were subsequently silicified. The dinosaur embryonic bones were highly vascularized, soft and flexible. They show fibrolamellar structure (J. R. Horner, P. J. Currie, 1994); besides bones, abundant calcified cartilage columns were found (J. R. Horner, P. J. Currie, 1994). A fibrolamellar framework found in Sołtyków specimen could represent both kinds of tissue.

In the subsequent stage of diagenesis the fibrolamellar structures were covered with globular iron minerals, most likely as a result of microbial activity — CO₂ waste attaches to Fe²⁺ to produce siderite, which was later transformed into iron oxides/hydroxides (K. Carpenter, 1998) — see Fig. 7.

It is difficult to say what kind of dinosaur those remains might represent. Elongated egg structures may be attributed both to basal ornithischians or theropods. Footprints of both groups of dinosaurs are common in the Sołtyków outcrop (Pl. II, Figs. 1, 2). One should shortly comment on the possibility, that the egg structures might represent other animals, for example tortoises. However, the size of the structures, the pattern of the clutch and the lack of any evidence of the presence of other potential egg-laying animals other than dinosaurs, makes this supposition very unlikely.

To sum up, I interpreted both spherical and ellipsoid structures as strongly altered dinosaur eggs (more precisely, I would call them the “post-egg structures”). Spherical structures would represent sauropod eggs, while ellipsoid ones might be laid by either basal ornithischians or theropods. The nesting site was found in just one place, but sandy, crevasse splay sediments deposited on a flood plain might represent a favourable nesting ground for many groups of dinosaurs. The coexistence with numerous, fairly diversified dinosaur footprints tends to support such a supposition. Joint occurrence of two different kinds of eggs in the same location can be easily explained by the taphonomical factors.
TAPHONOMY AND DIAGENESIS

All the described structures represent unhatched eggs. Because the spherical sauropod egg structures occur in the preserved nest structure, it is obvious that they represent an in situ nesting ground. In the contrary, ellipsoid egg structures are scattered throughout the sediment with different inclination angle and very chaotic pattern. It is also obvious that these eggs were redeposited from a nearby nesting site, most probably by the same flood current which covered the sauropod nest with sandy deposits. The sauropod eggs, which were heavier, spherical in shape, and laid in a shallow depression were much more current-resistant than the lighter and elongated ellipsoid eggs, which could have been easily moved and transported by a flood current. Dinosaur eggs can be transported a considerable distance (T. Tokaryk, J. Storer, 1991). The flood event probably caused the death of eggs and embryos. Eggshell domes acted as a “vault” for some time, until the empty space inside, left after decay of soft parts, was infilled by muddy matrix infiltrating through cracks and pores. In places, where some sandy materials entered the shells, burrow systems might develop (Pl. III, Fig. 4). Needles to say, decomposing eggs provided a very attractive “nutrition storage”, but the oxygen condition was a major problem. More porous sandy material could let some oxygen to get into the egg filling, changing conditions from anaerobic to dys-aerobic and providing a “feeding bonanza” for a brief period. Perhaps at that stage the remnants of some embryonic bones were silicified, which protected them from further decomposition. Solubility and mobility of silica could be temporarily raised by the presence of ammonia originating from decaying organic matter. Ammonia could also slow down the dissolution of calcium carbonate of the eggshell, but generally (in case of an unhatched egg) dissolution of eggshell can begin shortly after the death of the egg or embryo. Decay of the organic matter produces carbon dioxide and hydrogen sulphide lowering the pH of the water in the vicinity of the egg making the calcium carbonate of the shell more soluble (K. Carpenter et al., 1994a). After burial, dissolution can occur by hydrolysis involving groundwater (K. Krauskopf, 1979). The rate of dissolution grows as the pH gets lower. Fluvial deposits of Soptyków outcrop were characterised by the low pH, so eggshells built of calcium carbonate were dissolved and gradually replaced by an infiltrating clayey substance. Such a “mud capture” in sand producing mud matrix has been described by K. S. Matlack et al. (1989). At the next stage (associated with a deeper burial) precipitation of siderite occurred. In the vicinity of lacustrine deposits supersaturation of the iron ions delivered by the humus acids is characteristic. Siderite may precipitate as a result of bacterial metabolism. The latest stage was dominated by oxidation — this occurred after tectonical inversion of the Mid-Polish Trough and uplifting of the Holy Cross Mountains area, which occurred in
infilling was more sandy, some burrows can occur. Egg structures are built of clay minerals in the fluvial, rate of sedimentation and after burial. Poorest state of preservation, caused by the low pH conditions.

1. Nest environment: moderate — warm and humid climate, fluvial plain, prevailing horsetail and coniferous vegetation.

2. Sedimentological and chemical analyses of the nest and area adjacent to the nest: crevasse splay sandstones (wackestones), subordinately mudstones, deposited during flood events on a broad flood plain of a high-sinuosity, meandering river. Palaeosols with numerous plant roots and coal seams are common, numerous mud cracks, bivalve resting tracks and burrows, arthropod burrows and dinosaur footprints. Associated subfacies of river channels, levees and flood plain lakes have been recognised. Quartz, illite, kaolinite, smectite, iron minerals and various types of coal dominate; diagenetic processes involve calcium carbonate dissolution, infiltration of clay minerals, and iron minerals dissolution and precipitation. Low pH prevailed during sedimentation and after burial.

3. Type, shape and size of the nest: single, rounded, shallow (few centimetres deep) buried in substrate, about 30 cm of diameter, with up to six (with four preserved) post-egg structures. Ellipsoid egg structures were redeposited — the type of their original nest is unknown.

4. Associated flora and fauna within the nest: some scattered, unidentified floral remains; sauropod, theropod and basal ornitopod footprints were found nearby.

5. Arrangement of eggs within the clutch: a rim-shaped, regular clutch, 25 cm in outer diameter (four egg structures preserved, there were probably six of them).

6. General morphology (macrostructure) of the egg and eggshell: regular, spherical, slightly flattened, longer axis 10 cm, shorter 8 cm, covered with chip-like plates up to 3 cm² and 1.5 mm thick. Chip-like plates are laminated, built of clay minerals with lamina of secondary iron minerals. Same chip-like plates are found around egg structures and are scattered on the surface of egg-bearing layer. Egg structures are built of the clayey-silty-ferruginous matrix coated by a thin, discontinuous clayey-ferruginous coating.

7. Egg and embryonic histostructure — egg histostructure can not be described because of total diagenetic alteration. Inside the redeposited egg structures, some accumulations of faint, flattened, cylindrical structures have been found — they reveal silicified, fibrolamellar ultrastructure with some remnants of primary matter, which is rich in calcium. They probably represent embryonic remnants.

8. Biochemical analysis of the shell — impossible to perform.

9. Taphonomy: matrix is fluvial, rate of sedimentation was rapid (flood), the current transported and dispersed the smaller eggs from nearby nesting grounds and covered the nest of the spherical eggs with sandy sediment. In a case when the egg infilling was more sandy, some burrows can occur.

CONCLUSIONS

The eggs are strongly diagenetically altered and no obvious eggshell ultrastructure can be observed, therefore the egg parataxonomy (K. Sabath, 1991; K. Mikhailov et al., 1994) can not be applied in this case. According to some standards, there should be the evidence of eggshell structure to prove that a specimen is an egg (K. F. Hirsch, D. K. Zelenitsky, 1997). Despite that, one can state that the evidences shown in the present paper allow to name the objects eggs, or more precisely, the post-egg structures. Further examinations, including X-ray and computer tomography, will be performed to check the objects inside. Acidic conditions eliminated the eggshells, but the preservation potential for embryonic skeletons might be slightly better. All this might serve as a hint, that in many deposits of fluvial origin fossil dinosaur eggs may be in fact fairly abundant, but due to their poor state of preservation, caused by the low pH conditions they are often overlooked. In this context, one should not automatically reject indirect or circumstantial evidences, because they may help to eliminate some irrelevant interpretations and point to the accurate ones. Examining structures, which are so difficult to interpret, needs an interdisciplinary approach, including careful sedimentological and palaeoecological studies. K. Carpenter et al. (1994) proposed a scheme of such an approach. Following their scheme (perhaps it should be called the "egg identification form"), it is possible to "submit" a brief report on the material from Poland:
Dinosaur nesting ground from Early Jurassic fluvial...

Fig. 11. Scheme showing stages of taphonomy and diagenesis of the post-egg structures
1 - eggs are laid in the sediment, some crushed eggshells are derived from broken or hatched eggs; 2 - burial by the flood event, quick decomposition of the soft parts, infilling of the eggs by infiltrating detrital mud/clay (rarely sand) matrix through incipient cracks and pores (burrows can locally develop at this stage), local, inner silification associated with temporal presence of ammonia, and subsequent dissolution of CaCO₃ caused by acid conditions associated with gradual replacement by clay minerals by infiltration; 3 - deeper burial stage, compaction, precipitation of siderite; 4 - epigenetic stage, oxidation of siderite to limonite (=goethite and lepidocrocite), cracks infilling by iron minerals

Schéma przedstawiające cztery stadia tafonomii i diagenezy struktur jajowych
1 - jaja zioone w osadzie, anokolo pewna ilość pokruszonych skorupek pochodzących z pokruszonych lub wyklutych jaj; 2 - stadium pogrzebania przez powódź, szybki rozkład miękich części, wypełnienie przez infiltrujący, detrytyczny muł i il (rzadko piasek), przez zaczątkowe pokruche i pory (janki żerowiskowe mogą się lokalnie rozwiniąć w tym stadium), lokalna, wewnętrzna silifikacja wywołana obecnością amoniaku oraz następujące potem rozpuszczenie CaCO₃ spowodowane zakwaszeniem środowiska, postępujące wraz z rozpuszczaniem pustych przestrzeni przez minerale ilaste na drodze infiltracji; 3 - głębsze pogrzebanie, kompakcja i wtrącanie syderytu; 4 - epigenetyczne stadium utleniania syderytu do limonitu (getyty i lepidokrokozy), szczeliny wypełniajone mineralami żelazo-żelazistymi

10. Diagenesis: decomposition of soft tissue, partial cracking of the eggshell, infilling with clayey-silty matrix, in the same time local alilification associated with presence of ammonia, dissolution of calcite eggshell, gradual replacement by clay and ferruginous material, late epigenetic oxidation.

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Gniazda dinozaurów z wcześniej jurajskich utworów rzecznych z gór świetokrzyskich

Streszczenie
W dolinolokalnym (dolny hetang) odnaleziono wapienki kątowe odnowienia, które zostały zinterpretowane jako struktury powstałe w miejscu jaj dinozaurów. Jaja zostały prawdopodobnie złożone w plazmycznej ławicy reprezentującej glik-kwarcowy, w obrębie równie zalewowej ze względu na przemyślana. Zostały one zidentyfikowane przez procesy diagnostyczne i nie zachowało się pierwszej ułamek fragmentu jąca. Badania wraz z jednostką struktur ujawniają niwelację, klinowe, spłaszczone, cylindryczne struktury. Pod mikroskopem elektronowym ukazują oni węglono mocnu, bardzo dobrze złożoną do basso- wy kości lub wąską, zwiastującą charakterystycznych dla drożnych jadernopi, poddawany zmianom w postaci piłkowej, a następnie dwupłaszczyzny składu.

REFERENCES


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Dinosaur nesting ground from Early Jurassic fluvial...

Fig. 1. General view (in 1986) of the Soltyków outcrop showing different fluvial facies: fp — mudstones, claystones and coals of the flood plain/oxbow lake subfacies with numerous palaeosol levels; ch — main fluvial channels, sandstones with large-scale trough bedding, transport directions from the north to the south dominate; cr — crevasse splay channels, transport directions approximately perpendicular to the "main" channel directions. Fan-shaped crevasse splay deposits dominate in the bottom of the outcrop, when dinosaur nest and many footprints have been found.

Fig. 2. Dinosaur nest in the crevasse splay deposits. Three spherical egg structures are visible (inset). Arrows indicate current directions: sub-ordinate (thin arrow) and major one (thick arrow). North is on the right side of the photograph.

Fig. 3. Early sauropod footprint. The track was left by the large carnivorous dinosaur, Dilophosaurus sp. Photo G. Gierliński.

Fig. 4. Some fossils, trace fossils and sedimentary structures occurring in the crevasse splay deposits in the Soltyków outcrop: p — drifted plant fossils (left — Equisetites sp., right — unidentified coniferous plant); c — vertical sections of plant roots; L — Lockeia sp. (bivalve nesting track); d — desiccation cracks filled by sand. Vertical structure represents a groove cast. Lower surface of the sandstone layer.

EXPLANATIONS OF PLATES

FIG. 1. Fragment of the sandstone bed covering the nest from the top. The hollows correspond to the underlying egg structures, in one hollow (A) part of the clayey-terragenous infill is still visible. Note the partly preserved rim-shaped nest of spherical egg structures and scattered ellipsoid egg structures. The chip-like clayey plates occur on the underside of the nest structure. The erosion surface of the sandstone bed is covered by the sandstone. The footprints are visible (inset). Arrows indicate current directions: sub-ordinate (thin arrow) and major one (thick arrow). North is on the right side of the photograph.

FIG. 2. Sketch corresponding to the Fig. 1, explaining the arrangements of the egg structures. Note two generations of the structures and the regularity of the spherical structures within the rim. Arrow indicates the local current direction.

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PLATE II

Fig. 1. Large theropod footprint Kayentapus soltyskowensis (after G. Gierliński, 1995). This track was left by the large carnivorous dinosaur, Dilophosaurus sp. Photo G. Gierliński.

Fig. 2. Early ophiomorph Anomoepus sp. (after G. Gierliński, 1995). Coll. and photo — G. Gierliński.

Fig. 3. Early sauropod footprint Parabrontopodus sp. found in the next layer and in the same place as the dinosaur nest has been found. Comparison with other sauropod footprint found nearby indicates that this footprint was left by a juvenile sauropod. Coll. and det. — G. Piesiakowski.

PLATE III

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ILLUSTRATIONS

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Fig. 5. Clayey-ferruginous infilling of the egg structure i, revealing tiny, cylindrical, flattened structures (arrowed), covered with a dark matter. Black arrow points to the spot where the sample for the SEM investigations was taken from (see Text-figs. 6–9).

Iliażo-żelaziste wypełnienie struktury jajowej i, w którym zachowane są niewielkie, cylindryczne, spłaszczone struktury (strzałki), pokryte ciemną substancją. Ciemna strzałka oznacza miejsce, z którego pobrano próbkę do badań w mikroskopie elektronowym SEM (porównaj fig. tekstowe 6–9).
Fig. 1

Fig. 2

Grzegorz PIĘKNOWSKI — Dinosaur nesting ground from the Early Jurassic fluvial deposits, Holy Cross Mountains (Poland)
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