EPHEMERAL MARKS IN RIVER-MARGIN SUBSTRATUM PRODUCED BY THE AKENE OF THE SPINY COCKLEBUR (*XANTHIUM SPINOSUM*): POSSIBLE TRACE FOSSIL IMPLICATIONS

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Abstract. The occurrence, for the first time, of the *Xanthium spinosum* traces completes the list of pseudotraces produced by plant remains. The neoichnological study of this physical structure is important because it provides useful information to paleoichnology in the effort to discriminate non-biotic traces from biotic traces present in geological formations of different ages.

Key words*:* neoichnology, *Xanthium akene*, ephemeral marks, trace fossil

1. INTRODUCTION

Biogenic sedimentary structures, recent and fossil, represent traces of animal behavior on the surface or inside a substrate located in different depositional environments. The study of current traces belongs to neoichnology, and that of fossil traces to paleoichnology (*e.g.*, Bromley, 1990; Patel, 2012 for review). Neoichnological literature also records the existence of abiotic structures, produced on the surface of mud or sand by various bodies, driven by water or wind. The most numerous traces of this kind belong to objects carried by underwater currents (*e.g.*, Anastasiu & Jipa, 1983, p.129-133; Dżulyński, 1996, p. 104-109; 2001, p. 19-21, and others). In recent years, such sedimentary structures have been described, often bilobated, called „tilting marks", produced by swinging pairs of *Mytilus* valves (Wetzel, 1999) and other objects (*e.g.*, jellyfish or wood) (Wetzel, 2013), simultaneously with their movement in very shallow water. Similar structures, produced by wind, were reported by Jones (2006) in the case of tilting *Eucalyptus* and *Casuarina* leaves on the sand of the beach in the backshore area, the author suggesting that these traces can also be used as indicators of paleowind direction and orientation (Jones, 2006). For this study, we are interested in the ricochet traces produced by the objects transported by salting, a common phenomenon, both to the aquatic environment and to the wind environment. Being ultimately the product of physical means, the non-biogenic structure must be called the mark (*sensu* Seilacher, 1953), as recently recommended by Vallon *et al.* (2015). In connection with these pseudofossils, Cloud (1973) shows that they must be treated with great care because they can distort the reality of the evolution of organisms during geological eras. Since trace fossils are themselves sedimentary structures, their discrimination in relation to non-biogenic structures is more difficult than in the case of fossil bodies (Seilacher, 2007).

In the present paper is mentioned, for the first time, the ephemeral mark produced by the achene of the species *Xanthium spinosum*, with possible paleoichological implications.

2. MATERIAL AND DATA PRESENTATION

Located in the Carpathian Foreland, most of the Slănicul de Buzău hydrographic basin, where the Sârbești sector is located (Fig. 1a, b), was the object of several geological studies concretized in a complex geological and sedimentological synthesis of the Dacian Basin (Jipa & Olariu, 2009). In the recently published geological-paleontological Atlas of the Buzău Land Geopark (Brustur *et al.*, 2019), is recorded the multitude of detailed investigations, sedimentological, paleontological, paleoichnological, paleoenvironmental and natural heritage, carried out over time, but also within the international project GeoSust, carried out in the period 2014-2017*. The investigated material is represented by three marks produced by the spiny Cocklebur (*Hanthium spinosum*) driven by the wind (Fig. 2a, b), along with the footprints of domestic birds (*Meleagris gallopavo*) (Fig. 2c), both types of traces printed on the surface of a very fine slice of mud from the minor riverbed of the Slănicul de Buzău river (Fig. 1c).

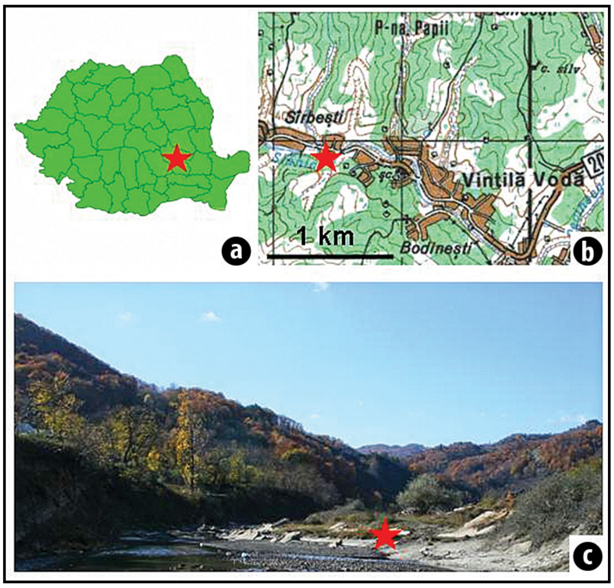

Fig. 1. *Xanthium* location: (**a**) Buzău County, (**b**) Sârbești village, and (**c**) Slănicului de Buzău Valley

Thus, the first mark (Fig. 2b$_1$), barely visible, shows the trace of the spikes that touched the surface of the mud, being arranged in the form of a parabola (Fig. 2d).

The second (Fig. 2b$_2$), more pronounced and quasi-oval in shape, illustrates the shock caused by the penetration of the achene into the mud, followed by the rapid detachment, at a new blow of wind. At a short distance and on the same trajectory, the achene was blocked by an irregularity of the relatively more consistent mud (Fig. 2b$_4$), an obvious testimony of the „shipwreck" of the producer at the crime scene! The seemingly senescent arrangement of the spike trace seems to indicate the balance of the achene before take-off (Fig. 2e).

The third mark (Fig. 2b$_3$), preceding the first two or produced, probably simultaneously, by another achene, has the shape of an insect impression, with head, thorax, abdomen and stilettos (Fig. 2f). Dimensions: length ~ 22-28 mm; width ~ 14-18 mm.

3. DISCUSSIONS AND FINAL REMARKS

It is known that the particles wind transport can be done in several ways which depend on the size of the particles and the wind speed. Thus, at lower speeds the small particles are entrained in suspension, and as the speed increases, the particles with a diameter of 100μm are lifted and moved by jumping. If the particles are larger (~ 500μm), the jump is much shorter, and the movement is done by repetition and / or creep (Kok *et al.*, 2012). Although the most common mode of dispersal of seeds or fruits is hydrocoria, seeds smaller than 0.1 g or up to 5 mm in diameter are moved by the wind (cf. Souza & Iannuzzi, 2012). According to Hughes *et al.* (1994), for seeds between 0.1 and 100 mg, all modes of dispersal are feasible, including anemocoria, as is the case with *Xanthium* achene.

The thorn of cholera (*Xanthium spinosum*), „a seemingly humble plant, with the hooks of the prickly fruit that nestles on the wool of sheep or the clothes of the passer-by", as characterized by Simionescu (1947, p. 197-198), is part of the ruderal plants, with flowers grouped in calatids provided with thorns bent at the tip, giving the appearance of false fruit or achene (Todor, 1968, p. 218-219). According to Simpson (2010), in *Xanthium* (family Asteraceae) achene is a multiple fruit, surrounded by a thorny envelope.

In the case of the *Xanthium* marks described above, the problem of morphological convergence between these physical structures and different trace fossils arises. In connection with this phenomenon, it is useful to recall the opinion of the authors Knaust & Hauschke (2004), according to which similarities in both categories of structures can only be apparent.

Thus, the arrangement after a parabola (Fig. 2d) or the quasi-oval arrangement of the spike impressions (Fig. 2e) may suggest the resemblance to a specimen of *Chondrites* isp., with the cross section of the galleries perpendicular to the stratification (Fig. 2g). The dense arrangement of the thorn impression group (Fig. 2b$_2$) is close to the scale imprint configuration on the *Meleagris gallopavo* heel (Fig. 2c). Interesting, however, is the mark with the morphology similar to an insect impression on which the stylus-shaped back can be recognized (Fig. 2f). With the pronounced axial part, but with much less developed lateral appendages, this mark bears similarities to the ichnospecies *Glaciichnium australis* from the West Antarctic Eocene, attributed to an arthropod that probably lived on the edge of a deltaic lake (Fig. 2h) (Uchman *et al.*, 2018).

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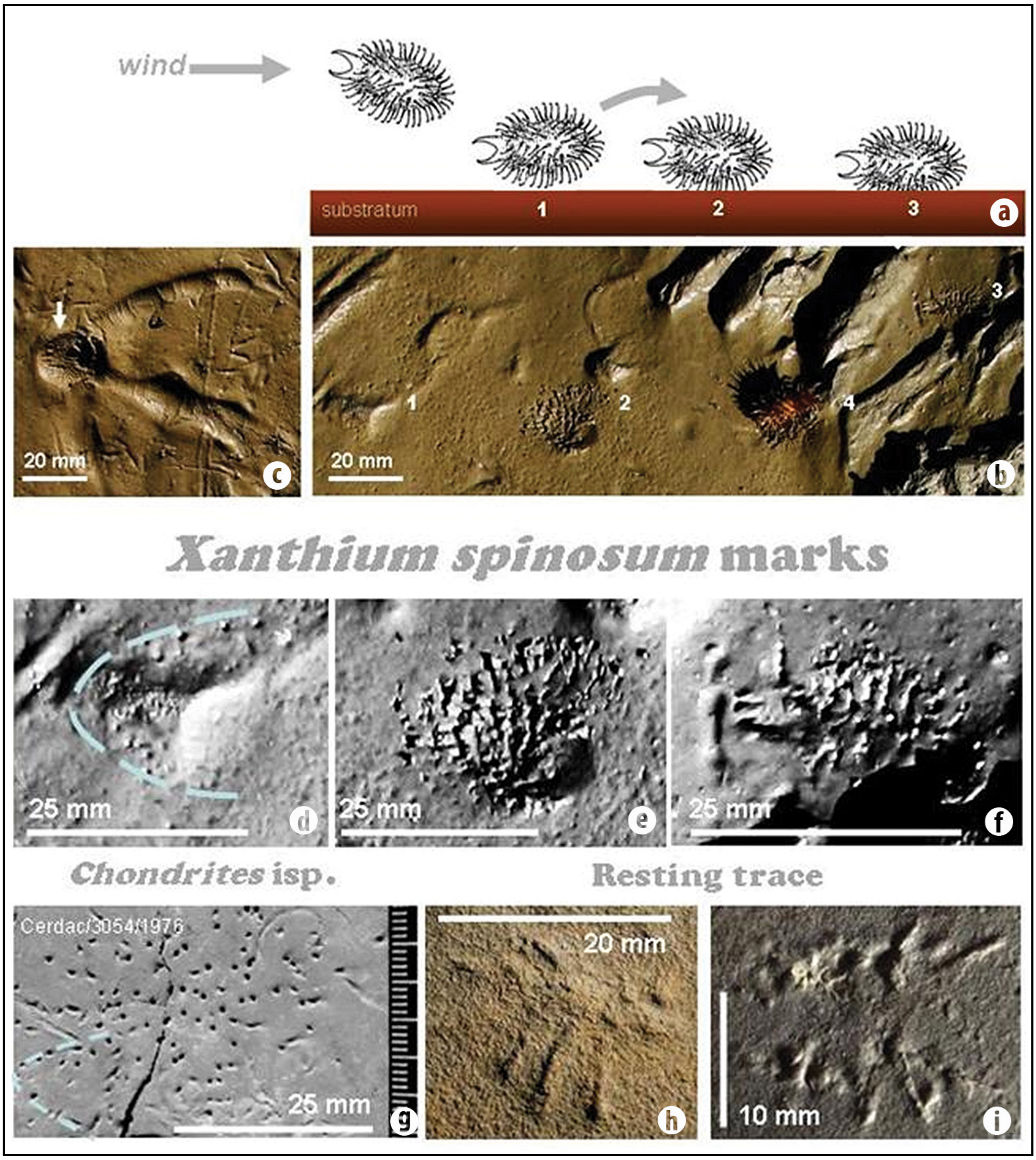

Fig. 2. *Xanthium spinosum* akena carried by wind: (**a**) Semi-consolidated mud substrate (idealized); (**b**) The succession of marks (1 ⟶ 3) produced by the impact of the *Xanthium spinosum* akene (*Xanthium* akene after: http://www.virtualherbarium.org/glossary/glossary.php?cid=65); (**c**) *Meleagris gallopavo* heel with scale imprints (white arrow) (photos b&c: T. Brustur, October 2017); (**d-f**) *Xanthium spinosum* akene marks: (**d**) Parabolic bites arrangement; (**e**) Quasi-oval dense bites arrangement; (**f**) "Insect"-like bites arrangement (close-up inlets from Fig. b_1, b_2, b_3); (**g-i**) Trace fossils: (**g**) *Chondrites* isp. (Upper Cretaceous, Tarcău Nappe, East Carpathians); (**h**) *Glaciichnium australis* resting trace (Eocene, West Antarctica – after Uchman *et al.*, 2018, Fig. $5e_2$); (**i**) *Gluckstadella cooperi* (Upper Carboniferous-Lower Permian, South Africa – after Buatois *et al.*, 2017, Fig. 7A)

A closer correspondent of this mark may be the fossil trace attributed to the ichnospecies *Gluckstadella cooperi* from the Paleozoic of South Africa (Fig. 2i), from the category of trace fossils of the type "bilaterally symmetrical short, scratched imprints" (Buatois *et al.*, 2017). Categorized by Keighley & Pickerill (2003) in the group "striated / bilobate pits", *Gluckstadella* is characteristic of the floodplain with ephemeral water holes in the Canadian Carboniferous. An arrangement of the marks left by the autotomy of the articles of the present species *Metacrinus rotundus*, similar to the *Xanthium* mark (Fig. 2f), was invoked by Gorzelak *et al.* (2020) to explain a behavior similar to the Lower Triassic isocrinid *Holocrinus* from North America (USA).

The presence of the *Xanthium* mark completes the list of pseudoforms grouped by Seilacher (2007) according to the hypothetical origin: similar to the fossil body, traces of objects (e.g., marks of ammonites, fish vertebrae, tabulated corals, plant remains), sedimentary structures, diagenetic structures and tectograms.

In summary, the neoichnological study of physical structures is particularly important because it provides useful information for paleoichnology to discriminate non-biotic traces from biotic traces, an operation that is often extremely difficult. In recent years, a lot of experimental neoichnology has been developed that brings substantial information for deciphering the traces of life from the geological past. Articles on this topic are available to anyone on the Palaeontologia electronica website (http://palaeo-electronica.org).

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