THE HURRICANE-PROD CAST: A TERRESTRIAL MECANOGLIPH FROM THE MIDDLE PONTIAN OF THE DACIAN BASIN (SLĂNICUL DE BUZĂU VALLEY, ROMANIA)

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Abstract. We present an unusual impact trace of hurricane-prod cast type, which has been possibly generated by the very strong atmospheric winds, produced, in the northern part of the Dacian Basin, during the latest Miocene, *i.e.* Pontian times. The above-mentioned hypothesis is based on the presence of the planimetric details, along with the reconstruction of the transported body and the existence of the undulations made by the impact shock.

Key words: paleowinds, terrestrial mecanoglyph, Early Pliocene, Portaferrian, Eastern Carpathian Foredeep.

1. INTRODUCTION

The oldest researches focused on "hieroglyphs" dated in Romania starting with the first decades of the 20th Century (Protescu, 1912; Mrazec, 1927). Subsequently, the mecanoglyphs from the Cretaceous-Paleogene flysch sediments of the Romanian Carpathians were used to solve various issues, such as: **a**) the establishment of the bed position (Noth & Krejci-Graf, 1929; Pătruț, 1955; Grigoraş, 1955; Băncilă, 1958; Popescu, 1958); **b**) the determination of the source areas and paleocurrent directions (Dimian & Dimian, 1962; Contescu *et al*., 1963; Dimitriu, 1964; Dumitriu & Dumitriu, 1965; Panin & Mihăilescu, 1967; Contescu *et al*., 1968; Jipa *et al*., 1973); **c**) the identification of the syndromic mecanoglyphs of a secondary origin in the Transcarpathian Flysch zone (Jipa & Mihăilescu, 1973). The mecanoglyphs of the Miocene molasse deposits have been previously studied by Paucă (1952), Panin (1961, 1964), Dimian & Dimian (1962) and Polonic & Polonic (1968), while those from the Eastern Carpathian Foreland were investigated by Macarovici *et al*. (1967), Jipa (2006) and Jipa & Olariu (2009).

Among the various structures of the mecanoglyph type from flysch and molasse sediments, a distinct category is represented by vectorial erosion structures, generated by objects that have been transported by water currents. Based on the investigations of Dżułyński & Walton (1965), Anastasiu & Jipa (1983) and Dżułyński (1996), the imprints of the current transportation objects may be grouped into continuous ones, such as dredging marks, including groove marks and chevron marks, and discontinuous, comprising impact and rolling marks, which are represented by prod marks, bounce marks, brush marks, saltation marks and roll marks. Usually, the prod marks have longitudinal striations and a sharp or a round apex, being quite small, that is 10-15 cm in length and up to 1 cm in depth (Dżułyński & Walton, 1965; Anastasiu & Jipa, 1983). Additionally, some of these mecanoglyphs may have sharp margins, due to the cut of the object stuck in the sediment; other mecanoglyphs are very elongated, short or large, features that indicate the impact of the surface with an object fallen under a big angle (Dżułyński & Walton, 1965). As directional structures, the tool marks and the scour marks represent the key for understanding the paleogeography of various sedimentary basins (Dżulyński, 1996; p. 102).

This paper presents the first occurrence of a new type of prod mark, within the Middle Pontian (Portaferrian) sediments from the Carpathian Foreland; some paleoenvironmental considerations are also advanced herein.

2. GEOLOGICAL SETTING

The region where the new mecanoglyph has been observed is situated in the Neogene Dacian Basin (**Fig. 1a**), being placed in the Slănicul de Buzău Valley, on the Sârbeşti locality territory, in the area of Buzău Land Geopark (**Fig. 1c**). The Middle Pontian deposits, cropping out at Sârbeşti, are situated on the western flank of the Berca-Arbănaşi anticline (*e.g.*, Macarovici, 1961; Jipa & Olariu, 2009), being characterized, from a paleoenvironmental point of view, by the occurrence of alternating continental and brackish up to marine facies. The continental sediments are fluvial ones, belonging to the alluvial channel paleoambiances and to those placed outside the channel. Lithologically, the former ones contain unstratified clays related to a flood paleoplain, fine-grained sands, showing flood sheets, coal and coaly clays and paleosoils. The brackish-marine sedimentation encloses stratified grey clays and sandstones showing symmetrical ripple marks. The aforementioned deposits were interpreted (Jipa & Olariu, 2009) as accumulated in a deltaic plain. Within this paleoambiance, the deltaic/fluvial channels have frequently migrated laterally, allowing the accumulation of the marine sediments in a side space temporary placed outside the fluvial influence.

Recently, the lithostratigraphy and the paleoichnologic content of a Middle Pontian (Portaferrian) succession from the Slănicul de Buzău Valley was interpreted (Brustur & Jipa, 2009) as follows: the presence of the sandy sandstones with numerous rhizolithes is linked to a paleosoil, probably situated at the edge of the sedimentary basin, supporting the influence of the hydrostatic level oscillations. The presence of this pedological turbation mirrored the colonization of the marginal lacustrine paleoenvironment with grassy vegetation and bushes, within a time of a local and/or regional regression. The continental episode, marked by a significant discontinuity surface at the Middle Pontian level, is followed by a marine transgression. This assumed sea level fluctuation is shown by the occurrence of an indurated sandy sequence, containing a numerous population of *Gastrochaenolites* (Brustur & Jipa, 2009). The above-mentioned ichnogenus is often associated with the erosional exhumation of sediments, previously buried, being typically linked to rapid sea level modifications (Carmona *et al*., 2007).

3. RESULTS

The prod mark has been identified on the fined-grained sandstone bed, 15-20 cm in thickness, on a surface of around 0.85 m^2, cropping out in the Slănicul de Buzău Valley (**Fig. 1c**). In the field, a sector of around 0.35 m^2 that contains the prod mark has been noticed (**Fig. 1d**). Taking into account the dimension, the weak rolling, along with its occurrence in the Slănicul de Buzău River bed, it is possible that this rock fragment comes from the top of the lower part of the Middle Pontian (Portaferrian) stage, as indicated in the stratigraphical column (**Fig. 1b**) illustrated in Jipa & Olariu (2009). In **Fig. 2** the planimetric details of the prod mark are shown (**Fig. 2a**), as well as the reconstruction of the aerial transported conic body (**Fig. 2b**).

The mold of the sedimentary structure related to the object impact shows, on the pelitic bed, the presence of a semiconical depression, ending with a sharp apex. Flattened lobes, with different lengths, are placed perpendicularly on the depression axis, at various distances. These lobes mark the bilateral expulsion of the mud, after the initial impact of the wind transported object (**Fig. 2a**). The lobes are disposed on different angles, *i.e.* between 55° and 85°, in relation to the depression axis; some of them have thickened terminations, illustrative for the mud overcrowding, at their distal end (**Fig. 2a, X**). The occurrence of these lobes with various shapes, dimensions and orientations, linked to the depression created after the object impact, is indicative for the synchronism of their formation with the depression, *i.e.* a syndepositional process. This genetic approach excludes the possibility that the prod mark was superposed on current ripple marks, as it may be interpreted, at first glance (**Fig. 1d**).

The mold of the impact depression shows several morphological particularities, allowing for a hypothetical reconstruction of the transported object (**Fig. 2b**): **a**) the tronconic shape, around 30 cm long and with a sharp edge; **b**) the presence of straight longitudinal striations or slightly curved, placed towards the base; **c**) the aspect of deformed body, probably due to the extremely powerful wind and materialized by apparently torsion portions (**Fig. 2b, X; Fig. 3**); **d**) the sharp contact between the depression and the host rock (**Fig. 2b, XX**); **e**) the presence, in front of the depression, of parabolic undulations produced by the impact shock (**Fig. 2a, XXX**).

4. DISCUSSION

In the Dacian Basin (Eastern Paratethys domain), the Pontian stage covers ca. 1 Ma. This stage corresponds, globally, to the upper part of the Messinian and the lower part of the Zanclean, including the Miocene/Pliocene boundary (Rădan & Rădan, 1998; Vasiliev *et al*., 2004; Snel *et al*., 2006).

During the Middle Pontian (= the Portaferrian substage), the Dacian Basin was supplied with clastic material from four active source areas, two of them in the intra-Carpathian regions and the other two in extra-Carpathian areas (Jipa & Olariu, 2009). The occurrence of the proximal sedimentary successions, as a transition between the marine sedimentation and the continental one (Jipa *et al*., 2006), including fresh water mollusks (*e.g.*, *Potamoscapha*) from the base of the Portaferrian (Macaleţ, 1997), signaled by various authors (Jipa & Olariu, 2009; Stoica *et al.*, 2012; Floroiu *et al*., 2013), shows a significant regression, possibly linked to the

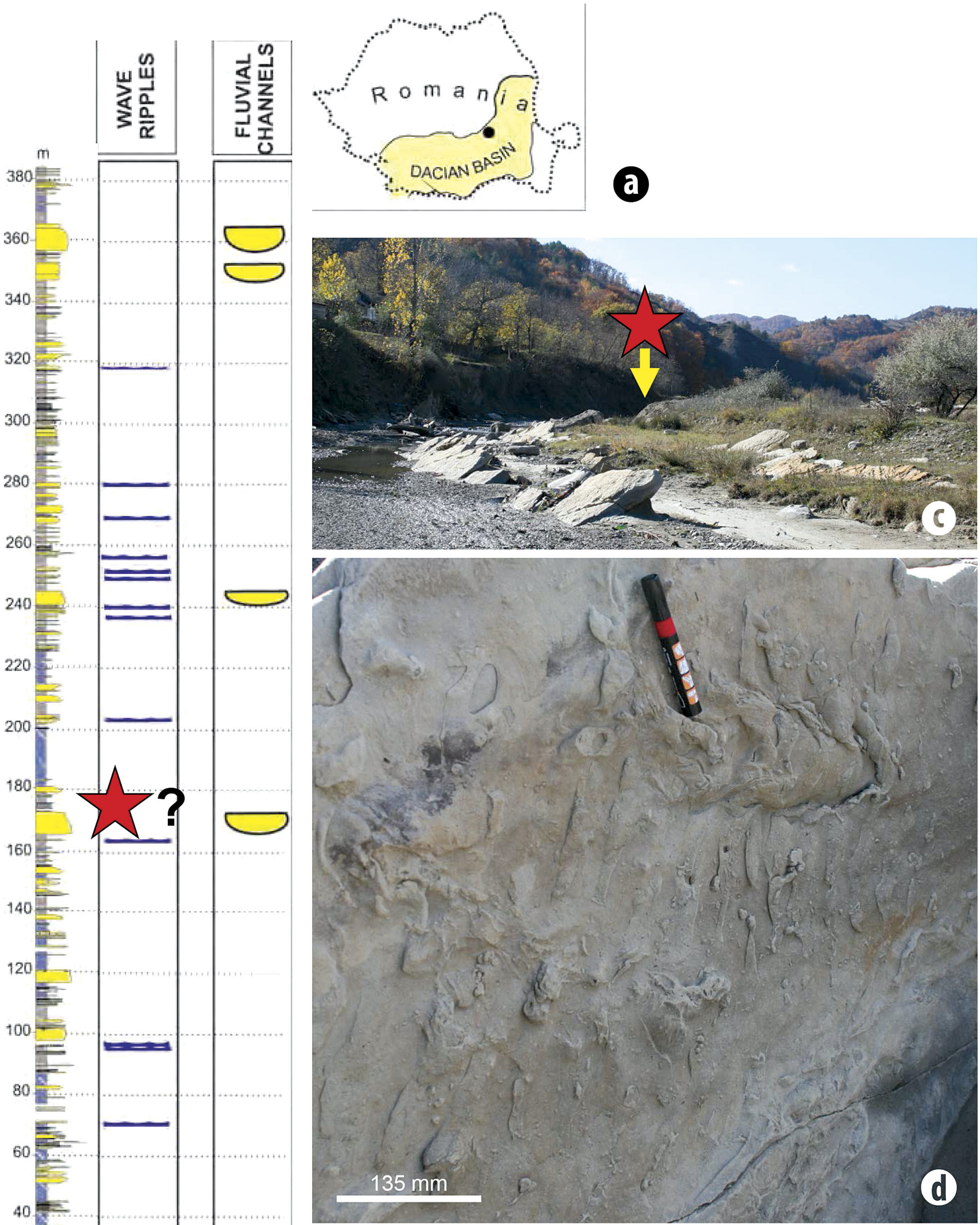

Fig. 1. a. Location of the studied Middle Pontian deposits at Sârbeşti, in the Dacian Basin, Romania (after Jipa & Olariu, 2009); **b.** The stratigraphical column of the Middle Pontian sediments with the position of the sequences characterized by ripple marks and fluvial channels (modified after Jipa & Olariu, 2009); **c.** The outcrop exposed in the Slănicul de Buzău Valley, at Sârbeşti; **d.** Detail of the sandstone bed containing the hurricane-prod cast (photo Titus Brustur, November 2012). The red star indicates the position of the sandstone bed with the impact mark from **b** and **c**.

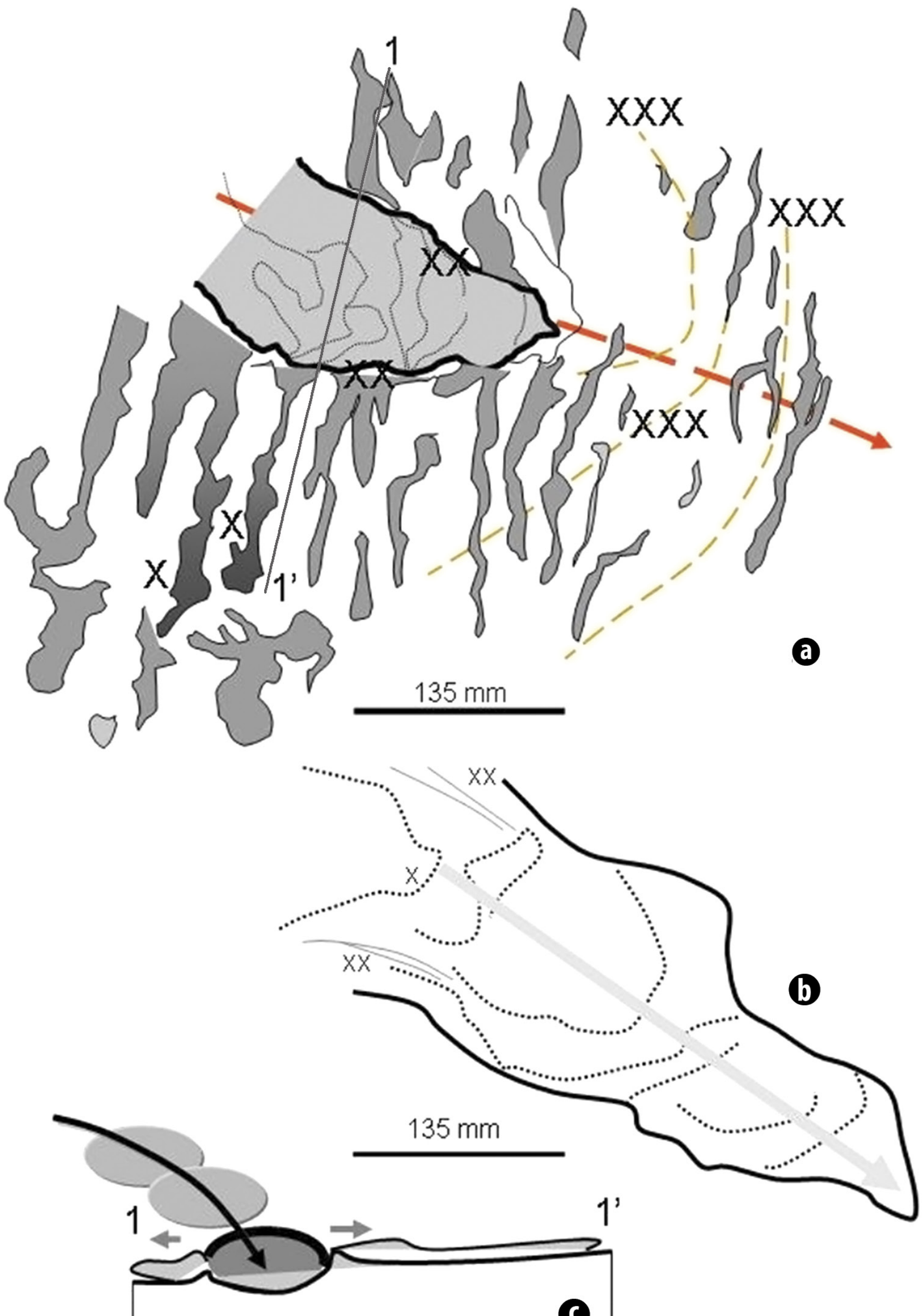

Fig. 2. Hurricane prod-cast **a**. Planimetric detail of the prod mark (drawing after the picture). Interrupted thick yellow lines mark the approximated contour of the sharp edge body ("**XX**") transported by the wind and the lateral lobes, perpendicularly disposed on the stick mark axis. The distal part of the lobes marked "**X**" represents the mold of the mud ejected after the impact; the undulations of the shock wave are noted "**XXX**". **b**. Reconstruction of the body transported by the wind, with the impression of the longitudinal striations ("XX") and of the deformed parts of the semiconsolidated material ("X"). **c**. Schematic section of the impact trace (not at scale; the arrows indicate the direction of mud lobe movement).

Fig. 3. The mold of the impact depression; note the longitudinal striations, the aspect of deformed material with torsion parts and mud lobes, perpendicularly disposed on the depression axis.

Messinian Salinity Crisis that produced a substantial sea level drop in the Mediterranean (Bache *et al*., 2012). Some authors (Suc *et al*., 2011) believe that this event triggered by the tectonics in the Mediterranean has also influenced the regime of the Eastern Paratethyan realm, leading to the opening of the Iron Gates and the partial desiccation of the Dacian Basin, by a pronounced fluvial drainage; yet, this issue is under debate, as several different hypotheses have been advanced.

In our opinion, a Late Miocene paleosetting, with exondated sectors with variable extension in which frequent thunderstorms took place, allowed the generation of a prod mark related to high winds. Such type of mark is for the first time described herein and we define it as "*the hurricane-prod cast*". The generation of this mecanoglyph type is illustrated in **Fig. 4.** We have selected the term "*hurricane*" to designate the high energy aerial transport (*sensu* Marcinowski & Radwanski, 2009), characteristic of the wind speeds and intensities in hurricanes and tornadoes range.

It is known that, at present, the hurricane and tornadoe wind speed may be as high as 152 km/h up to 250 km/h (Saffir-Simpson scale), and between 40 km/h and 300 km/h (Fujita scale), respectively. Some hurricanes have reached 322 km/h, and the tornadoes 483 km/h, with devastating effects.

In some cases, crossing the land, the hurricanes may be accompanied by vortices that sometimes produce a strong suction and take over heavy objects (Lăzărescu, 1980) or even peel the asphalt (Vesilind & Carsten, 2004).

We assume that the existence of some extreme meteorological events, as aforementioned, had generated, by suction, prod marks. Probably, this kind of mark has been made by the fragments released from the semiconsolidated pelitic sediment in a shallow small basin (**Fig. 4a**) or by a part of the mud cracks (**Fig. 4b**), followed by a wind small-distance transport and impact under a small angle of the body on the surface of a semiconsolidated clay, in another small basin (**Fig. 4c**). Previously, the perturbation of the lacustrine semiconsolidated sediments, at depths between 7 cm and 25 cm, was noticed in Florida (USA), following the crossing of the *Frances*, *Jeanne* and *Wilma* hurricanes (Jin *et al*., 2011).

The planimetric details, as well as the reconstruction of the transported body and the undulation existence made by the impact shock (**Fig. 2**) argue for a *scenario* similar to that above described. The argument of the existence of an aerial transport in the genesis of such kind of mecanoglyph is the prevailing, in the pre-Quaternary, of a climate similar to the present one; the climate simulations of the Pliocene times indicate a pronounced global warming, accompanied by the intensification of the atmospheric and oceanic circulation, along with the highest speed of the western-oriented winds (Poulsen, 2009).

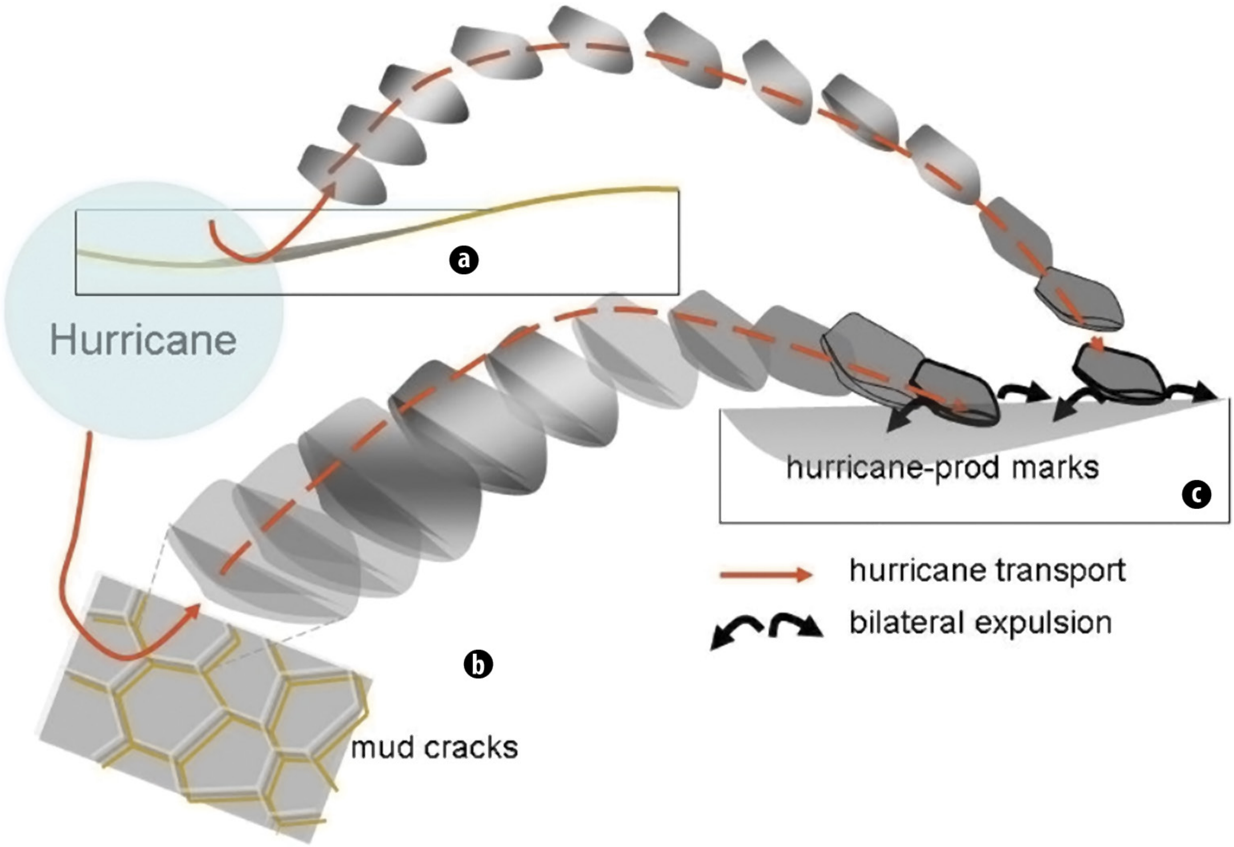

Fig. 4. Model of the impact trace of the hurricane prod-cast due to the dislocation, by a strong wind, of a semiconsolidated sediment from a shallow basin (**a**) or parts of the mud cracks surfaces (**b**); the transport in the atmosphere followed by the object impact in basins filled with mud, simultaneous with the bilateral expulsion of the mud, perpendicularly on the axis of the impact depression (**c**).

The tropical hurricane events and the thunderstorms were considered (Duke, 1985) the main cause of the appearance of the crossed stratification *hummocky*-type in at least 107 occurrences within the Proterozoic - Recent time interval; the distribution of such sedimentological structures shows that 73 % of them have been generated by the tropical hurricanes and 27 % are due to the intense winds, related to the thunderstorms produced at low latitudes. Additionally, Duke (1985) identified *hummocky* structures in the lacustrine sediments, linked to the occurrence of the high thunderstorms.

In the Dacian Basin of the Romanian Carpathians outer part, *hummocky* structures are present in the Upper Miocene sediments, *i.e*., during the Maeotian and Pontian Paratethyan stages (Jipa *et al*., 2006; Jipa & Olariu, 2009). Moreover, the existence of the strong winds during the Dacian (Early Pliocene) stage, argued by the presence of the aeolian sands, was used (Filipescu, 1940) to explain the thickening of the shells belonging to the mollusk *Prosodacna* and *Viviparus* taxa. This could be caused by the high disturbance of the Pliocene lake waters from the NE part of the Dacian Basin.

We exclude the origination of the above-mentioned mecanoglyph by rheoplasis, a mechanism described by Poll *et al*. (1981) and Plint *et al*. (1983) for explaining the presence of such structures in the Paleozoic continental sandstones from Canada. Therefore, we consider that the genetic model, as explained above, is plausible enough, including the rheologic behavior of the semiconsolidated sediment fragment, taken over and transported in the atmosphere by a strong wind similar to the nowadays hurricane.

However, a short distance transport may conserve the initial state of the pelitic material. Similarly, the initial state of the pelitic material, as the detached clay fragments that have been pushed by bottom currents, may generate longitudinal striations of the brush marks. This kind of traces was described in the Oligocene turbidites of the Polish Carpathians (Dżułyński, 1996).

The continuation of the sedimentological investigations, focused on the study of the inner structures and current mecanoglyphs (including those presented herein), may bring important information on the paleowinds orientation in the Dacian Basin during the Late Miocene times. Recently, De Vleeschouwer *et al*. (2015) noted the importance of the study of the ripple marks orientation in the reconstruction of the Middle Devonian paleowinds in the Orcadian Basin (Scotland), confirming the numerical paleoclimatic models.

5. CONCLUSIONS

a) The Miocene and Pliocene marine and lacustrine deposits of the Eastern Carpathian Foreland preserve numerous inner structures and directional mecanoglyphs of various types and origins (*e.g.*, Jipa *et al*., 2006; Jipa & Olariu, 2009).

b) The Middle Pontian (Portaferrian) that corresponds to the upper part of the global Messinian stage has recorded some paleoenvironmental events; one of these is the discontinuity surface marked by a regression (argued by the presence of paleosoils with *rhizolithe*), followed by a transgression, *i.e.* a marine sequence with *Gastrochenolithes* (Brustur & Jipa, 2009).

c) The presence of the inner structures, *hummocky*-type, in the Maeotian and Pontian sediments (Jipa *et al*., 2006; Jipa & Olariu, 2009), along with an impact trace of hurricane prod-cast type are possibly linked to the existence, in some areas of the Dacian Basin, in those times, of extreme meteorological phenomena, such as cyclones and tornadoes.

d) The study of oscillation orientation showed by the ripple marks and the hurricane prod-casts may indicate the directions of the Miocene-Pliocene paleowinds in the Dacian Basin, helping to carry out a more comprehensive picture of the climate evolution in the Eastern Paratethyan realm.

e) The presence, in the inner part of the Eastern Carpathian Foreland, of the upper Miocene and Pliocene deposits, showing lithological similarities with the turbidites as in the Milcov Formation, together with inner structures and mecanoglyphs of currents (Macarovici *et al*., 1967; Jipa, 2006) need detailed and systematic sedimentological investigations, in order to possibly identify the continuation of the orogen facies (*sensu* Paucă, 1952) in the Focşani-Pralea region.

f) The hurricane prod-casts have not been described, up to now, in any paper focused on sedimentary structures, neither in the foreign geological literature, (*e.g*., Pettijohn & Potter, 1964; Dżułyński & Walton, 1965; Dżułyński, 1996; Dżułyński, 2001), nor in the Romanian one (*e.g*., Pauliuc, 1962; Dimian & Dimian, 1962; Contescu *et al*., 1963; Panin & Mihăilescu, 1967; Contescu *et al*., 1968).

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REFERENCES

Anastasiu N., Jipa D. (1983) *Texturi şi structuri sedimentare*., Ed. Tehnică, Bucureşti, 319 p.

Bache F., Popescu S.M., Rabineau M., Gorini C., Suc J.-P, Clauzon G, Olivet J.-L., Rubino J.-L., Melinte-Dobrinescu M.C, Estrada F., Londeix L., Armijo R., Meyer B., Jolivet L., Jouannic G., Leroux E., Aslanian D., Dos Reos T., Mocochain L., Dumurdzanov N., Zagorchev I, Lesic V., Tomic D., Cagatay N., Brun J.P., Sokoutis D., Csato I., Ukarcus G., Cakir Z., (2012) A two step process for the reflooding of the Mediterranean after the Messinian Salinity Crisis. Basin Research, **24**: 125-153.

Băncilă I. (1958) *Geologia Carpaţilor Orientali*. Ed. ştiinţifică, Bucureşti, 367 p.

Brustur T., Jipa D. (2009) Suprafaţa de discontinuitate din Ponţianul Mediu din Valea Slănicul de Buzău: argumente paleoichnologice. http://www.geoecomar.ro/website/publicatii/supliment2009/8.pdf, 85-94, Bucureşti.

Carmona N.B., Mangano M.G., Buatois L.A., Ponce J.J. (2007) Bivalve trace fossils in an early Miocene discontinuity surface in Patagonia, Argentina: burrowing behavior and implications for ichnotaxonomy at the firmground-hardground divide. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **255**: 329-334.

Contescu L., Jipa D., Mihăilescu N., Panin N. (1963) Associations d'hiéroglyphes dans quelques séries de flysch des Carpathes Orientales Roumaines. 1962, *VIe Congr. de l'Assoc. Geol. Carpatho-Balcanique, I, Stratigraphie*, fasc. **1**: 61-68, Warszawa.

Contescu L., Jipa D., Mihăilescu N., Panin N. (1968) Semnificaţia sedimentologică a faciesurilor flişului paleogen din Carpaţii Orientali. *St. Cerc. Geol., Geofiz., Geogr., Geologie*, **11**/*2*: 513-526, Bucureşti

Dimian M., Dimian E. (1962**)** Cercetări sedimentologice privind zona flişului cretacic superior - paleogen şi a molasei miocene dintre văile Zăbalei şi Buzăului. *D.S. Com. Geol*., **XLIX**/1: 361-382, Bucureşti.

Dumitriu M. (1964) Arii sursă ale unor sedimente paleogene din Carpaţii Orientali. *St. Cerc. Geol., Geofiz., Geogr., Geologie*, **9**/*1*: 181-186, Bucureşti.

Dumitriu M., Dumitriu C. (1965) *Observaţii sedimentologice privind zona flişului cretacic-paleogen dintre văile Covasna şi Buzău*. *St. Cerc. Geol., Geofiz., Geogr., Geologie*, **10**/*1*: 265-271, Bucureşti.

De Vleeschouwer D., Leather D., Claeys P. (2015) Ripple marks indicate Mid-Devonian paleo-wind directions in the Orcadian Basin (Orkney Isles, Scotland). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **426**: 68-74.

Duke W.L. (1985) Hummocky cross-stratification, tropical hurricanes and intense wind storms. *Sedimentology*, **32**: 167–194. doi: 10.1111/j.1365-3091.1985.tb00502.x

Dżułyński S. (1996) Erosional and deformational structures in single sedimentary beds: a genetic commentary. *Ann. Soc. Geol. Polon.*, **66**/*2*: 101-189, Krakow.

Dżułyński S. (2001) Atlas struktur sedymentacyjnych fliszu Karpackiego. Atlas of sedimentary structures from the Polish flysch Carpathians. *Inst. Nauk Geol. Univ. Jagiellońskiego*, Kraków, 132 p.

Dżułyński S., Walton E.K. (1965) Sedimentary features of flysch and greywackes. *Development of Sedimentology*, **7**, Elsevier, Amsterdam, London, New York, 274 p.

Filipescu M.G. (1940) Étude géologique de la région comprise entre les vallées des Teleajen et du Slănic-Bâsca Mare. *C.R. Inst. Géol. Roum.*, **XXIII**: 78-101.

Floroiu A., Stoica, M., Vasiliev I., Krijgsman W. (2013) Pontian ostracods from Sanicul de Buzau section (Eastern Carpathian Foredeep). *Naturalista sicil*., S. IV, **XXXVII**/*1*: 131-132. ISSN online 2240-3442.

Grigoraş N. (1955) Studiul comparativ al faciesurilor paleogenului dintre Putna şi Buzău. *An. Com. Geol*., **XXVIII**: 99-219, Bucureşti.

Jin K.R., Chang N.B., Ji Y.G., James R.T. (2011) Hurricanes affect the sediment and environment in Lake Okeechobee. *Critical Reviews in Environmental Science and Technology*, **41**/*1*: 382-394.

Jipa D.C., (2006) Transportul materialului sedimentar în cursul evoluției Bazinului Dacic. In*:* Jipa D.C. (ed.) *Bazinul Dacic. Arhitectură sedimentară, evoluție, factori de control*: 88-116, GeoEcoMar, Bucureşti.

Jipa D., Mihăilescu N. (1963) *À* propos de l'origine des mécanogliphes syndromiques. *VIe Congr. de l'Assoc. Geol. Carpatho-Balcanique, I, Stratigraphie*, fasc. **1**: 5-10, Warszawa.

Jipa D.C., Olariu C. (2009) Dacian Basin. Depositional architecture and sedimentary history of a Paratethys sea. *Geo-Eco-Marina Special Publ*., **3**., Bucureşti, 264 p.

Jipa D., Mihăilescu N., Panin N. (1973) Directions des paléocourants dans le sillon paléogène du Maramureş. *Bull. VIe Congr. Assoc. Geol. Carp.-Balk., I, Stratigraphie*, fasc. **2**: 155-161, Warszawa.

Jipa D.C., Szobotka S., Brustur T., Avram C., Maximov G. (2006) Sedimentarea litorală neogen superioară în Bazinul Dacic. In: Jipa D.C. (ed.) Bazinul Dacic. *Arhitectură sedimentară, evoluţie, factori de control*, GeoEcoMar, Bucureşti, 135-163.

Lăzărescu V. (1980) *Geologie fizică*, Ed. Tehnică, Bucureşti, 511 p..

Macaleț R. (1997) Studiul lito-biostratigrafic al formațiunilor ponțiene de molasă dintre valea Buzăului şi valea Dâmboviței. Rezumatul tezei de doctorat., Univ. „Al. I. Cuza" Iaşi, 26 p.

Macarovici N. (1961) Observații stratigrafice pe structura Berca-Arbănaşi (cu privire asupra limitelor Dacianului). *St. Cerc. Geol.,* **VI**/*3*: 387-403, Bucureşti.

Macarovici N., Motaş I., Contescu L. (1967) Caractères stratigraphiques et sédimentologiques des dépôts sarmato-pliocènes de la courbure des Carpates Orientales. *Anal. Şt. Univ. „Al. I. Cuza"*, (serie nouă), secț. II (Ştiințe Naturale), b. Geologie-Geografie, **XIII**: 47-60, Iaşi.

Marcinowski R., Radwanski A. (2009) *A* unique habitat of endolithic biota: hurricane-induced limestone rubble in an Albian sand-mass of the Cracow Upland, southern Poland. *Acta Geologica Polonica*, **59**/*4*: 501-521.

Mrazec L. (1927) Les traces de reptation dans les vases de lagunes de la Mer Rouge. *D. S. Inst. Geol. Rom*., **VI** (1914-1915): 124–126, Bucureşti.

Noth R., Krejci-Graf K. (1929), II. Tektonische Beobachtungen am Deckenrande der Moldau. *N. Jahrb. Min*., Abt. B, **LXII**: 301-324.

Panin N. (1961) Asupra unor urme organice şi mecanice din miocenul de la confluența Putnei cu Zăbala. *St. Cerc. Geol*., **VI**/*1*: 63-73, Bucureşti.

Panin N. (1964) Coexistența urmelor de paşi de vertebrate cu mecanoglifele în molasa miocenă din Carpații Orientali. *St. Cerc. Geol., Geofiz., Geogr., Geologie*, **9**/*2*: 341-363, Bucureşti.

Panin N., Mihăilescu N. (1967) Direcții de curenți în flişul paleogen din Bucovina. *St. Cerc. Geol., Geofiz., Geogr., Geologie*, **12**/*2*: 477-484, Bucureşti.

Paucă M. (1952) Depozitele miocene presarmațiene din regiunea de curbură a Carpaților. *An. Com. Geol*., **XXIV**: 271-302, Bucureşti.

Pauliuc S. (1962) Contribuțiuni la studiul flişului cretacic şi paleogen dintre Bîsca Mare şi Zăbala. *D. S. Com. Geol*., **XLVI**: 305-316, Bucureşti.

Pătruț I. (1955) Geologia şi tectonica regiunii Vălenii de Munte-Cosminele-Buştenari. *An. Com. Geol*., **XXVIII**: 5-98, Bucureşti.

Pettijohn F.J., Potter P.E. (1964) Atlas and glossary of primary sedimentary structures, Springer-Verlag, Berlin, 311 p..

Plint A.G., Poll H.W. van de, Patel I.M. (1983) Experiment in rheoplasis during sediment intrusion. *Maritime Sediments and Atlantic Geology*, **19**: 11-19.

Poll H.W. van de, Patel I.M. (1981) Flute casts and related structures on moulded silt injection surfaces in continental sandstone of the Boss Point Formation: southeastern New Brunswick, Canada. *Maritime Sediments and Atlantic Geology*, **17**/*1*: 1-22.

Polonic P., Polonic G., 1968. Direcții de transport în molasa helvețiană dintre valea Sucevei şi valea Trotuşului. *D. S. Com. Geol.,* **LIV** (1966-1967): 205-215, Bucureşti.

Popescu Gr. (1958) Contribuții la stratigrafia flişului cretacic dintre valea Prahovei şi valea Buzăului cu privire specială asupra văii Teleajenului. *St. cerc. geol.*, **III**/3-4: 159-199, Bucureşti.

Poulsen Ch.J. (2009) Paleoclimate modeling, Pre-Quaternary. In: Gornitz V. (ed.) *Encyclopedia of palaeoclimatology and ancient environments*, pp. 700-709, ISBN 978-1-4020-4551-6, Springer.

Protescu O. (1912) Communications sur l'origine de certains grés à hieroglyphes. *D. S. Inst. Geol. Rom*., **III**: 63–67, Bucureşti.

Rădan S.C., Rădan M. (1998) Study of the geomagnetic field structure in Tertiary in the context of magnetostratigraphic scale elaboration. I. – The Pliocene. *An. Inst. Geol. Rom*., **70**: 215-231.

Snel E., Mărunțeanu M., Macaleț R., Muelenkamp J.E., van Vugt N. (2006) Late Miocene to early Pliocene chronostratigraphic framework for the Dacic Basin, Romania. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **238**: 107-124, Elsevier.

Stoica M., Lazăr I., Krijgsman W., Vasiliev I., Jipa D., Floroiu A. (2012) Paleoenvironmental evolution of the east Carpathian foredeep during the late Miocene-early Pliocene (Dacian Basin; Romania). *Global and Planetary Change*, **103**: 135-148.

Suc J.-P., Do Couto D., Melinte-Dobrinescu M.C., Macaleț R., Quillévéré F., Clauzon G., Csato I., Rubino J.-L., Popescu S.-M. (2011) The Messinian Salinity Crisis in the Dacic Basin (SW Romania) and early Zanclean Mediterranean-Eastern Paratethys high sea-level connection. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **310**: 256-272, Elsevier.

Vasiliev I., Krijgsman W., Langereis C.G., Panaiotu C.E., Matenco L., Bertotti G. (2004) Towards an astrochronological framework for the eastern Paratethys Mio-Pliocene sedimentary sequences of the Focsani basin (Romania). *Earth and Planerary Science Letters*, **227**: 231-247.

Vesilind J.P., Carsten P. (2004) Ştiinţă pură, noroc chior şi nervi de oţel la vînătoarea de tornade. *National Geographic România*, Aprilie: pp. 24-57.