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Skin impressions on stegosaur tracks from the Upper Jurassic of Portugal

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Abbreviations: ML, Museu da Lourinhã, Portugal; **SMA**, Sauriermusuem Aathal, Switzerland; **MCCM-LH**, Museo de las Ciencias de Castilla-La Mancha, Cuenca, Spain.

Stegosaur tracks, firstly identified in 1990s (White & Romano, 1994, 2001; Lockley & Hunt, 1998) have since become relatively common in the Lourinhã Formation (Mateus & Milàn, 2010; Mateus *et al*., 2011), with the first report of the ichnogenus *Deltapodus* Whyte & Romano, 1994 in 2008 (Mateus & Milàn, 2008). However, impressions of skin scales had not been investigated in detail yet, and only recently had the presence of a hoof (Herrero Gascón & Pérez-Lorente, 2016), despite its suggestion in the morphology of *Deltapodus* (Whyte & Romano, 2001).

Herrero Gascón & Pérez-Lorente (2016) published an analysis presenting *Deltapodus* casts from the Galve Basin (Spain), focusing notably on marks left by the hooves and skin scales. The authors observed a network of polygonal tuberculate scales not overlapping with no ordered variation of scale size; and determined that the hooves leave three types of marks: (1) ellipsoidal; (2) rounded tubular projections, either straight or curved; (3) or slightly tubular acuminate ones. The authors also observed anterior and posterior depressions in foot marks and proposed they must be associated with two separate calluses. This structure is congruent with a pes where metatarsal are inclined and phalanges hardly able to move relative to each others (Herrero Gascón & Pérez-Lorente, 2016). Similar observations were made in skin impressions from a stegosaurian rib cage (Christiansen & Tschopp, 2010)

and even in theropods (Cuesta *et al*., 2015), but not on sauropods, the skin of which appears to have had interlocking polygonal scales, arranged in rosettes (Platt & Hasiotis, 2006, Kim *et al.*, 2010).

Four footprints from Museu da Lourinhã (ML 1347, ML 1348, ML 1349 from and ML 2175) present small hillocks which are considered as impression of skin scales. ML 1347, found in Porto das Barcas (Mateus *et al.*, 2011), has notably the clearest and best preserved impression of skin scales, with almost all of its plantar side covered (Fig. 1, A). Digit II, digit IV and the heel lack partially this type of texture, due probably to sandy sediment on the surface (in the case of the digits) or alterations of the track after burial (in the case of the heel). Just posteriorly to digit III there is a bulge that could be where the skin folds behind the claw. A tubular structure passing transversely through the middle of the footprint is observable, probably a branch over which the dinosaur steped. While most of the track is covered by skin impressions, the level of preservation differs from one area to another.

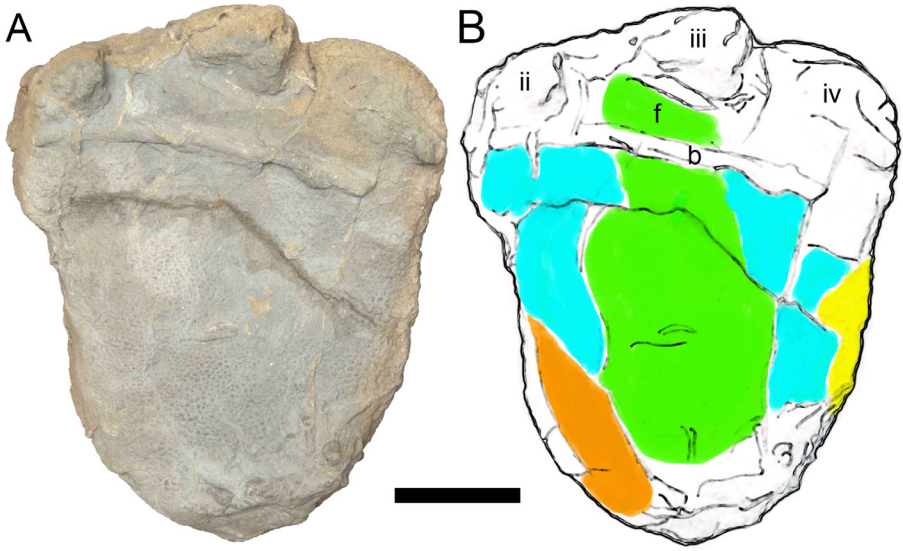

Figure. 1. ML 1347. **A**, picture in plantar view exhibiting the skin impressions, **B**, sketch with rough location of the different patterns observed: circular scales 2 to 3 mm wide (green); ovoid scales 5 to 7 mm wide (orange); circular scales 3 to 4 mm wide (cyan); hexagonal or rectangular scales 5 to 7 mm wide (yellow). **b**, tubular structure from branch, **f**, fold of skin, **ii**, second digit, **iii**, third digit, **iv**, fourth digit. Scale bar equals 10 cm.

However, four main characters can be recognized: (1) the arrangement of the scales seems to be random; (2) the scales in the center of the foot seem to be smaller than the ones on the margins, but scales from the same area are similar in size; (3) the scales are separated by small grooves in the center area and more closely spaced together in the margins; (4) the shape of the scales differs according the area where they are. The scale impressions, although closely similar and mostly arranged randomly, can be separated in four texture patterns observable on the track (Fig. 1, B): (1) *circular scales 2 to 3 mm wide* (green in Fig. 1, B): in the center of the track and behind digit III, covering the most of the track, spaced by grooves of 1 to 2mm, mostly eroded in the very center of the track; (2) *ovoid scales 5 to 7 mm wide* (orange in Fig. 1, B): on the medial part of the heel, with a groove of 1 to 2 mm, almost crescentic shape; (3) *circular scales 3 to 4 mm wide* (cyan in Fig. 1, B): near the sides, slightly bigger close to the lateral face, spaced by 2 mm grooves; (4) *hexagonal or rectangular scales 5 to 7 mm wide* (yellow in Fig. 1, B): limited to the lateral ridge of the track, from the posterior end to digit IV, without space between them. While no skin impression was found in the center of ML 1348, ML 1349 ML 2175, scale impressions found in the margins of these present the same patterns as in the margins of ML 1347.

The differences in size of the scales observed in ML 1347 may be due to the walking biomechanics during the step cycle. Indeed, the scales on the margins produced bigger marks because they follow the movement of the foot during walking while the ones in the center just spot the surface. Differences in the shape probably result of conservation conditions: the center of the track was more exposed to erosion and more sandy sediments is present in this area, resulting in less detailed preservation. Despite the differences in shape, size and space between the scales, the general pattern appears to be uniform with only slight random variations. The stegosaur foot scale pattern, especially the one observed on the lateral ridge, looks similar to the one observed on the rib cage of the stegosaur *Hesperosaurus mjosi* Carpenter *et al*., 2001 (SMA 0018) with small, non-imbricating and polygonal scales separated by shallow and narrow grooves (Christiansen & Tschopp, 2010). The pattern observed in the center and medial area of the ML 1347 shares similarities with the one observed in the foot of *Concavenator corcovatus* Ortega *et al.*, 2010 (MCCM-LH 6666), with

a random pattern and scales approximately circular (although slightly bigger than those in ML 1347), which is similar to what is observed in birds (Cuesta *et al*., 2015). It is also similar to the pattern in sauropod footprints, but distinguishable since sauropods exhibit interlocking polygonal scales, arranged in rosettes (Platt & Hasiotis, 2006; Kim *et al.*, 2010), while stegosaurs exhibit round to hexagonal scales, arranged uniformly without interlocking and separated by grooves. The presence of a bulge interpreted as a skin fold posteriorly to a digit in ML 1347 and very short digit impressions suggest that stegosaurs may have had a digitigrade foot structure but a plantiportal foot use. That means the animal walked on its digits, but the heel bones rested on fat tissues, as in elephants (Michilsens *et al.*, 2009). Consequently, the model proposed by Herrero Gascón & Pérez-Lorente (2016) is here supported.

REFERENCES

Carpenter, K.; Miles, C. A. & Cloward, K. (2001). New primitive stegosaur from the Morrison Formation, Wyoming. *The armored dinosaurs*, 55-75.

Christiansen, N. A. & Tschopp, E. (2010). Exceptional stegosaur integument impressions from the Upper Jurassic Morrison Formation of Wyoming. *Swiss Journal of Geosciences*, *103*(2), 163-171.

Cuesta, E.; Díaz-Martínez, I.; Ortega, F.; Sanz, J. L. (2015). Did all theropods have chicken-like feet? First evidence of a non-avian dinosaur podotheca. *Cretaceous Research,* 56, 53-59.

Herrero Gascón, J. & Pérez-Lorente, F. (2016). Hoof-Like Unguals, Skin, and Foot Movements Deduced from Deltapodus Casts of the Galve Basin (Upper Jurassic-Lower Cretaceous, Teruel, Spain). *Ichnos*, 1-16.

Kim, J. Y., Kim, K. S., Lockley, M. G., & Seo, S. J. (2010). Dinosaur skin impressions from the Cretaceous of Korea: new insights into modes of preservation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *293*(1), 167-174.

Lockley, M. & Hunt, A. (1998). A probable stegosaur track from the Morrison Formation of Utah. *Modern Geology, 23*, 331-342.

Mateus, O. & Milàn, J. 2008. Ichnological evidence for giant ornithopod dinosaur in the Upper Jurassic Lourinhã Formation, Portugal. *Oryctos,* 8, 47-52.

Mateus, O. & Milàn, J. 2010. A diverse Upper Jurassic dinosaur ichnofauna from central-west Portugal. *Lethaia,* 43, 245-257.

Mateus, O.; Milán, J.; Romano, M. & Whyte, M. 2011. New finds of stegosaur tracks from the Upper Jurassic Lourinhã Formation, Portugal. *Acta Paleontologica Polonica,* 56(3), 651-658.

Michilsens, F.; Aerts, P.; Van Damme, R. & D'Août, K. 2009. Scaling of plantar pressures in mammals. *Journal of Zoology,* 279(3), 236-242.

Ortega, F., Escaso, F., & Sanz, J. L. (2010). A bizarre, humped Carcharodontosauria (Theropoda) from the Lower Cretaceous of Spain. *Nature*, *467*(7312), 203-206.

Platt, B. & Hasiotis, S. 2006. Newly Discovered Sauropod Dinosaur Tracks with Skin and Foot-Pad Impressions from the Upper Jurassic Morrison Formation, Bighorn Basin, Wyoming, U.S.A. *Palaios,* 21(3), 249-261.

Whyte, M. & Romano, M. 1994. Probable sauropod footprints from the Middle Jurassic of Yorkshire, England. *Gaia,* 10, 15-26.

Whyte, M. & Romano, M. 2001. Probable stegosaurian dinosaur tracks from the Saltwick Formation (Middle Jurassic) of Yorkshire, England. *Proceedings of the Geologists' Association,* 112, 45-54.