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THE EFFECTS OF TECTONIC DEFORMATION ON DINOSAUR TRACKWAY MORPHOLOGY

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Rezumat

Efectele deformărilor tectonice asupra morfologiei pistelor de urme de paşi de dinozauri

Pentru geologi, deformările tectonice nu reprezintă un fenomen neobişnuit. Totuşi, până acum, ichnopaleontologii nu au acordat atenție efectelor deformărilor tectonice asupra morfologiei pistelor de urme de paşi de tetrapode. Deformările tectonice pot avea un impact profund asupra morfologiei pistelor de paşi, afectând toți parametrii care sunt în general priviți ca diagnostici în ichnotaxonomie, cum sunt: lungimea pasului, lărgimea urmei, angulația, simetria urmei şi mărimea urmei.

Este important, prin urmare, să se ia în considerare deformațiile, ale căror consecințe trebuie analizate înainte de a descrie o pistă de urme de paşi.

INTRODUCTION

Most Mesozoic sediments have been affected to some degree by tectonic deformation.

Numerous dinosaur trackways have been described yet, but so far, virtually no attention has been paid to the effects of tectonic deformation. In many cases, deformation only affected the track-bearing surface to a minor degree, but there are numerous descriptions of dinosaur trackways from steeply inclined or even vertical surfaces, e.g. the Barkhausen quarry (Germany, KAEVER & LAPPARENT, 1974); the Fumanya quarry (Spain, SCHULP & BROKX, in press) and various Swiss sites (MEYER & HAUSER, 1994). The sheer fact that the track-bearing level has been turned vertically almost certainly implies that also the trackways themselves have been distorted to some degree.

Invertebrate paleontology has been familiar with the effects of tectonic deformation for a long time. One of the most famous examples includes the use of deformed Spirifer brachiopods to determine the amount of strain (e.g. WELLMAN, 1962). Examples of tectonic deformation of vertebrate ichnites have been given by STÖSSEL (1995) and SCHULP & BROKX (in press). STÖSSEL described the deformation of Devonian tetrapod trackways, but merely in a qualitative approach without discussing in much detail the general consequences in trackway studies. The Fumanya tracksite in Spain (SCHULP

& BROKX, in press) presents another example of tectonically deformed trackways. Here, the tectonic deformation is described: a detailed qualitative approach is in preparation (BROKX et al. in prep).

With only two deformed tracksites specifically reported as such, tectonic deformation has been probably ignored or overlooked in many instances. Parataxonomic description of vertebrate tracks are primarily based on trackway morphology and geometry; as such awareness of the effects of tectonic deformation on morphology and geometry is very important. This short contribution theoretically explores some of the effects and consequences of tectonic deformation of some (imaginary) tridactyl bipedal dinosaur tracks, illustrated by three examples: 1). Compression parallel or perpendicular to a trackway and the resulting ornithopod/theropod confusion. 2). Compression oblique to the trackway and the resulting “limping dinosaurs' and 3). The effects of compression in preferred trackway orientation.

1). Ornithopod/theropod confusion

Often, it is difficult to distinguish between ornithopod and theropod pes prints. THULBORN (1990: 219-225) presented an overview summarizing 13 characteristic properties of theropod and ornithopod tracks. Some of these characteristics have only limited validity or apply only to particular preservational or depositional circumstances. Many other characteristics may be fundamentally altered by tectonic deformation, like footprint proportions, digit width, and interdigital angles.

A major difference between theropod and ornithopod tracks lies in the length/width ratio. Ornithopods generally have wider tracks with wider toes compared to theropods. THULBORN (1990) listed an average foot width/foot length (FW/FL) ratio of 0,73 ± 0,19 for coelurosaur theropods and 0,77 ± 0,14 for carnosaur theropods. FW/FL in small ornithopods averages 0,91 ± 0,18 and in large ornithopods an almost similar 0,90 ± 0,15. Obviously, there is some overlap already, but a minor compression in walking direction may turn less well-preserved theropod tracks in the realm of convincing ornithopod FW/FL values; compression of ornithopod tracks perpendicular to the walking direction make them appear more theropod-like (Fig. 1). In the same line of reasoning, the interdigital angles, also regarded as a diagnostic feature to distinguish theropods and ornithopods, are increased by anteroposteriorly directed compression. For obvious reasons, confusion is less likely to occur in well-preserved trackways, e.g. trackways with clearly preserved claw-impressions or other specific theropod or ornithopod features.

2). Limping dinosaurs

DANTAS et al. (1994) report 9 examples of asymmetrical dinosaur trackways. There is of course no reason to reject the possibility of limping dinosaurs at first hand; theropods for example, practiced a dangerous life-style, illustrated by the relatively high occurrence of healed bone fractures.

Especially if one or both pes prints display some patrological features (broken or missing toes), the evidence becomes very convincing. However, the possibility that the observed trackway asymmetry is caused by tectonic by tectonic deformation should always be considered. If the pace angulation of a bipedal dinosaur is significantly lower than 180^0, compression in the direction of, for example an R-L pace may significantly reduce the R-L pace length, while leaving the R-L pace-length less affected. This may lead to thye erroneous conclusion the trackway was made by a limping animal, leading to an overrepresentation of pathological dinosaurs in the trackway record interpretation.

3). Trackway orientation

Trackway direction of larger tracksites with many different individuals are often compiled in rose diagrams. The number of trackways running parallel or perpendicular to the axis of strain remains unchanged after deformation; trackways running oblique to the main axes, tend to "migrate" towards the direction of maximum extension; superimposing a bi-directional "overprint" on the existing trackway orientations. As many paleobiological, ethological and paleoenvironmental inferences are made based on trackway orientation patterns, the effects of tectonic deformation should be taken into account here as well.

Reconstructing dinosaur tracks

Once aware of the possibility thet trackways may be deformed, one can start using tracways to determine the strain the track-bearing surface was subjected to, in a similar way as Wellman's *Spirifer* (WELLMAN, 1962).

A data set large enough to provide statistically significant data, consisting of trackways running in more than one direction, can provide not only the total strain, but based on this, the deformed trackways can be projected back to their undeformed state (RAMSAY & HUBER, 1983; SCHULP & BROKX, in press; BROKX et al., in prep).

Using digital image processing software, the original trackway morphology can be restored. Most of the image processing software currently available on the market is capable of such operations.

CONCLUSION

Tectonically deformed dinosaur trackways are more common than appears from the literature. As strain fundamentally alters diagnostic properties of the trackways affected, awareness of the possible consequences of tectonic deformation is important. By making a statistical analysis of the trackway morphology, the total amount and direction of strain can be obtained, and using digital image processing software, correction for this strain can be made. An estimate of strain should become normal practice when describing vertebrate tracksites.

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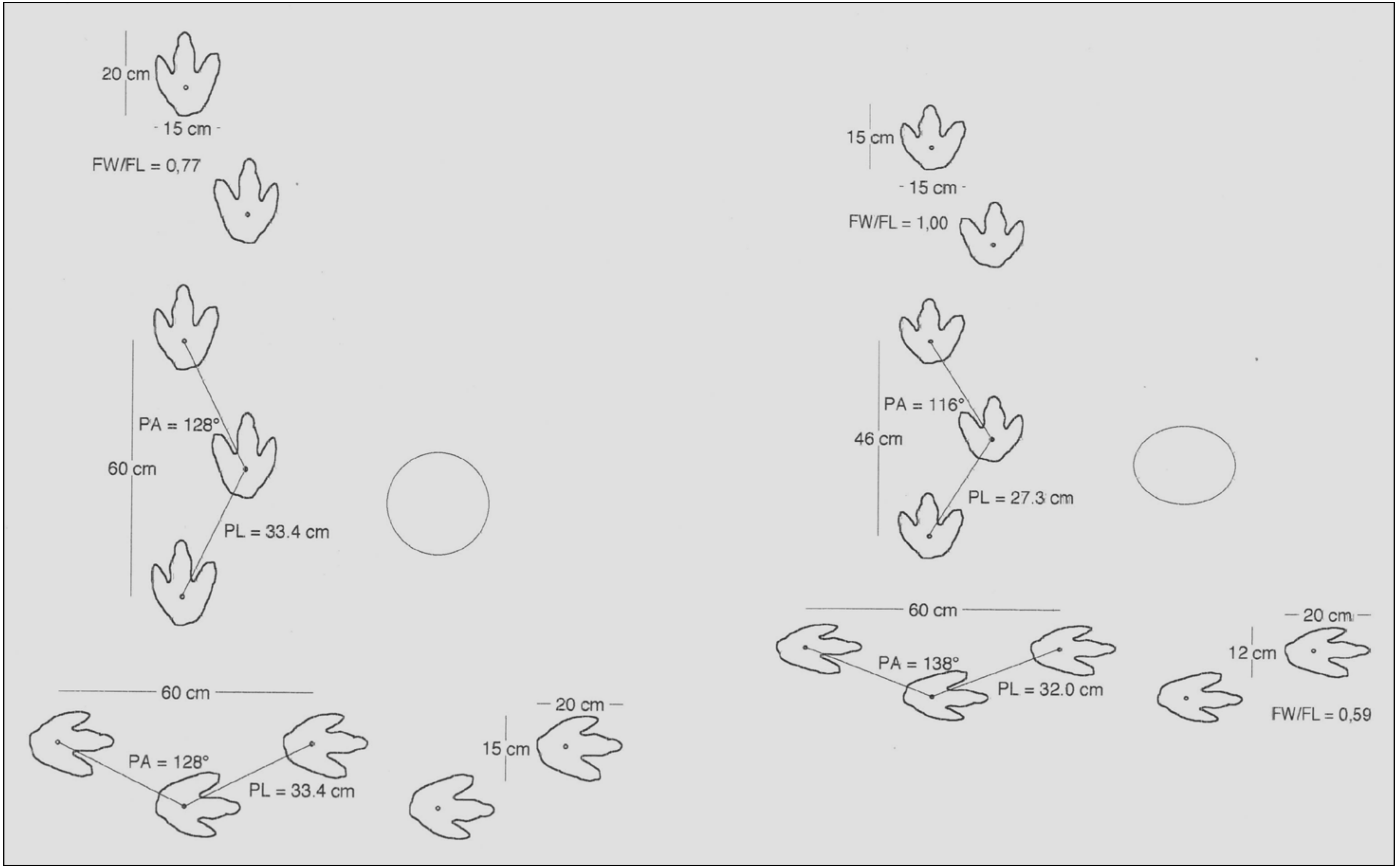

Fig. 1. A hypothetical compression of a bipedeal tridactyl tracway with an initial undistorted FW/FL ratio of 0,77 (Left). Right the distorted result; the FW/Fl value of trackway running perpendicular to the direction of compression decreases. Note that all other trackway parameters are affected as well.

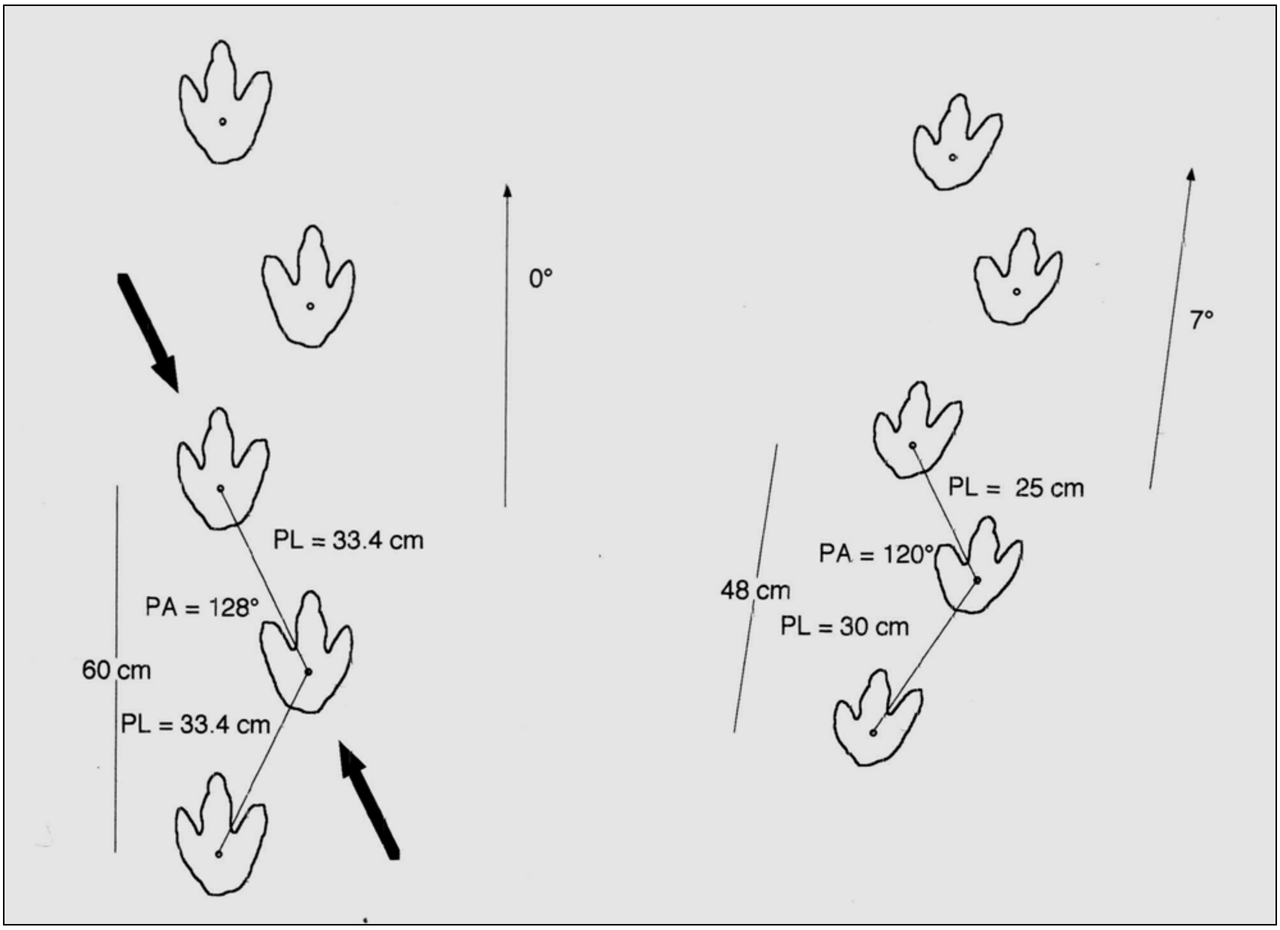

Fig. 2. Compression of a trackway parallel to one pace direction may create asymmetrical "limping" tracks. Note that the direction of locomotion is affected as well.