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QUANTITATIVE INTERPRETATION OF TRACKS FOR DETERMINATION OF BODY MASS USING FINITE ELEMENT ANALYSIS

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Analyses and interpretation of sauropod gigantism are essential for the understanding of evolutionary constraints and how these constraints impact Earth's geological and biological history. Bones of sauropods, of course, are not their only remains in the fossil record, but the second most common evidence for their former existence are footprints and entire trackways. In the past, mostly descriptive studies of tracks were done, but currently the focus is on understanding the paleobiology of the trackmaker. For this reason, experimentation with extant animals and innovative numerical approaches have grown in recent years.

Current numerical studies on this issue [1, 2, 3, 4] have as their main objective to qualitatively better understand the kinematics of the foot indenting the subsoil and to relate subsoil properties to footprint quality and preservation. In contrast, the research project introduced in [5] uses principles of soil mechanics to derive a novel concept based on Finite Element Analysis (FEA) for calculating the mass (i.e., the weight) of an animal from its footprints. To validate the approch a neoichnological field experiment with an African elephant was conducted and the elephant's weigth was numerically backcalculated. With this study the first component of a methodology for calculating the weight of extinct dinosaurs was demsonstrated.

This contribution introduces in detail the constitutive soil model and the 3D FEA model used in [5] for numerically backcalculating the applied load to a subsoil.

The FEA code used considers three spatial dimensions and was originally developed for the analysis of deformations in geotechnical applications. Soil behavior is simulated in a non-linear elastic-plastic manner. A realistic material model for the simulation of the behavior of different types of soil was used. When soil is subjected to primary loading, it shows an increase in stiffness with increasing stress and develops an irreversible plastic strain. The hardening soil model implements the stress dependent stiffness behavior of the soil and applies the appropriate stiffness modulus depending on the loading conditions. The required input parameters were determined in standard soil mechanics laboratory experiments.

The 3D FEA model including the loading characteristics of the foot and soil-foot interaction was varied systematically in order to identify impact of model parameters. The results obtained illustrate realistic soil behaviour due to vertebrate's anatomical characteristics in a novel way.

REFERENCES

[1] P. L. Falkingham, L. Margett, I. M. Smith and P. L. Manning. Reinterpretation of palmate and semi-palmate (webbed) fossil tracks; insights from finite element modelling. *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol. 271, 69 - 76, 2009.

[2] P. L. Falkingham, L. Margett and P. L. Manning. Fossil vertebrate tracks as paleopenetrometers: Confounding effects of foot morphology. *Palaios*, Vol. 25(1 - 2), 356 - 360, 2010.

[3] P. L. Falkingham, K. T. Bates, L. Margett and P. L. Manning. The 'Goldilocks' effect: preservation bias in vertebrate track assemblages. *Journal of the Royal Society: Interface*, Vol. 61(8), 1142 - 1154, 2011.

[4] K. T. Bates, R. Savage, T. C. Pataky, S. A. Morse, E. Webster, P. L. Falkingham, L. Ren, Z. Qian, D. Collins, M. R. Bennett, J. McClymont and R. H. Crompton. Does footprint depth correlate with foot motion and pressure?. *Journal of the Royal Society: Interface*, Vol. 83(10), 2013.

[5] T. Schanz, Y. Lins, H. Viefhaus, T. Barciaga, S. Läbe, H. Preuschoft, U. Witzel and P. M. Sander. Quantitative Interpretation of Tracks for Determination of Body Mass. *PLoS ONE*, Vol. **8**(10), 2013.