INTERNATIONAL SYMPOSIUM ON DINOSAURS AND OTHER VERTEBRATES PALAEOICHNOLOGY

FUMANYA-ST. CORNELI (Cercs, Barcelona)
October 4-8th 2005

FONS EUROPEU DE DESENVOLUPAMENT REGIONAL

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Consorci Ruta Minera
Dinosauria
by means of European Project INTERREG-IIIA funds

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Universitat Autònoma de Barcelona
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Welcome

The organizing committee welcomes the participants in the **International Symposium on Dinosaurs and other Vertebrates Palaeoichnology** in Fumanya (Cercs, Barcelona) and expresses its deepest thanks to the many contributors and colleagues that enthusiastically answered to our call making this issue possible.

The organizers hope the participants will enjoy of Fumanya-Vallcebre syncline geology and paleontological heritage. We are sure that there will be an appropriate place for discussing on tracks.

We hope the meeting will come up to everybody's best expectations!

The International Symposium on Dinosaurs and other Vertebrates Palaeoichnology has been made possible, thanks to the support and collaboration obtained from the Consorci Ruta Minera and Dinosauria (by means of European Funds, Project Interreg-IIIA), the Institut de Paleontologia M. Crusafont de Sabadell (Diputació de Barcelona), the Department of Geology of Universitat Autònoma de Barcelona, Museu de les Mines de Cercs, Fundación Patrimonio Paleontológico de La Rioja, Museo Geominero (IGME) and Obra Social "Fundació La Caixa".

The organizers would like specially to thank to Cercs town council and all the villages of Consorci Ruta Minera to rely on this and other palaeontological events and to Museu de les Mines de Cercs for their logistics facilities.

The organizing team was formed by:
Jean Le Loeuff, Bernat Vila, Josep Marmi, Àngel Galobart and Oriol Oms with collaboration of José Joaquin Moratalla (Museo Geominero, IGME) and Félix Pérez-Lorente (Fundación Patrimonio Paleontologico de La Rioja).

The Programme

OCTOBER 6TH, THURSDAY

9:00- 9:30h: Arrival and registration

9:30-10:00h: Welcoming Opening ceremony by À. Galobart and J. Le Loeuff

10:00-11:40 h: Oral Contributions

Chair: Jean Le Loeuff

TOPIC : NEW ADVANCES AND DISCOVERIES IN PALAEOICHNOLOGY

Triassic tetrapods palaeoichnology

10:00 HAUBOLD, H. and KLEIN, H. *Chirotherium barthii* - the very early beginning of dinosaurs.

10:20 KLEIN, H. and HAUBOLD, H. Between the type-specimens, transitional morphs in the footprints of Triassic archosaurs.

10:40 AVANZINI M. and MIETTO P. Tetrapod ichnological diversity in the Lower and Middle Triassic of Northern Italy and their potential contribution to continental biochronology.

TOPIC : DINOSAUR ICHNOLOGY AND BIOMECHANICS

Jurassic dinosaur tracks

11:00 WHYTE, M.A. and ROMANO, M. Dinosaur footprints associated with an ephemeral pool in the Middle Jurassic of Yorkshire, UK.

11:20-11:40h Coffee break

11:40-12:40 Plenary Lecture

Chair: Àngel Galobart

11:40 **Dr. FABIO M. DALLA VECCHIA**, Grupo Speleologico A.D.F., Museo Paleontologico Cittadino, Monfalcone, Italy

" THE IMPACT OF DINOSAUR PALAEOICHNOLOGY IN THE PALAEOGEOGRAPHIC-PALAEOENVIRONMENTAL RECONSTRUCTIONS: THE CASE OF THE PERIADRIATIC CARBONATE PLATFORMS "

12:40-14:40 LUNCH

14:40-17:00h Oral Contributions

Chair: Àngel Galobart

TOPIC : DINOSAUR ICHNOLOGY AND BIOMECHANICS

Jurassic dinosaur tracks

14:40 SANTISTEBAN, C. Meaning of dinosaurs footprints sites, Upper Jurassic of the Southwestern Iberian Basin, in the light of the sequence stratigraphy.

15:00 GIERLINSKI, G., MOSSBRUCKER, M.T., and SABATH, K. Stegosaurian footprints from the Morrison Formation of western United States and their implications for other finds.

15:20 LE LOEUFF, J. Late Jurassic sauropod tracksites of eastern France.

Lower Cretaceous dinosaur tracks

15:40 BIOSCA, J., OMS, O., and VALLÈS, F. Sedimentological significance of chelonian ichnites: example from the Artés Formation (Eocene from the Ebro basin, NW Spain).

16:00 JIMENEZ VELA, A., and PEREZ-LORENTE, F. A new great dinosaur footprint site: Barranco de Valdegutiérrez (La Rioja, Spain).

16:20 MILÀN, J., BROMLEY, R.G., and TITSCHACK, J. Vertebrate footprints from a new aeolian outcrop of Southern Rhodes, Greece.

16:40-17:20 h Coffee break

17:20-18:40h Oral Contributions

Chair: Bernat Vila

17:20 D'ORAZI PORCHETTI, S., NICOSIA, U., PETTI, F.M. and SACCHI, E. Dinosaur footprints from central and Southern Italy.

TOPIC: ICHNOLOGICAL HERITAGE (PRESERVATION AND SPREADING STRATEGIES)

17:40 SANTOS, V. F. and RODRIGUES, L.A. Scientific and cultural significance of some portuguese dinosaur tracksites.

17:40-19:00 h **Poster Session**

Chair: Josep Marmi

1. GARCÍA-RAMOS, J. C., PIÑUELA, L., and AVANZINI, M. From babies to giants: extreme sizes in sauropod tracks. Deltaic series of the Asturian Upper Jurassic (N Spain).

2. AVANZINI, M., PIÑUELA, L., and GARCÍA-RAMOS, J. C. Paleopathologies deduced from a theropod trackway. Upper Jurassic of Asturias (N Spain).

3. MATEUS, O., and MILÀN, J. Ichnological evidence for giant ornithopod dinosaurs in the Late Jurassic Lourinhã Formation, Portugal.

4. OMS, O., VICENS, E., ESTRADA, R., DINARÈS-TURELL, J., VILA, B., GALOBART, À. and BRAVO, A.M. The stratigraphic succession of the end-Cretaceous Vallcebre basin (eastern Pyrenees) and their dinosaur ichnological sites.

5. BADIA, M, PRADA, J.L., ALVAREZ, A., OMS, O., OSORIO, R. and OSORIO, I. Studies, essays and strategies to preserve the sauropod ichnites from Fumanya tracksite (eastern Pyrenees).

6. COBOS, A., ALCALÁ, L., ANDRÉS, J.A. and LUQUE, L. Conservation, protection and public education at dinosaur ichnites sites in El Castellar (Teruel, Spain).

7. BARCO, J.L., CANUDO, J.I. and RUIZ-OMEÑACA, J.I. Description of the tracksite of *Therangospodus oncalensis* type (Berriasian age, Soria).

8. CANUDO,J.I., BARCO, J.L., CUENCA-BESCÓS, G. and RUIZ-OMEÑACA, J.I. Presence of two different theropod footprints in the Valanginian-Hauterivian (Lower Cretaceous) of Villanueva de Huerva (Zaragoza, Aragón, Spain).
9. LÓPEZ, G. and ARAGONÉS, E. Oligocene mammal footprints from Castelltallat mountains (Catalonia, Spain).

10. NOE-NYGAARD, N., and MILÀN, J. A Reindeer footprint in a drilling core from the Bølling-Allerød lacustrine succession of the Little Slotseng kettle hole basin, South-eastern, Jylland, Denmark.

11. ANTÓN, M., LÓPEZ, G. and SANTAMARÍA, R. The Miocene ichnite site of Salinas de Añana and its relevant carnivore trackways (Alava, Spain).

OCTOBER, 7TH, FRIDAY

9:00-11:20h Oral Contributions

Chair: Fabio Dalla Vecchia

TOPIC: DINOSAUR ICHNOLOGY AND BIOMECHANICS

Upper Cretaceous dinosaur tracks

9:00 MANNING, P. Reverse-engineering dinosaur tracks and trackways.

9:20 HUH , M., PAIK I.S., HWANG, K.G. , and KWAK S. K. Late Cretaceous dinosaur tracks in southern costal area of Korea: variation and paleobiological implications.

9:40 LOCKLEY, M. The vertebrate ichnology database and landscape: a story of two decades of rapid global growth of collections and scientific education.

10:00 VILA, B., GAETE, R., GALOBART, À., OMS, O, and RIVAS, G. The last of the European dinosaurs: evidences from the Pyrenean tracks.

10:20 KUKIHARA, R., LOCKLEY, M. and HOLBROOK, J. A new look at the Cretaceous dinosaur freeway: evolving insights into paleoecology.

10:40 VILA, B., GALOBART, À. and OMS, O. The Fumanya sauropod tracksite: history of discoveries and additional data to titanosaur ichnology.

11:00 VILA, B., GALOBART, À., and OMS, O. Sauropod manus-dominated trackways: new evidences from the Fumanya tracksite (Upper Cretaceous, SE Pyrenees) and state of the art.

11:20-16:00h **Field Trip at Fumanya Tracksites** + LUNCH

16:00- 17:00h **Plenary Lecture** by

DR. MARTIN G. LOCKLEY, University of Denver, USA

" BEYOND THE FEET AND FOOTPRINTS: WHAT MORPHODYNAMICS AND HETEROCHRONY TELL US ABOUT THE RELATIONSHIP BETWEEN FEET, LIMBS AND THE WHOLE BODY".

17:20-17:40h Coffee Break

17:40-19:20h Oral Contributions

TOPIC: PALAEOICHNOLOGICAL RECORD OF NON-DINOSAUR VERTEBRATES

Chair: Oriol Oms

17:40 DE GIBERT, J. M. Fish swimming trails (*Undichna*): fossil examples, taphonomy and paleobiology.

18:00 LOCKLEY,M.G., KIM, J.Y. KIM, K.S. and ROBERTS, G. Hominid ichnology revisited: a brief overview of a neglected field

18:20 DE GIBERT, J.M., and SÁEZ, A. Bird and mammal tracks and invertebrate traces in Paleogene alluvial-lacustrine transition facies, NE Ebro Basin, Spain.

TOPIC: DINOSAUR ICHNOLOGY AND BIOMECHANICS

18:40 TORCIDA FERNÁNDEZ, F., IZQUIERDO MONTERO, L.A., HUERTA, P., MONTERO HUERTA, D., PÉREZ MARTÍNEZ, G., URIÉN MONTERO, V., CONTRERAS IZQUIERDO, R. and LLORENTE PÉREZ, C. A new interpretation for the formation of the Costalomo site dinosaurs footprints (Salas de los Infantes, Burgos, Spain).

18:40-19:20h Final Discussion and Conclusions

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Lectures

RELATIONSHIPS BETWEEN FEET, FOOTPRINTS, LIMBS AND THE WHOLE BODY: WHAT MORPHODYNAMICS TELL US ABOUT THE WHOLE ORGANISM

Martin LOCKLEY

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Organisms are complex and fully integrated systems whose morphology follows recognizable "directed" pathways that reveal the operation of intrinsic or 'formal' growth dynamics during ontogeny and phylogeny. This intrinsic dynamic is just as important as the "functional" approach which stresses extrinsic environmental influence.

All ontogenetic development and phylogenetic evolution is "regulated" by complex and variable chronobiological or heterochronic dynamics. For example in all higher vertebrates (reptiles, birds, mammals) the digit growth sequence is 4, (5), 3, 2, 1. Thus, retarded/decreased growth (paedomorphosis) typically leads to underdevelopment of inner digits (3-1), whereas accelerated/increased growth (peramorphosis) may lead to over-or hyper-development of these digits. (Compare theropods with sauropods and note the essential compensation principle: more inward means less outward growth and vice versa). Similar dynamics affect the morphology of primates.

In early ontogeny the higher vertebrate foot typically grows more than the limb (i.e., distal (d) > proximal (p) growth). Later in ontogeny relative limb growth is greater (p> d). These respective caudo-cephalic and cephalo-caudal patterns are like dynamic 'waves' of development that operate at all levels of biologic organization from Hox genes to foot, limb and whole body development. Thus primitive theropods have long narrow feet and relatively short limbs (d>p) whereas sauropods have shorter, wide feet and longer limbs (p>d). It is easy to see how an early cessation or slowing of growth would lead to the theropod condition, whereas a prolongation or acceleration of growth would lead to the sauropod morphology. (Pharmaceutical interference with human limb growth programs caused severe morphological mutation in the case of thalidomide).

Although paleontologists can not unravel the relationship between genes and macroevolution, they can understand the dynamics of relative growth in any organ or complex of organs (foot, limb and whole body) and begin to derive general morphodynamic laws. For example long feet and short legs typically are associated with a long body (trunk) and tail, short neck and small head (posterior emphasis = primitive condition). Conversely, short feet and long legs are associated with a short body (trunk) short tail and enlarged head and/or neck (anterior emphasis). Compare the primitive-derived polarity between salamander and frog, primitive archosaur and bird or prosimian and hominid. Such developmental (phylogenetic) convergence suggests that these, dynamics reiterate fractally throughout many groups and do not have merely functional explanations.

Recognition of the lawfulness of such morphodynamic patterns has many applications in ichnology. For example, one may begin to infer the leg length and body proportions from a footprint. Plantigrady and digitigrady reflect posterior and anterior emphasis respectively. Even the relative development of inner, central or outer digits (en-, mes- or ectaxony) corresponds to p>d or d>p emphasis. Outward rotation of feet represents anterior widening of stance as seen in Anglo-Saxon, whereas parallel, or inwardly rotated, feet indicates posterior widening (e.g. Celts). Thus, all natural groups (clades) show intrinsic variation between paedomorphic and peramorphic poles such as long feet-short legs and short feet-long legs, and with these characteristics one can trace a cascade of corresponding or compensatory morphologies.

From the conceptual viewpoint, it is not necessary to "explain" these dynamics by genetic determinism or "form follows function" adaptation scenarios (i.e., "bottom up" and "top down" explanations). *The organism is integrated with (not determined by) both the molecular (genetic) microcosm and the environment (macrocosm).* Such thinking is essential for an adequate appreciation of the fractal integration in complex organic systems. From a practical and systematic viewpoint, this integrated, morphodynamic approach has implications for cladistic analysis, because all characters (and taxa) are so strongly interconnected.

Thus a footprint, is not the isolated discovery of Robinson Crusoe, but one of many keys to understanding the whole organisms.

THE IMPACT OF DINOSAUR PALAEOICHNOLOGY IN THE PALAEOGEOGRAPHIC-PALAEOENVIRONMENTAL RECONSTRUCTIONS: THE CASE OF THE PERIADRIATIC CARBONATE PLATFORMS

Fabio M. DALLA VECCHIA

The vertebrate ichnofossils are greatly valuable in the palaeoenvironmental and palaeogeographic reconstructions. While skeletal remains can be subject to a prolonged transport and deposit in environments very different from those were the animal lived, footprints are always the evidence of an animal living (permanently or occasionally) in the place were they were impressed. Furthermore, the chance of ichnofossil preservation is probably much higher than that of bone fossilization.

The Mesozoic carbonate platforms of the Periadriatic area (Italy, Slovenia and Croatia) provide an emblematic example of a palaeoenvironmental/palaeogeographic change of paradigm due to the discovery of dinosaur footprints. They were considered by geologists as shallow marine environments, even intraoceanic (i.e. surrounded by the Tethys Ocean) during Cretaceous times. The discovery in the last 20 years of dinosaur bones and above all footprints in many places and at different stratigraphic levels has shown that the “shallow seas” were repeatedly or continuously populated by the large terrestrial animals, thus the reconstructions of those carbonate platforms as a sort of Mesozoic “Bahamas Banks” was at least partly wrong. The new record allows also testing its congruence with some palaeoenvironmental/palaeogeographic reconstructions, namely the detailed ones by DERCOURT *et al.* (1993, 2000). The places where dinosaur evidence has been found is always reported as “shallow marine” in those maps, very far away from continental areas during the Triassic, surrounded by deep marine basins during Jurassic and Cretaceous times. There is a correlation between the opening of an oceanic basin between the Periadriatic carbonate platforms and the Afroarabian Continent started during the Aptian and a change in the dinosaur fossil record. In particular, large tridactyl footprints are practically absent after the late Barremian, Albian and Cenomanian sauropods are always “dwarf” when compared to the size of those living in continental areas, Santonian dinosaurs are also small-sized, suggesting an isolation of the carbonate platforms. The Hauterivian-Barremian sample contains instead an abundance of large tridactyl footprints and the evidence of large sauropods. The results are just a first step toward the understanding of dinosaurs living “at the border”, obviously preliminary and subject to confirmation or confutation with the increase of the fossil record.

Finally, the ichnological sample and the palaeogeographic reconstructions can stimulate some reflections about the biology of the extinct dinosaurian clades and give some suggestion for the development of future research.

Abstracts

Abstracts

TOPIC : DINOSAUR ICHNOLOGY AND BIOMECHANICS

DINOSAUR FOOTPRINTS ASSOCIATED WITH AN EPHEMERAL POOL IN THE MIDDLE JURASSIC OF YORKSHIRE, UK

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A thin mudstone intercalation within channel sandstones of the Saltwick Formation (Middle Jurassic) of the Cleveland area of Yorkshire shows an interesting succession of aquatic traces followed by dinosaur tracks and then shrinkage cracks. The tridactyl prints, all made by the same type of small bipedal dinosaur, show a range of morphologies, including evidence of the metatarsal area, consistent with their having been made in soft cohesive mud. The pattern of shrinkage cracks is partly controlled by the prints. This sequence is comparable to the sequence of traces and structures which have been observed in a recent ephemeral pool and is interpreted as having formed in a similar environment. Uniquely for the Yorkshire area, the prints and cracks are infilled by small, now sideritised, pellets of problematic origin.

THE MEANING OF DINOSAURS FOOTPRINTS SITES, UPPER JURASSIC OF THE SOUTHWESTERN IBERIAN BASIN, IN THE LIGHT OF THE SEQUENCE STRATIGRAPHY

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The presence of dinosaur footprints in the fossil record is directly related to the environments in which these organisms developed their activities. However, this is of limited utility as an paleoenvironmental and paleoecological proxy due to the size, the mobility and the terrestrial habitat of these organisms (Hasiotis, 2002). The recurrent recognition of vertebrate ichnocoenoses, present in a limited number of depositional facies, allows the recognition of vertebrate ichnofacies. According to (Lockley *et al.* (1994), these ichnofacies do not follow any stochastic model and have a predictive character.

Since there is a stratigraphic and sedimentological control in the presence and distribution of the dinosaur footprints record, this record can be studied following the sequence stratigraphy principles. One example is the Upper Jurassic vertebrate ichnofacies record of Southwestern Iberian Basin.

During the Upper Jurassic and the Cretaceous, the Southwestern Iberian Basin was located in the eastern edge of the Iberian Plate and consisted in an engulfment of northern border of the Tethys. Around 800 m of continental deposits formed there, settled mostly in a wave-dominated deltaic system. This sedimentary record shows a high frequency cycle in which two orders of sequences can be differentiated: parasequences and depositional sequences. The parasequences have a transgressive-regressive character and are due to the arrangement of the delta environments conditioned by minor relative sea-level changes. The depositional sequences involve eustatic falls in the order of 10-30 m and are expressed in the sedimentary record through the formation of 15 m deep incised valleys with a transversal section up to 1 km (Santistenam & Esperante, 2004).

The dinosaur footprints sites are associated with overbank fluvial deposits and especially with beach sandstones. They contain medium and large sized footprints both from sauropods and theropods. There are few footprint sites in the parasequences materials, although they include a beach facies term. Most of them are located in the interior and in the top of the sandstone beds (beaches, barrier islands) whose formation is related with the incised valleys systems.

Although both in the parasequences and in the depositional sequences there are beach facies sections, considerable differences exist concerning the occurrence of footprints sites.

This can be explained in the context of the dynamics of each sequence type. Thus, the parasequences beach deposits developed at the start of relative sea-level fall. In this case, the footprints are more abundant in the overbank fluvial deposits of the delta plain than in the beaches. In the depositional sequences, the fossil trace sites occur in the beach facies that constitute the transgressive system track. In this geodynamical context, it can be inferred that most dinosaur footprint sites are located, considering the same depositional facies, in those ones that developed after a major eustatic fall in relation with the expansion of the habitats of a delta system in which the dinosaurs developed their activity.

Acknowledgement

This work has been supported by funds of the spanish Ministerio de Ciencia y Tecnología, reference BTE2001-0185-C02-02.

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STEGOSAURIAN FOOTPRINTS FROM THE MORRISON FORMATION OF WESTERN UNITED STATES AND THEIR IMPLICATIONS FOR OTHER FINDS

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Stegosaurian footprints were searched for since long time, but paradoxically, not in the strata that yielded classic osteological material of *Stegosaurus*, such as the Morrison Fm of the western U.S.A. Alleged stegosaurian tracks were described, e.g., from the Middle Triassic of Argentina (von Huene 1931), Lower Jurassic of Australia (Hill et al. 1966), Lower Cretaceous of Brazil (Leonardi 1984), Middle Jurassic of England (Whyte and Romano 1994) and Lower Jurassic of France (Le Loeuff et al. 1999). The concept of stegosaurian footprints proposed by Whyte & Romano (1994) became a standard in current ichnology. However, their sauropod-like elongate and plantigrade track named *Deltapodus* differs strongly from blunt-toed, digitigrade, large onithopod-like footprints from the Morrison Fm of Utah and Colorado (numerous specimens: pedal print cast associated with the manus of *Stegopodus* Lockley & Hunt 1998, CU-MWC 195.2; tracks from Cleveland-Lloyd Dinosaur Quarry, CEUM 20551, 20571, 22577, 8003, 9071; footprint from Yale Quarry #10, MNHM 8000), that better fit the stegosaurian foot pattern. Their supposed ornithopod origin is difficult to justify. First, the only known hoofed ornithischians that could have left such imprints in the Late Jurassic were stegosaurs. Secondly, the Morrison Fm of Utah already yielded tracks reflecting dryomorph foot pattern - the *Dinehichnus* Lockley, Santos, Meyer & Hunt 1998 (*Dinechichnus* specimen U-MWC198.3 corresponds well to the recently found complete camptosaur foot NAMAL 102). If, however, the *Stegopodus* pedal specimen (we propose to shift the emphasis from the manus to the pes in the revised diagnosis of this ichnotaxon) and similar ichnites from the Morrison Fm are indeed proper stegosaur footprints, the other candidate, *Deltapodus*, must have been left by a different trackmaker. We agree with McCrea et al. (2001) that its affinities are probably ankylosaurian. Ankylosaurian origin might be considered also in case of several other ichnites more or less similar to *Deltapodus* and the classic ankylosaur track of "*Metatetrapous*" Nopcsa 1923 (the holotype is unfortunately missing), like *Navahopus* Baird

1980, from the Navajo Formation of Arizona, *Apulosauripus* Nicosia, Marino, Marioti, Muraro, Panigutti, Petti & Sacchi 1999, from the Altamura Limestone in Italy and new, unnamed footprints from the Dakota Group of Skyline Drive (Colorado) similar to *Apulosauripus*. Moreover, such heel-dominated, short-toed forms within the *Navahopus*-*Deltapodus*-"*Metatetrapous*"-*Apulosauripus* plexus are morphologically different from gracile, relatively long-toed *Tetrapodosaurus* Sternberg 1932, traditionally regarded as an ankylosaurian track. Thus, the original Sternberg's interpretation of the latter as ceratopsian track might be correct, supporting early ceratopsians appearance in the Albian of the North America as supposed by Carpenter et al. 1999.

The discussed Morrison Fm material comprises only isolated pedal ichnospecimens (and only one tentatively associated manus print, thus hinting at bipedality of the trackmakers). The only known trackways with footprints similar to those from the Morrison Fm. come frome the Upper Jurassic of Asturias (Spain); these trackways demonstrate bipedal gait of their trackmaker. Therefore, part of the problem with identifying stegosaur tracks may lay in the common expectation that they should be quadrupedal. If they were rather bipedal or semibipedal (as long supposed by some authors, e.g., Bakker 1986), their trackways would only occasionally contain manus imprints. The massive but very short forelimbs suggest primarily bipedal locomotion in stegosaurs, and their quadrupedal defense posture, providing better leverage for the spiky, but fairly stiff tail.

LATE JURASSIC SAUROPOD TRACKSITES OF EASTERN FRANCE

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The first sauropod footprints discovered in Europe were described by Kaever and Lapparent in 1974 in the Kimmeridgian of Germany. Later discoveries were reported from the Late Jurassic of Spain, Portugal, Southern France, Switzerland and Croatia. Most of these trackways have been referred by Lockley and Meyer (2000) to the ichnogenera *Brontopodus* Farlow *et al.*, 1989 (wide-gauge sauropods) and *Parabrontopodus* Lockley *et al.*, 1994 (narrow-gauge sauropods); other ichnotaxa have been used by former authors (such as *Elephantopoides* Kaever and Lapparent, 1974 or *Gigantosauropus* Mensink and Mertmann, 1984), but were shown by Lockley *et al.* (1994) to be *nomina dubia*. It is thus convenient when dealing with Late Jurassic sauropod footprints to use the widely employed terms *Brontopodus* and *Parabrontopodus*.

The new tracksites are located near the village of Coisia, in the southern part of the Jura department, 10 kilometres north west of Oyonnax (fig 1). They have been discovered by the late Christian Gourrat in April 2004. The footprints are impressed in a limestone referred to the Tithonian Couches du Chailley Formation which represent a sub-tidal environment such as a lagoon separated from the open sea by a coral reef.

More than 200 pes and manus prints belonging to at least nine different sauropod trackways have been mapped. Most of the tracks are preserved as imprints (concave hyporeliefs) with sediment displacement rims. Some, on the north-eastern part of the slab, are more likely underprints. The best preserved trackways show a large oval pes print and a small crescentic manus print just in front of the pes print. There are no claw impressions. All the trackways are narrow-gauge (ichnogenus *Parabrontopodus*) with footprints situated close to the central axis of the trackways. The heteropody (manus-pes size ratio) is high for trackways 1 and 2 (about 1/6). The manus prints are outwardly rotated.

Other footprints are known in the same level about 1 km to the south-west of the sites here reported: further investigations in the French Jura might reveal a potential megatracksite comparable to the Swiss megatracksite described in the Northern Jura Mountains. From a palaeogeographical point of view the discovery of the footprints confirms that periods of emersion affected these sub-tidal environments. The Coisia tracksite represents the most important sauropod tracksite in France with a good potential for future studies: the removal of overlying beds could reveal several thousand square metres of the "dinoturbated" surface.

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LOWER JURASSIC DINOSAUR FOOTPRINTS FROM THE "GRAND CAUSSES" (FRANCE): DISCRIMINATION, INTERPRETATION AND COMPARISON

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"The Causses" is a near 3400 km2 large plateau located in the south of France. Here the first dinosaur footprints where found in 1935. After this area has yielded an ever-increasing number of ichnites now in excess of 500 specimens. These latter, 15 to 50 cm long, tridactyl or tetradactyl footprints of generally biped animals, were discovered at the surface of Hettangian to lower Sinemurian dolomite layers within 4 distinct stratigraphic units. The 35 sites bearing ichnites are located on the plateau margin.

For the first time, morphologic characters studied through descriptive statistic methods with the usual parameters and classical Student and Snédecor tests, allowed us, to divide the whole set of biped traces into 6 ichnospecies. Their definitions are further constrained by multivariate statistical results using Principal Component Analysis (PCA), Factor Analysis of correspondances (FAC) and Discriminant Analysis (DA). All have confirmed the morphologic observations. So that now, the following taxa are identified: *Grallator variabilis, G. lescurei, G. sauclierensis, G. minusculus, Eubrontes giganteus, Dilophosauripus williamsi*, cf *Moraesichnium, Ornithopus fabri*. The more immediatly visible differences relate to the interdigital II-IV divarication and the digit length ratio. To this panel, we must add *Batrachopus deweyi* and shapes suggesting *Trisauropodichnus* and/or *Anomoepus.* Among all ichnite associations described in the lower Liasic, the New England assemblage presents the most affinities with ours. It shows the ichnotaxa *Grallator, Dilophosauripus, Eubrontes, Batrachopus* without forgetting *Ornithopus fabri* which is close to *Ornithopus gallinaceus* from the Massachusetts and Connecticut basins.

On comparing the present early Jurassic ichnofauna of the Causses with the ones of the Middle and Upper Triassic formations of the eastern border of the Massif Central (France), it appears that tridactyl footprints become more and more numerous and large from Triassic to

Early Jurassic. In the Causses, these latest are prevalent but in Quercy (France), Poland, Italy, USA, they are also associated with Ornithopoda, Thyreophora and Sauropoda ichnites.

Footprint areas considered here were generaly under an arid climate. Animals were heavy and bulky possible Megalosaur trackmakers, and lighter and slender Coelophysids or Ceratosaurs. For all, these areas were pathways as the orientations of the trackways seem point out. The directions followed by these reptiles were without any important variation during the Hettango-Sinemurian stages.

These areas were also used from time to time by Crocodilomorpha and tetradactyl (I-IV) may be bipedal avian Theropods. However, the number of such trackways in sites, sometimes substantial, should not lead us to overestimate the trackmakers populations. These last were probably relatively moderately abondant in this inter-supratidal swamp environment.

In the Causses, ichnites are connected with former algo-laminated deposits (Algal mats) which were rapidly hardened by means of calcitisation of cyanobacteria. The result has been a moderate depth of footprints; autopodia disturbing only a few cm of the carbonate substrate.

Other fossils have been discovered: invertebrates with thin bivalve and gastropod shells, crustaceans tests and plants. These latter suggest the existence of paleomangroves like environments but also continental vegetation periodically overruning the swamp environment during regression/transgression cycles. At these times, wooded parts could become protecting, feeding, resting and nesting places.

GREGARIOUS BEHAVIOUR IN THEROPOD DINOSAURS INFERRED FROM NEW DATA ON *THERANGOSPODUS ONCALENSIS* FROM THE BERRIASIAN FUENTESALVO TRACKSITE (VILLAR DEL RÍO, SORIA, SPAIN)

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A considerable amount of evidence of gregariousness or herding in different groups of dinosaurs has been discovered in recent years, and the clearest ones have been obtained from the study of footprints. One of the most interesting areas in Europe for the study of possible evidence of gregariousness is the Early Cretaceous megatracksite of the Cameros Basin (Moratalla & Sanz, 1997). In its lower part is included the Oncala Group, in which has been recognised almost one hundred tracksites of tetrapod tracks. Particularly abundant are the tracks attributed to small and medium-sized theropod dinosaurs, like those found in Fuentesalvo site, the type locality of *Therangospodus oncalensis*. During cleaning and conservation works in Fuentesalvo we have discovered new trackways assigned to this ichnotaxon, making it possible for us to produce a more precise description of it.

Fuentesalvo locality is situated in Villar del Río (Soria) and is located in the Huérteles Alloformation of the Oncala group, deposited in shallow saline lacustrine environments), and dated as Berriasian (Martín-Closas & Alonso Millán, 1998).

The Fuentesalvo ichnological record is composed by 77 footprints (no undertracks), although only the 60 belonging to the trackways 1 to 12 are studied in this work. The footprints, preserved as concave epirrelief, are tridactyl mexasonic and show a single tapering pad on each toe. In the best-preserved ones, a further rounded pad, which was the heel and represents only around a third of the footprint length, can be seen. No marks attributed to nails or claws are observed. In some cases the toe II print may even be unconnected with the rest of the footprint. The angle between the prints of toes II and III, is smaller than the angle between toes III and IV. All the Fuentesalvo tracks are medium-sized, most of them displaying a length greater than the width (with an average of 22.9 cm in length, 20.0 cm in width and a L/W ratio of 1.16). The step length in the 12 studied trackways show an average of 58.8 cm, and a stride length average of 113.4 cm. The trackways are narrow (the step angle average is 169º).

The footprints of *T. oncalensis* presents greater length than width, relatively long toes with acuminate terminations and presence of a medial notch, and allow us to include within the theropod ichnological group, as the type-trackway (Moratalla, 1993; Lockley *et al*., 2000). As the average of the hip height of the Fuentesalvo trackmakers is 96 cm, the trackmaker can therefore be interpreted as a theropod of medium size, although as yet there are not enough data to attribute the tracks to any of the known clades from the Jurassic-Cretaceous transition.

In addition to similar morphometric characteristics, most of the trackways at the Fuentesalvo site show comparable size and biometrical features (45 out of 48 measured hip height calculations falls within the range of 0.8 to 1.1 metres), which indicates, in terms of size and age, a homogeneous population of a single theropod species could have produced these tracks. In the other side, the very similar orientation of most of the trackways (11 of them show a range of variation of only 15º, so was almost parallel) and estimated speed (between 0.92 and 1.09 m/s), as well as the fact that all are found in the same stratigraphical level, support the hypothesis that this population were a group of dinosaurs moving together. A final consideration is the observation of insufficient intertrackway spacing between some trackways (at least in the ones where the separation between the central lines is less than the sum of the trackway widths), which is explained by the movement of this group, due to the large number of individuals that comprise, not on a broad front but in several waves (at least three, the number of parallel trackways that shows superimposed footprints), as a herd. This means that the trackmarker of *Therangospodus oncalensis* was liable, at least at times, to move around in herds displaying gregarious behaviour.

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A NEW GREAT DINOSAUR FOOTPRINT SITE: BARRANCO DE VALDEGUTIÉRREZ (LA RIOJA, SPAIN)

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This paper describes several outcrops from a new dinosaur ichnological site, which is important due to the number of footprints it presumably contains. Other sites were described in the same area: three of them in 1979 (Brancas et al., 1979), another one in 2000 (Doublet, pers.com) and finally, two other tracksites were found in Barranco de Valdegutiérrez (BVG) in 2001. After all the field data amassed in the 2003 survey, a new prospection was planned for 2005, which has provided 29 new places with footprints in the eastern slope of BVG, with two important wide fossiliferous beds where the three common footprint types: theropods, sauropods and ornithopods are found, probably mixed among them. The estimates about the number of traces from BVG allow us to deduce that this site contains over 5000 footprints, the greatest number of dinosaur prints in a outcrop. The 31.000 m^2 of extension made the BVG the second extensive dinosaur footprint site, after the 500.000 m^2 Ardley site (Day *et al*., 2004). The discovery of a great number of dinosaur footprints is today possible in the Cameros region (Hernández *et al*,. in press).

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PRESENCE OF TWO DIFFERENT THEROPOD FOOTPRINTS IN THE VALANGINIAN-HAUTERIVIAN (LOWER CRETACEOUS) OF VILLANUEVA DE HUERVA (ZARAGOZA, ARAGÓN, SPAIN).

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"El Paso" site is an ichnological locality proposed by the Regional Government of Aragon as a Unesco World Heritage site. Its main interest is paleogeographic and lies in being one of the few well-known Valanginian-Hauterivian tracksites in the Iberian Peninsula as well as the first locality with dinosaur tracks in Zaragoza province. It is located in the Aguilón Basin, in which the outcrop of Weald facies are represented by sandstones and limestones of Villanueva de Huerva Formation (Valanginian - Hauterivian) and limestones with ostracods of Aguilón Formation (uppermost Hauterivian - basal Barremian), dated with carophytes. The studied locality is placed in the top of the Villanueva de Huerva Formation in its type section. Litologically the uppermost part of this formation is a calcareous succession with small marl levels. In the limestones there are abundant the algal laminations. The deposit is interpreted as a brief carbonated lacustrine system, generally of very low energy (Soria de Miguel, 1997).

The fossiliferous level is about 80 cm thick and presents tubular structures possibly produced by plants. In the upper surface, which is little exposed, shallow depressions can be observed (undertracks), as well as three theropod footprints, two grouped in one trackway (1.1 and 1.2) and another one isolated (2.1). Although there are no signs of skin impression, the footprint preservation does not suggest that the level with tracks is not the one where the trackmakers stepped on. Otherwise, all footprints present an abrupt edge, a wide mud trim and a good preservation indicating that they could be real footprints (no undertracks)

Trackway 1 is composed by two tridactyl and mesaxonic footprints. In the first one (1.1) only the anterior prints of digits II, III and III are preserved, and the second (1.2) is almost complete. Digits II and IV show great marks of claws strongly projected medially and laterally, respectively. Both footprints lack the anterior end of the digit III, which allow us to estimate a slightly greater length than the 46 cm measured in the most complete footprint (1.2). Width of footprint 1.2 is 50 cm. Digital pads can be observed in digit II, but not in digits III and IV. There is no *hallux* marks. Finally a quite short heel impression is observed (total footprint length / length of digit III ratio is around 1,4). Trackway 1 does not allow any taxonomical assignation up the moment.

Although functionally the trackmaker was tridactyl, the footprint 2.1 is a right tetradactyl one, because the *hallux* impression, small and medially projected, can be observed. The digit II is wide in the middle portion, acuminated at the tip and shows a single pad. The digit III is broad proximally but tapering distally, and slightly curved laterally. Digits II and III present marks of claws. The deep impression of the digit IV only allows to observe traces of digital pads. The footprint length and width are 44 and 37 cm, respectively. The heel impression is quite long, showing this footprint a total length / length of digit III ratio of more than 1,9. The features of this footprint are similar to those characterizing the ichnogenus *Buckeburgichnus* from the Berriasian of Germany (Lockley, 2000), and also present in the Aptian of La Rioja province (Spain), allowing us to suggest a preliminary assignation of the footprint 2.1 of "El Paso" locality to the this ichnogenus.

The marked differences between the two trackways of the ichnological site of "El Paso" allow to suggest that they belong to two different trackmakers, which implies the presence of two different taxa of theropod dinosaurs in the Valanginian-Hauterivian of the Zaragoza province.

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A NEW INTERPRETATION FOR THE FORMATION OF THE COSTALOMO SITE DINOSAURS FOOTPRINTS (SALAS DE LOS INFANTES, BURGOS, SPAIN)

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The Costalomo site, Salas de los Infantes, Burgos, has been reported in scientific papers since 1986, in which have tried to explain the peculiar formation of these footprints because are preserved in relief, above the outcrop surface.

In this work we review the previous hypotheses proposed by Platt (1) , Colectivo Arqueológico de Salas(2) , Bengoechea et al.(3) and Huerta Hurtado(4) .

During the summer of 2003 Costalomo site was object to an excavation and cleanliness of the surface under the jurisdiction of the Culture and Tourism Council of Castilla y Leon. The 2003 campaign enlarged the outcrop area to around 450 m² and revealed a large number of dinosaur footprints. They totalled 239 and greatly surpassed the previously known 30.They group into 20 trackways, classified as follows: 10 theropod trackways, 1 avian, 2 ornithopods, 2 sauropod and 5 indeterminate (5).

From the information obtained from the excavation, a new hypothesis is proposed for the formation of the “in relief” Costalomo footprints.

The outcrop exposes the Pinilla de los Moros Formation (6), that is dated in the upper Hauterivian - lower Barremian (7) . Comprises channel sandstones alternating with red claystones - flood deposits of a fluvial-lacustrine environment.

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THE VERTEBRATE ICHNOLOGY DATABASE AND LANDSCAPE: A STORY OF TWO DECADES OF RAPID GLOBAL GROWTH OF COLLECTIONS AND SCIENTIFIC EDUCATION

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Vertebrate ichnology was an obscure branch of ichnology and vertebrate paleontology until the 1980s. Once called 'the magnificent seven' Baird, Casamiquela, Demathieu, Ellenberger, Haubold, Leonardi and Sarjeant were, prior to 1985, essentially the first pioneer generation since Buckland and Hitchcock in the early 1800s. Until recently, only Hitchcock's Amherst College collection had any great value for ichnotaxonomic reference, and few authors other than the aforementioned seven pioneers, together with Lull and Peabody, had made extensive scientific contributions to the field.

Much has changed in the two decades since the First International Symposium on Dinosaur Tracks (Albuquerque 1986). In the western United States alone three major track collections (with x 1000 tracks) have sprung up at research centers in Denver, Colorado, Albuquerque, New Mexico and St. George Utah. Research groups associated with these two former institutions have published more than 500 papers and abstracts that pertain to the collections, the new type material they contain, and as many as 1000 sites in the western USA from which material originated. The Denver collection contains >1800 specimens covering many geologic periods. The New Mexico collection has a strong emphasis on Permian tracks and the St George collection, which is less than 5 years old, is devoted to the Lower Jurassic. Thus, there are four major collections in the USA, in addition to other significant North American collections and sites from western Canada documented by Currie, McCrea and others.

Several important collections and centers of track research can be identified in Europe. These, include various German collections (studied by Haubold and collaborators), French collections developed and studied by Demathieu, Ellenberger, Gand and colleagues, Italian collections centered on the Rome group (Conti, Nicosia, Leonardi and colleagues) and the Spanish collections housed at the new Museum of the Jurassic, Asturias (MUJA), which together with abundant sites (about 200) from La Rioja and adjacent provinces constitute a huge database, studied by many Spanish authors. These groups have mostly produced prolific scientific publications in recent years, added to by significant research and collecting by groups from other areas such as Northern Italy (Avanzini, Dalla Vecchia and others), Poland (Gierlinski), Portugal and the United Kingdom. European statistics are comparable to those produced in North America: i.e., many hundreds of publications pertain to at least 1000 sites.

Thulborn has pioneered tracksite documentation in Australia and various authors, notably Matsukawa and various Korean ichnologists, have helped develop vertebrate ichnology in East Asia. The field is also healthy in South America. In the interests of synthesis and summary, these groups and other interested participants might, in future years, help compile outline descriptions of these and other major collections under the cover of a single special volume, possibly for a journal like *Ichnos*. Such a synthesis would be a massive undertaking if all figured and curated material, research bibliographies and field sites were included and described in detail. However, collective efforts by the vertebrate ichnology community to summarize type material, with pertinent bibliographic entries and cogent assessments of the significance of collections could also be of landmark and historic value to future generations.

It is noteworthy that vertebrate ichnology is now sufficiently mature as a discipline to have spawned a number of conferences and special volumes devoted exclusively to the subject. Likewise the subject has gained increasing attention in special sessions at more general conferences on ichnology, paleontology and geology. Recent decades have shown us that vertebrate tracks are very common, far more so than previously supposed, and represent the greater part of the entire vertebrate fossil record in some regions. They also have excellent potential for public education and as outdoor interpretative resources. Thus, unlike many skeletal sites, which are often buried or 'cleaned out,' thousands of ancient fossil footprint sites, once considered archaic vestiges of the ancient landscape, have become part of the modern natural landscape, contributing to dynamic new interpretations of trackmakers and their deep time origins. Together with outdoor sites, collections and exhibits have also become an integral part of the cultural, educational and scientific landscape.

DINOSAUR FOOTPRINTS FROM CENTRAL AND SOUTHERN ITALY

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In the last few years, diverse dinosaur footprints bearing outcrops have been uncovered from central and southern Italy. Still standing problems concerning protection, preservation, and land ownership of the different ichnosites, slowed down their study and consequently the publication of data. Accordingly, the preliminary results of the ongoing studies are herein presented for the first time.

The track-bearing levels pertain to four different stratigraphic horizons in marine carbonate deposits (Late Jurassic, Early Cretaceous and Late Cretaceous) and belong to two structural domains: the Laziale-Abruzzese-Campano over-thrust domain and the Apulian foreland. These domains, interpreted as small separate carbonate platforms in most of the current paleogeographic models, were both implied in the orogen and joined in the Apennine belt.

Three distinct levels are presently known from the Apulian carbonate platform:

- several tridactyl and tetradactyl-elongated footprints, pertaining to a first level and ascribed to medium-sized theropods, were recognized on loose blocks of the piers of Mattinata and Manfredonia (Gargano Promontory, Foggia). The blocks belong to the Sannicandro Formation referred to the Late Jurassic–Early Cretaceous;
- the second level (Hauterivian), cropping out near the Borgo Celano village (Gargano Promontory, Foggia), has been detected from the San Giovanni Rotondo limestones (Hauterivian–Cenomanian). The Borgo Celano ichnocoenosis is represented mainly by tridactyl footprints ascribed to medium-sized theropods;

- the third level (Early Santonian) crops out in an abandoned quarry opened in the Altamura limestone (Turonian–Maastrichtian?) near the Altamura town (Bari). It includes thousands of medium-sized quadruped trackways ascribed to ornitischians.

A further level comes from the Laziale-Abruzzese-Campana carbonate platform. The outcrop, Cenomanian in age, is located 70 km south of Rome, near the Sezze town. Therein, trackways have been uncovered from three different bedding surfaces. The Sezze ichnocoenosis consists of several small-sized tridactyl footprints ascribed to theropods and of a large quadruped trackway attributed to a sauropod.

The above mentioned data, and some similar ones from the neighbouring areas (Istria, Dalmazia), are strong constraints for the paleogeographic reconstruction of the periadriatic area during the Cretaceous. At the present, it seems probable that two different immigration routes are necessary to justify the data: one from the Gondwana continent up to Cenomanian, and another from the Laurasia in the uppermost Cretaceous. These different routes imply continuous or repeated connection between the periadriatic carbonate platforms and the southern and northern main lands.

LATE CRETACEOUS DINOSAUR TRACKS IN SOUTHERN COSTAL AREA OF KOREA: VARIATION AND PALEOBIOLOGICAL IMPLICATIONS

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Abundant dinosaur fossils including dinosaur footprints, eggs and nests, teeth and bones have been found from the Cretaceous non-marine deposits of Korea. Among them, dinosaur tracks are the most common, and some tracksites are among the most famous in the world. In Korea, over 27 dinosaur track localities have been discovered from the Cretaceous in several basins. In particular, the dinosaur track sites in southern coastal area of Korea are distinctive. In the sites including Haenam, Hwasun and Yeosu areas, about 7,000 dinosaur tracks were discovered from the Late Cretaceous lacustrine deposits. Ornithopod tracks are the most common at most tracksites, and most of them are identified as *Caririchnium*, suggesting that hardrosaurid dinosaurs flourished in Korean Peninsula during the Late Cretaceous. It is characteristic that all of the Korean ornithopod tracks are bipedal. Most of the theropod tracks are found in Hwasun and Yeosu areas of the Late Cretaceous Neungju Basin. They consist of various types of small- to medium-sized birdfoot-like tracks compared to *Magnoavipes* and *Ornithomimipus*, and other large footprints (25 to 50 cm in length). Korean theropod tracks are relatively larger than the Jurassic ones. The variety of morphotypes and sizes of the footprints and the calculated body sizes in Hwasun area indicate that different theropods with various gaits inhabited in this area during the Late Cretaceous. On the basis of the speed and gait analyses, it is inferred that the small theropods in the area were trotting, while the large theropods were walking slowly. The Hwasun sites also show diverse gaits with unusual walking patterns and postures in some tracks. Among them, a trackway with increasing strides provides unusual opportunity to observe acceleration pattern of a theropod dinosaur. Sauropod tracks are also common in the Late Cretaceous lacustrine deposits of the Gyeongsang Basin. They vary in size, shape, and pattern of trackway, suggesting that diverse sauropods existed in Korean Peninsula. Most of the Korean sauropod tracks are 20 to 50 cm in size. The diversity of Korean dinosaur tracks suggests that various dinosaurs inhabited and evolved in Korean Peninisula during the Late Cretaceous.

SAUROPOD MANUS-DOMINATED TRACKWAYS: NEW EVIDENCES FROM THE FUMANYA TRACKSITE (UPPER CRETACEOUS, SE PYRENEES) AND STATE OF THE ART

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The origin of sauropod manus-only and manus-dominated trackways has been a matter of intense debate for a half a century. First hypothesis to explain them was proposed by Bird (1944) who though of a swimming condition for the sauropod trackmaker of the Lower Cretaceous trackway in Mayan Ranch site, Texas. Later, new data and revised trackways from Middle Jurassic of Portugal and Morocco, and Upper Jurassic of Portugal allowed to interpret this kind of evidences as a result of a selective undertrack phenomenon that only leaves the manus recorded (see Lockley *et al*. 1994 and references therein for a sinthesis). Currently, recent experimental works and discoveries add new controversy to the debate suggesting a swimming (Lee and Huh 2002), floating (Henderson, 2003) and semi-submerged sauropod (Wilson and Fisher, 2003) as likely trackmaker.

Since 2001, several new sauropod trackways were discovered and studied in the Fumanya tracksite area (Maastrichtian, SE Pyrenees). Two trackways have been studied at Mina Esquirol and Fumanya South sites. On this stratigraphic bedding surface both tracks and undertracks are found. The Mina Esquirol trackway is composed by a total number of fifteen footprints composing a length trackway of about 14 meters. There, footprint morphology together with the trackway pattern displays a clear succession of manus-only impressions attributed to a sauropod dinosaur in a walking gait. The comparative trackway from Fumanya South is composed by a total number of 73 footprints composing a trackway length of about 60 meters. The heteropody of the track permit to distinguish a complete sequence of hindprints and foreprints describing a symmetrical gait.

The ichnological comparison between the manus-only trackway with the other complete trackway (manus-pes) from the same bedding surface display an identical distribution of the manus pattern. This fact clearly supports an underprint phenomenon as the origin for manus-only trackways based on the differential loading between the hindfoot and the forefoot on an upper stratigrafic track-level. Therefore, it is unlikely that a single trackmaker would produce a similar autopod pattern when walking or swimming, because similar trackway patterns would reflect similar biomechanical traits. Search and identification of a clear and diagnostic trackway pattern seems relevant before any interpretation of the behaviour of the trackmaker.

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REVERSE-ENGINEERING DINOSAUR TRACKS AND TRACKWAYS

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The ridges and grooves of old vinyl records are converted to detailed information (sound) when a stylus reads surface geometry; fossil tracks also have the potential to play back detailed information, not of sound but of morphology, movement and rheology. The distribution, timing (duty factor) and intensity of pressure over the foot/sediment interface correlates with resultant track geometry. This in turn is controlled by sediment rheology at the time of track formation.

The combination of laboratory-controlled track simulations, coupled with field observations, has provided a clearer understanding of how fossil tracks were formed and preserved. The geometry of surface and subsurface traces should be studied with a view to tracks being regarded as dynamic 'records' of movement, not just static traces. However, this approach does not account for whole organism effects on track geometry.

Unravelling the morphology and movement of a foot that created a track is isolating but a part of a more complex locomotor system. Whilst the anatomy and morphology of the foot is important, so too are the many components that drive, limit and define the locomotion of an organism. A multidisciplinary approach that combines a clear understanding of anatomy (whole organism, limb, joints, etc.), biomaterials (bone, keratin, etc.), kinematics (of foot, limb, centre of mass, etc.) and substrate (before, during and after track formation) must be sought to provide a synthesis of methodologies that yield a robust approach to understanding fossil tracks and trackways. These methods might include the combination of laboratory track simulations, force plate analysis (live and prosthetic limbs), bracketing locomotor styles using EPB, analysis of body fossils, computer modelling of limb kinematics, analysis of biomaterials, application of finite and discrete element techniques and the construction of biomechanical models.

This is not a simple approach to studying tracks. However, the approach will enable access to additional information locked within track geometry and morphology.

THE LAST OF THE EUROPEAN DINOSAURS: EVIDENCE FROM THE PYRENEAN TRACKS

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The discovery of dinosaur tracks close to the Cretaceous-Tertiary boundary in many geologic formations of North America has shown the utility of the footprints as chronostratigraphical markers. Their autochtonous character provide an unmistaken proof of the presence of the animal in a restricted temporal and spatial context, with no possibilities of reworking processes such in the bone remains. Therefore they represent a valuable tool to analyze diversity patterns in the latest dinosaurs before their extinction. Up to now the uppermost track record is located in the Raton Formation (Colorado, USA) where a diverse ichnofauna composed by hadrosaurs, probable ceratopsians and large theropods close the boundary have been determined (Lockley *et al*., 2000).

Campanian and Maastrichtian formations from all over the world indicate a rich track record of dinosaurs. Nevertheless few of them show an ichnological record comparable with that of Raton Formation in terms of age and stratigraphic position. In Europe the dinosaur tracks from the uppermost Cretaceous of the Southern Pyrenees have become a really promising record to take into account when studying the dinosaur extinction.

The end Cretaceous record of the south Pyrenean sections (known in the literature as “Garumnian” or Tremp Formation) display three lithologic units deposited as a result of a marine regression: (a) basal transitional grey Garumnian (coals, mudstones and sandstones), (b) a fluvial lower red Member and (mudstones and sandstones) and (c) the Vallcebre limestones. The transition from (b) to (c) is isochronous and records the evolution from a fluvial environment (red-beds) to a lacustrine system. Despite no impact layer has ever been found in the Pyrenean continental sections, the Cretaceous/Tertiary boundary is located just below or a few meters within the lacustrine Vallcebre limestone after biostratigraphic and magnetostratigraphic determinations. This scheme is also found in the northern Pyrenees and Provence areas.

A few meters below the Cretaceous-Tertiary boundary (within chron 29r) two localities have been published, but recent findings reveal that footprints are not so rare. On top of that, localities that were first published require a current revision. New localities have been found in the last 20 meters below the K/T boundary. Track record consists on isolated footprints and likely trackways of hadrosaurs. Few sauropod footprints have also been identified. In some of the hadrosaur tracks, strong morphological similarities suggest strong affinities with ichnogenerus *Hadrosauropodus langstoni* from the Judith River Formation, Alberta (Lockley *et al*., 2003). A correspondence between the sedimentary environment and the type the trackmaker is also suggested.

All these localities represent the last dinosaur ichnological occurrence in Southern Europe, and they are in agreement with the Iberian faunal distribution proposed by some authors (Pereda *et al*., 2004 among others) for the Late Cretaceous. Track record from Pyrenees shows an outstanding abundance of hadrosaurs in latest times of the Upper Maastrichtian with scarce record of sauropods.

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A NEW LOOK AT THE CRETACEOUS DINOSAUR FREEWAY: EVOLVING INSIGHTS INTO PALEOECOLOGY

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The Cretaceous Dinosaur Freeway associated with Dakota Group (Albian-Cenomanian) of Colorado and New Mexico has informal status as the "type" example of the megatracksite phenomenon. Although at least 10 Mesozoic megatracksites have been reported from Europe and North America none are based on as many sites (>60), nor have any be as carefully tied to the sequence stratigraphy framework as is the case with the Dinosaur Freeway. Few if any are nearly as large (ca. 100, 000 km^2)

The present data base contains a count of 62 localities yielding about 1049 separate trackways (not individual tracks) of terrestrial vertebrates, comprising at least nine ichnotaxa including: 940 ornithopods (*Caririchnium)*, 75 theropods (2 *Magonavipes* morphotypes), 26 ankylosaurs (2 morphotypes), 8 birds (5 *Ignotornis* and 3 *Aquatilavipes*), 1 pterosaur and an estimated 110 additional crocodile swim tracks. This compares with a 1992 census that recorded 25 localities yielding 225 trackways in which only four ichnotaxa were recognized. Such a data base allows for a useful paleoecological census of vertebrate trackmakers in the region, and provides an indication of how such databases grow both quantitatively and taxonomically.

For example the vast majority trackways of terrestrial vertebrates (940/1049 = 90%) represent ornithopods (*Caririchnium*). 7% represent theropods (*Magnoavipes*), about 2.4% represent ankylosaurs and only 8 (less than 1%) represent birds. Based on geographical distribution (number of localities with a given track type) the dominant dinosaur track types, (*Carririchnium, Magnavipes* and ankylosaurian) occur at about 79, 34 and 5% of localities respectively. Similarly the different bird and pterosaur track types each occur at less than 2% of localities. Thus, there is broad agreement between the relative abundance of different track types throughout the region and the geographic distribution, as measured by the number of localities method. The main difference is that theropods tracks are more widely distributed than their relative abundance would suggest. Although 7% carnivores and 93% herbivores might suggest a realistic predator-prey ratio, the theropods were quite gracile forms too small to prey on most large ornithopods and ankylosaurs. If crocodiles are included then the ratio would change.

The crocodilian swim tracks occur at about 18% of localities. However, because crocodile swim tracks are inherently incomplete trackways, it is hard to estimate numbers that can be compared with the trackways of terrestrial animals. They represent almost 10% (110/1159) of the combined total for land based and aquatic vertebrates. Swim tracks typically occur in different sedimentary facies. Present studies aim to place all tracks in proper sequence stratigraphic and paloenvironmental context to further refine our understanding of these track distributions in space and time.

THE FUMANYA SAUROPOD TRACKSITE: HISTORY OF DISCOVERIES AND ADDITIONAL DATA TO TITANOSAURS ICHNOLOGY

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The Fumanya tracksite (South-eastern Pyrenees) is the largest outcrop for studying dinosaur ichnology in the european Maastrichtian. Coal mining activity was the real origin of Fumanya tracksite discovery. The first coal extraction works in garumnian sediments of the south of Pyrenees began at the end of XIX century at outcrops close to the Llobregat River. At Vallcebre sinclyne, the open mining works began at eighties and, in 1985, Lluis Viladrich, an amateur naturalist from Berga, discover the first tracks in Fumanya quarry. His preliminary observations were published in a local magazine, and also communicated to palaeontologists from "Crusafont" Palaeontological Institute. Surprisingly nobody paid attention at the almost vertical surface full of clear dinosaur tracks that appears below the coal level.

The first scientific works began ten years later. Le Loeuff and Martínez (1997) cited for the first time the occurrence of clear titanosaurid tracks in Europe but none quantitative data were published. First quantitative data came from Schulp and Brokx (1999) who presented a primary map of the main site and provide some new data on titanosaur tracks. More recently, an overview of the current outstanding titanosaurid tracksites by Lockley *et al* (2002) provides general synthetic data, based on Schulp and Brokx work.

Since that time other surfaces with dinosaur tracks are being studied. A more detailed observation on the field distinguishes up to four different outcrops-localities on a continuous track-bearing surface, covering a surface of up to 35,000 m^2 with a total amount of more than 3,000 tracks. They have been named Fumanya South (the classical site referred in previous papers), Mina Esquirol, Fumanya North and Mina Tumí. Since 2002 new mapping works have been undertaken in at least three of these four localities.

From the mapping new data and measurements on tracks and trackways have been collected. New data consists in at least ten new trackways mapped for the first time, including notable well-preserved examples of manus-only trackways (Vila *et al*., 2005). Extensive mapped tracks and measurements of manus and pes (> 120 tracks) permit to define with more accuracy the shape and morphological characters of the manus and pes prints of titanosaurs. Heteropody values are consistent with those of Schulp and Brokx (1999) but in disagreement with those from the synthetic data presented by Lockley *et al* (2002).

As noted Schulp and Brokx (1999), all the new trackways can be assigned to *Brontopodus* ichnogenerus on the basis of their trackway width. Here is also included a singular trackway from a likely juvenile sauropod trackmaker primary reported by Le Loeuff and Martínez (1997). The site has been reviewed and the tracks have been mapped for the first time. The trackway display a wide-gauge pattern.

The climatic conditions united to the great altitude of the tracksites have a great impact in the conservation of the original track bed. In less of ten years, the first layer disappears, leaving the underlaying sediments with only footprints preserved as undertracks. In fact erosion provides a dramatic example of undertrack phenomenon since only manus-dominated trackways are preserved as a result of partial erosion of complete manus-pes trackways. This great erosion and the menace of complete information and heritage losing impulsed a new project to study and protect the whole track complex. Vertebrate and plants remains have been recovered and the studies have extent to the close garumnian outcrops.

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FROM BABIES TO GIANTS: EXTREME SIZES IN SAUROPOD TRACKS. DELTAIC SERIES OF THE ASTURIAS UPPER JURASSIC (N SPAIN)

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The outcrops of Upper Jurassic rocks in the sea cliffs between Gijón and Ribadesella localities (Asturias, N Spain) show many beds with dinosaur footprints. Sauropod tracks are by far the most common ichnites in this area, although theropod, ornithopod and stegosaur tracks are also common. Other contemporary reptile imprints associated to the aforementioned beds include turtle, crocodile, pterosaur and lizard tracks.

The sauropod ichnites, some of them housed in the recently opened Jurassic Museum of Asturias (MUJA), exhibit frequently a good preservation, diverse shapes and sizes and occur as concave epireliefs or convex hiporeliefs in marl, limestone and sandstone beds.
Dimensions of trackmakers vary between very small individuals (some footprints are only 12 cm in length) and others with huge sizes, as the footprints of probably brachiosaurid in La Griega beach, close to the locality of Colunga and only at 1,5 km from the MUJA, with 1,25 m in diameter. They form part of narrow-gauge trackway associated to a transgressive surface. These two extreme sizes probably constitute the present records of the world, at least for the Jurassic.

Although sauropod dinosaurs tracks are clearly dominant in the Jurassic of Asturias, those of very young individuals are scarce, suggesting that its preservation in the fossil record is not common, as previously supposed, because of the assumed quick growing.

Baby dinosaur tracks

The smallest sauropod tracks constitute convex hiporeliefs in a sandstone bed of the Lastres Formation located in the proximity of the Tazones harbour, in the Villaviciosa council. Until now, 12 samples (6 manus tracks and 6 pes tracks) have been recovered and housed in the MUJA; in 5 of them, the undertracks are preserved too. The heteropody index between manus and pes is very low, varying between 1:1 and 1:2.

The manus prints show the characteristic crescentic outlines and some of them present the claw digit I impression. Their size ranges from 6-9 cm. (length) and 9-12 cm. (width).

The pes prints have an ovate to subtriangular aspect, frequently with the front part wider than the posterior part. Apparently they do not exhibit clear digit impressions. Dimensions range between 12-16 cm in length and 8-11 cm in width.

The forelimbs sunk less than the hindlimbs in the ground, although pes and manus tracks display very similar dimensions, suggesting that brachiosaurids should be ruled out in making them.

The trackmakers were probably very young individuals (babies) of a few months in age and less than 1 m tall (Lockley, 1994).

The environment in which the sauropod babies walked was probably a pond margin of a coastal plain next to a river bed in a fluvial-dominated deltaic complex.

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PALEOPATHOLOGIES DEDUCED FROM A THEROPOD TRACKWAY. UPPER JURASSIC OF ASTURIAS (N SPAIN).

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Although the references about traumatism and illness in dinosaur bones are very frequent, there are few reports about pathologies of these reptiles through studies of both isolated footprints and trackways, and the majority of them refer to limping dinosaurs (Tanke and Rothschild, 2002).

The example here presented refers to a theropod dinosaur trackway of four consecutive footprints, conserved as convex epireliefs. The tracks are preserved in a sandstone layer of the Lastres Formation, located in the Argüero seacliff, in the Villaviciosa council. This Formation is Kimmeridgian in age and constitutes the highest part of the Asturian Jurassic sedimentary succession. It represents deltaic sediments accumulated in the coast of an inland sea separated from the open ocean by a threshold or tectonic barrier which served as protection against the storms at the time. The dinosaur here reported walked on a sand bar accumulated during the crevassing of a principal distributary channel which belong a fluvial dominated deltaic complex. The Lastres Formation has yielded a high number of reptile footprints in the outcrops of the central-eastern asturian coast, among them dinosaurs, pterosaurs, crocodiles, turtles and lizards.

The tridactyl tracks in this trackway show the typical morphology of theropod pedal prints, with well preserved claw impressions. The most regular footprint (4) is 58 cm length and 43 cm width, while footprints (1) and (3) measures 58 cm in length and 58 cm in width. This last parameter is higher due to peculiar disposition of fourth digit in the first and third footprints, corresponding to right hindfoot. The interdigital angle between digits III and IV of these latter footprints is very high for theropod dinosaurs, being in this case, next to 90º. The same interdigital angle in the footprint (4) is 37º.

The trackway length is about 475 cm, the mean pace is 149 cm, the mean stride 280 cm and the mean pace angulation 142º. There are not substantial changes, for this short distance, in the pace and stride length.

Anomalous arrangement of the fourth digit in the right footprint suggests a pathology, although we can not determine if it is malformation or traumatism for fracture; the similarity in the pace length suggests that if it is a fracture, this was produced a lot of time before that owner trackway, as long as there is not evidences of limping in the reptile gait.

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ICHNOLOGICAL EVIDENCE FOR GIANT ORNITHOPOD DINOSAURS IN THE LATE JURASSIC LOURINHÃ FORMATION, PORTUGAL

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The Late Jurassic Lourinhã Formation contains a diverse dinosaur fauna comprising theropods, sauropods, stegosaurs, ankylosaurs and several genera of ornithopods. The sedimentology in the area favours preservation of footprints, and footprints from most of the dinosaurs represented by skeletal remains are present in the area. During fieldwork in the summer of 2003 a new, large, tridactyl footprint was found at the beach of Vale Frades, approximately 6 km north of Lourinhã, Portugal. The footprint was found together with a stegosaur footprint on a clay bed exposed within the tidal zone. The footprints were preserved as sandstone casts standing on a pedestal of clay. This unusual type of preservation is the result of the footprints having first been emplaced in clay, and then filled with sand. During the present day erosion from the sea, the harder sandstone cast of the footprints protects the subjacent clay layers from erosion. Owing to the immediate danger of erosion of, the footprint was collected and is now on display at Museu da Lourinhã (ML 1000). The footprint is 70 cm long and 69 cm wide, the toes are short and broad, with indications of short blunt claws. The divarication angle between the outer digits is close to 90 degrees. The dimensions and general morphology of the footprint identifies it as deriving from an ornithopod dinosaur with an estimated hip height of 4.13 metres. Although very large ornithopods are known from the Cretaceous, the largest known Jurassic ornithopod is *Camptosaurus* from USA, and the largest known from Portugal is the camptosaurid *Draconyx loureiroi.* Neither of these reached the body size suggested by the new footprint. So far the footprint described herein is s the only evidence for a Jurassic ornithopod of that size.

TOPIC : ICHNOLOGICAL HERITAGE (PRESERVATION AND SPREADING STRATEGIES)

SCIENTIFIC AND CULTURAL SIGNIFICANCE OF SOME PORTUGUESE DINOSAUR TRACKSITES

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In Portugal dinosaur tracksites are known from Bajocian-Bathonian through Middle Cenomanian. Two distinct tracksites from Middle Jurassic were identified. One is Vale de Meios quarry that reveals dozens of paralell theropod trackways and the other is the Galinha tracksite where there were identified long and wide-gauge sauropod trackways produced by individuals with 3 - 4 m to the hip and locomotion at a speed of about 4 -5 km/h. This tracksite reveals unique sauropod manus and pes morphology suggesting new ichnotaxa. Until now Galinha tracksite is a unique place to receive visitors interested in learning about dinosaur footprints. In addition there are two main areas with dinosaur tracksites that have provided us with significant paleobiological and paleoecological information, namely the Cabo Espichel region and the SW Algarve Mesozoic Basin. In the Upper Jurassic of Cabo Espichel region there were identified: unknown primitive theropods that lead to the ichnogenus *Megalosauripus* isp.; possible herd behavior among theropods; long and wide-gauge sauropod trackways attributed to *Brontopodus* isp. and *Brontopodus* aff. *B. birdi*; narrow-gauge sauropod trackways assigned to *Parabrontopodus* isp.; limping gait in theropod and sauropod trackways; evidence of herd behavior among two groups of different size sauropods, one of them formed by seven juveniles; slight *pes* marks in only manus sauropod trackways corroborate preservation factors instead of animals behaviour as a cause for this phenomenon. Three places with dinosaur tracks were recognized in the SW Algarve Mesozoic Basin: Foia do Carro tracksite presents sauropod trackways in two tracklevels from the Upper Jurassic and Praia da Salema and Praia Santa tracksites revealed small tridactyl footprints made by unknown theropods and well-preseved tridactyl footprints whose morphology allows the classification as *Iguanodontipus* isp. Besides the ichnological significance of these dinosaur tracks and tracksites, they are also valuable for public education and arouse public interest for Geological/Paleontological ichnoheritage.

THE STRATIGRAPHIC SUCCESSION OF THE END-CRETACEOUS VALLCEBRE BASIN (EASTERN PYRENEES) AND THEIR DINOSAUR ICHNOLOGICAL SITES.

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The continental Upper Cretaceous-Paleocene sediments that filled the southern Pyrenean basins are known as Tremp Formation (Mey *et al*., 1968) or "Garumnian". This last name was proposed by Leymerie in 1862 and is widely used in the Pyrenean geology (see historical review in Rosell *et al*., 2001). The Garumnian result from a Pyrenean marine regression that took place by the Campanian-Maastrichtian transition. At those times the Garumnian strata accumulated in an E-W foreland basin trough that was opened to the Atlantic. Two groups of successions occur depending on their tectonic setting. The first group are discontinuous successions that result from accumulation in low subsidence settings. These successions are relatively thin, with coarse grained sediments and abundant erosions. The second group of sections are thicker (up to 500 m of Cretaceous strata) and represent expanded and continuous stratigraphic records (do not contain important erosions), which consist mostly of muddy facies. This second group includes the studied section.

The regional stratigraphy of the south Pyrenean Garumnian sections displays up to four lithologic units (Rosell *et al*., 2001) which from base to top are: (a) a transitional Grey Garumnian (marls, coals, limestones and sandstones), (b) a fluvial Lower Red Garumnian (mudstones, sandstones, oncoliths and paleosols), (c) the lacustrine Vallcebre limestones and its equivalents and (d) an Upper Red Garumnian (mudstones, sandstones, conglomerates and limestones) deposited in several continental environments.

Up to date no detailed sedimentological studies exist in the Garumnian of the Vallcebre syncline if we exclude the unpublished work by Aepler (1967). So we have measured 7 subsections in detail to build up a 760-meter composite section. The section could eventually be extended upwards some tens of meters, since above the uppermost studied levels few isolated Garumnian outcrops exist which are not considered herein. The 760 m long composite section links several outcrops in the south flank and core of the Vallcebre syncline. The sedimentary succession displays a large regressive trends and includes the following lithologies: humic coals, black mudstones, limestones, blue marls, blue sandstones, dark mudstones, brown mudstones, pale red mudstones and fine grained sandstones, dark red mudstones and medium grained sandstones and coarse grained sandstones and microconglomerates. Sedimentology indicates a progressive regression from marine settings to lagoonal and finally to entirely continental environments.

Magnetostratigraphic studies clearly show that the age of these sediments is entirely Maastrichtian, being an expanded section that is probably among the thickest records for the continental Maastrichtian in the Old World. A robust chronological scheme is achieved which can be unambiguously correlated to the standard GPTS after biochronological constraints (charophyte, marine invertebrates, eggshells and other dinosaur remains).

Regarding dinosaur ichnology, several levels can be located in the section, thus providing a physical succession with several sites. Footprints appear both isolated or as outcrops of tracksites. The Fumanya tracksite contains more than 3500 footprints partly aligned in tracks. Sauropod footprints are found in transitional environments and are basically developed in carbonate environments. On the other hand, ornithopod ichnites are basically found inside channelized bodies or sheet sandstones. The succession also includes several oospecies of dinosaur eggs, and few sites with bones and teeth.

In the field trip we will visit Cretaceous sections located along the road that goes from Coll de Fumanya (Fumanya Sud site) to Coll de Pradell (and further to Saldes).

The whole references and article have been submitted to *Palaeogeoraphy, Palaeoeclimatology, Palaeoecology*.

STUDIES, ESSAYS AND STRATEGIES TO PRESERVE THE SAUROPOD ICHNITES FROM FUMANYA TRACKSITE (EASTERN PYRENEES)

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The tracksite of Fumanya has more than 3500 dinosaur footprints in several linked outcrops of the same stratigraphic surface. So that this site is among the world's largest outcrop of such kind. Fumanya Sud is among the most interesting outcrops, since it displays a surface of some 500 meter long by 60 meters high. Such surface is the footwall of an ancient opencast coal mine.

Decay and conservation studies together with engineering projects are integrated in a multidisciplinary approach, which includes palaeontology and geology.

The rock of the whole surface is a marly limestone that undergoes a fast decay as a result of the interaction of atmospheric effects (rain wash, snow and freeze) with rock microfracturation. The effect of large scale rock joints are also of crucial importance. Despite the general weathering of the site, on a microscopic scale decay is shown to result from microfractures and the presence of soluble salts. Runoff washing avoids the stability of films (of biological o or non-biological origin), so that rock is unprotected from environmental agents, thus enhancing decay. Runoff also removes iron oxides or hydroxides generation areas of different colour.

The determinations of minerals accumulated in fractures reveal the presence of gypsum, which is responsible of expansion and breaking of the rock. Microfractures act as a web enhancing the moving of several compounds such as gypsum, which separate microfracture as a result of its crystallization. In order to determine the most efficient treatment to be applied, several laboratory and *in situ* essays have been carried out so that we can study the behavious of rocks before and after the application of commercial consolidants and water-repellents. *In situ* essays include the application of paper pulp compresses to obtain soluble salts, essays with consolidants and water-repellents and weathering mappings.

Regarding laboratory studies, we have carried out petrological determinations, XRD, scanning microscope, vacuum absortion, free desortion in water, capillary suction, expansion, salts crystallization and product penetration. The obtained results permit to select the ideal product for this rock type and the natural conditions of the site. To determine hydric properties of rock, 39 cubic samples edged 5 cm were used to study the rock with or without product applications (24 and 15 samples, respectively). Each product was applied to four samples drop by drop or with a brush and only four sides of each cubic sample were treated (the later was done in order to better compare site conditions with and without treatment).

Together with the conservation studies, an engineering project for Fumanya Sud is also being developed. Such project include topography, runoff control and proposals of talus modification. The detailed topography provides the frame where to plan and project any future project or action. The runoff control project includes the study of the hydrological regime, and the design of a set of ditches that stabilize the regolith above the site and captures runoff waters so that they cannot affect the site directly (runoff, infiltration, freeze etc.) or indirectly (infiltration from within the rock).

It is concluded that a long-term preservation of Fumanya Sud site could be planned in a medium size portion (tens of meters) after building a relatively simple structure in the northern part of the site. This simple building would be unnoticed and fully integrated in the landscape. Since the mid eighties (when ichnites were unearthed) no conservation works have been undertaken in Fumanya Sud if we except a very small outcrop at Mina Tumí (close to Fumanya Sud) that recently has been restored successfully. If no restoration is carried out in this, in a few years hardly any dinosaur track will be visible.

CONSERVATION, PROTECTION AND PUBLIC EDUCATION AT DINOSAUR ICHNITES SITES IN EL CASTELLAR (TERUEL, SPAIN)

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The great palaeontological heritage of Teruel province, and an interest in conserving these sites for both scientific research and public education, has led official institutions to pursue a number of initiatives for its patrimonial evaluation. Thirteen of the numerous dinosaur ichnite sites from Teruel have been declared Bien de Interés Cultural (Site of Cultural Interest) and one of them (El Castellar) has been included in a proposal for inclusion in the UNESCO World Heritage List. The Aragón Government is developing a plan to evaluate its palaeoichnological heritage and the public interest by investing in selected sites. In this sense, ichnite sites from the El Castellar area (Teruel, Spain) have been analysed from a scientific and educational point of view by the Fundación Conjunto Paleontólogico de Teruel-Dinópolis.

A great number of dinosaur tracks have been recorded in the Upper Jurassic and Lower Cretaceous sedimentary deposits of El Castellar. Among these, special attention has been paid to the El Castellar, Camino el Berzal, El Pozo and El Hoyo sites. The first three, from the Villar del Arzobispo Formation (Tithonian-Berriasian), contain a number of sauropod footprints and a few theropod tracks. The last one, El Hoyo, shows two theropod trackways in the Barremian Camarillas Formation. To determine the priorities for conservation, we have carried out a quantitative study of the physical-chemical deterioration of the sites.

Due to its high socio-cultural value, two palaeo-ichnological tourist routes have been proposed in the area. The routes take into account not only the sites´ scientific value, but also the surrounding landscape and the presence of related fossil bones. The main route covers the three sites closer to El Castellar village. An alternative trip includes the El Hoyo site, more distant from El Castellar and the main road. Moreover, the proposal includes a plan for site sustainability and adaptability to visitors and the inclusion of other local naturally and culturally valuable sites. Dinosaur fossil bones and replicas could be included in the planned *in situ* installations. All of these proposals have been included in a technical report presented to the Aragón Government. The report includes site descriptions, an evaluation of their heritage, suggested conservation measurements and proposals for tourism infrastructure.

TOPIC : NEW ADVANCES AND DISCOVERIES IN PALAEOICHNOLOGY

FOSSIL EGGS AND COPROLITES: A NEW APPROACH IN THE PALEOBIOLOGICAL INTERPRETATION (BAURU BASIN, UPPER CRETACEOUS, BRAZIL)

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The fossil record from Bauru Basin is represented by vertebrate (dinosaurs, crocodylomorphs, quelonians and fishes), invertebrate (gastropods, bivalves) and vegetal fragments. The paleoichnological evidences that compound part of these fossil remains are constituted by fossil eggs and coprolites produced by dinosaurs and crocodylomorphs.

This contribution related the occurrences of fossil eggs and coprolites found in siliciclastic sediments from outcrops of Adamantina and Marília formations (Upper Cretaceous), belongs to the Bauru Basin, were collected in the Marília County and General Salgado County, of São Paulo State (Adamantina Formation) and the Uberaba County, of Minas Gerais State (Marília Formation).

The Marília Formation is characterized by deposits associated to a proximal-medium braided fluvial system. The Adamantina Formation is characterized by a distal braided fluvial system, with alluvial plains and intermittent small lakes. Both these formations were deposited under hot semi-arid climate.

In the Marília Formation, these ichnofossils are related to the sauropods, preserved in a large number of eggshells and rare complete eggs, however, the most of coprolites are entire and much rolled. In the Adamantina Formation, the eggs and coprolites are associated to the crocodylomorphs, founded in channel bar (sand flat), partial or totally preserved. The eggs were preserved isolated or in clutches, entire or in fragments of eggshells. Likewise, the coprolites are isolated, broked or entire, and rare agglomerated specimens.

These occurrences, registered in these sedimentary rocks, show a kind of association between coprolites (feeding habits) and fossil eggs (reproduction habits), and not only reveals the development of the stable paleopopulation (young and adult individuals), independent of those reptiles taxa (sauropods and crocodylomorph), as well are evidences of adaptation of these continental organisms to paleoenvironmental conditions.

Topic : PALAEOICHNOLOGICAL RECORD OF NON-DINOSAUR VERTEBRATES

Chirotherium barthii – THE VERY EARLY BEGINNING OF DINOSAURS

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The discovery of the tetrapod footprints called *C. barthii* dates back to 1833, followed by the description as the very first scientifically named tetrapod ichnotaxon by J. J. Kaup 1835. A decade later Dinosauria was coined for few osteological taxa from the Jurassic and Cretaceous. At this time and during the following century any relation between dinosaurs and the famous ichnotaxon of the early Triassic was hard to demonstrate by substancial facts.

Nevertheless, the imagination that the footprints and trackways called *Chirotherium* and *C barthii* in particular must belong to animals close to the ancestorship of dinosaurs arose already at the beginning of the 20th century (Walther 1917, Willruth 1917, Soergel 1925). A closer relationship between *C. barthii* and the problem of the origin of the dinosaurs has been formulated with some restrictions in the 1970’s (Demathieu &- Haubold 1978). In the last two decades the phylogenetic hypothesis and cladistic character analyses opened a new window for the understanding of the early evolution of Dinosauria, as nesting within the crown group Archosauria. With this concept and the related pattern of characters the footprints and trackways of *C. barthii* can be demonstrated as to be evident of one of the first steps within Archosauria to the Dinosauria-Aves clade. *C. barthii* presently known globally from trackbearing deposits at the Olenekian-Anisian transition demonstrates:

- full erect gait by narrow trackway pattern, pace angulation close to 180 degrees,
- preformed dinosaurian tridactyl pes is shown by the dominant digit group II-IV,
- preformed bipedal gait is evident by the comparative small manus imprints, and
- the dinosaurian manus digit pattern is shown by reduced function of manus digit IV and V.

The pattern of the Dinosauriformes-Dinosauromorpha-Dinosauria clade is shown to be completed during the Triassic by the sequence of ichotaxa *C. barthii* – *Sphingopus* – *Parachirotherium* – *Atreipus* – *Grallator* (Haubold & Klein 2000, 2002).

Principal information, documenting the early stage of this sequence, comes from the type locality of *C. barthii* near Hildburghausen, Germany. Geological horizon is the Thuringian

Chirotherian Sandstone, Solling Formation, Buntsandstein, of basalmost Anisian. The discovery of 1833/35 concerns a track-surface of about 120 m². During 2003-2004 the main part of the type series has been documented: 70 slabs in 30 museums and collections in Europe. The background of his activity was the construction of a monument ordered by the town of Hildburghausen (Haubold & Schulz 2003). Within this project a large number of the original *Chirotherium barthii* slabs were brought together as casts. These casts were used to reconstruct a part of the original surface. And they were finally assembled to a 3 x 10 m sized surface made of hard plastic mounted at the market place close to the historic major hall in Hildburghausen. The surface displays a selection of 22 slabs with 130 manus and pes imprints, along 40 meters of trackways of *C. barthii*. In front of the track-surface a bronze life size reconstruction of the trackmaker is positioned. This *Chirotherium*-animal follows the skeletal reconstructions of basal archosaurs like *Euparkeria* as interpreted by Paul (2002).

Whenever a discussion about *Chirotherium*, its morphology, interpretation, determination, and its meaning for ichnotaxonomy will be held, this should be done at the "*Chirotherium*-Monument" in Hildburghausen (www.hildburghausen.de).

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BETWEEN THE TYPE-SPECIMENS, TRANSITIONAL MORPHS IN THE FOOTPRINTS OF TRIASSIC ARCHOSAURS

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Footprints of Triassic archosaurs as present in chirotherians and grallatorids are principally characterized by certain features permitting the discrimination of different morphotypes resp. ichnotaxa, ichnogenera in particular. However the distinct imprint shape clearly observed in their type-specimens and hence their ichnotaxon base is sometimes questioned by the presence of transitional morphs revealing influence of different substrate conditions and/ or functional variation. On extended track surfaces that display a large number of imprints or along extended trackways this can be recognized. Problems arise when taxa are established on isolated imprints only, a practise that lead to a high number of taxa in the past, resp. oversplitting of the ichno-record.

Methodically the application of landmark analysis techniques seems to be helpful in the differentiation of imprint forms by supplying more objective data. Thereby anatomically controlled, homologous fixed points in the footprint are determined first. These so-called landmarks are connected to a polygon, which might represent a kind of abstraction of the original footprint shape. By superimposition of the polygons of the different imprints their forms can be easily compared. Differences and similarities of their shape become distinctly visible (see Karl and Haubold 1998; Klein and Haubold 2003, 2004).

Three examples of morph transition in Triassic archosaur tracks partly show similar patterns of variation concerning shape and number of imprinted digits or cross-axis-angle. *Synaptichnium* sp. and *Brachychirotherium* sp. from the siliciclastic marginal facies of the Muschelkalk (Middle Triassic, Anisian) of Germany seem to be part of a preservational series. It brings under question the presence of *Brachychirotherium* at some track surfaces of the Middle Triassic. *Parachirotherium – Atreipus - Grallator* from the Middle Keuper (Upper Ladinian to Norian) of Germany and "*Brachychirotherium*" – "*Pseudotetrasauropus*" from the Redonda-Formation (Chinle Group, Upper Triassic) of New Mexico show transition from pentadactyl to tridactyl and quadrupedal to bipedal pattern. The changing track-morphology is controlled by different substrate condition, variable gait, and evolutionary tendencies in the structure of the locomotor apparatus. Ichnotaxonomic problems which arise from this situation are not solved so far. At the moment comprising series of transitional track morphs in a plexus by using all names of included morphotypes as proposed by Haubold and Klein (2000) seems a practicable way.

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TETRAPOD ICHNOLOGICAL DIVERSITY IN THE LOWER AND MIDDLE TRIASSIC OF NORTHERN ITALY AND ITS POTENTIAL CONTRIBUTION TO CONTINENTAL BIOCHRONOLOGY

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Recent research has led to the discovery of vertebrate tracks in several sites of the Italian Southern Alps. These ichnoassociations appear particularly important due to their excellent state of preservation and the ample vertical distribution of the trampled levels.

Up to now many taxa have been recognized. The most abundant are the footprints of lizard -like reptiles referable to the ichnogenus *Rhynchosauroides* Maidwell 1911. Also present are trackways and footprints that can be attributed to arcosaur trackmakers. Amongst these the ichnogenera *Chirotherium* Kaup 1835, *Brachychirotherium* Beurlen 1950, *Isochirotherium* Haubold, 1971, *Synaptichnium* Nopcsa 1923, *Parasynaptichnium* Mietto 1987, and *Parachirotherium* Kuhn 1958 have been recognised. The ichnological material also includes a few isolated prints referable to probable therapsid reptiles, procolophonids and arthropod trails.

The Permo-Triassic palaeogeography of the Alpine region originated a peculiar geological situation and well exposed sections in which marine sediments, footprint rich continental deposits and volcanites are interfingered. The resulting mixed sections have enabled us to build a framework of stratigraphic and chronological data in which tetrapod footprint-based evolutionary groups can be recognised (Avanzini et al., 2001).

Several observations can be made about the distribution of the tetrapod footprints found in the Southern Alps, in relation to the Lower and Middle Triassic sequence stratigrapy of the same area (Gianolla, De Zanche and Mietto, 1998). From these observations results that levels with tetrapod footprints are much more common in the upper parts of the TST, on the boundary with the maximum flooding surfaces. Sometimes these are depositional sequences, or are sequences of minor order. In these situations the preservation of the trampled layers is optimal due to the rapid burying that occurs during the rapid rise of the sea in conditions of marine ingression. From this point of view, the recognition of layers with footprints in the stratigrafic successions, together with sedimentological analysis could be extremely useful in terms of sequence stratigraphy.

On the basis of the ranges of single ichnotaxa, it is possible to define a series of units that are characterised by a occurrence of a peculiar ichnological association.

The Scythian is characterised by the scarce presence of vertebrates, a factor that is undoubtedly linked to environmental conditions (palaeogeography) which did not favour the permanence in the Southern Alps of complex and consistent faunal associations. The Scythian ichnoassociations are dominated by *Rhynchosauroides* amongst which *R. palmatus* (Permian survivor) and R. schochardti are peculiar.

In the Anisian, a progressive increase in the complexity of the ichnoassociations and the size of the taxa from the Bithynian to the Illyrian is documented. Unlike what happened at the base of the Pelsonian, the Middle Pelsonian and the Illyrian are dominated by medium-large chirotheroids.

The detailed analysis of the stratigraphical distribution of ichnofaunas crossed with the sequence stratigraphy and the ammonite biostratigraphy as led to the identification, within the Pelsonian - Illyrian interval of several taxa characterised by a narrow vertical distribution associated to taxa which have a more generalised presence in the Anisian. Is seems likely therefore, that the use of these ichnoassociations could represent a useful instrument for the definition of continental units which do not have elements traditionally used for dating.

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FISH SWIMMING TRAILS (*Undichna*): FOSSIL EXAMPLES, TAPHONOMY AND PALEOBIOLOGY

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The importance of fish in the vertebrate ichnological record is much lesser than that of tetrapods. That, of course, has to do with the fact that fish are swimmers that inhabit the water body, and many of them never or only occasionally interact with the sedimentary substrate. Nevertheless, several types of fish trace fossils are known, including burrows (such as those produced by lungfish), excavation pits (such as those produced by rays) and swimming trails. The latter are the most frequent and they are formed by fish swimming while touching the benthic floor. These fossil trails are classified within the ichnogenus *Undichna*, which currently includes thirteen valid ichnospecies. All of them are characterized by the presence of one or several, paired or unpaired sinusoidal trails produced by the contact, with the sedimentary substrate, of one or several, paired or unpaired ventral anatomical elements (fins, in most cases).

The morphology of a particular trace fossil of *Undichna* is controlled by a set of factors: a) ventral anatomy of the trailmaker, b) mode of swimming, c) trajectory, d) speed, and e) external factors (current, type of substrate, etc.). A and b have to be considered in ichnotaxonomy (at the ichnospecies level) while the others are responsible for taphonomic and minor-behavioral variations that do not warrant ichnotaxonomic treatment.

Undichna is commonly found in fossil sites that have also yielded fish body fossils. This allows in many occasions for a comparison between the anatomy of the presumed trailmaker (as interpreted from trail parameters) and the anatomy of those fish species known from the body fossil record. This comparison may lead to the assignation of the fossil trail to a particular fish species with a variable degree of certainty.

Although fish have inhabited almost any aquatic environment since the Devonian and before, the fossil record of *Undichna* exhibits an irregular paleoenvironmental and stratigraphic distribution. This situation is in part a reflection of a bias resulting from taphonomic factors. *Undichna*, by being a subaquatically-produced epigenic trail, has a low preservation potential.

Nevertheless, the combination of a series of factors - absent or scarce burrowing infauna, semiconsolidated very-fine-grained sediment, low energy conditions, rapid burial (Gibert et al., 1995) - may contribute to increase that potential. All known occurrences of *Undichna* comply with those taphonomic conditions as indicated by sedimentological and ichnological data. Thus, *Undichna* is preferentially, but not only, preserved in lacustrine settings with stressed benthic ecological conditions (such as those derived from low oxygenation or low temperature) and in settings affected by short-term subaquatic conditions (such as those taking place in intertidal flats or alluvial floodplains).

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VERTEBRATE FOOTPRINTS FROM A NEW AEOLIAN OUTCROP FROM SOUTHERN RHODES, GREECE

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In coastal areas of the SW part of the island of Rhodes, Greece, Aeolian sediments represent the latest depositional phase, and are presumed to have a Late Pleistocene to Early Holocene age. The aeolianites are ooilitic, the ooids having large sand-sized nuclei, and are lightly cemented by a vadose meniscus cement. In a road cutting, supplemented by minor sections in small, ancient stone quarries nearby, the sedimentary architecture and trace fossils are visible. The dunes have a ramp morphology and contain three horizons of palaeosols that divide the Aeolian sediments into three units. The palaeosols contain rhizoliths and poorly preserved invertebrate trace fossils. The aeolianites contain tracks of mammals, distinguished in five size classes. Vertical sections allowed representative measurements of 79 tracks and limited horizontal surfaces supplied 4 measured tracks. The three smallest size-classes are probably of artiodactyls. The largest class probably was produced by probascidians. A bedding-plane view of one track indicates that the next-largest class may be the work of camels. If this is the case, and the bedding-plane specimen is convincing, it is the first record of Pleistocene or Early Holocene camels on Rhodes. The ichnofauna differs in the three investigated units, suggesting different fauna compositions in the different times of deposition.

SEDIMENTOLOGICAL SIGNIFICANCE OF CHELONIAN ICHNITES: EXAMPLE FROM THE ARTÉS FORMATION (EOCENE FROM THE EBRO BASIN, NW SPAIN)

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The Ebro basin (NE of the Iberian Peninsula) has a Cenozoic sedimentary filling of up to 3000 meters. The basin has two sedimentation stages: a lower marine and an upper continenal one. Continental lithologic units (dominated by the Artés formation) occur in both stages. The disconnection from the sea took place at the beginning of the Priabonian (Eocene) together with the sedimentation of the a thick evaporite sequence. This sequence comprised the precipitation of a thick chloride unit at the basin depocenter (Cardona formation), and to a thinner sulphate belt (Òdena gypsum). Laterally, this sulphate belt evolves to carbonate stromatolithic that further evolve to the red beds of the Artés formation. The architectural and genetic relationships of this lateral evolution is complex, since the continental units of the marine and continental stages are rather similar.

The study of the ichnological record (both vertebrates and invertebrates) found in the Artés formation provide interesting evidences that help the undestanding of the basin continentalization. We present and discuss a set of icnites found in several slabs in a site found in 1995 in the surroundings of the city of Manresa (Barcelona province). In several layers of laminated mudstones superimposed small tracks which are regular, sinuous and continuous. Manus and pes are observed and indicate a tetrapod and quadruped tailed animal. A large number of parameters and measures were taken in order to get some features of the track maker, which clearly belong to a little turtle. Abundant swim tracks are also found, which suggests deposition in quiet waters with changing water level. The whole set of sedimentological and ichnological data indicate deposition in a clastic muddy plain laterally related to algal mats.

We have also experimented with the tracks produced by a young specimen of the Florida turtle (*Chrysemys scripta*).

The experimental pattern is very similar if compared with that of the fossil tracks. So that a turtle close to the present day *Emydidae* family could have been the track maker. This attribution is in agreement with the only turtle skeletal remains found in similar stratigraphic positions of the area.

BIRD AND MAMMAL TRACKS AND INVERTEBRATE TRACES IN PALEOGENE ALLUVIAL-LACUSTRINE TRANSITION DEPOSITS, NE EBRO BASIN, SPAIN

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During the Late Eocene-Oligocene (Priabonian-middle Rupelian) two fluvial fans (megafans) occupied the south-Pyrenean margin of the eastern Ebro Basin (Spain). They passed distally into a shallow, low gradient lacustrine system (playa-lake) developed in the center of the basin under semiarid climatic conditions. Depending on the lake level, the distal part of the fluvial fans developed terminal fans (low lake level) or fluvial-dominated deltas (high lake level) (Sáez *et al*., in press).

The terminal fan deposits are constituted by thin tabular sandstone beds amalgamated or intercalated with finely-laminated mudstones. The sandstones display low density turbidite-like features (indicative of subaqueous deposition) deposited by sheet and flash floods. Nevertheless, these facies bear an important and very distinctive paleoichnological record consisting of vertebrate tracks and invertebrate trails, pointing out short-lived subaquatic conditions. Inorganic sedimentary structures, such as rain drops or desiccation cracks are in agreement with trace fossil interpretation.

Although trace fossils are abundant in several localities, this contribution is mostly based in material from the section at Sanaüja (Lleida province). The vertebrate trace fossil assemblage is characterized by the abundance of bird footprints. These consist of three digits pointing forwards and a much shorter one (not always preserved) pointing backwards. The ichnotaxonomic attribution of these avian tracks is still undecided, although they are temptatively attributed to the ichnogenus *Charadriipeda*.

Mammal footprints are much rarer. They include cf. *Entelodontipus* and *Plagiolophustipus* cf. *montfalcoensis*. The first are locally numerous small didactylar footprints (less than 2 cm long) produced by a small artiodactyl. Only two tracks corresponding to *Plagiolophustipus* have been recovered. They are tridactylar with a central larger digit and about 4 cm long. They can be attributed to a paleotherid (Perissodactyla). While avian footprints can be interpreted as produced by a shorebird species living and feeding at the lakeshore, the ungulate tracks probably correspond to animals that approached the lake margins for drinking.

A fourth type of vertebrate footprint is seen in some outcrops as vertical sections. They have a variable width (between 5 and 10 cm) and may penetrate the sandy sediment up to 10 cm or more producing a downward bending of the layers around the footprint. Preservation does not allow ichnotaxonomic or tracemaker assignation for these structures, although they had to be produced by a mammal of larger size and weight than those producing the previously described tracks.

Invertebrate traces include horizontal meniscate burrows of the ichnogenus *Taenidium*. They are common and often responsible for extensive bioturbation on top of sandstone beds. *Taenidium* was probably produced by worms or insect larvae.

The described trace fossil assemblage corresponds to the Scoyenia Ichnofacies as Buatois and Mángano (1995) redefined it. This archetypal ichnofacies is known to characterize settings with an oscillating water table, occasionally but not permanently submerged. Vertebrate tracks and invertebrate meniscate trails are preferentially produced and preserved in wet softgrounds which can be very extensive in low-gradient lakes. In particular, the vertebrate ichnoassemblage corresponds to the 'shorebird ichnofacies' of Lockley *et al*. (1994), which can be considered as a subset of the Scoyenia Ichnofacies and typifies lakeshore (and also tidal shore) depositional settings.

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OLIGOCENE MAMMAL FOOTPRINTS FROM CASTELLTALLAT MOUNTAINS (BARCELONA, SPAIN)

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Ichnological studies on the exceptional mammal footprints site at Can Prat Barrina have been worked out (Aragones and López, 2001). The site is located in the northern side of the Castelltallat mountains, close to Sant Mateu de Bages (Barcelona, Spain), 500 m. south of the Prat Barrina farm. Tracks and isolate ichnites are located at the top of a fine sandstone bed. To avoid damage, no excavation was realised and no fossils remains were collected from the site. Geologically it belongs to the northern slope of the Suria semidiapiric anticline, located in the tertiary facies of the Ebro Basin. The sediments are dated as Lower Oligocene in previous geological studies (IGME, 1973, Sáez, 1987).

Some hundreds of ichnites are recognised, they mainly corresponds to one single ichnospecies, produced by a medium to big size mammal, probably an artiodactyl as being inferred from the ichnites morphology.

The first report of tertiary ichnites from the Ebro Basin was published by Hernández-Pacheco (1929), describing some birds' footprints from Peralta de la Sal. Fifty years later, Casanovas-Cladellas and Santafé-Llopis (1974) described the first vertebrate ichnites from the Agramunt syncline. This paper was the beginning of a set of papers of different authors on the rich and diversified ichnites from the Agramunt area (Casanovas-Cladellas and Santafé-Llopis, 1982, Santamaría, López and Casanovas-Cladellas, 1989-90 and Prats and López, 1995).

The lithology of the Prat Barrina site represents an ancient lakeshore, very close to the shoreline according to Cohen *et al.* (1991) data. Ichnites show different degrees of preservation that are clearly related to the humidity degree of the sediment as well as to the deformation of the soft sediment related to movement of a high number of these big mammals.

The great concentration of big vertebrates at the lakeshore, the different preservation degree of ichnites and the deformation of the sediment seems to support the palaeoclimatic hypothesis of a temporally rain climate, common of the alluvial systems.

Entelodontipus

The dimensions and shape of the ichnites are very close to those of the authopods of the suid *Entelodon* (Romer, 1966), and bone remains of *Entelodon magnum* are known from the close Oligocene site of Rocallaura, Segarra (Golpe, 1971). We tentatively relate the ichnites of the Prat Barrina site to the ichnogenus *Entelodontipus*.

This ichnogenus has been also reported in other areas of the Ebro Basin as the Agramunt syncline (Casanovas-Cladellas and Santafé-Llopis, 1982, and Prats and López, 1995) and Olcoz area, in the Navarra province (Astibia, del Valle, and Murelaga, 1994).

Footprints tracks are exceptionally numerous and a lot of them are crossing and overlapping ones to others. Artyodactil displacement occurs at the side of a temporal lake as reported from the sediment texture and deformation, especially at the site areas showing the highest ichnite density. A main track direction is recognised, following a parallel way to the Castelltallat Mountains in both to NW and to SE. The tracks direction shows an outward journey and return to a water reservoir area to drink. A great morphological variation is observed in the same ichnospecies, mainly reflecting the sediment consolidation degree on each part of the site as well as the different size and velocity of each animal.

Acknowledgements:
We thank Joan Muns, owner of Can Prat Barrina, and his family, as well as Anna Duocastella, owner of Can Biosca, for their support and help during the fieldworks, allowing us access to their properties. The Arqueological Survey of the "Direcció General del Patrimoni Cultural" has allowed us to develop the fieldworks.

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A REINDEER FOOTPRINT IN A DRILLING CORE FROM THE ALLERØD-BØLLING AGE SUCCESSION OF LILLE SLOTSENG BASIN, SOUTH-EASTERN JYLLAND, DENMARK

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A Subfossil reindeer track was localised in a drilled core from the Late Glacial Slotseng lacustrine basin, located in the south eastern part of Jylland near the town of Jels. It was dated to 11,795 ±80 ^{14}C yr BP or around 13,780 cal yr BP. During an earlier excavation of the site four skeletons of reindeer were recovered from the early Bølling succession dated to 14.200 cal yr BP. The Slotseng lacustrine basin is a kettle hole basin and almost circular with a diameter of 23 m. The over all transgressive late Glacial and regressive Holocene lake sediment succession covers the time period from 16,000 to around 8,000 cal yr BP years. The basin sedimentation starts with old melt water deposits just below the Bølling Interstadial (GI 1-e), followed by older Dryas (GI 1-d), Allerød, (GI 1-c, 1-b, 1-a) and Younger Dryas (GS 1) which terminates the Late Glacial succession. Preboreal algal gyttja and near shore woody peat from the Boreal and onset of the Atlantic Time, cover the basin. Hitherto, no convincing tracks have been recognized and described from drill cores. The reindeer track from the Slotseng Basin is the first convincing track recognized from a drill core section.

THE MIOCENE ICHNITE SITE OF SALINAS DE AÑANA AND ITS RELEVANT CARNIVORE TRACKWAYS (ALAVA, SPAIN)

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The lower Miocene tracksite located near Salinas de Añana (Alava, Spain) (Laumen, 1989; Antón *et al*., 1993, 2004) shows an exceptionally well preserved assemblage of vertebrate ichnites. About 60 square meters of the site have been excavated until now. More than 700 footprints have been recorded and many of them belong to clear trackways.

The greater part of the ichnites are attributed to mammals, but the ratio between carnivores and herbivores is surprisingly, the site shows a high 10 proportion of carnivore tracks (3 out of 5 mammal ichnospecies) and a high number of individual trackways (15), some including over 50 consecutive footprints. Co-occurring with this high and impressive number of ichnites related to carnivores, there are others related to a small ruminant, as well as many footprints of a small artiodactyl that cannot be easily grouped into individual trackways and are attributed to a member of the family Cainotheridae. In addition to the mammalian trackways, the site also preserves two bird ichnospecies.

The Salinas de Añana section that includes the track-bearing beds is sedimentologically characterized by an alternation of sandstones and silt beds with load casts related to the high original water content of the sediment, some fine-grained limestones with charophytes, and Pulmonata gastropods related to lake facies.

This stratigraphic sequence clearly corresponds to the distal part of a fluvial system close to some lakes (facies association FA VII of Dreikluft, 1996). The sediments are dated as Burdigalian in previous geological studies and the ichnites are consistent with this age (Antón *et al*., 2004).

The carnivore tracks:

The great abundance of carnivore trackways is remarkable, considering that carnivore ichnites are rare in the fossil record, so that even in exceptional tracksites with long trackways of other mammals only isolated footprints of carnivores are usually found. Also, and in the rare cases where trackways are available, preservation of morphological detail is usually poor. The tracks from Salinas allow the most detailed study to date of the locomotion of Miocene carnivores, as well as morphological comparisons that reveal the phylogenetic affinities of the trackmakers.

The carnivore ichnites are classified as *Felipeda lynxi* Panin & Avram, 1962, *Felipeda parvula* ichnosp. nov. and *Canipeda longigriffa* Panin & Avram, 1962, and they are attributed to a felid, to an undetermined small aeluroid, and to a herpestid, respectively. The long trackways allow determination of gaits, which include lateral sequence walks and diagonal sequence trots, and of speed, which ranges from 0.4 to 1.4 m/s. Froude numbers range between 0.1 and 0.8, agreeing with gait interpretations and speed calculations.

The felid trackways provide the first known evidence of group travelling in fossil cats. This would indicate that, as in modern cats, cubs remained with their mother at least until reaching nearly adult size.

The herpestid footprints show modern-grade adaptations for terrestrial locomotion and digging.

The mongoose tracks are significant because herpestid fossils are first recorded in Europe by MN4, in the early Aragonian. The abundant tracks of a minute artiodactyl attributed to the family Cainotheridae are also important because this family is last recorded in biochronological zone MN 6. According to the biochronological scheme proposed by Mein (1979), the above data date the site between the beginning of MN4 (20 Ma) and the end of MN 6 (15 Ma).

All the tracks are preserved in a fine-grained limestone, indicating an ancient lakeshore. The remarkable detail of the footprints suggests that they were produced near the shoreline, within the strandline zone. In this zone the water content of the sediment allows excellent preservation of small animal footprints, but high bioturbation tends to destroy them quickly, so burial must occur within days of ichnite production to allow preservation. These data point to a lacustrine basin subject to sudden, seasonal floods, one of which buried the tracks and led to their preservation. This conclusion is also supported by detailed sedimentologic studies and regional palaeogeographic reconstructions on our studied area (Dreikluft, 1996; Laumen, 1989), that consistently report the presence of braided rivers and ephemeral floodplain lakes during the Oligocene and lowermost Miocene in this region.

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HOMINID ICHNOLOGY REVISITED: A BRIEF OVERVIEW OF A NEGLECTED FIELD

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With few exceptions, there has been little detailed documentation of many interesting hominid tracksites, especially in mainstream literature. Thus, hominid ichnology has been something of a neglected field that falls between various anthropological and paleontological sub disciplines. Indeed hominid ichnology is difficult to define, because traces include not only footprints, but all manner of other records ranging from butcher marks on bone to cave art, inscriptions, traces of building construction and, arguably, almost every other trace of human activity. For practical purposes therefore we confine our discussion to footprints that have a minimum antiquity of several centuries or millennia. Based on these criteria there are many tracksites, some recently discovered, that are being re-investigated or investigated for the first time. The results of these studies will appear in a forthcoming volume that will be the first to embrace the whole hominid track record from +3 million years until recent historical times.

The most famous and oldest (Pliocene, ca. 3 mya) hominid footprints, from Laetoli in east Africa, have been attributed to australopithecines. The African track record also yields Early Pleistocene (> 1 mya) tracks attributable to *Homo erectus*. In the adjacent continent of Europe, no such ancient tracks are known, despite the recent discovery of “mid” Pleistocene tracks in Italy estimated at about (325,000- 385,000 yrs). However, Europe is famous for many late Pleistocene sites, especially those associated with cave sites where track preservation is often of high quality. There are also a growing number of reports of Holocene, Mesolithic and Neolithic sites associated with estuarine, littoral and settled sites.

By comparison with Africa and Europe there are comparatively few reports of ancient tracks in other parts of the old world (Asia and Australasia), although recent reports of “Late Pleistocene” tracks from Korea are of great interest. Likewise in the new world reports of hominid tracks are scare, and restricted to comparatively recent (Holocene) deposits, as would be predicted by the inferred historical patterns of hominid migration. However, this picture is changing as new reports emerge of pre-Holocene tracks in Chile and Mexico.

Hominid tracksites can be broadly divided into surficial, outdoor and subterranean, cave sites. The former often reveal many mammal and/or bird tracks that help reconstruct local paleoecology. A significant proportion of such sites occur in volcanogenic substrates. Cave sites only reveal associations of hominid and mammalian carnivore tracks. At both outdoor and cave sites differences in the size, morphology and distribution of hominid tracks have generated inferences about the age, health and behavior of the trackmakers.