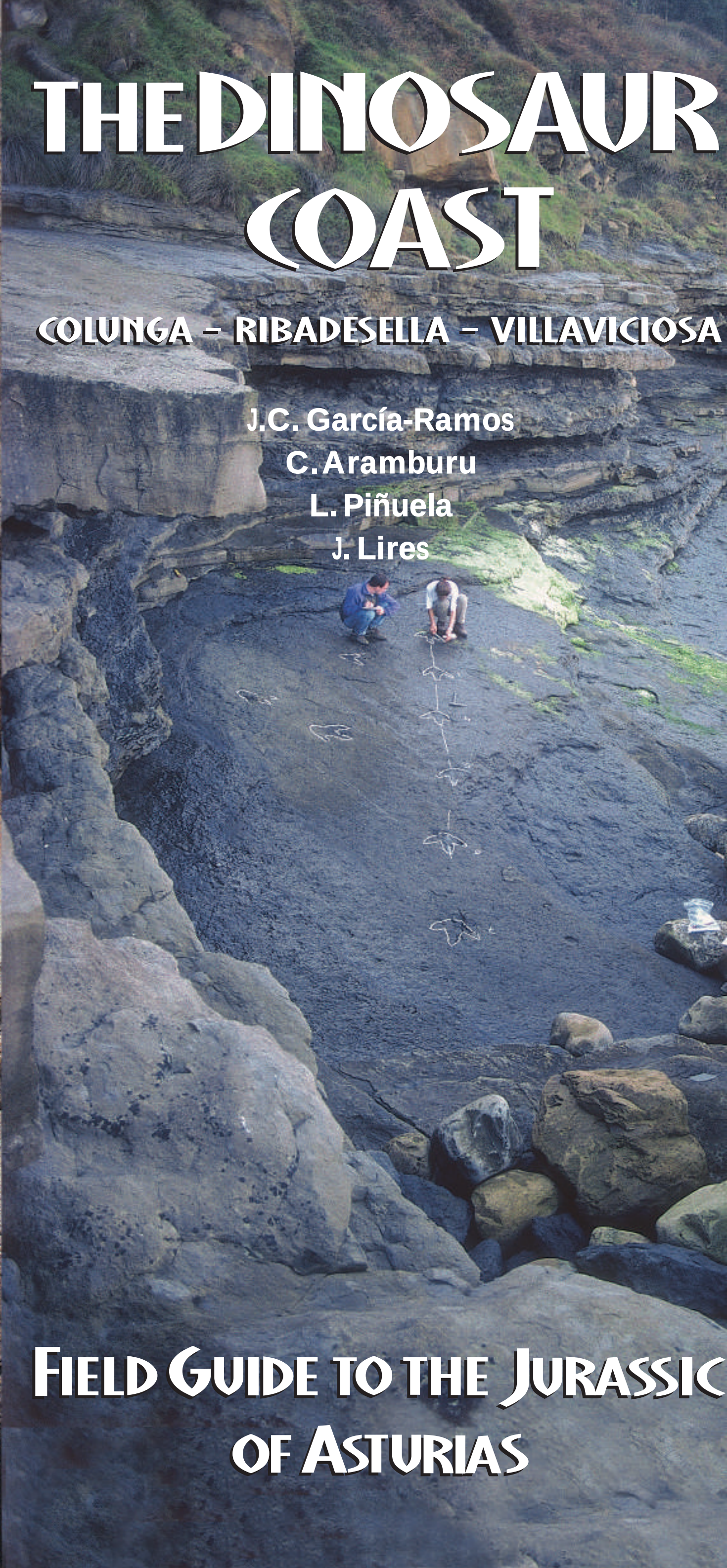

# THE DINOSAUR COAST

## COLUNGA – RIBADESELLA – VILLAVICIOSA

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## FIELD GUIDE TO THE JURASSIC OF ASTURIAS

# Index



## Field guide to the Jurassic of Asturias:



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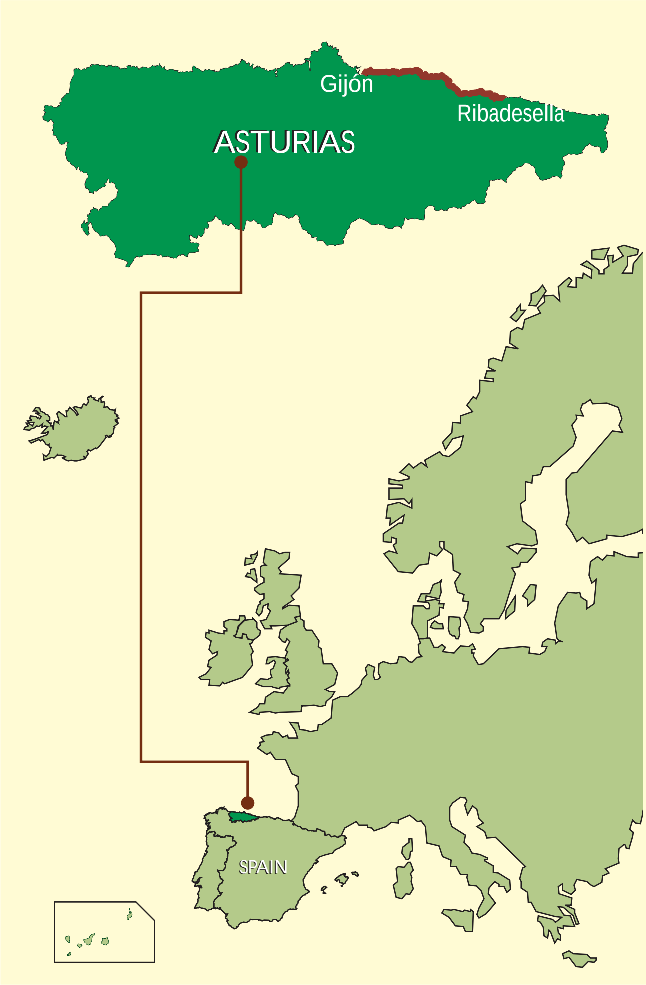
**Front cover:** Trackers studying the trackway of a bipedal dinosaur. El Toral cliffs (Villaviciosa)

**Back cover:** Pes print of a flying reptile (pterosaur) preserving skin impressions

# THE DINOSAUR COAST

The Dinosaur Coast refers to the section of the Asturian coast between the villages of Gijón and Ribadesella, which contains abundant footprints and fossil bones from dinosaurs and other Jurassic reptiles.

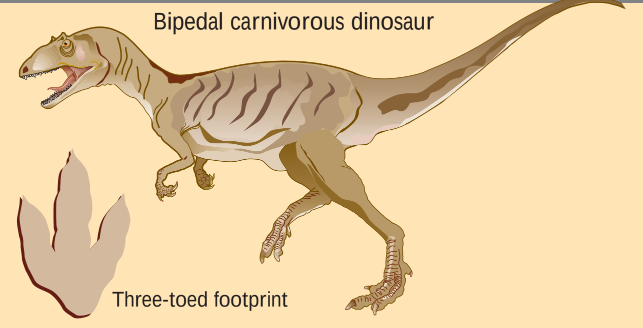


The term "dinosaur" (terrible lizard) was coined by the British paleontologist Richard Owen in 1841. However, the first bones initially attributed to these unknown reptiles were found in several localities in the south of Britain in the 1820s.

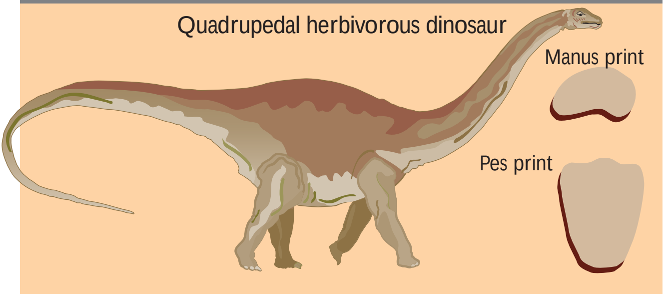
Dinosaurs represented a particular group of land reptiles of great evolutionary success, which ruled our planet over a period of about 165 million years, extending from 230 m.y. (when they appeared in the Late Triassic) to 65 m.y. ago (time of their extinction at the end of the Cretaceous). This period of time corresponds to the greatest part of the Mesozoic Era. There were still 63 m.y. to go before the human race appeared on Earth.

Over their extensive lifespan dinosaurs diversified and went through numerous evolutionary transformations. Moreover, they lived in a variety of ecological niches, all of them on dry land, though they could also sporadically wander into the waters of lakes, marshes, rivers and bays. Nevertheless, none of them were aquatic or could fly, unless birds are regarded as their descendants, as the latest research suggests.

## THEROPOD




## SAUROPOD



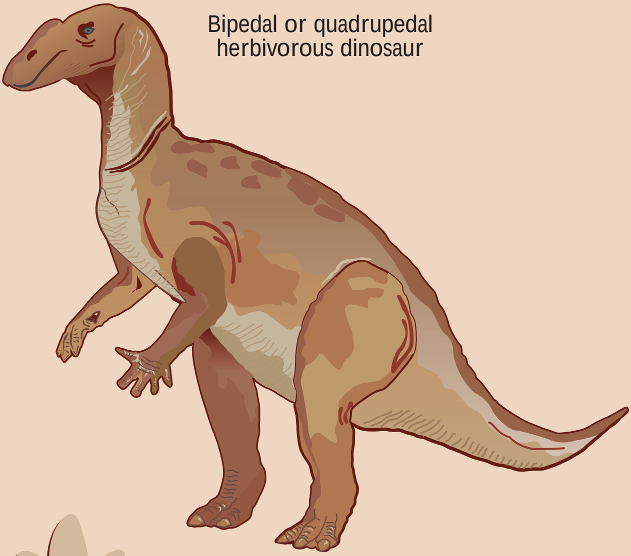
The size of dinosaurs varied widely, ranging from the bird-size of the smallest adults to the eighty-ton-weight of the largest specimens (roughly the weight of 20 elephants).

A characteristic of dinosaurs is that their extremities emerge below their body, in a vertical orientation, whereas in most reptiles the extremities emerge laterally in an arched orientation.

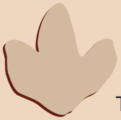
Dinosaurs can be classified according to their pelvic structure in two distinct groups: saurischians (reptile-hipped) and ornithischians (bird-hipped). The former include theropods (carnivorous, bipedal and three-toed) and sauropods (herbivorous and quadrupedal). Ornithopods (herbivorous, bipedal and three-toed; sometimes also quadrupedal) stood out among ornithischians, together with duckbilled, plated (stegosaurs), armoured (ankylosaurs) and horned dinosaurs (ceratopsians). All these were herbivorous.

According to their mode of locomotion, dinosaurs can be classified into bipeds and quadrupeds. The former, such as theropods and most ornithopods, walked upright like big flightless birds (ostriches), though some of them (certain ornithopods) could also move on their four limbs on the ground. In contrast, quadrupeds, such as sauropods, or horned, plated and armoured dinosaurs, moved on fore- and hindlimbs simultaneously, like present-day rhinoceros.

## ORNITHOPOD



Bipedal or quadrupedal herbivorous dinosaur



Three-toed footprint.

Natural cast of a small carnivorous dinosaur footprint in a sandstone bed with desiccation cracks

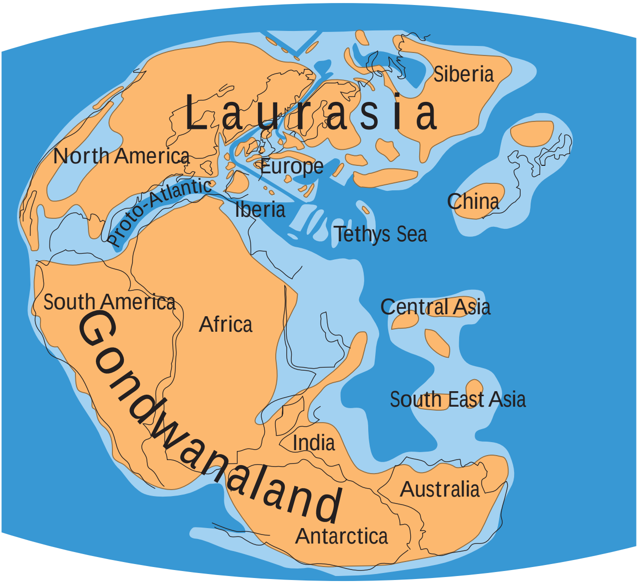
The term "Jurassic" owes its name to the Jura Mountains, which extend along the border between France and Switzerland.

The Jurassic Period, which lasted about 62 m.y. (from 206 m.y. to 144 m.y. ago) is situated between the Triassic and the Cretaceous periods and constitutes the central part of the Mesozoic Era, in turn limited by two significant biological events: the late Permian extinction (the most devastating of all known extinction processes) at its beginning and the late Cretaceous extinction (the most famous one because dinosaurs became extinct in it) at its close.

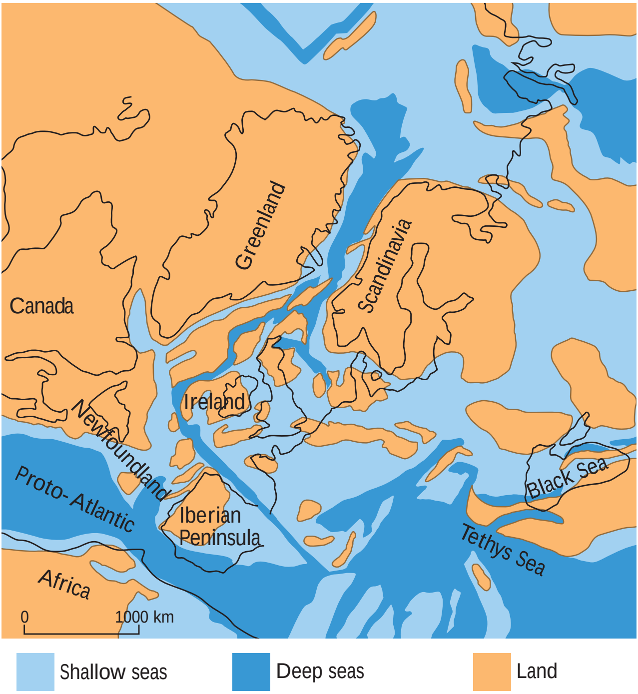
As regards dinosaurs, this was the time when big sauropods flourished as the dominant life-form. They appeared in the Early Jurassic and reached their peak and highest diversification in the Late Jurassic. Birds appeared in the Late Jurassic as well. Grass did not exist and flowering plants had not yet developed.

It was at the start of the Jurassic that the progressive breaking up of the supercontinent Pangea began, which gradually gave rise to the continents and water masses as they exist today. In that world there was an apparent lack of ice at the poles and the temperature differences between the polar and the equatorial regions were far less marked than nowadays.

Fossil tree-trunk with roots in upright position




**Tentative reconstruction of continents and oceans during the Upper Jurassic, 150 million years ago. After Benton (1996) and Ziegler (1988)**



When moving on a soft sediment (mud or sand) dinosaurs left a series of impressions called footprints or "ichnites". A set of footprints heading in a particular direction is termed a "trackway".

**Bipedal dinosaur trackways in several directions. Oles cliffs**

Footprints can provide valuable information about the behaviour of dinosaurs and the environment in which they lived. In addition, the study of tracks enables us to complete the data obtained from their fossilized bones.

Unlike bony remains, which need to be extracted from the rock and cleaned up for further study and classification in the laboratory, tracks often provide a more direct type of information through examination of the surface of the bed in which they occur. Tracks also indicate the exact place where the dinosaur walked, whereas bones are not always found where the dinosaur died, but were often transported by currents.

Careful study of the footprints can indicate if the dinosaur was small or large, herbivorous or carnivorous, whether it walked on two feet (bipedal) or both fore- and hindlimbs (quadrupedal), the approximate shape and number of toes/fingers on the hindfoot or forefoot, and if the print was from the left or right limb.

Various measurements can be made on the single prints, such as length, width and depth for bipedal or quadrupedal dinosaurs; additional features such interdigital angles can be measured for tridactyl prints from theropod and ornithopod dinosaurs. In quadrupedal dinosaurs, it is also possible to measure the manus-pes length and the manus-pes distance.

Among quadrupeds, the outstanding characteristic of sauropods was that they left pes footprints which were very different from manus footprints, both in shape and size. Hindfoot print are bigger and they usually end in five very short toes, whereas forefoot prints seldom show finger impressions. On the contrary, other quadrupeds, such as armoured dinosaurs and horned dinosaurs, show only minor differences in the shape and size of tracks of their fore- and hindlimbs.

In footprints from three-toed bipedals, the ends of the toes can be either rather blunt (ornithopods) or very sharp-pointed, corresponding to imprints of claws (theropods).

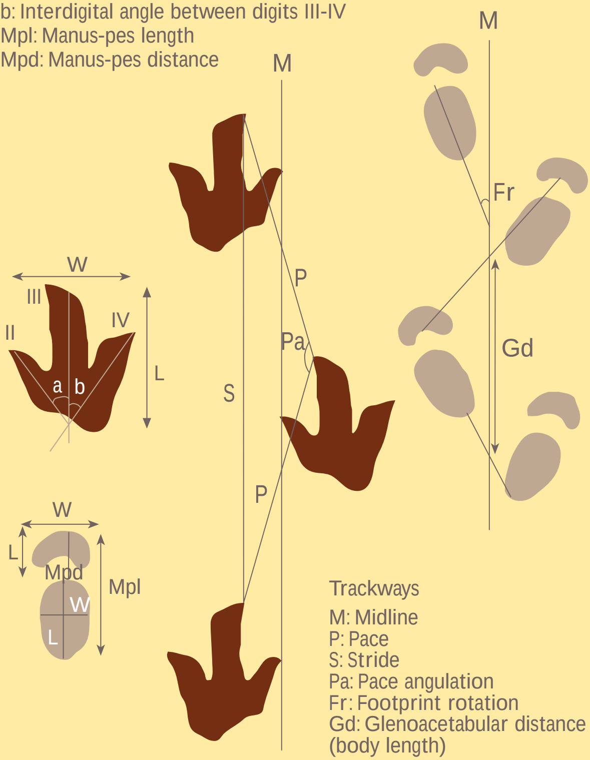
In the trackways (both from bipedal and quadrupedal dinosaurs), common measurements are the pace and pace angulation, the stride, footprint rotation (the angle the prints form with the midline of the trackway) and the internal and external width of the trackway. The body lenght, or glenoacetabular distance, is measured only for quadrupeds.

As a rule, quadrupedal dinosaur trackways are wider than those of bipeds, as a result of their different body structure. Moreover, trackway width is in turn inversely proportional to the length of limbs and to the animal´s movement speed.

## MEASUREMENTS USED IN DESCRIBING BIPEDAL AND CUADRUPEDAL DINOSAUR TRACKS AND TRACKWAYS

Individual tracks

L: Footprint length
W: Footprint width
a: Interdigital angle between digits II-III
b: Interdigital angle between digits III-IV
Mpl: Manus-pes length
Mpd: Manus-pes distance




Trackways

M: Midline
P: Pace
S: Stride
Pa: Pace angulation
Fr: Footprint rotation
Gd: Glenoacetabular distance (body length)

# Tracks Fossilization

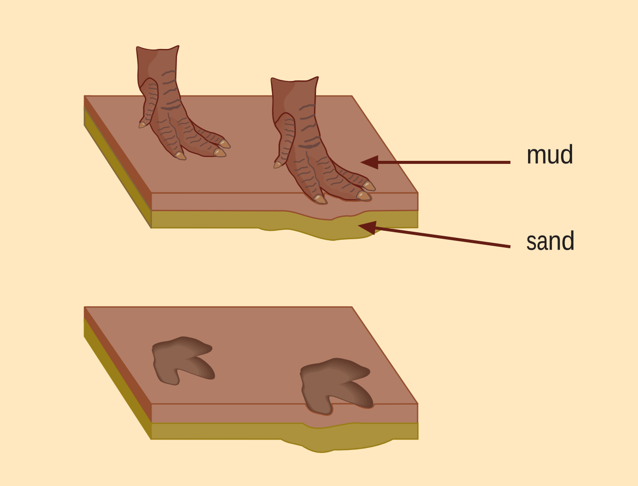
The dinosaurs left their footprint in a soft substrate (like we leave our footprints in soft mud). Only later, after being deeply buried, was this soft substrate converted into hard rock.

For a track to fossilize in a bed a series of conditions must be previously met. First of all, the composition of the sediment on which the track is created must be different from that which fills it afterwards. This happens, for example, when a dinosaur treads on mud leaving a hollow which is later covered by sand, resulting in a natural cast. Furthermore, it is essential that once formed the track should not be destroyed by erosive agents such as water currents or wave action. A track can also be altered by biological agents such as the steps of other dinosaurs.

When a dinosaur trod on soft ground, it caused a deformation not only on the upper bed but also on the immediately underlying strata, where it also created impressions of increasingly more diffuse and rounded shape called "undertracks".

The depth of a certain footprint will depend on the weight of the dinosaur as well as on the texture and composition of the sediment on which the animal treads. Thus, for instance, deeper tracks will be created on the soft mud of a pool than on the sand of a beach. Also, there will be differences between two sediments with the same composition but a different degree of moisture (for example, water-saturated mud or dry mud). In the former the depth of a track will be bigger and its contour more diffuse.

## Formation and preservation of footprints



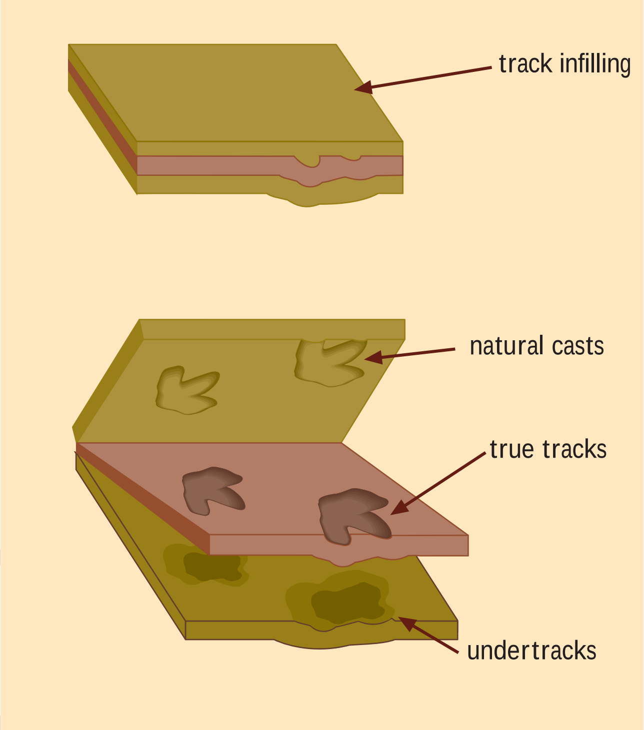
# The Jurassic Landscape in Asturias

The most spectacular rock outcrops from the Jurassic in Asturias extend along a practically continuous segment of coast between Cape Torres (west of Gijón) and 2 km east of Ribadesella, limited in both cases by important faults which relate them to much older rocks belonging to the Paleozoic Era.

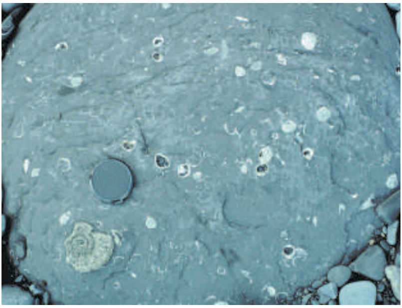
One way to order these rocks systematically consists in grouping them together in sets of similar features known as "formations".

According to this criterion, the Jurassic rocks in Asturias can be classified into different formations, chronologically ordered from the oldest to the youngest, thus creating a so-called "stratigraphic series".

Detailed study of these rock formations has allowed a reconstruction of the Jurassic landscape in Asturias. This look back on the past, however, cannot be assessed in a general way, but through successive stages, as the landscape underwent many changes over a long period of time that lasted 62 million years.



# THE GREAT MARINE INVASION IN THE EARLY JURASSIC



**Cross-section of a marine grey marl with oil-infilled brachiopods and a pyritized ammonites fragment**

The Gijón Formation, which marks the beginning of the Jurassic history in our region, consists of limestones and dolomites which accumulated on a flat, irregular coast, rich in carbonate muds, in a slightly arid climate. This favoured the accumulation of salts, exploited until a short time ago near Gijón. The relief was rather flat, without mountains, and the coastline was NW-SE oriented.

A bit later the sea level began to rise slowly, spreading all over the region, which sometimes was submerged down to depths of even 50 m. That sea displayed a rich and varied fauna with predominance of molluscs, brachiopods, crinoids, crustaceans and worms. Bivalves and cephalopods (ammonites and belemnites) were abundant among molluscs. There were also big sea reptiles, such as icthyosaurs and plesiosaurs, swimming in these warm waters. Evidence of these species has remained in their fossilized bones.

The most characteristic marine rocks from this first half of the Jurassic are the thick rhythmic successions, made up of limestone-marl alternations, like the ones cropping out on the cliffs in Huerres (Colunga), Peñarrubia (Gijón), and on the beaches of Rodiles and Vega.

These rhythmites, known as Rodiles Formation, contain different dark grey marly levels (black shales), rich in organic matter which even generated oil. Remains of it have been preserved in the inside of some fossils and in small rock fissures.

**Fossil shells of cephalopods (belemnites) and bivalves in a marine limestone. Santa Mera cliffs**

# The Tectonic Activity in the late Jurassic

**Folded and faulted Jurassic strata. Oles cliffs**

At the outset of the Late Jurassic the landscape in Asturias underwent a drastic change which resulted in a quick uplift and emersion of the land due to the tectonic activity. This gave rise to an irregular relief, specially marked towards the southwest. Siliceous sediments originated in this part of the region and began to be deposited in the whole area. These sediments arose from the relief erosion of Paleozoic rocks which showed above the surface of the ground because of fault activity .

The material resulting from the erosion of this relief (gravel, sand, mud) was drifted by river courses to a coast which must have lain to the east of the region. This material makes up the Vega Formation nowadays.

The climate exhibited certain aridity at that time, judging both by the existence of carbonate fossil soils called "caliches" and by the vertical arrangement of root traces, which evidences a low phreatic level.

The area corresponding to present-day Sueve Range was also partially raised by faulting, and most Jurassic marine rocks accumulated in the previous stage were eroded away by natural agents.

This emersion, which resulted in a sudden shift from sea to continental conditions, became spectacularly displayed in the geological record due to a distinct contact between carbonate and siliceous rocks, such as that which can be observed in the Jurassic rock successions on the coastal cliffs in Huerres (Colunga), El Puntal and Santa Mera (Villaviciosa), Lastres and the beaches of Peñarrubia, La Griega, Vega and Ribadesella. This rock contact represents a "stratigraphic gap", because the sequence lacks many rocks, at least from the Mid-Jurassic.

From this stage, where the whole land emerged as dry land, we find the first signs of dinosaurs: isolated vertebrae in the gravel beds of Jurassic rivers, together with various footprints (ichnites).

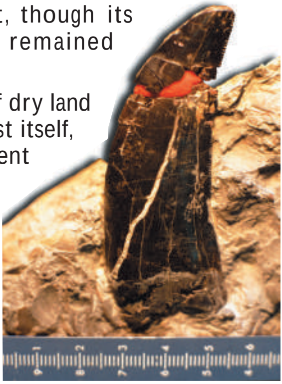
In some of the inactive river channels and certain depressions on side areas lay occasional small pools and fresh water ponds where algae and minute crustaceans (ostracods) proliferated. Nevertheless, most of these areas situated between channels remained in the open air and, as a result, their sediments were oxidized, which produced the typical reddish coloration of the Vega Formation strata.

A new rise of the Jurassic sea level moving forward from the northeast progressively flooded the central eastern part of the Asturian region. Here settled a low irregular coastline, with plentiful dark muds rich in organic matter and variable proportions of sand borne by small deltas. These flowed into a tideless inland sea, cut off from the open sea by a "threshold" or barrier which served as protection against the storms at the time. Between this threshold and the coastline lay a large depression of still brackish waters, at the bottom of which a great amount of muds was laid down.

The sediments which were deposited in these environments turned into the rocks that today make up the Tereñes Formation. These rocks contain high levels of dark-coloured mudstones, very rich in dense accumulation of fossil shells (gastropods and bivalves) called "coquinas" or "shelly beds".

The final episodes of the Jurassic history of the region, which gave rise to the rocks of the Lastres Formation, were characterized by an increase in the activity of the river system, which resulted in a bigger proportion of sand supplies on the coast, due to the activity of small deltas. This caused the coast to extend even further north-east, though its previous NW-SE orientation remained unaltered.

Dinosaurs lived in those areas of dry land close to the coast, and on the coast itself, as can be inferred from the frequent findings of fossil bones and, especially, of footprints. The fossils found in Tereñes and Lastres Formations prove that the vertebrate fauna was rich and varied, including dinosaurs, crocodiles, turtles, flying reptiles (pterosaurs) and fishes.



**Tooth of a large-sized carnivorous dinosaur (theropod)**

In marshy and swampy areas of the coastal plain the vegetation was varied: from ferns to trunks over 11 m long and about 1 m wide. In some cases we can even notice the remains of petrified forests in which the stumps have kept their original position and preserved their roots. The woody parts of the trunks, fossilized and hydrocarbon-impregnated, have produced jet, a variety of lignite highly appreciated in jewellery which has been long exploited in Asturias, especially in the coastal area of the borough of Villaviciosa (Oles, Argüero, Quintes, Tazones, etc.).

The Jurassic landscape was very different from the landscape at the present time. Asturias was placed in Upper Jurassic times at a paleolatitude about 33º N. The coast was not yet cliffed and it did not show the present west-east orientation, either. Moreover, the Cantabrian Mountains and the present inland reliefs did not yet exist. The formation of these mountain reliefs was due to the Alpine Orogeny, which reached its peak about 30 million years ago, during the first half of the Tertiary Era, and it also caused the inclination that the Jurassic strata show nowadays.

# Dinosaur Tracks in Asturias

**Footprints of two bipedal dinosaurs (theropods). Natural casts. Note that the differences in relief are determined by the reptile weight. Quintes cliffs**

Plain evidence of the abundance and variety of dinosaurs in Asturias in the Jurassic is provided by the numerous findings of footprints in the three formations of the Late Jurassic (Vega, Tereñes and Lastres), which crop out on the coastal cliffs in the boroughs of Villaviciosa, Colunga and Ribadesella.

From an analysis of the tracks found in Asturias and comparison with other known sites the following conclusions can be drawn:

There is evidence of both bipeds (theropods and ornithopods) and quadrupeds (mostly sauropods) in the region.

The frequent occurrence of footprints preserved as natural casts in the outcrops often allows an accurate reproduction of the anatomical features of the fore- and hindfoot of the dinosaurs which created these tracks (claws, toe pads, irregular skin texture, and so on).

Judging by the size of tracks, there were dinosaurs of very varied proportions in our region, from small ones, the size of a present-day bird, to huge ones, as is the case of brachiosaurs. Some of the footprints left by sauropods, such as those found on the beach of La Griega or on the cliffs in Tereñes, are the biggest tracks known in Spain and are among the largest in the world.

**Tridactyl footprint of a bipedal herbivorous dinosaur (ornithopod). Natural cast. Scale 10 cm**

The main groupings of footprints appear around former deltaic areas on the coastal plain, especially inland and on the banks of small deltaic channels next to their mouth, as well as in areas bordering marshes, swamps and lagoons situated between those channels.

Some of the footprints constitute rather long trackways, like the ones on the cliffs in Oles, those west of Tazones and Tereñes, or those in Merón and Ribadesella beaches.

To sum up, this area can be said to represent the most important Jurassic site of dinosaur tracks in Spain. It is also the Spanish site with the largest number of quadrupedal dinosaur footprints (mostly sauropods).

In 2002, a Jurassic museum will be inaugurated near the La Griega beach in the village of Colunga. The Government of Asturias is currently working to designate the dinosaur footprints as a Natural Monument. The Asturian formations with dinosaur footprints, along with similar sites elsewhere in the Iberian Peninsula, are also candidates for designation as UNESCO Heritage Monuments.

**Pes footprint of a big sauropod. Five toe marks are clearly visible. Quintueles cliffs. Scale 10 cm**

# THE HISTORY OF LIFE ON THE EARTH

The geological time scale showing the first appearance of the main organisms. Age in millions of years.

| GEOLOGICAL ERAS AND PERIODS | | |
|---|---|---|
| CENOZOIC | QUATERNARY | HOLOCENE |
| | | PLEISTOCENE |
| | TERTIARY | PLIOCENE |
| | | MIOCENE |
| | | OLIGOCENE |
| | | EOCENE |
| | | PALEOCENE |
| MESOZOIC | | CRETACEOUS |
| | | JURASSIC |
| | | TRIASSIC |
| PALEOZOIC | | PERMIAN |
| | | CARBONIFEROUS |
| | | DEVONIAN |
| | | SILURIAN |
| | | ORDOVICIAN |
| | | CAMBRIAN |
| PRECAMBRIAN | | |

AGE

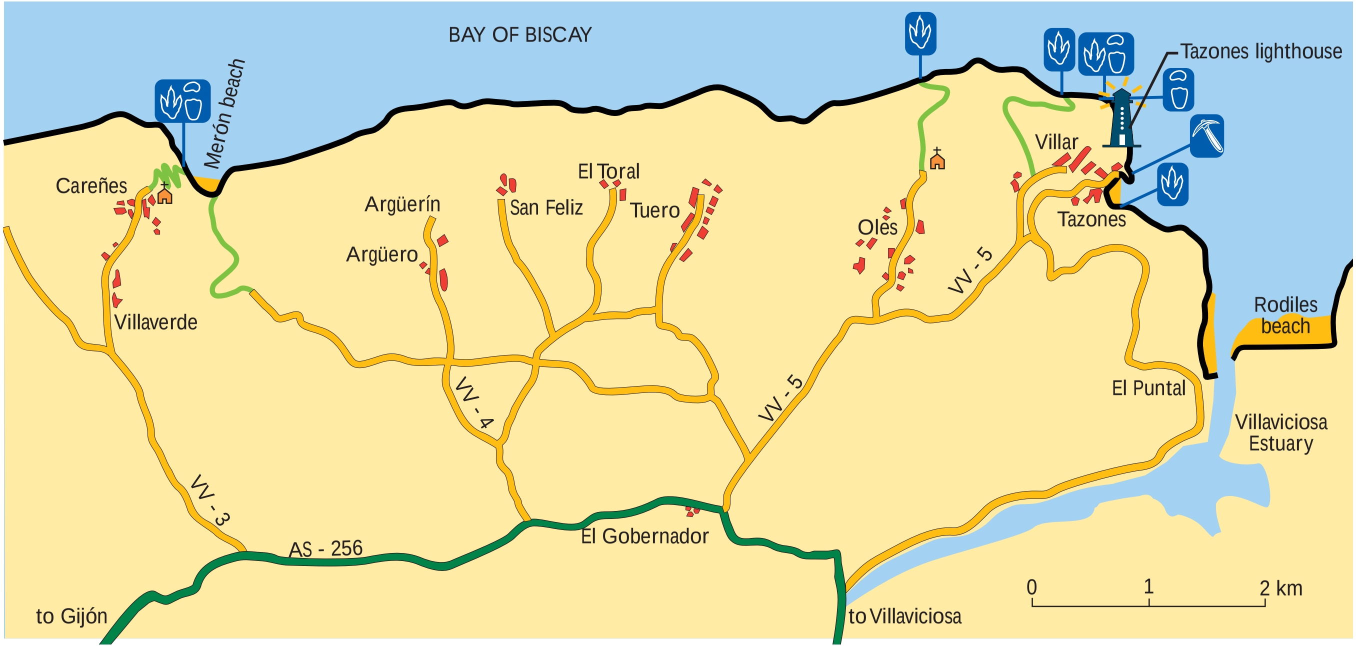
- 0,01
- Neanderthal man
- 0,80 — *Homo antecessor* (Atapuerca)
- 1,77
- 5,3
- Hippos
- Hominids
- 24
- Seals
- Apes
- Camels
- 34 — Mass extinction
- Whales
- Bats
- Monkeys
- 55
- Horses
- 65 — Mass extinction
- Ants, snakes
- Marine turtles
- 144
- Flowering plants
- Birds
- Salamanders
- 206 — Mass extinction
- Small mammals
- Pterosaurs
- Dinosaurs
- 248 — Mass extinction
- Aquatic reptiles
- 290
- Mammal-like reptiles
- Reptiles
- Arborescent vegetation
- 362 — Mass extinction
- Primitive sharks
- Amphibians
- Insects
- 409
- Spiders
- Land animals
- 439 — Mass extinction
- Land plants
- Corals
- 510
- Fishes
- Molluscs, echinoderms
- 570 — Crustaceans
- 2500 — Green algae
- 3500 — First organisms
- 4000
- 4600 — Formation of the Earth

# Field Guide to the Jurassic of Asturias

Merón beach
Oles cliffs
Tazones cliffs
Tazones lighthouse cliffs

Lastres cliffs
La Griega beach

Vega beach
Tereñes cliffs
Ribadesella beach



BAY OF BISCAY
Tazones lighthouse
Merón beach
Careñes
Villaverde
Argüerín
Argüero
San Feliz
El Toral
Tuero
Olés
Villar
Tazones
Rodiles beach
El Puntal
Villaviciosa Estuary
VV - 3
VV - 4
VV - 5
VV - 5
AS - 256
El Gobernador
to Gijón
to Villaviciosa
0
1
2 km

# Merón Beach

Manus and pes prints from a trackway of a sauropod dinosaur. Merón beach cliffs

Merón beach has two accesses. For the first, from local highway route AS-256 take the turnoff to the town of Careñes. We leave the car in Careñes and pick up a dirt road that leaves from the town church and heads downhill towards the beach (900 m). For the second access, from local highway route AS-256 take the turnoff to the town of Argüero. Follow the signs to the beach down a narrow but paved road until it turns into a dirt road that goes down to the beach.

Once at the Merón beach, head west along the base of the sea cliffs for about 600 m until you arrive at a sandstone bed of the Lastres formation which is nearly horizontal. A trackway from a quadrupedal dinosaur (sauropod), formed by 12 consecutive prints of the hindfoot and forefoot, crosses the surface of this bed. A few dispersed tridactyl prints from a bipedal dinosaur also occur in this bed.

Footprint of a bipedal carnivorous dinosaur (theropod) preserved as a sandstone cast. Note the V-shaped digits with narrow claw-marks

# OLES CLIFFS

Leaving from the same local highway route AS-256, near the village of El Gobernador, take the turnoff to the villages of Oles and Tazones. From Oles, a narrow paved road heads north in front of the old church of Oles and at the end there is a small place to park the car.

**Natural cast of a large-sized theropod footprint. Oles cliffs. Scale 10 cm**

From this parking area, follow the dirt road for about 900 m until it connects with a small trail just after a 90° turn to the west, which will end just above a wide sandstone bed tilted 18° toward the sea. In this bed, there are 12 trackways from bipedal dinosaurs oriented in different directions. The rocks of this area belong to the Lastres Formation, and there are several sandstone beds with ripple marks from the currents and waves of the Jurassic.

**Several theropod dinosaur trackways at Oles cliffs**

# TAZONES LIGHTHOUSE CLIFFS

The information panel is situated at the beginning of a path which starts on the left-hand side of the road leading to the lighthouse. The signs along this path show the way to the cliff, which lies 1300 m further away. Right here, on a slab of rock sloping slightly towards the sea, lies the first three-toed dinosaur footprint. From this point we walk on eastwards along the bottom of the cliff, and 200 m further ahead we reach the surface of a sandstone bed that is 25º seaward-inclined. This layer exhibits plenty of three-toed footprints which intersect in different directions forming several trackways, as well as a tail drag. The tail drag is a rare example in the fossil record, since, contrary to previously held beliefs, it is now known that dinosaurs walked with the tale outstretched to maintain balance.

On the surface of the adjacent strata with the same orientation we can also see various manus and pes footprints of quadrupedal dinosaurs (plan view), as well as the vertical section of an extremely large track, possibly belonging to a sauropod.

Sixty metres further away in the same direction, on the vertical face of the cliff, we can find other sections of quadrupedal dinosaur footprints, in the form of protuberances, filled with sandstone. These are found on the base of the sandstones strata or are encased in underlaying grey marls.

The set of rocks which these sites contain includes sandstones, mudstones and marls and it belongs to the Lastres Formation.

**Cliffs east of Tazones port with strata of Tereñes Formation containing bipedal dinosaur tracks (arrow)**

# Tazones Port

We set off from the information panel and walk on along the beach and the cliff. Approximately 120 m ahead of us lie several

**Trackways of sauropod dinosaurs moving right. Note manus and pes prints. Tazones lighthouse cliffs**

three-toed bipedal footprints, heading in different directions. These dinosaur footprints appear on the surface of a grey stratum (about 45º inclined) of the Tereñes Formation and some of them make up a trackway.

About 480 m further on we find another three-toed dinosaur footprint, forming a natural cast on the base of an eaves-shaped sandstone projection which protrudes a few meters higher above. We are now within the Vega Formation, of fluvial origin.

On the cliff at the west end of Tereñes, a few metres beyond the breakwater in the port, we can observe a magnificent example of a vertical fault. The fault lies within an alternating succession of sandstones, mudstones and marls belonging to the Lastres Formation. A few metres ahead we notice several examples of vertical root traces, surrounded by a pale green halo against a reddish rock background. These structures represent Jurassic fossil soils.

BAY OF BISCAY
Lastres lighthouse
Luces
AS - 257
Lastres
Lastres beach
La Griega beach
Future location
of the: JURASSIC
MUSEUM
N - 632
to Villaviciosa
Colunga
to Ribadesella
to Arriondas
to Infiesto
0
1
2 km

# LASTRES CLIFFS

From the coastal road N-632 near the village of Colunga, take the local route AS-257 that leads to Lastres. Approximately 1.5 km after passing Lastres, you arrive at Luces and take a turnoff to the right down a narrow paved road that leads to the Lastres lighthouse. About 650 m before reaching the lighthouse, take a path about 850 m until reaching the base of the sea cliffs. Near there, and a bit to the east, there is a loose block of sandstone with two dinosaur casts, a three-toed footprint of a bipedal dinosaur and a crescent-shaped track (the manus print of a sauropod).

**Tridactyl footprint of a bipedal dinosaur. Sandstone cast at the Lastres cliffs. Scale 20 cm**

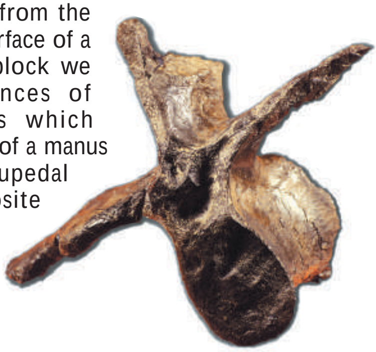
Following the base of the cliffs towards the west for 300 m, you arrive at some sandstone beds tilted 24° towards the sea in which there are various tridactyl footprints of bipedal dinosaurs and a sauropod trackway (which is being gradually eroded by present-day wave action).

**Fragment of a fossil tree-trunk. Lastres cliffs**

La Griega beach (Colunga), locatted in the centre of The Dinosaur Coast

This route begins at the information panel situated on the right bank of the estuary, immediately beyond the bridge, close to the camping site.

Starting from here we walk towards the cliff on the east side of the beach. About 500 m from the information panel, on the surface of a single reddish sandstone block we observe two protuberances of decimetrical dimensions which correspond to natural casts of a manus and a pes print of quadrupedal dinosaurs heading in opposite directions.



Vertebra of a marine crocodile. Cliffs between La Griega and Lastres beaches

Following the very edge of the cliff for about 150 m, we come to a sandstone slab, slightly sloping seawards. Its surface is cut across by small cracks of tectonic origin (joints) running in different directions. Less than one metre higher up lies a grey limestone of the Tereñes Formation which contains minute gastropod fossils and various large, roughly rounded depressions (occassionally up to 1,30 m wide) with a bulky peripheral outline. What we are looking at are the footprints of big quadrupedal dinosaurs (sauropods), which used to move along a coastal pond. Judging by their size, these footprints can be regarded among the largest in the world. Their badly-preserved condition, however,

**Crocodile tooth 4 cm in length. Cliffs between La Griega and Lastres beaches**

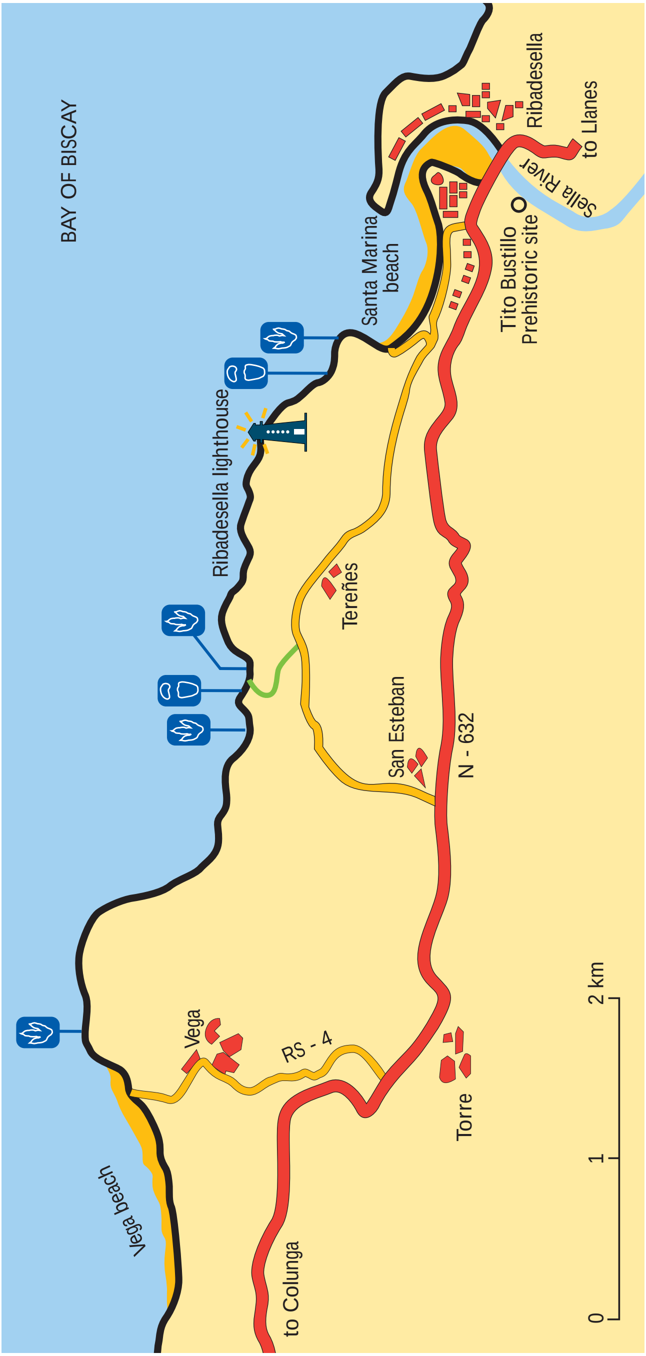
makes it difficult to observe them in detail. In addition, there is a trackway formed by 8 footprints of a slightly smaller sauropod.

Three-toed footprints occur on the sides of that surface as well; some of them make up a trackway. These tracks belong to bipedal dinosaurs, though they are more difficult to identify.

About 30 m further on we come upon an area of red sandstone of the Vega Formation containing vertical pale green-coloured root traces. They are evidence of fossil soils and represent the vegetated areas between Jurassic river courses.

The distance between the information panel and the end of the route is about 600 m.

**Exceptionally large footprints of a quadrupedal dinosaur. La Griega beach**


BAY OF BISCAY
Ribadesella
to Llanes
Sella River
Tito Bustillo
Prehistoric site
Santa Marina
beach
Ribadesella lighthouse
Tereñes
San Esteban
N - 632
Vega
RS - 4
Torre
Vega beach
to Colunga
0
1
2 km

# Vega Beach

From the coastal highway N-632, head west from Ribadesella 6 km until arriving near the town of Torre. From here, take the paved road 1.8 km to the Vega beach. A few meters from the eastern end of the beach parking lot, there are outcrops of the limestones and dolomites of the Gijón Formation, upon which there is a series of alternating limestones and grey marls (Rodiles Formation). The Rodiles Formation, exposed in beds tilted towards the east, contains abundant marine fossils such as brachiopods, belemnites, ammonites, bivalves, etc.

**Tridactyl footprint of a bipedal dinosaur. Natural cast on the base of a sandstone bed. Vega beach**

Above this alternating series there is a one-meter thick layer of conglomerate with siliceous clasts, and then alternating gray sandstones and red mudstones belonging to the Vega Formation. These deposits are fluvial in origin. Approximately 8 m above the conglomerate layer, there is a bed of sandstone tilted about 50° towards the northeast. At the base of this bed there are several tracks of tridactyl bipedal dinosaurs.

**Contact between the calcareous marine beds (right) and the siliceous continental succession because of the retreat of the Jurassic sea. Vega beach**

**Dinosaur tracksites at the Tereñes cliffs (arrows), with the Sueve Range in the background**

To start this route we take the road leading up to Tereñes until we reach a height where this road makes a sudden turn to the left, at the crossroads. From the information panel at this point, we take a narrow slightly sloping road, and about 200 m further down we turn right onto a path leading to the cliff. The cliff is made up of Tereñes Formation strata which slope seawards.

Once on the cliff we begin to walk westward (on our left). Here we can see various dinosaur footprints, and also three trackways. Two of them belong to three-toed bipedal dinosaurs

**Trackway of a sauropod dinosaur showing manus and pes footprints. Tereñes cliffs**

whereas the other, very spectacular, is attributed to quadrupeds and consists of both manus and pes footprints.

In a small cove situated 90 m southwest of the Peñón del Forno lies a reddish sandstone block (Vega Formation) fallen to the bottom of the cliff. On its now vertical stratification plane we see some small three-toed footprints left by bipedal dinosaurs.

The total length of the walk along the base of the cliff is about 400 m. Apart from the footprints the cliff also contains striking examples of Jurassic desiccation cracks.

**Detail of a manus-pes set in the sauropod dinosaur trackway shown in the anterior photograph. Scale 10 cm**

# Ribadesella Beach

This route begins on the promenade at the west end of Santa Marina beach, where the information panel stands. If we look southwards, we will see some grey limestones from the Carboniferous Period which stick out on the relief as a vertical

**Quadrupedal dinosaur trackways. Cliffs west of Ribadesella beach**

wall. This wall roughly coincides with an important fracture known as "Ribadesella Fault ", which runs through the inner part of the town and borders the Jurassic rocks that extend from here to the coastal cliffs.

Along this walk we find a rhythmic alternation of thin layers of limestone and dark grey marls bearing plenty of marine fossils (Rodiles Formation). These accumulated in a shallow open sea which covered all Asturias at that time.

This calcareous series is suddenly interrupted by the presence of the first layers of conglomerates, sandstones and reddish lutites of fluvial origin (Vega Formation). Intercalations of calcareous fossil soils ("caliches") bearing vertical root traces typical of a semiarid climate, and grey marls and limestones of lacustrine origin, are occasionally presents.

The net erosive contact between this calcareous marine succession and the overlying continental sequence resulted in a sudden elevation of the sea floor, which emerged due to the tectonic strain; this gave rise to a lack of sedimentation and erosion which constitutes a "stratigraphic gap".

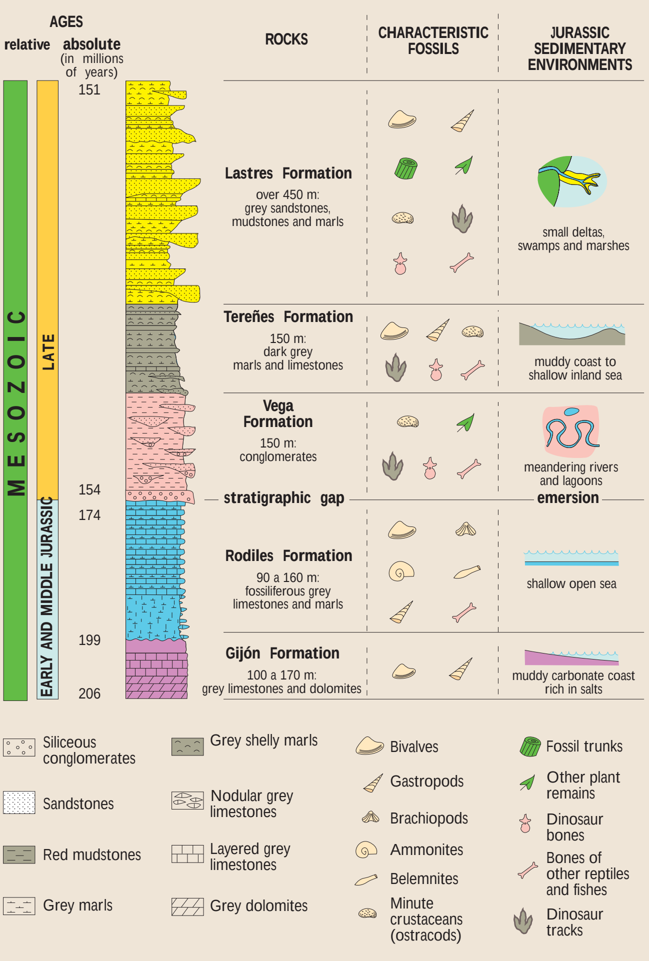
As we approach the end of the promenade, we come to new alternation of greyish marls and limestones with some interbedded sandstones on the lower part (Tereñes Formation), which at that time represented a low coastal area, very rich in muds.

Such a succession, which extends westwards along the cliff, comprises different layers rich in minute bivalves ("coquinas") together with desiccation cracks and frequent dinosaur footprints. The latter occur on the surface of the strata either as roughly rounded depressions (quadrupedal dinosaur tracks) or as three-toed imprints (bipedal dinosaur tracks).

On the way down to the cliff from the end of the promenade we can observe some of these footprints. From this point, about 150 m further west along the base of the cliff lies a large slab of sandy limestone (about 80º seaward-inclined) which shows diffuse ripple marks due to the wave action at the time. Several footprints of quadrupedal dinosaurs (sauropods) can be discerned on this slab.

**A dense concentration of sauropod tracks on a bed of the Tereñes Formation. Cliffs between Tereñes and Ribadesella**

# JURASSIC ROCK FORMATIONS OF ASTURIAS




**Quadrupedal dinosaur tracksite**

**Bipedal dinosaur tracksite**

**Other sites of geological interest**



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