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Research on the Origin of Humans – The Discovery of Human, Dinosaur, and Monkey Footprint Fossils on the Coast of Juehua Island in Western Liaoning, China

Jin Chunhua*

Department of Engineering Management, School of Business Administration, Liaoning Technical University, China

***Corresponding Author:** Jin Chunhua, Department of Engineering Management, School of Business Administration, Liaoning Technical University, China.

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Abstract

In 2023, Jin Chunhua, a teacher at Liaoning Technical University, first discovered a fossil track assemblage of humans, dinosaurs, their nests, monkeys, and other animals on the coast of Juehua Island, Xingcheng, western Liaoning Province, China. Subsequently, she led a research team to the island to conduct preliminary photographic documentation, measurements, and replication of the 3D models trackways. Preliminary identification and analysis revealed that the tracks included those of humans, dinosaurs, and primates. The rock strata preserving the tracks exhibited characteristics of a palaeo-coastal tidal flat. Taxonomic attribution and locomotor patterns were determined mainly based on evidence, including the geometric outlines, dimensional parameters, plantar pressure distributions, and stratigraphic positions of the tracks. Human tracks consisted of adults and children, both shod and unshod, exhibiting standing, walking, and running behaviors. Dinosaur tracks included theropods, sauropods, and a newly discovered webbed-footed morphotype. Primate tracks resembled the hand and footprints of macaques. Traces indicative of advanced civilizations were also present, such as depictions of humans riding horses, stone tools, and boat anchors.

Studies of the track-bearing coastal strata and the overstep structures in western Liaoning showed that a common geological event occurred in the track-bearing coastal area and western Liaoning during the Early Cretaceous. The tracks on the Juehua Island coast are closely related to the Jehol Biota of western Liaoning. The discovery and study of these fossil tracks confirmed that human ancestors coexisted with dinosaurs. Human civilization was far more advanced than that of contemporaneous dinosaurs and primates, indicating that humans did not evolve from primates. Thus, the discovery of fossil tracks on Juehua Island, western Liaoning, China, provides important clues for research on human origins, human civilization and history, dinosaur evolution, classification, and extinction, as well as the origin and evolution of animals.

Keywords: Juehua Island, Human Origins, Human Footprints, Fossils, Dinosaurs

Introduction

Since Darwin proposed the macroevolutionary inference that humans evolved from apes, international research on human origins has been ongoing for more than 100 years. One key milestone was provided by scientists such as Ruvolo M (1995), whose molecular biological evidence indicated that the most recent common ancestor of humans and chimpanzees lived in the late Miocene, approximately 7–6 million years ago, after which lineages evolved separately toward humans and extant chimpanzees [1,2]. Fossil studies of apes serve as the most direct and robust evidence for research on human origins, and fossils of apes have been discovered in many regions worldwide. In 1961, Leakey recovered an upper jaw and some dental fossils of fossil apes dating to 14 Ma at Fort Ternan in western Kenya. In the following year, partial jaw bones and teeth were discovered on Maboko Island in Lake Victoria, about 100 km from the first site. Leakey regarded these fossils as representing Kenyapithecus, a very early fossil ape related to humans [3].

Since the 1970s, De Bonis et al. have relocated and discovered new fossil ape localities in Macedonia, northern Greece. Accordingly, De Bonis et al. named these materials Ouranopithecus macedoniensis [4]. To date, fossil apes from the middle and late Miocene have been found at multiple sites in Europe and Asia, including Dryopithecus, Ankarapithecus, Sivapithecus, Ouranopithecus, and Lufengpithecus [5]. In 1995, three researchers from the Institute of Vertebrate

Paleontology and Paleoanthropology, Chinese Academy of Sciences—Wang Jingwen, Tong Yongsheng, and Huang Xueshi—and two American scholars, Dr. Mary Dawson and Dr. Christopher Beard, discovered Eocene mammalian fossils belonging to the Eosimiidae (Primates) in Yuanqu County, Shanxi Province, China. Further analyses of mandibular and tarsal bones in 2000 supported the hypothesis that Eosimias represents a common ancestor of monkeys, apes, and humans, pushing back the origin of anthropoids by 10 million years [6].

The relationship between African and Eurasian fossil apes suggests that the common ancestor of extant great apes and humans probably lived during the Middle Miocene, approximately 16–10 Ma. During this period, African apes gradually declined and dispersed into Eurasia, where fossil apes persisted until about 7 Ma [7]. There exists a multi-million-year fossil gap between apes and humans. Scientists can hardly confirm the common ancestry of humans and apes merely by discovering so-called “ape-human or human-ape fossils”. Furthermore, using isolated, incomplete, atypical, non-universal, and unrepresentative fossil specimens as evidence for the inevitability of species origin and biological evolution is neither sufficient nor reasonable [8]. What drove fossil apes to evolve into humans? The catastrophic theory of human origins has played a dominant role. Bernard Wood argued that biological evolution and development could not have occurred gradually, and each mass extinction event represents a watershed in species evolution [9]. This view was strongly supported by American scholar Chip Walter, who proposed that new species mainly arise from catastrophic changes in external environments that trigger biological transformations [10]. Chip Walter inferred that the primate lineage leading to humans became isolated on the eastern side of the arid East African Rift Valley during a period of dramatic global environmental change approximately 7 million years ago. This isolated lineage subsequently evolved independently into a group of apes that gradually gave rise to bipedal *Australopithecus*, ultimately leading to the emergence of anatomically modern humans around 200,000 years ago [11].

The origin of monkeys is closely linked to the origin of humans, and thus searching for the earliest monkeys is essentially searching for the earliest primates. Anthropoid primates include three groups: New World monkeys, Old World monkeys, and apes. In biological taxonomy, only the first two are defined as “monkeys”. The two major monkey groups diverged and evolved independently at least 30 million years ago, making them easily distinguishable morphologically: New World monkeys are classified under Platyrrhini, while Old World monkeys (Cercopithecoidea) belong to Catarrhini. Early apes originated from Old World monkeys [12]. In 2022, Jinglei Zhai et al. collected six *Macaca fascicularis* embryos from Carnegie stages 8–11 and performed in-depth transcriptomic analyses on 56,636 single cells, aiming to investigate the close evolutionary relationship between non-human primates and humans [13]. In 2023, Chinese scientists used third-generation sequencing technology to obtain 27 new primate genome sequences and analyzed a total of 50 primate genomes covering most families, especially obtaining key information at critical evolutionary nodes. Combined with fossil time data, researchers inferred that the most recent common ancestor of all primates appeared between 68.29 Ma and 64.95 Ma. This time interval is very close to the end-Cretaceous mass extinction event that caused the extinction of non-avian dinosaurs approximately 66 Ma ago, suggesting that the evolution of primates may have been influenced by this mass extinction event [14].

Chronologically, the current mainstream view holds that humans emerged during the Quaternary period of the Cenozoic Era, after the demise of the dinosaurs. This indicates that human ancestors did not coexist with dinosaurs. Dinosaur remains and footprints have been discovered not only in inland areas but also repeatedly along coasts and on islands. For example, in 2007, Fabio Massimo Petti et al. studied and reported dinosaur footprints from marginal marine environments of the Early Jurassic in Italy [15]. The largest sauropod dinosaur footprint site in Europe from the Upper Jurassic has been discovered in northern Switzerland, where footprints occur in tidal flat deposits with mud cracks at the easternmost locality [16]. Sauropod dinosaur footprints have also been found in Middle Jurassic lagoons on the Isle of Skye, Scotland [17]. Between 2000 and 2006, Andrew R.C. Milner et al. investigated a well-preserved assemblage of large dinosaur swim-trace fossils at the St. George Dinosaur Discovery Site at Johnson Farm (SGDS) in southwestern Utah, USA [18]. No human footprints have been recovered from these coastal localities that yield dinosaur footprints. If both dinosaur and human footprints were preserved together on Earth, such occurrences would provide evidence that human ancestors coexisted with dinosaurs.

Did humans originate from apes? Did they originate in Africa? Did they coexist with dinosaurs? To date, numerous questions and controversies remain, lacking robust fossil evidence. On July 21, 2023, Jin Chunhua of China landed on Juehua Island, Xingcheng, western Liaoning Province, and discovered abundant fossil footprints of humans, dinosaurs, apes, monkeys, and other animals coexisting along the southern coast of the island. This discovery provided realistic fossil evidence for the study of human origins. The following passage analyzes the fossil footprints to investigate the origin of humans.

Previous Work on the Track Fossils from Juehua Island Geological Background

Xingcheng City, China, was located on the northeastern margin of the North China Craton and constituted an important component of the North China Platform. The North China Craton, situated in eastern China, has a geological evolution history of nearly 4 billion years. Unlike other ancient and stable cratons, the North China Craton underwent significant changes in the physical and chemical properties of its lithosphere during the Mesozoic, accompanied by lithospheric thinning, and the continental crust was reactivated due to intense reworking and accretion [19,20]. These processes

resulted in a topographic slope from northwest to southeast across the Xingcheng area, with low mountains and hills in the northwest, hilly terrain in the central part, and coastal plains in the southeast. Archean crystalline basement rocks were exposed in the region, and sedimentary cover sequences were extensively developed from the Mesoproterozoic onward. Magmatic activity occurred from the Proterozoic to the Mesozoic, dominated by intermediate- acid intrusive rocks in the early stages and intermediate- basic volcanic rocks in the late stages, with well- developed faults [21–22]. Juehua Island of China lay in the Bohai Sea and was the largest island in the Liaodong Bay. Its geographic coordinates were 40°29'56"N and 120°48'25"E. It covered an area of 13.5 square kilometers with a coastline of 27 kilometers, and was only 12.6 kilometers away from Xingcheng, the coastal city of western Liaoning. Previous geological investigations confirmed that the island also formed part of the North China Craton and was originally connected to the mainland. A major earthquake during prehistoric times triggered the collapse and faulting of the coastal continental shelf, leading to the separation and subsidence of most of the area from the mainland, thus forming the island, as shown in Figure 1.

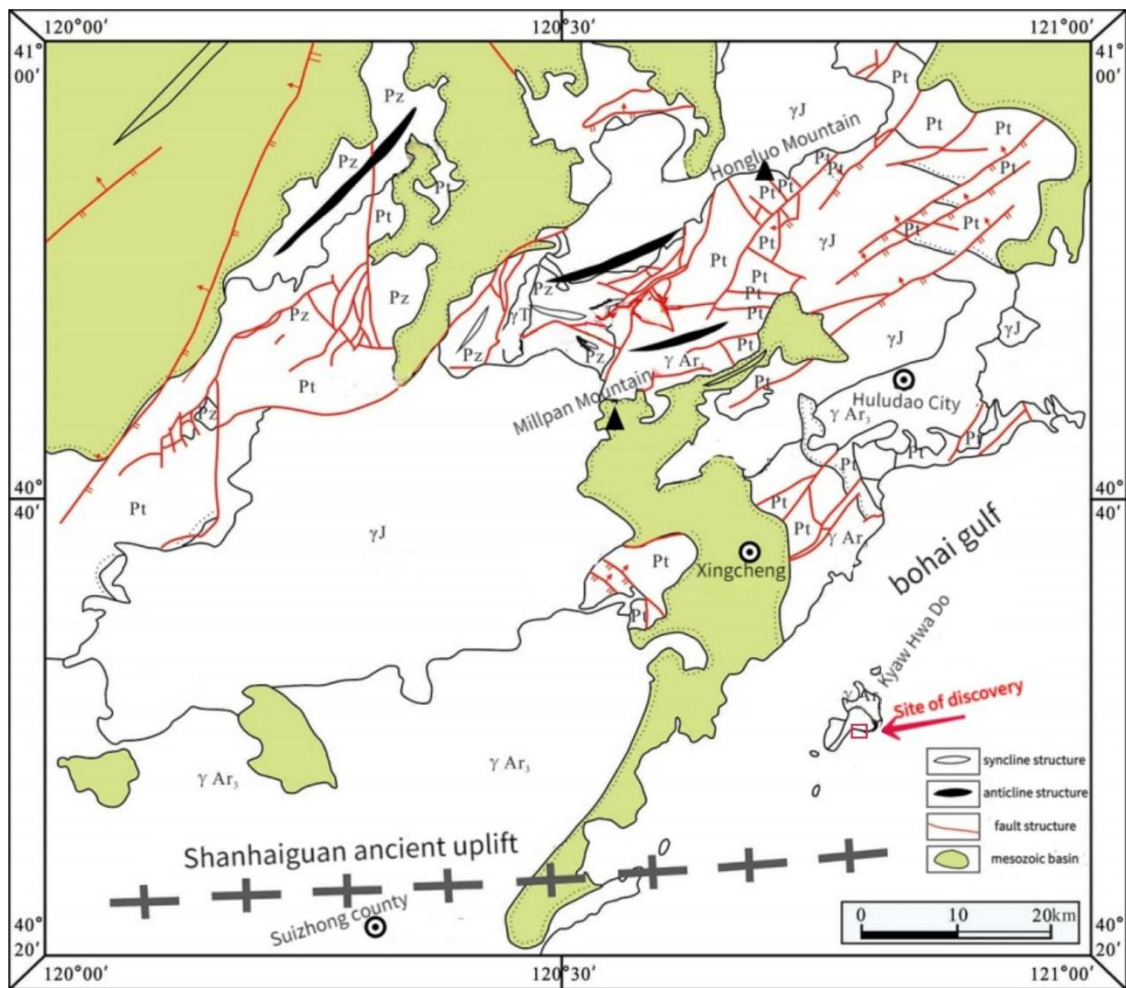


Figure 1: Tectonic Outline Map of the Xingcheng Area, Western Liaoning, and Fossil Locality (Modified After Cui Fanghua, 2020, Modified by Wu Yuange, 2024)

Palaeogeographic Environment

All track fossils occurred along the coastline of the southern coastal area of Juehua Island. The coastal strata there were discontinuous, trending approximately northeast–southwest, with stacked large- scale rock bodies and scattered massive rocks (see Figure 2).



Figure 2: The Footprint Coast of Juehua Island

All of the footprints were impressed on the same suite of palaeo- coastal sediments. The trampled surface displayed typical tidal flat characteristics, preserving traces such as ripple marks, desiccation cracks, burrows, and granular textures. The footprint- bearing rocks consisted mainly of grey, greyish- black, and yellowish- brown carbonate rocks and silt- bearing sandstones. The spatial position of the palaeo- coast recorded by the footprint- bearing strata were determined on the basis of sedimentology and coastal physical processes.

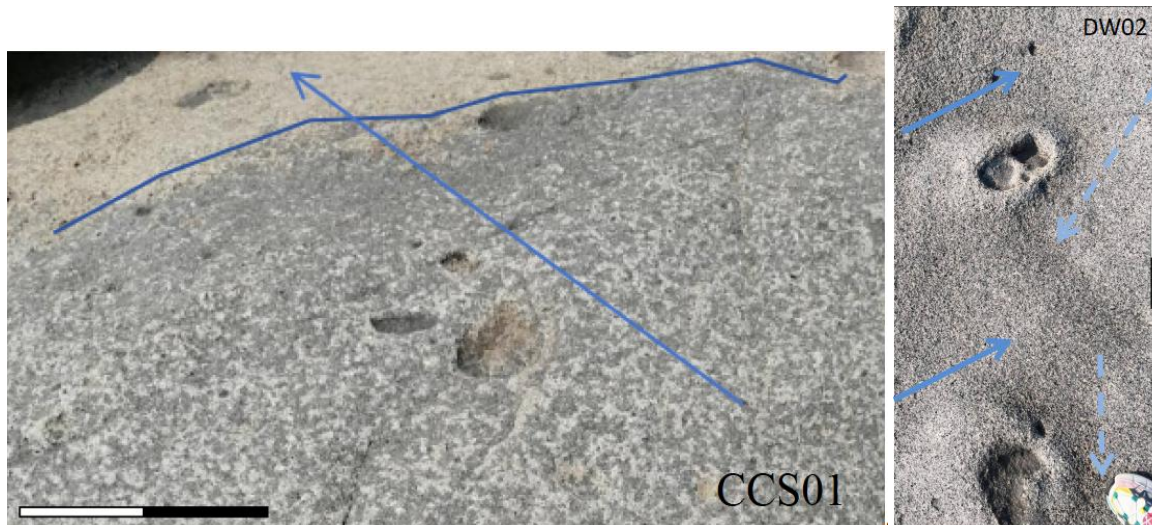


Figure 3: CCS01, Scale Bar 50 cm Figure 4 DW02, Scale Bar 10 cm CCS01Description

The study area exhibited distinct marginal marine facies. Sediments on both sides of the boundary differed, with significant contrasts in sand content. Sedimentary structures formed by cyclic wave action were also preserved on the surface. Footprints on both sides of the boundary showed marked deepening, and both occurred within the intertidal zone, with repeated intervals extending from the intertidal to the supratidal zone.

DW02 Description

Most footprints were depressed below the surrounding surface, while in a few areas, the bottom and margins of the footprints formed elevated platforms that were higher than the adjacent strata. These features were formed by successive scouring and sediment deposition induced by opposing high- energy tidal currents. Such settings represent tidal channels within a tidal flat system, where the coastline was locally incised by tidal inlets.

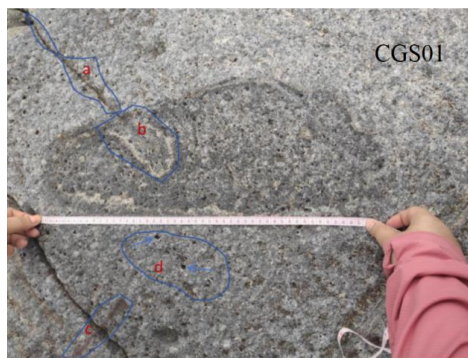


Figure 5: CGS01



Figure 6: DW-01CGS01 Description

The sediments in the study area contain centimetre- scale ooids. A fracture occurs in Zone A, through which tidal water washed into Track Zone B. A distinct trail is present in Zone C, and obvious burrows occur in Zone D. Based on these bedding structures, the site is interpreted to represent the supratidal zone of a palaeocoast. DW-01 Description: The sediments in the study area were dominated by loess and sand. Trample footprints were well preserved, indicating that the site represented a supratidal flat marsh with argillaceous deposits. The palaeogeographic environment of the footprints was the intertidal zone and supratidal flat marshes of a tidal flat setting.

Field Work

To identify the fossil footprints, multiple field investigations were conducted. Basic photographic and measuring tools were employed to carry out an initial documentation of the entire area where the fossil footprints were located.



Figure 7: Fieldwork

Primarily, the locations of the footprints were numbered and recorded, the geomorphology of the hosting area was described, and geometric parameters, including length, width, and depth of the footprints were measured, as shown in Figure 8.


Position number	13	Local landform features: Located in a coastal rock fault zone, the rock surface is flat	
	Geometric parameters		
	Front length: 11cm	Rear length: 5cm	
	Front width: 10cm	Rear width: 6.5cm	
	Front depth: 4.5cm	Rear depth: 2.5cm	

Figure 8: Footprint Record Sheet

To better identify the footprints, field- based moulding and replication were carried out to produce 3D models of the fossil footprints. The fossil footprints were situated on the modern coast and were strongly affected by tides; during high tide, parts of the footprints were submerged by seawater. Accordingly, the replication material was required to be a slurry capable of filling the entire footprint space, minimally influenced by seawater during setting and solidification, and characterized by a short setting time. High- sulfate- resistant rapid- hardening sulphoaluminate cement was adopted, which featured rapid setting, early strength development, and non- shrinkage properties.

A procedural workflow for footprint replication was established: footprint cleaning → release agent application → cement slurry preparation → installation of flexible mould frames → grouting → compaction and smoothing → consolidation

→ retrieval of 3D footprint models → soft packaging. This work was conducted over three days, from October 27 to 29, 2023. Fieldwork was constrained by tides in the Xingcheng coastal area, and the replication tasks were scheduled at different intervals according to the tidal regime illustrated in Figure 9. A total of 36 3D footprint models were replicated. Some of the replicated 3D models fractured during transportation and handling by boat, as shown in Figure 10.

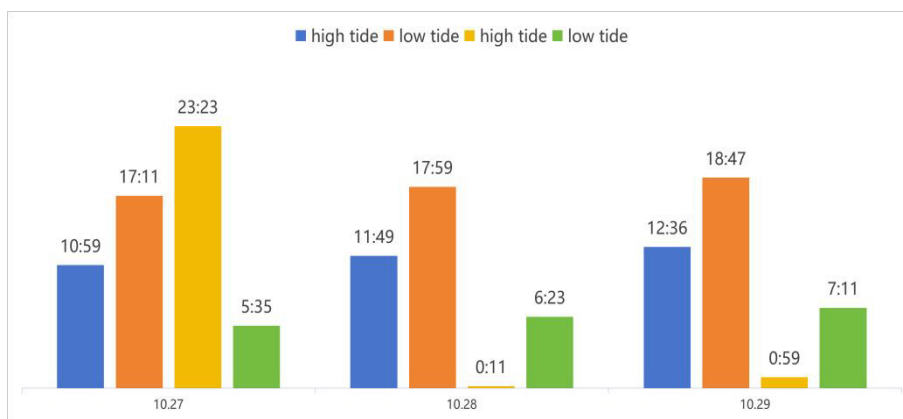


Figure 9: Diagram of Tidal Regime at Xingcheng

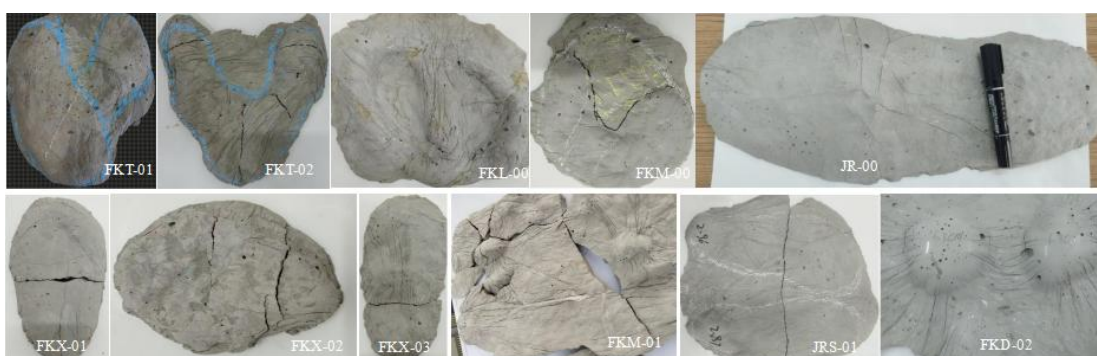


Figure 10: Partial Replicated Footprint Models

Material Processing

A large number of footprints were photographed and collected, among which 95 identifiable human footprints (including those from bipedal standing), 1 trace of a human riding a horse, 43 clusters of animal footprints (including individual prints), 1 footprint of a quadrupedal running animal, 1 footprint of a quadrupedal crawling animal, 1 tool mark, and 3 dinosaur egg clutches were recognized. In addition, some footprints could not be identified, and numerous footprints were not photographed or recorded. Most human footprints indicated walking or running along the coast, while a small proportion showed walking toward the ocean; most animal footprints represented random trampling on the ancient coast, and a small number of animal footprints indicated movement toward the sea. To facilitate subsequent research, a numbering system for human footprints was established. A three-level inventory coding system was developed using a list management approach, as shown in Table 1.

For identifiable dinosaur footprints, theropods were coded as KLS, sauropods as KLC, and other animals as DW, with sequential numbers appended to each code.

Code type		Code
Tier 1	Adult	C
	Minor	W
Tier 2	Barefoot	G
	Shod	C
Tier 3	Single foot	D
	Both foot	S

Table 1: Coding Inventory of Human Footprints

Human Fossil Footprints

Human fossil footprints on Juehua Island were more abundant than those of other taxa. The identification of human footprints and the analysis of the basic identity and behavior of ancient humans provided important evidence for inferring events that occurred at that time.

Bare Single Footprints

Bare single footprints on the coast of Juehua Island were more numerous than footprints wearing footwear. They were produced by adults, children, and adolescents, with distinct foot morphologies.



Figure 11 Barefoot Footprints

Figure 11

- **Description of WGD-03** : The geometric outline of the footprint was distinct, with a foot length of 21 cm (measurement error $\leq \pm 5$ mm; the same applied to other specimens). It was likely produced by a child. Clear heel, metatarsal arch, lateral region, anterior metatarsal region, and toes were present, indicating a bare footprint. The trampling depth in the metatarsal arch region was relatively shallow, indicating that the trackmaker possessed a foot arch. The right margin of the footprint was deeper, at 15 mm, indicating that the body's center of gravity was shifted to the left, and the individual was probably about to turn left while walking.

- **Description of CGD-05**: The depth of this footprint was generally uniform, consistent with footprints produced by normal human walking on a flat beach. The hallux was prominent, the anterior sole was relatively broad, and the foot length was 27 cm, indicating a right footprint left by an adult. The posterolateral portion of the heel (within the red wireframe) exhibited the same trampling depth as the heel itself, which represented a scraping mark formed when the posterolateral heel contacted the ground during locomotion. Many modern individuals also displayed such a heel-scraping gait while walking.

- **Description of CGD-01**: This footprint measured 39 cm in length. Based on the foot length- to- height ratio of modern humans, the maker's height was estimated to be 2.34 m to 2.73 m, indicating a giant individual; the footprint was from a left foot. The heel and anterior metatarsal regions were deeply impressed. The depth order among different regions was as follows: heel > anterior metatarsal region > lateral region > metatarsal arch. A cavity existed in the toe area, formed as mud was removed by the toes during liftoff. To determine what kind of dynamic behavior produced such a footprint, several human movement experiments were conducted. It was found that only a forward- left jump could likely result in this type of footprint. The heel struck the ground first, yielding the greatest depth. The anterior metatarsal region then contacted the substrate, resulting in the second- greatest depth. The lateral small toes and the hallux flexed downward successively before the foot lifted away from the area.

Consequently, the toes applied a strong force into the mud and removed sediment upon liftoff.

Single Footprint with Shoe

The shoe sole impression was relatively flat, with no plantar impression present. Individual footprints with shoes included those of adults and minors, and differences in foot shape could be observed from the geometric characteristics of the shoe soles.



Figure 12 Footprints with Footwear

Figure 12

- **Description of CCD- 01** : The shoeprint was located on the top of a large rock slope along the coast. The footprint formed after trampling had been washed by seawater. The sole length was 38 cm, the maximum width was 10.4 cm, and the average depth was relatively shallow. The print indicated normal walking toward the ocean.
- **Description of WCD- 01** : This shoe print was located on a coastal slope. The sole length was 18 cm, with an average depth of 1.5 cm. It was left by a child walking normally downhill.
- **Description of CCD- 02** : This shoe print was located on a coastal slope. The left side of the footprint formed after trampling exhibited relatively obvious seawater erosion marks. The sole length was 21 cm, the maximum width was 10.2 cm, and the individual had walked normally along the ocean.

Bipedal Footprints

Complete bipedal footprints were rare; however, each bipedal footprint in Figure 12 was typical. The step lengths of both CGS- 01 and CGS- 02 were not measured.

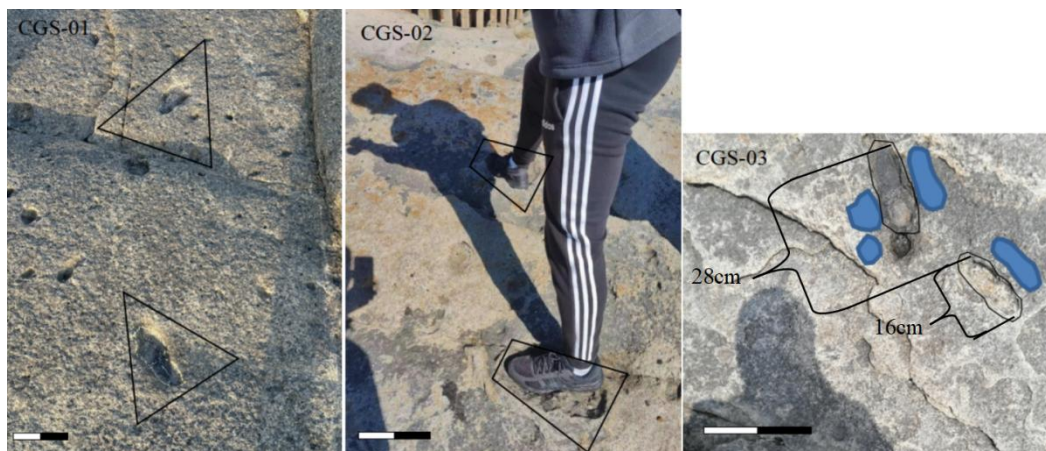


Figure 13: Bipedal Footprints, scale bar 10 cm

- **Description of CGS- 01** : Two bare footprints were found within two triangular areas at this site. The halluces were prominent, and the foot morphologies were consistent. Based on the orientation of the halluces, the anterior footprint was identified as the right foot, while the posterior one was the left foot. These constituted a pair of bare footprints left by an individual running along the coast. The feet exhibited a turning motion during running, although the turning angle was not substantial. The original orientation of the anterior footprint was altered because the sediment block where it was located had undergone relatively intense post-depositional compressive forces.
- **Description of CGS- 02** : This pair of shod footprints was left on a slope. The staff member performed actions corresponding to the footprints. The staff member stood 1.83 m tall and exhibited a relatively long stride length, indicating obvious uphill running motion.
- **Description of CGS- 03** : This was a pair of shod footprints from normal walking. The sole length was 16 cm and the stride length was 28 cm, left by a child. The upper footprint belonged to the right foot and overlapped with an animal footprint. In the overlapping area, the geometric outline of the animal footprint was distinct, indicating that the animal stepped on the site after the human had trampled it.

Stationary Footprints

Six sets of stationary bipedal footprints were identified. Those that could be fully confirmed are shown in Figure 14.

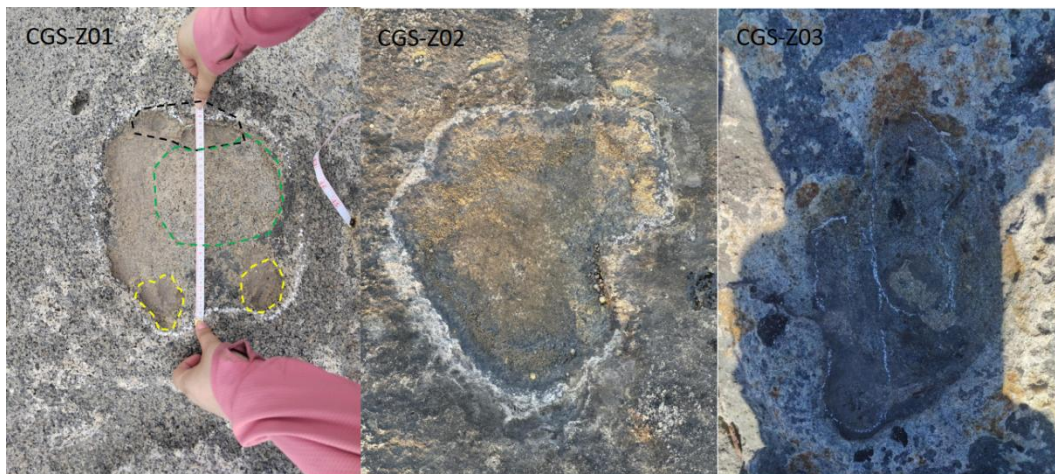


Figure 14: Stationary Footprints (CGS-Z02 and CGS-Z03 were not measured)

- **Description of CGS- Z01** : Within the studied area, distinct impressions of the left hallux, as well as the right hallux and second toe, were observed inside the black wireframe; this stationary impression was relatively flat. At the heel regions of both feet (marked by the yellow wireframe), there were later trampling impressions from other animals. Over most of the anterior portion of the right foot (marked by the green wireframe), repeated trampling traces from another type of animal with a flat plantar surface were present.

- **Description of CGS- Z02** : This was a pair of standing footprints with relatively broad feet, heels close together and toes apart. The trampling depth was relatively uniform, suggesting that the maker might have been flat-footed.

- **Description of CGS- Z03** : The two feet in the studied area displayed a staggered standing posture, with distinct heels. Their margins were damaged after lithification.

Beach Petroglyphs

Beach rock paintings were discovered in the shallow coastal waters of Juehua Island. These artworks were created by ancient humans on the palaeobeach and subsequently lithified. Following marine transgression onto the land, these paintings were frequently submerged in seawater.

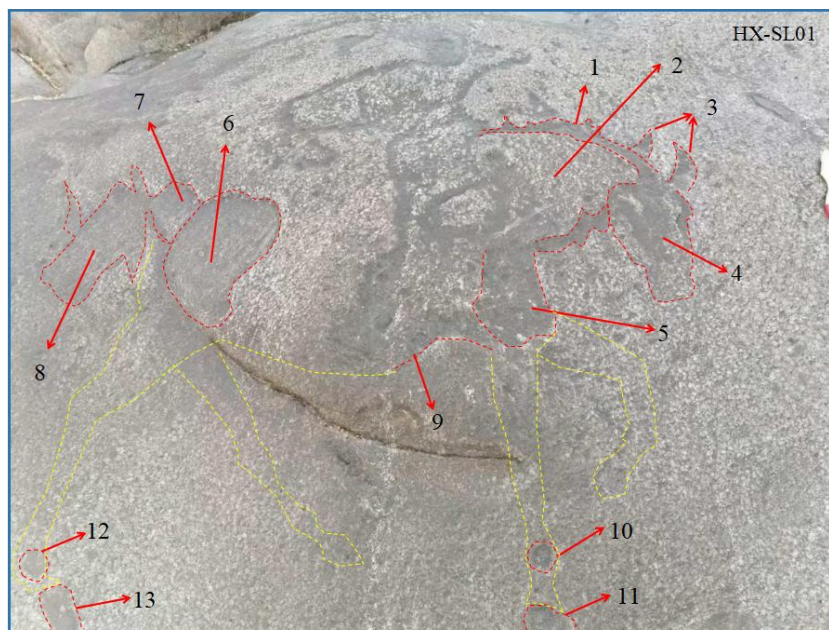


Figure 15

1 – Horse's mane 2 – Horse' neck 3 – Horse' ears 4 – Horse's head 5 – Horse's chest 6 – Horse's rump 7 – Bound horse's tail 8 – Horse's tail 9 – Horse's belly

10 – Fetlock joint of the foreleg 11 – Hoof of the foreleg 12 – Fetlock joint of the hind leg 13 – Hoof of the hind leg

Figure 15: Beach Engravings (Mounts)

Description of HX- SL01 : An analysis was performed on the mount depicted in the beach petroglyph, which was outlined with a red dashed line. Based on its body structure and geometric contour characteristics, the creature was identified as a horse. The limbs of the horse had been eroded by seawater, leaving only portions of the ankle joints and hooves of the legs; these parts were supplemented and delineated with a yellow dashed line. The root of the horse's tail was bound, a practice applied to war horses in ancient China, suggesting that this tradition had been passed down from ancient times. According to the postural and kinematic characteristics of the horse's limbs, the animal was interpreted as a horse in a running state.

1–Mo'e guan 2–tassel 3–cotton robe 4–cloud collar 5–object held in the

left hand 6–belt 7–back of the hand 8–fingers 9 –Pistol-shaped Implement

10–crotch-seamed pants 11–boots 12–Stirrup-shaped Implement 13– dart bag

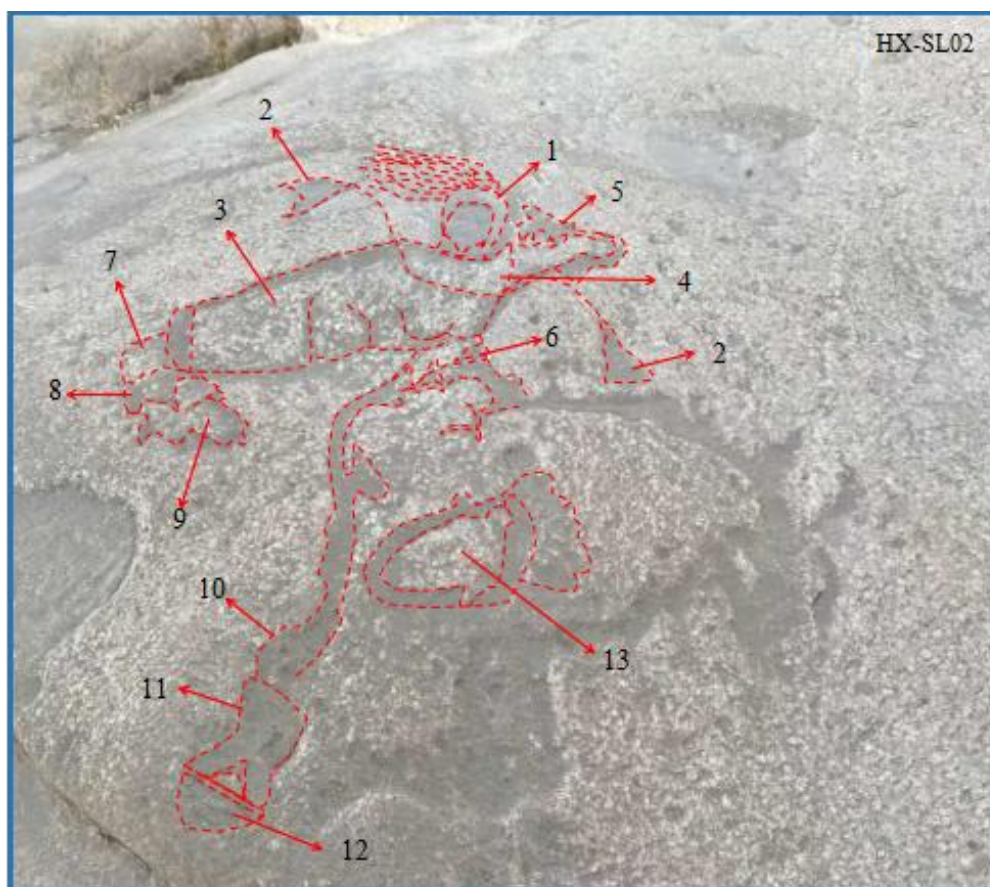


Figure 16: Beach Engravings (Human Figures)

Description of HX- SL- 02

The figure's attire and adornments were outlined with a red dashed line. Based on the delicate facial features and breast characteristics, the depiction clearly represented a beautiful female. She wore a high ponytail, with long hair flowing in the wind; on her head was a hat- like ornament, likely a type of crown known in ancient China as a mo'e guan (forehead band crown), a form of traditional headwear. The figure was dressed in a garment similar to an ancient Chinese robe, apparently with a type of shoulder covering referred to in ancient China as a yun jian (cloud shoulder). Tassels decorated the cloud shoulder and fluttered on both sides of the figure in the sea breeze. The figure possessed a slender waist, consistent with typical female body proportions; wrinkle- like structures at the waist were interpreted as a waistband. She clearly wore short boots and stood upon an object that likely functioned as a stirrup. Obliquely strapped to her body, anterior to her thighs and posterior to the horse's neck, was a pouch resembling an ancient Chinese quiver. However, it did not contain arrows, as the objects protruding from it were much shorter, with only arrow- tail- like ends visible.

These were likely throwing dar commonly used as concealed weapons in ancient China; thus, the pouch identified as a dart quiver.

The female figure firmly held one object in each hand, pointing toward the direction of movement. The dorsal surfaces of the hands and fingers were clearly distinguishable. The edges of the held objects were delineated with a red dashed line.

- blade
- back of the sword
- sword knot
- handle of the sword
- sword tassel knot 6—sword tassel

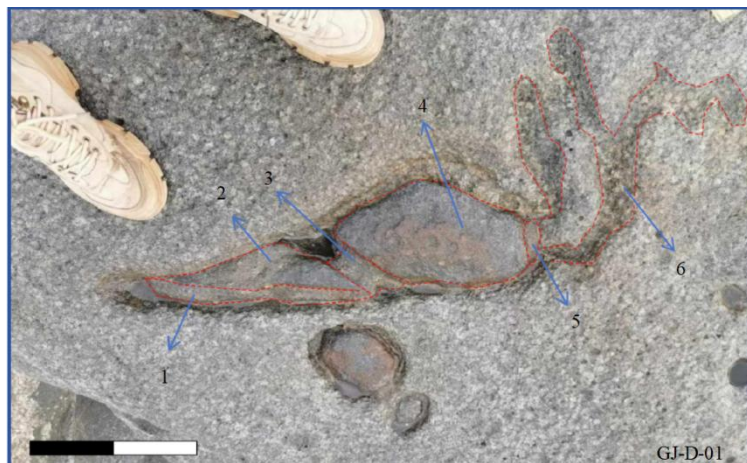


Figure 17: Tool Marks, scale bar 10 cm

Description of GL- D- 01: Not far from the beach petroglyph, knife- like traces were observed: the upper one was a knife, and the lower one was a small shovel. The edge of the upper knife was distinct, with an upturned tip, indicating that the knife was sharp. The upper part of the handle was convex and curved, while the lower part was flat; such a geometric design was highly ergonomic to the human hand. The end of the handle was decorated with a tassel, which might also have facilitated extraction from the dart quiver. The blade was approximately 20 cm long, and the handle was of similar length, resembling a modern dagger. The lower tool was short, with a round handle; the shovel part was oblong, with a pointed tip. Were the two tools merely painted? Apparently not—they were real objects left on the beach. They were likely metallic and were eventually corroded by seawater, with metallic elements integrated into the underlying beach sediment, allowing faint traces of rust to be discerned. The tools were corroded and reworked by seawater simultaneously. Owing to the obstruction of the physical objects, reverse seawater flow eroded grooves along the tool margins. The knife tassel was oriented parallel to the direction of seawater flow.

Identification of Dinosaur Footprints

Dinosaur footprints were discovered along the coast of Juehua Island, identified mainly based on the geometric characteristics of the impressions. Footprints of theropods, ornithopods, and sauropods were all present, but no continuous walking trails were found; their distribution was scattered.

Theropod (Ornithopod) Dinosaur Footprints



Figure 18: Theropod Footprints

- **Description of Figure 18:** The three footprints in Figure 18 all showed distinct three toes and were relatively flat. They were suspected to have been left by theropod dinosaurs, though they might also have been produced by ornithopods.

- **Description of KLS- 01:** The basic geometric outline of the three toes was inversely conical, and the angles between adjacent toes were nearly identical. The impressions of digits I and III were relatively flat, whereas digit II within the yellow wireframe displayed raised sedimentary mud, indicating that the middle toe had exerted greater force and undergone digital flexion during movement. The footprint also preserved a metatarsal region (Region IV), which differed from the typical toe- walking habit of dinosaurs. The footprint was oriented away from the ocean, and the site was an upward- sloping terrain. The dinosaur likely adopted a posteriorly shifted center of gravity and walked uphill toward the coastal margin.

- **Description of KLS- 02:** The footprint in the studied area was relatively flat, showing two partially overlapping impressions of different sizes. Both shared the same geometric outline, possessed three toes with clear digit- tip marks, while the remaining areas were damaged by seawater scouring. They were probably produced by two closely related dinosaurs of different generations walking along the coastal zone in roughly the same direction.

- **Description of KLS-03:** The studied area only exhibited distinct three- toed impressions formed after trampling, indicating movement along the coastline. The inland area of western Liaoning near Juehua Island preserves the world-famous Jehol Biota. According to Xinhua News Agency of China, the earliest known tyrannosaur fossil in the world was unearthed in Chaoyang City, Liaoning Province, China. Preliminary scientific investigations suggested that this tyrannosaur lived in the Early Cretaceous, approximately 120 million years ago, more than 50 million years earlier than comparable tyrannosaur specimens discovered in North America, Mongolia, and other regions. Ji Q. et al. discovered tyrannosauroid skeletal fossils from the Early Cretaceous Jiufotang Formation in Kazuo, western Liaoning.

The specimens were characterized by a tall anterior maxillary body and prominent vertical crests on the lateral surface of the ilium, with an estimated total body length of 9–10 m. Several morphological features distinguished this taxon from Late Cretaceous tyrannosaurids, leading to the establishment of a new genus and species: *Sinotyrannus kazuoensis* gen. et sp. nov. This taxon may represent one of the earliest known tyrannosaurid lineages [23]. Iguanodontian fossils, referred to as *Bayannurosaurus* [24]. were recovered from Lower Cretaceous strata in the Urat Rear Banner region of Inner Mongolia Autonomous Region, China. *Bayannurosaurus* a large, basal ankylopollexian dinosaur that lived in the Early Cretaceous (ca. 125 million years ago) [25]. Two hind claws of this dinosaur were preserved; each claw possessed three robust digits, with the distal segments thicker than the proximal ones, forming an inversely conical shape. Theropod dinosaurs (tyrannosaurids) and ornithopod dinosaurs (iguanodontians) existed in western Liaoning approximately 100 million years ago.

Sauropod Dinosaur Footprint

Description of Figure 19 : The six footprints in Figure 19 all displayed flat soles and uniform trampling depths. Based on their geometric outlines, the following classification was recognized KLC-00, KLC-02, KLC-03, and KLC-04 belonged to one type of impression, while FKKL-00 and KLC-01 represented another type. These footprints varied in size; KLC-00 measured 55 cm in length and was identified as a giant footprint. Consequently, they could not have been produced by any hoofed mammal, but were most likely left by giant sauropod dinosaurs. The footprints KLC-00, KLC-02, KLC-03, and KLC-04 resembled the hind-foot impressions of sauropod 3D herbivorous dinosaurs in Figure A, whereas the footprints FKKL-00 and KLC-01 resembled the fore-foot impressions of the same sauropod 3D herbivorous dinosaurs in Figure A.

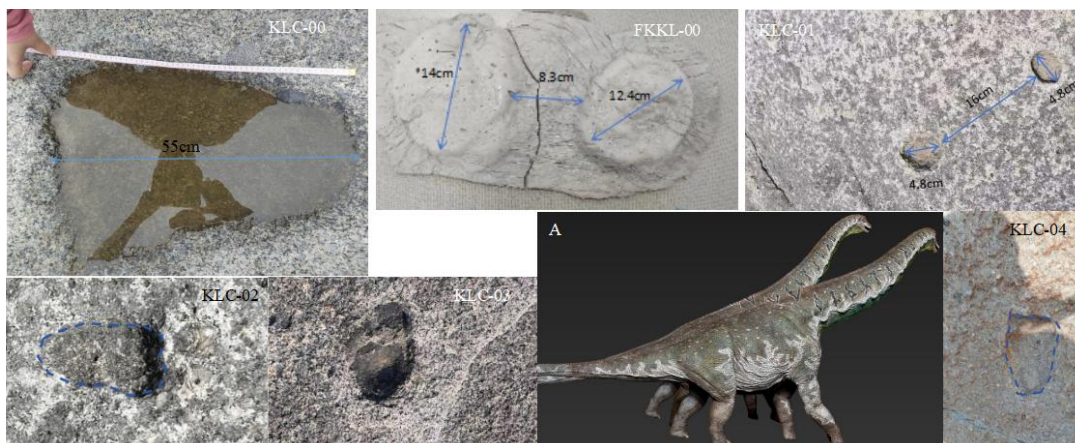


Figure 19: Sauropod Dinosaur Footprints (A from zcool.com.cn)

These footprints were trampled at different locations along the coast, as indicated by variations in sediment composition at each imprint site. The footprints differed in size, with lengths ranging from 5 cm to 55 cm, suggesting a dinosaur group consisting of individuals of different age groups. The forefeet of this dinosaur type were roughly cylindrical in shape. The two forefoot prints in FKKL- 00 were not produced by the same individual, since their geometric dimensions differed and the distance between them was only 8.3 cm, which was extremely small. The two forefoot prints in KLC-01 possessed identical geometric dimensions and were separated by a distance of 16 cm. This distance was consistent with the body width and skeletal structure of a dinosaur, indicating that the two forefoot prints were made by a single individual.

Large sauropod dinosaur fossils have been discovered in western Liaoning near Juehua Island. Dongbeititan dongi was the first large sauropod dinosaur identified from the Jehol Biota of western Liaoning. It reached approximately 11 meters in body length and 4 meters in height, and was a quadrupedal herbivorous dinosaur that lived during the Early Cretaceous [26].



Figure 20: Psittacosaurus (Image A from www.travel.qunar.com, Image B from www.nipic.com, Image C from xlgtx.com)

Panels A, B, and C in Figure 20 show fossils of Psittacosaurus, a small ornithomimid dinosaur. The phalanges of their feet varied in length, decreasing successively from the outer to the inner digits, forming a semilunar outline. It can also be seen from Panel C that the distribution pattern of their limb bones was identical: the phalanges decreased in length from lateral to medial, displaying a semilunar morphology.

KLC- 05, KLC- 06, and FKKLC- 11 exhibited identical semilunar geometric outlines, similar to the pedal skeletal morphology of Psittacosaurus mentioned above. However, the coastal footprints had flat soles without digital marks, resembling impressions made by dinosaur feet bearing semilunar fleshy webbing. Abundant fossils of Psittacosaurus have been discovered in western Liaoning, China. This dinosaur inhabited Asia during the Early Cretaceous, from approximately 123.2 million to 110 million years ago [26]. If these footprints were produced by Psittacosaurus on the beach, it could be inferred that Psittacosaurus was not an ornithomimid with clawed digits, but possessed webbed feet covered with fleshy tissue. This suggests that Psittacosaurus may have been an amphibious dinosaur living in coastal and lacustrine environments, frequently swimming and foraging in water. This revises previous interpretations that regarded it as a herbivorous dinosaur. Therefore, Psittacosaurus is temporarily classified among sauropod dinosaurs.

Others

Some specimens from the coast of Juehua Island, western Liaoning, remained ambiguous during identification. Two examples are given as follows:

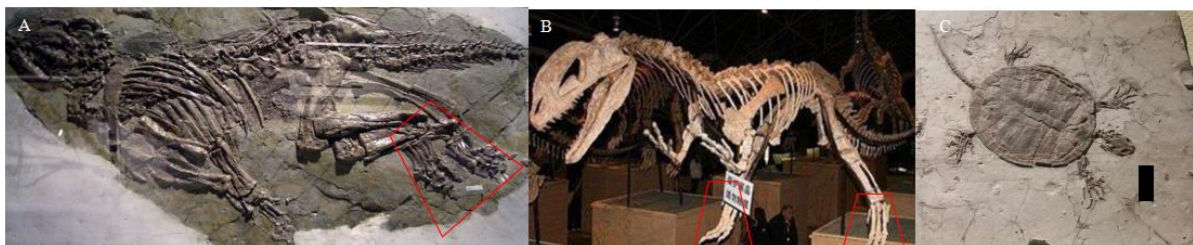


Figure 21: Fossils of Dinosaur and Turtle (Image from www.baike.so.com)

Figure 21 Shows the Following

A is a fossil of Jinzhousaurus, a genus of iguanodontian dinosaur that lived during the Early Cretaceous, approximately 125 million years ago. Its fossils were discovered in western Liaoning, China, and it regarded as the only known dinosaur of this type in the 21st century [27]. B is a fossil of Beipiaosaurus. The generic name Beipiaosaurus was derived from its type locality, Beipiao, western Liaoning, China. It lived in the Early Cretaceous, about 124.6 million years ago, and was the largest known feathered dinosaur [28].

C is a turtle fossil. The webbing of its limbs had decayed, exposing the pedal skeleton with elongated phalanges. The phalanges of both Jinzhousaurus and Beipiaosaurus were also elongated. Did they really touch the ground like the claws of theropod and ornithopod dinosaurs? Is it possible that they possessed webbed feet similar to those of turtles?

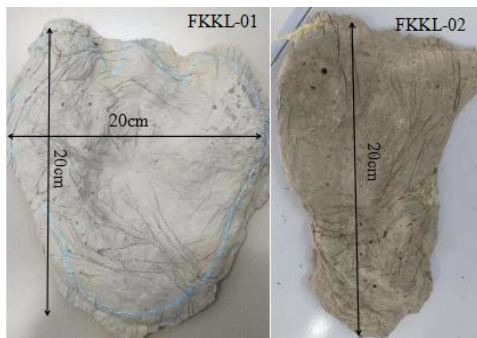


Figure 22 : 3D Model of Replicated Footprints

FKKL-01 and FKKL-02 were 3D model footprints replicated in the field. Their footprint thickness was generally uniform, with distinct three-toed marks at the toe tips, indicating that they were not produced by hoofed animals. The geometric outlines of their soles were curved, and a pit was present in the middle of the FKKL-01 footprint. These features indicated that their pedal bones were curved and elongated. The sole was continuous without separate digit impressions, suggesting that the tracks were formed by webbed feet. This demonstrated that diverse dinosaur taxa with high aquatic adaptability once inhabited the coastal area of Juehua Island, western Liaoning. If dinosaurs with such webbed feet were fossilized, their feet would likely be preserved as skeletal fossils similar to the webbed feet of turtles.

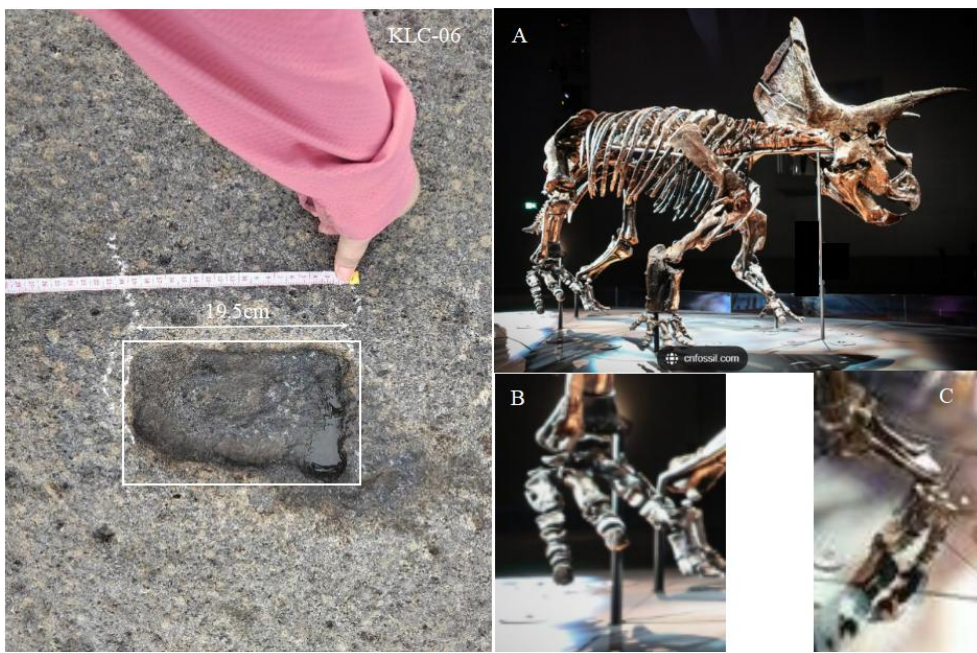


Figure 23: KLC-06 Footprint

Panel A in Figure 23 shows a fossil of a ceratopsian dinosaur, which belonged to the ornithopod dinosaurs. It possessed three toes with almost no divergence between them; the three toes were nearly parallel and lay on the same plane (see Panel C). Moreover, both ends of each digital bone were relatively flat. As a result, the overall geometric outline of the entire foot skeleton was rectangular.

Description of KLC-06: The footprint in the studied area had a flat base and uniform trampling depth, with a rectangular geometric outline. The toe region was distinct and showed three digit marks; in particular, the lower digit tip exhibited a deeper impression, while the heel region transitioned into a square with rounded corners. These characteristics were generally consistent with the skeletal features of the ceratopsian hindfoot. However, the footprint base lacked complete digit traces, indicating that it was produced by a foot with a fat pad and hoof-like structure. If KLC-06 was made by a ceratopsian dinosaur, should it still be classified as an ornithopod?

In 2002, Xu Xing from the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences discovered a new primitive ceratopsian dinosaur in western Liaoning. *Liaoceratops*, which lived in the Early Cretaceous approximately 130 million years ago, was the earliest known neoceratopsian in the world. It was a quadrupedal herbivorous dinosaur [29].

Dinosaur remains discovered in western Liaoning to date were mostly from the Early Cretaceous or even earlier periods. It remains to be confirmed whether the dinosaur footprints on Juehua Island were produced by dinosaurs of that age along the coast.

Monkey Footprint

Among the numerous footprints on Juehua Island, some traces resembled the hand and foot impressions of primates, though they occurred only as isolated individual prints scattered along the beach.

Characteristics of Modern Monkey Hands and Feet

Taking the Tibetan macaque (*Macaca thibetana*) from Mount Emei, Sichuan Province, China, as an example (see Figure 24), the basic characteristics of monkey hands and feet were analyzed. Monkeys represented a type of plantigrade animal. The metatarsal bones of the foot were longer than the phalanges, resulting in an elongated sole. The divergence angle between the hallux and the rest of the foot could even exceed 90° , a degree of abduction not achievable by the human hand. With the exception of the hallux, the other four toes typically displayed an arched downward curvature, with their distal ends flexed toward the ground.



Figure 24: Sitting Tibetan Macaque

The pollex (thumb) of the monkey's manus was shorter than the hallux of its pes. It made firmer contact with the ground, and its abduction angle relative to the palm was less than 90° , smaller than that of the hind foot. The flexion of the fingers was relatively flexible, allowing vertical bending between the phalangeal joints.



Figure 25: Walking Tibetan Macaques

The Tibetan macaque was capable of bipedal locomotion but preferred quadrupedal walking. During touchdown, the sequential contact regions of the foot were as follows: toes → partial metatarsals → entire metatarsals → tarsals (which occasionally contacted the ground). The abduction angle between the hallux and the rest of the foot exceeded 90° . During lift-off, the sequential contact regions were: tarsals → metatarsals → toes → toe tips. When the monkey placed its palm on the ground during locomotion, the contact sequence was: fingertips → phalanges → palm; the sequence was reversed during lift-off. Prior to contact, the fingers were flexed, with the distal phalanges particularly curved inward.

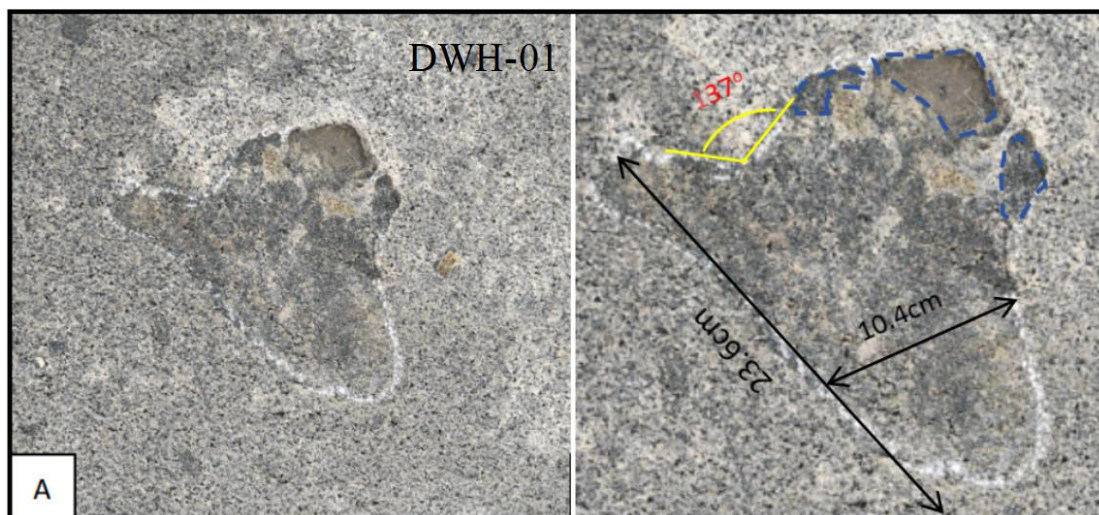


Figure 26: DWH-01 Footprint

Description of DWH-01: This trace exhibited a distinct thumb and palm or sole impression. The human palm is square-shaped and possesses an arch, resulting in a very faint impression of the central region. This palm impression was relatively uniform, indicating that the maker lacked a palmar or plantar arch. The geometric shape of the palm and the absence of a palmar or plantar arch were consistent with the characteristics of monkey hands and feet, allowing the conclusion that this was a hand or footprint made by a monkey. The abduction angle between the thumb and the other four digits exceeded 90°, and the four digits were flexed, as no complete impressions of these digits were preserved. Such digital characteristics matched the toe features of monkey soles.

The distal parts of the four digits lacked impression material, which may have resulted from soil adhering to the fingertips being removed as the monkey’s sole lifted off the substrate. From the depth distribution of the entire impression, the contact pressure exerted by the maker during locomotion was inferred as follows: the highest pressure occurred at the fingertips of the four digits, while the lowest pressure appeared at the tarsal region. Such a pressure pattern could only be produced by the sole of a monkey during normal walking along the coast. Both during touchdown and lift-off, the toe tips maintained contact with the ground, resulting in the maximum pressure in the toe tip region.

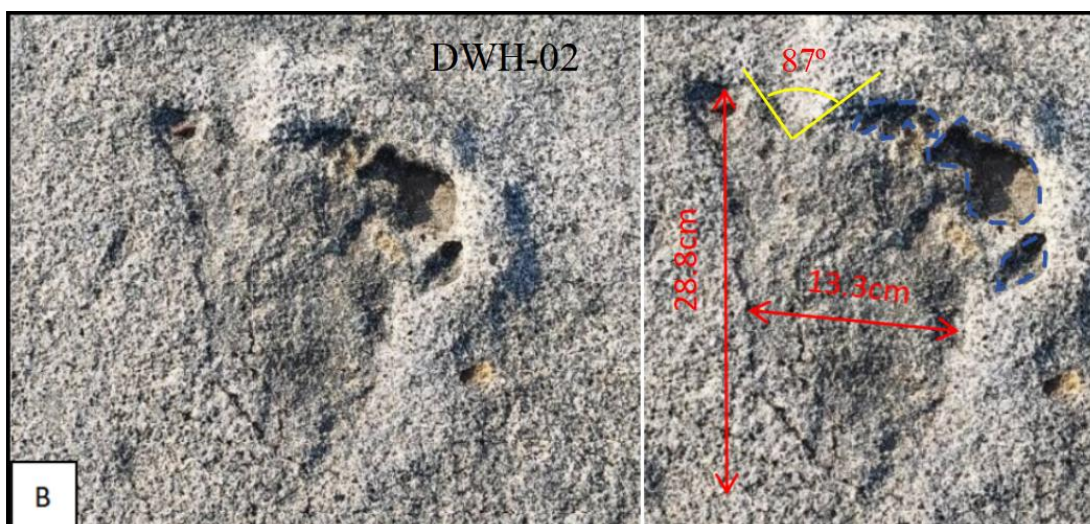


Figure 27: DWH-02 Footprint

Description of DWH-02: This trace also displayed a distinct thumb and palm or sole impression, and its overall geometric outline was similar to that of DWH-01. It was not a human palm print and was likely another hand or footprint of a monkey. The abduction angle between the thumb and the remaining four digits was much smaller than that of the aforementioned sole, approaching 90°, a feature consistent with the palm of a monkey. A pit formed in the thumb region due to mud removal, indicating that the contact pressure here was greater than that of the thumb in DWH-01. This characteristic was consistent with the contact pattern of the hands and feet of the Tibetan macaque. The distal parts of the four digits lacked impression material, which resulted from the flexible fingers and their large bending angle during locomotion. The distal phalanges pressed inward against the substrate and carried away a large amount of mud when lifting off. Such preservational characteristics agreed well with traces left by a monkey’s palm during normal walking.

The DWH-02 trace was damaged by seawater scouring, as evidenced by the eroded features in the lower-left part of the palm impression and the area anterior to the digit margins, where high and uneven concentrations of sand grains and particulate materials were present. Seawater scouring occurred both against and along the direction of the monkey's movement, indicating that the study area was a high-energy tidal zone and a tidal channel. The greater accumulation of raised muddy sediments along the anterior digit margins suggested that the kinetic energy of seawater was higher against the direction of travel than along it. This indicated that the monkey was walking toward the ocean, since the return flow in the tidal channel was relatively weak.

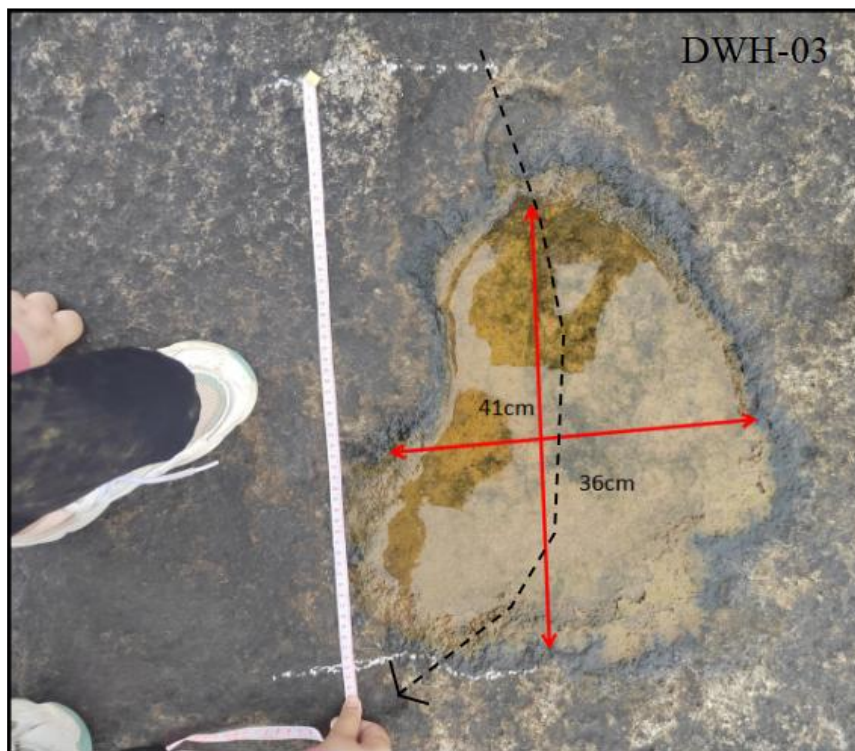


Figure 28 DWH-03 Footprint

Figure 28

Description of DWH-03 : The geometric outline of this trace was similar to those of DWH-01 and DWH-02, but its geometric dimensions were considerably larger, resulting in a greater trampling depth. Although the margins of the trace had been subjected to prolonged seawater scouring, it could still be confirmed that the thumb was adducted close to the other four digits and was relatively short. These characteristics closely resembled those of a monkey's palm, suggesting that the footprint was likely produced by a large monkey. The curved lateral margin of the palm indicated a leftward turning movement, with pressure applied to the left side of the palm and the thumb, leading to adduction.

The presence of primate hand and foot traces of different sizes on Juehua Island indicated that monkeys of various body sizes once lived together here.

Geological Events

Why were all these footprints stacked together on one section of the coast? The most likely explanation was that they had jointly experienced a large-scale tectonic movement, which caused dramatic geological transformations in this area.

Geodynamic Model

The coastal area where the rock footprints were preserved on Juehua Island shared uniform tectonic and geodynamic characteristics. In chronological order, after the footprints were formed, the strata underwent overlapping tectonics and diagenesis. At a later time, crustal torsion, compression, and collision further modified the entire geological structure and geomorphology of Juehua Island. This study focuses on the geological events that occurred after the formation of the footprints. The most significant effect of this event was the formation of stacked coastal sediments and the overlapping structures of the mountains near the coast.



Figure 29: Overlap Structure on the Coast of Juehua Island

The areas studied in A, C, and D of Figure 29 represent mountain structures adjacent to the footprint fossil coast. Marine sedimentary rocks cut into the lower parts of the nearby mountains, forming an overlapping structure bounded by an unconformity, in which older rocks overlie younger rocks. The mountains strike NNE (north-northeast), and the rock layers are nearly parallel to the horizontal plane. In the study area of Panel D, stratified fractures developed in the joints of the marine sedimentary rocks.

The area studied in B of Figure 29 is the major turning point of the coast where the footprints were distributed. The stratigraphic strike changed from SSW (south-southwest) to NNE (north-northeast). Marine sediments were deposited in layers, and their dip direction and dip angle varied along the curved coastline. At one measured site, the orientation was recorded as $44^\circ \angle 25^\circ$. How did the stratified overlapping structure form?

The Genesis is Analyzed Below

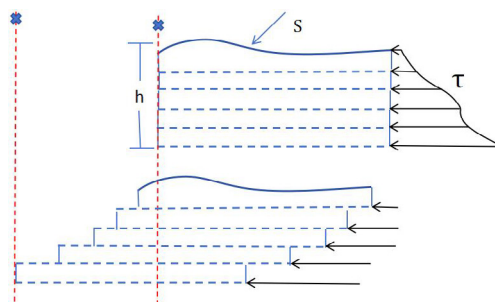


Figure 30

s-coastal marine facies sediment surface; h-thickness of marine sediments in which the geological movement occurred; τ -The shear stress between the layers of marine sediments. Figure 30 Schematic diagram of the dynamic model for basal overlap structure. According to field geological investigations of multiple areas in western Liaoning by Jin Chunhua et al. and years of geological research by other scholars, the tectonic dynamics responsible for this geological event were determined to increase nonlinearly with depth from the surface downward. Such a dynamic distribution caused vertical variations in the horizontal displacement of coastal sedimentary rocks under different stress levels, resulting in the formation of a stacked structure, as shown in Figure 30. The surficial coastal sedimentary rocks experienced the weakest tectonic force and remained nearly in situ. Deeper coastal sedimentary rocks were displaced horizontally over the greatest distance, encountered mountains near the coast, and then cut into and accumulated at the base of these mountains. The enormous volume of marine sedimentary rocks observed along the shores of Juehua Island and in adjacent mountains indicates that the ancient coast was relatively flat and extensive.

Many blocky footprint rocks such as those shown in



Figure 31: Were Found.

Footprints occurred not only on the top surfaces but also on the sides of these rock blocks.

The Causes are Analyzed below

Coastline and dynamic direction	Stress state of coastal sediments	Footprint distribution mode

Figure 32: Blocky Footprint Rocks on the Coast of Juehua Island

Figure 32 Schematic diagram of the relationship between coastline and dynamic direction When the geodynamic F stress is perpendicular to the ancient coastline, sediments in the coastal area are compressed along the stress σ_1 direction, subjected to uniaxial principal stress. This uniaxial compression causes the sediments to cement into coastal rocks, with footprints forming exclusively on the upper surface. When the geodynamic stress F is non-perpendicular to the ancient coastline, sediments are similarly compressed along the stress direction but experience biaxial principal stress σ_2 . This results in the sediments being compressed in two directions, forming massive blocks. The sedimentary rocks ultimately cement into massive rocks, with footprints distributed on both the upper surface and lateral sides.

Thrust-nappe structures are widely distributed in many areas of western Liaoning, and Juehua Island represents one of these regions. The geological event identified in this study was the same tectonic event responsible for the formation of thrust-nappe structures in western Liaoning during the Middle Jurassic to mid-Early Cretaceous. The formation of thrust-nappe structures in western Liaoning was related to the final closure and collision of the Mongol-Okhotsk Ocean between the Siberian Plate and the North China Plate, as well as the westward subduction of the Paleo-Pacific Plate beneath the East Asian continent. Large-scale lithospheric thinning of the North China Craton occurred during the

Mesozoic [30]. Based on geochemical analyses of zircon and rutile from the Early Cretaceous basalt porphyrites in the Xingcheng area of the North China Craton, combined with relevant regional geological data, He Dengyang et al. (School of Earth Sciences and Resources, China University of Geosciences) suggested that the magma of the Xingcheng basalt porphyrites was of ancient island-arc type. The termination time of Mesozoic lithospheric thinning in the North China Craton can be constrained to the late Early Cretaceous at approximately 105 Ma. Retreat of the steeply subducting Paleo-Pacific Plate served as the first-order geodynamic mechanism for lithospheric thinning of the North China Craton, with thermochemical erosion or delamination as the second-order mechanism [31].

It could be confirmed that all types of footprints formed during the same geological event, and the humans, dinosaurs, and other animals represented by the footprints existed synchronously.

Induced Transgression and Volcanic Eruption

During this geological event involving the subduction and compression of the Paleo-Pacific Plate beneath the continental plate, other geographic changes and geological hazards were also triggered, such as tsunamis and marine transgressions.

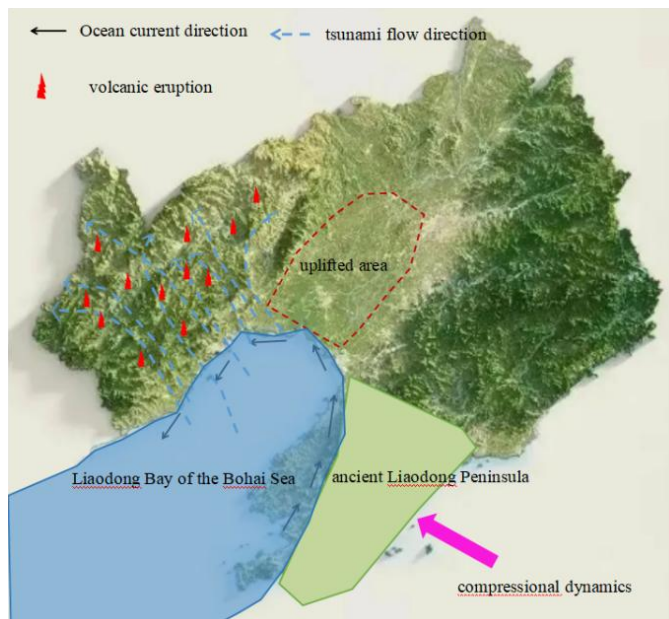


Figure 33: Schematic Diagram of Transgression and Volcanic Eruptions Triggered by Early Cretaceous Geological Events

As shown in Figure 33, the compressive tectonic force originated from the southeast direction. This movement affected not only the crust and mantle beneath but also caused the displacement and uplift of the overlying continental landmasses. The ancient Liaodong Peninsula shifted from its original position to its present location, and the coastal southern Liaoning area was uplifted, resulting in a reduction in the area of the ancient Liaodong Peninsula. This also indicated that the sea level of the Liaodong Bay during the Early Cretaceous was much higher than today. The flow direction of currents in the Liaodong Bay is indicated by the black arrows in Figure 32, showing a counterclockwise circulation. Due to subduction and compression between plates, seawater from the Liaodong Bay, together with connected lagoons (e.g., the Xingcheng Lagoon) and coastal swamps, invaded and inundated the western Liaoning inland in the form of tsunamis. The main direction of inundation was toward the Chaoyang area, followed by parts of Jinzhou.

The flow path was also influenced by the direction of marine currents, causing expansion both eastward and westward: westward to Chengde in northern Hebei, and northeastward to Fuxin. The Chaoyang area received the largest volume of through-flow water and had the greatest water storage capacity, owing to the widespread Jurassic basins in this region. The water may have also reached adjacent Inner Mongolia regions, such as Chifeng and Aohan Banner. Massive volcanic eruptions occurred simultaneously with the seawater incursion into western Liaoning. Volcanic activity was distributed across almost the entire western Liaoning area, and also took place in adjacent regions such as northern Hebei .

Coupling Traces of Geological Events and Disasters

During the Early Cretaceous, the western Liaoning area was subjected to both marine transgression and volcanic eruptions. Coupling traces of volcanic structures, tsunamis, marine transgression, marine regression, alluviation, sedimentation, and geological disasters were preserved in this region.

The Main Characteristics of these Geological Traces are as Follows

Volcanic Belt Structures: Volcanic rock basins of the Yixian Formation during the Early Cretaceous developed within three NE-trending volcanic eruption belts, namely the Jinxi-Jinzhou-Yixian-Fuxin volcanic eruption belt, the Jianchang-Kazuo-Chaoyang volcanic eruption belt, and the Sanshijiazzi-Lingyuan-Tieyingzi volcanic eruption belt [32].

Sedimentary-Volcanic Traces: The Yixian Formation volcanic rock series was predominantly developed in most areas of Xingcheng, including volcanic successions of basalt-andesite-dacite-rhyolite, such as those in the Caozhuang area and Dongbali quarry in Xingcheng. In the Jianshan area of Xingcheng, the Yixian Formation volcanic rocks were subdivided into pyroclastic rocks, lavas, sedimentary-volcanic rocks, sedimentary rocks, and subvolcanic rocks [33]. In multiple basins across Fuxin, Chaoyang, Lingyuan, Kazuo, and Jianchang, the lower lithology of the Yixian Formation was dominated by intermediate-basic volcanic lavas, while the upper part consisted of tuffaceous fine-grained sedimentary rocks, volcanic breccias, and pyroclastic rocks [34]. It was precisely because marine incursion and volcanism occurred in coupling that various types of volcanic rocks and other lithologies were formed under the combined effects of marine alluviation, sedimentation, chemical reactions, and cooling of volcanic lavas, especially exhibiting distinct sedimentary-volcanic characteristics.

Heterogeneous Characteristics of Sedimentary Rocks: The Early Cretaceous Yixian Formation was scattered in distribution, and complete, continuous stratigraphic sections were rarely preserved. The correlation between different strata was complex. Accordingly, long-standing debates existed over the stratigraphic framework of this area, and no consensus had been reached among different researchers [35]. In some areas, the Yixian Formation was composed of four volcanic cycles and at least seven sedimentary beds. The heterogeneity of sedimentary rocks in different regions was caused by the superposition of multiple factors in different areas: marine incursion into the continent encountered varied geography, geomorphology, hydrology, and rock-soil conditions, which generated distinct hydrodynamic regimes, combined with volcanic eruptions of different scales and types.

Characteristics of Brackish and Saline Lakes: Marine water invaded the inland areas and advanced mainly along plains, rivers and lakes, intermountain basins, fault troughs, etc. When it encountered low-lying rivers and lakes, part of the seawater was retained there, forming brackish and saline lakes. Based on petrological and sedimentary facies studies of carbonate rocks from the Yixian Formation at Laogonggou, north of Yingwoshan, Wangjiagou, and Zaocishan sections in western Liaoning, Gong et al. (2011) concluded that the carbonate rocks of the Yixian Formation in western Liaoning were deposited mainly in brackish to saline floodplain waterlogged depressions and shallow lacustrine environments.

Characteristics of Tsunamites, Transgression and Regression: Distinct tsunamites were developed in the coastal areas of western Liaoning. As the tsunami energy dissipated continuously, the potential energy of the encroaching seawater weakened gradually toward the inland areas, and sedimentation became dominant progressively. Obvious tsunamites were distributed in the sedimentary sequences of the Jianshan, Shoushan, Chapeng'an, Mopan Mountain, and Wanghaisi areas in Xingcheng, a coastal city. Sedimentary records of transgressive to regressive cycles of shallow marine facies were identified in the Bajiazi, Yangjiazhangzi, Gangtun and Niangniangmiao areas of Xingcheng [36].

Characteristics of Disturbed Geological Chronology: New landforms were formed by geological compression and displacement (thrust-nappe structures, fault zones, basins, etc.), transport and entrainment induced by marine incursion (various gravels, silts, clays, etc.), and diverse types of volcanic eruptions (intermediate-basic volcanic rocks and pyroclastic rocks, with local intercalations of intermediate-acidic, acidic, and alkaline volcanic rocks, pyroclastic rocks, and sedimentary rocks). New "composite rocks" were formed by the superposition of older strata and volcanic rocks from different geological periods. This resulted in numerous controversies and a lack of unified consensus in determining their geological tectonic movements and geochronological ages.

Was the Habitat of the Jehol Biota a Homeland for Dinosaurs?

Abnormal Death of the Jehol Biota

Western Liaoning of China was the main discovery area of two major biotas, the Jehol Biota and the Yanliao Biota. Fossils of dinosaurs, early birds, primitive mammals, abundant bivalves, gastropods, conchostracans, insects, fish, shrimp, amphibians, reptiles, birds, and other organisms were discovered in the lacustrine sediments of the Jehol Group. These fossils were preserved at a repository-like level, recording a rich and relatively complete ecosystem [37]. What caused the death of dinosaurs in the Jehol Biota? The Yixian Formation sediments bearing numerous Jehol fossils contained abundant volcanic tuffaceous components. Large volumes of volcanic gases, ash and aerosols released during volcanic eruptions led to rapid changes in climate and environment. Therefore, volcanic eruptions were inferred to be the direct cause of the mass mortality of these organisms [38].

This conclusion was accepted by most researchers, but objections still existed. For example, the fossil-bearing horizon of the Jianshigou Bed in the Yixian Formation at Sihetun, western Liaoning, consisted of black mudstone without obvious volcanic materials, which puzzled some scholars. Aquatic reptiles living in freshwater lake bottoms (such as *Manchurochelys* and *Manchurosuchus*) were not directly exposed to terrigenous volcanic gases. Meanwhile, lakes showed a significant lagged response to climatic changes in the atmosphere, resulting in relatively weak impacts of terrigenous volcanic activity on the living environments of aquatic reptiles in freshwater lakes. Accordingly, considerable disagreements still existed regarding the cause of the mass mortality event represented by fossil beds dominated by aquatic reptiles such as *Manchurochelys* and *Manchurosuchus* in western Liaoning [39]. It could thus be seen that the mass extinction of the Jehol Biota in western Liaoning was probably caused not solely by direct volcanic eruptions. In addition, the taphonomic characteristics of Jehol Biota fossils indicated that they suffered abnormal death. In fossil assemblages of naturally deceased organisms, weak juvenile and elderly individuals were dominant and scattered, and

the dead organisms usually displayed peaceful postures. The Jehol Biota exhibited mass mortality, and some vertebrate fossils preserved painful states before death. For instance, fish fossils had open mouths and twisted vertebrae, showing struggles before death; in contrast to naturally deceased turtles and tortoises, in which heads and limbs retracted into the carapace, fossils of *Manchurochelys* showed extended necks, straightened or upturned tails, and limbs thrust beneath the bedding plane, representing short-term struggling postures before death; the right forelimb wing phalanx of *Haopterus gracilis* was tightly bitten in its mouth, resulting from painful struggling during death [40]. Such large-scale synchronous biological mortality suggested that these organisms likely perished in the same major catastrophic event.

Insufficient Support from Ecological and Climatic Conditions

Scholars at home and abroad conducted studies on plant fossils of the Jehol Biota in western Liaoning, China. For example, Duan Shuying (1997) held that, based on the occurrence of plants such as *Phoenicopsis*, *Czekanowskia*, *Pityocladus*, *Schizolepis*, and *Elatocladus*, "these features indicated that the climatic environment during this period was unfavorable for plant growth, and was quite different from that of the Middle Jurassic and Early Cretaceous. This accorded well with the global shift to hot and arid conditions during the Late Jurassic" [41]. Zhu Weiqing questioned the previous view that the Yixian Formation in Beipiao, western Liaoning, was deposited under a hot and arid climate, based on the abundance of hygrophilous trees and herbs in the Yixian Formation, and argued that the vegetation indicated a warm and humid living environment [42]. Based on the properties and assemblage characteristics of the Yixianian flora, Zheng Shaolin et al. suggested that the Yixianian flora was of late Jurassic age, and inferred that it grew under a semi-arid to semi-humid, or seasonally arid, subtropical or subtropical to warm-temperate climatic environment [43]. In addition, plants such as tree ferns and cycads, which required warm and humid paleoclimatic conditions, occurred in the interior of western Liaoning, and these were inconsistent with the local inland climate at that time. Abundant fossil spores and pollen were discovered in the interior of western Liaoning [44]. Which were rich in marine phytoplankton (diatoms), indicating the occurrence of a marine transgression event in the gray marlstones in the upper part of the Yixian Formation. In other words, hygrophilous plants and marine phytoplankton that conflicted with the local arid climate appeared in the interior of western Liaoning (the habitat of the Jehol Biota).

During the Early Cretaceous, the interior of western Liaoning (the locality of the Jehol Biota) was characterized by an arid and hot climate. Most areas consisted of high mountains, sparsely vegetated desert lands, and grasslands with few trees, where only xerophytic plants grew. How could such limited plant resources have supported large herbivorous dinosaurs as well as various medium- and small-sized herbivorous dinosaurs? Such a simple geographical environment could not have provided suitable habitats for a diverse fauna. It was therefore inferred that this region might not have been their original living habitat. Some event must have transported the remains of the biota to this site from elsewhere. Volcanic eruptions might not have been the direct cause of the mass mortality of the biota, but rather a secondary disaster. In addition, dinosaur fossils discovered in the Jehol Biota from the interior of western Liaoning consisted only of skeletal remains, with no evidence of in-situ life activities, such as footprints, dinosaur eggs, or egg clutches. This further confirmed that the interior of western Liaoning was not the actual homeland of dinosaurs, nor was it the original habitat for most of the recovered organisms.

Causes of Extinction of Dinosaurs and Other Organisms

Tsunamis and marine incursion devastated nearly all organisms along the coast, including dinosaurs, birds, mammals, insects, and other animals, which were swept into the flood currents. Non-aquatic animals, such as most dinosaurs, insects, and birds, drowned rapidly, struggling painfully in the torrents until death. Their carcasses were carried by the floodwaters toward the interior of western Liaoning. Due to collision and friction, most animal carcasses, especially large individuals, suffered varying degrees of damage; only a small number remained intact or nearly intact and successfully reached low-lying areas such as basins in the interior of western Liaoning, completing their "transportation" and final deposition. Naturally, aquatic-dwelling dinosaurs were not spared either; they were also carried by the flood currents on the journey to the interior of western Liaoning. Plate collision was accompanied by sustained volcanic activity. In some areas, volcanic lava and ash were incorporated into the passing floodwaters or the final deposition sites of the organisms, causing poisoning and mortality among aquatic and amphibious animals. Variations in hydrodynamic conditions across different regions resulted in diverse sedimentary types. These biological remains were eventually buried in various sediments, forming different types of sedimentary rocks and thus being preserved. Therefore, tsunamis induced by oceanic plate subduction and compression, together with marine incursion into the interior of western Liaoning, were the primary causes of death and posthumous transportation of dinosaurs and other marine and coastal organisms. Volcanic eruptions acted as a secondary cause responsible for the death of some organisms.

Homeland of the Dinosaurs

Dinosaur track fossils and numerous dinosaur egg clutches were both preserved on the coast of Juehua Island.

Typical Examples are Listed as Follows



Figure 34: Dinosaur Egg Clutch 1

A large number of dinosaur egg clutches were also discovered along the coast of Juehua Island, one of which is shown in Figure 34. It presented two eggshell fossils from a large dinosaur, with traces of egg-white layering, indicating that the eggshells might have been broken. The lithological composition where the eggshells were found revealed that this area was once a mixed zone of fine sand and silt. Such lithology typically occurred only at the margin between the coast and land, or in coastal marsh environments. This indicated that the dinosaur egg clutches were formed at the edge of the ancient coast.

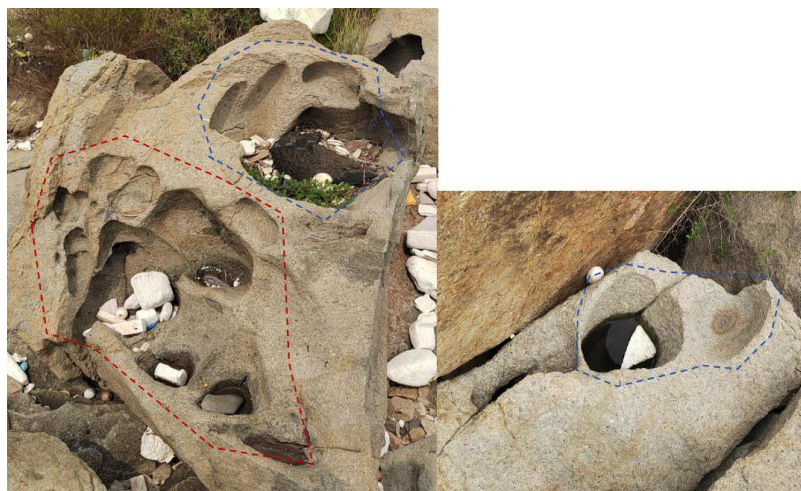


Figure 35: Dinosaur Egg Clutch 2

The host rock of the egg clutch shown in Figure 35 was dominated by silt, containing medium- to coarse- grained sand. Such sandy sedimentary characteristics also indicated a coastal margin setting, namely the ancient coastal edge. In the left figure, the eggshells within the blue frame were smaller than those above; one end of the eggshells was pointed, and the other was elliptical. Furthermore, several eggshell morphologies occurred in this area, suggesting that eggs from multiple dinosaur species were laid and incubated together. Based on the above research and analysis, dinosaurs during the Jehol Biota period frequently inhabited the ancient coast of western Liaoning, such as the ancient coast of Juehua Island. Dinosaurs buried their eggs in the warm coastal sands, which were located in the supratidal zone beyond the reach of tides, forming a nursery ground. The temperature within the sand deposits was highly suitable for egg incubation.

The Cretaceous represented a typical greenhouse climate period in geological history, and a series of international studies had been conducted on this period [45]. During the Early Cretaceous, the obliquity of the Earth's axis was smaller, which resulted in less distinct seasons in western Liaoning compared with the present. Solar radiative heat was much higher than today, leading to higher temperatures in the mid- latitude region of western Liaoning, even higher than temperatures at the modern equator [46]. The climate of the Early Cretaceous in China was closely related to the basin- range pattern formed by the Yanshanian Movement and the Cretaceous transgressive events. A series of mountain uplifts caused by the Yanshanian Movement blocked the incursion of warm and humid marine monsoons from the ancient Pacific Ocean, maintaining a hot and arid climate in the inland areas of western Liaoning.

The coastal areas, however, were hot and humid zones, forming a paradise for diverse plants and all organisms, and providing abundant food resources for herbivores. According to paleogeographic studies of the coastal regions of western Liaoning, the Huludao and Jinzhou areas contained large-scale bays, with freshwater deltaic swamps along the coast. The Xingcheng area possessed mangrove zones at the intersection of freshwater and seawater input, as well as freshwater-dominated lagoons. Both areas hosted numerous coastal mountains and inland uplands, as well as slopes formed by arched structures . (See Jin Chunhua, Coastal and Mountain Dwelling Civilization,Paleogeography chapter) These environments provided habitats for a variety of animals and served as major feeding grounds for carnivorous dinosaurs. Therefore, the ancient coast and coastal regions were likely the true homeland of dinosaurs.

Traces of Ancient Human Migration
Traces of Ship Anchors

Under the influence of geological events, the remains of dinosaurs and other organisms on Juehua Island were transported to the interior of western Liaonia and eventually preserved as fossils. However, human remains and those of some other animals from Juehua Island were absent from these localities. Why did they not perish in this geological event and become fossilized together? It was possible that humans, monkeys, and other animals had already abandoned their original habitats and migrated to other regions prior to the geological event. During the search for migration evidence, traces of ancient ship anchors were discovered on the coast of Juehua Island.



Figure 36: Beach Anchor

Ships were anchored and secured to beaches primarily by means of beach anchors. Various types of beach anchors existed at the time, as illustrated in Figure 36. Type B represented the most conventional ship anchor, equipped with two flukes. When dropped into water or sand, the flukes would embed themselves into the substrate or beach, providing holding capacity while remaining relatively easy to retrieve. Vessels were then held in waters or along the coast via anchor chains or cables. Type A referred to an array of beach anchors used for mooring, where numerous ships could be secured simultaneously. Type C denoted homemade beach anchors innovated and fabricated independently. Several cracks of considerable depth were discovered in the footprint area along the coast of Juehua Island. The cracks were widest in the middle and gradually narrowed toward both ends. Similarly, the cracks were deepest in the middle and gradually became shallower toward the termini. Surrounding the grooves, sedimentary rocks of a certain width were depressed several centimeters below the surrounding rock mass, resembling a brim along the grooves, as shown in Figure 36. These features were not produced by natural processes but appeared to be artificially formed. by fishermen. Consequently, the forms of anchors employed to secure ships at beaches were flexible and diverse.



Figure 37: Partial Remains of Beach Anchor

Several cracks of considerable depth were discovered in the footprint area along the coast of Juehua Island. The cracks were widest in the middle and gradually narrowed toward both ends. Similarly, the cracks were deepest in the middle and gradually became shallower toward the termini. Surrounding the grooves, sedimentary rocks of a certain width were depressed several centimeters below the surrounding rock mass, resembling a brim along the grooves, as shown in Figure 37. These features were not produced by natural processes but appeared to be artificially formed.

- **Description of GJCM-01:** It was a nearly linear fissure, severely eroded by seawater. Its geometric parameters were as follows: length 290 cm, maximum depth 38 cm, minimum depth 10 cm, groove rim width approximately 6 cm; the fissure was oriented NEN (south by southeast).

● **Description of GJCM-02:** It was deflected by a geological event and was not measured. However, its groove rim was distinct. Local magnification revealed two small pits on the rim, suspected to be footprints of a small animal. These footprints were formed after the creation of the special fissure, indicating that the fissure and the footprints of animals and humans were contemporaneous. Numerous footprints were also distributed around the special fissure.

● **Description of GJCM-03:** It was a nearly linear fissure, with relatively minor damage caused by seawater erosion. Its geometric parameters were as follows: maximum depth approximately 25 cm, minimum depth approximately 7 cm, rim width approximately 8 cm, and orientation SSW (north-northwest).

What kind of implement had created these fissures? Based on the geometric morphology and dimensional variation of the fissures, they were reconstructed as shown in Figure 38, as illustrated below.

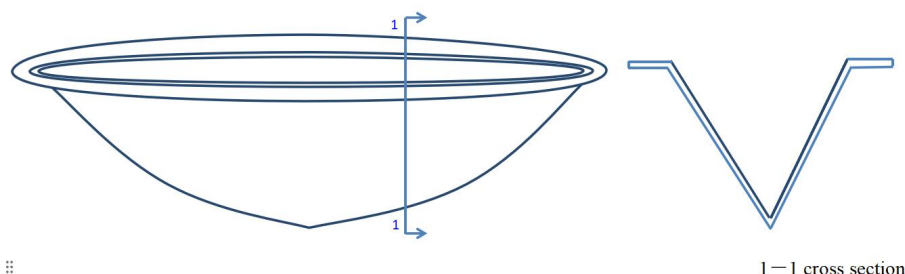


Figure 38: Schematic Diagram of the Ancient Beach Anchor on Juehua Island

From the sectional view and front view in Figure 38, it could be seen that the object tapered gradually downwards and toward both ends. It mainly consisted of two parts: a flattened main body and a brim-like structure. Was it an implement used for collecting marine resources? Given its small capacity and narrow internal space, this was clearly not the case. It was suspected to be an anchor for securing vessels on the beach.

Its performance as a beach anchor was evaluated against the following criteria:

High holding power represented the most fundamental performance requirement. The ancient Juehua Island beach anchor penetrated vertically into the sand, and its penetration depth increased with greater anchor mass. Its working mechanism relied on friction between the outer surface of the anchor and the sediment, as well as fluid suction, which differed from that of modern fluke- type anchors.

It could adapt to a variety of different substrates. The ancient Juehua Island beach anchor was suitable for all beach areas except rocky bottoms. It possessed a robust structure. The ancient Juehua Island beach anchor exhibited high structural stability and could withstand various complex loads during the processes of anchoring, weighing, and mooring of vessels. It exhibited good stability and ease of penetration into the substrate. The ancient Juehua Island beach anchor was approximately conical in two dimensions, allowing it to penetrate the sand easily. Its surface adhered closely to the sediment, resulting in excellent stability. It featured a short penetration distance. Although the ancient Juehua Island beach anchor was relatively long, its vertical height was much smaller, and this design resulted in a short penetration distance.

It required a low pulling force. The conical design at the lower part of the ancient Juehua Island beach anchor reduced the pulling force. In addition, the brim structure allowed the anchor to be retrieved easily by prying the brim during recovery. It exhibited excellent self-cleaning properties. The ancient Juehua Island beach anchor possessed an overall teardrop shape, which facilitated the release of sediment during retrieval from the substrate and thus achieved a self-cleaning effect.

It provided a unique safety guarantee, a characteristic exclusive to the ancient Juehua Island beach anchor. A great variety of organisms inhabited the coastal area of Juehua Island, including large herbivorous and carnivorous dinosaurs, various small and medium-sized dinosaurs, other ancient fauna of Juehua Island, as well as humans. Had the ancient anchors been identical to modern ones, their protruding components would have injured animals that stepped on them or been damaged by the animals.

The brim- equipped design of the ancient Juehua Island beach anchor ensured that the entire anchoring structure was level with the beach surface, or even buried beneath it. The surface was sufficiently flat and did not hinder or impede the movement of animals. The ship's cable could be secured between the upper part of the flattened main body and the underside of the brim, allowing the cable to be buried in the sand.

As can be seen from the above analysis, such a tool satisfied the functional requirements of a marine anchor, and its design concept was better adapted to the working environment. These distinctive grooves were most likely traces left by anchors. The presence of such anchors indicated that humans had already constructed watercraft at that time. The existence of anchors in different specifications also suggested that vessels of varying sizes existed. Overall, the

geometric dimensions of these ancient anchors were larger than those of modern anchors. The longest anchors were comparable in size to those used on modern motherships, implying that large-scale vessels, possibly in considerable numbers, likely existed during that period. The emergence of boat anchors indicated that humans had already acquired the necessary conditions for migration.

Footprints of Marching toward the Ocean

On the coast of Juehua Island, traceable footpaths indicated that animals had moved toward the ocean, as shown in the following tracks

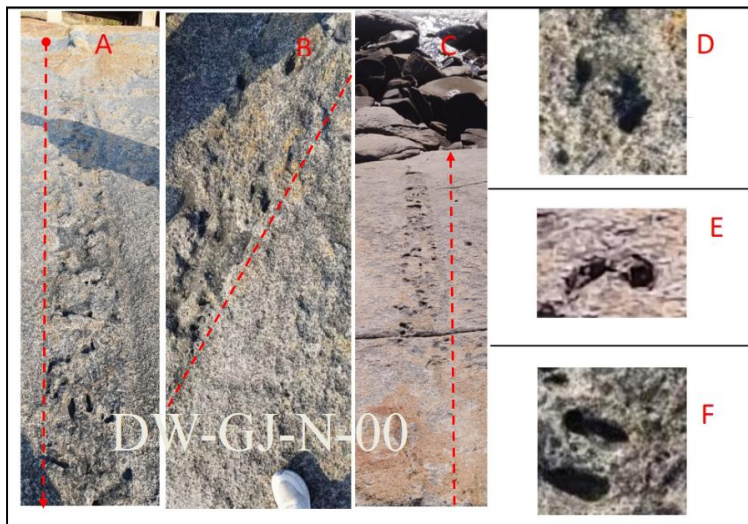


Figure 39: DW-GJ-N-00 Footprint

Description of DW- GJ- N- 00: The study area was a rocky coastal slope where trackways of varying widths were discovered. Segment A represented the upper part of the slope, Segment B the middle section, and Segment C the lower slope, which sometimes extended into seawater. The trackways contained scattered and disordered animal footprints, a small number of which remained distinct and clear, as shown in D, E, and F. The taxonomic identification of this animal was documented in the relevant chapters of 《Coastal and Mountain Dwelling Civilization》 by Jin Chunhua. These tracks were formed by animals moving in groups and in formation. Based on the orientation of the footprints, it was determined that the animals had descended from the mountains and advanced toward the ocean.

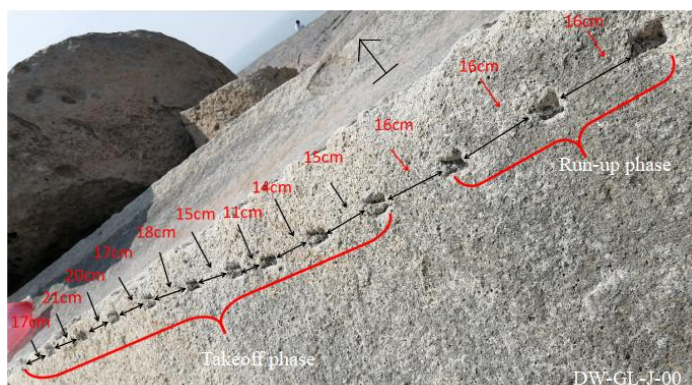


Figure 40: DW-GJ- J-00 Footprint

Description of DW- GL- J- 00: This set of footprints was preserved on the inclined lateral surface of a coastal boulder, consisting of a continuous trackway left by a toed animal. Several footprints on the right side were initially tridactyl and gradually became didactyl, with the two toes progressively shortening. These traces were left by a volant animal, formed during a running takeoff and gliding sequence. Detailed taxonomic identification and analysis were provided in the relevant chapters of 《Coastal and Mountain Dwelling Civilization》 by Jin Chunhua. It could be readily observed that this animal took flight toward the ocean.

In addition to the two examples mentioned above, other traces of movement toward the sea included the human footprints CCD- 01 and CCD- 02, as well as the monkey footprints DWH- 02, documented in the preceding research.

Why did humans and animals travel toward the ocean? They could not have committed suicide by entering the sea, as no supporting evidence existed. Only one plausible hypothesis remained: they were likely heading toward boats moored on the shore. Unlike humans, animals lacked the conscious intent to board vessels voluntarily. They would have required human assistance, or even herding, which would most probably have left footprints indicating human chasing and

running. As described in the earlier records of CGS- 01 and CGS- 02, one track showed running along the coast, and the other showed running up a slope with a directional change. Based on this evidence, it was highly probable that humans had guided some of the ancient Juehua Island animals onto boats and evacuated from this homeland.

Conclusions

Did human ancestors ever coexist with dinosaurs? In 2002, several American scientists concluded using the gene comparison method that the ancestors of primates appeared more than 80 million years ago, during the Cretaceous Period—the same time when dinosaurs lived. Carl Baugh of the Creation Evidence Museum in the United States firmly maintained that “human footprints” occurred alongside dinosaur tracks near Glen Rose, Texas, and conducted multiple excavations of the supposed human footprints. However, these features appeared indistinguishable from numerous other abrasions, cracks, and erosion traces in the area [47].

The discovery of footprints indicating the coexistence of humans, dinosaurs, monkeys, and other animals on Juehua Island in western Liaoning, China, confirmed that primates lived during the Cretaceous, the same geological period as dinosaurs. It also verified that early human ancestors coexisted with dinosaurs, and that humans at that time already possessed the ability to make clothing, ride horses, and manufacture tools. Human civilization was far more advanced than that of dinosaurs and primates of the same period, and humans did not evolve from primates.

The presence of dinosaur nests and walking footprints on Juehua Island indicated that the coastal region was their habitat. The fossil footprint assemblage on Juehua Island was closely related to the Jehol Biota in the interior of western Liaoning, both formed during a large-scale geological event involving interactions between oceanic and continental plates in the Early Cretaceous. This event forced humans and some animals to evacuate in advance. Under the combined effects of tsunamis, marine transgressions, and volcanic activity, numerous organisms and dinosaurs were compelled to leave their coastal habitats, and their remains were transported to the interior of western Liaoning, eventually forming fossils.

The human footprints on Juehua Island were abundant and represented individuals of different ages, shoes for different functions, and various foot morphologies. Among them, several barefoot footprints preserved complete geometric features of the plantar surface.



Figure 41: CGD-11 and WGD-13 Footprints

CGD-11 and WGD-13 possessed the clearest plantar geometry, preserving the entire sole, including the heel region, arch region, toes, and other segments. To investigate the plantar geometry of early humans, a trial comparison was performed, and the results were consistent with the author’s own plantar geometry. Professional equipment should be used to collect plantar data for quantitative studies, including plantar imaging and plantar mechanics.

Throughout recorded human history, no other site, like Juehua Island, has yielded such a large-scale, diverse, and concentrated assemblage of fossil footprints of humans, dinosaurs, monkeys, and other animals. Therefore, Juehua Island in western Liaoning, China, represented the optimal research base for the origin of humans and numerous animal species. Only preliminary fieldwork and research had been conducted to date, and extensive work remained to be carried out systematically and in detail. These included: mapping the distribution and movement of ancient human populations along the palaeocoast and reconstructing simulated 3D models; investigating the palaeogeology, palaeontology, stratigraphy, and palaeoenvironment of the footprint-bearing strata; and performing detailed analyses of the area through mineralogy, palynology, biostratigraphy, and sedimentology. Further research would also involve the taxonomic identification of all animal tracks, as well as detailed studies of pedal structure and locomotor patterns.

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Author Contributions

Jin Chunhua discovered the fossil footprint site on Juehua Island and designed the entire research project. Jin Chunhua planned and led the inaugural geological survey along the island's coast, mapping the footprint distribution, and established the parameters and protocols for measurement. Jin Chunhua led the field team in documenting and measuring the in-situ footprints. Jin Chunhua performed the preliminary identification and classification of the collected photographic data and formulated the plan, material selection, and preparation for the 3D replica project. Jin Chunhua subsequently led a second field expedition to create 3D replicas of selected footprints. To provide a broader geological context, Jin Chunhua conducted extensive field investigations in the Xingcheng area, western Liaoning, and integrated these findings with a comprehensive review of existing geological literature and local information to identify and confirm the majority of the tracks. Jin Chunhua wrote the manuscript.

Competing Interests

The author declares no competing interests.