Chapter - 12

CHAPTER XII

RECONSTRUCTION OF THE PALAEOECOLOGY, AND PALAEOENVIRONMENTS BASED ON MORPHOLOGICAL CHARACTERS OF THE VERTEBRATE FAUNA

The dinosaurian fossils of Kutch are very important in relation to their palaeoecological, palaeoenvironmental, and palaeobiological significances. The fossilisation at Anjar and foot prints and tracks at a number of places suggests important clues to their living habits and habitats. For convenience, these are dealt with separately considering their chronological entry in the stratigraphic sequential order.

XII.1. THARAUDA AREA: DINOSAURIAN TRACKS OF UPPER JURASSIC/ CRETACEOUS AGE:

The dinosaurian tracks at Tharauda comprise of bipedal, tridactyl, theropods and ornithopods (without claws). The foot prints occur on an intercalated sequence of compact calcareous sandstone and shale forming the topmost unit of the Katrol Formation of Mesozoic group near NE of Ratanpur. These are grouped into three different categories depending upon their shapes. The tridactyl Ornithopod foot prints, the depth of incision on substrate varies between 2 to 5 cm. The depth of incision of foot prints further depend on the nature, condition and type of substrate at the time of passing over by the dinosaurs. A subsequent filling of the foot print depressions by the siltstone suggest active sedimentation. All the impression of phalanges toes and claws are not reflected in Ornithopods. The impression heel cushion pads and callous pods and muscular webs are visible in case of Theropod foot prints. The Theropod foot prints show better impression and disposition of the toes and phalanges. The impression of the claws are preserved at the tip of the toe impression. In case of one of the Ornithopod foot prints there is a distinct long median phalangeal and claw impression. The claw impression is disposed in slightly rotated fashion, pointing away from the central line of progression indicating that the trace maker disposed maximum weight on the central phalange and subsequently adjusted the toes by rotating at the time of forward leaning and stepping in order to lower the centre of gravity to provide stability. The oblique and rotated orientation of the phalangeal digit with claw suggest horizontal as well as vertical motion implying thrusting effect while stepping as in case of reptiles and birds.

The footprints at Tharauda show consistency in shape and size (Fig. 16). The direction of progression (for Ornithopod tracks) was towards N75°E. The individual moved with a reasonable fast speed (about 12 to 15 km/hr). The equidistant foot prints and the clarity suggests that the animal was moving in a walking posture with positive gaits. In the bipedal tridactyl foot prints, the foot prints not associated with the distinct impression of the claws were (on Bed A) interpreted to be of Ornithopods whereas those with claws

were thought to be of Theropod dinosaurs (on bed B). In case of the Theropod tracemaker, the hip height is assumed to be 0.610 to 1.0 m, whereas in case of the Ornithopod dinosaurs, the hip height was assumed to be 1.70 m. The foot prints suggest that part of the tracemakers were heavily built. The foot print of Theropod on bed B suggest a muscular (web) connecting the ends of the toes and the interdigital areas. Such members (webs) were common in case of some theropods which could have facilitated their dominance/dwelling in the aquatic (shallow water) environments implying an amphibious role. Some of the large sauropods were definitely amphibious in nature even though their skeleton did not show adaptability to aquatic conditions.

The osteological consideration of different tracks suggest that the trace makers at Tharauda were possibly Theropod, coelurosaurianous, Ornithopods and Iguanodon camptosaurs. Lockely and Houck (1986) and Leonardi (1989) have recorded the coelurosaurian foot prints that occur abundantly at different places in the desertic environment and in the low lying back swamp coastal forests containing green gymnospermic vegetation. The muscular web connecting the frontal parts of Phalangeal digit are considered by them as the adaptation for a back thrust for walking in the desert sands as well as for a back stroke when used as pedal while moving/swimming in shallow lakes, shores.

The sedimentary rocks and the sedimentary structures at Tharauda indicate that this area formed a part of a low coastal palaeo forest with lowlands around brackish/ fluvial lakes in the back of swamp areas. The main constituents of the forest and grasslands were the gymnosperms and the coniferales as evidenced by the gymnospermic plants and fossil wood spread over the area. Dinosaurs frequently visited lakes/ponds along the sandy and muddy shores. These lakes/ponds were very shallow and often used to get dried due to solar heat during sub-aerial exposures as evidenced in formulations of sun cracks and mud cracks within the associated sediments. Preferential use of such environments by the dinosaurs have been recorded from different parts of the world by Winkler and Murry (1989), Horner (1982), Horner and Makela (1979) and Kuazenov and Konstantin (1989). The dinosaurs moved along lake margins, strand lines, sand barriers and preferred sediments for nesting sites.

XII.2. PAKHERA AND FATEHGARH AREA (DINOSAURIAN TRACKS OF CRETACEOUS AGE):

At Pakhera the quadruped dinosaurs foot prints belonging to Sauropods are found on the top of the bedding surface of an indurated ferruginous sand and shale/siltstone intercalated sequence. At Pakhera, the foot prints comprise deeply incised (about 100 cm) circular to rectangular impressions. The size variation for different foot prints are given in table-VII and signify those by full grownup adult dinosaurs, subadults and juveniles. The juveniles foot prints comprise relatively smaller overall rectangular shaped impressions of pes measuring 12 to 16 cm in width and 9 to 10 cm in length and 21 cm in width at the

broadest end. The primary impressions of toes and phalanges are seen as depressed parts on the front side of the impression. The depth of incision in case of smaller ones is about 1.0 cm on substrate. In case of impression of adults the measures about 41 cm in length and 28 cm width. The impression due to digits appear as 5 to 10 cm deep elongated depressions on substrate. The foot prints show steeper angle of incision on front and anterolaterals (-10°), whereas the rear sides are gentler and indicate gradual slope in foot prints with a forward slippage of the pes/manus after stepping and before leaning and lifting for next step. The sub-adult and juvenile steps show relatively lesser depth of incision., The successive impressions of manus and pes indicate overlapping relationship and positive gaits. The foot prints indicate a clumsy heavily built trace makers in a slowly walking mode with shorter forelimbs as compared to the hind limbs. The direction of progression is towards due south. The speed of walking computed by using Alexander's (1976) formula indicate that the subadults, juveniles moved at speeds of 2.16 and 2.5 km/hour respectively which is in complete harmony considering the hip height, glenoacetabular distance and the projected body length of the subadults and the juveniles. The speed estimated and detail description of foot tracks indicate a well organised herd with different age, group moving over the prograding deltic bar sense parallel to water bodies/channels. There is absence of impression of claws in case of Pakhera area. The overall depth of incision of the foot prints on the substrates show deeper incision (about 5 cm to 10 cm) in case of subadults and adults. The front part of the impression are deeply incised as compared to rear parts of impressions. The impressions of pes measure 33 cm in length and 28 cm in width and those of manus measure 41 cm in width and 28 cm in length. Digital and phalangeal impressions are reflected as depressed at linear parts. The general absence of claws impressions is regarded due to Ornithopod trace makers.

The foot prints at Pakhera consist of adults and subadults progressing in south. In case of the subadults, the track width varies between 12 to 38 cm stride between 42 to 49 cm, pace between 24 to 28 cm and glenoacetabular distance between 28 to 33 cm. Two age groups of subadults/juvenile are inferred on the basis of the size of the foot prints. Another sub-adult track shows variation track width between 1 15 cm to 1.47 cm, pace between 0.89 m - 1.17 m, stride between 1.04 m to 1.3 m, and glenoacetabular distance between 1.61 to 2.0 m. Different age groups have been inferred in case of adults also. The juvenile/subadults foot prints are found towards western side of the tracks and relatively larger foot prints are found towards eastern side.

From the above evidences, it can be inferred that the herd moved slowly, keeping harmony in movements with their juvenile counterparts. At Pakhera the foot prints do not show distinction of digital impression and distinction is not possible as they are not clear but they are equal in length.

XII.3. FATEHGARH AREA: UPPER CRETACEOUS DINOSAURIAN FOOT PRINTS AND FOOT TRACKS:

At Fatehgarh the foot prints of quadruped dinosaurs, adults, subadults and juveniles are found on the hard, compact, current bedded, burrowed quartzitic sandstone of Bhuj Formation The top of the bedding surface of the sandstone is heavily trumpeted with foot prints. The foot prints at Fatehgarh are broadly grouped into following groups according to their morphological features.

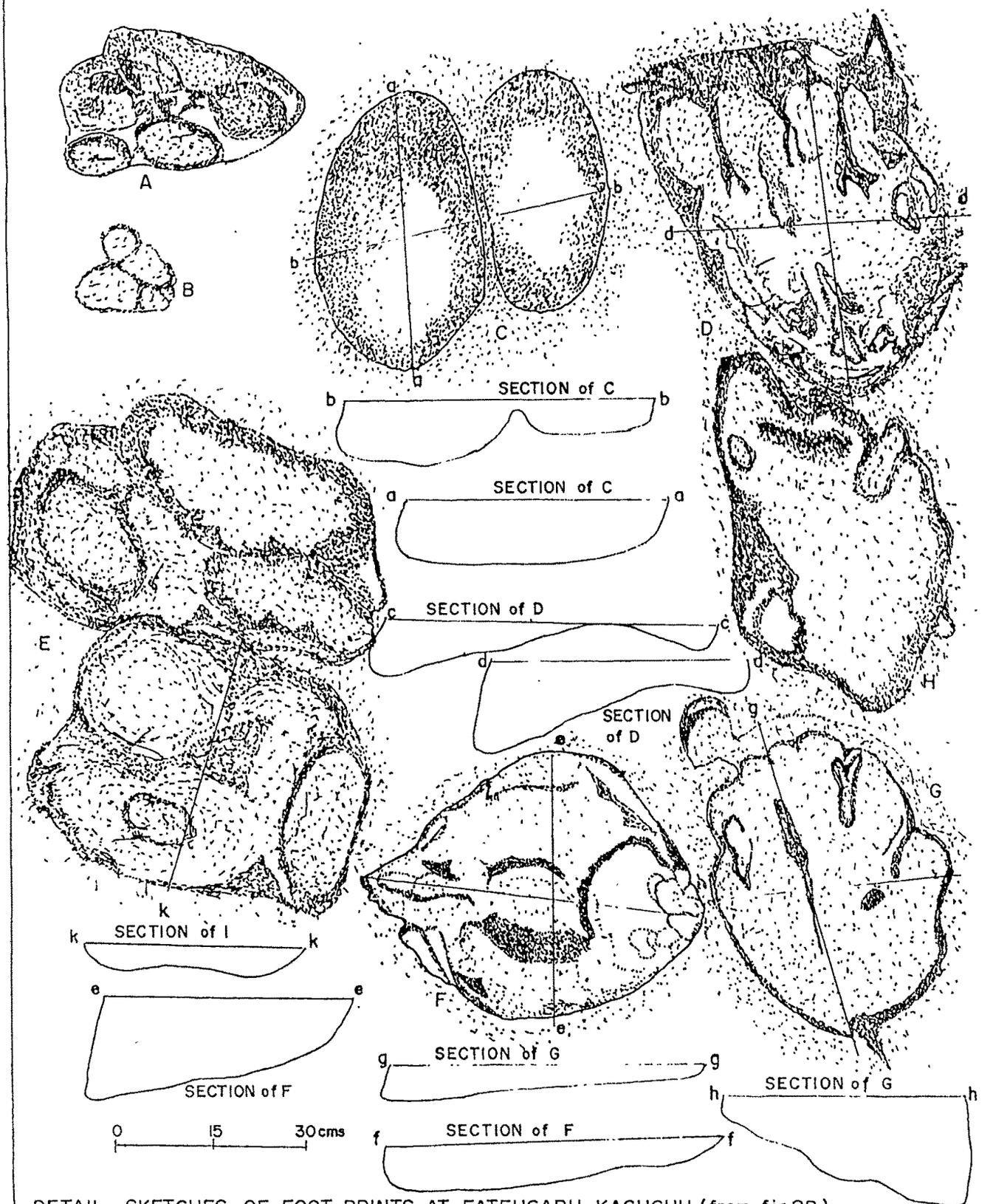
XII.3.1. Narrow Rectangular front:

Narrow Rectangular front and relatively narrow tapering long rectangular at rear end are observed in Plate-III, IV Figs. 13, 14, 15. The largest well preserved impressions under this category measures 50 cm in length and 22 cm in width. The smaller foot prints measures 10 cm, in length and 5 cm in width. Some impressions show markings of digits (phalanges toes and claws). The impression of largest toe measures 6 cm in length and is about 5 cm in diameter at the base. The impression of claws is faintly visible in the photograph of the foot prints which on reconstruction (Fig.14) appears to be conical in shape about 6 cm in length and 2 cm wide at base. The impression of claws is sharp, slightly curved with a sharp pointed apical portion.

Impressions of claws are seen at end of all the digital portion in the foot prints in such a category. The impression due to claws appear as slightly depressed portions on the substrate but the same appear as the slightly raised portions in the plaster cast impressions. The impressions of the intervening muscular pads and webs are reflected as slightly depressions and as raised ridges in the plaster casts of individual foot prints. These foot print impressions are about 80 cm deep on the front side and gentler on the rear side and are steeply incised (-10° to -15°) in front as well as on inner side towards the line of procession (Fig. 15) This represents a right side rear foot print impression of a five toed adult quadruped sauropod. The impression of Pes and Manus show primary type of overlap relationship indicating a very heavy clumsy type of animal with a very slow leisurely walking mode

XII.3.2. Diamond shaped (Rectangular type):

The foot prints of this category are roughly rectangular to diamond shaped and are slightly compressed at the rear and at the front ends (Plate-IV, V). The impressions of toes and claws are prominently reflected in some of the impressions/casts. The impressions due to claws are sharp and dome shaped digressions (Fig.13) and at times these are slightly curved and are gradually tapering (Fig.13). The average for prints measures 30 cm in length and 20 cm in width. The varying degree of details in the impression of the phalanges, digits and muscular pads, may be due to the difference in the walking modes, postures of the individuals and may also be due to the varying conditions of the substrate. The impressions are steeper (-15°) deeply incised (about 10 cm on front and on inner side near



DETAIL SKETCHES OF FOOT PRINTS AT FATEHGARH, KACHCHH (from fig.2D) SHOWING SOLE MORPHOLOGY (A to I), DEPTH OF INCISION ON SUBSTRATES IN SECTIONS

THE FOOT PRINTS AND CORRESPONDING SECTION PROFILES ARE SHOWN BY SAME LETTERS

Fig 13 Interpreted sketches of dinosaur foot prints at Fatehgarh, Kutch.

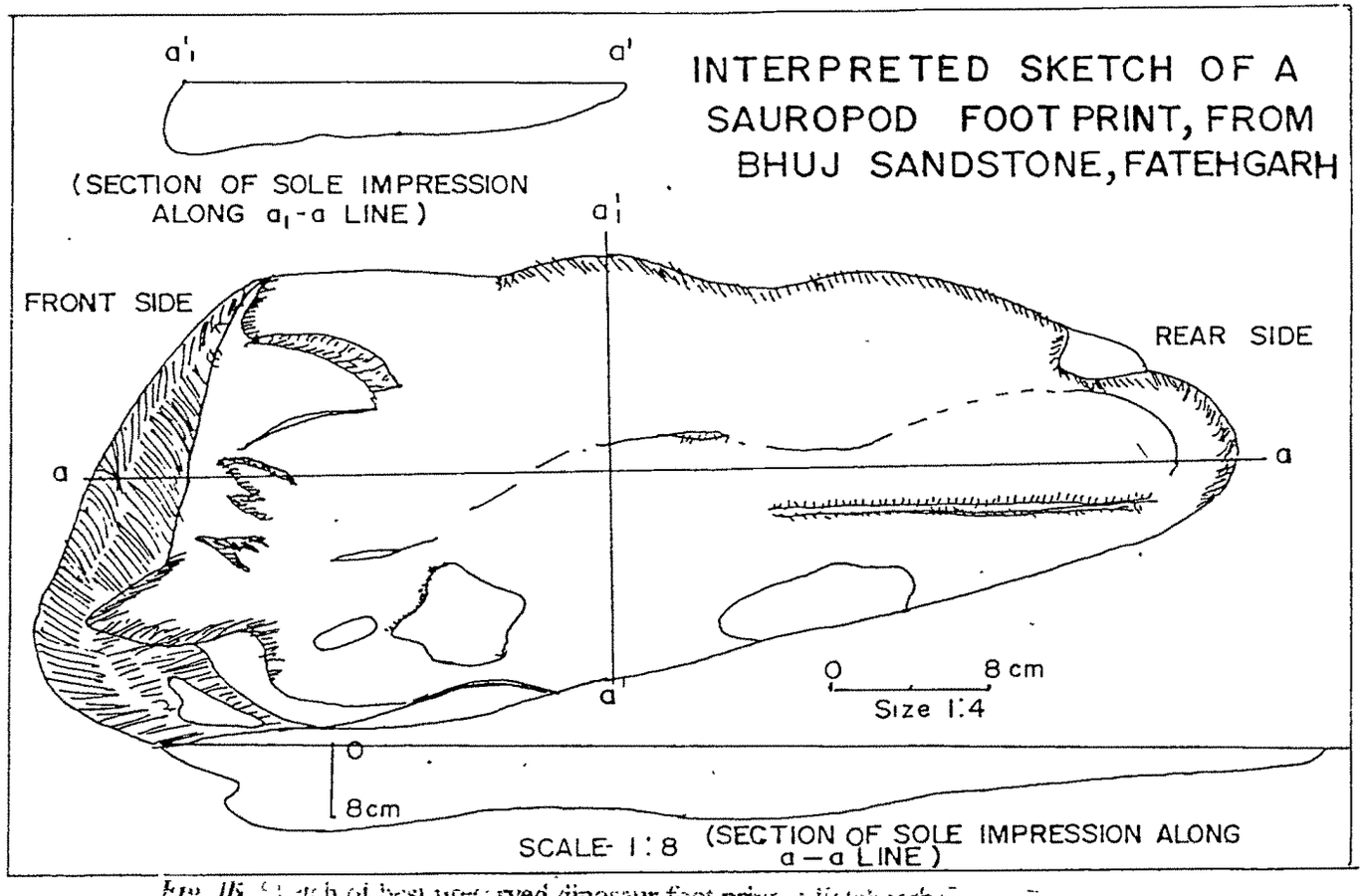


Fig. 14 Sketch of best preserved dinosaur foot print at Fatehgarh, Kutch.

the line of progression), whereas the rear end is gentler and shallower in all the cases (Fig.13) as shown in the longitudinal and transverse sections of the sole impressions. This reflects heavily built five toed clumsy individuals in leisurely walking modes.

XII.3.3. Oval and oblong type:

These type of impressions can broadly be grouped into oval and oblong shaped prints and this group include impressions with oval shaped deep depressions in central part (Fig. 13; Plate-V) or with overall rectangular shape in front and oval in the rear end (Fig. 13). The impression of the digits and phalange are reflected as small oval shaped depressions, systematically disposed within the sole impression. The oval shaped portions measures 30 cm along longer axis and 20 cm along shorter axis. The average depth of incision varies from 5 to 10 cm. The depth of incision is more on front side (10 cm) as compared to the rear side (about 50 cm.) The angle of incision of the substrate is steeper (-20°) on the front side and on the rear side. This reflects the leisurely walking mode with average strides of trace makers. Primary coupling type of overlap (Sarjeant, 1975) relationship is observed in case of such foot prints (Fig-13) and also in case of diamond shaped and rectangular shaped foot prints (Plate IV). The detail study of such impressions for reconstruction of sole morphology indicates a sort of spongy cushion like pods in the soles in case of the foot print impressions shown in fig. 13. Lucas and Hunt (1989) have indicated presence of such heel and toe cushioning pads in case of dinosaurian prints from North America. Detail reconstructions of impressions were attempted (as shown in figure 13 and 14) on the basis of detail recording of surface drawings.

XII.3.4. Semi Circular type of impressions:

At Fatehgarh track site two prints are different in over all shape as compared to the others. In one such set (plate IV) oval shape has a distinct notch on western end. They are indicating southeasterly direction of progression. It measures 45 cm in length (longer axis) and 35 cm on shorter axis and possibly reflects an adult foot print (Plate V/2). The impression of pes is associated with an overlapping the manus impression. The impressions of claws, digits / or phalangeal details are not visible (Fig.13). Such impressions show close resemblance to the impressions of manus of Breviparous taghbaloutensis reported from Morocco and from rocks of Morison Formation from the Purgatore valley north America by Lockely et al (1986). The trace maker had adoption for swimming also. The overall relationship and comparison of the above prints with the foot prints at Fatehgarh indicate sharp morphological differences. In case of these impressions no features are observed except the impressions of muscular scars. The absence of digital impression may suggest that these prints were imprinted in the later stage when the water level was increased, and therefore, the impressions do not show detail features as similar to others

XII.4. STATISTICAL DETAILS OF FOOT PRINTS:

The overall depth of incision of the foot prints indicate about 10 cm depth on

coarse sandy substrates at Fatehgarh These foot prints are steeper (-10°) slope 8 to 10 cm deep in front and about 2 cm to 7 cm deep anterolaterals whereas the rear sides are gentler with a zone of seepage (about 10° to 15°c) with a broad zone corresponding forward push in frontal parts of the foot prints. The cross-sections of the foot prints in different directions (Fig.13) also show the same detail. Foot print depths varies between 2 cm to 25 cm have been recorded from north American tracks sites by Lockely (1986). The Fatehgarh foot tracks directions are shown in table I. The pace angulation (of Sarjeant, 1975), varies between 120°-130°. The average overlap is of primary type with positive gaits where the digits of the foot prints show inclination and rotation towards the central line of locomotion of pes and manus. The sub adults foot prints show average pace 0.86 m, 1.60 m average stride and 1.1 m average glenoacetabular distance. Their track width is 0.5 m. The adult foot tracks show 1.3 m average pace, 2.0 m average stride and 1.4 m glenoacetabular distance. The track width in case of the adult is 1.0 m. The variation in the glenoacetabular distance, stride pace and size of foot prints belonging to same morphological types suggests that a large portion of the population belonged to the same group or herd of quadruped sauropods with majority members of subadults and adults and few juveniles belonging to the same species. The morphological types with different parameters are given in table-VIIA.

XII.5. OVERALL PATTERN OF TRACKS PRESERVATION AND WALKING HABIT OF DINOSAURS:

The detail map (Fig-15) show the overall patterns of all the categories and the type of foot prints. Detail analysis of different parameters of all individual foot prints are not possible as details of stride pace are not available in all the cases. The smaller foot prints are concentrated in the central part as well as on the northern part of the track in case of Fatehgarh and towards contact with bed B, towards western side of the tracks in Pakhera. The foot prints show a regular arrangement from one end of the track to the other end across the direction of progression. In case of Pakhera and Fatehgarh, the juvenile foot pints are seen near the subadults. One adult foot track is seen on the extreme south in the foot tracks at Fatehgarh and to the extreme east in case of Pakhera. Careful observations of the large scale map of tracks at Fatehgarh indicate that the adult foot prints are super imposed by juvenile and subadults foot prints and these in turn are overlapped by adult foot prints, indicating that a sequence of movement including change in direction was controlled by the adult trace makers on forwards, rear and southern sides of the moving congregation Though the extreme northern part of the foot tracks are not completely preserved at Fatehgarh due to erosion and at Pakhera, these are not exposed fully on west due to overlapping relationship by bed B. The exposed part of the foot tracks at Fatehgarh shows at overall spearhead disposition of the congregation of tracks. Foot prints of structured herds of dinosaurs have been found from many places in north America by Bird (1944), Baker (1968), Ostrom (1972), Coombs (1975), Farlow (1987), Gallup M.R.C. (1974, 1989), Lucas and Hunt (1939), Tweedie (1977, Dodson et al (1970), Lockely (1980),

and Lockely et al (1986), Sarjeant (1975). Bird (1954) has indicated that the dinosaurs had colonial habits and that they hunted or grazed/browsed in herds. The adults guarded the juveniles and subadults from all sides during movements. The dinosaur foot prints at Fatehgarh point to all these facts. The average moving speed (velocity) for herd comes to around 02.35 km/hour in case of Pakhera, around 2.75 km/hour in case of Fatehgarh (based on Alexabder's 1975 formula). This suggest that the herd at Pakhera and Fatehgarh were very slow progressing, where the adults kept pace and maintained harmony in movements with the juveniles and the subadults. In case of Fatehgarh and Pakhera, some foot prints (Plate-V and Fig.15) have gentler slope on the rear side and steep (-10° to -20°) deeper incision (-10cm) on front and front lateral and inner side towards line of progression indicates slight forward sliding of the heel to engage the frontal claws and pads firmly into the sediments and subsequently rotated pes in clockwise direction to maintain a balance as well as provide friction for forward thrust for next stepping. The individual prints show deeply and heavily incised first and central claws in the substrate (Fig-13) indicating palaeoenvironmental adoption by animals in getting friction for stabilising itself from slippage by engaging inner side of pes/manus and larger parts footpads. The smaller fore limb impressions (Plate IV) indicate unequal length and size of the manus and pes of the animals. The fore limbs were shorter. The animal further lowered the centre of gravity by rotating the pes/manus and for forward leaning for next stepping. The detail morphological analysis of the foot prints at Fatehgarh and Pakhera indicates that the bodies of the trace makers were bent standing towards anterior. The animals moved with a slide, stabilise and lift sequence of limbs giving overall start and stop postures with enough time for choosing space for next step. The speed of motion (about 2.25 to 2.50 km/hr) is in harmony with the assumptions based on morphometry of the foot prints.

XII.6. OSTEOLOGICAL CONSIDERATIONS AND THEIR IMPLICATIONS:

The detail morphological analysis of the foot prints indicate that the rectangular and diamond shaped foot print impressions are of five toed, quadrupedal dinosaurs. The claws were pointed, conical. The claws on the last digit are sharp and pointed. The consideration of theropods is ruled out by the quadruped type of the prints leaving a possibility of trace makers to belong to either Sauropods or Ornithopods In case of Ornithopods, the claws are blunt type on all the digits. In case of Fatehgarh, the impressions of claws are pointed conical type ruling out the possibility of Ornithopod trace makers.

In case of the rectangular foot prints, the digit I is strongly clawed and impression of metatarsals are short but stout and pronounced The foot print impressions are broad and spreading with elephantine shape (Fig 13). such impressions described by Lockely et al (1986) and Lockely and Gillete (1989) from Morisson formation are due to manus and pes unequal quadruped sauropods. The osteological details (Romer (1956) suggests that fore limbs were shorter 2/3 to 3/4 in size of the hind limbs

In case of the diamond shaped impression (Fig. 13/F and G), the impressions show prominent first digit is slightly compressed but stout with a claw. Second digit is unconstricted straight with a claws at the end. The third digit is also constricted. Fourth digit is reduced half the size of II digit and has distinct large pointed claws at the end. The first digit is reduced in size and is with a claw. The impressions of phalangel joints show enlargement of proximal end (Fig. 13/A, B and D). The first three digital impressions show relatively larger impressions of metatarsals. The impressions of the phalangel joints are wider providing mobility to digit foot digging and scratching as suggested by Gallup (1989) in case of some trace makers of north America. Apart from these the wider and stronger joints and larger toes with claws would help to dissipate the weight load of the body and permit the motion of the individual claws in horizontal and vertical planes.

There are some impressions (Fig.13E) in which the impressions of digits/phalanges are not clear, while there are some impressions (Fig. 13C) which show uniform oval shape with strong impressions of pads. These impressions indicate different direction of progression. The outer side of the pes show larger reduction in size giving over all convex configuration to outer side and overall diamond shape to the foot prints. The impressions of claws are angled and point towards median digit (digit.II). Such claws are on the digit I, II and IV (fig.14). The claws impressions at Fatehgarh are slightly incurved. Digital impression show spreading in the pes. The sole structure Fig.13 shows a thick heel pad and toe callus pads. The digital impressions and claw impressions showing similar overall impressions are comparable to the Breviparopos taghbaloutensis reported by Lockely et al (1986) and Lockely and Gillette (1989). This form was common during Cretaceous in Gondwana continents, where reports are found from Morocco, South Africa, South America.

From the osteological consideration two types of quadruped sauropods, Breviparopus and Pleurocoelus sp. were inferred at Fatehgarh whereas at Pakhera the probable trace makers were some form of quadruped Ornithopods. Such Sauropod foot prints are abundantly recorded in the geological sequences of prograding deltaic environments from different parts of the world.

XII.7. PALAEOENVIRONMENTAL AND PALAEOECOLOGICAL SET UP:

From all the above studies it becomes apparent that the dinosaurs preferred flat to low lying grounds with inland coastal lakes, lagoons or river channels and flood plains as their habitat. The major part of the foot tracks located in different parts of world similarly indicate dominance in the above mentioned setups. It is rather interesting to note that in continental setups with semi-desertic conditions some theropods like coelurosaur foot prints have been recorded from North America and Mongolian regions. The low coastal plains and mud flats gently sloping flood plains and river channels delta regions provided thick shrubby forests with gymnospermy conifers as food for the herbivore dinosaurs. The lakes in the back swamps and coastal areas also provided coastal vegetation and relatively

soft sandy moist lagoonal and river margins as well as the lacustrine and inner channels as the ideal places for nesting sites. Such regions were relatively safer for nesting purpose. The fossil records at different stratigraphical levels in some formations for a considerable length of time, indicate that the dinosaur preferred some site for hatching/habitats. The herbivore dinosaurs grazed/ browsed in herds and moved in different groups, with adults, subadults and juveniles. The adults guarded the juveniles and subadults from any possible outside dangers of carnivores. They also preferred a scheduled, lonely flat as hatchery with soft sediments and behaved like present day flamingo/cranes for nesting by scratching digging pit in soft sediments. They visited the nesting sites frequently over generations. The younger ones also lived and stayed in nest colonies some period after hatching. They diversified and developed special adoptions to surrounding by some modification in bodies. In case of Anjar and Tharauda Pakhera areas, the similar fact of sites fidelity by titanosaurs, Iguanodon and Megalosaurus, coelurosaurs is observed. The initial record from Katrol indicates presence of Iguanodon during coelurosaurs and other dinosaurs. The low coastal set up with lakes and vegetation was preferred by herbivorous. The herbivore population attracted the carnivore like the coelurosaurs. The same area reveals presence of quadruped herbivores, during lower Bhuj time near Pakhera and from Fatehgarh areas during the Upper Bhuj sedimentation.

At Anjar, the Titanosaurus, Megalosaurus and Iguanodon and hypsilophodontid inhabited the area after eruption of second flow and during the deposition of second Intertrappean bed. The freshly formed trappean country with small lakes, ponds and thick shrubby vegetation along the river/nallah courses were preferred by these dinosaurian species for more than 2 million years. The fossils of same dinosaurian species are recorded from the third Intertrappean bed. The very larger basin margins and near shore environment do not seem to have attracted dinosaurs. This inference based on the absence of dinosaurian fossils in the rock records of such environments, is significant.

The associated fossils found with dinosaurian forms comprise fern spike cycades conifers, ginkgo, ferns and seeds of gymnosperms and palmae, some flowering plants and creepers and gramini stems. The fore droppings of coprolite remains (dried) with intestinal grooves suggest diet of considerable roughage (fibrous vegetation) and mud (as suggested by Broughton, 1981) for extracting nutrients from the mud. The coprolite suggests vegetation matter and clay with some invertebrate fragments as main constituents.

XII.8. COMPOSITION AND AGE OF ANJAR DINOSAURIAN FAUNA:

The major part of the skeletal elements at Anjar site belong to and show affinity to the Titanosauridae family and to those of Titanosaurs sp. Titanosaurs remains are found from many places from the uppermost Cretaceous localities at Rahioli, Jabalpur, Dongargaon and from Kallamedu area of south India. This form along with Iguanodon, Megalosaur and hypsidophodon (based on the evidence of small, elongated eggs noted in the second Intertrappean bed of Anjar) were common in Anjar during the Uppermost

Cretaceous time The dinosaurian elements mentioned earlier (like teeth, bone, fossils, eggs) and associated ornithoid eggs (avian), charophytes and diverse assemblage of ostracodes and invertebrates indicate uppermost Cretaceous (Maestrichtian elements) age, however, it may be noted that the absolute dating has indicated an age between 65.4 and 65.2 m.y. for the third Intertrappean bed at Anjar which is partly the Danian age. Further studies on the microbiota is under progress under a collaborative programme. Radiometric ages given by Venkatesan and Pande (PRL, Ahmedabad) indicate the Deccan Volcanism started during Upper Cretaceous and continued till Tertiary and ended at around 61.0 (±) m.y. ago.
