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Ichnotaxonomy of trace fossil of the Upper Triassic Nayband Formation, Tabas Block, Central Iran

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Abstract
This study includes a thorough systematic analysis of the ichnological record in the Late Triassic siliciclastic Nayband Formation of the Tabas Block, Central Iran. A total of 48 ichnospecies representing 28 ichnogenera are identified and their preservation aspects, paleoecological aspects, producers and behavioral aspects are discussed. The ichnofauna includes *Arenicolites, Asterosoma, Bergaueria, Chondrites, Cochlichnus, Cylindrichnus, Diplocraterion, Helminthopsis, Gordia, Gyrochorte, Lockeia, Macaronichnus, Monocraterion, Ophiomorpha, Palaeophycus, Paleodictyon, Phycodes, Phycosiphon, Planolites, Protovirgularia, Rhizocorallium, Rosselia, Scolicia, Skolithos, Taenidium, Teichichnus,* and *Thalassinoides.* The high ichnodiversity and bioturbation intensity of the Nayband trace fossil suite seem to represent proliferation of epifaunal and infaunal habits, experiencing a high diversification of marine communities after the drastic reorganization of marine ecosystems during the Late Triassic. Further studies focused on the ichnological signatures of these deposits will provide more detailed information to improve the current paleoecologic and paleoenvironmental interpretations of the Nayband Formation deposits.

Keywords*: Ichnotaxonomic Analysis, Nayband Formation; Upper Triassic, Diversification*

Introduction
Ichnotaxonomic analysis of the trace fossil assemblages from the Upper Triassic of the Nayband Formation in the Tabas Block, Central Iran, enhances the record of this group in the Triassic of the various structural zones of Iran. Siliciclastic layers of the Nayband Formation contain well-preserved, ample and diverse trace fossil assemblages, which serve as valuable indicators of the evolution of lifestyles of marine benthic organisms and the palaeoenvironmental conditions prevailing during that time. Due to less susceptibility to taphonomic bias, particularly in siliciclastic layers of the Nayband Formation, the presence of trace fossils is very useful for providing broad paleoenvironmental constructions. The purpose of this paper is to describe the trace fossils, their preservation aspects and determine the palaeoecological parameters.

Geological setting
The study area is located in the central part of the Central-East Iranian Microcontinent (CEIM) in the Tabas Block (Alavi, 1991; Aghanabati, 2004). The Tabas Block is an intra-continental depression and part of the CEIM (Takin, 1972) that has experienced a complex structural history (Fig. 1). Final collision between the CEIM and Eurasia in the Middle-Late Triassic time (Early Cimmerian tectonic phase) resulted in the formation of highlands, which served as a source for the thick siliciclastic sediments of the Nayband and Shemshak Formations (Wilmsen *et al.,* 2009; Fürsich *et al.,* 2009). The Upper Triassic (Norian-Rhaetian) deposits of the Nayband Formation are distributed over a large area in central and eastern Iran (Seyed-Emami, 2003). The type locality of the Nayband Formation crops out at the southern area of the Kuh-e Nayband (Nayband Mount), approximately 220 km south of the Tabas city in northeastern Iran where it reaches a thickness of about 2220 m (Fürsich *et al.,* 2005). Four members have been recognized within the Nayband Formation (Kluyver *et al.,* 1983), which in stratigraphic order are including: 1. Gelkan Member (silts, sandstones), 2. Bidestan Member (carbonate rocks), 3. Howz-e-Sheikh Member (silts, sandstones) and 4. Howz-e-Khan Member (carbonate rocks).

The major objective of the present study is the Upper Triassic sediments of the Nayband Formation exposed in one section located over a large area, north of Kerman Province in eastern of the city of Zarand. However, this formation in the studied area is subdivided into Gelkan and Howz-e-Sheikh Members mainly composed of shales and sandstones, dark-green silty calcareous shales, siltstone and partly limestone, but the Bidestan and

Howz-e-Khan members were not recorded in this area. The Nayband formation overlies the shallow water carbonate platform sediments of Shotori Formation (attributed to Middle Triassic) with an unconformity bedding contact, and is normally underlain by the Ab-e-Haji Formation (Lower Jurassic). In contrast, the lack of micro and macro fauna in studied succession, trace fossils are fairly common in the Gelkan and Howz-e-Sheikh members, but not studied in detail yet. The Nayband Formation is Upper Triassic (Norian to Rhaetian) in age based on the studies that provided valuable biostratigraphic information (Nützel *et al.,* 2003 Fürsich *et al.,* 2005; Senowbari-Daryan 2005). In the present study, one section has been documented and sampled in a locality about 35 km E of the Zarand in Kerman Province with geographical coordinates of N30°5′26″, E56°57′34″ (top of section) (Fig. 1).

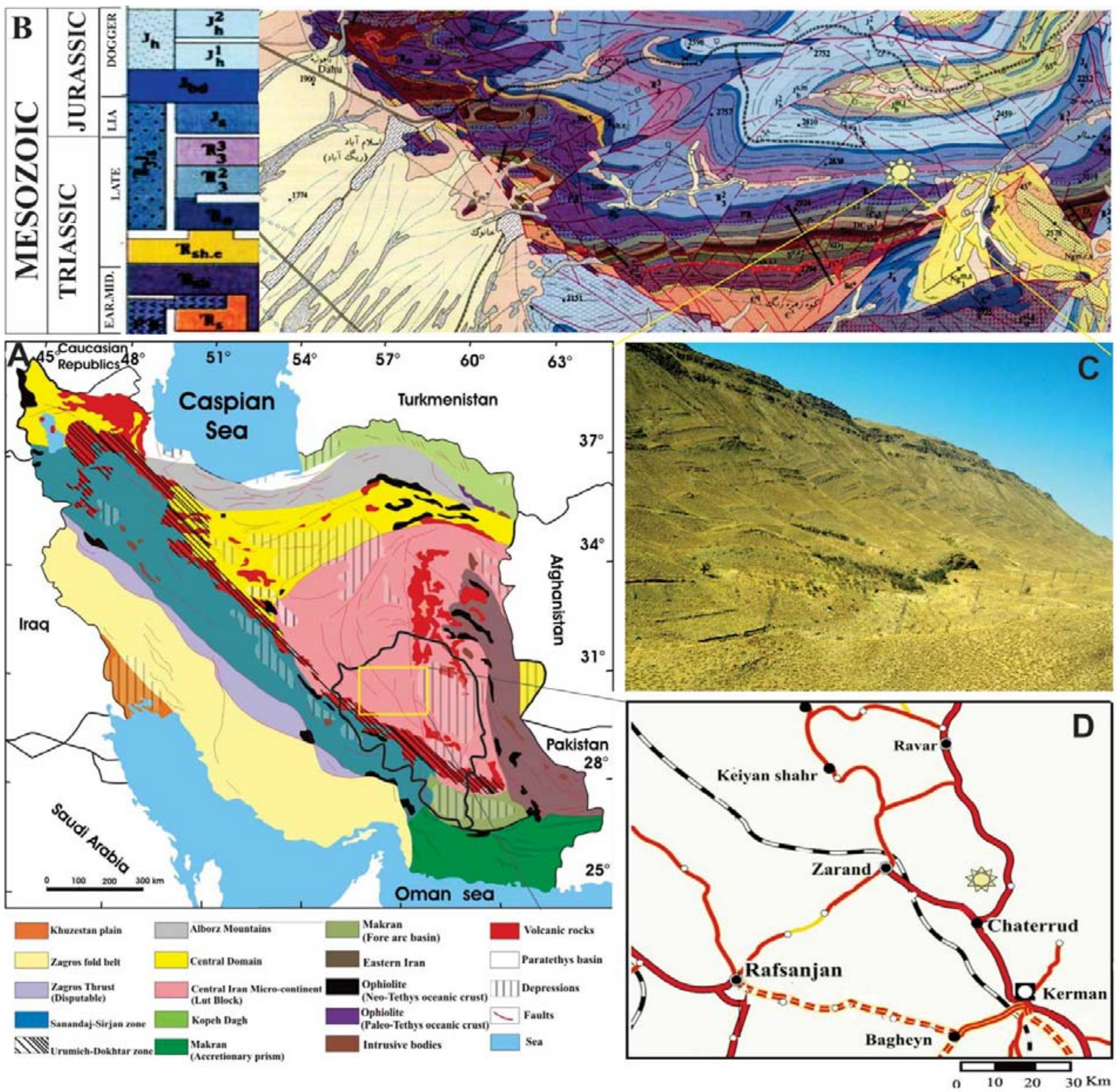

Figure 1. A. Map showing the geology of Iran with its structural provinces, after Stöcklin (1968) and Nezafati (2006). B. Map showing the geology of north of Kerman Province in Zarand area (Vahdati-Daneshmand, 1995). C. Panoramic view of upper part of the lower member (Gelkan) and the upper member (Howz-e-Sheikh) of the Nayband Formation. D. The Nayband Formation is located within the Tabas Block in Central-East Iranian Microcontinent (CEIM); location map of the studied area, 35 km E of the city of Zarand.

Sedimentary environment

A facies analysis of the Upper Triassic, shallow marine Nayband Formation in the Tabas Block, Central Iran, emphasizing the role of ichnological data, was presented by Bayet-Goll (2016) and Bayet-Goll and Neto de Carvalho (2017). The collected data have been presented on one stratigraphic section (Figs. 2a, b). During the description of different lithofacies, attention has been paid to bed geometry and contact of layers, faunal content, the potential of trace fossils as tools for reconstructing depositional conditions, sedimentary textures and structures, bounding surfaces, and lateral/vertical variations of facies and thicknesses. The facies scheme comprises two facies associations: The Facies Association A consists of four facies and records deposition in fluvial-dominated delta (Fig. 2). A normal succession of the facies association A includes prodelta massive mudstone and siltstone (facies A), distal delta front heterolithic association of sandstones and mudstone (facies B), proximal delta front upward-thickening association of flat bedded tabular sandstones (facies C), distributary channel fill sandstones with planar lamination and cross bedding (facies D). Ichnological data in the facies association A, strongly supports the river-dominated deltaic interpretation and provides additional criteria by which such successions may be identified (Bayet-Goll 2016; Bayet-Goll & Neto de Carvalho 2017). The offshore and shoreface deposits (Facies Association B) comprise five facies, based on sedimentological and ichnological characteristics.

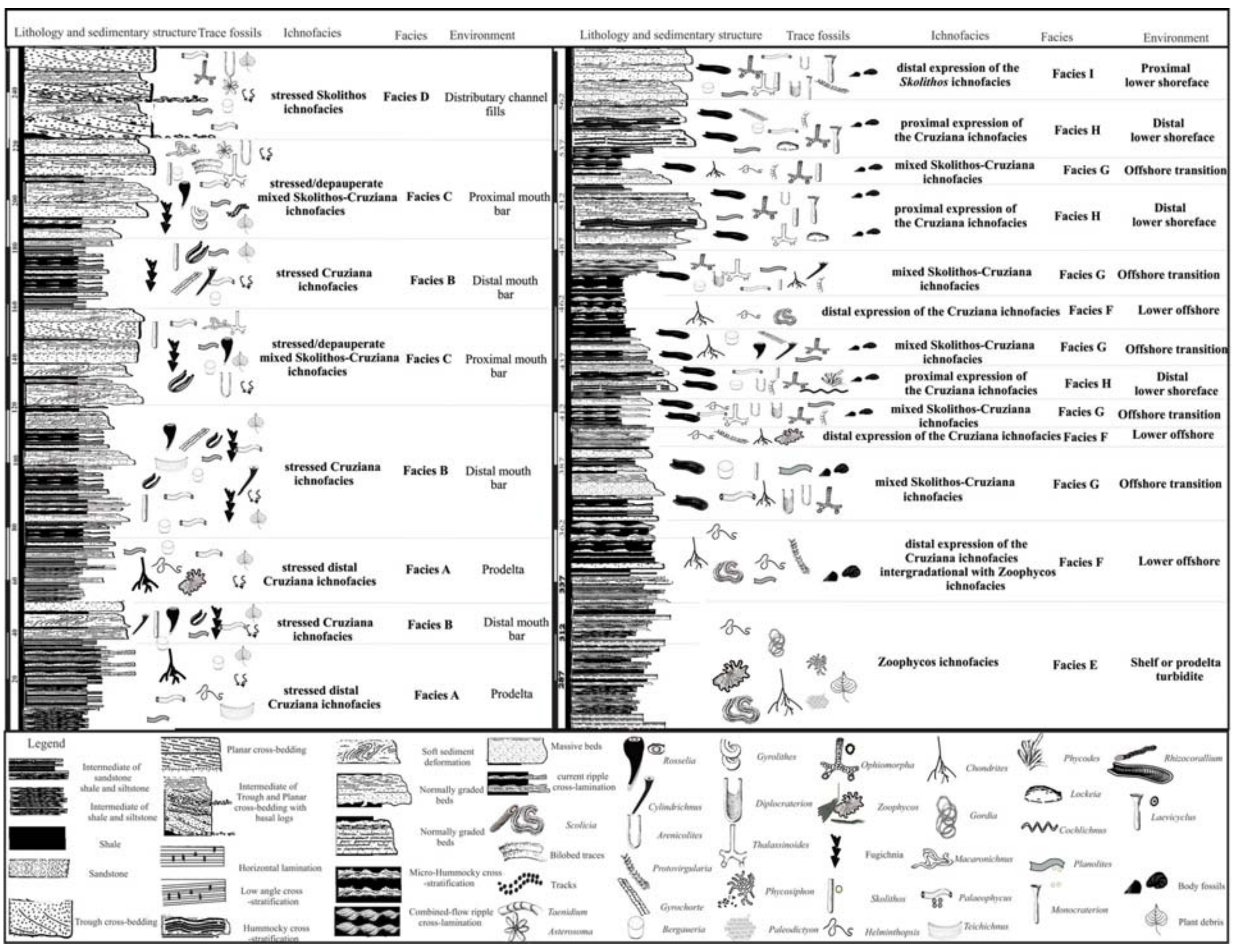

Figure 2. Stratigraphic sections measured at Zarand showing the sedimentological-ichnological characteristics and interpretation of the depositional environments of the Nayband Formation (modified of Bayet-Goll, 2016), includes: river-dominated delta facies succession and the open-marine facies association. Some symbols used for trace fossils in this study are on the basis of schematic split-core expression after Seilacher, 2007.

These facies are: shelf (facies E); lower offshore (facies F); offshore transition (facies G); distal lower shoreface (facies H); proximal lower shoreface (facies I) (Fig. 2). The occurrence of diverse and robust trace fossil suites characteristic of both the archetypal *Cruziana* Ichnofacies and the *Skolithos* Ichnofacies, suggest low sedimentation rates, sufficient nutrient supply and the presence of oxygen near the water bottom, induced by mixing of water by waves, and a relatively stable substrate (Bayet-Goll *et al.,* 2017).

Systematic description of the trace fossils

Ichnogenus *Arenicolites* Salter, 1857, Ichnospecies *Arenicolites* isp. (Figs. 3A)

Description: Vertical U-tubes preserved in full relief, seen with numerous paired tubes, and circular in cross section. Most of the specimens are found in the horizontal surface, and occasionally vertical cross-sections have been recognized. The burrows consist of vertical U-tubes without spreite. Tubes are characterized by a structureless infill that are compositionally different to identical from the sedimentary matrix of the host rock.

Sand filled, in most cases burrow fills are distinct and different than the host sediments. Burrow diameter of tubes is 2-5 mm with 10-20 mm spacing of limbs.

Remarks: Ethologically, *Arenicolites* is interpreted as permanent dwelling burrows of suspension-feeders (domichnion) from annelids (Bromley 1996). This trace is interpreted as a eurybathic trace fossil recorded in diverse environments (e.g., Pemberton *et al.,* 2001). *Arenicolites* occurs in both delta and open marine deposits including proximal mouth bar, distributary channel fills, offshore transition, distal lower shoreface, proximal lower shoreface.

Ichnogenus *Asterosoma* Otto, 1854, *Asterosoma* cf. *radiciforme* Von Otto, 1854 (Figs. 3C, D)

Description: They are very uncommon and occur as slightly inclined cylindrical and flattened tunnels, preserved as full relief with horizontal tunnels. In the bedding plane perpendicular section, they show radial or star-like pattern with tapering ends. They consist of cylindrical tunnels radiating outward and upward from a common point at the base. Central tubes are eccentrically filled with structureless material similar to that of the host rock. These are unbranched and gently curved with smooth external surfaces and without any obvious annulations and grooves. Burrow diameter varies from 5 to10 mm. Maximum burrow length is about 12 cm.

Remarks: *Asterosoma* has been interpreted as a deposit-feeding activity of worms/annelids and decapod crustaceans (Neto de Carvalho & Rodrigues, 2007). The cylindrical to bulbous tubes radiating outward and upward from a common point are attributed to the deposit-feeding activity while the cylindrical tunnels reflect locomotion behavior (Schlirf, 2000). *Asterosoma* as an uncommon trace occurs in delta deposits (distal mouth bar and proximal mouth bar).

Ichnogenus *Bergaueria* Prantl, 1945, Ichnospecies *Bergaueria* isp. (Fig. 3E)

Description: This ichnogenus shows hypichnial mound in the lower surface of sandstone beds with hemispherical termination, oval in outline, and rounded or flattened base. The walls of the burrow are unornamented and the burrow fill is structureless. The diameter of the burrow is about 2 to 10 mm, and depth is about 5 to 8 mm.

Remarks: This trace is interpreted as a eurybathic trace fossil recorded in diverse environments (Fillion & Pickerill, 1990; Uchman 1995). *Bergaueria* is regarded as a cubichnial or domichnial burrow produced by suspension feeders and results from the activities of a cerianthid or actinarian anemones (Fillion & Pickerill, 1990). *Bergaueria* occurs in both delta and open marine deposits of the Nayband Formation.

Ichnospecies *B. hemispherica* Crimes et al., 1977. (Fig. 3F)

Description: Hypichnial mound with hemispherical termination on lower surface of sandstone beds, vertically arranged, oval in outline. The walls of the burrow are unornamented and the burrow fill is essentially structureless. The diameter of the burrow is 10 to 15 mm and depth is 5-8 mm.

Remarks: *B. hemispherica* is distinguished from other species of *Bergaueria* by more flattened underneath. *B. hemispherica* occurs in the delta deposits of the Nayband Formation.

Ichnospecies *B. perata* Prantl, 1945 (Fig. 5g)

Description: Shallow cylindrical burrows with hemispherical termination on lower surface of sandstone beds and bearing a small central depression. The burrows are characterized by smooth and unornamented walls, and are elliptical in horizontal cross-sections. The burrow fill is essentially structureless. The diameter of the burrow is 8 mm and depth is about 4 to 8 mm.

Remarks: *B. hemispherica* occurs in the open marine deposits (offshore transition) of the Nayband Formation.

Ichnogenus *Cochlichnus* Hitchcock, 1858,

Ichnospecies *Cochlichnus* isp. (Fig. 3H)

Description: These are curved, smooth, unbranched, sinuous epichnial ridges. The convex epirelief surface trails are uniform with high sinuosity.

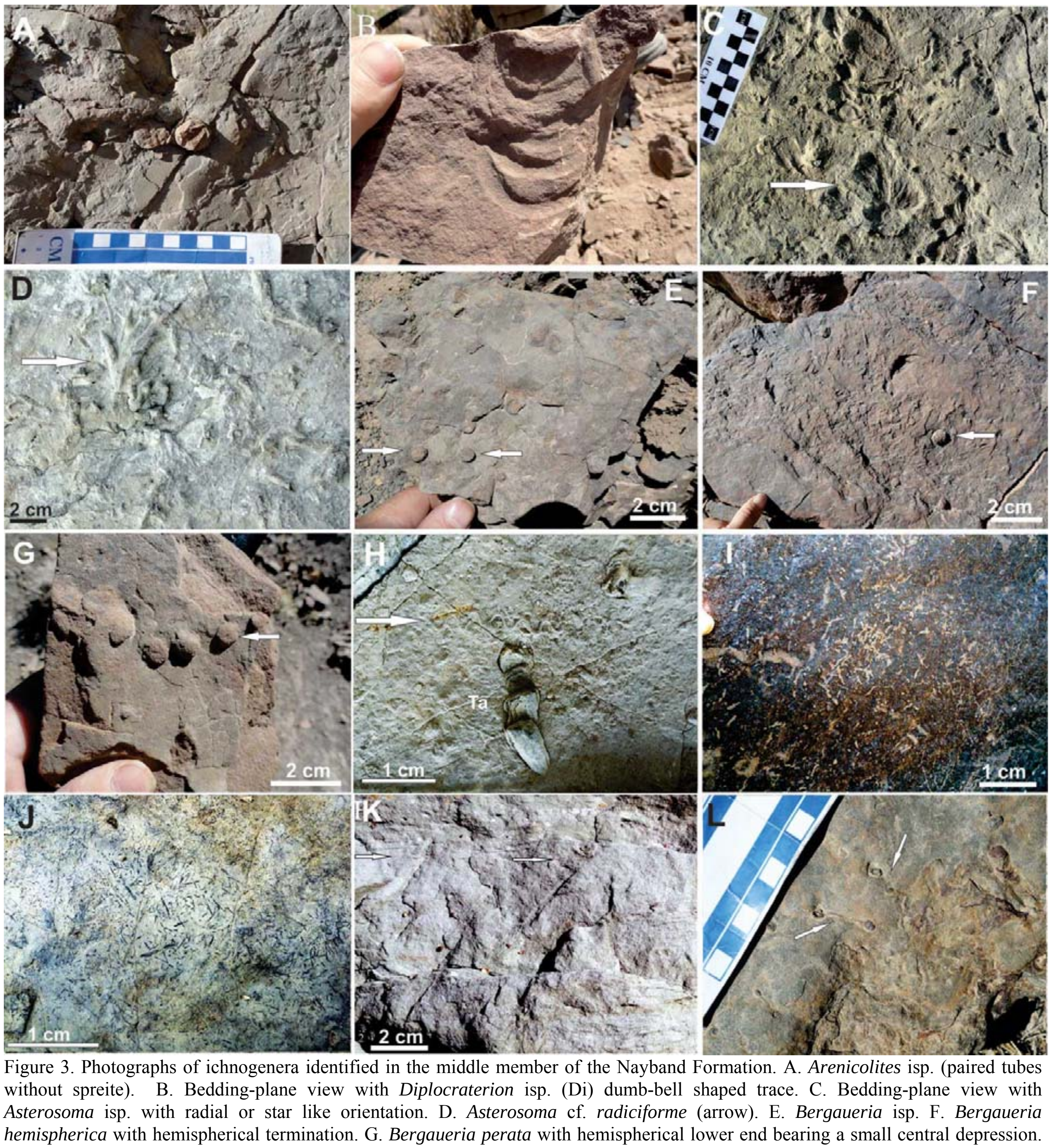

Figure 3. Photographs of ichnogenera identified in the middle member of the Nayband Formation. A. *Arenicolites* isp. (paired tubes without spreite). B. Bedding-plane view with *Diplocraterion* isp. (Di) dumb-bell shaped trace. C. Bedding-plane view with *Asterosoma* isp. with radial or star like orientation. D. *Asterosoma* cf. *radiciforme* (arrow). E. *Bergaueria* isp. F. *Bergaueria hemispherica* with hemispherical termination. G. *Bergaueria perata* with hemispherical lower end bearing a small central depression. H. *Cochlichnus* isp. (arrow) and *Taenidium* isp. (Ta). I. *Chondrites* isp. J. *Chondrites intricatus.* K. *Cylindrichnus* isp. showing slightly curved concentrically lined cylinders with distinct mud lining. L. *Diplocraterion* isp. dumb-bell shaped trace.

They cross-cut a rippled surface at right angles. The diameter of the burrow is about 1 to 2 mm and is constant throughout the length of the burrow. The burrow length varies from 10 to30mm. The amplitude of curves is less than 5 mm, and wavelength is about 3 to6 mm.

Remarks: *Cochlichnus* occurs in conditions with relatively slow sedimentation, and is considered as grazing trail to locomotion trail of a worm-like organism (Bromley 1990). This trace as subordinate elements of the *Cruziana* ichnofacies occurs in the open marine deposits of the Nayband Formation.

Ichnogenus *Chondrites* Von Sternberg, 1833, Ichnospecies *Chondrites* isp. (Fig. 3I)

Description: *Chondrites* is characterized by horizontal to slightly oblique, endichnial burrow system with tree-like branching appearance. The tree-like burrow system with numerous downward radiating branches of straight to gently curved tunnels are filled with darker material (dark-grey to brown mud) than the host rock. The burrow diameter is 1 to 2 mm and bifurcation angles remain constant.

Remarks: The ichnogenus *Chondrites* is regarded as a feeding system of unknown trace-makers related to infaunal deposit-feeders (fodinichnion) (Bromley 1990) due to its extremely deep penetration. This fodinichnian burrow with its extremely deep penetration is formed due to chemosymbiotic style of life related to r-behavior of a trace maker, tolerant to very low oxygen environments (Seilacher 1990; Fu 1991). *Chondrites* typically occurs in tranquil environments with adequate nutrient supply of prodelta, shelf, lower offshore facies of the Nayband Formation.

Ichnospecies *C. intricatus* Brongniart, 1828, (Fig. 3J)

Description: These are characterized by endichnial, downward penetrating tree-like branched tunnel system with straight to gently curved tunnels. In this trace, tunnels show branching at sharp angles. The color of the sediment fill is different from that of the host rock. The width of tunnels is constant in all specimens, being about 1 mm. Bifurcation angles remain constant <45° in all specimens.

Remarks: *C. intricatus* is distinguished from other species of *Chondrites* by its fine branches and acute angle of branching.

Ichnogenus *Cylindrichnus* Toots in Howard, 1966, Ichnospecies *Cylindrichnus* isp. (Fig. 3K)

Description: *Cylindrichnus* is characterized by endichnial, full relief, straight to slightly curve burrows with slightly tapering over their length of several centimeters. These traces are dominantly vertical to sub-vertical, and are represented by slightly curved concentrically lined cylinders with distinct mud lining. The cylinder thickens upward and tapers downwards. These traces are up to 15 cm in length and 5 to 12 mm across.

Remarks: The ichnogenus *Cylindrichnus* is known from slightly turbulent nearshore water or shallow-marine environments with sufficient bottom water circulation (Goldring 1996). The curved concentrically lined cylinders with distinct mud lining represent dwelling structure of filter feeding organisms such as worms/annelids (Goldring 1996). In our case study, *Cylindrichnus* occurs in both delta and open marine deposits including distal mouth bar, proximal mouth bar, offshore transition.

Ichnogenus *Diplocraterion* Torell 1870, Ichnospecies *Diplocraterion* isp. (Fig. 3B, L)

Description: *Diplocraterion* is characterized by short U-shaped protrusive spreiten-burrows with parallel limbs or dumb-bell shaped structures consisting of two subspherical openings of the vertical tubes joined by a lamina of reworked material (i.e., spreite) on the bedding planes. The tubes, up to 5 mm in diameter, are smooth and unlined; the distance between openings is usually 10–30 mm.

Remarks: *Diplocraterion* is interpreted as a domichnial trace fossil produced by suspension-feeding polychaetes and crustaceans (e.g., Fillion & Pickerill, 1990). The occurrence of spreiten-structures reflects the burrowing organism's reaction to erosion or deposition of sediments (Pemberton *et al.,* 2001). In this study, *Diplocraterion* occurs abundantly in association with other suspension-feeding traces, in open marine deposits.

Remarks: This ichnogenus is considered as a eurybathic trace fossilwith limited environmental use (e.g. Buatois *et al.,* 1998; Pemberton *et al.,* 2001). *Helminthopsis* is interpreted as grazing trails produced by deposit-feeder organisms, probably polychaete annelids (Uchman 1998). In this study, *Helminthopsis* occurs in both delta and open marine deposits, including prodelta, shelf, lower offshore, offshore transition.

Ichnospecies *H. abeli* Książkiewicz, 1977, (Fig. 4C)
Description: Unbranched, horizontal, smooth, cylindrical to sub-cylindrical burrow consists of winding to irregularly meandering trails. The occurrence of open meanders and horseshoe-like turns following a slightly irregularly meandering course is common. Branching or overlapping is not observed. Burrow diameter varies from 5 to 8 mm, and is constant throughout the length of the burrow. Maximum burrow length is about 45 mm.
Remarks: The differentiation of *Helminthopsis* ichnospecies should be based on the surficial winding geometry of the trace fossil. *H. abeli* is distinguished from other species of *Helminthopsis* by its horseshoe-like turns and straight segments.

Ichnospecies *H. hieroglyphica* Heer in Maillard, 1887, (Fig. 4D)
Description: *H. hieroglyphica* is characterized by convex hyporelief, irregularly meandering, horizontal, cylindrical, unbranched burrows. These traces are marked by alternating winding, more or less straight courses or box-like hieroglyphic meanders. The traces are about 8–10 mm wide with maximum length of about 5 cm. The burrow diameter is constant throughout the strata, and fill is identical to the matrix.
Remarks: *H. hieroglyphica* as grazing trails produced by deposit-feeders is distinguished from other species of *Helminthopsis* by more or less straight courses or box-like hieroglyphic meanders.

Ichnogenus *Gyrochorte* Heer, 1865, Ichnospecies *Gyrochorte* isp. (Fig. 4E)
Description: *Gyrochorte* is characterized by long, straight or curved burrows preserved in epirelief, parallel to the bedding. These trails consist of plaited ridges with biserially arranged long parallel ridges. The two closely spaced parallel trails are separated by a deep furrow. Each trail has a width of about 8-10 mm and length of about 20 to 80 mm.
Remarks: *Gyrochorte* is considered as grazing trails produced by detritus-feeding worm-like animals, probably polychaete annelids or mollusk that moving obliquely through the sediment and created a bilobed, vertically penetrating trace (Buatois *et al.,* 1998; Gibert & Benner, 2002). The ichnogenus *Gyrochorte* is known from a wide range of marine environments, and is associated with a wide range of salinities (Gibert & Benner, 2002). *Gyrochorte* occurs in both delta and open marine deposits, including distal mouth bar, proximal mouth bar, offshore transition, distal lower shoreface sediments.

Ichnospecies *G. comosa* Heer, 1865, (Fig. 4F)
Description: This ichnospecies is characterized by long, sinuous and curved, horizontal trails consist of backfill structures, which are biserially arranged as plaited ridges with long parallel ridges. Studied specimens are 5- 8 mm wide and most of them are preserved as convex epireliefs.
Remarks: This trace as subordinate elements of the *Cruziana* ichnofacies occurs in the open marine deposits (offshore transition) of the Nayband Formation.

Ichnogenus *Gordia* Emmons 1844, Ichnospecies *G. marina* Emmons, 1844, (Fig. 4G)
Description: Unbranched and curved meandering burrows with irregular courses that show winding and looped segments without sharp-angled turns, annulations or arcuate shapes. The overlapping of the meanders is common. These are smooth worm-like trails with uniform thickness. The length of the trail is about 4 to 7 cm. The diameter of burrow is about 3 to 6 mm.
Remarks: *Gordia* is interpreted as pascichnial grazing trails, produced by deposit feeders (Buatois *et al.,* 1998). Various tracemakers can be considered such as polychaete annelids in brackish to fully marine environments. Therefore, this ichnogenus can be considered as a "facies-crossing" trace occurring in a variety of ichnofacies (e.g., Pemberton *et al.,* 2001). The specimens collected in the Nayband Formation occur abundantly in association with other grazing traces from open marine deposits.

Ichnogenus *Gyrolithes* de Saporta, 1884, Ichnospecies *Gyrolithes* isp., (Fig. 4H)
Description: These cylindrical burrows are preserved as endichnial corkscrew-shaped spiral burrows at the top of laminated sandstone beds. They are rarely present in the study area. The burrows are filled with structureless sand and identical to the host rock. These burrows consist of a non-striated single whorl without annulations or surface ornamentation. The burrow width is about 5-8 mm and spiral diameter is about 6-10 mm.
Remarks: *Gyrolithes* as a deep dwelling burrow produced by different kinds of crustaceans and polychaetes is typical of the shallow marine *Cruziana* ichnofacies (Bromley 1996).

Figure 4. A. Fugichnia within distal delta-front sandstones. B. *Helminthopsis* isp. (arrows). C. *Helminthopsis abeli* on the lower surface of fine-grained sandstone. D. *Helminthopsis hieroglyphica* more or less straight courses or box-like hieroglyphic meanders. E. *Gyrochorte* isp. F. *Gyrochorte comosa,* showing biserially arranged as plaited ridges with long parallel ridges. G. *Gordia marina* of irregularly meandering burrows; with looped segments and over-cross. H. *Gyrolithes* isp. corkscrew-shaped spiral (Gy) associated with *Planolites beverleyensis* (Pl). I. *Laevicyclus* isp. individual burrow and concentric around a central shaft. J. The rippled top surfaces with vertical structures and pervasive *Skolithos* isp. and *Laevicyclus* isp. (La), *Arenicolites* isp. (Ar) and *Palaeophycus* isp. (Pa). K. *Macaronichnus* isp. irregularly trails composed of a core surrounded by a mantle. L. Bedding-plane view of sandstone beds with *Monocraterion tentaculatum* (Mo) showing burrows radiating from an elevated central knob, with *Palaeophycus heberti* (Pa) and vertical dwelling burrows (?).

The occurrence of this ichnogenus along with the brackish settings of the delta supports an opportunistic behavior for the producers in a context of environmental stress related to high and/or fluctuating salinities. According to Buatois *et al.* (1998), the occurrence of deep dwelling burrows with vertical helical morphology reflects a specialized burrowing architecture to seek refuge from extreme salinity fluctuations in brackish-water environments.

Ichnogenus *Laevicyclus* Verma, 1970, Ichnospecies *Laevicyclus* isp., (Fig. 4I, J)
Description: Vertical, straight, simple, cylindrical structures showing more or less uniform diameter, preserved in epirelief. The vertical cylindrical body make right angle to the bedding plane and appear as regular concentric circles. Individual burrows are concentric around a central shaft. The maximum outer diameter is about 15-18 mm; the shaft diameter is 3-6 mm and the depth of the burrow is 60 mm.
Remarks: The ichnogenus *Laevicyclus* is regarded as an opportunistic and facies-crossing trace with a suspension-feeding and domichnia function and considered to be a circular trace of suspension feeding animals (Uchman 1995). The evidence of vertical structures with central tubes, perpendicular to bedding surfaces reflects the burrowing organism's reaction to environmental factors, such as settings with strong wave and current energy. The specimens collected in the Nayband Formation occur abundantly in association with other suspension-feeding traces from open marine deposits, including lower shoreface.

Ichnogenus *Lockeia* James, 1879, Ichnospecies *Lockeia* isp., (Fig. 3C)
Description: Convex hyporelief and small, stout, high standing, bilaterally symmetrical, almond-shaped with a smooth surface. They show the presence of tapering at both ends. The size varies greatly, but the shape remains more or less constant. They occur as isolated, and their dimension varies in different burrow populations, with observed length of 10 -15 mm, width of 4-7 mm and height of 3-8 mm.
Remarks: This ichnogenus is distinguished from other species of *Lockeia* in having an almond-like stout nature. *Lockeia* is considered as resting traces of small burrowing bivalves, perhaps semi-sessile forms (Bromley 1996; Buatois *et al.,* 1998). The specimens collected in the Nayband Formation occur rarely in open marine deposits in lower shoreface facies.

Ichnogenus *Macaronichnus* Clifton and Thompson, 1978, Ichnospecies *Macaronichnus* isp., (Fig. 4K)
Description: Endichnial or epichnial, cylindrical, straight to slightly curved, irregularly trails with open to tight meander bends parallel to slightly oblique to the stratification. They are composed of a core surrounded by a mantle. The core is composed of sediment that is lighter in color than the host rock (quartzose sand), whereas the mantle is darker and is composed of non-quartzose components relative to the host sediment. Burrow diameter varies from 3 to 8 mm
Remarks: *Macaronichnus* is interpreted as a pascichnion produced by vagile, deep deposit-feeding worms (Pemberton *et al.,* 2001). According to Savrda *et al.* (1998), the light-colored fills represent ingestion sediments by tracmaker, whereas the mantle represent sediments that have been rejected and pushed to the side. It is common in sandy facies from the delta deposits with high to moderate energy, including proximal mouth bar.

Ichnogenus *Monocraterion* Torell, 1870, Ichnospecies *M.* cf. *tentaculatum* Torell, 1870, (Fig. 4L and 5A)
Description: Vertical conical structures are characterized by central shaft surrounded by concentrically laminate at right angle to the bedding plane. They show a series of dark concentric rings in transverse sections. Mud lining is present along burrow wall of both tubes and funnels. The maximum outer diameter is about 15-20 mm and the shaft diameter is 5 mm and the depth of the burrow is 150 mm.
Remarks: *Monocraterion* is interpreted as the permanent dwelling of suspension or detritus feeders of worm-like organisms in response to high or frequent sedimentation and/or erosion events (Pemberton et al., 2001). Funnel-like concentrically laminated structures were constructed by upward migration of animal inhabiting tube. The occurrence of this ichnogenus along with open marine settings of proximal lower shoreface on sandy and high-energy substrates, and its close association with other suspension-feeder traces support an opportunistic behavior for the producers in a context with environmental stress related to conditions of rapid sedimentation.

Ichnogenus *Ophiomorpha* Lundgren, 1891, Ichnospecies *Ophiomorpha* isp., (Fig. 5B, C)
Description: These are vertical, long straight, cylindrical, branched or unbranched burrows, horizontal or sub-horizontal to the bedding plane, showing more or less uniform diameter.

Figure 5. A. Vertical, conical structures of *Monocraterion* isp. B. *Ophiomorpha* isp. (arrows). C. *Ophiomorpha nodosa* showing smooth interior walls and nodose exterior surfaces;Y-shaped branching. D. *Ophiomorpha irregulaire* possesses walls composed of dense, irregularly distributed ovoid pellets. E. *Palaeophycus tubularis* (Pa). F. *Palaeophycus* cf. *annulatus* with ?*Laevicyclus* isp. with body fossils (arrows). G. *Palaeophycus heberti,* thickly lined. H. *Palaeophycus striatus* showing margins lined and ornamented by longitudinal parallel grooves associated with *Phycodes* isp. (Phy). I. *Paleodictyon* isp. With *Gordia* isp. (Go). J and K. ? *Phycosiphon* isp. L. *Planolites* isp. (white arrows), with body fossils (yellow arrows). M. *Protovirgularia rugosa* arranged in chevron-shaped. N. *Protovirgularia rugosa.* O. *Rhizocorallium irregular*.

The interior of the burrow is smooth, whereas the exterior is typically ornamented with pellets. Length and diameter of the burrow are variable. Here, the length varies from 10 to 15 cm, and the diameter is about 5 to 10 mm.

Remarks: *Ophiomorpha* is generally interpreted as a dwelling structure (domichnial) of a suspension-feeder, passively filled, usually related to oxygenated situations and cohesive substrates. *Ophiomorpha* as a deep dwelling burrow is mainly produced by shrimps comparable to recent callianassids (Frey *et al.,* 1978). The pelleted wall lining of *Ophiomorpha* is considered to be as supporting the structure to prevent collapse of unconsolidated sediment during and after burrow construction (Ekdale *et al.,* 1984). The occurrence of this ichnogenus associated with both delta and open marine deposit on sandy and high-energy substrates and in close association with other suspension-feeder traces supports an opportunistic behavior for the producers.

Ichnospecies *O. irregular* Frey et al, 1978, (Fig. 5D)

Description: They are cylindrical, branched or unbranched burrows with vertical and horizontal components, horizontal or sub-horizontal to the bedding plane. The burrow tubes have thick wall composed of dense, irregularly distributed ovoid pellets with variable size. In general, the surface of burrow is covered by irregular elongated pellets, which are arranged perpendicular to the long axis of the burrow. The length varies from 5 to 9 cm, and the diameter is about 5 to 10 mm.

Remarks: *O. irregular* is distinguished from other species of *Ophiomorpha* in having irregular pellets (irregular wall granules) oriented perpendicular to the long axis of the burrow without bilobate or conical pellets with horizontal meander maze galleries (Uchman 2009).

Ichnospecies *O. nodosa* (Lundgren 1891), (Fig. 5E)

Description: Endichnial, horizontal, vertical to sub-vertical, branching burrow systems. Cylindrical burrows are very common and usually represented by smooth interior walls and distinct nods exterior surfaces consisting of dense, regularly distributed pellets. Occasionally, branched burrow systems showing the Y- shaped branches. The diameter of the burrow ranges from 2-3 cm and the diameter of the pellets varies from 1-2 mm. The length varies from 10-20 cm.

Remarks: The dwelling structure of suspension feeding crustaceans as lined by three-dimensional burrow systems from shallow-water deposits is mainly represented by *O. nodosa* while deep sea forms by *O. rudis* (Tchoumatchenco & Uchman, 2001).

Ichnogenus *Palaeophycus* Hall, 1847, Ichnospecies *Palaeophycus* isp., (Fig. 4J)

Description: Straight to slightly curved, smooth-walled, horizontal, endichnial, cylindrical burrows showing mud linings. The burrow fill does not exhibit any internal structure (burrow fill more loosely packed, passive). The burrows are filled with the same sediment as the host rock. They display densely packed sandstone walls with 1 to 2 mm thick. The diameter and length of the burrow ranges from 8 to 12 mm and 3-10cm, respectively.

Remarks: The presence of features showing collapses of the burrow walls due to absence of burrow lining reflects the semi-permanent nature of the burrows. The indurated wall lining of the burrows with densely packed sandstone is related to substrate coherence of the host rock. The occurrence of this ichnogenus with both delta and open marine deposits supports eurybenthic facies-crossing form for *Palaeophycus*.

Ichnospecies *P.* cf. *alternatus* Badve, 1987, (Fig. 5G)

Description: These are straight to slightly curved, cylindrical, unbranched, distinctly lined burrows. They show thin fine striation or annulations arranged serially on the burrows. Striations consist of thin wavy ridges and grooves, best developed where annulations are absent. The specimens exhibit little burrow collapse. The burrows are filled with structureless sand, identical to the surrounding materials. The diameter of the burrow is about 8mm and is constant throughout the length of the burrow. The length varies from 30-80 mm;

Remarks: Possessing striation and annulations differentiates the ichnospecies *P. alternatus* from other ichnospecies of *Palaeophycus* (Pemberton & Frey, 1982). The annulations are interpreted to be produced by peristaltic movements of the trace makers (Pemberton & Frey, 1982).

Ichnospecies *P. heberti* (Saporta, 1872), (Fig. 5H)

Description: This ichnospecies is characterized by straight to slightly curved, horizontal, endichnial, cylindrical burrows showing thickly lined. The burrow wall linings typically consist of agglutinated sediment, coarser and better arranged than the host rock. The burrow fill is structureless and identical to the host rock. The length of the burrow is 30-70 mm whereas the diameter is constant in a given specimen and is 10 mm.

Remarks: *P. heberti* is distinguished from *P. tabularis* by its thick wall lining and from *P. alternatus* by lack of alternating annuli and striae (Pemberton & Frey, 1982).

Ichnospecies *P. striatus* Hall, 1852, (Fig. 5I)

Description: These are straight or slightly curved, unbranched, horizontal, endichnial burrows. The burrow is predominantly elliptical in cross-section and displays fine, continuous, parallel longitudinal striations. The burrow lining is thin. The burrow fill is structureless and identical to the host sediments. The length of the burrow is 50-100 mm whereas the diameter is constant in a given specimen and is 10 mm.

Remarks: *P. striatus* is distinguished from the other species by its ornamentation of parallel and continuous grooves (Pemberton & Frey, 1982). The longitudinal striations within the burrows probably reflect production by organism's setae or bristles as the trace makers moved (Schlirf 2000).

Ichnospecies *P. tubularis* Hall, 1847, (Fig. 5F)

Description: These are unbranched, endichnial or hypichnial, straight to slightly curved cylindrical to subcylindrical burrows with more or less smooth thinly walled. They show discrete lining without ornamentation. The burrow fill is structureless and and has the same lithology of the host rock. The maximum observed length is 100 mm with diameter of 10 mm.

Remarks: *P. tabularis* is distinguished from *P. heberti* by a consistently thinner lining (Pemberton & Frey 1982). This ichnogenus is associated with both delta and open marine deposits of the Nayband Formation.

Ichnogenus *Paleodictyon* Meneghini, 1850, Ichnospecies *Paleodictyon* isp., (Fig. 5J)

Description: *Paleodictyon* in the Nayband Formation comprises a honeycomb-like polygonal network, relatively regular, preserved in positive relief with equidimensional to elongate horizontal meshes. The inner dimensions of the polygons are up to 4 mm wide, and the casts of the cylindrical burrows themselves are up to 1 mm in diameter. This trace is randomly distributed on the bedding plane.

Remarks: *Paleodictyon* is indicative of deep marine oligotrophic waters and is typically considered to be a shallow-tier trace fossil. *Paleodictyon* is regarded as farming trace fossils and trapping meiobenthic organisms or cultivating micro-organisms within the sediment (Uchman 1995). *Paleodictyon* occurs in shelf facies of the Nayband Formation and is associated with trace fossil suites attributable to the *Zoophycos* ichnofacies.

Ichnogenus *Phycodes* Richter, 1850, Ichnospecies *Phycodes* isp., (Fig. 5I)

Description: This ichnogenus is composed of loosely packed bundle of tunnels, preserved as horizontal cylinders on a horizontal plane. It consists of a few thick and irregular branches that originate in a palmate or flabellate form from the same point. The diameter of the branches is about 5 to10 mm wide and the lengths of individual branches are up to 70 mm. The burrow fills are distinct and different than the host sediments.

Remarks: *Phycodes* is interpreted as a dwelling-feeding structure, produced by sediment-feeding vermiform annelid, during the penetration of nutrient-rich deposits (Fillion & Pickerill, 1990). *Phycodes* occurs in distal lower shoreface facies of the Nayband Formation.

Ichnogenus *Phycosiphon* Fischer-Ooster, 1858, Ichnospecies *Phycosiphon* isp., (Fig. 5K)

Description: This ichnogenus is composed of small, narrow and sinuous to U-shaped tubes recurving as a series of lobes as protrusive spreiten-structures. These protrusive spreiten-structures are parallel to the bedding plane. There is no perceptible trace of spreiten between arms. The burrows are filled with fine-grained material and surrounded by a mantle containing coarser grains than the central fill. The tunnels diameter is normally less than 1 mm and the lobes have widths ranging from 2 to 6 mm.

Remarks: According to Wetzel & Bromley (1994) it is regarded as an opportunistic behavior for the producers in a context with environmental stress related to poorly oxygenated sediments. It is mostly found in shelf facies rich in mudstone and shale associated with the *Zoophycos* ichnofacies.

Ichnogenus *Planolites* Nicholson, 1873, Ichnospecies *Planolites* isp., (Fig. 5L)

Description: *Planolites* is identified as simple, horizontal to subhorizontal, straight to gently curved, unbranched burrows preserved in convex hyporelief. These traces are predominantly cylindrical, smooth-walled and unlined. The burrow occurs as a single isolated specimen or as crowded masses, in which cross-over interpenetrations are common. These traces are characterized by a structureless infill that is compositionally different from the sedimentary matrix of the host rock. The length of the burrow varies from 2 to 5 cm and the diameter from 5 to 10 mm.

Remarks: These structures are regarded as extremely facies-crossing form, recorded in shallow-marine, deep-marine, brackish and continental environments (e.g. Pemberton *et al.,* 2001). *Planolites* is interpreted as feeding structures, product of vermiform deposit feeders, actively back-filling their burrows (Häntzschel 1975; Vossler & Pemberton, 1989). The occurrence of *Planolites* in both delta and open marine deposits with a wide range of salinities supports eurybenthic facies-crossing form for *Planolites*.

Ichnospecies *P. beverleyensis* Billings, 1862, (Fig. 4H)

Description: These traces are characterized by the presence of cylindrical to sub-cylindrical, smooth walled, straight to gently curved burrows. The observed burrows are exceptionally long and usually without burrow wall or burrow lining. These are unbranched, sinuous to straight horizontal structures, and are preserved in full relief without annulations and grooves. Sediment fills are essentially structureless, but texturally/lithologically different from the host sediment. The length varies from 10 to 100 mm, and the diameter is about 5 to 10 mm.

Remarks: *P. beverleyensis* occurs in both delta and open marine deposits of the Nayband Formation.

Ichnogenus *Protovirgularia* McCoy, 1850, Ichnospecies *P. rugosa* Miller and Dyer, 1878, (Fig. 5M, N)

Description: These are long, horizontal or sub-horizontal cylindrical burrows preserved as positive epirelief on rippled sandstone beds and also at the sandstone–mudstone interface. *Protovirgularia* is identified as bilobated and straight to gently curved ribs arranged in chevron-shaped, consisting of an elevated median line and lateral wedge-shaped appendages with biserial pattern along external. Burrow diameter varies from 5 to10 mm. Maximum burrow length is about 7 cm.

Remarks: *Protovirgularia* is interpreted as a combined activity of search for food and locomotion and commonly assigned to the activity of cleft-foot bivalves and scaphopods (Seilacher & Seilacher, 1994). It is mostly found in offshore and lower shoreface facies of the Nayband Formation associated with trace fossil suites attributable to the *Cruziana* ichnofacies.

Ichnogenus *Rhizocorallium* Zenker 1836, Ichnospecies *R. irregular* Mayer 1954, (Fig. 5O and 6C)

Description: These are horizontal, straight or slightly sinuous, U-shaped protrusive spreiten-burrows, disposed parallel to the bedding plane. Marginal tubes and numerous closely-spaced spreiten are distinct. Marginal tubes are filled with fine- to medium-grained sediments identical to the host rock. The spreiten are preserved as closely spaced, curved ridges between the arms of the tube. The tubes are circular in outline, smooth, unlined, and up to 10 mm in diameter. The distance between the limbs is usually 30 to 60 mm. Burrow diameter varies from 5 to 7 cm. Maximum burrow length is about 25 cm.

Remarks: Considering the great variety in forms and the numerous ichnospecies of *Rhizocorallium*, *R. irregular* is generally attributed to primary deposit-feeding habit on the basis of its slightly sinuous and comparatively long size and the presence of possible burrows branches, whereas *R. jenense* is a characteristic feature of the primary suspension-feeding habits (Fürsich 1974). The occurrence of *R. irregular* in in open marine deposits of the Nayband Formation without features of vertical connections to the surface supports deposit-feeding habits for the tracemaker. The close association *R. irregular* with grazing traces in the same horizons supports this interpretation.

Ichnospecies *R. jenense* Zenker 1836, (Fig. 6A, B)

Description: *R. jenense* is identified as simple, horizontal, straight to slightly sinuous, short U-shaped protrusive spreiten-burrows with parallel limbs, which are horizontal or oblique to the bedding plane. However, the burrows are dominantly of retrusive type, and are commonly oblique to the bedding plane. Well-developed scratch marks have been found in the spreiten and marginal tubes. The distance between the limbs is usually 20 to60 mm. Burrow diameter varies from 5 to 8 cm. Maximum burrow length is about 14 cm.

Remarks: *R. jenense* is interpreted as burrows of suspension feeders (Fürsich 1974) or scavenging organisms (Rodríguez-Tovar *et al.*, 2007). It seems that the great variety in forms and orientation of *R. jenense* on the substrates in shorface and offshore facies of the Nayband Formation is related to the substrate cohesiveness and availability of the nutrients (Seilacher 2007).

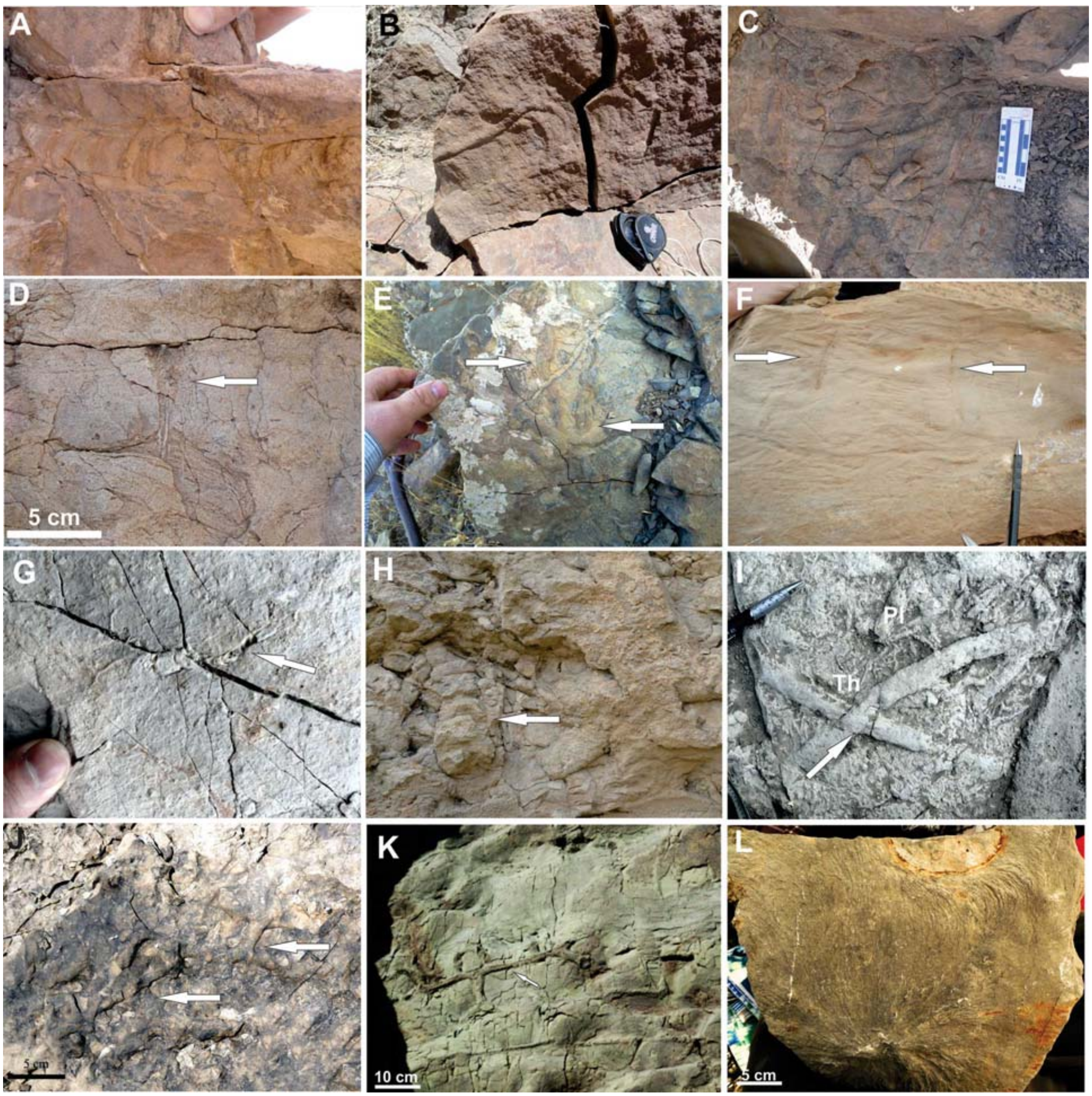

Figure 6. A. *Rhizocorallium* isp. B. *Rhizocorallium jenense.* C. *Rhizocorallium irregular* with variation in dimension and irregular curvature of tubes. D. *Rosselia* isp. a funnel-shaped burrow represented by a central tube. E. *Scolicia* isp. bilobate hypichnial ridge divided by a semicircular axial furrow. F. *Skolithos* isp. G. *Taenidium cameronensis* with chevron-shaped sediment packets. H. *Teichichnus* isp. showing stacked circular U-shaped burrow. I. *Thalassinoides horizontalis*. J. *Thalassinoides paradoxicus.* K. *Thalassinoides suevicus* showing Y- shaped bifurcations; swelling at the point of bifurcation with smooth surface, associated with *Planolites* isp. (Pl). L. *Zoophycos* isp..

The studied specimens are associated with transgressive surface produced during a period of non-deposition, before and at the beginning of the subsequent deposition.

Ichnogenus *Rosselia* Dahmer, 1937, Ichnospecies *Rosselia* isp., (Fig. 6D)

Description: *Rosselia* is composed of vertical or subvertical funnel-shaped burrows with straight to slightly curved concentrically lined cylinders and distinct mud lining. *Rosselia* is characterized by endichnial/epichnial, full relief, funnel-shaped burrows with a central tube filled with sandy sediment and surrounded by concentric muddy lamination. The funnel-shaped burrows thicken upward and tapers downwards. These traces are up to 5 cm in length and 1 to 2 cm across.

Remarks: These traces are interpreted as permanent dwelling burrows of filter feeding organisms (Fillion & Pickerill, 1990). In this study, *Rosselia* is found in both delta and open marine deposits in a wide range of salinities. The occurrence of environmental stress related to high and/or fluctuating salinities, and an inferred higher hydrodynamic energy, favouring the opportunistic occurrence of filter feeding organisms.

Ichnogenus *Scolicia* Quatrefages, 1849, Ichnospecies *Scolicia* isp., (Fig. 6E)

Description: *Scolicia* is preserved usually as bilobed backfill ribbon-like traces or bilobate hypichnial ridges in convex hyporelief. These traces show smooth winding or meandering burrows, and are divided by a semicircular axial furrow that occasionally occupies up to two-thirds of the ridge width. In some cases, *Scolicia* is characterized by flat medial ridge that is longitudinally divided by a shallow furrow or crest. The trail is typically 20-30 mm wide and up to 10 cm in length.

Remarks: The ichnogenus *Scolicia* is known in a broad range from shallow-marine to submarine fans as a combined activity of food search and locomotion of gastropods and irregular echinoids (Uchman 1995). It is mostly found in shelf facies, rich in mudstone and shale, associated with trace fossil suites attributable to the *Zoophycos* ichnofacies. Their distribution and association with other grazing and locomotion traces in silty–mud substrates indicate low energy conditions.

Ichnogenus *Skolithos* Haldeman, 1840, Ichnospecies *Skolithos* isp., (Fig. 6F)

Description: These are characterized by vertical to steeply inclined, straight, simple, unlined, cylindrical, unbranched burrows. It occurs as closely-spaced (dense occurrences) or isolated tubes on the bedding planes. It is also appearing as circular outlines perpendicular to the bedding plane and standout as high relief burrow with a structureless fill. The diameter of the burrow is about 5 to 8 mm. Burrow length varies from 5 to 12 cm.

Remarks: Dense occurrences of *Skolithos* are referred to as 'pipe-rock' ichnofabric (Pemberton *et al.,* 2001). *Skolithos* is interpreted as a domichnion structure made by annelids and suspension feeding polychaetes (Pemberton *et al.,* 2001). It is common in sandy facies from both delta and open marine deposits with high to moderate energy.

Ichnogenus *Taenidium* Heer 1877, Ichnospecies *Taenidium* isp., (Fig. 3H)

Description: These are characterized by unbranched, unlined, straight to gently winding, smooth burrows. The burrows are commonly horizontal, distinctly meniscate and elliptical in cross-section. The menisci show unequal thickness and relatively low curvature. On the bedding planes, constricted annuli and back-fill laminae are prevalent within the winding burrows. Burrow diameter varies from 5 to 10 mm.

Remarks: *Taenidium* is attributed to the activity of an advanced organism, probably combining the activity of deposit-feeding and locomotion. The meniscus structures may arise from physical sorting during the animal's progress through the substrate (Bromley 1996). The specimens collected in the study area are preserved within siltstone–mudstone interlayers of open marine deposits (offshore transition), associated with trace fossil suites attributable to the *Cruziana* ichnofacies.

Ichnospecies *T. cameronensis* Brady, 1947, (Fig. 6G)

Description: These are horizontal to sub-horizontal burrows preserved as concave hyporelief or endichnial burrows at the sandstone–mudstone interface. *T. cameronensis* is identified as unbranched, unlined, and straight to curved with meniscate backfill structures. The burrows are filled with equal meniscate packets, which are less than the width of the burrow. The menisci are characterized by deeply arcuate, well-spaced and

lack significant walls. The burrow width varies from 5 to 10 mm.
Remarks: *T. cameronensis* differs from other ichnospecies of *Taenidium* in having deeply arcuate menisci.

Ichnogenus *Teichichnus* (Seilacher, 1955), Ichnospecies *Teichichnus* isp., (Fig. 6H)
Description: *Teichichnus* is identified as straight to broadly curved, unbranched, unlined, horizontal stacked circular U-shaped burrows. The vertical to inclined tunneled burrows or retrusive spreiten are preserved as endichnia. The stacked tubes show meniscate laminae bowing downwards. The maximum observed length of the burrow is about 8 cm and width is 2 to 3 cm.
Remarks: *Teichichnus* is considered as feeding or combined feeding–dwelling activity of vermiform animals such as polychaetes and sipunculan worms (Mángano *et al.,* 2002). The vertical to inclined tunneled burrows with spreiten laminae is resulted from the vertical shift of horizontal burrow and repeated burrowing episodes by an infaunal deposit-feeding organisms due to moving back and forth in the same vertical plane (Pemberton *et al.,* 2001). It is mostly found in prodelta and distal mouth bar facies, rich in mudstone, and is associated with trace fossil suites attributable to the stressed distal expression of the *Cruziana* ichnofacies.

Ichnogenus *Thalassinoides* Ehrenberg, 1944, Ichnospecies *T. horizontalis* Myrow, 1995 (Fig. 6I)
Description: This ichnospecies is preserved as thick horizontal burrows, disposed parallel to the bedding plane without any ornamentation. *T. horizontalis* as three-dimensional, unlined, horizontal burrow system is preserved in full relief and seen with Y/T-shaped branching. Most of the specimens are found in the horizontal surface without any vertical offshoots. The length of the structures varies from 2 to 15 mm.
Remarks: *Thalassinoides* is considered as combined feeding–dwelling activity produced by crustaceans or other type of arthropods (Ekdale 1992). *T. horizontalis* is distinguished from other species of *Thalassinoides* by the absence of the vertical shafts and its constant diameter of the individual tunnels. *T. horizontalis* occurs in lower shoreface facies of the Nayband Formation, and is associated with suites of the *Cruziana* ichnofacies.

Ichnospecies *T. paradoxicus* Rieth, 1932, (Fig. 6J)
Description: This ichnospecies is characterized by smooth, irregularly branched burrow systems consisting of a horizontal network connected to the surface by a more or less vertical shaft. These are horizontal to slightly oblique burrows preserved as convex hyporelief or endichnial burrows. Branched burrow systems are characterized by smooth-walled cylindrical to elliptical burrows with variable and irregular diameter. Bifurcations are commonly Y-shaped and also show swelling at the junctions. Burrow diameter varies from 20 mm to 50 mm and length of the structures observed varies from 1 to 15 cm.
Remarks: *T. paradoxicus* is distinguished from the other species *T. horizontalis* by the presence of the vertical shafts and branch dichotomous (Howard & Frey 1984).

Ichnospecies *T. suevicus* Rieth, 1932, (Fig. 6K)
Description: This ichnospecies is characterized by horizontal three-dimensional burrow system spread on the bedding surface. *T. suevicus* is characterized by the presence of smooth-wall, more or less regularly branched burrow system preserved as convex hyporelief with cylindrical burrows of variable diameter. They show Y-shaped bifurcations in the horizontal system with swelling at the point of bifurcation, and are regularly branched at right angles, forming box-works. The burrow diameter varies from 2 mm to 5 cm, and the length of the observed structures varies from 10 to 40 cm.
Remarks: The diagnostic features of this ichnospecies include swelling at the points of branching and the presence of large burrow systems from polygon framework. *T. suevicus* occurs in offshore and shoreface facies of the Nayband Formation, and is associated with suites of the *Cruziana* and *Skolithos* ichnofacies.

Ichnogenus *Zoophycos* (Massalongo 1855), Ichnospecies *Zoophycos* isp., (Fig. 6L)
Description: These are endichnial, curved, horizontal to sub-horizontal spreiten structures with helicoidally coiled forms. They are characterized by the presence of numerous, more or less U- or J-shaped protrusive burrows of variable length and orientations. The spreiten structures show circular to elliptical outline in planar view. The diameter of the whorls increases away from the openings.

Remarks: This ichnogenus was deposited under limited environmental conditions with quiet-water settings, abundant organic matter and low oxygen levels. *Zoophycos* is considered as a feeding system of unknown trace-makers related to infaunal deposit-feeders; interpreted as a fodinichnion (Bromley 1990). It is mostly found in prodelta and shelf/lower offshore facies, rich in mudstone, and is associated with trace fossil suites attributable to the stressed distal expression of the *Cruziana* ichnofacies and *Zoophycos* ichnofacies.

Fugichnion (escape structures) (Fig. 4A)

Description: These are vertical to sub-vertical, unlined burrows comprising successively stacked, longitudinally nested individual burrows. The burrows show down warping of strata in their central part. Units of the host rock display disturbance of strata continued through the burrow. The vertical section transverse to long axes of the burrow displays laminae bowing downwards. The burrow diameter varies from 5 to 20 mm, and the length of the observed structures varies from 5 to 20 cm.

Remarks: These structures are common in shallow-marine environments and developed under high sedimentation conditions (e.g., Bayet-Goll *et al.,* 2017). Fugichnia is developed in response to episodic sedimentation and its deep penetration is formed due to an attempt to rapidly burrow towards the sediment-water interface (Bromley, 1996). It is mostly found in the mouth bar facies on sandy substrates.

Conclusion

The trace fossils of the Upper Triassic succession of the Nayband Formation of the Tabas Block, Central Iran are abundant and ubiquitous in nature. Total 49 ichnospecies belonging to 28 ichnogenera were identified and classified according to their morphological characters. Ethologically, this assemblage includes locomotion, grazing deposit-feeding, deep-tier deposit-feeding, dwelling/deposit-feeding, surface detritus-feeders, suspension-feeding structures, passive carnivores, escape structures (fugichnia). The trace fossil assemblage has proved major role for the paleonenvironmental interpretation of these sediments and accordingly depositional paleoenvironments of the Nayband Formation.

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