

# Some deep-marine ichnofossils from Labuan and Klias Peninsula, west of Sabah

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**Abstract:** The Temburong Formation comprises fine grain flysch, deposited in a distal part of a submarine fan system. Twenty five taxa of ichnofossils were identified. The ichnofossils are grouped into the *Nereites* ichnofacies. The ichnofacies was further divided into two subichnofacies namely *Paleodictyon* and *Ophiomorpha rudis* subichnofacies. The *Paleodictyon* subichnofacies is characterized by a high diversity of ichnofossils, discovered in the medium to thinly bedded turbidite at a distal lobe of a submarine fan. The *Ophiomorpha rudis* subichnofacies contains low diversity and is commonly found in thick-bedded sandstone channels and proximal lobes of a submarine fan system.

**Abstrak:** Formasi Temburong terdiri daripada endapan “flysch” berbutir halus yang diendapkan pada bahagian hujung suatu system kipas laut dalam. Dua puluh lima taksa ichnofosil telah dikenal pasti. Ichnofosil dikelompokkan kepada ichnofasies *Nereites*. Ichnofasies ini dibahagi pula kepada dua subichnofasies iaitu subichnofasies *Paleodictyon* dan *Ophiomorpha rudis*. Subichnofasies *Paleodictyon* dicirikan oleh kepelbagaian yang tinggi ichnofosil yang ditemui dalam tubidit yang berpelapisan nipis dan sederhana di bahagian hujung cuping kipas laut dalam. Subichnofasies *Ophiomorpha rudis* mengandungi kepelbagaian yang rendah dan sering ditemui dalam batu pasir tebal pada palung dan pangkal cuping sesuatu sistem kipas laut dalam.

**Keywords:** Ichnofossils, Temburong Formation, ichnofacies, submarine system.

## INTRODUCTION

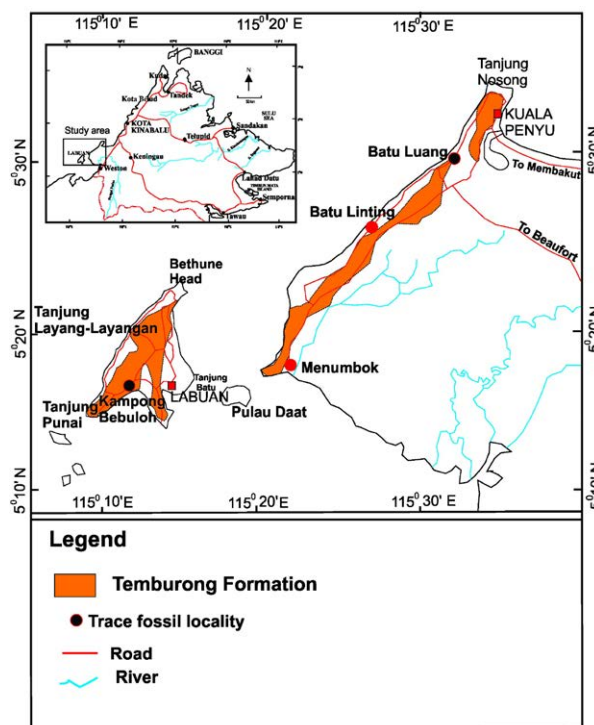
Ichnofossils in Malaysia are not well studied compared to other fossils. Occurrence of Miocene ichnofossils in the Temburong Formation, in Labuan has been briefly reported by Lee & Yap (2006). They noted fifty eight forms belonging to forty-two ichnogenes. Early research on ichnofossils of North Borneo has been carried out by Keij (1965). He described two new species from the Belait Formation in Brunei and Labuan. Recently, Norzita & Lambiasi (2014) studied the relationship between ichnofossils and depositional environments of the Belait Formation in Brunei. They recognized two ichnofacies; *Skolithos* and *Cruziana* ichnofacies representing shallow marine shoreface environment.

The Temburong and the Belait Formations are two lithostratigraphic units which are based on the rock sequences exposed in the Temburong and Belait Districts in Brunei Darussalam. Geologists simply adopt the name as Malaysian lithostratigraphic units.

During our fieldwork to Labuan and Klias Peninsula, we discovered abundant ichnofossils exposed in two outcrops in Labuan Island and Klias Peninsula. The ichnofossil assemblages are very much different from those of the Belait Formation. The growing knowledge on the study of trace fossils provides up to date information about the taxonomy, distribution, and the importance of ichnofossils in sedimentology. The information enables us to explore the ichnofossils which are quite abundant especially in the Temburong Formation. The aims of this study are to identify the ichnofossils and their significance in sedimentology.

## GEOLOGICAL SETTING

Labuan Island and Klias Peninsula are located in the western part of Sabah (Figure 1). The Labuan Island consists of two major formations namely the Temburong and Belait



**Figure 1:** Distribution of the Temburong Formation in Labuan and Klias Peninsula showing ichnofossil locality.

formations (Madon, 1994). The Klias Peninsula comprises six lithostratigraphic units i.e. the West Crocker, Temburong, Setap Shale, Meligan, Belait and Liang formations (Wilson & Wong, 1964). The rock sequence in Klias Peninsula exhibits very complex structures. The geology of the area needs to be re-examined especially the Setap Shale and Meligan formations.

Our observation suggests that the previously known the Setap Shale and Meligan formations in Klias Peninsula (Wilson & Wong, 1964) are actually belonging to the Temburong Formation. The Temburong and West Crocker formations are of the same age. Both formations were deposited in a submarine fan system. The sandstone dominated West Crocker Formation was deposited at the proximal part of the fan and fining towards the distal part where the mudstone dominated Temburong Formation was deposited (Jackson *et al.*, 2009; Zakaria *et al.*, 2013). The Temburong Formation is more argillaceous compared to the West Crocker Formation. It comprises intercalation of dark indurated mudstone and thin bedded sandstone with rare occurrence of limestone lenticles. The thickness of the sandstone and the mudstone varies. It is difficult to draw the boundary between the two formations. Hutchison (2005) grouped them together as the West Crocker Formation.

In present study, we focus only on the Temburong Formation which contains a lot of ichnofossils. The Temburong Formation is unconformably overlain by the Middle to Late Miocene shallow marine Belait Formation. The Belait Formation is unconformably overlain by the Liang Formation which forms small isolated outcrops in Klias Peninsula.

### DESCRIPTION OF THE OUTCROPS

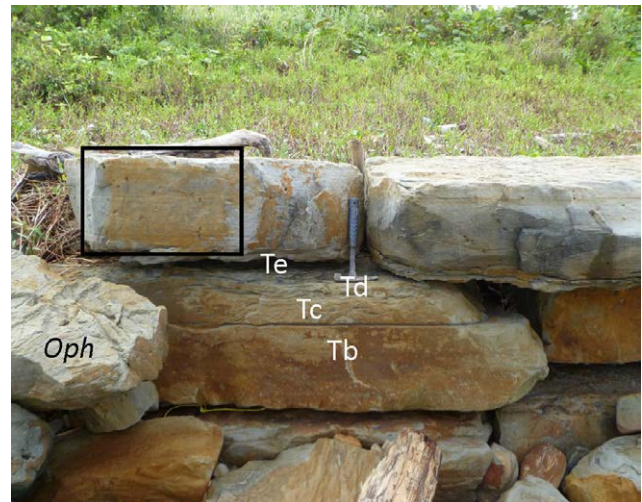
The Temburong Formation is well-exposed at Kampung Bebuluh, Labuan Island (5°16'44.57"N, 115°11'24.02"E) and Batu Luang, Klias Peninsula (5°31'18.37"N, 115°31'15.09"E) (Figure 1). The outcrops exhibit some variations in lithology. The outcrop at Kampung Bebuluh generally comprises thinly bedded turbidite sandstones and mudstones with a strike and dip 065/68. The sandstone has a sharp base and exhibits incomplete Bouma sequence from Tb or Tc to Te. The mudstone is more dominant than sandstone in some parts (Figure 2). The outcrop at Batu Luang exhibits similar rock association comprises interbedded sandstone and mudstone with a Lower Miocene lenticular limestone (Junaidi *et al.*, 2018). The thick sandstone shows a Bouma sequence Tb to Te. The sandstone is almost horizontal and contains a lot of ichnofossils belonging to the ichnogenus *Ophiomorpha* (Figure 3). The Temburong Formation at this locality exhibits very complex structures.

### CLASSIFICATION OF ICHNOFOSSILS

Ichnofossils are initially classified mainly based on morphology (Książkiewicz, 1977; Uchman, 1998). This is the simplest classification and easy to utilize but it does not conform to the rules of the International Code of Zoological Nomenclature (ICZN). Today many researchers



**Figure 2:** Outcrop of middle to thin bedded turbidite sequences and mudstone dominant at Kampung Bebuluh, Labuan.



**Figure 3:** Outcrop of Turbidite sandstone (Tb to Te of Bouma sequence) with *Ophiomorpha* at Batu Luang, Klias. (*Oph. Ophiomorpha* on the surface of sandstone. Small holes in the box indicate *Ophiomorpha* burrows).

have adopted an ethological classification based on the behavior of the animals that produce ichnofossils (Seilacher, 1953; Häntzschel, 1975; Rindsberg, 2012; Vallon *et al.*, 2016). It is important for taphonomic interpretation and for reconstruction of depositional environments. Twenty five taxa of ichnofossils are identified and classified into five ethological categories (Uchman & Wetzel, 2012; Vallon *et al.*, 2016).

1. **Agrichnia** (Farming traces): delicate ichnofossils consist of mostly shallow, regularly patterned burrow systems. Agrichnia are typically produced in deep-sea environments, just below the sediment surface of hemipelagic mud. They are usually preserved in positive hyporelief at the lower surface of turbidite sandstones. Their morphologies range from network structures to branched winding and meandering structures (Ekdale *et al.*, 1984; Uchman, 2003; Rindsberg, 2012; Vallon *et al.*, 2016).

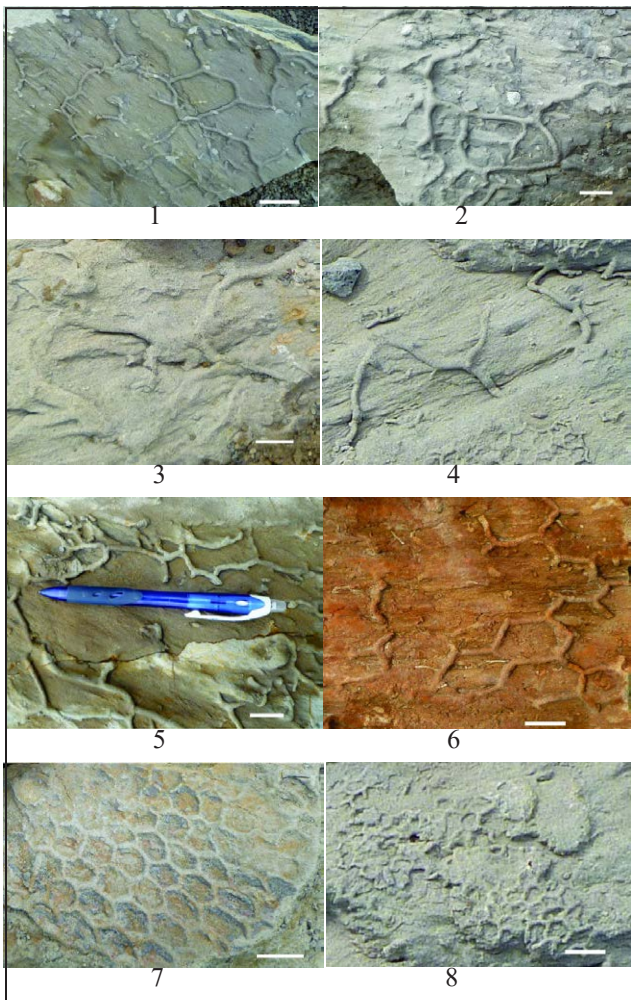
a. Network structures. Ten ichnotaxa are identified.

*Megagraption submontanum* (Azpeitia Moros) (Figure 4, nos. 1, 2)

*Megagraption irregulare* Książkiewicz (Figure 4, nos. 3, 4)

*Protapaleodictyon spinata* (Geinitz) (Figure 4, no. 5)





**Figure 4:** Agrichnia (Scale bar = 1cm)

1. & 2. *Megagraption submontanum* (Azpeitia Moros); 3. & 4. *Megagraption irregulare* Książkiewicz; 5. *Protopaleodictyon spinata* (Geinitz); 6. *Paleodictyon italicum* Vyalov & Golev; 7. *Paleodictyon majus* Meneghini; 8. *Paleodictyon miocenicum*. Sacco

*Paleodictyon italicum* Vyalov & Golev (Figure 4, no. 6)  
*Paleodictyon majus* Meneghini (Figure 4, no. 7)  
*Paleodictyon miocenicum* Sacco (Figure 4, no. 8)  
*Paleodictyon minimum* Sacco (Figure 5, no. 1)  
*Paleodictyon strozzii* Sacco (Figure 5, no. 2)  
*Paleodictyon imperfectum* Seilacher (Figure 5, no. 3)  
*Paleodictyon* isp (Figure 5, no. 4)

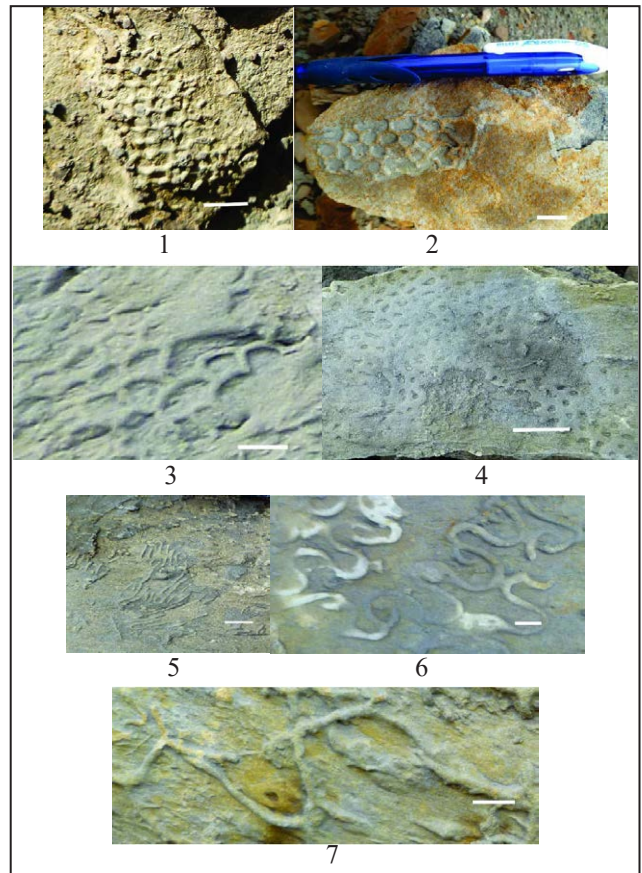
b) Branched winding and meandering structures; Two ichnospecies are recognized.

*Helminthoraphe flexuosa* Uchman (Figure 5, no. 5)  
*Cosmoraphe lobata* Seilacher (Figure 5, no. 6)

**2 Repichnia** (Locomotion traces) structures produce during the movement of organisms (Seilacher, 1953; Rindsberg, 2012; Vallon *et al.*, 2016).

*Helminthopsis* isp. (Figure 5, no. 7)

**3 Domichnia** (Dwelling traces), open burrows occupied by tracemakers and created as permanent or



**Figure 5:** Agrichnia (1-6), Repichnia (7). (Scale bar = 1cm).

1. *Paleodictyon minimum* Sacco; 2. *Paleodictyon strozzii* Sacco; 3. *Paleodictyon imperfectum* Seilacher; 4. *Paleodictyon* isp.; 5. *Helminthoraphe flexuosa* Uchman; 6. *Cosmoraphe lobata* Seilacher; 7. *Helminthopsis* isp.

semi-permanent domiciles (Seilacher, 1953; Bromley, 1996; Rindsberg, 2012; Vallon *et al.*, 2016). Three ichnospecies were identified.

*Ophiomorpha rudis* (Książkiewicz) (Figure 6, no. 1, 2)  
*Ophiomorpha annulata* (Książkiewicz) (Figure 6, no. 3)  
*Thalassinoides* isp. (Figure 6, no. 4)

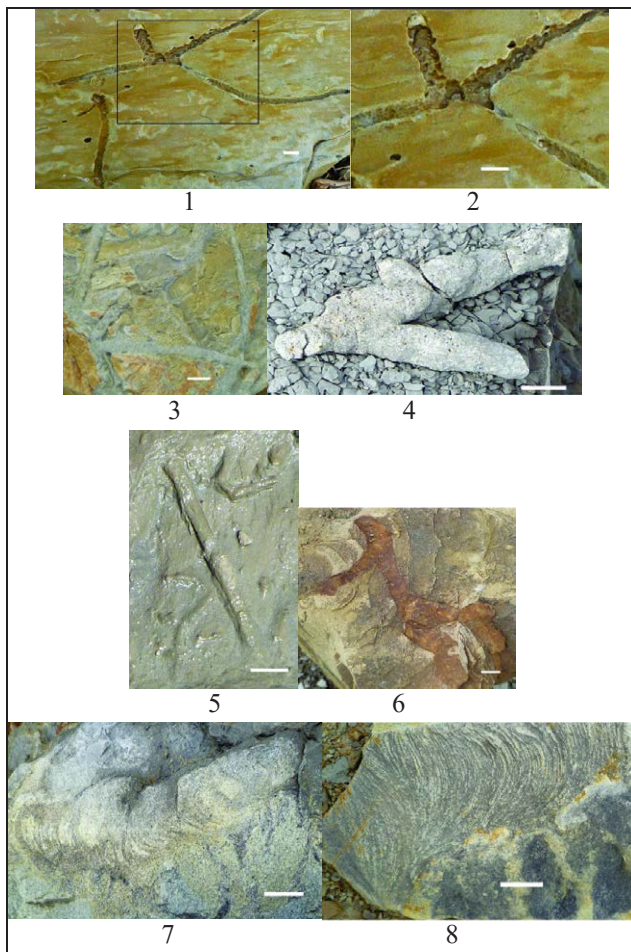
**4 Fodinichnia** (Feeding traces) traces of deposit-feeding within the substrate (Seilacher, 1953; Rindsberg, 2012; Vallon *et al.*, 2016).

*Halopoa* isp. (Figure 6, no. 5)  
*Phycosiphon hamata* (Fischer-Oostar) (Figure 6, no. 6)  
*Zoophycos insignis* Squinabol (Figure 6, no. 7)  
*Zoophycos* isp. (Figure 6, no. 8)

**5 Pascichnia** (Grazing traces): mostly horizontal burrows produced by vagile deposit-feeding organisms (Seilacher, 1953; Rindsberg, 2012; Vallon *et al.*, 2016).

*Scolicia vertebralis* Książkiewicz (Figure 7, no.1)  
*Scolicia* isp (Figure 7, no. 2, 3)  
*Protovirgularia dzulynskii* (Książkiewicz) (Figure 7, No. 4)  
*Desmograption cf. dertonensis* (Socco), (Figure 7, no.5)  
*Nereites* isp (Figure 7, no. 6)





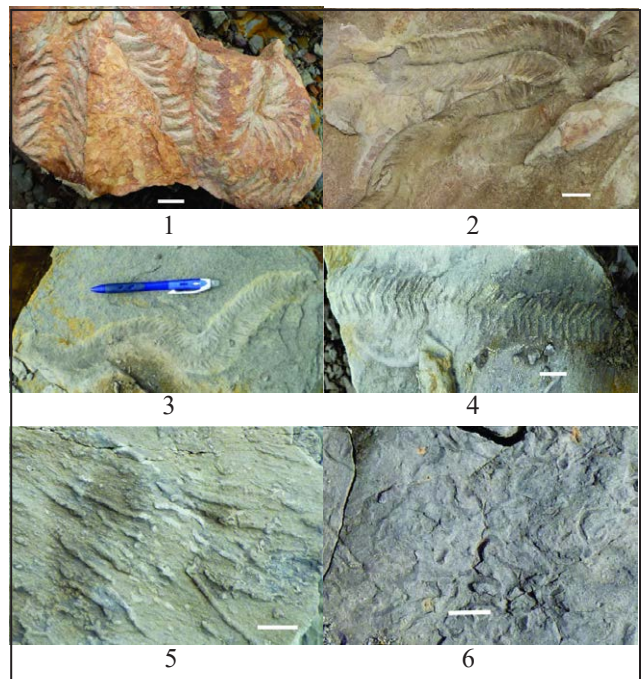
**Figure 6:** Domichnia (1-4), Fodinichnia (5-8). (Scale bar = 1cm)  
 1. & 2. *Ophiomorpha rudis* (Książkiewicz); 3. *Ophiomorpha annulata* (Książkiewicz); 4. *Thalassinoides* isp.; 5. *Halopoa* isp.; 6. *Phycosiphon hamata* (Fischer-Oostar); 7. *Zoophycos insignis* Squinabol; 8. *Zoophycos* isp.

### ICHNOFACIES

The ichnofacies model was introduced by Seilacher (1967) to distinguish between the different ichnofossil associations that characterized their depositional environments. Deep-marine flysch deposits are characterized by the *Nereites* ichnofacies which includes complex agrichnial burrow systems produced by unknown invertebrates, in which they trap meiobenthos or farm micro-organisms in generally oligotrophic deep-sea environments. The ichnofossils are known as graphoglyptids (Seilacher, 1977; Miller, 1991; Uchman, 2003).

Seilacher (1974) subdivided the *Nereites* ichnofacies into two subichnofacies for distal deep-water environment i.e. *Paleodictyon* subichnofacies for sandy deposits and *Nereites* subichnofacies for muddy deposits. Uchman (2001, 2009) added *Ophiomorpha rudis* subichnofacies for thick-bedded sandstones in channels and proximal lobes in a deep-sea fan system. The *Ophiomorpha rudis*–*Paleodictyon*–*Nereites* subichnofacies represent a trend from proximal to distal lobe of a submarine fan system (Uchman & Wetzel, 2012).

The ichnofossil assemblage in this study represents the *Nereites* ichnofacies which was deposited in the distal



**Figure 7:** Pascichnia (Scale bar = 1 cm.)

1. *Scolicia vertebralis* Książkiewicz; 2. & 3. *Scolicia* isp.; 4. *Protovirgularia dzulynskii* (Książkiewicz); 5. *Desmograpton* cf. *dertonensis* (Socco); 6. *Nereites* isp.

part of a deep-sea fan system. The assemblage can further be divided into two subichnofacies namely *Paleodictyon* subichnofacies and *Ophiomorpha rudis* subichnofacies (Uchman & Wetzel, 2012).

The *Paleodictyon* subichnofacies is characterized by the occurrence of high diversity of ichnofossils including *Megagrapton*, *Protopaleodictyon*, *Paleodictyon*, *Helminthoraphe*, and *Cosmoraphe*. This assemblage is found in the upper part of thin bedded mudstone just below the thin bedded turbidite sandstone successions at the Kampung Bebuloh, Labuan. The subichnofacies represents the distal part of lobes of a submarine fan (Uchman, 2007; Uchman & Wetzel, 2012). The *Ophiomorpha rudis* subichnofacies contains a very low diversity of ichnofossils mainly *Ophiomorpha rudis*, and *Ophiomorpha annulata*. The assemblage is discovered from the thick sandstone at Batu Luang, Klias. The sandstone probably represents channels or proximal lobes in a turbidite succession (Uchman, 2001; 2009). Generally, the *Paleodictyon* and *Ophiomorpha rudis* subichnofacies indicate a lobe of a submarine fan environment (Uchman & Wetzel, 2012).

The ichnofacies of the Temburong Formation are essentially different from those of the Belait Formation. The different ichnofacies suggests both formations were deposited in two different depositional environments. The Temburong Formation characterized by the *Paleodictyon* and *Ophiomorpha rudis* subichnofacies indicates a lobe of the submarine fan environment while the Belait Formation characterized by the *Skolithos* and *Cruziana* ichnofacies represents a shallow marine shoreface environment (Norzita & Lambiase, 2014). The ichnofacies concept is very useful

in determining the depositional environments. It can be used to differentiate between the deep-water Temburong and the shallow-water Belait formations.

### CONCLUSIONS

The Temburong and the West Crocker Formations form a submarine fan system. The mudstone dominant Temburong Formation was entirely deposited in the distal part of a submarine fan. Twenty-five taxa of trace-fossils were identified from two outcrops at Kampung Bebuloh, Labuan and Batu Luang, Klias. Trace fossils were grouped into the *Paleodictyon* and *Ophiomorpha rudis* subichnofacies. The *Paleodictyon* subichnofacies characterises the distal lobe of deep-sea environment and the *Ophiomorpha rudis* subichnofacies represents the sandstone channel or proximal lobe of a submarine system. Ichnofossils are good indicators for depositional environments.

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