

生物過去活動的證據：生痕化石

Trace Fossil, the Evidence of Past Biological Activities

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隱形的化石？—認識「生痕化石」

生痕化石，或稱為遺跡化石，是生物活動所遺留在岩層中的痕跡；不同於生物在自然環境中所保存下來的「實體化石」殘骸。比起廣為人知的實體化石，在野外更為常見的「生痕化石」似乎顯得默默無聞。這些痕跡廣泛的包含了腳印、爬痕、鑽孔、咬痕、巢穴、糞便化石及蛋殼等(圖1)。只有「活著」的生物製造出來的痕跡才可以被稱為生痕化石。舉例來說，螃蟹在沙地上爬行留下的足跡，經過長時間被保存下來可稱為生痕化石，但若是死亡後的螃蟹軀殼被風或水流拖曳而留下的痕跡，就不能稱為生痕化石了。

生痕化石是科學家研究古生物的工具

生痕是生物活動的化石紀錄。實體化石則提供我們生物的外觀訊息。重建後的暴龍骨骼可以大致呈現出牠的體態，但無法表明牠過去的活動方式；相較之下，生痕化石就保存了不同生物之間互動的方式。最著名的例子是科學家可以利用恐龍的足跡化石，來重建掠食者追捕獵物的方式。臺灣野柳地質公園中的砂岩上所保存下來的生痕化石，也可展現2千萬年前魴魚獵食藏在洞穴裡的蝦子跟蠕蟲(圖2)。因為在不同的時空中，生痕化石都可以記錄生物的活動方式，所以藉著研究不同年代、不同地點所形成的生痕化石，我們就可以推測這些生物隨著時間演化，變換活動方式的過程。除此之外，



圖1 生痕化石代表化石化的行為。例如下圖中的恐龍足跡化石(英國，年代為侏羅紀時期)，跟在沈積物中的海膽覓食爬痕化石 *Scolicia*(西班牙 Zumaia，年代為始新世時期)。

Figure 1. Trace fossils represent fossilized behavior. Here a dinosaur foot print from the Jurassic of Britain, and *Scolicia*, a trace fossil made by sea urchins who feed their way through the sediment (Eocene, Zumaia, Spain).

Trace fossils, sometimes called ichnofossils, are the fossilized trace of the activities of living animals. In contrast to body fossils, which are the preserved remains of the actual organism, trace fossils can be seen as a fossilization of the animals' behavior.

This includes fossilized foot prints and trackways, for example by dinosaurs, burrows made by animals such as worms or crustaceans, bite marks, etchings and borings into shells, coprolites (fossilized poop), nests and egg shells, and so on (Figure 1). Only traces produced by living organisms are classified as trace fossils. This means that, for example, the imprints of a crab

running on a sediment surface are classified as trace fossils if they are preserved in the geological record,

while marks produced by a dead crab that is dragged across the surface by wind or water is not considered as a trace fossil, because the marks were not produced by a living organism.

Because trace fossils are the result of the activities of living organisms, in a way they can be considered as fossilized behavior. While body fossils can tell us a lot about what the organism looked like, for example the skeleton of a *Tyrannosaurus rex*, the skeleton won't tell us much about what the animal did while it was alive. Trace fossils, on the other hand, can record the interaction between different organisms at the time when they were alive. Famous examples include tracks of dinosaur foot prints showing how a predator chased a herd of herbivores, or as demonstrated in the sandstones in the Yehliu Geopark, how stingrays fed on shrimps hiding in their burrows in the seafloor 20 million years ago (Figure 2). Because trace fossils represent fossilized behavior, they can be useful when we try to understand how different organisms interacted in the past, and how certain kinds of behaviors have evolved over time. Furthermore, since behavior is often a response to certain environmental conditions, such as water depth or food supply, trace fossils are frequently used to characterize the paleoenvironment in sedimentological studies.

8 生物的行為常常和生活環境有緊密的關聯，例如特定的水深、或是食物的供給量，因此生痕化石也時常作為辨識古環境的工具。

生痕化石費疑解

通常只靠生痕化石難以決定何種生物是痕跡的製造者，只能以「行為」來作為分類的依據，而不是製造者本身。大部份的生痕化石可以被歸納為五類行為的產物：穴居、濾食、覓食、棲息、爬行。

觀察生痕化石要特別注意不同的生物可能會製造

出外觀幾乎完全相同的生痕化石。舉例來說，甲殼類(例如蝦、蟹)所留下的覓食痕跡，可能會跟蠕蟲在沙裡鑽出居住構造的痕跡非常相似。如果我們把故事說得再複雜一點，同一種生物也有可能留下好幾種不同的痕跡；就像圖中的兔子一樣，在一天的活動中，牠可能此刻在柔軟的沙地上留下跳躍和拖曳的足跡，下一刻在別處挖土的時候又留下洞穴或通道(圖3)。

在本期的臺灣博物館季刊中，我們要介紹幾篇有趣的生痕化石研究。

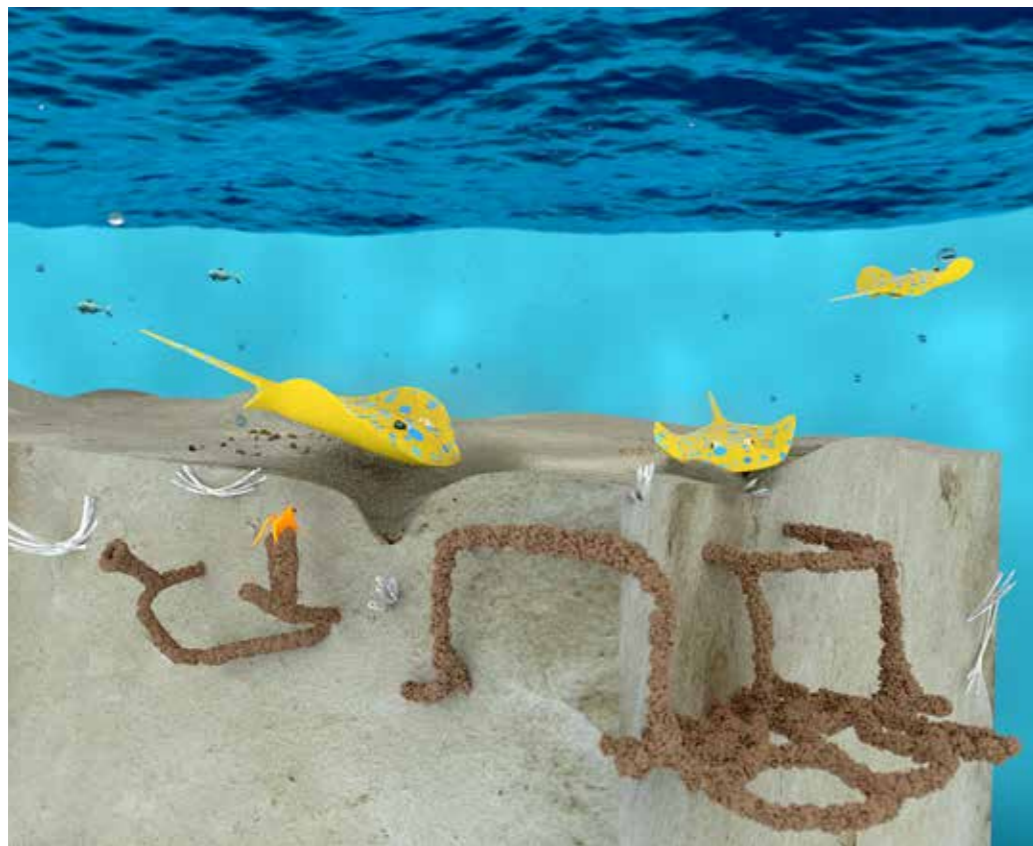
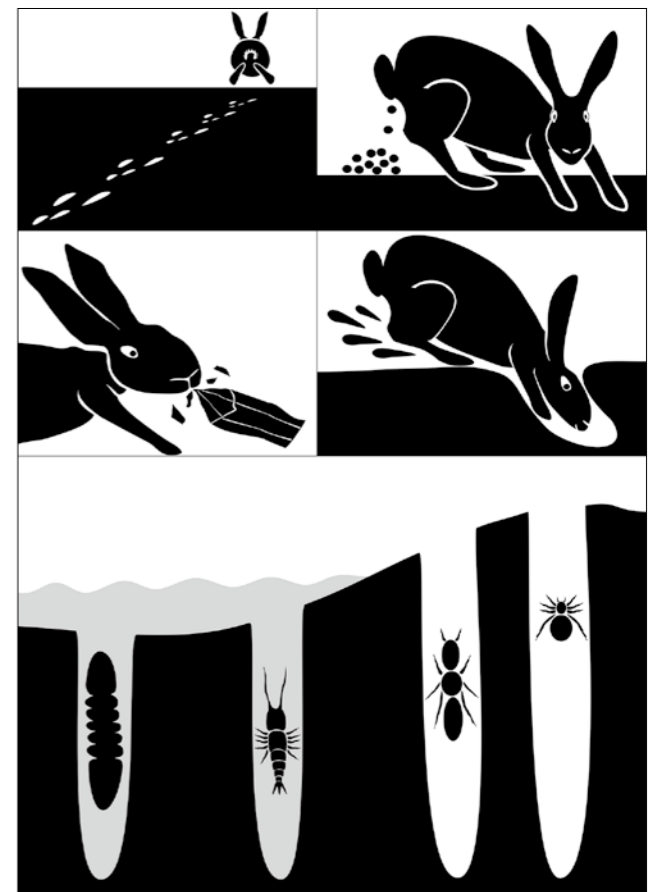


圖2 生痕化石通常是我們研究過去生物間互動的最好方式，根據在野柳地質公園所發現的魷魚覓食生痕化石研究，以動畫圖模擬2千萬年前在大陸棚上魷魚獵食蝦類的情景(魷魚覓食生痕化石與動畫圖)。
Figure 2 Trace fossils are often the only way to learn how different organisms interacted with each other in the past. Here is an example of a scenario showing how stingrays hunted for shrimps on the continental shelf about 20 million years ago reconstructed from trace fossils found in the sandstones at the Yehliu Geopark.

It is often not possible to determine exactly which animal that produced a certain trace fossil. Trace fossils are therefore classified according to what kind of behavior they represent, rather than the causative organism. Most trace fossils can be categorized into one of five categories: dwelling traces, feeding traces, grazing traces, resting traces, and creeping or crawling traces. However, it is important to realize that because the trace fossil preserved in the sediment represents a certain behavior, different organisms engaging in the same kind of behavior may produce almost identical traces. For example, feeding traces left by crustacean and worms in the sediment sometimes look very similar. To complicate things further, one kind of organism may produce a large number of different types of trace fossils depending on what kind of behavior it engaged in. Just think of the types of traces a rabbit may produce in one day: footprints and trackways when moving around on a soft substrate, burrows and tunnels when it digs into the soil, gnaw marks when feeding, and coprolites from its poop (Fig-

圖3 同一種生物可以製造出多種不同型態的生痕化石；而不同的生物在表現相同行為時也可能製造出非常類似的生痕化石。例如海中的蠕蟲、蝦類，以及陸地上的昆蟲及蜘蛛，都會製造簡單直立型的管穴。
Figure 3. The same organism can produce many different types of trace fossils. However, different animals may produce similar trace fossils because they engage in the same behavior. For examples, worms, crustaceans under water, and insects and spiders on land are all known to build simple, straight vertical burrows.



ure 3). In the same way, many organisms produce different trace fossils depending on the activity they were engaged in.

In this special issue of the *Taiwan Natural Science*, we present a number of intriguing studies exploring the meaning of trace fossils left in the sediment millions of years ago!