

遺跡探蹤——第十四屆國際生痕化石研討會紀實

Report from the 14th International Ichnofabric Workshop

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會議概況

國際生痕化石研討會 (International Ichnofabric Workshop, IIW) 1991 年首次在挪威舉辦，之後協議

每兩年舉辦一次。目的是讓世界各地的生痕化石研究

學者齊聚一堂，提供平台發表近期生痕化石在世界各

地的研究現況，與其在沈積學、地層學及古環境上的

應用研究，提出新的見解或想法、尋求合作，以及在

意見上相互切磋。今 (2017) 第十四屆國際生痕化石研

討會 (IIWXIV) 是由國立臺灣大學 (以下簡稱臺大) 與

國立臺灣博物館 (以下簡稱臺博館) 共同合作舉辦。由

於臺博館與本研究團隊有良好合作經驗，共同合辦以

移動式「珍奇櫃」展出臺灣生痕化石的展覽已在臺灣巡

迴展出兩年，目前在蘭陽博物館長期展出。此外，臺

博館與臺大博物館群之間有簽署館際合作協議，加上

本研討會與臺博館自然史研究屬性相符，因而在本次

會議主辦人臺大地質科學學系施路易副教授與臺博館

的協議下，促成本次研討會於臺博館南門園區小白宮

舉辦。小白宮是日治時期的建築，歷史悠久、建築外

觀精緻細膩，地點位於交通便利的臺北市中心，帶有

恬靜氛圍，目前以作為多功能展示及活動使用為主。

本次研討會聚集了來自4大洲、16個國家、共38

位研究學者 (圖1)。會議包含三天的專題演講及海

報報告，共計發表44篇學術論文，涵蓋了生痕化石

研究在各個領域的進展；此外於會議中安排一天前

往東北角海岸進行地質勘查，並於會後進行五天的

環島野外地質勘查。值得一提的是本次研討會有首

次從印尼及蘇丹來的研究學者，分享生痕化石在當

地的初始萌芽研究，具有特殊意義，本研究團隊也

會持續關注生痕化石研究在這些國家的後續發展。

特邀講題

研討會首日特邀講者 Andreas Wetzel

(Geologisches Institut, Universität Basel,

Switzerland) 的演講主題為《沉積學中的生痕構造分

析》，以「海相紅層」、「黑頁岩」以及「河口沈積」三

種極端的沈積環境為例，提出現今的生痕構造分析

在沉積學上雖能「定性」評估環境因子的變化，但對

於環境事件演變過程的「定量」分析方法了解仍十分

匱乏，須朝這方面努力。

會議第二天的特邀講者 Gabriela Mángano

(University of Saskatchewan, Canada) 在她的《寒武

紀大爆發—探索顯生宙拂曉之動物與底質互動》演

講中，精彩且生動地描述，生痕化石可以提供一條

平行於實體化石的珍貴線索，來探究著名的寒武紀

生物大爆發事件。即使在埃迪卡拉生物群跟伯吉斯

頁岩化石群中間隔2千萬年的沈寂，生痕化石紀錄

在此期間仍持續蓬勃發展；特別是前寒武紀時期，

生痕多樣性及歧異度更有全球性的顯著增加。她參

與近期在伯吉斯生痕化石群的研究中更提出「現

地」底棲沉積的證據，不同於以往認為伯吉斯頁岩

Trace Fossil Detectives :
International Ichnofabric
Workshop



圖1 (左)第十四屆國際生痕化石研討會主視覺;(右)與會者於臺博館南門園區小白宮合影

Figure 1. (Left) IIWXIV logo. (Right) The group photo of IIWXIV (The 14th International Ichnofabric Workshop) participants outside of the White Palace workshop venue.

Introduction of IIWXIV

The “International Ichnofabric Workshop” was first-

ly held in Norway in 1991, since then it has been held

every two years in countries around the world. The

core value of this workshop is that it provides an oppor-

tunity for ichnologists to meet in one place to discuss

their research progresses, exchange ideas and seeking

for possible future collaborations. The 14th Internation-

al Ichnofabric Workshop (IIWXIV) was hosted by

National Taiwan University (NTU) in cooperation

with the National Taiwan Museum (NTM).

The collaboration between NTU and the Museum

arose from a jointly organized exhibition on Taiwanese

trace fossils in the form of a movable “Cabinet of Cur-

iosity” (See article by Chao-Ling Kuo). In continuing

this successful collaboration, and as part of a memoran-

dum of understanding between the NTM and NTU,

the Museum offered its meeting hall in the “White

Palace” at the Nanmen Park of the Museum as a venue

for the Ichnofabric Workshop. The “White Palace” is

an exquisitely preserved historical building from the

Japanese Colonial Period. Today the building features

state-of-the-art conference facilities, and is convenient-

ly located in the heart of the city, yet it retains a tran-

quil ambience through its placement inside the Nan-

men Park area.

Altogether, there were 38 active researchers repre-

senting over 16 countries from four continents attend-

ing this workshop, which included 44 presentations in

different oral and poster sessions covering a variety of

topics focusing on ichnologic research progress (Figure

1). It was interesting to notice that for the first time we

had participants from Indonesia and Sudan. The work-

shop always welcome an infusion of new blood, and we

would like to follow the future developments in the

ichnofabric studies from those countries.

Summary of keynote talks

The first keynote talk “*Ichnofabric Analysis in*

Sedimentology” was given by Andreas Wetzel (Geolo-

gisches Institut, Universität Basel, Switzerland) on the

first day of the workshop. He reminded us of the chal-

是從淺海運送到缺氧的深海環境中沈積的理論。伯吉斯生痕化石群除了反映含氧變化之外，甚至能提供底棲動物群落結構演化的重要線索。

最後一天的特邀講者 Renata G. Netto (Geology Graduate Program, Unisinos University, Brasil)，以《牠們活下來了！生痕構造揭露生物逆境容忍行為》分享她如何處理棘手的生痕製造者行為。逆境容忍生物在沈積物中的擾動記載很少，且目前的研究還不夠全面。若要區分逆境容忍生物與機會主義生痕製造者更不容易，尤其在水平出露的露頭上通常不易辨別出來。她建議以露頭垂直剖面上的生痕構造分析，觀察生痕製造者在事件前後所製造的生痕系列變化，以辨別其中差異。

野外勘查

國際生痕化石研討會的野外勘查通常是最具挑戰但與會者也最感興趣的部分，我們在野外勘查中讓與會者實際走訪、觀察臺灣著名的地質地形。

會議中我們安排一天至東北角海岸勘查露頭，如野柳地質公園、八斗子(圖2)及番仔澳的露頭，這些砂岩露頭上有極為豐富的生痕化石，如魷魚覓食生痕化石、蠕蟲鑽孔生痕化石及蝦類掘穴生痕化石等俯拾皆是，簡直可以說是生痕化石研究者的樂園。臺大地質系施路易教授團隊過去在這幾個地點有一些研究成果發表，因此格外把握這次跟其他生痕化石專家討論的機會。

在會後5天的環島野外勘查中，難得有機會參訪一些非常獨家的景點，例如苗栗中油探採研究所岩芯庫(圖3，中油探採所特地準備來自不同地質環境、

並且有生痕擾動現象的岩芯樣本供與會者近距離研究觀察)、大安溪峽谷(圖4)、921 地震博物館、泥火山、惡地地形、利吉混同層、小野柳、三仙台(火山島)、八仙洞(抬升海蝕洞)、石梯坪海岸風景區(凝固的火山碎屑流)、壯麗的太魯閣峽谷以及清水斷崖。在前往北部海岸之前，大家刻意停留在一個更新世大桶山層的露頭，因為那裡有一群神秘未知的生痕化石「砂手指(暫名)」(圖5)。「砂手指」出現在厚厚的砂岩底部，各個生痕化石研究者把握機會仔細觀察砂手指所在的岩壁，竟然發現了好幾組以不同角度並列的平行刮痕(圖5-C)，這暗示甲殼類動物(例如蝦子、螃蟹)可能是砂手指的生痕製造者；有些與會者也提到砂手指跟現今觀察到龍蝦製造的痕跡很類似。離開了砂手指生痕化石，野外勘查的最後一站來到鼻頭角地質公園(圖6)，與會者穿越大大小小的石塊、深入到鼻頭角地質公園裡，沿途所見生痕化石數量之多，令人嘆為觀止！「你們可以輕易在這裡耗掉整個週末研究生痕化石！」來自加拿大的Shahin Dashtgard如此說道。此外，與會者在鼻頭角公園裡還發現好幾個螃蟹實體化石，有幾個被掩埋時還在管穴裡。會是一個快速沉積的事件導致牠們突來的死亡嗎？還是另有其他原因？又是



圖2 會議中野外勘查—八斗子(中新世大寮層露頭)
Figure 2. Intra-workshop field trip: Badouzi (Miocene Dalian Formation outcrop)

challenge remaining to be solved: to construct quantitative ichnological methods for evaluating environmental processes of certain events. Andreas chose to demonstrate this approach by showing three examples of extreme depositional settings: oceanic red beds, black shales and estuarine deposits.

In the keynote talk of the second day, Gabriela Mángano presented “*The Cambrian Explosion: Exploring Animal-Substrate Interactions at the Dawn of Phanerozoic*,” in which she investigated the trace fossil records of the Cambrian explosion. She showed that trace-fossil can provide parallel clues to body-fossils, because of their continuous occurrence in the geological records even during the 20-million-year gap between Ediacaran assemblages and Cambrian Burgess Shale assemblages. It was also surprising to learn from her recent work that she found trace fossil evidence of *in situ* benthic communities in Burgess-type deposits, which have previously been considered as being transported from the shallow water to anoxic deep water depositional environments.

In the last keynote talk “*They Will Survive! Ichnofabrics Uncover Stress Tolerance Behavior*,” Renata

G. Netto explored some approaches to handle enigmatic behaviors of the trace makers. Compared to other well-known traces like invertebrate burrows, bioturbation patterns generated by stress-tolerant organisms are not yet fully understood. Her advice of observing the shift of trace fossil suites before/after an event on a vertical exposure could be helpful to differentiate opportunistic and stress-tolerant behavior.

Field Excursions

The workshop would not have been complete without an opportunity to bring our participants to the most impressive geological sights which Taiwan has to offer.

During the main workshop, an intra-workshop field trip was arranged to the outcrops in the northeast coast of Taiwan. Those included Yehliu Geopark, Badouzi (Figure 2) and Fanziao, where the outcrops can only be described as a paradise for ichnologists. The sandstones contain abundant trace fossils such as *P. waitemata*, *Schaubcylindrichnus* and *Ophiomorpha*. A number of papers of the trace fossils from these outcrops have been published by Dr. Löwemark’s research group. Therefore, it was of great interests to hear the opinions/comments from other ichnologists.

After the main workshop followed a five-day field trip round the island, during which we enthusiastically explored some very unique stops including the CPC Corporations core repository (Figure 3, CPC Corpo-



圖3 苗栗臺灣中油股份有限公司探採研究所岩芯庫探訪
Figure 3. CPC Corporation Taiwan and core repository, Miaoli



圖4 臺中大安溪峽谷
Figure 4. Daan Gorge, Taichung

ration had prepared a number of cores from different environments for us, and we were really impressed of their hospitality), Daan gorge (Figure 4), the 921 Earthquake museum, mud volcanoes, badlands, Lichi Mélange, Xiaoyehliu, Sanxiantai (volcanic island), Baxiendong (uplifted sea caves), Shitiping (pyroclas-

tic flows), Taroko marble gorge and Chingshui Cliff. Before we reached the northern coast, we visited an outcrop in the Oligocene Tatungshan Formation, where a group of mysterious trace fossils temporarily called “*sand-fingers*” were observed (Figure 5) at the bottom of a thick layer of sandstone. Our experts ex-



圖5 (A) 神秘的「砂手指」生痕化石(更新世大桶山層露頭)；(B) Al Curran 教授正在觀察一個崩落石塊上的砂手指。從照片上可以清楚的觀察到此未知生痕化石的結構—具有像手指一樣的形狀；(C) 有些與會者認為在「砂手指」生痕化石所在的砂岩底部發現的這些平行痕跡是甲殼類動物製造的刮痕，而另外幾個與會者不排除是貝殼印痕的可能性。

Figure 5. (A) The mysterious “*sand-finger*” trace fossils (Oligocene Tatungshan Formation outcrop). (B) Professor Al Curran is examining a fallen boulder with “*sand-finger*” trace fossils. From the picture, it is clear to see the finger-like structure of the trace fossils. (C) Some participants interpreted them as a set of parallel scratch marks at various angles, possibly engraved by crustaceans; while others suggested shell imprints.



圖6 鼻頭角地質公園（中新世桂竹林層露頭）。與會者在新鮮的露頭上研究生痕化石。右下角的圖圖是在鼻頭角公園內發現的螃蟹化石。

Figure 6. Bitoujiao Geological Park (Miocene Kueichulin Formation).

Workshop participants explored the well-exposed outcrops. We also showed the participants a number of crab fossils which were buried in the burrows (the round picture in the lower right corner). Could it be a rapid depositional event that caused their deaths?

另一個待解謎題。

來自美國史密斯學院、現年77歲的Allen Curran教授（圖7，Kenan Professor Emeritus of Geosciences, Smith College, USA）是與會者中少數沒有缺席任何一屆國際生痕化石研討會的與會者，他樂意跟我們分享個人對於研討會的觀察：

國際生痕化石研討會在沈積地質學研究中是獨一無二的盛會，我們是規模相對較小的生痕化石研究者族群，從世界各地聚集而來，公開發表近期研究、面對面討論、以及一同參與野外實地勘查。此研討會自1991年舉辦開始，一直提供與會者一個非常好

的殿堂來測試新的想法，並且不管在古沈積環境還是現生沈積環境相關的生痕化石組織分析問題及應用上，都能夠有非常深入的討論。除此之外，研討會的野外勘查行程讓與會者有絕佳的機會去探索學習研討會舉辦國家當地的地質構造，以及主辦單位安排的文化活動。

國際生痕化石研討會足跡從挪威橫跨到紐西蘭、以及這一次的舉辦地點—臺灣，作為所有與會者中「唯二」參與過歷屆（共十四屆）國際生痕化石研討會的成員之一，若說我在這個研討會的帶領之下，閱歷了大半個地球，這話一點也不假。與許許多多的國際同儕甚至腳下踩的地質環境交流互動的機會，對我來說一直是絕佳的探險和與眾不同的學習經驗！

會議討論及未來展望

國際生痕化石研討會一直是生痕研究者展示創新想法與疑問的最佳殿堂。在演講結束後，與會者討論未來展望。依照慣例，在大家的討論之下，2019年的國際生痕化石研討會決定由Andrew K. Rindsberg教授主辦，地點在美國阿拉巴馬州。本研究團隊誠摯感謝所有與會者、協辦單位與臺灣獨特精彩的生痕化石（圖8），讓本次研討會參與的每一個與會者都留下豐碩且難忘的回憶！



圖7 Allen Curran 教授與太太 Jane Curran。Allen Curran 教授過去27年來從未缺席國際生痕化石研討會。
Figure 7. Professor Allen Curran and his wife Jane Curran. For the last 27 years, he never missed any IIW.



圖8 (A)海膽鑽孔生痕化石；(B)被動填充鑽孔生痕化石 (Passively filled burrow)；(C)互相截切的蝦類掘穴生痕化石 (*Ophiomorpha*)。

Figure 8. (A) Sea urchin burrows (B) Passively filled burrow (C) Two *Ophiomorpha* cross-cutting each other

amined them diligently, and found some suspected scratch marks (Figure 5C), which indicate that crustaceans (such as shrimps and crabs) might be the trace makers. In the end, the whole trip concluded with the Bitoujiao Geopark (Figure 6), where enormous amounts of trace fossils just waited to be examined and explored. “*You can easily spend the whole weekend studying these trace fossils in this place!*” said one of the participants, Shahin Dashtgard. Near the farthest end of the sandstone platform in Bitoujiao Geopark, we surprisingly discovered a number of well-preserved crab fossils, whose features indicate that they were buried while still alive in their burrows! Could it be a rapid depositional event that caused their deaths? Another mystery to be solved!

Professor Allen Curran (Kenan Professor Emeritus of Geosciences, Smith College, USA, Figure 7) is one among the very few who has made it to all the IIW, he would like to share his personal perspectives of this workshop with us:

In drawing together a relatively small-sized group of ichnologists from around the globe for presentations, face-to-face discussion, and field trips, the International Ichnofabric Workshop (IIW) is a unique event in sedimentary geology. Beginning in 1991, these workshops have offered participants a perfect venue to test new ideas and to engage in real discussion on a wide range of problems and applications of ichnofabric analysis related to interpretation of both ancient and mod-

ern depositional environments. In addition, the associated field trips all have provided attendees with the opportunity to visit and learn about the geology of the workshop's regional setting, and all organizers have included local cultural activities in their workshop plans.

As one of only two attendees at all fourteen previous IIW events ranging from Norway to New Zealand, and most recently Taiwan, I can truly say that I have seen a great part of the world via the ichnofabric workshop series. It has been a great adventure and a unique learning experience, both for the opportunity to interact with so many international colleagues and for the great geology throughout!

Discussions and the future of IIWXIV

“Ichnofabric workshop” is always the best venue to showcase new innovative ideas and to throw out new questions. On the last day of the oral presentations, workshop participants focused their discussions on the ichnofabric future. As is tradition at the Ichnofabric Workshop, on the last day of the workshop we decided where we should go in two years’ time for the next workshop. After a long discussion and some hesitation from the next organizer, Andrew K. Rindsberg accepted to organize the 2019 workshop in Alabama, USA. Finally, we sincerely appreciate all our participants and collaborators (and of course those intriguing trace fossils, Figure 8), who made this workshop extremely fruitful and truly memorable!

