PALEOPIONEERS: EARLIEST EVIDENCE OF ANIMAL LIFE ON LAND

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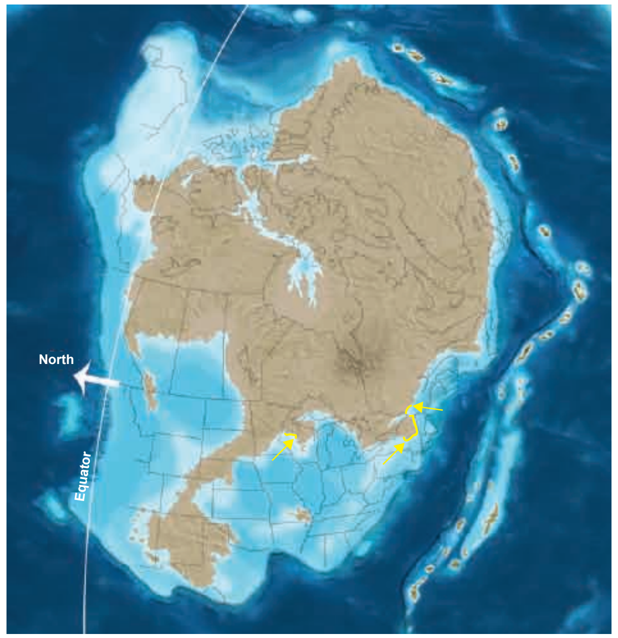
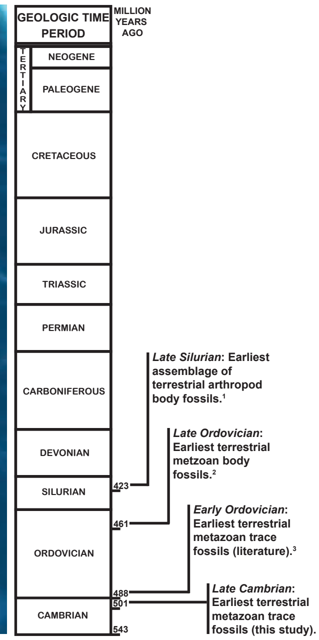




Five hundred million years ago, animals emerged from the oceans onto tidal flats of the ancient continent Laurentia (above). These pioneers provide the earliest record of animal life on land. Sandstones from Wisconsin, New York, and Quebec contain some of the best evidence to support this hypothesis. The evidence is scarce and includes raindrop-imprinted bed surfaces that survived the typical array of erosional processes. One exceptional surface from WI bears cross-cutting relationships between raindrop imprints and trackways. Study of these relationships demonstrates that animals were living in subaerial conditions.

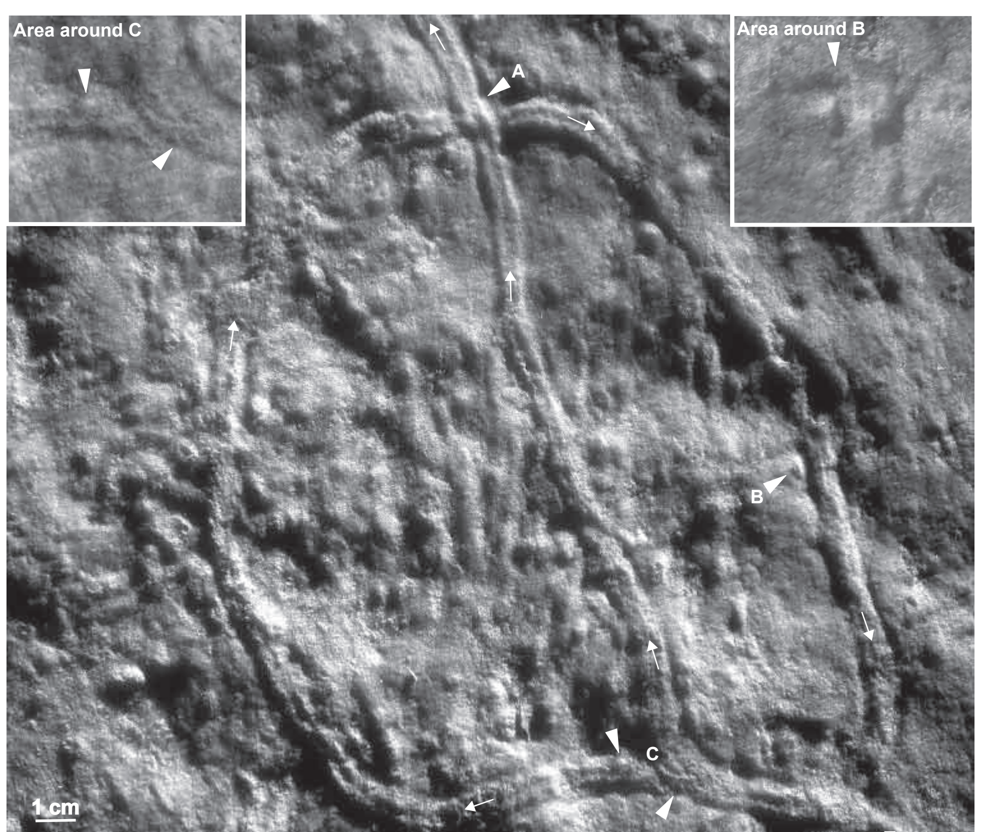


FIGURE 1
Cast of surface containing a trilobate trackway and raindrop imprints.

Cross-cutting relationships between features on this surface provide information about the ages of those features relative to each other. For example, the looping trace fossil above crosses itself at A, which allows reconstruction of the trace maker's direction of locomotion. The trackway enters from the bottom corner, crosses itself near C, and exits in the top center.

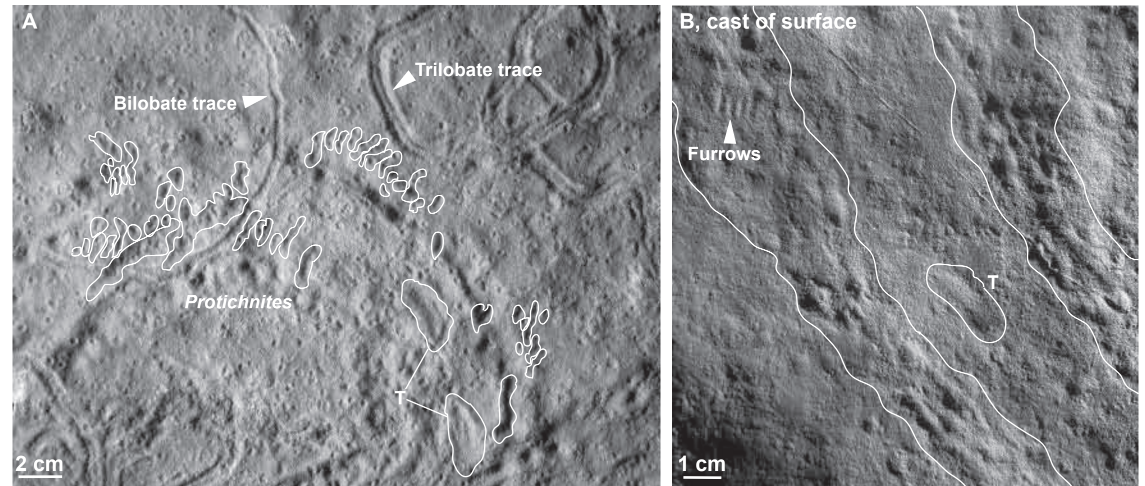


FIGURE 2
There are three types of trace fossils on the surface (A). *Protichnites* is produced by a large arthropod. It is defined by parallel sets of footprints and medial tail drag grooves (T). Certain *Protichnites* are associated with splayed scratches (outlined in A). These might indicate loss of traction as the trace maker turned a corner. Other *Protichnites* with indistinct and lumpy footprints (trackway outlined in B) include enigmatic perpendicular furrows. Could the trace maker have been scraping a microbially-bound substrate for food?

A second type of trace fossil consists of an irregularly meandering trench bounded by a ridge of excavated sediment on either side (A). Specimens average less than 1 cm in width. Some exhibit tight looping whereas others are nearly straight. These traits can converge. Three potential trace makers are suggested. i) Small arthropods, including certain millipedes and crustaceans, are capable of producing analogous bilobate grooves on a liquefied substrate.[4] ii) Gastropod may also produce simple furrows.[5] iii) Surface-moving worms can plow similar troughs.[6]

The third type of trace fossil on the surface is a trilobate trail. Two troughs are flanked by two outside levees and a low middle ridge (Fig. 2A). Similar traces are found in NY, but those display parallel rows of stipple marks, interpreted as footprints (Fig. 3). The WI and NY traces probably share a common producer. Deep puncture marks in the furrows of the WI traces evoke the NY footprints. Both are ~1 cm wide and show low sinuosity. One WI trace has a distinct offset (Fig. 4), which is a movement difficult to attribute to a wormlike maker. Certain arthropods create trilobate ribbons on soft surface films atop hard substrates.[4] This sedimentary condition might be mirrored in microbially-bound surfaces. Evidence of microbial binding is found on the WI surface (Fig. 5). The NY traces are akin to slightly younger trackways thought to have been made by millipede-like organisms.[7]

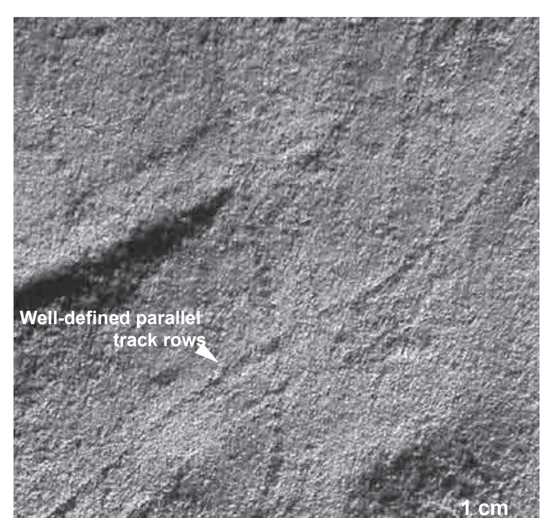


FIGURE 3
Track-laden surface
from the Potsdam Formation of NY.

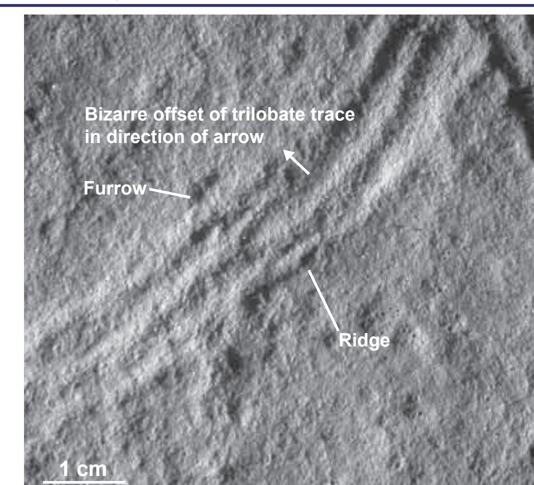


FIGURE 4
Cast of surface containing an offset trilobate trackway and raindrop imprints.

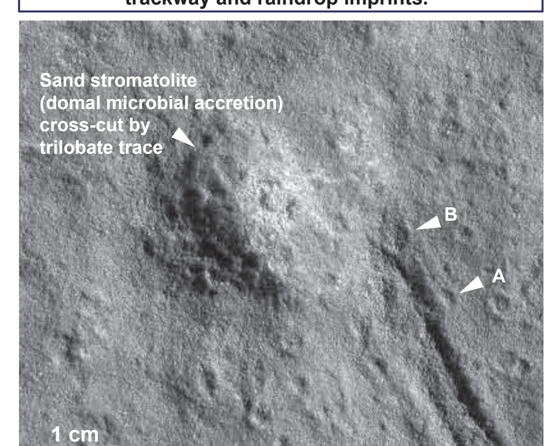
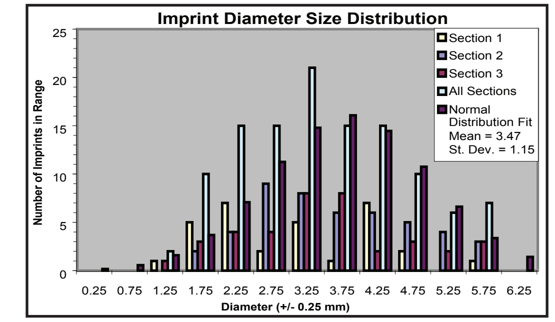
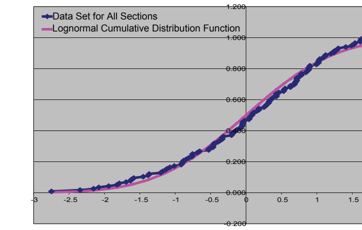


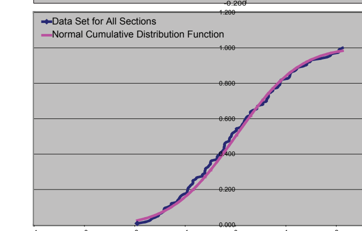
FIGURE 5
Surface containing a trilobate trackway, sand stromatolite, and raindrop imprints

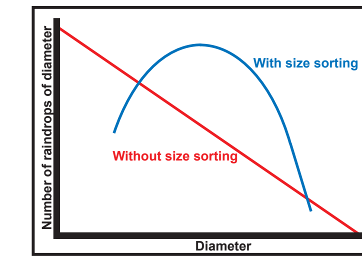


How does one know that the imprints were made by raindrops? Both raindrop imprints and gas escape structures appear as craters with well-defined rims.

1. In cross-section no vertical escape shafts were observed. Vertical vents are diagnostic of gas escape.
2. In three randomly selected $25\ cm^2$ sample areas, no imprints with diameters greater than 6.00 mm were found (above). Raindrops break up at ~5.5 mm in the atmosphere. This constraint does not exist for gas escape structures.
3. Modern raindrop imprints exhibit a lognormal size distribution (bottom right). Full raindrop spectra are loglinear, but this is not the case when small drops go unrecorded. Application of the chi-square goodness-of-fit test to our data shows that at a significance level of 25%, one cannot reject that the imprint diameters are distributed normally or lognormally (above right). Our small sample population made both distributions fit the data equally well.







The presence of raindrop imprints on the studied surface indicates subaerial exposure. Some imprints are halved by trace fossils (Figs. 1B, 5A, 6A). Other imprints lie atop traces (Figs. 1C, 5B, 6B and C, 7A). These cross-cutting relationships imply that traces were created during or between rain events.

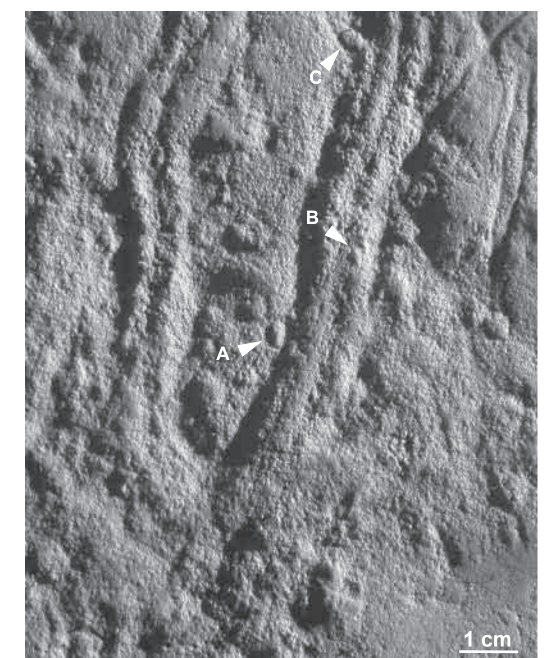


FIGURE 6
Cast of surface containing trilobate trackways and raindrop imprints.

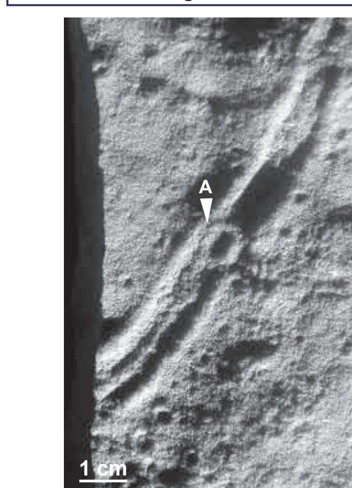


FIGURE 7
Surface containing a trilobate trackway and raindrop imprints.

SUGGESTIONS FOR FURTHER RESEARCH

One could expose sand to natural rainfall to analyze modern vs. fossil imprint distributions. One could also determine whether the rain system recorded on the imprinted surface was continental or maritime, because there is a difference in large drop size frequency between the two types of systems. Experimentation with modern animals could help constrain possible trace makers. Work on the preservational influence of microbial mats could help reveal their taphonomic role in raindrop preservation.

ACKNOWLEDGEMENTS

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