Frontispiece: Trackways of multiple *Laoporus* as exposed in the Coconino Sandstone near Seligman, AZ 1991 by Potomac Museum Group. Eventual size of this specimen reached 5m x 15m and was excavated in 260 pieces weighing nearly 4,000 pounds. It is part of the collections at Ulster Museum, Belfast, Ireland. Hal Halvorson seated at far end.

LOWER PERMIAN TRACKS AND TRACES IN THE SCIENCE MUSEUM OF MINNESOTA

ICHNOFOSSILS III

Bruce R. Erickson
Fitzpatrick Curator of Paleontology
Hal E. Halvorson and Jon M. Kramer
The Potomac Museum Group

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CONTENTS

INTRODUCTION

References to trace fossils in the collections of the Science Museum appear in the Scientific series of SMM as Ichnofossils I and II: 1979 by R.C. Melchior and B.R. Erickson, Paleontologic Notes on the Wannagan Creek Quarry Site (Paleocene – North Dakota), Vol. 4 (4); and 1981 by Glen T. Sawyer, A Study of Crocodilian Coprolites From Wannagan Creek Quarry, (Paleocene – North Dakota) Vol. 5 (2)

This publication, Ichnofossils III, is concerned exclusively with traces preserved in the Coconino Sandstone (Lower Permian: Mid Leonardian) of Coconino County, Arizona, USA. Numerous expeditions between 1980 and 2006 conducted by the Potomac Museum Group of Brooklyn Park, Minnesota resulted in collections of some 275 individual sandstone plates (slabs) that are now permanently housed in the Science Museum of Minnesota. These collections constitute unique evidence of Permian life as biogenic structures as well as environmental events. They are here brigaded into five major sections: Invertebrate Traces; Vertebrate Traces; Mixed Assemblage, Paleoenvironmental Traces; and Problematica. The latter includes ambiguous traces as well as structures that are numerous and distinct enough to warrant discussion about their implications regarding the paleoenvironment, as well as the behavior and adaptations of the potential trackmakers themselves.

Ichnofossils (trace fossils) are among the most abundant evidence of past life ranging from the Paleozoic to the near Recent. This becomes apparent if one considers that, in the course of a lifetime, a single animal has the potential of leaving many thousands of tracks and traces, but only a limited number of body parts in the fossil record. However, due to the vicissitudes of the paleoenvironment, most of these fragile traces were quickly destroyed before they were preserved. In some deposits such as the Coconino Sandstone, body parts such as teeth and bones are absent, which attests to the conditions under which the tracks were made. Among the evidence of vertebrates only quadrupedal forms are recognized.

The question of the origin of the Coconino Sandstone is a much debated subject. Were the Paleoenvironmental conditions under which the sandstone was originally laid down, with its traces, subaerial or subaqueous? In this publication we do not compulsively attempt to argue for either. We do offer interpretations for each specimen (plate) as to identity, at some level, and possible behavior of the primary trackmaker(s), and, as in the case of the trackmakers, comments on the possible environmental facies. It should be noted that many researchers have now realized that Gilmore and other early Coconino authors generated far more ichnotaxa than is warranted by the tracks themselves. In many cases, seemingly different prints can be left by the same animal, depending on several factors. For instance, the speed and angle at which the Trackmaker travels across the deposit – this is, up-slope, or down-slope, or cross-slope. Other factors that may influence the preservation are: moisture content, surface texture, wind speed and direction, subsequent erosion and/or distorting of the sediments, and finally post-depositional mechanics. In addition, the irregularities of underprinting have been recognized as a preservation mechanism in many of the Coconino tracks, calling into question many of the original descriptions (Brand and Kramer 1996) (Figure 1). The evidence from this Ichnocoenose indicates that subaerial as well as subaqueous depositional environments existed, and included many microenvironments that were altered even daily between moist to wet and dry conditions. The trackmakers' identity would also bear on an environmental interpretation, if for example, the ichnotaxon *Laoporus* is regarded as an amphibian rather than reptile, as is generally thought, different life style requirements would necessarily put paleoenvironmental interpretations into different lights. See Brand, 1996, for discussion of salamander tracks.

This volume is not a catalogue in the usual sense wherein specimens are systematically listed by taxonomic name, author, date, locality, horizon and relative citations, as few have been formally described in the scientific literature. As noted above, all of the material presented has the same provenience. The purpose of this volume is to provide a reference and preliminary analysis of some 114 new trackbearing sandstone plates, as a resource for previously described tracks, many of which were interpreted on less than perfect imprints, and may need revision, as well as for recognition of possible new ichnotaxa. Specimens listed herein that have been described previously in the literature are provided with biographical information. It is estimated that over twenty invertebrate and vertebrate ichnotaxa are represented by the evidence presented here. Color matching of all the figures was done to agree with the color of the original specimens.

A footprint that leaves a depression in a sedimentary substrate can be read as a concave epirelief pattern of the foot showing varying degrees of detail (Fig. 1B). Such concave prints often penetrate deeply and produce an "underprint" (Fig. 1C) in the underlying sedimentary layer. If the original imprint is not obliterated by wind or water erosion, subsequent sediments may fill the original concave imprint (Fig. 1B), and be preserved as a convex hyporelief "infilling" of the original imprint (Fig. 1A). Parting laminations (PL) occur between the laminae (layers) of the Coconino Sandstone Formation due to differences in composition, grain size, mineralogy of the laminae, which cause separation of the laminae. The results of the above conditions have produced the specimens discussed in this volume.

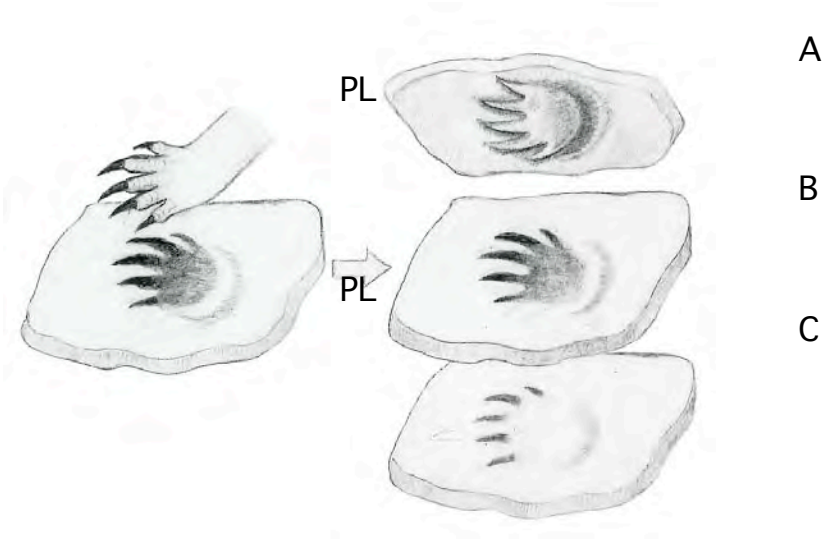

FIGURE 1. Track formation. A, infilling of original foot impression, in hyporelief. B, Original foot impression in concave epirelief. C, Obscured, original foot impression preserved as an "underprint".

ACKNOWLEDGEMENTS

We thank the following individuals and institutions for their assistance and support with this project: Ray Colby photographed all of the specimens except that in Figure 24 which was done by Robert Spading; Hal Halvorson and Jon Kramer produced the Frontispiece, Figures 2 and 5; Julie Martinez assisted with field and lab work, and contributed Figure 1. Janet Maxim, Doug Sievers, Dave Fordyce, George Hecht, Simon Braddy, Maurizio Comar, Clayton Black, Mike McAnneny and several others spent endless hours digging and then trudging uphill and down carrying hundreds of pounds of specimens back to the truck; Vernon Morris, Thad Ludwiczak, and Janine Halvorson also assisted in the field and general project support; Susan Roverud did lay up and proofreading; Lois Erickson provided word processing and William Mason contributed supplies and materials during development of specimens; Earnestine and Monte Shawver family contributed lodging, field work, food, supplies; Figure 3 was provided courtesy of USNM; Figure 4 courtesy of Northern Arizona University, Cline Library, Special Collections and Archives. Richard Benson and Becky Huset reviewed the manuscript; Don Baird consulted and advised on the Coconino Formation. The Ray Alf Museum provided a cast of the type specimen of *Octopodichnus* original cat. no. RAM JF 5905.

We wish to thank George Ast for showing us some key outcrops many years ago.

Publication of this volume was made possible through the generosity of the Potomac Museum Group.

GEOLOGIC HISTORY

The Coconino Sandstone is a stratified deposit that is widespread in northern Arizona, outcropping in many places throughout the Coconino Plateau for which it is named. Its boundaries roughly correspond with the plateau itself. The most famous exposures are, of course, in the Grand Canyon where it forms characteristic tan-colored cliffs in the upper canyon walls (Fig. 2). Other important exposures are found south of Grand Canyon along the Aubrey Cliffs (Fig. 5) and in the prolific flagstone quarries north of Ash Fork and Williams. The Coconino was first described as a distinct geologic unit by Darton (1910) who defined it as the middle member of the "Aubrey Group", a construct no longer used (the Supai, Darton's lower Group member, is now considered a Group unto itself).

The first footprints found in the Coconino strata were discovered in 1915 by Charles Schuchert who was, at the time, on the faculty of Yale University (Gilmore, 1926). Schuchert brought the prints to the attention of R.S. Lull, another Yale professor, who subsequently published a short paper on them (Lull, 1918). Starting in 1924, Charles W. Gilmore (Fig. 3) made a thorough search of the Coconino in the Grand Canyon area, collecting hundreds of track specimens, mostly along the Hermit Trail. These were deposited in the National Museum, where he was Curator of Vertebrate Paleontology. Gilmore published several papers and described many new ichnospecies from these collections (Gilmore 1926, 1927, 1928).

The first comprehensive investigation and description of the Coconino stratigraphy was not made until two decades later when Edwin McKee (Fig. 4) became the Grand Canyon park naturalist. In his epic, The Coconino Sandstone – Its History and Origins, McKee set the stage for future debate on the subject by stating that the Coconino sands were deposited in large part by wind (McKee, 1933).

The Coconino Sandstone has an enigmatic lithology. The strata consist of well-sorted, fine-grained, heavily cross-bedded, quartz-cemented quartz sandstone which periodically yields finely detailed tracks and traces, sometimes in abundance and sometimes of great length. For example, the long trackway shown in the frontispiece has a continuous trail of over six meters as exposed. Due to the structural and lithologic similarities between the Coconino and other more studied sandstones of the region (the De Chelly, Navajo, and Wingate), it was originally postulated that the Coconino paleoenvironment represented purely aeolian deposits and was essentially a large erg (Noble, 1922). For lack of any evidence to the contrary, subsequent authors agreed with this assumption (Darton, 1926; McKee, 1947, 1979; Land, 1964). But it was not until the late 1930s that the theory was actually tested. At the Museum of Northern Arizona, L.F. Brady conducted elaborate experiments using live animals tracing around on sand surfaces. He varied the ambient temperature and moisture content of the sediment composed primarily of dry sands. Peabody, (1959) came to similar conclusion.

However, some researches questioned the mode in which the tracks were made and how they were preserved. In the late 1970s, Leonard Brand of Loma Linda University conducted laboratory experiments in which he concluded the tracks could only have been made subaqueously (Brand 1977). In follow-up papers, Brand and others continue to promote the subaqueous theory. Traces found on the plates in the present assemblage indicate that they were made under environmental conditions varying from dry to possible total submergence in water. Analyses of these plates are confined to brief descriptions and in some cases interpretation of the paleoenvironment are suggested.

Figure 2. The Grand Canyon in Northern Arizona and the continuity of the Coconino Formation as exposed (arrows) near the top of the canyon rim.

Figure 3. Charles W. Gilmore

Figure 4. Edwin McKee at Tuba City, AZ dino track site.

Figure 5. Escarpment of Aubrey cliffs north of Seligman, Arizona where many important trace fossils have been recovered from the cliffs and talus slopes of the Coconino Formation.

I. INVERTEBRATE ICHNOFAUNA

Catalogue Number: SMM P88.1.1 FIGURE 6.

Primary Trackmaker: aff. *Octopodichnus* sp. (Arachnida).

Mode of Preservation: concave epirelief.

Analysis: *Octopodichnus* is perhaps one of the most readily recognized invertebrate trackways of the Coconino Sandstone. Its foot imprints that alternate as sets of 4 on either side of midline closely resemble those made by spiders. The specimen figured here is a single trackway exhibiting a walking stride. Foot imprints 1-3 are in line at an angle of about 50 degrees with midline; imprint 4 is closer to midline and posterior to imprint 3. Some imprints show subtle bifurcation, which suggests the presence of a claw at the end of the tarsus. Direction of progression is indicated by the arrow.

This plate represents the original sand surface that received the impressions of the feet. The impressions are in concave epirelief. Their clarity and sharpness suggests that the sand surface was damp or moist. The breadth of this trackway varies from 5-6 cm. To illustrate the source of these tracks, Alf, (l968) inked the feet of several living spiders including Tarantula (*Dugesiella hentzi*) which he allowed to travel over white paper. The resulting trackway patterns were very similar to that of *Octopodichnus,* thus suggesting that the fossil trackway was made by a spider.

Scale equals 10 cm.

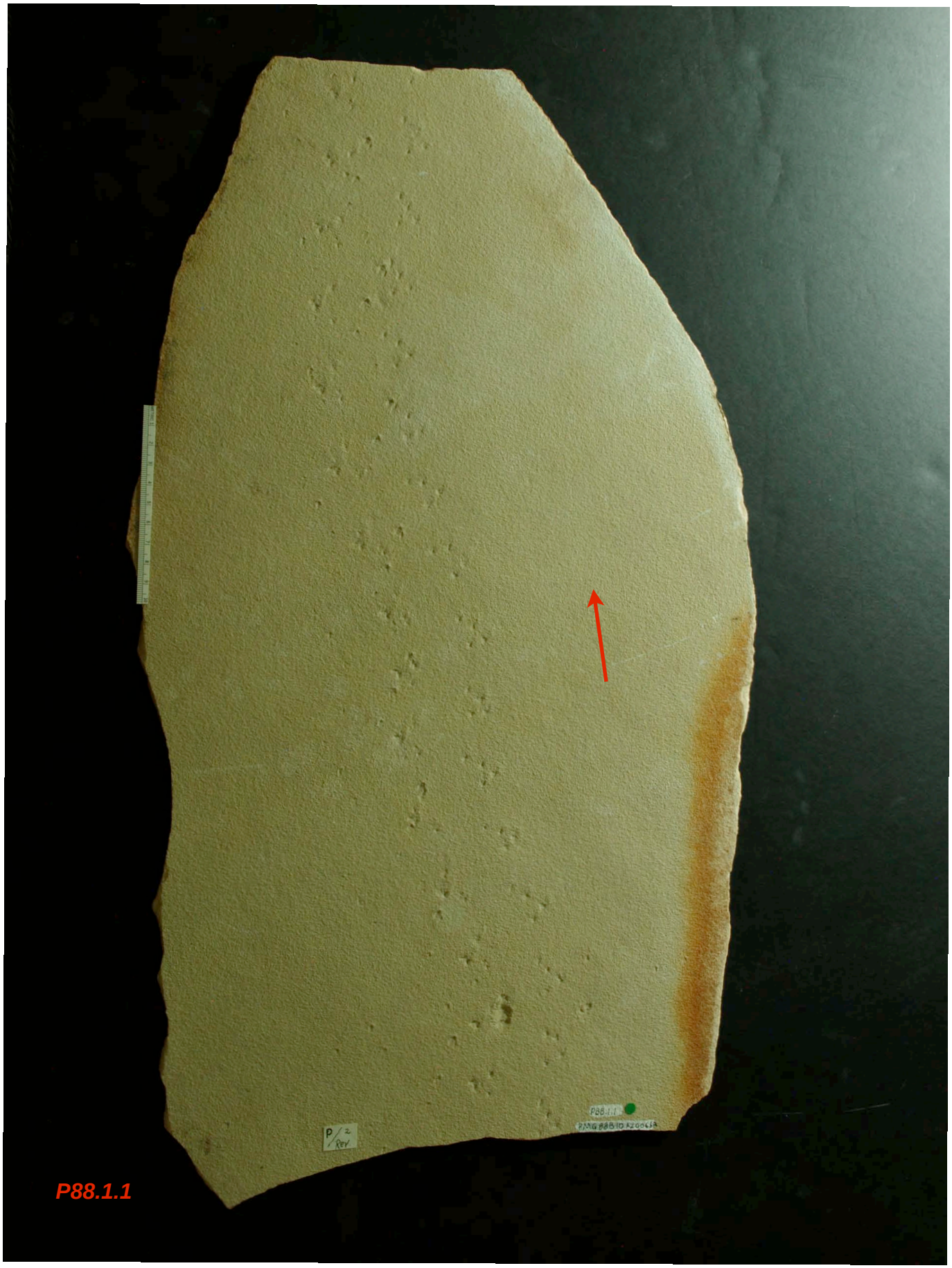

FIGURE 6

Catalogue Number: P87.7.19 FIGURE 7.

Primary Trackmaker: Invertebrate/undet..

Mode of Preservation: concave epirelief (Insecta).

Analysis: Two pieces of sandstone showing sections of a single trackway with median drag mark, maximum breadth 1.5 cm, possible second parallel trackway obscured. Scale equals 3 cm.

Catalogue Number: P87.7.35 FIGURE 8.

Primary Trackmaker: Invertebrate *Paleohelcura tridactyla* (Arachnida).

Mode of Preservation: concave epirelief.

Analysis: Partial trackway with sets of three podial prints, on either side of midline, characteristic of *Paleohelcura*. Scale equals 3 cm.

Catalogue Number: P87.7.43 FIGURE 9.

Primary Trackmaker: Invertebrate aff. *Octopodichnus* sp. (Arachnida).

Mode of Preservation: Convex hyporelief.

Analysis: Partial trackway with distinct impression of podials in groups of four, characteristic of *Octopodichnus*. Scale equals 3 cm.

Catalogue Number: P87.7.47 FIGURE 10.

Primary Trackmaker: Invertebrate cf. *Octopodichnus* sp. (Arachnida).

Mode of Preservation: concave epirelief.

Analysis: Two trackways, one crossing the other, breadth of main trackway 5.0–5.6 cm. Scale equals 3 cm.

FIGURE 7

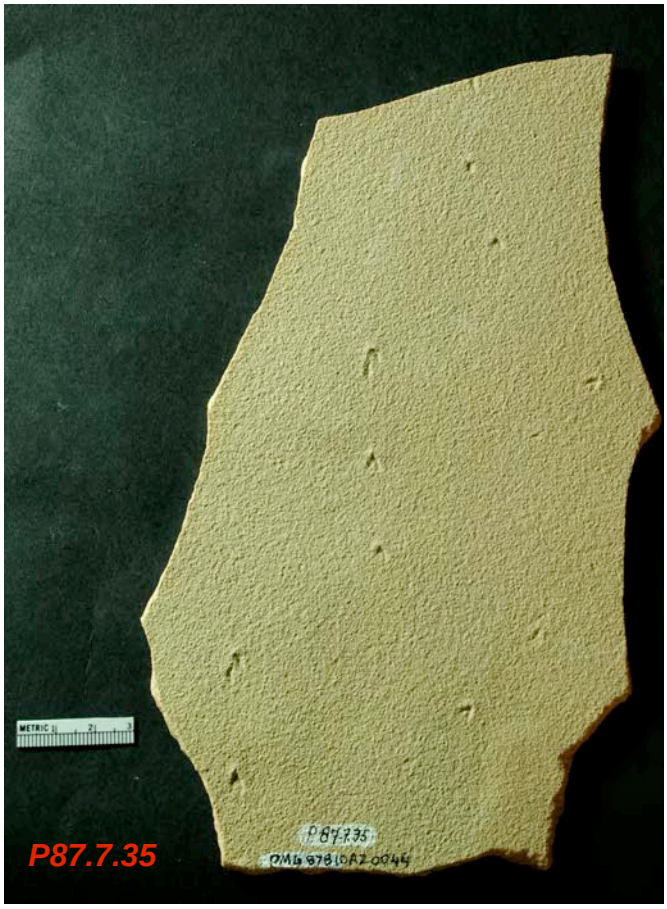

FIGURE 8

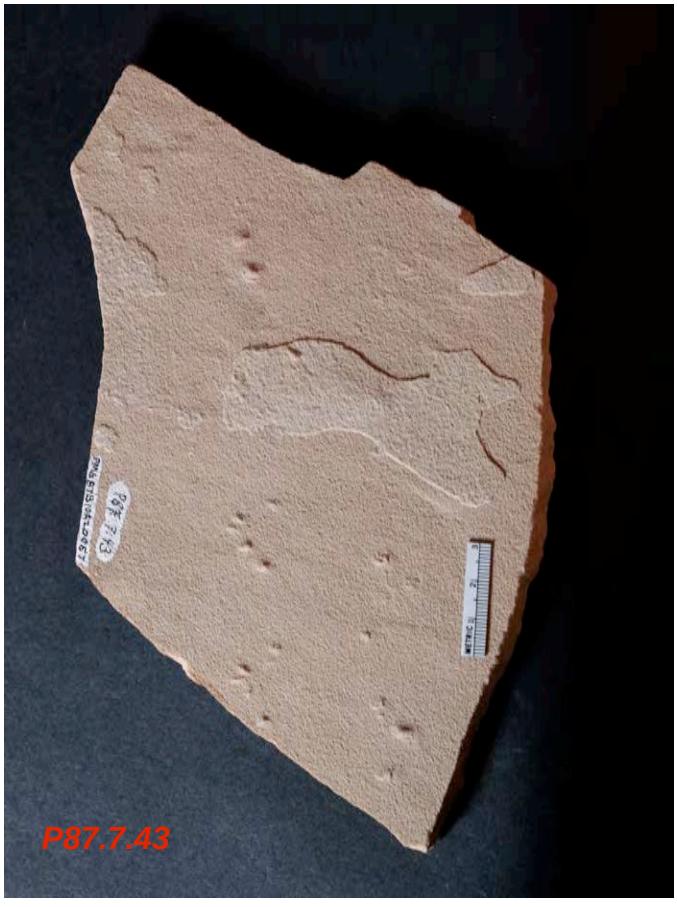

FIGURE 9

FIGURE 10

Catalogue Number: P87.7.36 FIGURE 11.

Primary Trackmaker: Invertebrate undet.

Mode of Preservation: convex hyporelief.

Analysis: Trackway distinct with well-defined podial imprints, suggestion of possible second trackway on same path.

Scale equals 3 cm.

Catalogue Number: P87.7.46 FIGURE 12.

Primary Trackmaker: Invertebrate aff. *Octopodichnus* sp. (Arachnida).

Mode of Preservation: convex hyporelief.

Analysis: Trackway showing clear imprints of four podials on either side of midline, deeper podial imprints on right, probable down slope side, maximum breadth of trackway 5.6 cm. Scale equals 3 cm.

FIGURE 11

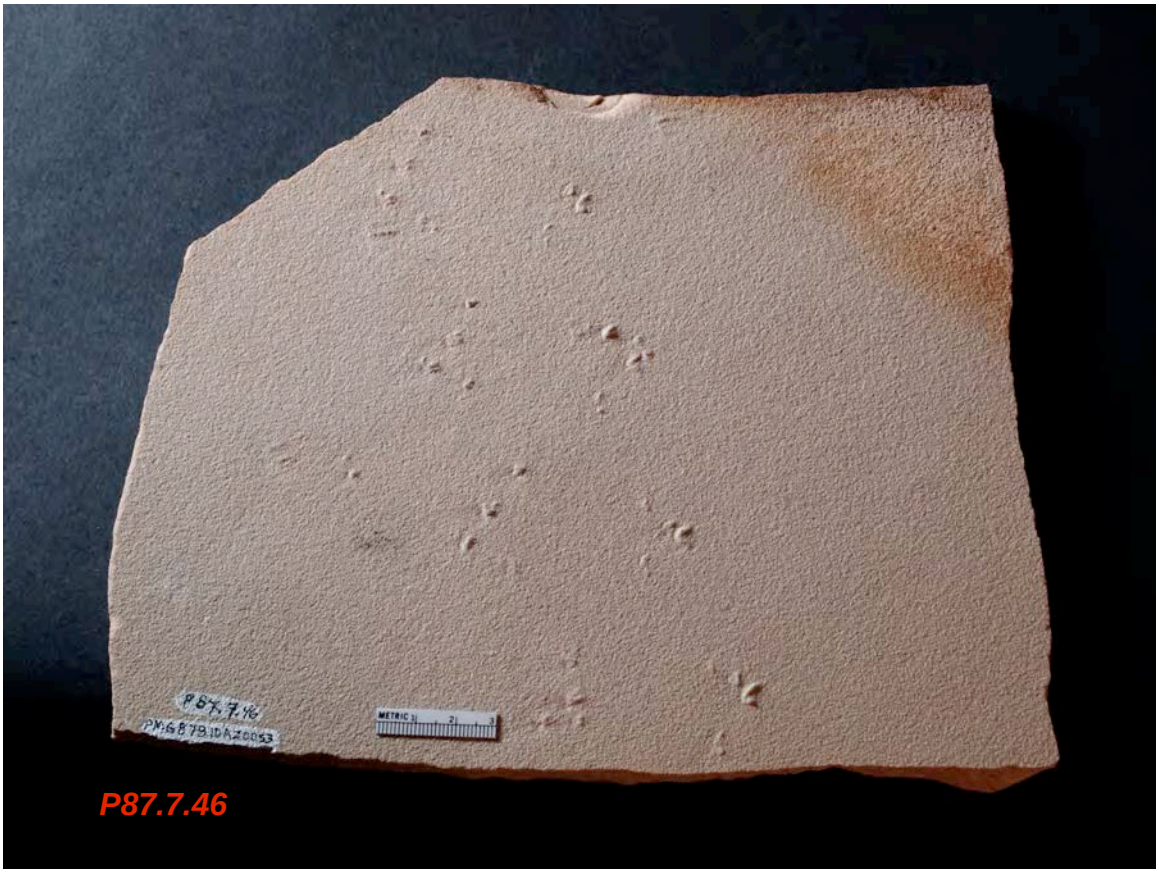

FIGURE 12

Catalogue Number: P87.7.51 FIGURE 13.
Primary Trackmarker: Invertebrate cf. *Paleohelcura* sp. (Arachnida).
Mode of Preservation: convex relief.
Analysis: Trackway showing normal stride indicated by strong half, other half of trackway obscured. Scale equals 6 cm.

Catalogue Number: P87.7.63 FIGURE 14.
Primary Trackmaker: Invertebrate undet.
Mode of Preservation: concave epirelief.
Analysis: Long, uninterrupted trackway, maximum breadth 2.5 cm. Scale equals 3 cm.

Catalogue Number: P2005.2.1 FIGURE 15.
Primary Trackmaker: Invertebrate undet.
Mode of Preservation: concave epirelief.
Analysis: Probable, single trackway, clear imprints with faint “tic” marks. Breadth of trackway 7.5 cm. Scale equals 3 cm.

Catalogue Number: P2006.8.16 FIGURE 16.
Primary Trackmaker: Invertebrate undet.
Mode of Preservation: convex epirelief.
Analysis: Multiple podial markings and associated “drag” mark on one side, talus specimen, weathered. Scale equals 6 cm.

FIGURE 13

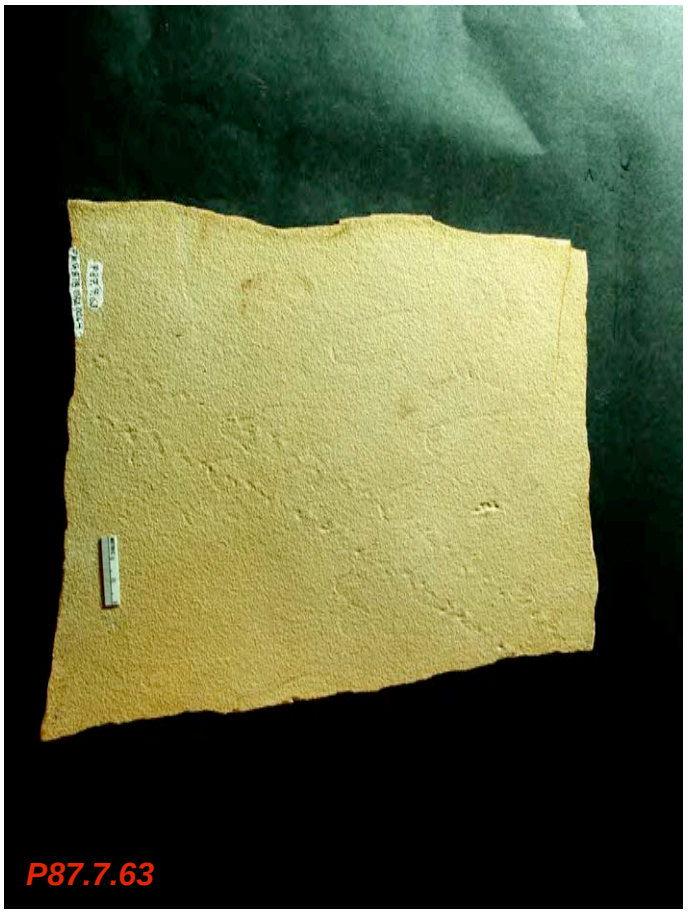

FIGURE 14

FIGURE 15

FIGURE 16

Catalogue Number: P87.7.56 FIGURE 17.

Primary Trackmaker: Invertebrate undet.

Mode of Preservation: convex hyporelief.

Analysis: Two trackways indicated, may represent different taxa or trackway of the same individual traveling in the opposite direction, deepest imprints on right may indicate down slope side, maximum breadth of trackway 1.5 cm. Scale equals 3 cm.

Catalogue Number: P2005.2.7 FIGURE 18.

Primary Trackmaker: Invertebrate cf. *Scolecoprus* sp. (Annelida).

Mode of Preservation: convex relief.

Analysis: Trails appear to terminate as burrows. Scale equals 3 cm.

FIGURE 17

FIGURE 18

Catalogue Number: P2006.8.2 FIGURE 19.

Primary Trackmaker: Invertebrate (Insecta).

Mode of Preservation: concave/convex relief.

Analysis: Two, long, curved trackways are interpreted as being those of insects, and may represent a single taxon. Each trackmaker evidently had six legs as indicated by 2-3 pairs of footprints. Some of these imprints angle outward at 30° or more. Breadth of each trackway is 1.22 – 2.2 cm.

Further interpretation of behavior of these trackmakers has two individuals converging near the center of the plate. The trackmaker on the right shows an interruption in its progression near what appears to be imprints of another, also unidentified invertebrate (long arrow), after which it continued its progression, with indication of drag marks (short arrow), possibly from injury to an appendage. This scenario assumes that these imprints are coeval. Scale equals 6 cm.

FIGURE 19

Catalogue Number: P2006.8.13 FIGURE 20.

Primary Trackmaker: Invertebrate (Arthropoda).

Mode of Preservation: convex hyporelief.

Analysis: Arthropod trackway showing continuous trail and median “tail” drag, alternating sets of three to four footmarks on either side of midline, trackway produced prior to overlying, large vertebrate foot imprints, also shown as high convex features. Scale equals 3 cm.

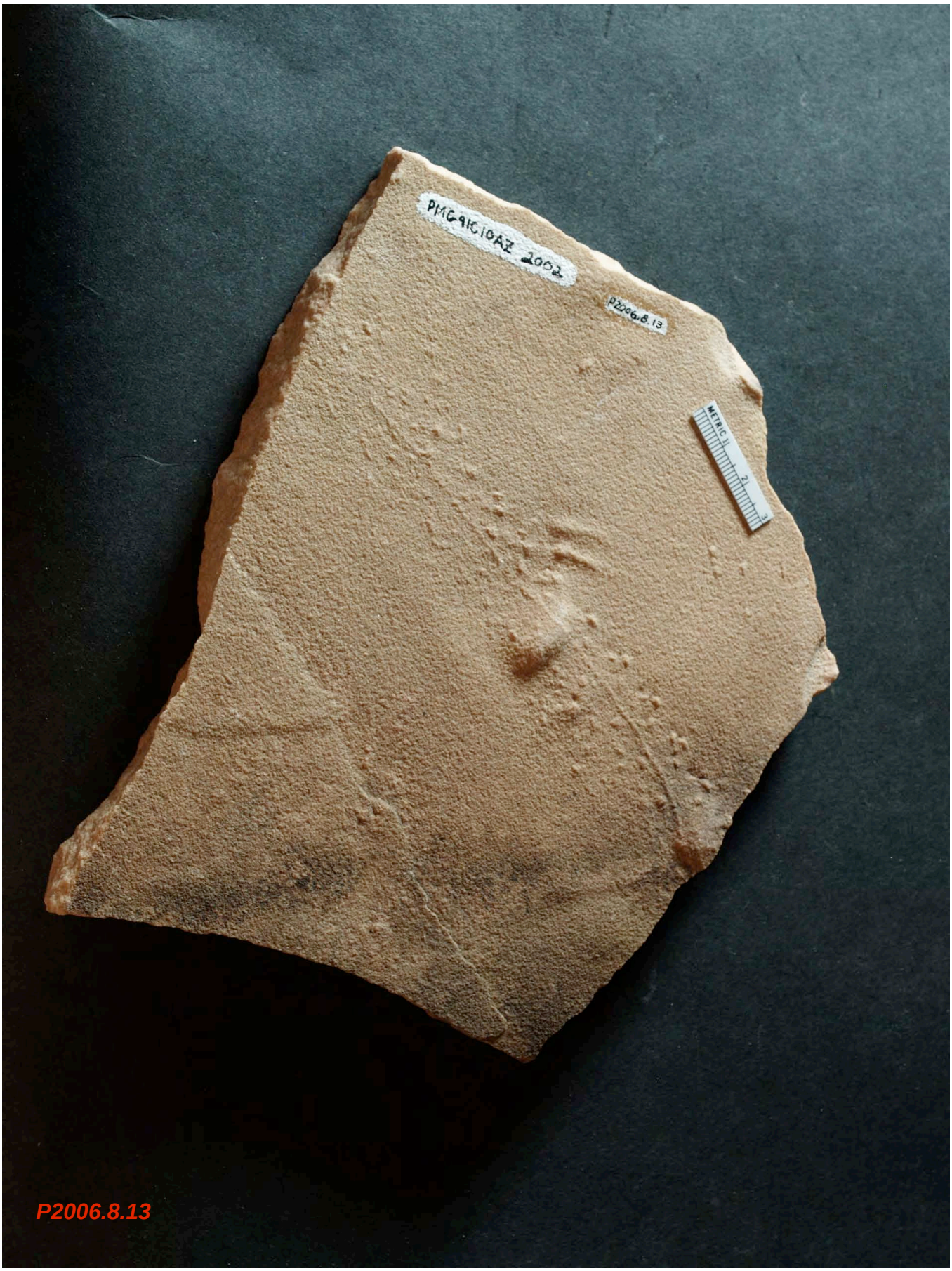

FIGURE 20

Catalogue Number: P2006.8.17 FIGURE 21.

Primary Trackmaker: Invertebrate.

Mode of Preservation: concave epirelief.

Analysis: Trackways of two invertebrates indicated by A, B. Probable vertebrate tracks (center of plate) in general alignment with the invertebrate trackways. Scale equals 3 cm. A resembles *Permichnium*, (ref. Fig. 86).

FIGURE 21

Catalogue Number: P2006.8.10 FIGURE 22.

Primary Trackmaker: Invertebrate cf. *Octopodichnus* sp. (Arachnida).

Mode of Preservation: concave epirelief.

Analysis: Crossing trackways displaying impressions of paired sets of four podial prints per stride, no tail drags, breadth of trackways 2.5 cm, may represent tracks of single individual. Scale equals 3 cm.

Catalogue Number: P2006.8.11 FIGURE 23.

Primary Trackmaker: Invertebrate aff. *Octopodichnus* sp.(Arachnida).

Mode of Preservation: convex hyporelief.

Analysis: Sharply defined trackway with characteristic sets of four footprints on either side of midline, maximum breadth 6.5 cm. Scale equals 3 cm.

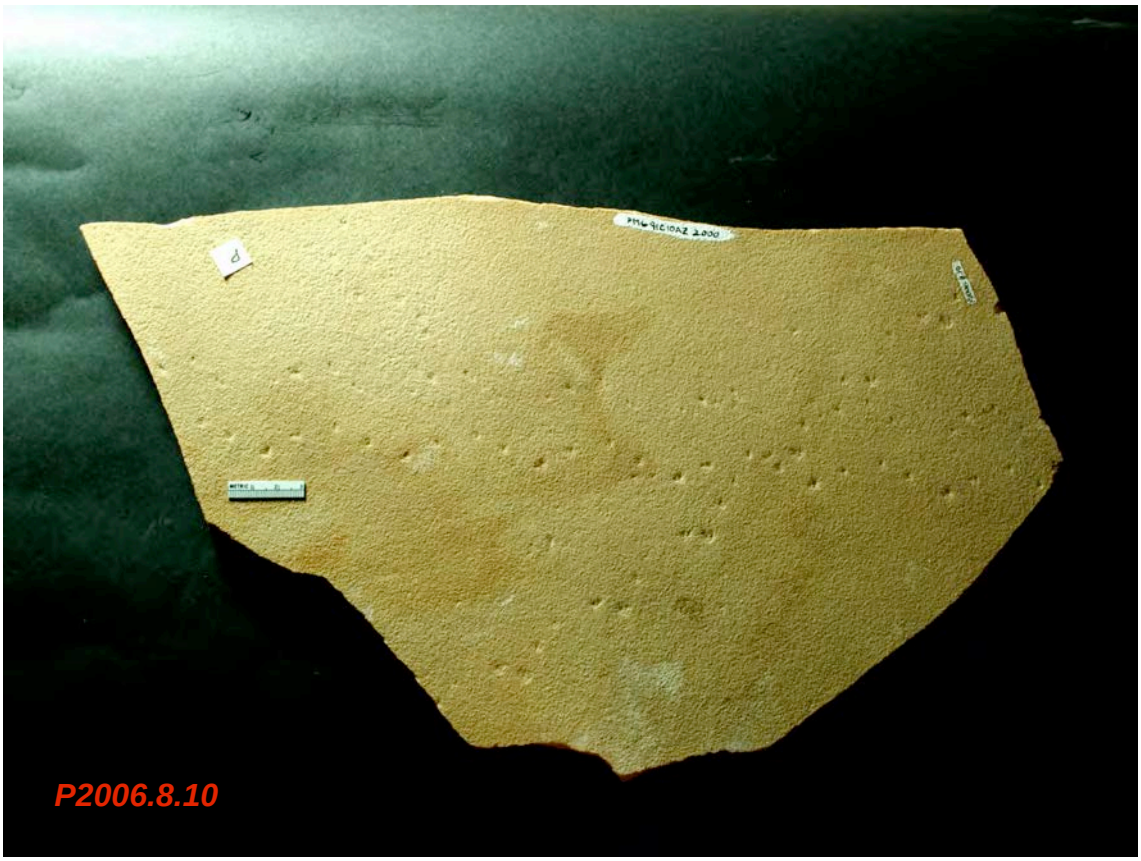

FIGURE 22

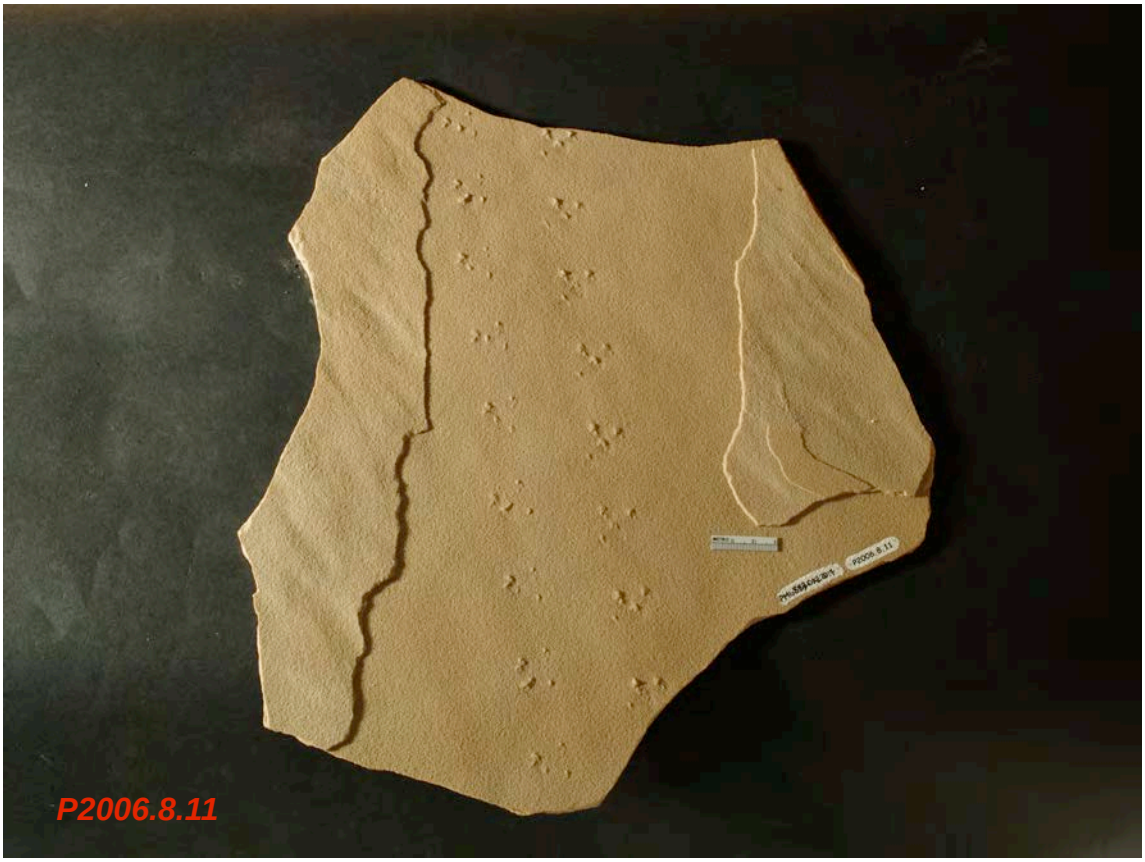

FIGURE 23

II. VERTEBRATE ICHNOFAUNA

SMM P98.7.1 (FIGURE 24).

The primary trackmaker on this plate is *Laoporus*, a probable reptile with a broad, short manus and pes, each displaying five strong digits. Other tracks and traces on this plate are evidence of various reptiles as well as those of invertebrates.

As today, deserts of the Permian were both dry and wet. Desert sand dunes have height with crests of loose sand that are shaped by the wind. Interdunes (between sand dunes) are low and often wet from collected rainwater. Animal tracks are made on dry dunes as well as in low, wet places like interdunes.

This plate of Coconino sandstone holds many foot tracks that were made mostly by vertebrates. These tracks occur as concave relief impressions as the trackmakers traveled across the surface of a sand dune. They moved in up-slope, cross-slope, and down-slope progression, each leaving a distinctive trail. Movements up-slope are characterized by claw prints pointing up slope, or nearly so, and crescents behind the heel of each foot as it sank into the sand (A). Cross-slope travel is revealed by a horizontal or diagonal trackway with the claw marks pointing up hill at each Step (B). Occasional foot drags are shown as “tic” marks (T). Down-slope movement is represented by elongate depressions with sand “build-up” at the lower (downhill) end (C), and in some cases have claw marks pointing down hill.

Analysis leads to the conclusion that the tracks were made on a gently sloping dune face. It is also likely that the tracks were made at different times, because of their numbers, and in cases, where a foot depression was made over an earlier print partly obscuring it.

Collecting a large trackway plate, such as this, is facilitated by “parting lamination” between lamina, where bedding planes (usually thin) separate the sandstone into layers often exposing a surface with tracks. Separation of lamina may occur because of differences in sand grain size, the presence of clay, lime or iron content and/or the variation in consistency of dryness or wetness of the various lamina. Plate size approx. 114 x 154 cm.

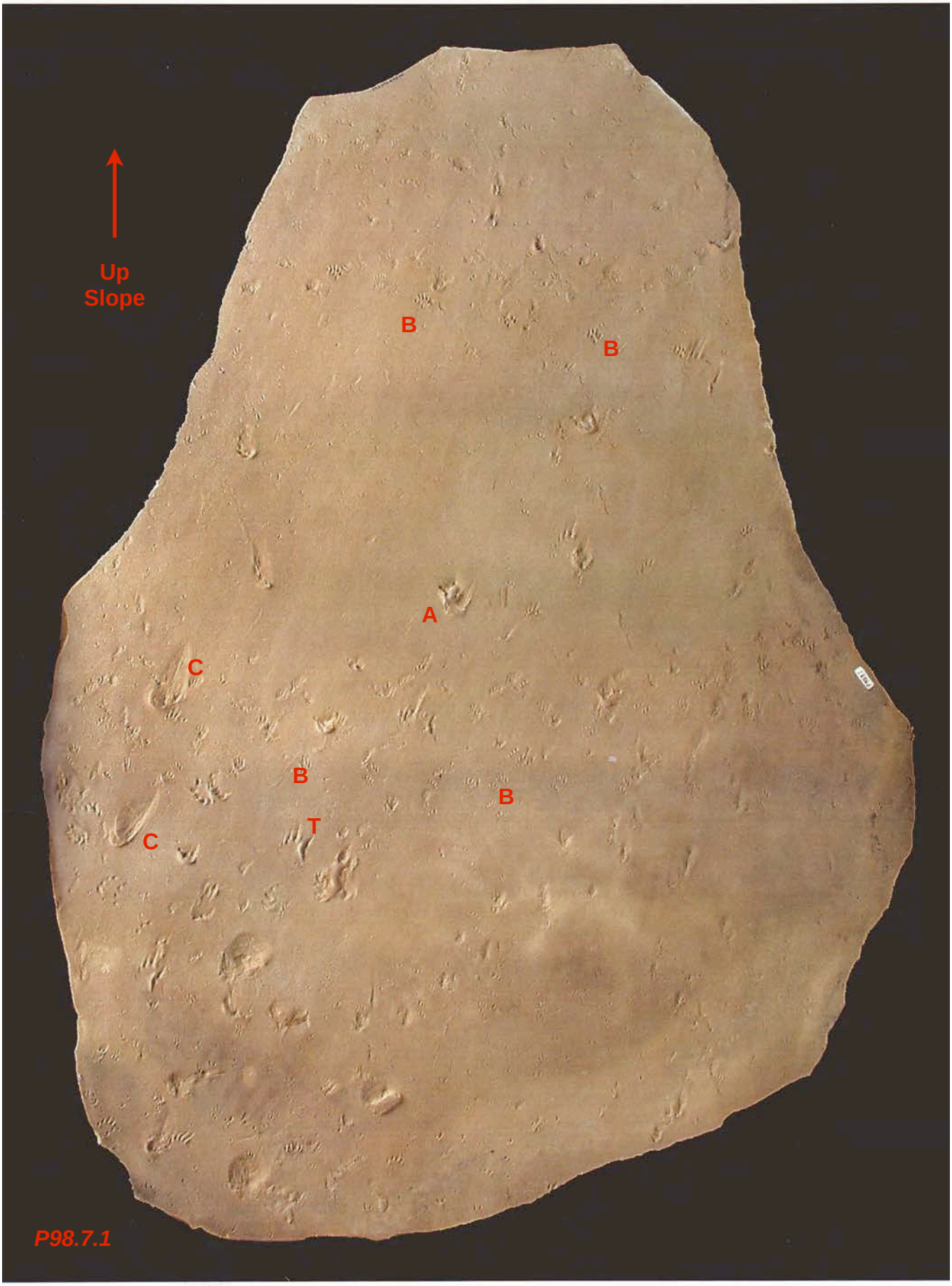

FIGURE 24

Catalogue Number: P87.7.10 FIGURE 25.

Primary Trackmaker: Vertebrate, cf. *Laoporus* sp.

Mode of Preservation: convex relief.

Analysis: Two sets of prints (fore and hind feet) showing toe and heel imprints and related substrate markings of foot drag or sinking. Scale equals 3 cm.

Catalogue Number: P87.7.22 FIGURE 26.

Primary Trackmaker: Vertebrate, cf. *Laoporus* sp.

Mode of Preservation: convex relief.

Analysis: Two partial footprints (toes only) on two lamina. Scale equals 3 cm.

Catalogue Number: P87.7.32 FIGURE 27.

Primary Trackmaker: Vertebrate, cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Several digitigrade footprints displaying trailing mark from each toe claw, partial trackway indicated. Scale equals 3 cm.

Catalogue Number: P87.7.33 FIGURE 28.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: convex hyporelief.

Analysis: Tracks with faint toe prints and deep, wide heel prints, (plantigrade), indication of more than one individual. Scale equals 3 cm.

FIGURE 25

FIGURE 26

FIGURE 27

FIGURE 28

Catalogue Number: P87.7.55 FIGURE 29.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave underprint.

Analysis: Trackway, digitigrade with more prominent toe imprints on right side, direction of travel (arrow) breadth of trackway 7 cm. Scale equals 3 cm.

Catalogue Number: P97.1.9 FIGURE 30.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: convex epirelief.

Analysis: Long trackway with indistinct foot impressions, walking stride, more than one individual present. Outward angulation of some prints 50° - 70° from midline. Scale equals 6 cm.

Catalogue Number: P97.1.2 FIGURES 31.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave epirelief.

Analysis: Dorsal view of single print half, high heel crescent, talus, weathered specimen. Scale equals 6 cm.

Catalogue Number: P97.1.2 FIGURES 32.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave epirelief.

Analysis: Sectional view of same print as above, half infilling of foot depression and showing individual toe impressions in cross section (arrow) along margin of plate. Talus, weathered specimen. Scale equals 1 cm.

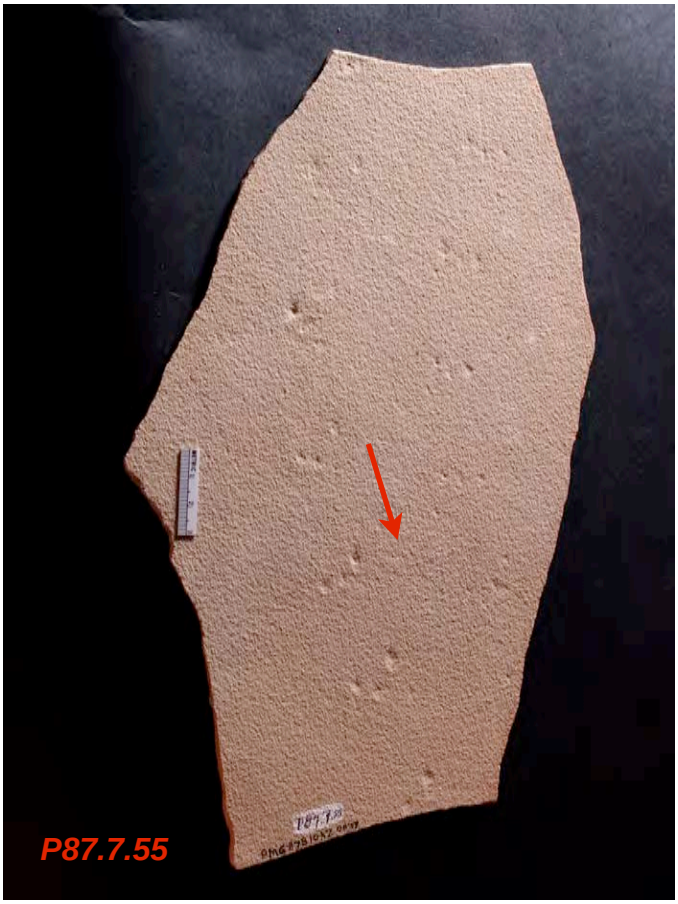

FIGURE 29

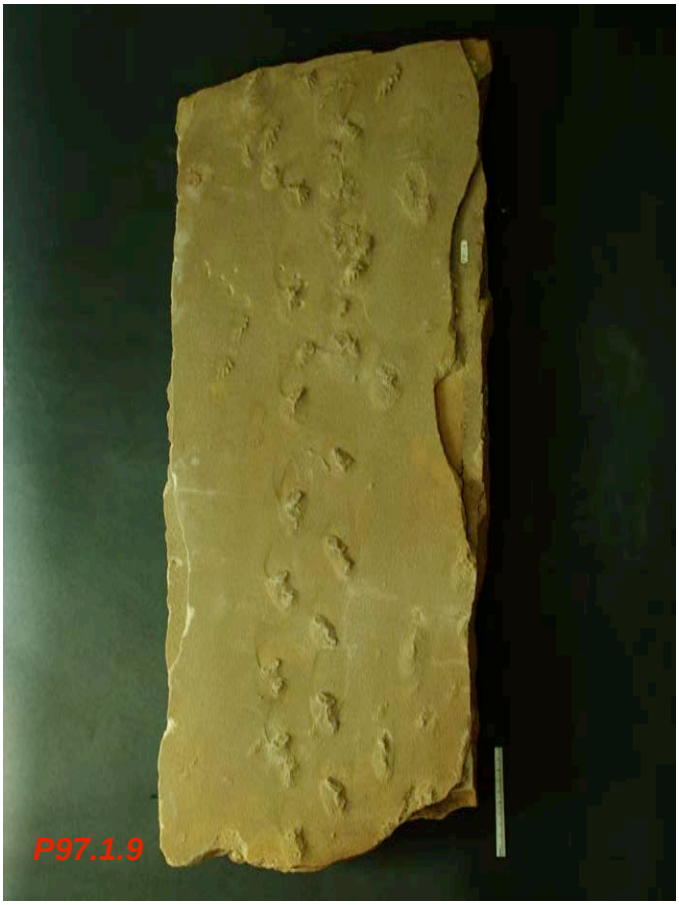

FIGURE 30

FIGURE 31

FIGURE 32

Catalogue Number: P2006.8.25 FIGURE 33.
Primary Trackmaker: Vertebrate aff. *Laoporus* sp.
Mode of Preservation: convex hyporelief.
Analysis: Single, sharply defined footprint with four toe prints each producing long, narrow trailing marks. Scale equals 6 cm.

Catalogue Number: P2006.8.37 FIGURE 34.
Primary Trackmaker: Vertebrate undet.
Mode of Preservation: concave epirelief.
Analysis: Two sets of fore and hind foot impressions showing long trailing marks, plate with evidence of scour by wind or water. Scale equals 3 cm.

Catalogue Number: P2006.8.46 FIGURE 35.
Primary Trackmaker: Vertebrate cf. *Laoporus* sp..
Mode of Preservation: convex hyporelief.
Analysis: Two sets of fore and hind foot impressions with distinct toe and heel imprints, trailing marks present. Scale equals 3 cm.

Catalogue Number: P2006.8.51 FIGURE 36.
Primary Trackmaker: Vertebrate cf. *Laoporus* sp.
Mode of Preservation: convex hyporelief.
Analysis: Partial trackway of slow moving animal, deep fore and hind foot imprints with distinct toe prints, breadth of trackway 6 cm. Scale equals 3 cm.

FIGURE 33

FIGURE 34

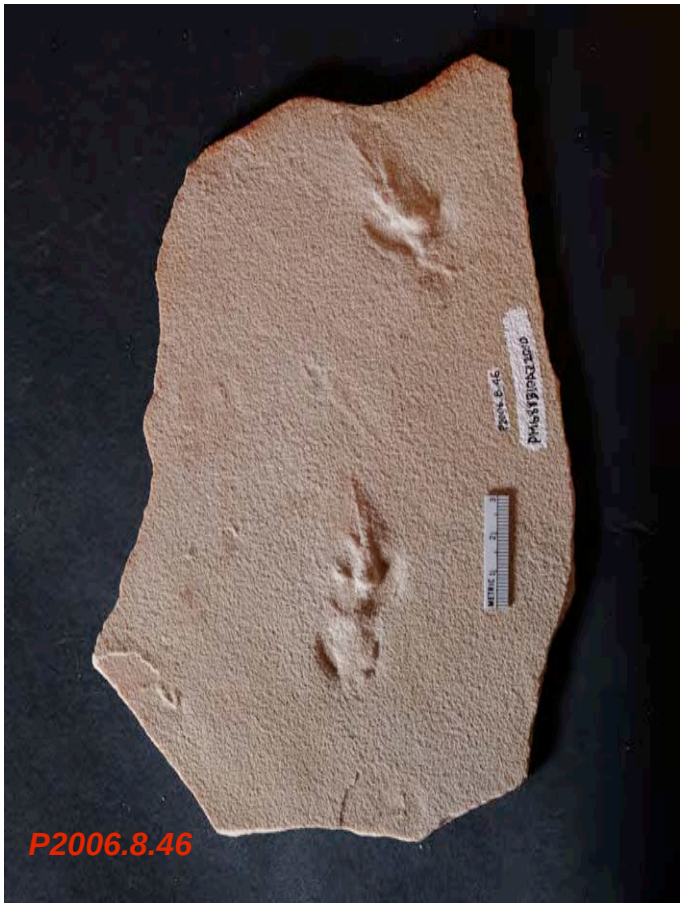

FIGURE 35

FIGURE 36

Catalogue Number: P2006.8.57 FIGURE 37.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Partial trackway with distinct, deep imprints of fore and hind feet. Slow progression indicated. Scale equals 3 cm.

Catalogue Number: P2006.8.60 FIGURE 38.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave relief.

Analysis: Two deep imprints of different sizes, both with heel crescents, largest showing long toe drag marks that may indicate irregular stride. Scale equals 3 cm.

Catalogue Number: P2006.8.92 FIGURE 39.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief (underprint).

Analysis: Partial trackway showing only digital prints. Scale equals 3 cm.

Catalogue Number: P2006.8.66 FIGURE 40.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Several deep imprints of feet with prominent toe and claw features, plantigrade movement indicated. Scale equals 3 cm.

FIGURE 37

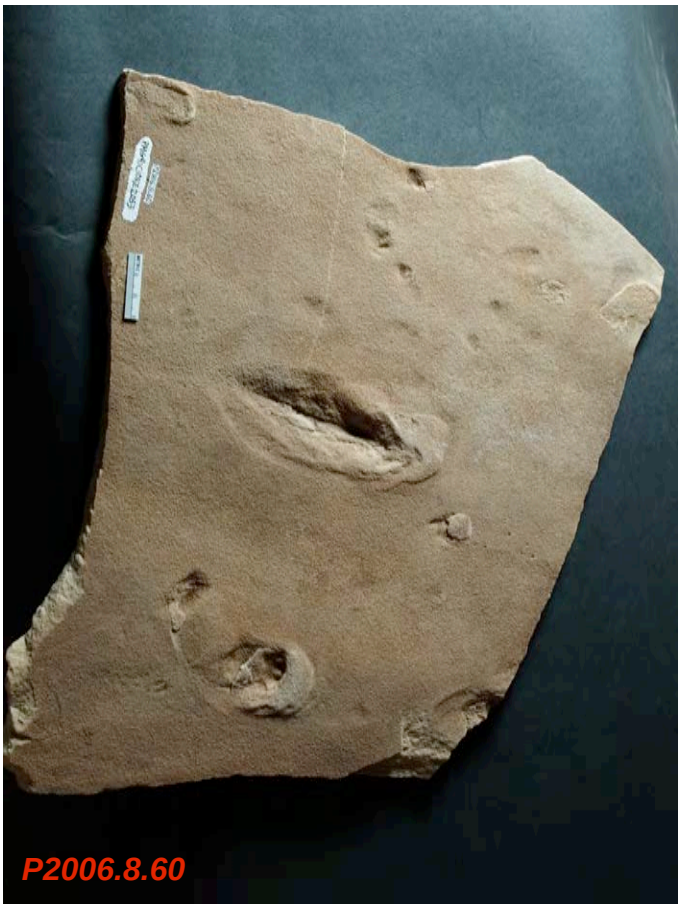

FIGURE 38

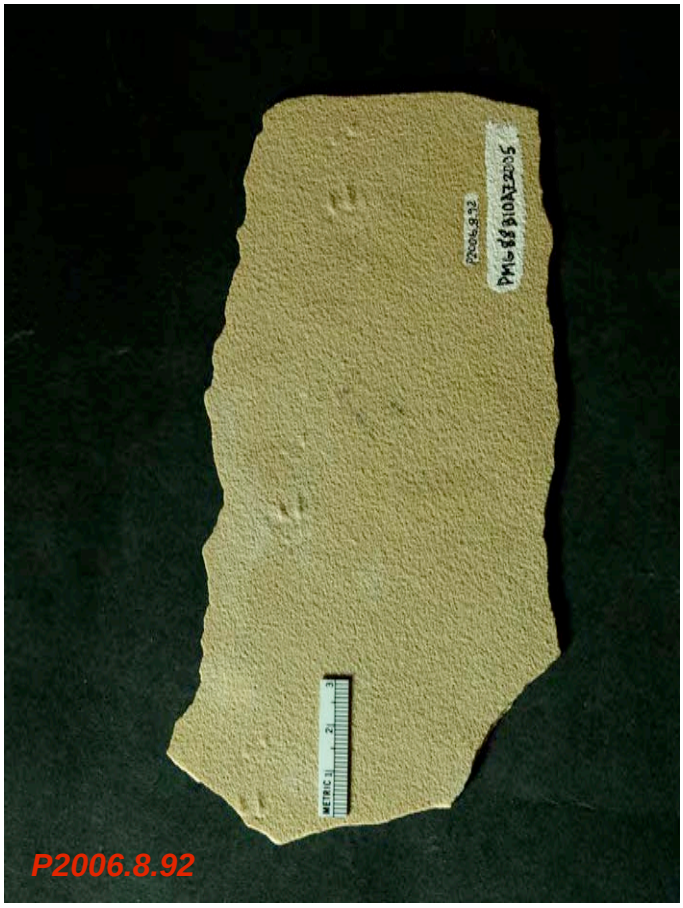

FIGURE 39

FIGURE 40

Catalogue Number: P2006.8.78 FIGURE 41.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Deep, distinct footprints with prominent toe imprints. Scale equals 3 cm.

Catalogue Number: P2006.8.80 FIGURE 42

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Digitigrade trackway showing long trailing marks from all feet made on inclined surface. Scale equals 3 cm.

Catalogue Number: P2006.8.82 FIGURE 43

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Deep impression of foot with four toe prints partly overstepping earlier imprint with sand crescent formation. Scale equals 3 cm.

Catalogue Number: P2006.8.86 FIGURE 44.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Numerous prints of fore and hind feet with some infillings. Exposed imprints have well defined toe and claw marks of plantigrade stride. Scale equals 3 cm.

FIGURE 41

FIGURE 42

FIGURE 43

FIGURE 44

Catalogue Number: P2006.8.89 FIGURE 45.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Trackway section having widely spaced imprints (long stride) of toes and heel crescents, breadth of trackway est. 2-5 cm. Scale equals 3 cm.

Catalogue Number: P2006.8.90 FIGURE 46.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: concave epirelief (underprint).

Analysis: Scattered toe and claw prints. Scale equals 3 cm.

Catalogue Number: P2006.8.96 FIGURE 47.

Primary Trackmaker: Vertebrate aff. Laoporus sp.

Mode of Preservation: convex epirelief.

Analysis: Trackway with broad foot pad imprints and some toe marks, irregular stride, breadth of trackway 8.0-8.5 cm, surface also shows what may be “saltation” marks. Scale equals 3 cm.

Catalogue Number: P2006.8.114 FIGURE 48.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave relief.

Analysis: Various foot marks, weathered, talus specimen, details mostly obscured. Scale equals 3 cm.

FIGURE 45

FIGURE 46

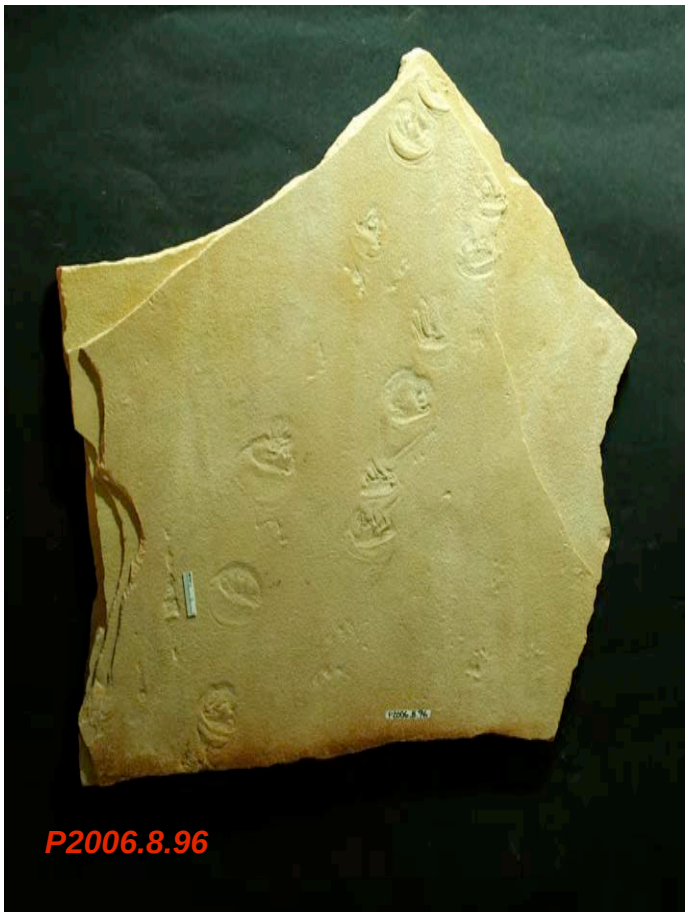

FIGURE 47

FIGURE 48

Catalogue Number: P2006.8.138 FIGURE 49.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave relief.

Analysis: Unclear tracks of unknown vertebrate(s), talus specimen. Scale equals 10 cm.

Catalogue Number: P2006.8.141 FIGURE 50.

Primary Trackmaker: ? Vertebrate undet.

Mode of Preservation: Unknown.

Analysis: Single trackway of presumed vertebrate, infilled and modified by paleoenvironmental agents, imprints angled outward some 20°- 40° from midline. Scale equals 6 cm.

Catalogue Number: P2006.8.142 FIGURE 51.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Single, straight trackway with some infilled impressions, unfilled impressions show clear heel and toe marks, breadth of trackway 5 cm, direction of travel (arrow) talus specimen. Scale equals 6 cm.

Catalogue Number: P2006.8.81 FIGURE 52.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Trackway of individual with regular stride on ripple marked surface, prominent heel crescents, breadth of trackway 8 cm, direction of travel (arrow). Scale equals 6 cm.

FIGURE 49

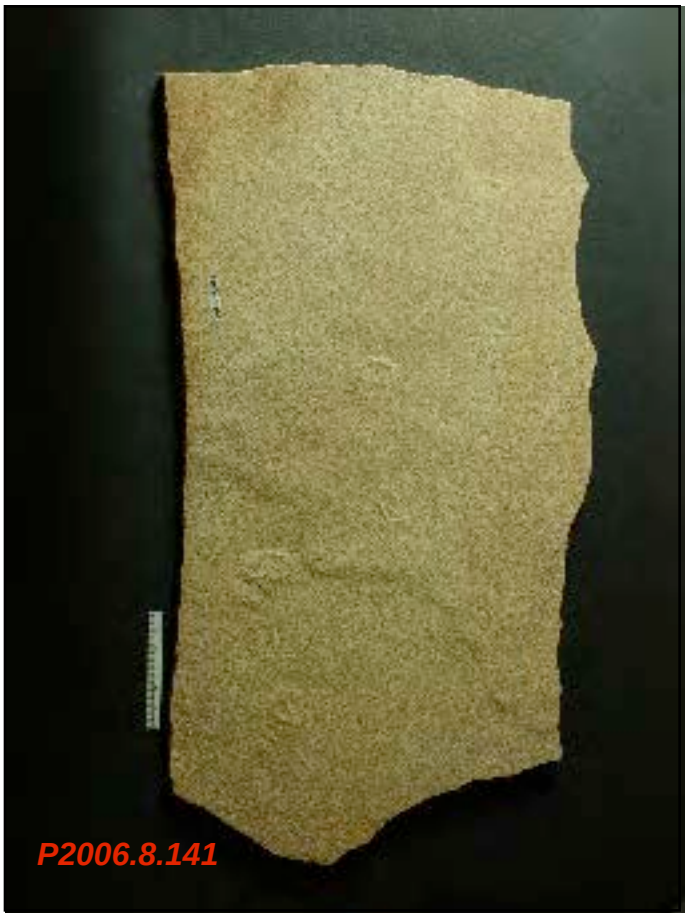

FIGURE 50

FIGURE 51

FIGURE 52

Catalogue Number: P2006.8.29 FIGURE 53.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: concave hyporelief.

Analysis: Two track sets with clear toe marks. Underprint. Scale equals 3 cm.

Catalogue Number: P92.25.1C FIGURE 54.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave epirelief (cast).

Analysis: Three trackways of different size individuals, all showing heel crescents on downslope side of trackway (bottom). Scale equals 6 cm.

FIGURE 53

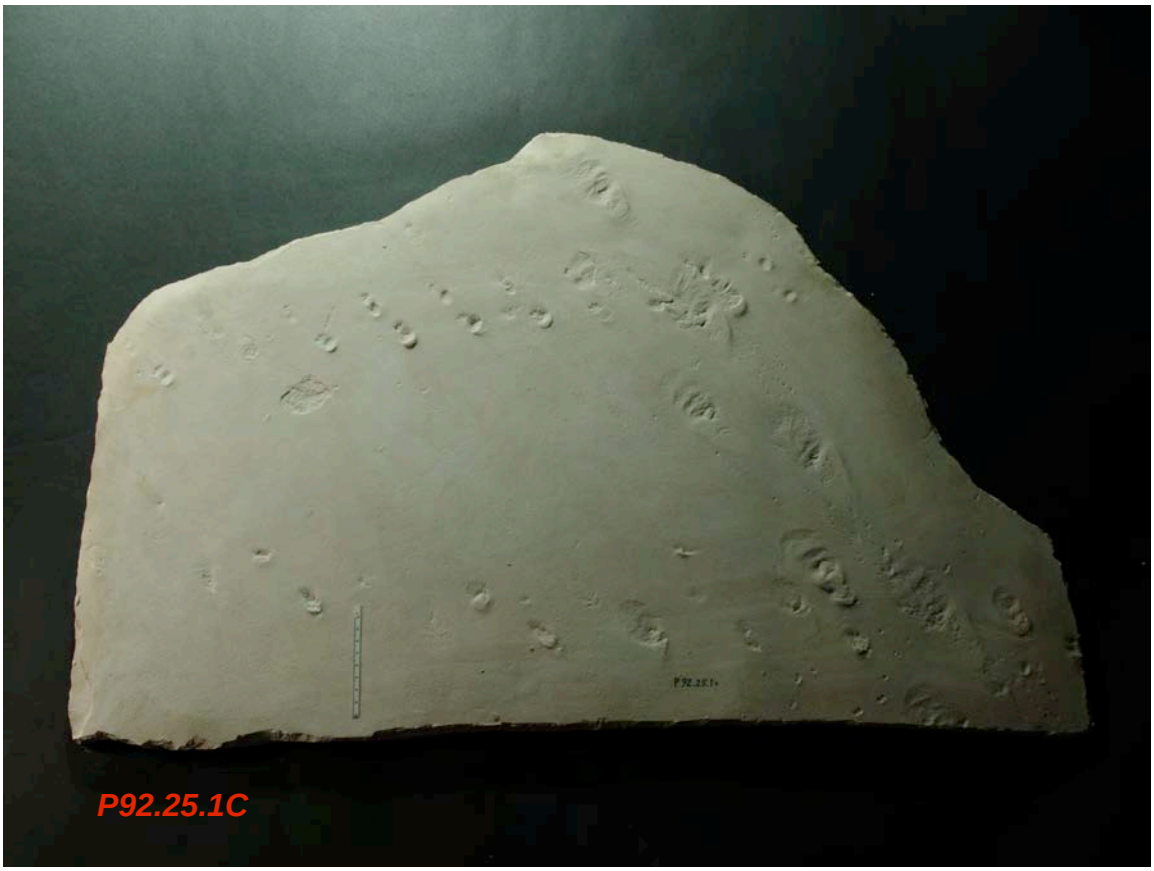

FIGURE 54

Catalogue Number: P97.1.5 FIGURE 55.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Trackway showing sharp digit and heel imprints, measurable walking stride, maximum breadth of trackway 6-7 cm, stride 92 cm, pace 63 cm, stride of fore and hind feet equal. Scale equals 3 cm.

Catalogue Number: P97.1.7 FIGURE 56.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave hyporelief.

Analysis: Partial trackway with deep imprints of fore and hind feet, slight development of heel crests, suggests walking stride, surface of substrate has suggestion of rain drop prints. Scale equals 3 cm.

FIGURE 55

FIGURE 56

Catalogue Number: P97.1.8 FIGURE 57.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Well-developed trackway with deep depressions resembling those of *Laoporus*, each foot has trailing marks and some development of heel crescents, moist or wet conditions suggested. Scale equals 10 cm.

Catalogue Number: P97.1.11 FIGURE 58.

Primary Trackmaker: Vertebrate *Laoporus,* sp.

Mode of Preservation: convex hyporelief.

Analysis: Clearly defined trackway of downslope progression with buildup of sand cusps in front of each foot, heel imprints are less clear, prominent, weathered, talus specimen. Arrow indicates down-slope direction. (Note: marks at left edge of plate are tool marks).

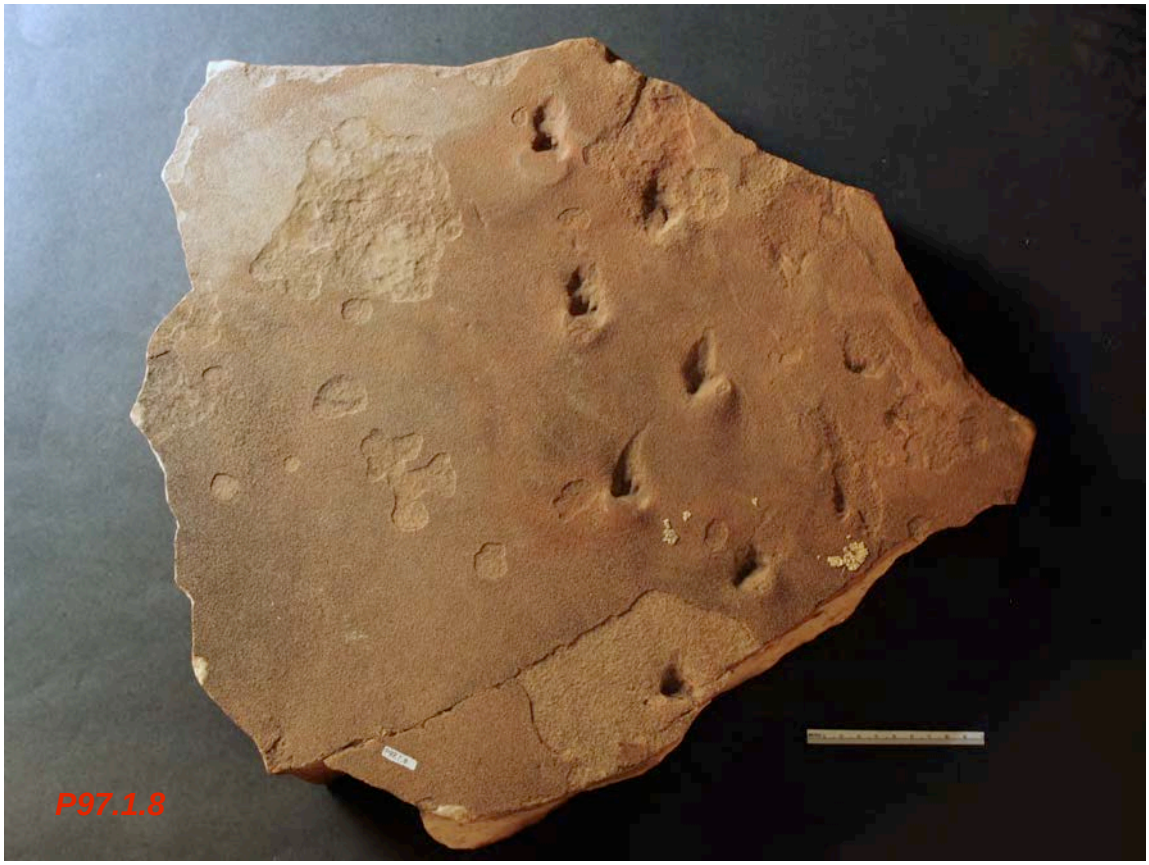

FIGURE 57

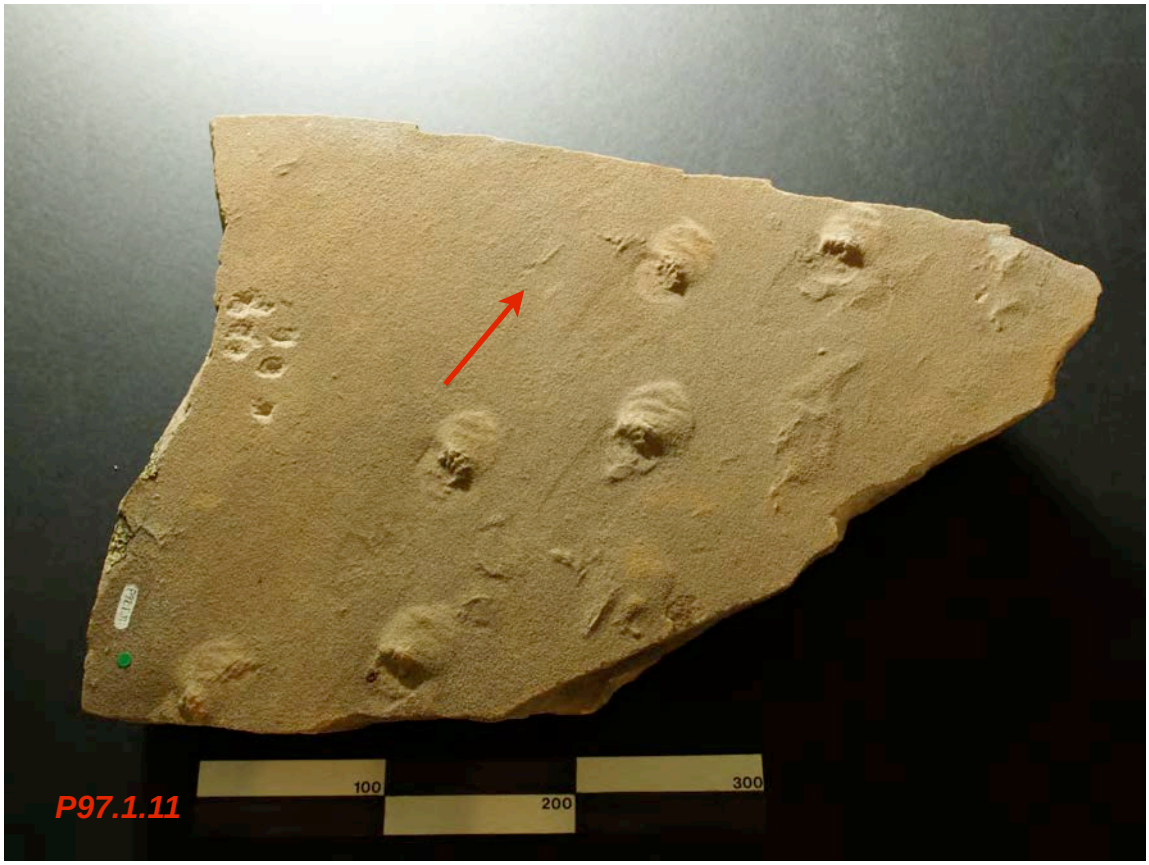

FIGURE 58

Catalogue Number: P2000.6.3 FIGURE 59.

Primary Trackmaker: Vertebrate cf. *Laoporus*, sp.

Mode of Preservation: convex hyporelief.

Analysis: Trackway produced by *Laoporus* moving diagonally across ripple marked surface. Scale equals 10 cm.

Catalogue Number: P2003.9.2 FIGURE 60.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief (underprint).

Analysis: Numerous footprints scattered over surface with many irregularities. Scale equals 3 cm.

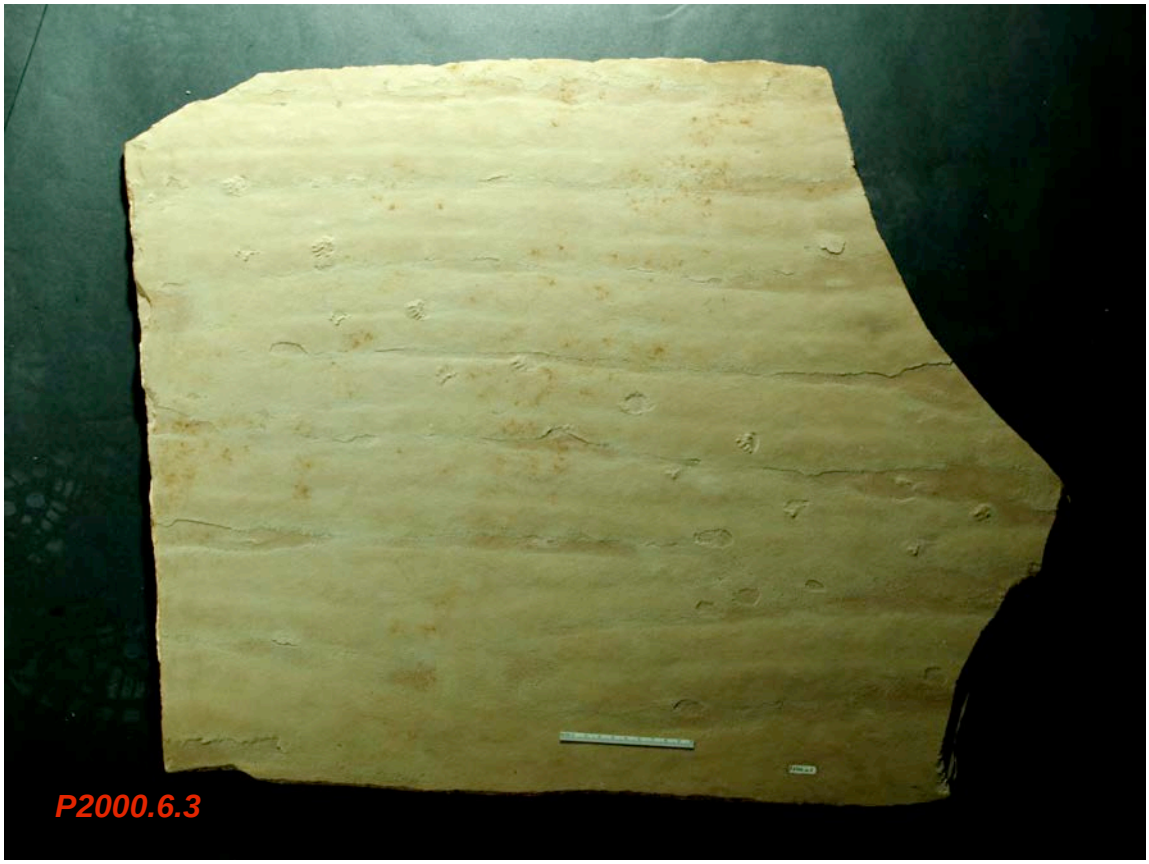

FIGURE 59

FIGURE 60

Catalogue Number: P2003.9.6 FIGURE 61.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Section of trackway with clear imprints of digits on either side and pronounced, sinuous, median tail or belly drag track, est. breadth of trackway 14 cm. Scale equals 3 cm.

Catalogue Number: P2006.8.5 FIGURE 62.

Primary Trackmaker: Vertebrate (undetermined).

Mode of Preservation: convex/concave (part and counterpart).

Analysis: Imprint of digits of a single foot with long trailing marks. Scale equals 3 cm. Invertebrate traces also present near lower margin of plate.

FIGURE 61

FIGURE 62

Catalogue Number: P2006.8.32 FIGURE 63.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex/concave (part and counterpart).

Analysis: Digitigrade imprints are preserved as one side of a trackway represented on part and counterpart. Scale equals 10 cm.

Catalogue Number: P2006.8.40 FIGURE 64.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Multiple imprints (several individuals) in high relief with clear digital and heel features, all tracks oriented similarly, some show prominent trailing marks from toes, direction of travel (arrow). Scale equals 3 cm.

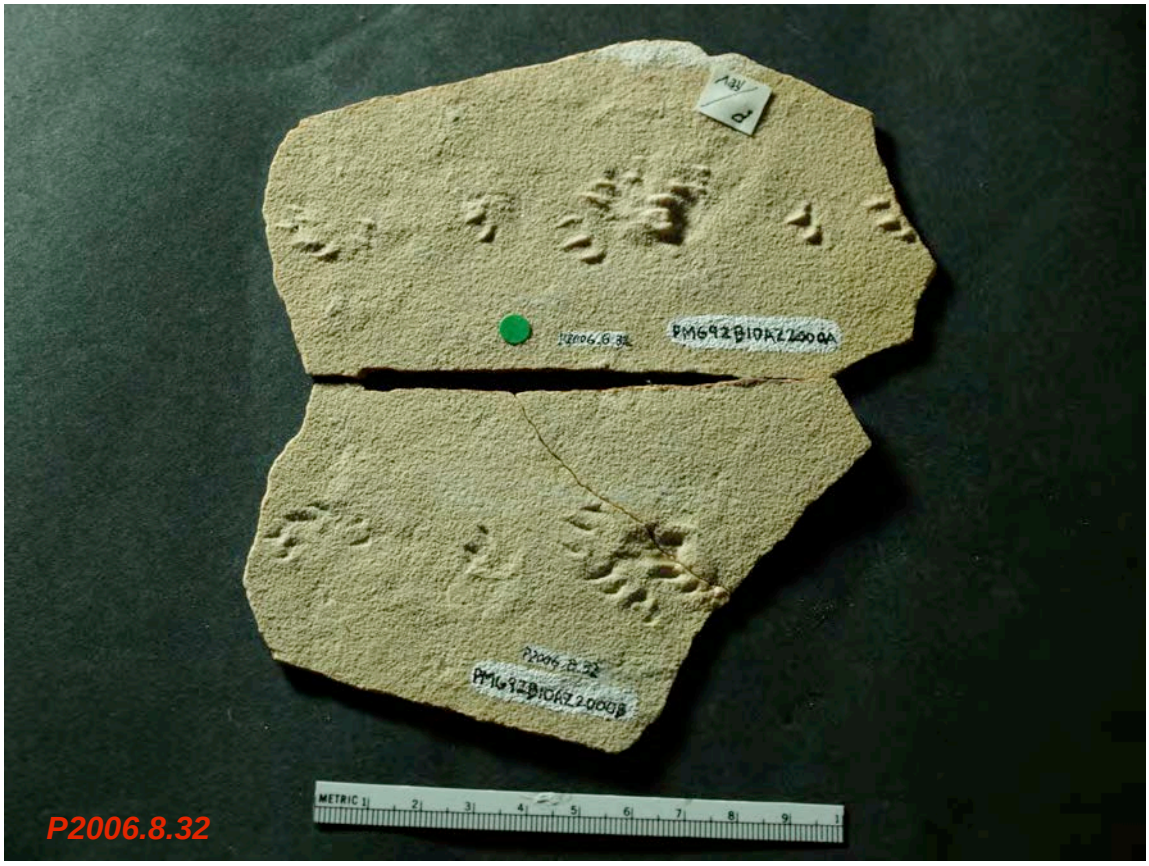

FIGURE 63

FIGURE 64

Catalogue Number: P2006.8.41 FIGURE 65.

Primary Trackmaker: Vertebrate (undetermined).

Mode of Preservation: concave relief.

Analysis: Imprints probably left in wet or damp ground surface. Scale equals 3 cm.

Catalogue Number: P2006.8.42 FIGURE 66.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Section of trackway showing clear digitigrade progression, walking stride moving across ripple-marked ground surface. Signs of weathering on surface. Scale equals 10 cm.

FIGURE 65

FIGURE 66

Catalogue Number: P2006.8.43 FIGURE 67.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Imprints of two feet with toe marks deeply impressed, showing side slump of sand as if moving cross-slope, moist substrate also indicated. Scale equals 3 cm.

Catalogue Number: P2006.8.44 FIGURE 68.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Concave epirelief with infilling of most foot impressions, open imprints show overstepping, more than one individual indicated. Scale equals 3 cm.

FIGURE 67

FIGURE 68

Catalogue Number: P2006.8.45 FIGURE 69.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp..

Mode of Preservation: concave epirelief.

Analysis: Numerous foot imprints, some showing toe and heel marks, others infilled with matrix, talus specimen. Scale equals 3 cm.

Catalogue Number: P2006.8.55 FIGURE 70.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: concave epirelief (underprint).

Analysis: Clear trackway produced by animal moving cross-slope as indicated by deep prints of left side showing some down-slope crests, right, upslope prints showing less pressure from weight. Scale equals 3 cm.

FIGURE 69

FIGURE 70

Catalogue Number: P2006.8.56 FIGURE 71.

Primary Trackmaker: Vertebrate *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Section of Plantigrade trackway with distinct fore and hind foot imprints, some digital impression and bold heel marks, with crescents, breadth of trackway 10-12 cm, est. Scale equals 3 cm.

Catalogue Number: P2006.8.61 FIGURE 72.

Primary Trackmaker: Vertebrate *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Trackway of animal moving cross-slope as indicated by inwardly angled underprints, with deeper down-slope prints, breadth of trackway est. 10 cm. Scale equals 3 cm.

FIGURE 71

FIGURE 72

Catalogue Number: P2006.8.77 FIGURE 73.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief (underprints).

Analysis: Toe prints from several feet, associated elongate features suggest coprolite traces or non-organic structures, talus specimen. Scale equals 3 cm.

Catalogue Number: P2006.8.95 FIGURE 74.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Remnant of trackway possibly produced during rain shower as inferred by associated raindrop prints. Scale equals 3 cm.

FIGURE 73

FIGURE 74

Catalogue Number: P2006.8.104 FIGURE 75.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: concave epirelief.

Analysis: Numerous footprints exposed on overlying and underlying layers of matrix, talus specimen. Scale equals 3 cm.

Catalogue Number: P2006.8.136 FIGURE 76.

Primary Trackmaker: Vertebrate cf. *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Two pairs of fore and hind feet indicated, numerous scattered footprints with some infilling exposed, talus specimen. Scale equals 6 cm.

FIGURE 75

FIGURE 76

Catalogue Number: P2006.8.140 FIGURE 77.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave epirelief.

Analysis: Foot imprints left by several animals traveling in the same general direction, weathered, talus specimen. Scale equals 10 cm.

Catalogue Number: P2006.8.137 FIGURE 78.

Primary Trackmaker: Vertebrate aff. *Laoporus* sp.

Mode of Preservation: convex relief.

Analysis: Remnant of trackway displaying fore and hind foot imprints, digital impressions have trailing marks, heel impression also distinct, talus specimen. Scale equals 10 cm.

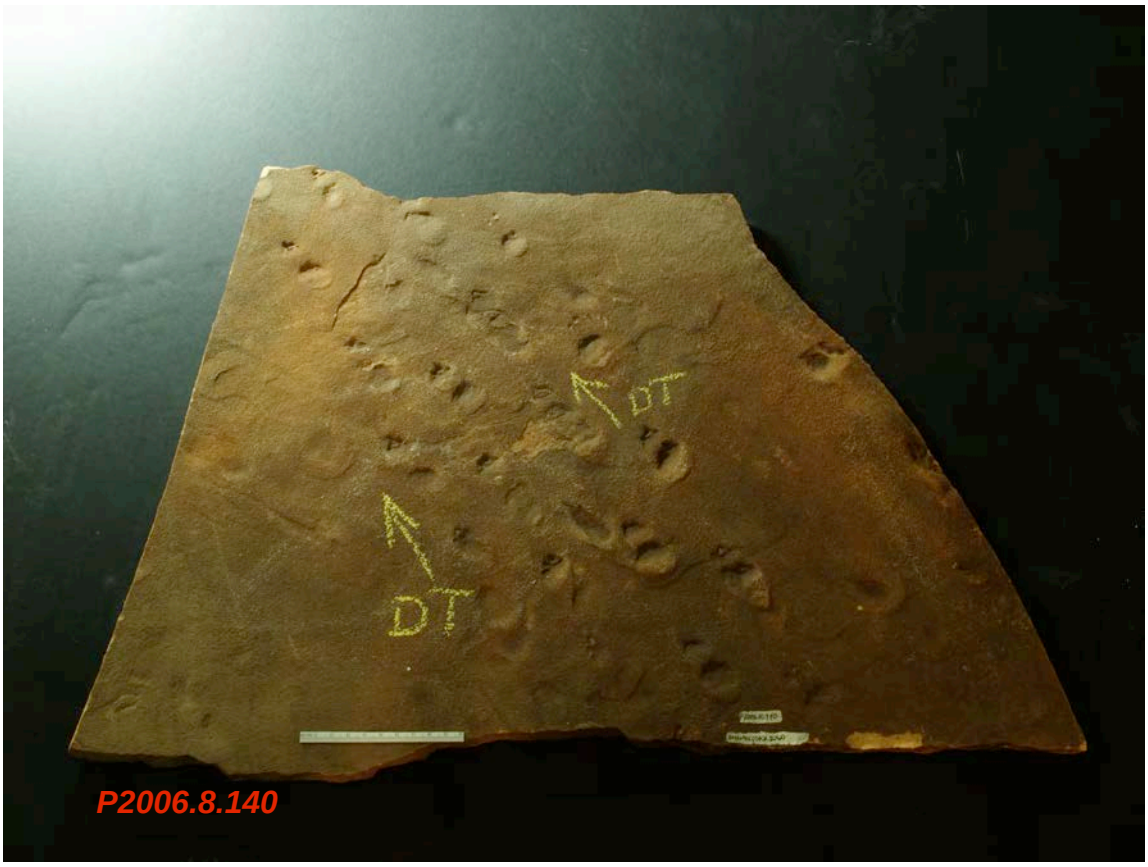

FIGURE 77

FIGURE 78

Catalogue Number: P2001.14.1 FIGURE 79.

Primary Trackmaker: Vertebrate.

Mode of Preservation: convex hyporelief.

Analysis: Continuous trackway of small animal for a length of 188 cm as preserved, maximum breadth of trackway 3 cm. Several other, larger trackways intersect the primary trackway. Sandstone plate approx. 188x90x9.5 cm.

FIGURE 79

Catalogue Number: P2006.8.3 FIGURE 80.

Primary Trackmaker: Vertebrate *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Large plate (slab) with a number of trackways all traveling in one general direction, “herd”. Most impressions clear and distinct, substrate is rippled surface, plate dimensions: approx. 120x90.8x2.6 cm. Reference: (Lockley and Hunt, 1995).

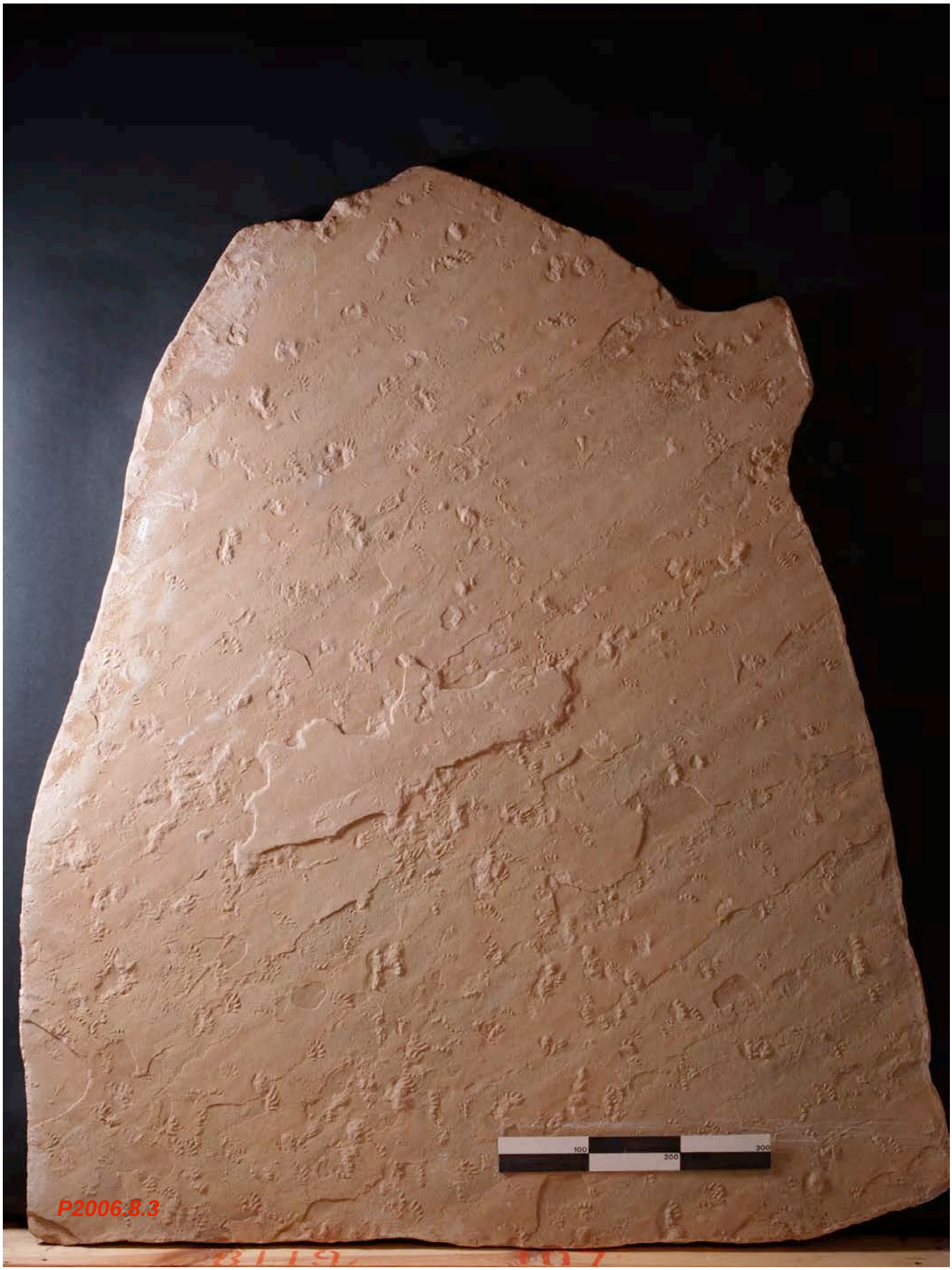

FIGURE 80

atalogue Number: P2006.8.100 FIGURE 81.

Primary Trackmaker: Vertebrate *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis: Large plate nearly covered with footprints, presenting the appearance of a “herd”. Arrow indicates direction of travel. (A.) indicates convex hyporelief of remnant of layer underlying the large plate.

FIGURE 81

Catalogue Number: P2006.8.149 FIGURE 82.

Primary Trackmaker: Vertebrate *Laoporus* sp.

Mode of Preservation: convex hyporelief.

Analysis Many foot tracks, individual trackways not easily determined, general trend of tracks indicated by arrow. Light area is calcified deposit.

FIGURE 82

III. MIXED ICHNOTAXA

Catalogue Number: P2000.6.2 FIGURE 83.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: Part and counterpart.

Analysis: The numerous imprints present on this specimen provide evidence of at least four distinct primary trackmakers. Each of the trackways is preserved in epi (lower) and hyporelief (upper) on part and counterpart plates. The sequence of trackway formation, which includes at least two invertebrates (1 and 2) and two vertebrates (3 and 4) is discussed below. Mixed ichnotaxa assemblages such as this are not uncommon in the Coconino Sandstone strata and indicate the abundance of life during the Lower Permian.

These tracks were not made concurrently; however, the sequence of their formation can be proposed. Clarity and completeness of these trackways indicate that there was a relatively short time lapse in their origins before infilling began. Subsequent deposition of sand produced the trackway infillings shown in the upper plate in convex relief.

A crude morphological classification for the chevron-like “prods” and parallel striae shown by (1) are reminiscent of the scorpion ichnogenus, *Paleohelcura*, which in this analysis, appears to have been made earlier than the other primary trails. (2) is regarded as the trackway of the spider ichnotaxon, aff. *Octoprodichnus* sp., and followed *Paleohelcura* in the sequence shown by overstepping by the former. (3) is identified as the ichnotaxon *Laoporus* sp., by its clear, continuous trackway displaying fore and hind foot pairs. This trackway overruns and interrupts the trails of *Paleohelcura* and *Octopodichnus* where they converge. (4) was the last trackway in this sequence. Time differences between the formation of each trackway is uncertain. The indistinct depressions left by trackmaker (4) obliterated parts of the prints of *Laoporus* (3) as well as parts of the tracks of the other forms.

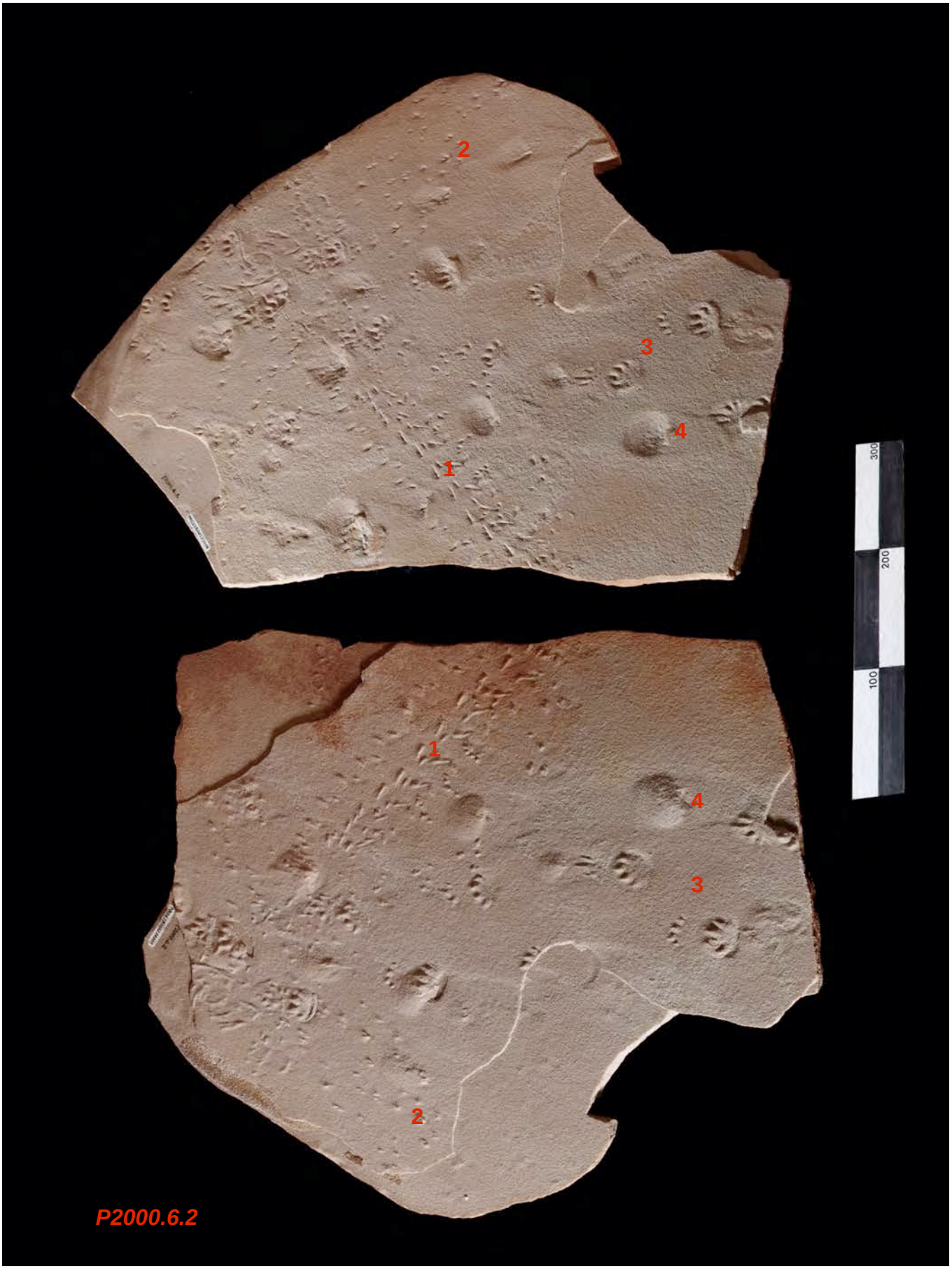

FIGURE 83

Catalogue Number: P2006.8.79 FIGURE 84.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: convex hyporelief.

Analysis: Tracks of at least two taxa (invertebrate: cf. *Octopodichnus* sp. and vertebrate: cf. *Laoporus* sp.). Scale equals 3 cm.

FIGURE 84

Catalogue Number: P87.7.58 FIGURE 85.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: concave epirelief.

Analysis: Trackway of small vertebrate *Laoporus* with clear prints (center of plate) showing long stride (5-6 cm), breadth equals 3.5 cm. Larger vertebrate indicated by widely spaced underprints right of track of *Laoporus*. "Ghost print" of undetermined invertebrate occurs along left side of plate. Scale equals 3 cm.

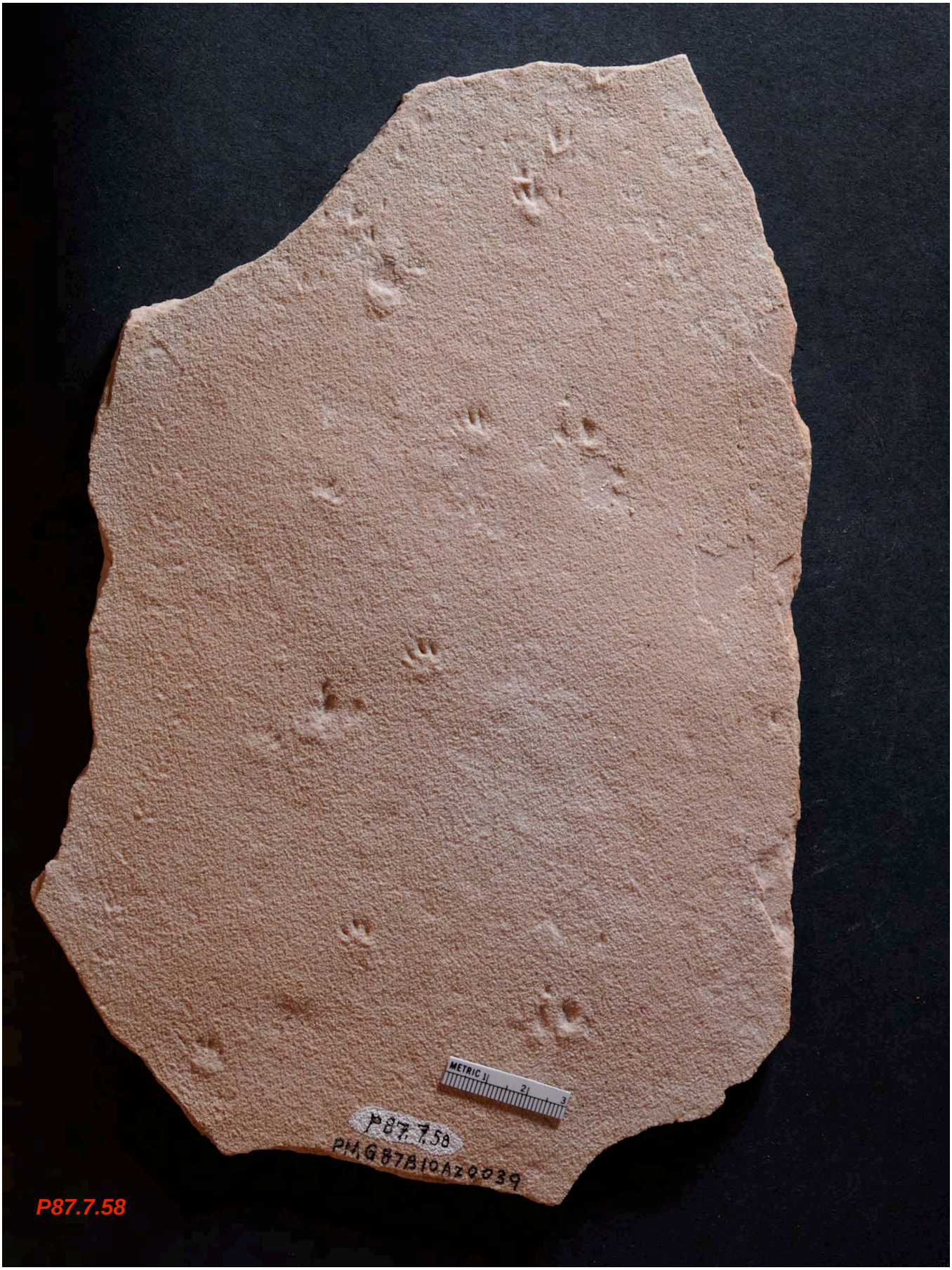

FIGURE 85

Catalogue Number: P92.3.1 ICHNOTYPE FIGURE 86.

J. M. Kramer, B. R. Erickson, M. G. Lockley, A. P. Hunt, and S. J. Braddy, 1995. Pelycosaur Predation In The Permian: Evidence From Laoporus Trackways From the Coconino Sandstone With Description of A New Species of Permichnium. In Lucas, S. G. and Heckert, A. B. (eds.). Early Permian footprints and facies. New Mexico Museum of Natural History and Science, Bulletin No. 6.

Mode of Preservation: Toponomical = preserved part & counterpart in epirelief and hyporelief.

Analysis: Epirelief trackways of *Permichnium coconinensis* (A) and *Laoporus* sp. (B) occurred concurrently as indicated by the "schuffle" marks (C) at their junction. The resulting interaction is interpreted as possible predation by *Laoporus*. Existing paleoenvironmental conditions were dry as further revealed by the "schuffle" marks which are sharply defined and lack of evidence of sand fluidity such as would be expected under subaqueous conditions. A second trackway of a smaller vertebrate (possibly *Laoporus*) (D) is also noted. Its time of occurrence however is uncertain and may have been the cause of the digression of the trackway of *Permichnium* at (E). Scale equals 10 cm.

FIGURE 86

Catalogue Number: P2000.6.1 FIGURE 87.

Primary Trackmaker: Invertebrate cf. *Permichnium* sp.

Mode of Preservation: concave epirelief.

Analysis: Long continuous trackway, partly infilled, associated with some other vertebrate tracks. Scale equals 10 cm.

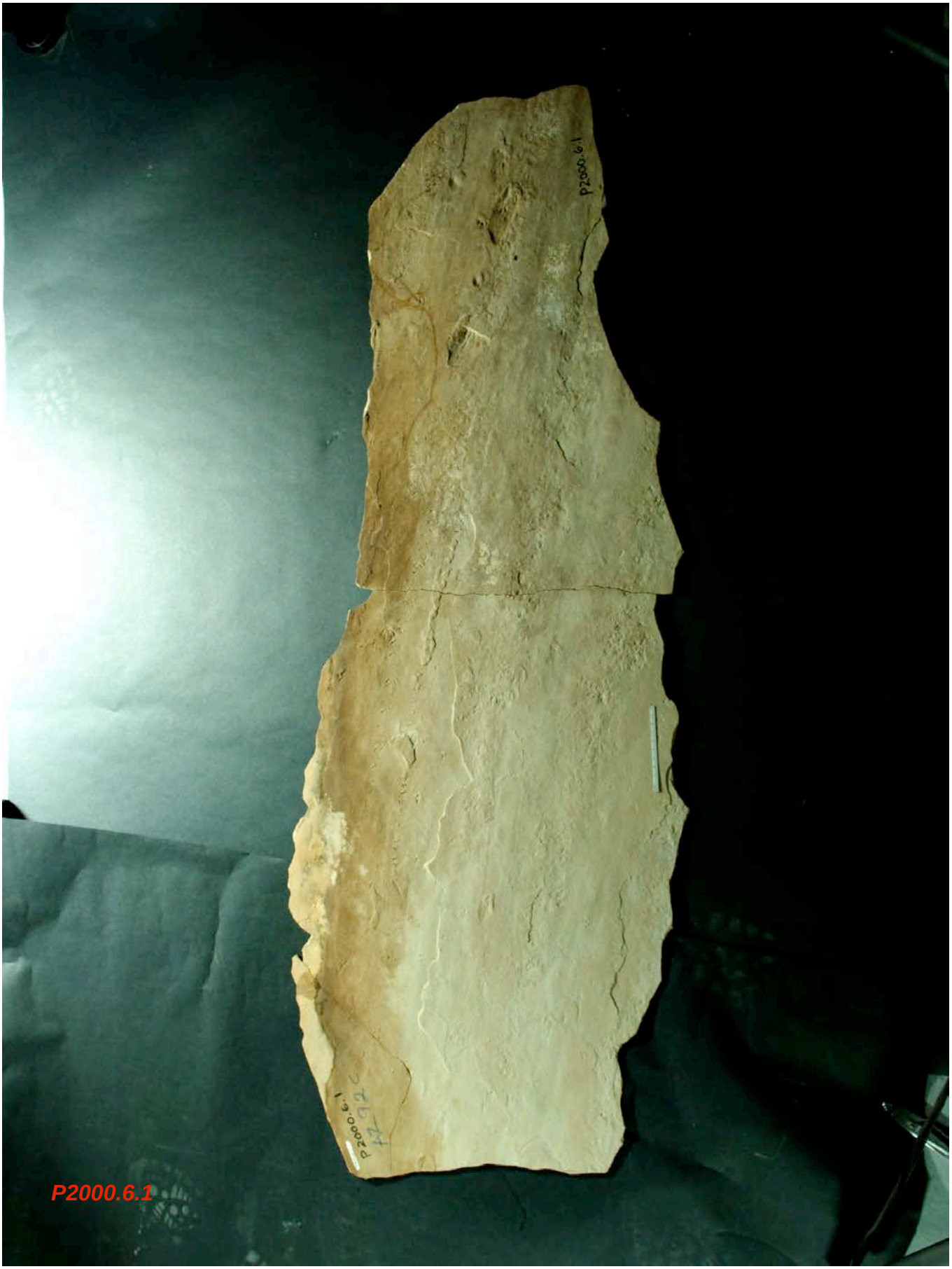

FIGURE 87

Catalogue Number: P2005.2.4 FIGURE 88.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: concave epirelief.

Analysis: Trackway of invertebrate with irregularly placed footprints, few indistinct associated tracks of probable vertebrate, talus specimen. Scale equals 3 cm.

Catalogue Number: P2006.8.1 FIGURE 89.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: concave epirelief.

Analysis: Partial trackway of invertebrate intersects trackway of undetermined vertebrate weathered talus specimen. Scale equals 3 cm.

FIGURE 88

FIGURE 89

Catalogue Number: P2006.8.9 FIGURE 90.

Primary Trackmaker: Vertebrate, *Laoporus* sp. and invertebrate, undet.

Mode of Preservation: convex hyporelief.

Analysis: Well-defined *Laoporus* prints showing claw trailing marks and associated invertebrate tracks representing either *Paleohelcura* sp. or *Octopodichnus* sp. or both. Cross-slope travel indicated. Scale equals 3 cm.

Catalogue Number: P2006.8.59 FIGURE 91.

Primary Trackmaker: Mixed assemblage.

Mode of Preservation: concave epirelief.

Analysis: Long sinuous invertebrate trackway runs the length of the plate cf. *Octopodichnu*s sp. vertebrate imprints enlarged and distorted because of the fluid consistency of the substrate, estimated breadth of vertebrate trackway 20 cm, invertebrate trackway breadth est. 4-5 cm. Scale equals 3 cm.

FIGURE 90

FIGURE 91

Catalogue Number: P2006.8.76 FIGURE 92.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: concave epirelief.

Analysis: Tracks of unknown taxa – two possible partial trackways inferred, surface eroded shortly after track formation. Scale equals 3 cm.

Catalogue Number: P2006.8.144 FIGURE 93.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: concave epirelief.

Analysis: Large vertebrate impressions partly infilled, invertebrate trackway on left is judged to have been made by cf. *Octopodichnus* sp. weathered, talus specimen. Scale equals 10 cm.

FIGURE 92

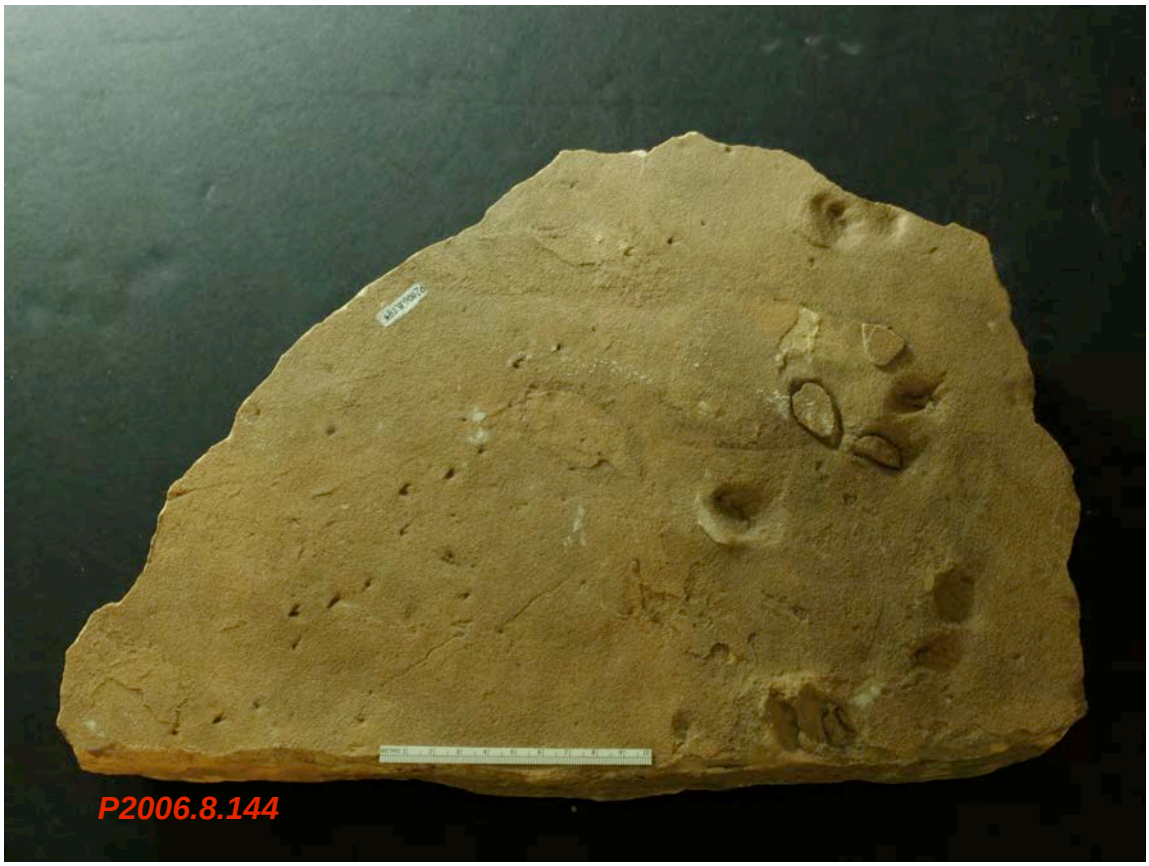

FIGURE 93

Catalogue Number: P2006.8.147 FIGURE 94.

Primary Trackmaker: Mixed taxa.

Mode of Preservation: Convex.

Analysis: Large vertebrate trackway mostly infilled, numerous scattered invertebrate podial imprints weathered, talus specimen. Scale equals 10 cm.

FIGURE 94

IV. PALEOENVIRONMENTAL TRACES

Catalogue Number: P2006.8.145 FIGURE 95.

Primary Trackmaker: Invertebrate undet., Rain drop prints.

Mode of Preservation: concave epirelief.

Analysis: A long trackway of small invertebrate in convex relief having well-developed podial imprints opposite one another is indicated. Intermittent imprints are present also in places along this trackway. These are less prominent but suggest the presence of several podials on either side of the trackmaker's body. An average maximum breadth of this trackway is 2 cm.

The ground surface over which the Trackmaker traveled is prominently marked by deep raindrop prints that were made in a fine-grained sand now a fine-grained sandstone indicates a subaerial event. The substrate holds various size raindrop impressions that are separated by wide spaces indicating only a light rain shower rather than a heavy rain. Overprinting of the trackway by raindrop depressions is shown. A few other incidental marks from invertebrate and vertebrate forms are present also in convex relief.

Plates included in this section exhibit evidence that emphasizes Lower Permian paleoenvironmental conditions. A few plates further show incidental traces of possible biogenetic origin. Scale equals 10 cm.

FIGURE 95

Catalogue Number: P97.1.6 FIGURE 96.

Primary Trackmaker: Rain prints/ripple marks.

Mode of Preservation: convex.

Analysis: Raindrop prints in more or less even rows indicate the crests or ridges of ripple marked surface, vermiform trail cross the plate normal to the ridges and troughs of the ripple pattern (near lower center of plate). Scale equals 10 cm.

FIGURE 96

Catalogue Number: P2005.2.5 FIGURE 97.

Primary Trackmaker: Rain prints.

Mode of Preservation: convex hyporelief.

Analysis: Raindrop prints modified either by wind or water movement, direction of flow indicated by sand trail on the lee sides of the raindrop prints. Scale equals 3 cm.

Catalogue Number: P2006.8.105 FIGURE 98.

Primary Trackmaker: Wind or water currents.

Mode of Preservation: convex relief.

Analysis: Irregular ridges and troughs formed in high and low relief either by wind or water movements. Scale equals 3 cm.

FIGURE 97

FIGURE 98

Catalogue Number: P2005.2.2 FIGURE 99.

Primary Trackmaker: Rain prints.

Mode of Preservation: Unknown.

Analysis: Two more or less parallel bands of raindrop prints on low profile ridges indicate ripple traces. Scale equals 3 cm.

Catalogue Number: P2006.8.122 FIGURE 100.

Primary Trackmaker: Rain prints.

Mode of Preservation: convex relief.

Analysis: Multiple well-defined raindrop “craters” with evidence of subsequent wind scouring. Scale equals 10 cm.

FIGURE 99

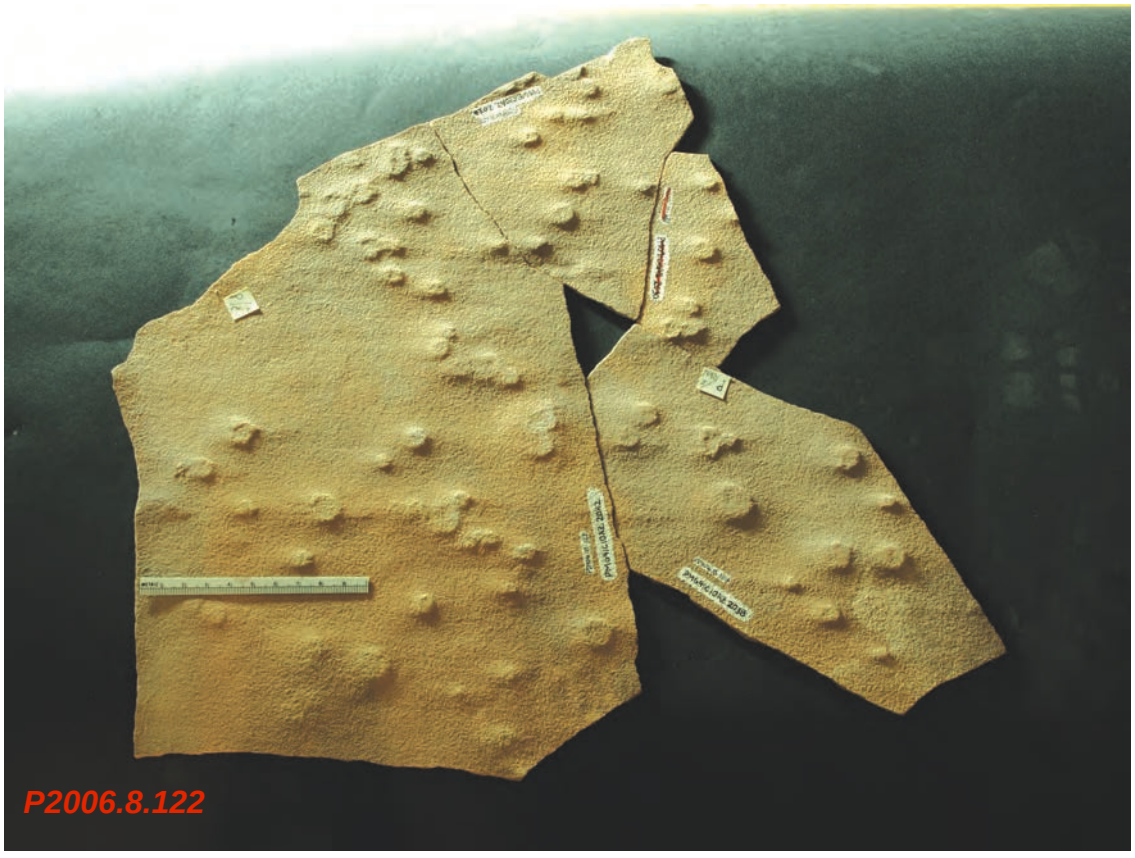

FIGURE 100

COCONINO SPECIMENS – VERTEBRATES/PALEO/PROBL

Catalogue Number: P2006.8.106 FIGURE 101.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: “Slump” feature across ripple pattern, recent lichen growth also on surface. Scale equals 3 cm.

Catalogue Number: P2006.8.108 FIGURE 102.

Primary Trackmaker: Vertebrate undet.

Mode of Preservation: concave epirelief.

Analysis: Tracks of vertebrate and invertebrate modified by flow pattern of substrate surface. Scale equals 3 cm.

Catalogue Number: P2006.8.110 FIGURE 103.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: “Slump face”. Scale equals 3 cm.

Catalogue Number: P2006.8.111 FIGURE 104.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: Ripple or slump features. Scale equals 3 cm.

FIGURE 101

FIGURE 102

FIGURE 103

FIGURE 104

COCONINO SPECIMENS – VERTEBRATES/PALEO/PROBL

Catalogue Number: P2006.8.116 FIGURE 105.

Primary Trackmaker: Rain prints.

Mode of Preservation: convex relief.

Analysis: Raindrop prints of various sizes. Scale equals 3 cm.

Catalogue Number: P2006.8.117 FIGURE 106.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: Possible raindrop prints obscured by uneven substrate. Scale equals 3 cm.

Catalogue Number: P2006.8.119 FIGURE 107.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: concave relief.

Analysis: Raindrop prints with elevated perimeters, some indication of wind or water scour. Scale equals 3 cm.

Catalogue Number: P2006.8.121 FIGURE 108.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: Possible slump (slip face) features. Scale equals 3 cm.

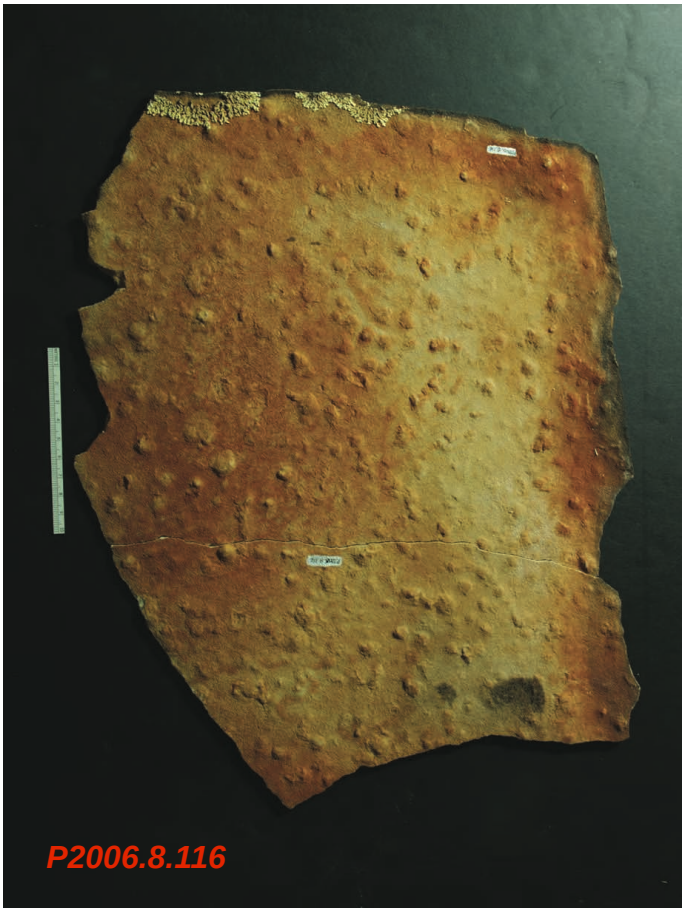

FIGURE 105

FIGURE 106

FIGURE 107

FIGURE 108

COCONINO SPECIMENS – VERTEBRATES/PALEO/PROBL

Catalogue Number: P2006.8.131 FIGURE 109.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: Ripple pattern, narrow bands on two laminae, weathered, talus specimen. Scale equals 3 cm.

Catalogue Number: P2006.8.133 FIGURE 110.

Mode of Preservation: concave relief.

Analysis: Multiple imprints randomly scattered over surface of plate. Scale equals 3 cm.

Catalogue Number: P2006.8.134 FIGURE 111.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: convex hyporelief.

Analysis: Raindrop prints and modified left margin of plate. Scale equals 3 cm.

Catalogue Number: P2006.8.135 FIGURE 112.

Primary Trackmaker: Environmental agent(s).

Mode of Preservation: Unknown.

Analysis: Surface of deep irregular ridges – slump or ripple marks. Scale equals 3 cm.

FIGURE 109

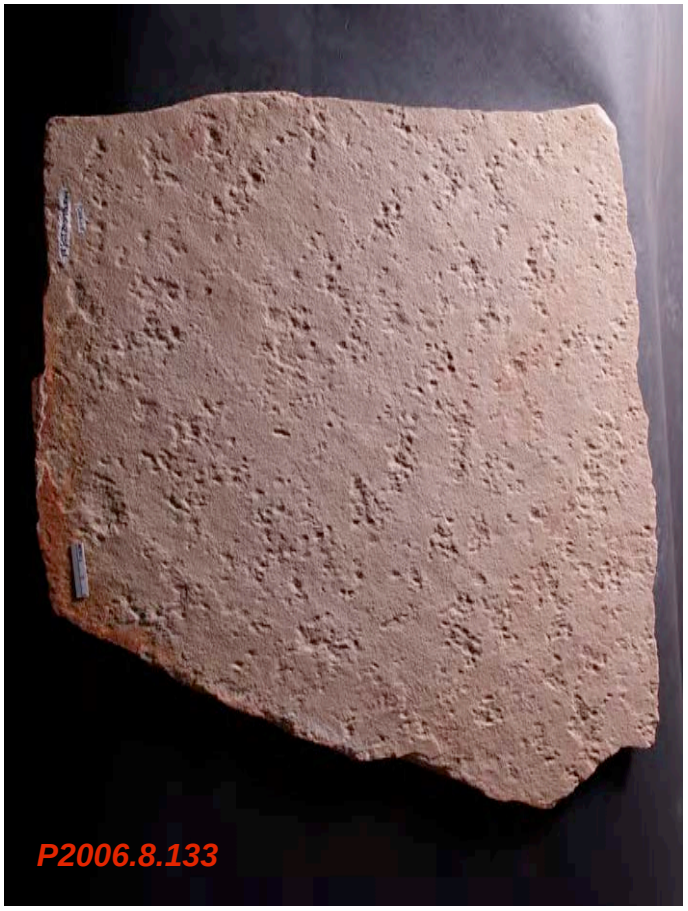

FIGURE 110

FIGURE 111

FIGURE 112

V. PROBLEMATICA

SMM P2003.9.4 and P2005.2.6 (Figure 113).

The two specimens in Figure 113 introduce the “Problematica” section, wherein traces of possible biogenic origin or evidence of other causes of sediment alteration are indicated.

P2003.9.4 (Top) has sinuous trails in convex relief, each with a central groove and a node-like termination. These trails are similar to the common ichnotaxon *Diplopodichnus* described by Brady (1947), which he compares to those of a recent milleped. These traces can be reasonably compared to various worm-like amphipod and gastropod trails (Chamberlain, 1975; Hakes 1976). Ethological classification may represent: crawling (Repichnia), feeding (Fodinichnia), and/or grazing (Pasciehnia) behavior.

P2005.2.6 (bottom) exhibits several ovoid depressions with short chevron-marked trails. These are similar to those described by Hakes (1976), as *Chevronichnus* with Lockeia at the end. Chevron marks associated with *Chevronichnus* however, point in the opposite direction as those associated with the present specimens.

A second trace on plate P2005.2.6, is a circular depression (arrow), indicating the opening of a burrow. The burrow continues through the sandstone plate of 4 cm thickness, at a slight angle, as indicated by its cross-section on the reverse of this plate. These traces are evidence of probable crawling (Repichnia), feeding (Fodinichnia) and in the case of the burrow, dwelling (Domichnia) behavior. Scale equals 3 cm for each specimen.

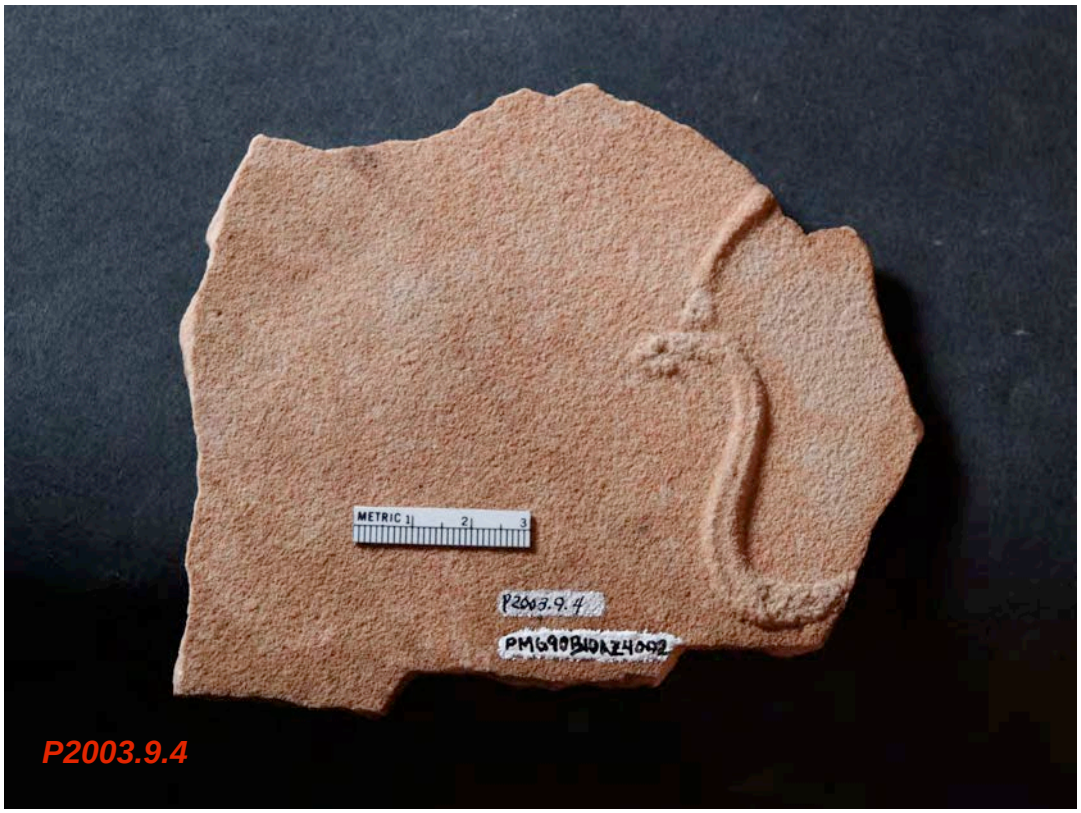

FIGURE 113

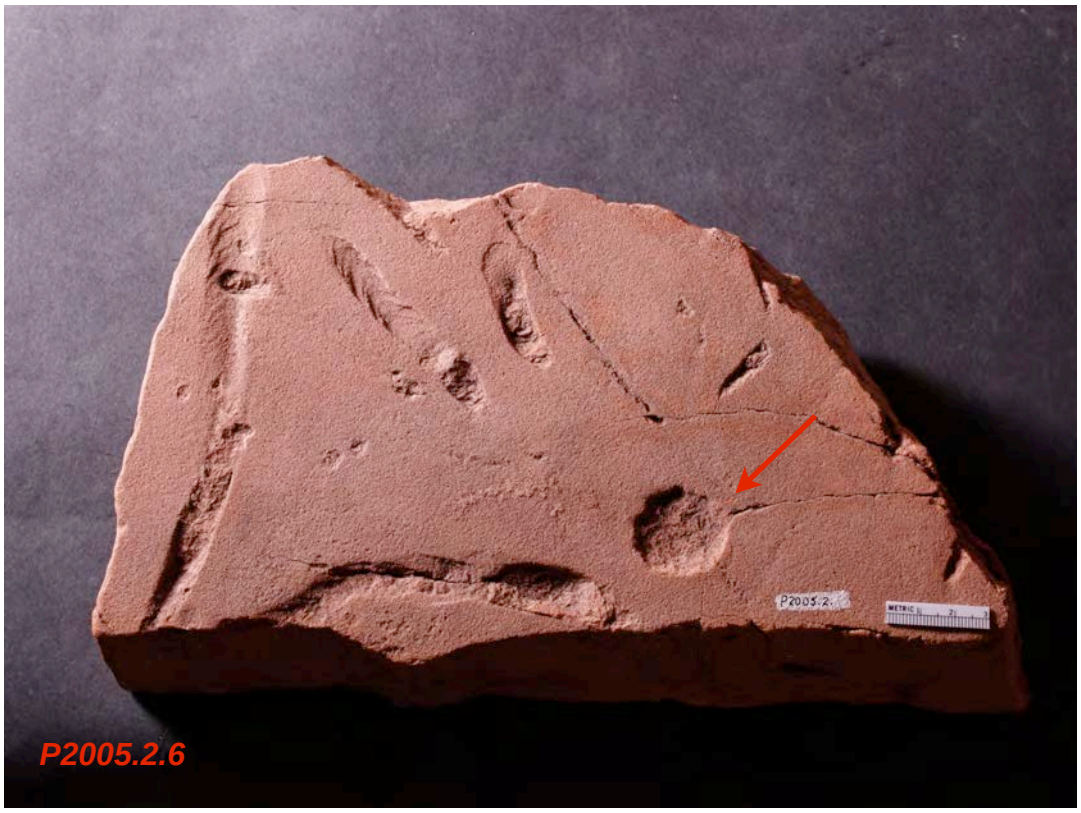

FIGURE 113

COCONINO SPECIMENS – VERTEBRATES/PALEO/PROBL

Catalogue Number: P87.7.28 FIGURE 114.

Primary Trackmaker: Unknown possible fecal mass.

Mode of Preservation: convex relief.

Analysis: Large amorphous form, 8x15 cm, substrate has pebbled surface, reverse side has infilled vertebrate tracks. Scale equals 3 cm.

Catalogue Number: P97.1.4 FIGURE 115.

Primary Trackmaker: Unknown.

Mode of Preservation: Unknown.

Analysis: Possible burrow section, 2.4 cm. dia. truncated. Scale equals 3 cm.

Catalogue Number: P2003.9.1 FIGURE 116.

Primary Trackmaker: Unknown, possible coprolites.

Mode of Preservation: convex relief.

Analysis: Two traces: one short globular, other elongate, sinuous. Scale equals 10 cm.

Catalogue Number: P2003.9.5 FIGURE 117.

Primary Trackmaker: Fracture filling.

Mode of Preservation: convex relief.

Analysis: Non-organism related, fractured ground surface filled by sediments. Scale equals 3 cm.

FIGURE 114

FIGURE 115

FIGURE 116

FIGURE 117

COCONINO SPECIMENS – VERTEBRATES/PALEO/PROBL

Catalogue Number: P2003.9.3 FIGURE 118.

Primary Trackmaker: Unknown.

Mode of Preservation: convex relief.

Analysis: Curved trail appears to end in burrow. Faint vertebrate feet impressions also present (upper right). Vermiform trail is similar to *Diplopodichnus* which is a deep ploughing, burrowing form (Brady, 1947). Scale equals 3 cm.

Catalogue Number: P2006.8.4 FIGURE 119.

Primary Trackmaker: Problematicum.

Mode of Preservation: concave relief.

Analysis: Imprints of unknown organism or event showing discontinuity of traces and “tic” marks, discontinuity suggests saltation of organisms or objects becoming airborne at times. Scale equals 3 cm.

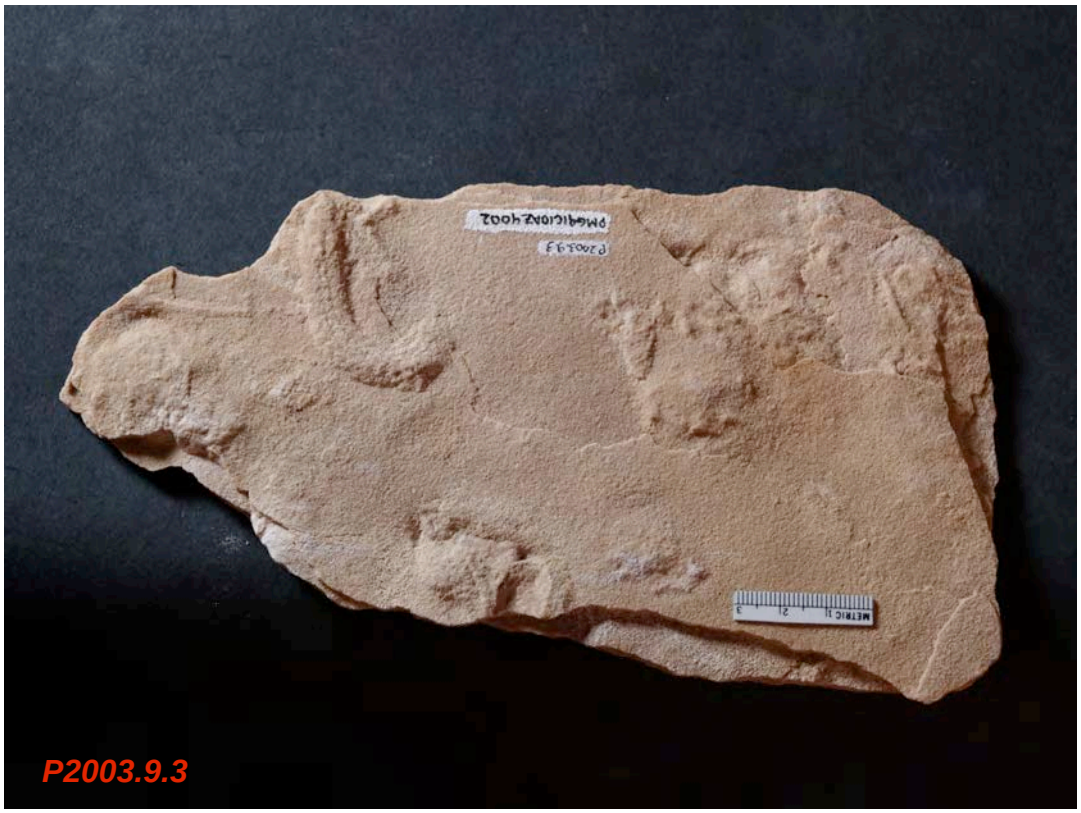

FIGURE 118

FIGURE 119

COCONINO GLOSSARY

aeolian – Derived, or caused, by the wind. Sometimes synonymous with subaerial.

down-slope – To move in direction of lower topographic relief.

epirelief – A relief surface in which the imprint is concave (original impression).

cross-bedding – A depositional structure which involves the truncating of one bedding plain by another at a different angle. Cross-beds are very common in sandstones, especially in Aeolian deposits.

cross-slope – To move across a slope.

Cubichnia – Resting trace.

Domichnia – Dwelling trace.

erg – A large terrestrial accumulation of loose, often mobile, sands and sand dunes.

Fodinichnia – Feeding structure.

hyporelief – A relief surface in which the imprint is convex (infilled side).

ichnofossil – Also referred to as *trace-fossil*. A track or trace of direct biologic activity which most often is not associated with body fossils. Ichnofossils may include: burrows, trails, footprints, coprolites.

Pascichnia – Grazing feature.

print – see track.

Repichnia – Crawling **trace**.

ripple – Referred to here as a wind or water created regular, sinuous and often coherent surface pattern formed during initial deposition of the Coconino sands. The morphology of ripples often is cited as an indicator or subaerial or subaqueous origin.

slump – Rock material that has slid down from high slopes.

subaerial – Refers to a terrestrial depositional environment that forms under essentially normal dry ("below air") conditions.

subaqueous – Refers to a depositional environment which forms below water.

track, trackway – Impression made by the weight of an animal bearing down on the surface of impressionable sediments. A "footprint". A trackway refers to a continuous series of these impressions.

underprint – A footprint or trail which is manifested as impressions in layers below that of the actual surface which the track maker was walking on.

up-slope – To move up hill.

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