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FOSSIL FOOTPRINTS FROM THE GRAND CANYON

(With Twelve Plates)

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INTRODUCTION

Tracks of extinct quadrupeds were first discovered in the Grand Canyon in 1915 by Prof. Charles Schuchert, and specimens collected by him at that time were made the basis of a short paper by Dr. R. S. Lull[1] in which were described two species, *Laoporus schucherti* and *L. nobeli,* from the Coconino sandstone.

In the summer of 1924, the locality was visited by Dr. John C. Merriam, president of the Carnegie Institution of Washington, who made a small collection of tracks which were later presented to the United States National Museum. While at the locality, Doctor Merriam conceived the idea of having a permanent exhibit of these footprints *in situ* on the Hermit Trail, to teach a lesson as to the great antiquity of the animal life that once roamed over these ancient sands—a lesson that could not fail to be understood by the veriest tyro in geological phenomena. This plan was presented to Hon. Stephen F. Mather, director of the National Park Service, who immediately became interested in the project, and, with the aid of friends of the Park Service, arrangements were perfected whereby, in the late fall of 1924, the writer was detailed to visit the locality and prepare such an exhibit, and at the same time to make a collection of the footprints for the United States National Museum. Both of these undertakings were successfully carried out.

The collection made for the Museum, consisting of a series of slabs some 1,700 pounds in weight and carrying a great variety of excellently preserved imprints, is of more than usual interest, especially in coming from a locality and formation in which but the two species of Ichnites mentioned above have been recognized previously. Even with the diversity of forms now secured, it is quite

[1] Amer. Journ. Sci., Ser. 4, Vol. 45, May, 1918, pp. 337-346, pls. 1-3.

apparent that all varieties to be found at this locality are not represented. It is upon this collection and the one made by Doctor Merriam earlier in the year that the present study is based.

FIELD EXHIBIT OF FOSSIL FOOTPRINTS

A preliminary survey of the locality on the Hermit Trail showed that the natural conditions were most favorable for the preparation of an exhibit of the tracks *in situ*. The rather steep slope of the cross-bedded sandstone on whose surface the tracks are impressed stands at an inclination of nearly 30 degrees facing toward the Trail, over which, in the course of a year, hundreds of tourists travel on mule back in making their pilgrimage to the bottom of the canyon. Furthermore, it was found that the upper superimposed layers or laminæ scaled off in large sheets, thus uncovering the tracks and trails beneath. The preparation of this exhibit required first the removal of the overburden of loose dirt and broken rock down to the more compact layers, and then the quarrying off of the loose upper laminæ until a solid and continuous face covered with footprints was reached. In this way a smooth surface 8 feet wide and 25 feet long was uncovered, as shown in plate 1, figure 1. The upper surface of this large slab has a great many tracks and trails leading up the slope, a few passing over and under the more or less horizontal strata shown at the top. At the side of the slab and leading up from the trail a flight of stone steps was laid in order to facilitate examination by those interested in a closer inspection of the footprints. At the base of this main exhibit, other large slabs lying close to the trail were similarly cleared off (see pl. 1, fig. 2), so that there are now several hundred square feet of rock surface forming a permanent exhibit of the various tracks and trails that are to be found here.

The great antiquity of these footprints, which occur from 900 to 1,080 feet below the level of the present rim of the canyon, is clearly demonstrated at this locality. It is obvious that since the day when those animals impressed their feet in what at that time was moist sand, more than 1,000 feet of rock-making materials were piled up in successive strata above them, and this does not take into account many hundreds of feet more that have been eroded off from the present top of the canyon wall. The great length of time required for the cutting away or erosion of the rock to form the deep canyon, and the even longer time necessary for the original deposition of this great vertical mass of stone is, when translated into terms of

years, if that were possible, so stupendous as to be almost beyond human comprehension.

It is hoped that the object lesson so graphically taught by this unique exhibit may serve as an example to stimulate the preparation and preservation of other natural phenomena to be found in our government-controlled parks, monuments, and reservations.

GEOLOGICAL OCCURRENCE

The Coconino sandstone of the Hermit Trail in which these tracks occur is considered Permian in age.[1] In this section it has a total thickness of 350 feet, but, so far as known, footprints are found only in the lower half. The greater part of the material here described was collected from one level about 150 feet above the base of the formation (see fig. 1). A few tracks were found at a level of 20 feet above the base, the lowest point at which imprints appeared. Between these two extremes, tracks were observed at several levels, and there is reason for believing that they may prevail continuously throughout the lower part of the sandstone. At the 150 foot level, tracks were traced laterally for a distance of 700 to 800 feet.

The Coconino sandstone is described by Noble as follows:[2]

> The Coconino sandstone is a pale-buff fine-grained cross-bedded sandstone whose distinctive features are its massive appearance, the huge scale of the cross-bedding, and the uniform fineness of the component grains of sand. The massiveness of the sandstone, which is due to the coarseness of the cross-bedding, causes it to weather into the highest and most precipitous cliff in the upper wall of the canyon.
>
> The formation is made up of lenticular beds, each of which is truncated by the bed above it in such a way that, as outlined in cross section or cliff faces, the beds commonly form irregular wedges whose sides are sweeping curves. Each wedge consists of innumerable thin inclined laminæ. Horizontal bedding is absent except near the base of the formation, where it is inconspicuous. . . . The laminæ form parallel curves that flatten downward. Commonly at the top of a wedge they are inclined at angles of 15° to 25°, or exceptionally 30°, but near the base of a wedge they bend and become horizontal or nearly horizontal.

The fossil tracks occur on the upper surface of these inclined laminæ. In removing the laminæ it was found that the underlying surfaces were often devoid of tracks, while the very next layer might be thickly covered. Sometimes as many as four distinct kinds of tracks were found on one surface. Some slabs were literally covered with imprints and curiously enough all pointed in the same direc-

[1] Noble, L. F., Prof. Paper 131, U. S. Geol. Surv., 1922, p. 26, pl. 19.

[2] *Op. cit.*, p. 66.

tion—up the steep slope of the sandstone layer, suggesting an old trail leading to the water, or possibly recording a great migration of animal life such as is occasionally known to take place among the animals of the present time. Of all the trails collected and the still greater number observed in the field, but one exception to the uphill movement was noted, this being the tracks of a large quadruped, which clearly pointed down the hill (see p. 30). In this connection it is interesting to quote from Sir William Jardine's *Ichnology of Annandale* (p. 5):

> It is a curious fact that nearly all the footprints are impressed as if the animal had walked from west to east or from where we presume water to have been toward the land.

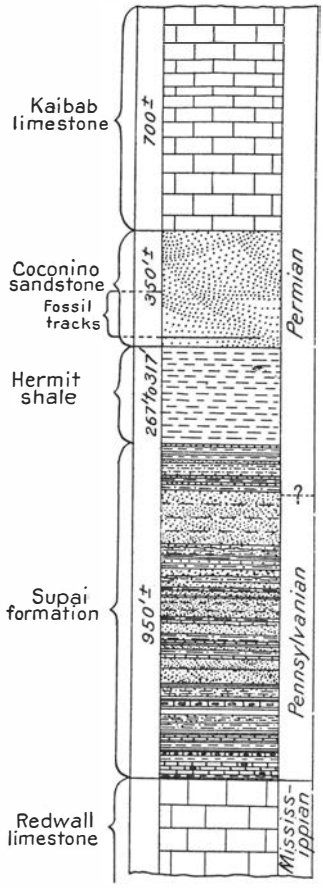


FIG. 1.—Upper part of the geological section at Hermit Trail. Position and extent of track-bearing strata indicated. Section (modified) after Noble.

No doubt tracks occur in the Coconino sandstone at many other localities, having been reported on the rocks near "Dripping Spring," also in the Hermit Basin, but the usual precipitous face of the formation, except in a few favorable places, does not permit searching for them.

Because of the many resemblances in structural and lithologic features to the De Chelly, Navajo, and Wingate sandstones, all of which Gregory[1] regards as most certainly comprised of dune deposits, Noble is of the opinion that the Coconino sandstone is essentially of æolian origin.

That the evidence afforded by footprints of extinct animals may, in the absence of other fossil criteria, be of value in the correlation of widely separated formations, seems to be indicated by the recognition of generically like, if not specifically similar, tracks found in the Coconino sandstone of the Grand Canyon

[1] Gregory, H. E., Prof. Paper 93, U. S. Geol. Surv., 1917, pp. 31-34, 53-55, 57-59.

and in the Lyons sandstone of Colorado. The latter is regarded by Henderson[1] as late Pennsylvanian, but Willis T. Lee, in an unpublished manuscript, reaches the conclusion that the sandstones carrying the footprints in Colorado are Permian, which would seem to be more nearly in accord with the evidence furnished by the fossil tracks. Doctor Lee, in a letter under date of June 18, 1925, has kindly furnished the following statement in advance of the publication of his paper:

> In this manuscript it is shown that the rocks formerly called Lyons include representatives of two distinct formations, one of Pennsylvanian age and one of Permian age and that the name Lyons sandstone is now restricted by the U. S. Geological Survey to the cross-bedded sandstone near Lyons, Colorado, which has been quarried extensively—that is, to the upper 100 feet of the rocks formerly called Lyons. The upper sandstone was found to overlap older formations and to be closely associated with rocks containing invertebrates believed to be of Permian age. These invertebrates are found in many places in limestone stratigraphically above the Lyons sandstone—that is, in the lower part of the Lykins formation. The Lyons sandstone as restricted is structurally more closely associated with the Lykins formation of probable Permian age than with the underlying Ingleside formation, of Pennsylvanian age, and is therefore regarded as Permian.

SYSTEMATIC DESCRIPTION OF GENERA AND SPECIES

The best preserved and most characteristic of the fossil footprints collected from the Hermit Trail are described in the following pages. The list of described forms might have been lengthened had it seemed wise to include all of the various kinds of imprints found, but in several instances the evidence was so meager as to deter one from the adoption of such a course. The possibility of acquiring still further material from this locality in the immediate future made it injudicious to describe tracks of which only a few imprints are known.

This study has resulted in the founding of a considerable number of new genera and species representing the only adequate Permian Ichnite fauna known from North America. Its chief value, however, is in recording a fauna which, as previously stated, may, in the absence of other fossil criteria, be of value in geological correlation. It has not been possible to place, with assurance, more than one or two of these newly described forms in a definite class. In a few instances suggestions are made as to the animal to which certain of the tracks may be attributed, but there now seems no possibility of definitely connecting them. Should there eventually be found a way of uniting the two lines of evidence, it is hoped that these tracks

[1] Henderson, Junius, Journ. Geol., Vol. 32, No. 3, 1924, p. 227.

may aid in bringing about a better understanding and interpretation of the habits and characteristics of the animals that made them.

Genus DOLICHOPODUS, new genus

Generic characters.—Quadrupedal. Pes long and narrow. Fourth digit long, slender, and curved outward. Three (?) toes in manus, which is placed behind and outside tracks of the pes. Toes acuminate, clawed, fifth digit of pes wanting. Feet turned strongly inward toward line of movement.

DOLICHOPODUS TETRADACTYLUS, new species

Plate 4, fig. 1

Type.—Catalogue number 11,123, U. S. N. M. A slab carrying a consecutive series of eight footprints.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (150 feet above base), Permian.

Description.—Stride about 230 mm.; width of trackway, 51 mm. *Hindfoot:* Four digits, fifth wanting, fourth long, slender, curved outward. Three inner digits progressively shortened. All toes acuminate except possibly the first. Heel rounded. Length of track 32 mm., width 15 mm. Length of digit I, 4 mm.; digit II, 5 mm.; digit III, 7 mm.; digit IV, 16 mm. *Forefoot:* Three (?) parallel digits, toes acuminate. Placed behind and outside hind foot.

The selected type of this species is a consecutive series of eight footprints divided equally between the fore- and hindfeet of the right and left sides of an animal walking in a straight course. The imprints made by the forefeet are so indistinct as to be visible only by special lighting, and this, combined with the narrow trackway and length of stride at first gave the impression that the track was made by a bipedal animal. These front impressions fall behind and outside of the deeper imprints of the hindfeet, and in an oblique light three short parallel digits are clearly discernible, the outer two being of equal length and sharply pointed. The inner toe is much shortened. The toes of both feet are directed strongly inward toward the median line of the trackway.

The striking feature of the more deeply impressed tracks of the hindfeet, which, by the way, are quite unlike any others yet found at this locality, is the presence of a long, slender fourth digit terminated by a sharp claw that curves outward. On the inner side

of this long toe distinct impressions of three digits which become progressively shortened toward the inner posterior side of the foot are to be noted in two of the tracks. The second and third toes are sharply pointed with a tendency to turn outward as does the fourth. The termination of the short first toe is imperfect but it seems to have a rounded end. It is strongly divergent and is directed straight inward at a right angle to the long axis of the foot. There is no evidence of a fifth digit, but if present it would certainly have been registered because of the depth of the foot impressions as a whole. All of the toes with the exception of the first of the hindfoot are directed forward in line of the course of movement.

The unusual feature of the tracks of the hindfeet being strongly in advance of those of the forefeet, the reverse of the usual condition, raises the question of their proper identification. The reasons for considering the deeply impressed tracks as having been made by the hindfeet are their larger size, narrower trackway, and deeper impression, for otherwise the weight of the body must have rested chiefly on the forefeet—an unreasonable supposition.

The impressions of the forefeet offer but little opportunity for comparison with described forms, but those of the hindfeet bear certain resemblances to the tracks

FIG. 2.—*Dolichopodus tetradactylus.* Type, No. 11,123. U. S. N. M. Diagram of series of footprints. About ½ natural size.

of *Dromopus agilis* Marsh, such as the long, curved fourth digit with curved claw, as shown in figure 3. The absence of a fifth toe on the outside of the foot, the reversed curvature of the digits, and the hindfoot impression behind the fore show, however, that the two sets of tracks were made by quite different animals.

The footprints of *Dolichopodus tetradactylus* appear to have been made by an active animal with long hind limbs and a comparatively light body. That this creature carried the greater part of its weight almost entirely upon the hind limbs seems to be shown by the great depth of the imprints made by the hindfeet.

FIG. 3.—*Dromopus agilis* Marsh. Diagram of left fore and hind footprints. ½ natural size. (After Marsh.)

A survey of the known vertebrate fauna of the Permian discloses only one form, *Araeoscelis,* which, in its structure, is suggestive of a type of animal that might make a trackway similar to the footprints under consideration. Perusal of Williston's osteological description shows that a complete pes of this animal is unknown, but the restoration (see fig. 4) shows a fifth digit. In commenting on the number of digits Williston says:[1]

> Only four metatarsals are preserved together in any one specimen, though the presence of the first tarsal would seem definitely to indicate the presence of the full five.

It would seem, therefore, that *Araeoscelis* must be ruled out of consideration as the maker of these tracks. On the other hand, the lack of evidence of a fifth toe in the tracks may be due to its failure to

[1] Williston, S. W., Journ. Geol., Vol. 22, 1914, p. 390.

impress, but the depth of the hindfoot impressions as a whole leads to the conclusion that this digit was probably absent. An important distinction is thus furnished also between *Dolichopodus* and *Dromopus* which in many other features closely approach each other. If correctly restored the feet of *Araeoscelis* fulfil nearly all requirements for their correlation with the footprints called *Dromopus agilis* by Marsh.

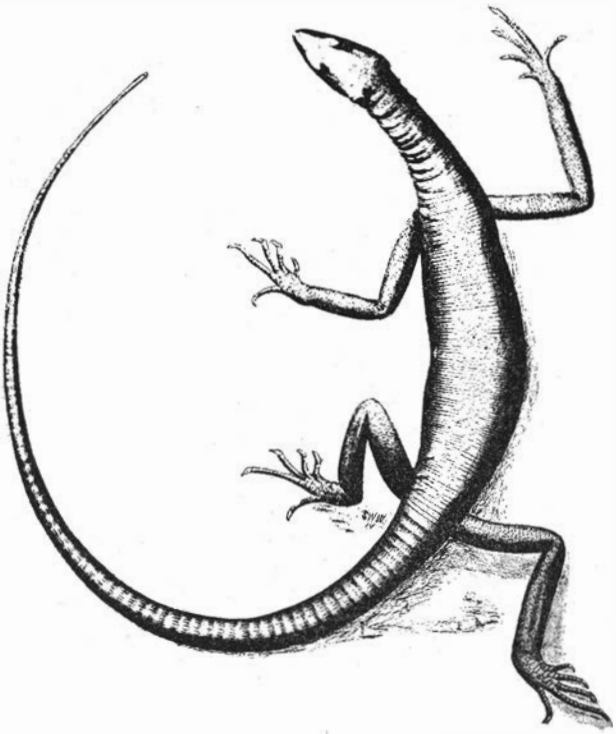


FIG. 4.—Restoration of *Araeoscelis*. An animal whose foot, limb, and body structure suggests the type of creature that made the tracks of *Dolichopodus*. About ¼ natural size. (After Williston.)

Resemblances in the general plan of the footprints here described to the feet of *Araeoscelis* leave but little doubt of their reptilian origin.

NANOPUS MERRIAMI, new species

Plate 4, fig. 2

Type.—Catalogue number 11,146, U. S. N. M. One slab (obverse) on which there is a consecutive series of tracks about 450 millimeters in length.

Type locality.—Hermit Basin, Hermit Trail, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 20 feet above the base), Permian.

Description.—Stride 62 mm., width of trackway, 50 mm. *Hindfoot:* Length 15 mm., width 12.7 mm.; four toes, the inner slender, sharp, and closely parallel to the second, the two median toes parallel

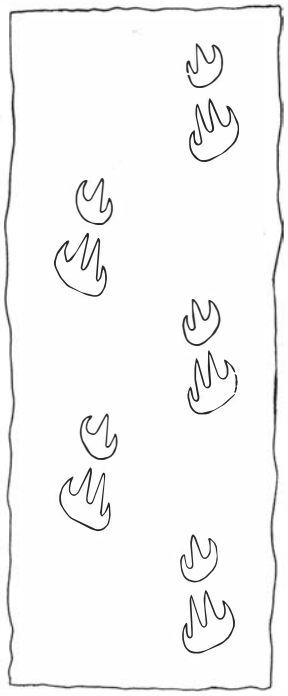


FIG. 5.—*Nanopus merriami.* Type, No. 11,146, U. S. N. M. Diagram of series of footprints. About ½ natural size.

and directed straight forward, tips acuminate, clawed. Outer toe shortened and well set off from the third. Sole suboval, weakly impressed, nearly as long as the toes. Length of digit I, 5 mm.; digit II, 7.5 mm.; digit III, 7.2 mm.; digit IV, 4.5 mm. *Forefoot:* Length about 11 mm., width 9.5 mm; three toes, outer slightly divergent, inner and outer digits shorter than median and subequal in length. Sole small, suboval, weakly impressed. Toes appear to bear slender, pointed claws. Length of digit I, 4.5 mm.; digit II, 6 mm.; digit III, 4.6 mm. The weight of the animal, judging from the depth of the

imprints of the feet, must have been about equally distributed between the fore and hind limbs.

The series of tracks selected as the type of the new species *Nanopus merriami* are of especial interest from the fact that they mark the lowest horizon in the Coconino sandstone where fossil footprints were found *in situ*. This level is about 20 feet above the base of the Coconino sandstone, or about 1,080 feet below the rim of the canyon. Only the obverse of the foot impressions was secured (see pl. 4, fig. 2), but a plaster cast shows the imprints as clearly as they were on the original rock surface.

The presence of three and four digits respectively on the manus and pes; parallel grouping of the two middle toes of the hindfoot, which are subequal in length; forefoot placed in front of the

FIG. 6.—*Nanopus caudatus* Marsh. Outline of left fore and hind footprints. Natural size. (After Marsh.)

hind; broadly rounded sole; and small size (see fig. 5) constitute a group of characters found in the genus *Nanopus*[1] from the Coal Measures of Kansas (fig. 6), a genus with which the present species seems to have its closest affinities. The genus *Barillopus* established by Matthew[2] upon footprints from the Coal Measures of Nova Scotia has a similar digital formula (see fig. 7) but the subequal length and parallel grouping of the three outer digits of the pes, the widely divergent toes of the manus, and the placing of the hindfoot upon the track of the fore, seem sufficient to show the distinctness of *Barillopus* from the footprints under consideration. The slenderness of the digits terminated with sharp claws in *Barillopus* are, however, more in accord with the present specimen than the heavy toes with rounded extremities without claws in the type of the genus *Nanopus*.

[1] Marsh, O. C., Amer. Journ. Sci., Vol. 48, 1894, p. 82, pl. 2, fig. 1, pl. 3, fig. 1.
[2] Matthew, G. F., Canadian Rec. Sci., Vol. 9, No. 2, 1903, p. 103.

After careful consideration of the characters briefly reviewed above, the weight of evidence seems to favor the reference of the present specimen to the genus *Nanopus*. Three species have previously been described, *N. caudatus* Marsh, *N. obtusus* Matthew, and *N. quadratus* Matthew.

The specific distinctness of *Nanopus merriami* from *N. caudatus* is shown by the more slender form of the digits terminated by sharp claws, relatively shorter soles, smaller size, and lack of tail trace. The last mentioned feature is probably unimportant, for the dragging of the tail must often have depended on the occupation of the animal. The lack of claws, strongly divergent outer toe, unequal length of the two middle digits of the pes, heavier digits, quadrate form of

FIG. 7.—*Barillopus arctus* Matthew. *a*, Left hindfoot; *b*, left forefoot. About twice natural size. (After Matthew.)

the sole, and forefoot placed behind the hind, effectually distinguish the Canadian species from *Nanopus merriami.*

No tracks referable to this species were found in the higher track-bearing levels of the Coconino sandstone, but larger collections are necessary before one can be assured that they are confined to the lowermost part.

Marsh was of the opinion that *Nanopus caudatus* in all probability favored a reference to the Amphibia, but the nature of the animal indicated by the impressions of *N. merriami,* although a matter of conjecture, might with equal probability be considered reptilian.

The species is named for Dr. John C. Merriam, president of the Carnegie Institution of Washington, who was instrumental in bringing about the arrangements whereby this excellent series of footprints was acquired for the national collections.

Genus LAOPORUS Lull

The genus *Laoporus* is characterized by Lull as follows:

Generic characters.—Quadrupedal, without tail trace, with four digits in the manus and five in the pes, semiplantigrade, broad-soled, with short digits which in the impressions lack phalangeal pads. Traces of claws appear to be present but they have no grasping predatory function. Feet turned inward toward the line of march.

Footprints of the genus *Laoporus* are found more commonly than any other at the Hermit Trail locality. The large slab shown in plate 1, figure 1, has nearly one-half of its surface literally covered with these tracks, and a second slab (see pl. 1, fig. 2) is similarly decorated.

The closest affinities of *Laoporus* seem to be with *Limnopus* Marsh[1] (see fig. 8), and while the latter has a similar digital formula, the heavy, thickened toes with rounded extremities apparently lacking claws, the strongly divergent fifth digit, and the overlapping of the hindfoot impressions on those of the forefoot, seem sufficient to distinguish this genus from *Laoporus*.

Lull[2] comments on the character of the animals making the tracks ascribed to *Laoporus* as follows:

The creatures which made the footprints were quadrupeds of moderate size, with broad, stumpy feet, apparently clawed, and having at least four toes in front and five behind. The hindfoot, which is somewhat larger, bore a proportionately greater share of the creature's weight, especially in the smaller species [*L. schucherti*]. The limbs were apparently short, with a wide trackway, implying a bulky body. No trace of a dragging tail is discernible on any of the specimens, and the body was carried clear of the ground.

These observations apply equally well to the new materials discussed in the following pages. At this time I see no way of definitely determining whether the impressions are amphibian or reptilian in origin.

LAOPORUS NOBELI Lull

Plate 5, fig. 2; plate 6

Laoporus nobeli, Lull, Amer. Journ. Sci., Vol. 45, 1918, pp. 339-341, pl. 2, text fig. 2.

A beautifully preserved trackway (No. 11,148, U. S. N. M.) from a level 150 feet above the base of the Coconino sandstone (see pl. 5, fig. 2) is identified as pertaining to *Laoporus nobeli* Lull,

[1] Marsh, O. C., Amer. Journ. Sci., Vol. 48, 1894, p. 82.
[2] Lull, R. S., Amer. Journ. Sci., Vol. 45, 1918, pp. 339-341.

and while none of the imprints have more than three toes registered, the close agreement in foot proportions, width of trackway, and length of stride all point to its affinities with the above mentioned genus and species.

As originally determined by Lull, *Laoporus* has four toes on the manus and five on the pes, this being fully substantiated by the paratype (No. 8422, U. S. N. M.) upon which the genus is partially based, and which has been of the greatest assistance in arriving at a proper identification of the recently acquired material. The shallowness of the prints on slab No. 11,148, U. S. National Museum, largely explains the absence of the missing toe impressions, and that there were other toes is evidenced by the lateral projection of the foot mass, entirely sufficient to have carried the proper number of additional digits.

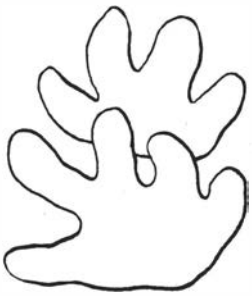


FIG. 8.—*Limnopus vagus* Marsh. Outline of fore and hind footprints of left side. Natural size. (After Marsh.)

A second slab (No. 11,122, U. S. N. M.) from the same level has on its surface a considerable number of footprints (see pl. 6) which also seem to belong to this genus and species. While these do not form a well-defined trackway, the clearness of many of the imprints contributes to a much better understanding of the detailed structure of the feet than has hitherto been obtained. All of the better impressed tracks are slightly larger than those of the type and other specimens, as may be seen by reference to the table of comparative measurements (p. 16), but those of the forefoot are almost identical in all other features with the paratype.

A study of the paratype in combination with these new specimens gives such a different conception of the plan of the feet from those depicted by Lull as to require a new drawing which is shown in figure 9. The manus, as clearly shown in the paratype, has only four digits, but they are distinctly separated at their bases, with a short, slender first digit and a slightly longer but divergent fourth. Digits

two and three are parallel, subequal in length, and distinctly separated. The palm is narrow antero-posteriorly, with the heel strongly rounded off toward the external side. In all of these respects the new material is in perfect accord with the excellent impression of the forefoot of the paratype, as shown in figure 9A. This figure was made from a cast, the specimen showing the obverse side of the imprint only.

The digits of the pes, instead of being short and blunt as originally depicted, are relatively long and distinctly separated. Only one of the footprints on the slab numbered 11,122 shows any evidence of a fifth toe (see fig. 9C) and its presence in the other tracks of this genus and species would be unsuspected if it were not for the

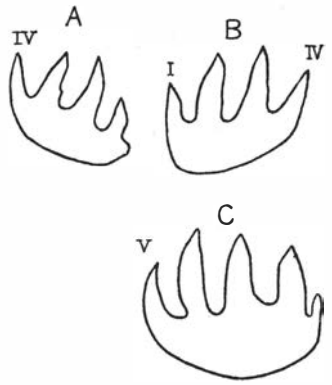


FIG. 9.—*Laoporus nobeli* Lull, *A*, Outline of left forefoot. Paratype, No. 8,422, U. S. N. M. *B, C*, Fore- (right) and hindfeet (left) of No. 11,122, U. S. N. M. All ¾ natural size.

claw drag showing five in the paratype. The evidence is conclusive in this respect, as first recognized by Lull, for where the creature dragged the hindfoot of the left side there are five distinct narrow scratches. The first toe, although relatively short, is distinct; the second, third, and fourth are of subequal length; the fifth is seldom plainly impressed. All are acuminate.

A critical examination of Lull's illustration of the type[1] specimen shows that the imprints are rather shallowly impressed and for that reason fail to give a true conception of the foot plan, especially as to the character of the digits. This will explain the great disparity existing between the original figures and the present conception (see fig. 9) based upon more abundant and better preserved specimens.

[1] *Loc. cit.*, pl. 2, fig. 1.

In addition to the specimens mentioned above, the collection contains numerous short series of tracks, none of which is worthy of special mention. In plate 9 is shown a trackway of *Laoporus nobeli* diagonally crossing that of *Baropezia eakini.*

COMPARATIVE MEASUREMENTS

	Type No. 2, 144 Yale Mus.	Paratype No. 8,422 U. S. N. M.	No. 11, 148 U. S. N. M.	No. 11, 122 U. S. N. M.
MANUS	*mm.*	*mm.*	*mm.*	*mm.*
Length	20.0	20.2	19.0	21.0
Width	21.0	22.5	23.0	25.0
Length of digit I	....	6.0	3.0	8.5
Length of digit II	....	12.5	9.0	13.0
Length of digit III	....	10.0	9.0	11.5
Length of digit IV	....	6.5	....	8.8
PES				
Length	22.0	24.0	24.0	26.0
Width	31.0	28.5	28.0	32.5
Length of digit I	....	....	....	5.0
Length of digit II	....	....	6.0	12.0
Length of digit III	....	....	10.0	12.5
Length of digit IV	....	....	10.5	15.0
Length of digit V	....	....	....	....
Length of stride	112.0	119.0	105.0	....
Width of trackway	....	100.0	104.0	....

LAOPORUS COLORADOENSIS (Henderson)

Plate 7, figs. 1, 2

Limnopus (?) coloradoensis Henderson, Junius, Journ. Geol., Vol. 32, No. 3, 1924, p. 228, figs. 1, 2, 3.

Through the courtesy of Prof. Junius Henderson of the University of Colorado, the type and figured specimens of *Limnopus ? coloradoensis* (Nos. 13238, 14140 and 14141, Univ. of Colo.) from the Lyons sandstone (*Permian*), Lyons, Colorado, were loaned me for study and comparison with the footprints from the Grand Canyon.

In the original description this species was questionably referred to the genus *Limnopus* founded by Marsh[1] upon tracks from the Coal Measures of Kansas. (See fig. 8.) The presence of five distinct digits in the pes and four in the manus, with traces of claws,

[1] Marsh, O. C., Amer. Journ. Sci., Vol. 48, 1894, p. 82.

lack of phalangeal pads, broad soles and feet turned inward toward the line of movement, with forefoot placed in front of the hind, are all features indicating its affinities with the genus *Laoporus*. The dimensions of the imprints, width of trackway, and length of stride indicate its closest affinities to be with the smaller of the two described species, *L. schucherti* Lull, but the distinct separation of the fifth digit from the fourth of the pes, and the shorter length of digits one and four of the manus appear to show its distinctness from that species.

A rather indistinct trackway (No. 11,176, U. S. N. M.) collected by Dr. J. C. Merriam at the Hermit Trail locality shows a few hind-foot impressions that, except for their larger size, are indistinguishable from those of *Laoporus coloradoensis,* to which species they are referred. (See pl. 7, fig. 1, and compare A and B, fig. 10.)

More abundant specimens may show that *L. coloradoensis* and *L. schucherti* are synonymous, in which event, on the ground of

FIG. 10.—*Laoporus coloradoensis* (Henderson). *A,* Outline of left hind footprint. Type, No. 13,238, University of Colorado. *B,* No. 11,176, U. S. N. M. The same side. Both ¾ natural size.

priority, the specific name *coloradoensis* must be abandoned. For the present it seems best to retain both names, even though they cannot be adequately distinguished.

Upon examination of the two slabs of footprints (Nos. 14,140 and 14,141, Univ. of Colo.) illustrated by Henderson[1] I am quite assured that they have been properly referred to *L. coloradoensis.* Specimen No. 14,140 has quite a different arrangement of the tracks in that they form a continuous series not set off in pairs as in the type and other figured specimen. The width of trackway, however, agrees with the other two. The change of gait may have been brought about as Henderson suggests, by the animal creeping up a steep bank where travel was difficult. All details of the imprints on these two referred slabs are obscure. The foot structure is well shown in the accompanying figures, and their proportions are given in the table of measurements.

[1] *Loc. cit.,* figs. 1 and 3.

COMPARATIVE MEASUREMENTS

	Type of *L. schucherti*	Type of *L. coloradoensis*	Specimen No. 11,176 U. S. N. M.
	mm.	*mm.*	*mm.*
Length of stride	73.8	85.0[a]	109.0[a]
Width of trackway	60.0	72.0	85.0
MANUS			
Width of impressions	16.8	16.8	19.0
Length of digit III	5.8	5.0	....
PES			
Width	21.0	20.0	27.0
Length to tip of digit III without claw	18.2	14.5	18.7
Length of digit I	4.8	4.0	4.0
Length of digit II	7.3	5.5	8.0
Length of digit III	8.5	8.0	8.5
Length of digit IV	12.2	9.0	9.8
Length of digit V	6.0	4.0	3.5
From tip to tip of outer digits	16.00	17.0	24.0

[a]=average.

Genus BAROPEZIA Matthew

This genus was founded by Matthew[1] on specimens from the Coal Measures of Nova Scotia and included two species, *Baropezia sydnensis* (Dawson) and *B. abcissa* Matthew. Footprints from the Grand Canyon have a considerable resemblance to those of *B. sydnensis* in size, triangular form of the imprints of the pes, and smaller manus with short, heavy toes radially arranged, and I therefore tentatively refer the following new species to this genus.

BAROPEZIA EAKINI, new species

Plates 8 and 9

Type.—Catalogue number 11,137, U. S. N. M. Consists of a short consecutive series of deeply impressed tracks of which the obverse side is also preserved.

Paratype.—Catalogue number 11,138, U. S. N. M. Consists of a large slab of consecutive tracks that are less deeply impressed than the type.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

[1] Matthew, G. F., Proc. and Trans. Roy. Soc. Canada, 2d Ser., Vol. 10, 1904, p. 100.

Geological occurrence.—Coconino sandstone (150 feet above base), Permian.

Description.—Stride about 123 mm.; width of trackway about 144 mm. *Hindfoot:* Length 44 mm.; width 51 mm. Sole subtriangular, deeply impressed in type. There were five distinct subequal toes; digits short, with broadly rounded terminations without trace of claws, though there may have been a bluntly rounded nail. Fifth digit slightly divergent. *Forefoot:* Length about 28 mm.; width about 47 mm. Sole suboval, inside and front most deeply impressed. Five distinct radially arranged toes, and, as in the pes, short with

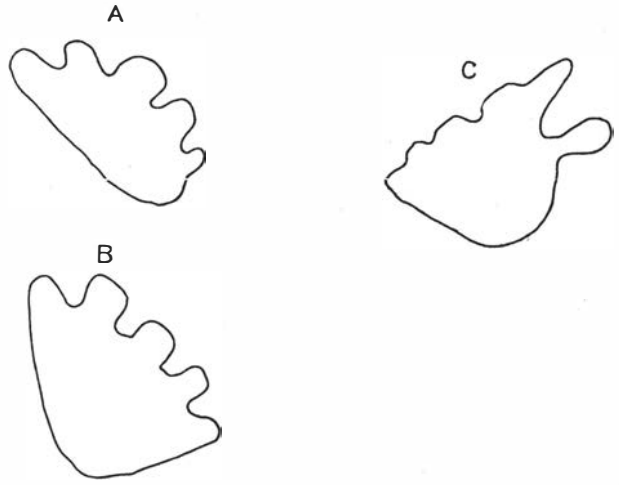


FIG. 11.—*Baropezia eakini.* Outline of footprints showing width of trackway and relative positions. Type, No. 11,137, U. S. N. M. *A,* Left forefoot; *B,* left hindfoot; *C,* right hindfoot showing deformed fourth and fifth digits. About ½ natural size.

bluntly rounded extremities, first much reduced, others apparently subequal in size; fourth and fifth divergent.

This species has the print of five toes on the hindfoot and apparently five on the fore. The tracks made by the hindfoot of the right side differ so from those of the left (compare fig. 11 and pl. 8) as to clearly indicate that the right has suffered injury causing two toes, the fourth and fifth, to protrude prominently outward from the side of the foot. This same peculiarity, though less distinctly indicated, is noted in the paratype (pl. 9) which leads to the conclusion that both series of tracks were made by the same individual. The paratype, a beautifully preserved trackway, is a striking example of the unreliability of the information to be obtained from fossil foot-

prints, even when the tracks seem to be fairly well impressed. Of more than 30 distinct tracks, none registers more than three toes, and were it not for the deformity of the toes of the right hindfoot, showing that the tracks of both type and paratype were made by the same animal, there might be some doubt as to their reference to the same species.

The digital formulæ of *B. sydnensis* and *B. abcissa* (figs. 12 and 13) as determined by Matthew, are 4-3 and 4-4 respectively. That

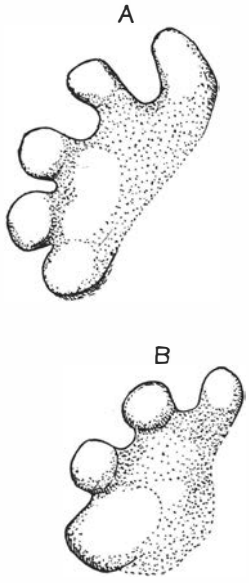


FIG. 12.—*Baropezia sydnensis* (Dawson). *A*, Mould of right forefoot; *B*, mould of right hindfoot. ½ natural size. (After Matthew.)

both may have additional toes which did not register seems quite probable, especially in the light of the two series of tracks discussed above. That Matthew was cognizant of such a possibility is indicated by his comment on the pes of *B. sydnensis* that "the first digit may be potentially present." Considered from the evidence furnished by this new material, it would seem quite certain that *B. sydnensis* has a formula of 5 and 4 digits instead of 4 and 3. There is also reason for thinking that Matthew may have been mistaken in his identification of the relative positions of the two tracks. In the narrowness, fore and aft, of the sole impression, the divergence of digit one, and in the relative size and arrangement of the other

digits, the imprint called *hindfoot* by Matthew certainly bears a closer resemblance to the track of the manus in *B. eakini* than to that of the pes. Furthermore, the subtriangular sole of the so-called

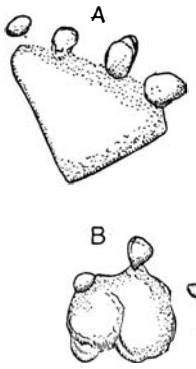


FIG. 13.—*Baropezia abcissa* Matthew. *A,* Mould of right hind-foot; *B,* mould of left forefoot. ½ natural size. (After Matthew.)

forefoot has its nearest counterpart in the pes of *B. eakini.* For these reasons it would appear that *B. sydnensis* also agrees with *B. eakini* in planting the forefoot in front of the hind instead of behind it as originally determined by Matthew.

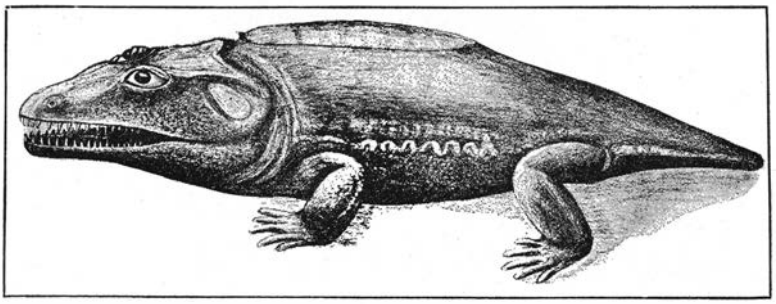


FIG. 14.—Restoration of *Cacops aspidephorus* Williston, a stego-cephalian amphibian from the Permian of Texas. (After Williston.)

The average distance between fore and hind tracks of the same side of *B. eakini* is about 16 millimeters. The feet turn in strongly toward the median line of the trackway. The front of the feet is always deepest impressed, probably because the animal was climbing a slope, an inference substantiated by the flow structure behind the tracks made by the material displaced by the feet. The toes of

both fore- and hindfeet are short and rounded without trace of claws, though they may have been terminated by blunt, rounded nails. In all, there are on the two slabs 45 tracks about equally divided among the four feet of the animal.

The creature making these tracks was apparently a short, squat quadruped with a wide body, and evidently slow of movement as indicated by the short stride. There is no evidence of a tail drag on

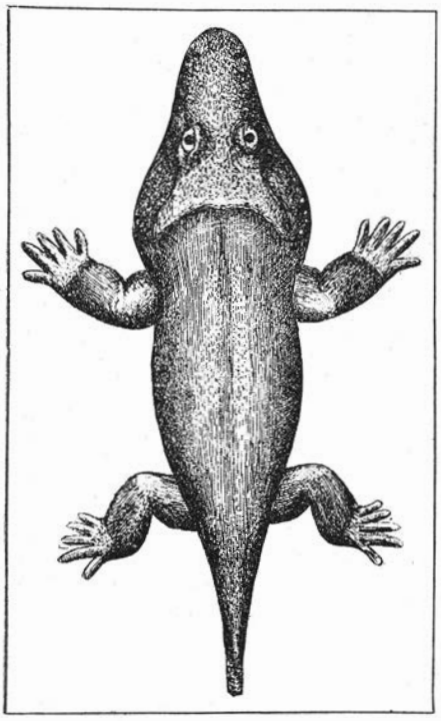


FIG. 15.—Restoration of *Trematops milleri* Williston. An amphibian from the Permian of Texas. (After Williston.)

either of the slabs. The forefoot impression is always placed in front and slightly outside the hind.

In reviewing the known Permian animals in search of the possible makers of these tracks, two forms were found, *Cacops aspidephorus* and *Trematops milleri*,[1] either of which appears to have the proper proportions to leave a trackway similar to the one under discussion, both being relatively short, wide bodied creatures with short, stubby tails and large five-toed feet without claws (see figs.

[1] Williston, S. W., Journ. Geol., Vol. 22, 1914, pp. 61-62.

14, 15). Either of these animals would seem to fulfil all requirements in so far as the character of an animal can be visualized from a study of its tracks. The absence of a tail drag would also be accounted for by the presence of this short, stubby tail. According to Williston, *Cacops* has a length over all of about 20 inches, whereas *Trematops* is 36 inches long. If the above suggested correlation has any merit whatsoever, these tracks are at once placed as belonging to the stegocephalian branch of the Amphibia.

The specific name of *Baropezia eakini* is in honor of Mr. J. R. Eakin, superintendent of the Grand Canyon National Park, whose generous assistance contributed so much to the success in making this collection of fossil tracks.

Genus AGOSTOPUS, new genus

Generic characters.—Quadrupedal with five digits in the manus and four in the pes; plantigrade; broad soled with three clawed digits in the pes. Feet directed inward, hindfoot placed in front of forefoot impressions. Short limbed, wide bodied.

AGOSTOPUS MATHERI, new species

Plate 10

Type.—Catalogue number 11,135, U. S. N. M. Consists of a trackway some 700 millimeters in length, showing consecutive imprints of all the four feet.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (150 feet above the base), Permian.

Description.—Length of stride, 134 mm.; width of trackway, 199 mm. *Hindfoot:* Length about 67 mm., width 65 mm. Sole broad, palmate, quadrately rounded, longer than digits. Four digits, median two curved outward, outer three acuminate, probably terminated by sharp claws. First digit short, heavy, obtusely rounded, without claw. Length of digits, I=4 mm., II=18 mm., III=22 mm., IV=18 mm. *Forefoot:* Length (estimated) 35 mm., width about 63 mm. Sole suboval, smaller than hindfoot; apparently five short digits, fifth reduced and projecting outward at a right angle to the long axis of the foot.

In addition to the slab of footprints selected as the type, the collection contains two slabs (Nos. 11,133 and 11,150) pertaining to this species. The imprints, especially of the hindfeet, are clearly pre-

served, but the toes of the forefeet are usually cut off by the flow of sand crowded out by the heel of the hindfoot, thus destroying the evidence for a positive determination of the length of the toes of the manus.

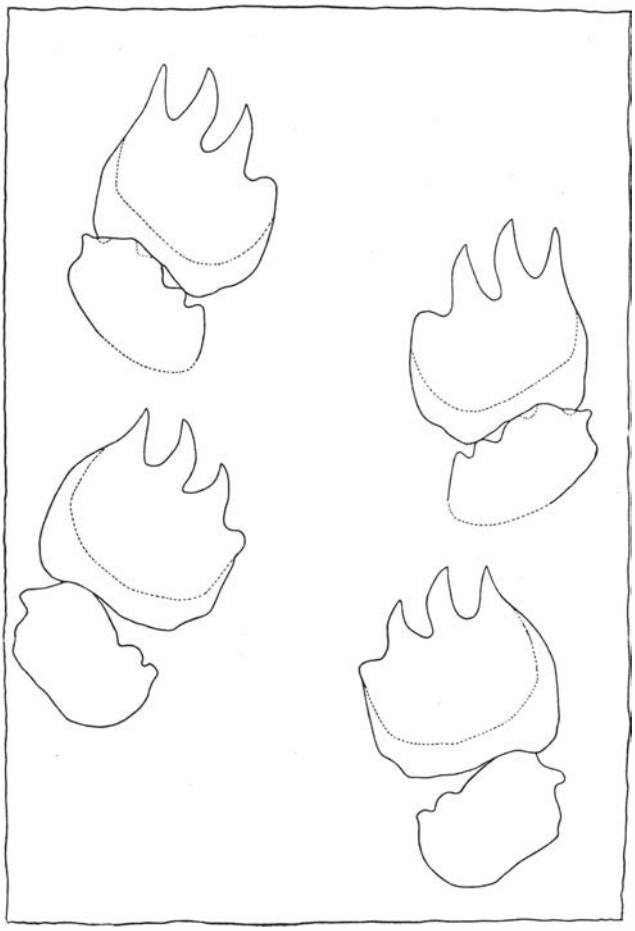


FIG. 16.—*Agostopus matheri.* Type, No. 11,135, U. S. N. M. Diagram of trackway. $\frac{1}{3}$ natural size.

In the presence of four toes on the hindfoot and five on the fore, these tracks closely resemble *Megapezia pineoi*[1] from the Lower Carboniferous of Nova Scotia, but here their similarity practically ends, since they differ so much in size, length and arrangement of

[1] Matthew, G. F., Proc. and Trans. Roy. Soc. Canada, 2d Ser., Vol. 10, 1904, pp. 102-104, pl. 2, figs. 4-4a.

the digits, and in the proportions and shape of the sole as to fully indicate their generic distinctness. It therefore becomes necessary to erect a new genus for their reception and the name *Agostopus matheri* is proposed. The specific name is for Hon. Stephen F. Mather, director of the National Park Service, whose personal interest was so largely responsible for the opportunity of making this important collection of fossil footprints.

The stride is comparatively short for so large an animal and the steps, as well as the width between the right and left rows, are remarkably uniform. The forefoot is placed behind and a little outside the line of tracks made by the hindfoot. The heel seems to be broadly rounded, as indicated by the broken line shown in figure 16. The heavier outer line of the pes tracks represents the outline of the disturbed sand which was pressed out by the impact of the foot. All of the tracks show distinct imprints of the soles, as may be seen in plate 10.

Inasmuch as the hindfoot is set partly on the toe marks of the antecedent impression of the forefoot, it resembles *Barillopus* Matthew, but its much larger size, sole longer than digits, different digital formula, and lack of tail mark at once distinguish it from that genus.

On the forefoot there are apparently five toes, all of which appear to be short. In arriving at the number of digits it was assumed that the divergent projection on the outside of the imprint represents a fifth toe. Such a protuberance is present in several of the tracks though there is a variation in shape and size, as indicated in figure 16.

Both fore- and hindfeet turn inward toward the center of the line of march. The creature making these tracks was evidently a short-legged, wide-bodied animal, apparently of sluggish habits.

Genus PALAEOPUS, new genus

Generic characters.—Quadrupedal, hindfoot somewhat the larger, always most deeply impressed. Five digits in pes, three or more in manus. Manus in direct line of pes tracks. Sole longer than toes. Broad, short toes without a trace of claws. Feet directed straight forward. Long limbed with regular stride.

PALAEOPUS REGULARIS, new species

Plate 5, fig. 1

Type.—Catalogue number 11,143, U. S. N. M. Slab containing a straight series of tracks of a single individual 1,200 millimeters in length.

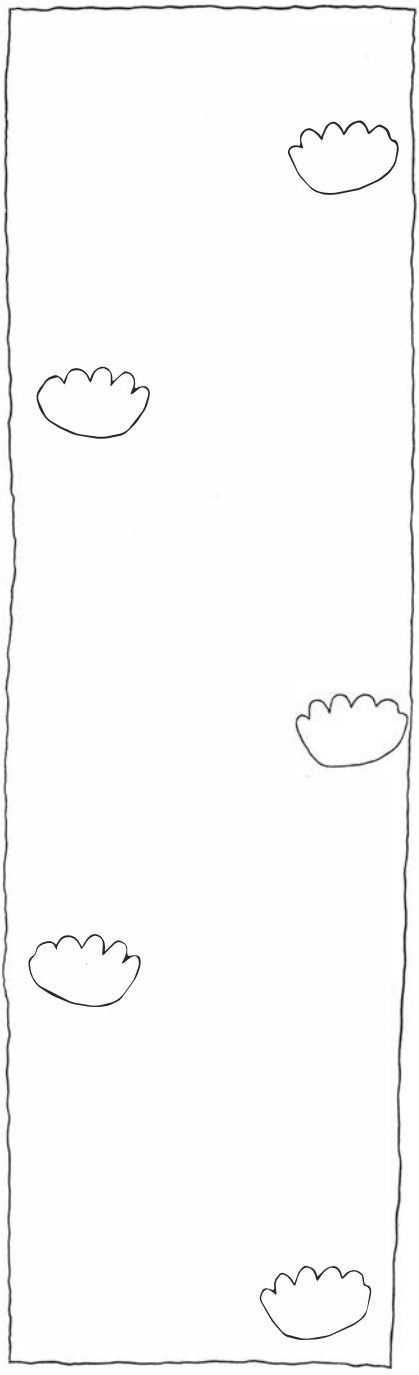


FIG. 17.—*Palaeopus regularis.* Type, No. 11,143, U. S. N. M. Diagram of trackway. ½ natural size.

Paratype.—Catalogue number 11,144, U. S. N. M. Obverse slab on which is a consecutive series of footprints 1,330 millimeters in length. The reverse of this series is a slab in the museum at the Grand Canyon National Park.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 150 feet above base), Permian.

Description.—Comparative measurements of the type and paratype show a fairly close agreement except in the length of stride, which is 152 millimeters in the type and 106 in the paratype, the width of trackway being 100 millimeters in both. *Hindfoot:* Length, 15 mm. in both type and paratype, width, 28.5 mm. in type, 25 mm. in paratype. Stumpy and larger than manus, and with five toes, short and without claws. Directed straight forward, often overlapping track of manus. *Forefoot:* Length of type, 11 mm., paratype, 10 mm.; width, type 20 mm., paratype 19.5 mm. Smaller and more shallowly impressed than pes, and with three (?) toes, short and without claws. Placed directly in line with hindfoot.

The trail made by this species is distinctive on account of the straight trackway and precise regularity of the imprints, especially those made by the hindfeet. The paratype was origi-

nally a slab 9 feet in length, the trackway extending the full length without the slightest deviation to the right or left.

The forefoot impressions are usually dimly impressed or absent. In many places on the type slab this is due to the hindfoot having been placed directly on top of the fore, thus obliterating the imprint. Often, however, only the posterior half is thus wiped out. In the paratype the hindfoot is shown falling in advance of the fore, evidently caused by a slower gait and slightly shorter stride. Judging from the relative depth of the impressions of the fore- and hindfeet, the greater part of the weight of the animal was borne by the latter. The ratio of foot length to length of stride is about 1 to 8.

The feet were broad and stumpy with digits largely buried in the mass of the foot. A few of the impressions made by the pes show five short, rounded toes (fig. 17). None of the forefoot impressions of the type gives any idea of the number of digits, but in the paratype a few are suggestive of the presence of at least three.

On the type slab (see pl. 5, fig. 1, reproduced from a photograph) a few shallow, half obliterated footprints of the manus may be seen immediately in advance of those of the pes; in the paratype the imprints of the manus fall behind those of the pes.

The creature making these tracks was evidently narrow-bodied, with long legs, and walked with an upright, mammalian-like stride. Such an arrangement of quadrupedal tracks could be accounted for only in this way. The straightness of the trackway and regularity of the stride at once distinguishes the trail of *Palaeopus regularis* from all others found at the locality.

Genus BARYPODUS, new genus

Generic characters.—Quadrupedal, with three digits in both manus and pes. Digits long, nearly parallel, well separated; appear to be joined by web. Sole subquadrate, longer than digits. Forefoot placed well forward of hind, both turned strongly inward.

BARYPODUS PALMATUS, new species

Plate 11, fig. 1

Type.—Catalogue number 11,134, U. S. N. M. Consists of a slab on which are single impressions of a fore- and hindfoot.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (150 feet above base), Permian.

Description.—Length of stride unknown. *Hindfoot:* Length, 115 mm., width, 87 mm.; sole palmate, longer than toes and longer than wide. Three toes, long, directed forward, and apparently without claws. Length of first digit, 37 mm.; second, 54 mm.; third, 38 mm. First digit slightly divergent, third protrudes slightly beyond the border of the web. *Forefoot:* Length, 108 mm., width, 58 mm. Outline of foot semi-rectangular with a distinct blunt, hook-like protuberance on inner posterior angle of heel. There seem to be three

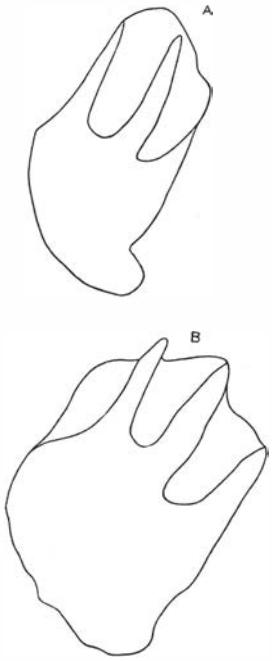


FIG. 18.—*Barypodus palmatus.* Type, No. 11,134, U. S. N. M. *A,* Diagram of forefoot; *B,* diagram of hindfoot. ⅓ natural size.

toes, the inner one being short, the outer two long, slender, and directed straight forward, all within the mass of the foot. The median toe, as in the pes, is most deeply impressed. Extremities of the toes show no trace of claws. Length of inner digit, 15 mm.; second, 52.5 mm.; third, 47 mm. At the base of the toes distinct cross ridges indicate the presence of creases. Forefoot 135 mm. in advance of the hindfoot impression.

Although the specimen selected as the type of this genus and species furnishes rather meager information concerning the tracks,

they are so distinct from the other footprints forming the collection from this locality that they seem worthy of description.

This form is remarkable for the large, heavy, semiquadrate soles and the apparent presence of web-like flanges that seem to extend between and beyond the tips of the toes. The presence of such a web is indicated in both manus and pes, but more especially the latter, by the depression of the sand between the toes and the numerous cross ridgings marking the surfaces. Its distinct outline is shown in figure 1, plate 11.

The large size of the animal making these tracks is indicated by the size of the footprints and depth of the impressions. Further material will be needed to elucidate the outlines of the feet, and it would not be at all surprising to find that there were additional toes. The web-like character of the feet is also found in the Triassic *Otozorum*[1] but this fact does not necessarily imply any relationship since the great size and different digital formula of the Mesozoic tracks at once distinguishes them. Although subequal in size with tracks here designated *Allopus ? arizonae,* those of *Barypodus palmatus* are at once distinguished by the long, slender, webbed toes, and by the lengthened quadrate form of the sole impressions.

A correlation of these tracks with any of the known Permian animals cannot be attempted without additional material, whereby the details of foot structure, length of stride, and width of body could be determined. The largest animals now known from the Permian are *Dimetrodon* and *Edaphosaurus,* either one of which may have been sufficiently large and heavy to make these tracks, but both have five well-developed digits, and it is hardly probable that either had webbed feet.

ALLOPUS? ARIZONAE, new species

Plate 11, fig. 2

Type.—Catalogue number 11,123, U. S. N. M. Consists of a consecutive series of footprints 8½ feet in length.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (150 feet above base), Permian.

Description.—Stride about 530 mm.; width of trackway about 330 mm. *Hindfoot:* Length about 60 mm., width about 85 mm. Apparently five toes which are very short with bluntly rounded ex-

[1] Hitchcock, Edward, Ichnology of New England, 1858, p. 123, pl. 33, fig. 4.

tremities without claws. Third toe broadest. Two outer toes slightly diverted from three inner as in *Allopus littoralis* Marsh. Sole impressed but its posterior outline obscure; it appears to have been broadly rounded as in *Allopus*. Foot turned strongly inward toward the line of movement. *Forefoot:* Length (estimated) 45 mm., width about 72 mm. Two toes clearly recorded, but there may have been one or two more. Digital terminations especially broad and without claws. Sole appears to be broadly rounded behind. Footprint deeply impressed on the inside, angle of inclination inward toward the line of movement and less than the hindfoot.

The specimen selected as the type of this new species is the trackway of a quadruped and consists of eight pairs of footprints equally divided between the right and left sides. In size, length of stride,

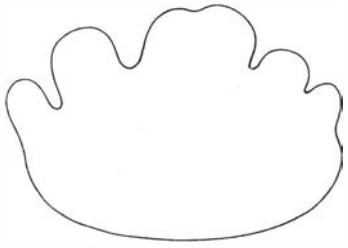


FIG. 19.—*Allopus? arizonae.* Type, No. 11,123, U. S N. M. Sketch of left hindfoot. About ½ natural size.

and toes with blunt, rounded extremities without claws, these show a marked resemblance to *Allopus littoralis* Marsh[1] from the Coal Measures of Kansas. I shall, therefore, tentatively refer these tracks to the genus *Allopus,* although there are differences which suggest that they probably pertain to a distinct genus.

The tracks are deeply impressed, but the sand was apparently so soft that the detailed foot plan was not recorded. Furthermore, the trail is crossed diagonally by the trackway of a second large animal, apparently of the same species, which in several instances stepped upon the footprints of the first, thus contributing still further to the difficulty of their proper interpretation. The last three pairs of the left side are the most distinct and the description is based almost entirely upon these six impressions of the fore- and hindfeet.

The consecutive series of tracks is unique from the fact that this was the only trackway found at this locality leading down the inclined slope; all others were ascending. For that reason there is

[1] Marsh, O. C., Amer. Journ. Sci., Vol. 48, 1894, p. 83, pl. 11, figs. 4, 4a.

some doubt as to the length of stride and the relative position of the imprints as representing the normal gait. For example, the imprint regarded as having been made by the manus falls behind and slightly inside the line of the larger impression made by the pes. In *Allopus littoralis,* as interpreted by Marsh, the positions are reversed.

The less number of digits on the manus and greater on the pes serves at once to distinguish this species from *A. littoralis* with its five and four respectively. However, until the detailed structure of the feet of this new form is more completely and positively known, it appears best to refer it to this established genus.

Marsh regarded the tracks of *Allopus* as having been made by a large labyrinthodont animal but the reduced number of digits in the manus does not suggest their assignment to any of those forms known from their skeletons.

As noted above, at the time this series of tracks was made the sand must have been thoroughly saturated with water as evidenced by the fact that it flowed back into the tracks from both sides, leaving a narrow longitudinal depression at the center where the flows failed to merge. Furthermore, on the down-hill side of the imprints, especially those made by the pes, the displaced sand has flowed downward for a distance of 200 to 225 millimeters. Three successive flows, one above the other, are registered, as indistinctly shown in figure 2, plate 11.

These features raise the question as to how an aeolian deposit of sand on a slope of 30 degrees could become so fully saturated with water. It could hardly be accounted for by submergence for under that condition the smaller tracks would hardly be registered so distinctly as many of them are. It permits of the suggestion that perhaps a further study of their origin, in the light of this new evidence, may bring about a modified conception of the æolian theory as accounting for the original deposition of these sandstones.

Genus PALEOHELCURA, new genus

Generic characters.—Foot apparently tridactylous; long axis of each cluster of three placed strongly diagonal to direction of movement. Tail trace.

PALEOHELCURA TRIDACTYLA, new species

Plate 12, fig. 1

Type.—Catalogue number 11,145, U. S. N. M. Consists of a slab about 560 mm. long, having a trail traversing the entire length.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (a loose slab from hillside at a point about 125 feet above the base), Permian.

The trail here described consists of two parallel lines of tracks between which the drag of a caudal appendage is clearly registered. The lateral lines are formed by clusters of three imprints, evidently made by tridactyl, pointed extremities, the longer axis of which stands at about 45 degrees to the line of direction. The clusters al-

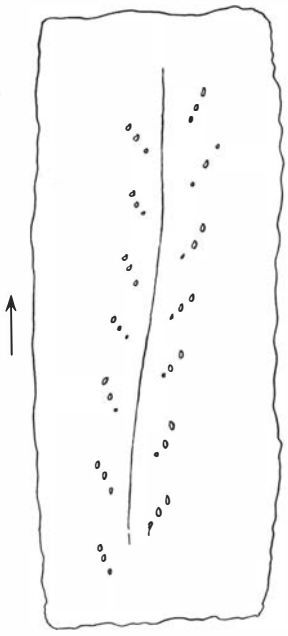


FIG. 20.—*Paleohelcura tridactyla.* Type, No. 11,145, U. S. N. M. Diagram of trackway. Arrow indicates line of movement. ½ natural size.

ternate on the two sides. This alternating movement of the limbs of opposite sides is indicated in the undulating movement of the tail drag, which is quite clearly shown in plate 12, figure 1. The direction of movement is indicated by the drag of the toes as being in the direction shown by the arrow (fig. 20). The inner toe seems to be the smallest; the outer two are subequal in size. The greatest width of the trackway is 22 millimeters, length of stride about 17 millimeters, distance between single imprints of each cluster about 3 millimeters, and width of each cluster of three about 8.5 millimeters.

In looking at this specimen, one is struck by the general distinctness of the outlines and the perfection of preservation, but an attempt to refer it to a particular class of animals results in great perplexity. The wonder is that an animal, apparently so small and light, should have left any impression that could be converted into rock. It is quite unlike any of the described trails attributed to crustaceans, myriapods, or insects, and yet it gives every indication of having been made by some invertebrate animal. The specimen has been examined by the several specialists in the United States National Museum dealing with these groups, and all disclaim its relationship to any with which they are familiar.

Regardless of my inability to definitely classify these tracks, their distinctive character makes it desirable to name them, and the new genus and species *Paleohelcura tridactyla* is proposed for their reception. It is my impression that they represent the trail of some

FIG. 21.—Undescribed trackway in museum at Weimar, Germany, from the Triassic. ½ natural size. Sketch by O. Abel.

invertebrate; they certainly do not display features indicative of the foot of any known vertebrate animal.

On a recent visit to the United States National Museum, the distinguished paleontologist, Prof. Othenio Abel, called my attention to a series of tracks preserved in the museum at Weimar which bear a certain resemblance to the tracks under consideration. These are shown in figure 21, reproduced from a sketch by Professor Abel who generously permitted its use. This series of tracks is from the Bundsandstein (Triassic) between Schonalkalden and Trowback near Nesselberg, and are therefore somewhat younger than the Grand Canyon specimen. They show the same grouping in threes set at an oblique angle to the median line of movement, and with a similar relative width of trackway. They differ, however, in their larger size, lack of tail trace, and in having the clusters of the two sides opposite, whereas the clusters alternate in the Arizona form. While these distinctions are important, the Austrian specimen is of interest in being

the only one known which bears any great resemblance to those here described.

A second slab (No. 11,141, U. S. N. M.) which was originally a part of that bearing the type, has on its surface a continuation of the *Paleohelcura* trail evidently made by the same individual. It differs from the type in having only a single toe mark on each side of the tail drag for one-half of its linear extent, the remaining half showing two imprints. In only three or four instances are all three toes registered. This serves to emphasize the necessity of securing abun-

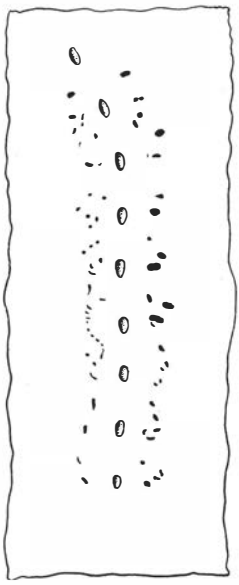


FIG. 22.—*Mesichnium benjamini.* Type, No. 11,155, U. S. N. M. Diagram of trackway. ½ natural size.

dant material for the study of fossil tracks if the chances of error are to be reduced to the minimum.

Genus MESICHNIUM, new genus

Generic characters.—Digital formula unknown. Row of regularly spaced oval depressions between the parallel lines of tracks.

MESICHNIUM BENJAMINI, new species

Plate 12, fig. 2

Type.—Catalogue number 11,155, U. S. N. M. Consists of a small slab on which is a trail about 300 millimeters in length.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (150 feet above base), Permian.

In plate 12, figure 2, is shown a photographic reproduction of two parallel lines of footprints which clearly represent the trail of some animal, but which, in most of its details, is quite obscure. The one distinctive feature is the presence of a median row of suboval depressions regularly spaced and for half the length of the trail deeply impressed; on the other half they are either shown faintly or missing entirely. The width of the trackway is 22.4 millimeters; distance between depressions of median row averages about 15 millimeters, which also represents the length of stride. Whether these median pits were formed by a caudal appendage or by a descending ventral protuberance on the body is of course impossible to determine. It would seem most logical to regard them as having been made by a short, stubby tail.

The direction of movement is shown on the forward border of the pits by the drag made by the appendage causing the oval depressions, as contrasted with the more perpendicular posterior side of the imprint.

The trail is quite different from any other in the collection, and I find nothing like it described. That it was made by some invertebrate there is little doubt, but no clue has been found as to the particular animal.

The specific name is in honor of Dr. Marcus Benjamin, who for many years has so ably edited the scientific publications of the United States National Museum.

SUMMARY

That both vertebrate and invertebrate animals are present in this collection of footprints is certain, but with the exception of the classes Reptilia and Amphibia among the former, quite certainly represented by the tracks designated *Dolichopodus tetradactylus* and *Baropezia eakini* respectively, it was found impossible to assign the other forms to their proper class with any degree of assurance.

No skeletal remains are known from the Coconino sandstone and consequently no direct clue is offered as to the makers of any of these tracks. A study was made of the Permian vertebrate fauna found in the adjacent regions in the hope that forms might be found whose structure would indicate responsibility for some of the imprints. This search was not entirely in vain, for in the Permian *Araeoscelis*

with its light body, long, slender limbs, and lizard-like foot structure, we have a reptile which fulfils all essentials for the type of animal that made the tracks designated *Dolichopodus tetradactylus;* and in *Trematops* and *Cacops,* with wide, short bodies and short, heavy limbs, are amphibians of the right proportions to have made trails similar to those called *Baropezia eakini* and *Agostopus matheri.* I do not wish to imply that the tracks were made by these animals, but the type of creature to which they may be attributed is quite certainly represented. The evidence for such correlation must not be taken too seriously, since at present there seems no way of definitely linking up the two lines of evidence.

No strictly bipedal animals have yet been found in this fauna, all being quadrupedal, and these vary greatly in size from one of a few inches in length to the largest which may have attained a length of several feet.

Attention should be called to the fact that probably none of these trails shows the normal walking gait, due to the fact that all were impressed by animals climbing a steep slope in soft sand, and this effort has probably, in all instances, shortened the stride. That all of the trails observed, with one exception, lead in a common direction—that is, up the face of the slope—is difficult of explanation. This applies not only to the level where most of the collection was made but also to all other levels in the Coconino where tracks were seen, both perpendicularly and horizontally. It is also of interest to note that the three series of footprints of *Laoporus coloradoensis* from the Lyons sandstone of Colorado show the same characteristic.

The Ichnite fauna of the Coconino sandstone now consists of the following described genera and species:

VERTEBRATES

Dolichopodus tetradactylus, n. gen., n. sp.
Nanopus merriami, n. sp
Laoporus schucherti Lull
Laoporus nobeli Lull
Laoporus coloradoensis (Henderson)
Baropezia eakini, n. sp.
Agostopus matheri, n. gen., n. sp.
Paleopus regularis, n. gen., n. sp.
Barypodus palmatus, n. gen , n. sp.
Allopus? arizonae, n. sp.

INVERTEBRATES

Paleohelcura tridactyla, n. gen., n. sp.
Mesichnium benjamini, n. gen., n. sp.

The above fauna, taken as a whole, shows that its affinities lie nearest to those described from the Carboniferous Coal Measures rather than to the later Mesozoic Ichnites. This is indicated by the presence in the Coconino of two and possibly three genera common to the Carboniferous, whereas not a single genus of the Triassic was recognized. Furthermore, the facies of the fauna is Carboniferous in aspect as shown by the relatively small size of the animals, all of which are quadruped, as contrasted with the considerable number of very large forms and the many three-toed bipedal animals of the Triassic. The Coconino footprint fauna also seems to have closer relationships to the Ichnite fauna from the Middle Coal Measures of Kansas, described by Marsh[1] than to the more extensive faunas from the Coal Measures of Nova Scotia described by Dawson[2] and Matthew.[3]

The present fauna is founded upon specimens having well-marked characters, and being from a single locality and well-established horizon, have a value of their own in throwing light upon the land vertebrate life during the deposition of the Coconino sandstone. If they have but little value in themselves, they may eventually shed much light on the habits and characteristics of the Permian animal life.

PSEUDO-TRACK-LIKE MARKINGS

Plate 2, fig. 2

Under this heading attention is called to some peculiar track-like markings found on a massive sandstone of the Supai formation in that part of the Grand Canyon known as "Fossil Bay." While these are not regarded as having been made by animals, they are of interest on account of their superficial resemblance to tracks made by horses' hoofs, and since their origin is as yet unexplained, these notes are published in the hope that it may lead to a fuller investigation.

These markings were called to my attention by Mr. Samuel Hubbard, leader of the Doheny Scientific Expedition of 1924, who had long known of their existence through information obtained from the Supai Indians who regarded them as tracks made by a band of horses. They thickly cover an area of several hundred square feet in extent and have the appearance of semi-oval rings, frequently with the two posterior extremities prolonged backward, but seldom con-

[1] Marsh, O. C., Amer. Journ. Sci., Vol. 42, 1894, pp. 81-84.
[2] Dawson, J. W., Geol. Mag. London, Vol. 9, 1872, p. 251.
[3] Matthew, G. F., Canadian Rec. Sci., Vol. 9, No. 2, 1903, p. 105.

verging sufficiently to meet behind. All the rounded or oval ends, as may be seen in the illustration (pl. 2, fig. 2) are pointing in a common direction. They vary in size but their general contours are fairly alike.

None of these markings occurred in regular sequence and none was found giving evidence of having been impressed into the surface of the sand. After a careful examination it was my conclusion that they do not present a series of fossil tracks, but were nothing more than a staining of the sandstone, the deeper coloration making them

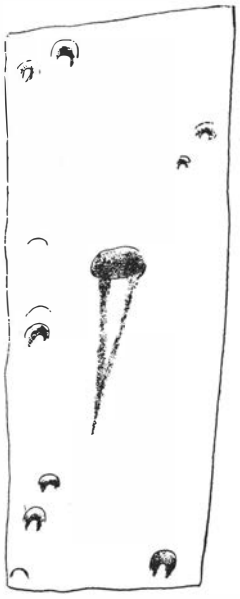


FIG. 23.—*Hoplichnus equus* Hitchcock. Doubtfully regarded as animal tracks. 1/7 natural size. (After Hitchcock.)

stand out clearly against the lighter colored background of sandstone. A few through weathering showed surface depression but a section obtained in one place clearly indicated that this deep coloration extended downward into the sandstone for at least four inches.

In a search of the literature in an attempt to get light on the origin of these curious markings, it was of interest to find that Hitchcock[1] had described supposed tracks (see fig. 23) from the Triassic of Connecticut which bear a striking resemblance to those under consideration. Their resemblance to a horse's hoof was apparently recognized

[1] Hitchcock, Edward, Ichnology of New England, 1859, p. 134, pl. 24, figs. 3-7.

by Hitchcock who applied to one the name *Hoplichnus equus*. Although unable to reach any conclusion as to the class of animals to which they might be attributed, Hitchcock was of the opinion that they were true tracks and not discolorations. He attempts to show that they occurred in regular sequence and were depressed below the general surface level. Hay[1] remarks: "It is doubtful whether or not this genus of foot marks was produced by a vertebrate animal."

Sir William Jardine described some hoof-like tracks from the New Red Sandstone of Scotland under the name *Chelichnus gigas*.[2] While these have the same hoof-like shape without the appearance of toes or claws, they do show a distinct pace and uniform alternate progression.

May it not be that the Supai markings are stains resulting from the decay of some gelatinous medusa-like animals that were stranded on a sandy beach?

[1] Hay, O. P., Bull. 179, U. S. Geol. Surv., 1902, p. 546.
[2] Ichnology of Annandale, 1853, p. 9, pl. 1.

EXPLANATION OF PLATES

PLATE 1.

PAGE

FIG. 1. Slab of footprints *in situ* on the Hermit Trail, Grand Canyon National Park. This slab is 8 by 25 feet and located 950 feet below the rim or 150 feet above the base of the Coconino sandstone. The mule trail may be seen in the lower left-hand corner. 2

2. The same, but taken from a point farther down the trail. The surface of the slab in the foreground is also covered with numerous tracks. The slab shown in plate 9 was collected from the exposed layer. Continuation of the trackway may be seen in the center foreground. 2

PLATE 2.

FIG. 1. Pack mules loaded with slabs of footprints starting up the trail for the top of the canyon. All the specimens were transported to the top of the canyon in this manner.

2. Unidentified track-like markings found on the sandstones of the Supai formation in "Fossil Bay," Grand Canyon National Park. These occur on a massive band of sandstone 1,673 feet below the level of the canyon rim. 37

PLATE 3.

General view of the foot track locality on Hermit Trail looking east. Photograph taken before clearing off the débris from the hillside. Photograph by Robert Carson of the Doheny Scientific Expedition.

PLATE 4.

FIG. 1. *Dolichopodus tetradactylus,* new genus and species. Type, No. 11,123, U. S. N. M. Imprints of digits of the manus are dimly shown behind and slightly outside those of the pes. Less than $\frac{1}{2}$ natural size 6

2. *Nanopus merriami,* new species. Type, No. 11,146. U. S. N. M. About $\frac{1}{5}$ natural size..... 9

PLATE 5.

FIG. 1. *Palaeopus regularis,* new genus and species. Type, No. 11,143, U. S. N. M. Imprints of forefeet occasionally seen directly in front of those made by the hindfeet. About $\frac{1}{6}$ natural size..... 25

2. *Laoporus nobeli* Lull. No. 11,148, U. S. N. M. Lateral digits not impressing in this trackway. About $\frac{1}{3}$ natural size..... 13

PLATE 6.

Laoporus nobeli Lull. No. 11,122, U. S. N. M. Tracks of the smaller species *L. schucherti* may be represented on this slab by some small imprints at the bottom. About $\frac{1}{4}$ natural size..... 14

PLATE 7.

FIG. 1. *Laoporus coloradoensis* (Henderson). No. 11,176, U. S. N. M. From the Coconino sandstone, Grand Canyon, Arizona. Tracks slightly larger than the type but very similar in all other respects. Slightly less than $\frac{1}{2}$ natural size..... 16

2. The same. Type, No. 13,238, Colorado University. From the Lyons sandstone, Colorado. Slightly more than $\frac{1}{2}$ natural size... 17

PLATE 8.

Baropezia eakini, new species. Type, No. 11,137, U. S. N. M. The lower portion cast from the obverse slab. The deformed digits of the right pes are clearly shown. About $\frac{1}{2}$ natural size..... 18

PLATE 9.

Baropezia eakini, new species. No. 11,138, U. S. N. M. Crossed diagonally by a trackway of *Laoporus nobeli* Lull. Trackway of former made by same individual that made the type as shown by the deformed digits of the right hindfoot. About $\frac{1}{5}$ natural size.. 19

PLATE 10.

Agostopus matheri, new genus and species. Type, No. 11,135, U. S. N. M. A large footprint of some unidentified animal has blotted out part of the tracks of the right side. About $\frac{1}{4}$ natural size..... 23

PLATE 11.

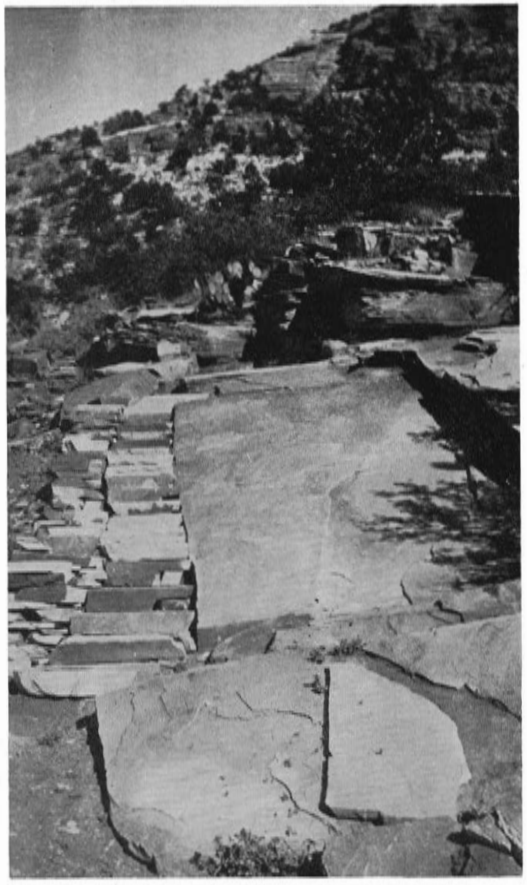
FIG. 1. *Barypodus palmatus,* new genus and species. Type, No. 11, 134, U. S. N. M. Fore-and hindfeet. Less than $\frac{1}{3}$ natural size..... 27

2. *Allopus? arizonae,* new species. Type, No. 11,123, U. S. N. M. Oblique view of the large slab. Crossed diagonally by a trail of *Laoporus* and also by a second trackway of *Allopus.* About $\frac{1}{14}$ natural size. 29

PLATE 12.

FIG. 1. *Paleohelcura tridactyla,* new genus and species. Type, No. 11,145, U. S. N. M. Tail drag clearly shown between the parallel rows of tracks. More than $\frac{1}{2}$ natural size..... 31

2. *Mesichnium benjamini,* new genus and species. Type, No. 11,155, U. S. N. M. The direction of movement was toward the top. More than $\frac{1}{2}$ natural size..... 34



1 Fossil footprints *in situ*, Grand Canyon National Park. 2

(For explanation, see page 40)

1

2

Above, Transporting slabs of fossil footprints.
Below, Unidentified track-like markings, Grand Canyon National Park.

(For explanation, see page 40)

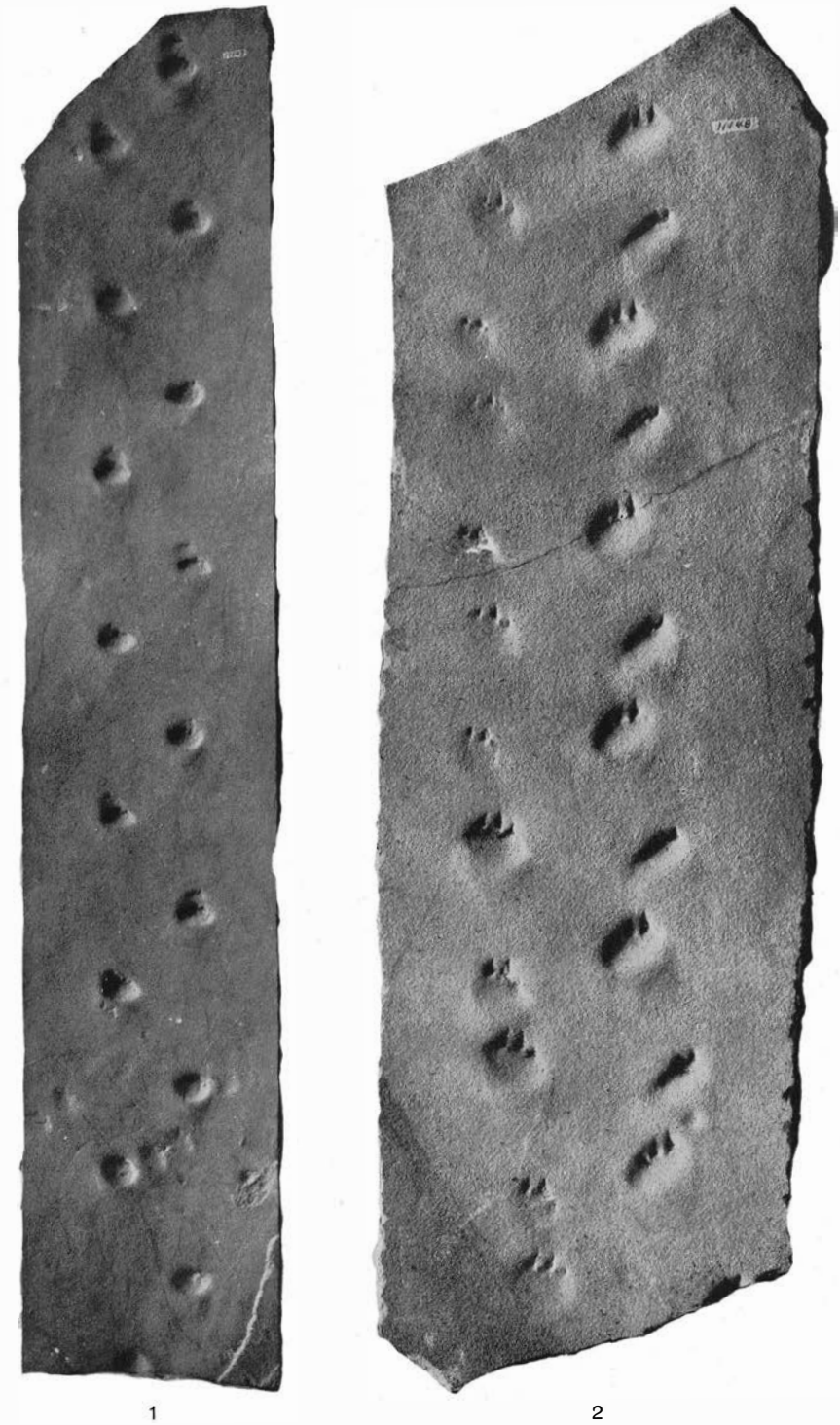
General view of fossil footprint locality, Grand Canyon National Park.

(For explanation, see page 40)

1 2

Fossil footprints from the Grand Canyon.

(For explanation, see page 40)



1 2

Fossil footprints from the Grand Canyon.

(For explanation, see page 40)

Fossil footprints from the Grand Canyon.

(For explanation, see page 41)

1 2

Fossil footprints from the Grand Canyon.

(For explanation, see page 41)

Fossil footprints from the Grand Canyon.

(For explanation, see page 41)

Fossil footprints from the Grand Canyon.

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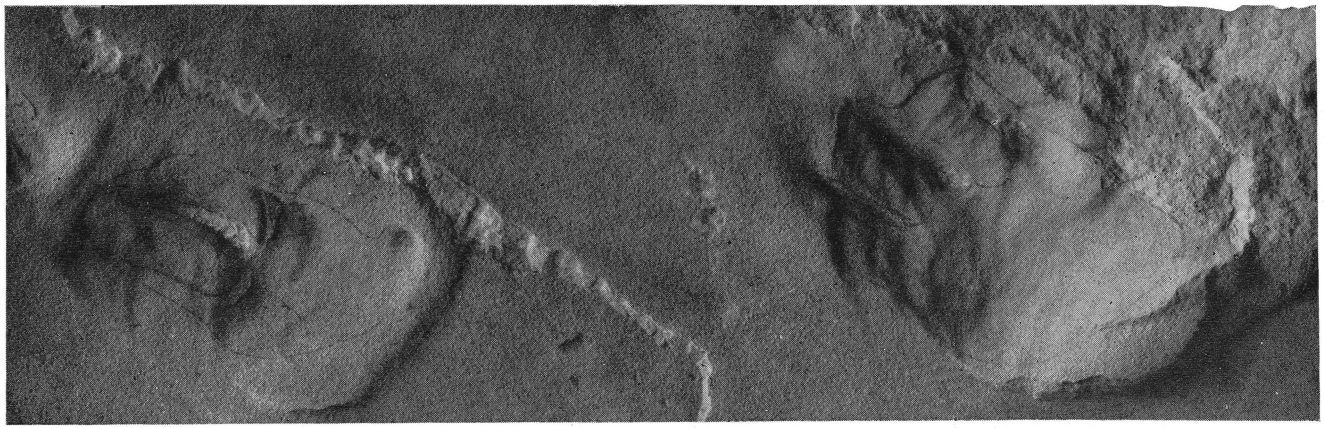
Fossil footprints from the Grand Canyon.

(For explanation, see page 41)



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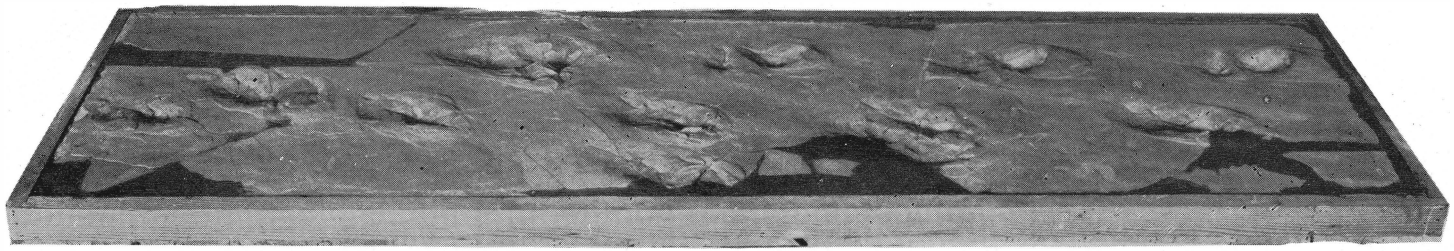

2

Fossil footprints from the Grand Canyon.

(For explanation, see page 41)

1 2

Fossil footprints from the Grand Canyon.

(For explanation, see page 41)