REPRINT FROM ***DINOSAUR TRACKS AND TRACES***
Edited by DAVID D. GILLETTE AND MARTIN G. LOCKLEY
Cambridge University Ptress, 1989

COAL MINES AS LOCALITIES FOR STUDYING DINOSAUR TRACE FOSSILS

LEE R. PARKER AND JOHN K. BALSLEY

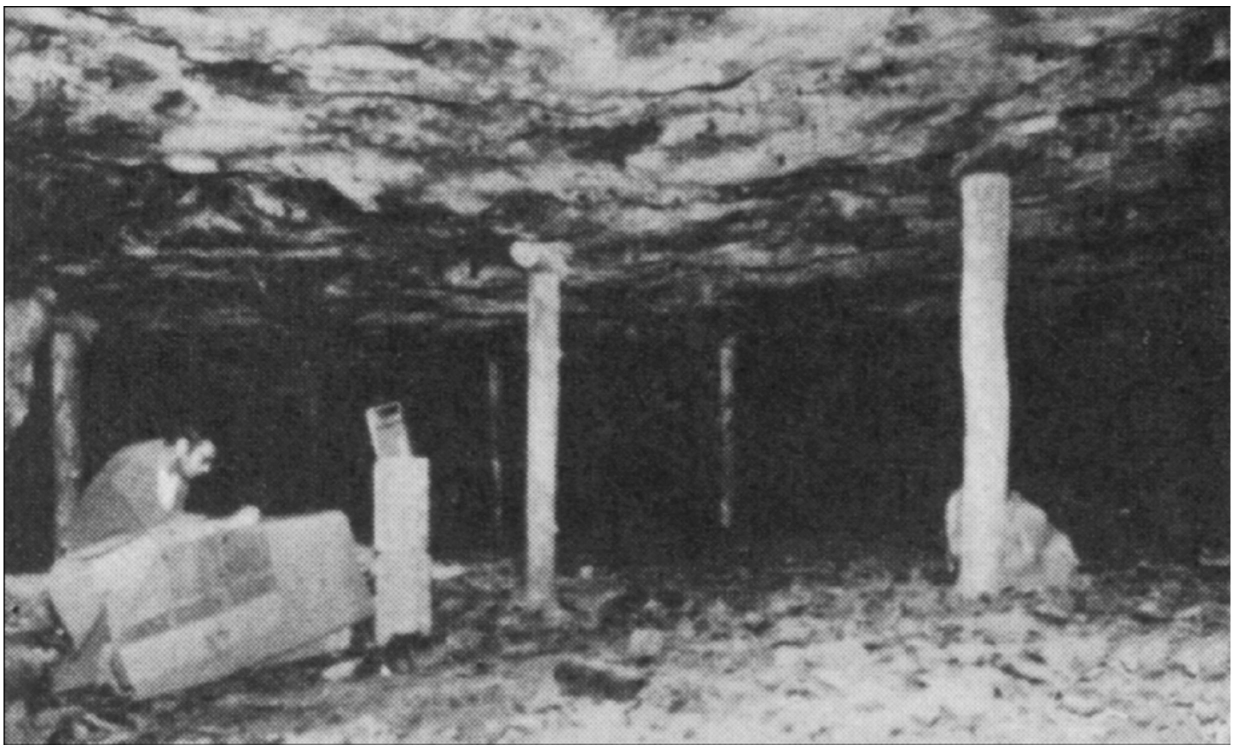

Figure 2. Coal mine in the Kenilworth Coal, near Kenilworth, Utah, east of Helper, showing numerous overlapping round-bottomed dinosaur footprint casts extending down from the roof. Here, the roof's texture of irregular-shaped lumps extends down from the surface as far as 30 cm. Few distinguishable foot prints can be identified, but innumerable toes, heels and partial footprints overlap one another randomly. The swamp surface had been heavily bioturbated, or "dinoturbated".

Abstract

Dinosaur footprint casts have been observed at three major horizons within coal mines in the Upper Cretaceous (Campanian) Blackhawk Formation near Price, Utah. These include the mine floor, the mine roof, and in sediment above the roof seen only in rock-fall areas. Carbonaceous sandstones in the floor were formed as brackish and subsequently freshwater swamps became established on foreshore sediment, close to the shoreline. A small, bipedal animal producing footprints 11 cm long walked in one of these youthful swamps. Sediment exposed in the mine roof, after coal is removed, often has preserved in it thousands of footprint casts of numerous types and sizes of animals which had walked on the peat blanket of much older swamps. In certain areas the soft peat surface had been heavily bioturbated by dinosaur activities with many footprints partly overlapping and obscuring previous tracks. Fossil plants occur with many of these footprints.

Selected coal pillars which support the roof have been removed in some mines, allowing overburden to fall to the floor. These

These localized rock-fall areas display several levels of fluvial and lacustrine sedimentation some distance above the surface of the coal. It is evident in these units that dinosaurs walked in lake-margin muds, often causing footprint-bioturbation here too. Tail drag features are present in one mudstone. In addition, more than 50 tracks of a large bird which produced footprints 15 cm long occur in a 2 x 2.5 m area of mudstone.

Introduction

This report describes natural casts of dinosaur trace fossils we have observed in coal mines of east-central Utah near the cities of Helper and Price. All mines have been within coals of the Upper Cretaceous (Campanian) Blackhawk formation. We have been able to examine twelve mines within several coal beds and have seen footprint casts in most of them. However, because of certain mining techniques and various factors of preservation, most mines display few specimens of significance. Only four mines have abundant tracks where thousands have been seen (Balsley and Parker 1983, Parker and Rowley 1989, Parker and Balsley in prep.). They are so common in some areas of mine roof that they overlap and obscure one another. In addition to these in Utah, we have been able to study mines in time-equivalent coals near Rock Springs, Wyoming (Rock Springs Formation), and near Cuba, New Mexico (Menefee Formation), where we have seen similar dinosaur traces.

Previous Work

Peterson (1924) first reported natural casts of dinosaur footprints from Rocky Mountain coal mines. He illustrated a track collected in the roof of the now-abandoned Castlegate Mine (Kenilworth Coal, Blackhawk Formation), north of Helper, Utah, and sketched a bipedal trackway in the now-abandoned Ballard Mine (Neslen Coals, Price River Formation) north of Thompson. He also mentioned a collection from the Panther Mine (Castlegate B Coal, Blackhawk Formation), north of Helper. Subsequently, Lull (Strevell 1932) sketched a bipedal trackway and described 8 species of *"Dinosauropodes"* from the now-abandoned Standard Mine (Castlegate A and B Coals, Blackhawk Formation) west of Helper. This collection is housed in the Utah State Natural History Museum, University of Utah, in Salt Lake City (Frank L. DeCourten pers. comm.). A popular account of mine footprints has been written by Wilson (1969). Although Lull's study (Strevell 1932) represented an excellent beginning for studying the biology of the Cretaceous swamp fauna, there were no further studies of dinosaur traces in Utah until we began recording them as part of our examination of the geology, paleontology, and paleoecology of the Blackhawk Formation (Parker 1976, 1979). During field studies we began using the planar surfaces which coal mine roofs and floors provided as a way to extend outcrop exposures of sedimentary features and fossil plants. Dinosaur trace fossils were immediately observed and recognized as an important part of the paleontology of Cretaceous coals (Parker 1980, 1981; Parker and Balsley 1977, in prep.; Balsley and Parker 1983; Parker and Rowley 1989).

Recently, Lockley et al. (1983) and Lockley (1986) have photographed and mapped dinosaur tracks from coal mines of western Colorado. They list previous studies which have mentioned or illustrated dinosaur footprints in mines of east-central Utah and western Colorado. Additionally, Bass et al. (1955) and Ratkevich (1976) have illustrated single footprints from Colorado mines.

Horizons of Preservation

Dinosaur trace fossils occur in three general horizons within coal mines: the floor, deposited with initial stages of swamp development; rock of the immediate roof which was in direct contact with the coal being mined; and in areas where roof-rock has fallen exposing fluvial and lacustrine units as much as 2 m above the coal surface.

The Mine Floor

Occasionally, large thick slabs of coal and rock from mine floors are warped or buckled upward, sometimes violently, because great amounts of energy are directed into the floor from overburden weight by way of coal pillars. Such features are termed mine "bumps" and are of some significance in mine safety (Osterwald and Dunrud 1966). Three small dinosaur tracks were observed on the lower surface of slabs which had been loosened from the floor of a mine in the Kenilworth Coal,

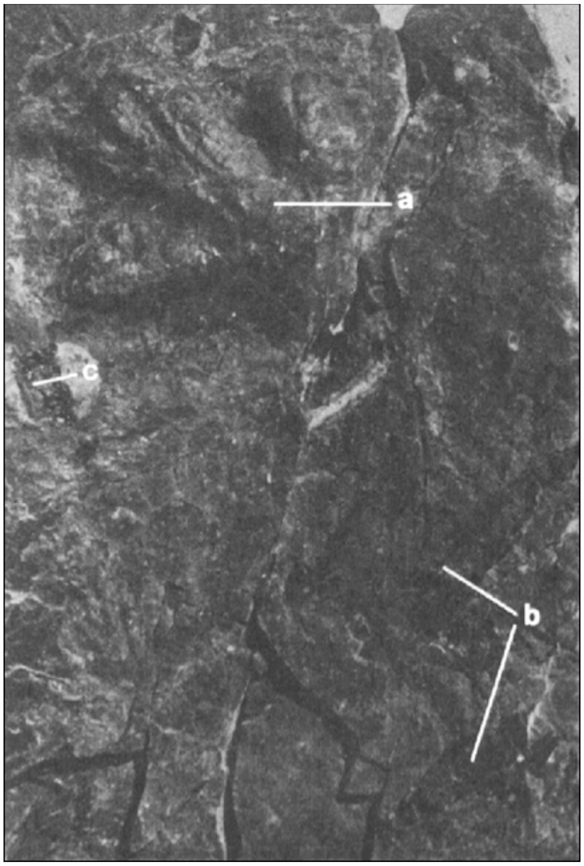

Figure 1. Small three-toed footprint **(a)**, dicotyledon leaves **(b)** and vitranized twig **(c)** on a slab from mine floor. Footprint is 11 cm long.

near Kenilworth, Utah, east of Helper. These specimens were part of a sequence of left andright footrints made by a single small three toed bipedal animal. One specimen (Fig. 1) was removed from a carbonaceous sandstone slab 2.3 m long, 2 m wide and 25 cm thick. Broad dicotyledon leaves occur on the surface of this rock close to the footprint (Fig. 1). On other slabs, more fossil plants occurred at the same stratigraphic level including fragments of the palm *Phoenocities imperialis*, plus leafy twigs of the conifers *Sequoia cuneata* and *Moriconea cyclotoxon*. About 18 cm below these tracks, leafy twigs of a third conifer, *Araucaria* sp., are abundant, and the only fossil plant collected at that stratigraphic level.

Primary sedimentary features of this mine floor indicate that leafy twigs of *Araucaria* sp. were deposited on the surface of foreshore or beach sands in brackish mangrove like plant communities, similar to certain extant communities in the Southern Hemisphere where Araucaria sp. is the only woody plant preserved (Balsley and Parker 1983). These swamps developed very close to the shoreline. With seaward progradation of the shoreline, these paralic swamps eventually became less influenced by marine conditions. This allowed several plant communities composed of many ferns, conifers, broadleaved trees, and palms to succeed the *Araucaria*-dominated community. They became the important peat-producing plants of all the Blackhawk coals (Parker 1976, Balsley and Parker 1983). The animal which made these footprints was walking on a mixture of peat and sand in the young freshwater swamp. Sand in this environment is of the same type as that in the foreshore below. It was apparently blown landward into the swamps or deposited from occasional wash-over fans during storms (Balsley and Parker 1983). The swamp surface here was slightly above sea level and within a short distance, 1 or 2 km, of the shoreline. Footprint casts of this size and type have not been observed elsewhere and may have been produced by an animal which was restricted to paralic delta plane environments.

The Mine Roof

As coal is mined it usually separates from the roof rock, exposing sedimentary features and various types of fossils which occurred on the immediate surface of the Cretaceous swamps. Roof rock is usually of fluvial origin, deposited into the swamps as overbank sediment when local rivers flooded. Footprints in the peat of the swamp surface were filled with this sediment, preserving a record of the most recent activities of the dinosaur fauna. Such features as bipedal walking patterns, feeding behavior around coalified trees, and resting positions are evident (Parker and Balsley in prep.). Thousands of footprints occur at this coal-roof rock contact. In many mines the roof is so covered by footprints overlapping one another that the entire surface for several hundred square meters is completely bioturbated or “dinoturbated”. One such roof surface is within the same Kenilworth Coal mine as the small animal track described from the mine floor.

Here, the roof has a texture of irregular-shaped lumps extending down from the surface as far as 30 cm (Fig. 2). Few distinguishable foot prints can be identified, but innumerable toes, heels and partial footprints overlap one

Figure 3. Footprint in roof surface about 35 m away from the area shown in Figure 2. They do not overlap one another and their shape is well-defined.

another randomly. In a nearby area, footprints are more separated from one another and distinct in shape and size (Fig. 3). This roof surface has in it at least eight different track types within an area of about 100 m square. It includes one specimen 96 cm in length, the largest we have seen. In another Blackhawk mine, 14 track types have been collected from the same kind of roof surface (Parker and Rowley 1989). We recognize the probability that footprints of a single animal species would be preserved differently, depending on animal age, behavior (feeding, progressing, resting), and substratum (kind of peat, kind of clastic sediment). Nevertheless, morphological consistency among numerous specimens (often hundreds of specimens) of a single track type leads us to believe that several animals co-existed in certain swamp forests. Dinosaur traces and their relation to other fossils in

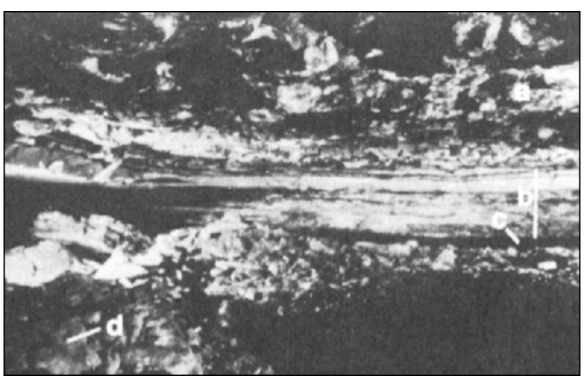

Figure 4. View of roof-fall area approximately 14 m wide. Top half of photo **(a)** shows an oblique view of a horizontal surface. Numerous irregular structures extending downward are overlapping dinosaur footprint casts produced on a muddy surface. Parallel bedding in center **(b)** is at the edge of the roof fall, showing lateral views of lacustrine bedding. Black layer **(c)** is the top of the Castlegate A Coal. Rubble which has fallen to the floor includes a large three-toed dinosaur footprint cast **(d)**, 67 cm long.

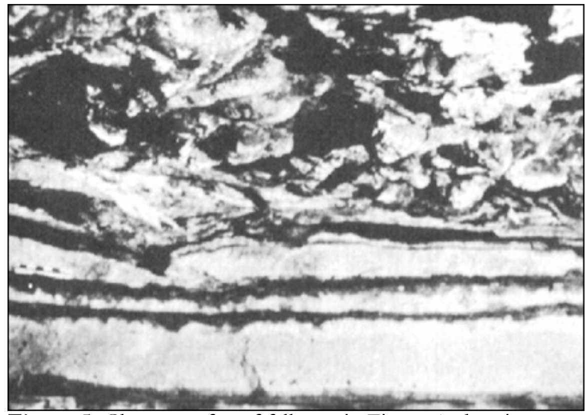

Figure 5. Close-up of roof fall area in Figure 4, showing footprint bioturbation and lacustrine bedding. Scale is 16 cm long.

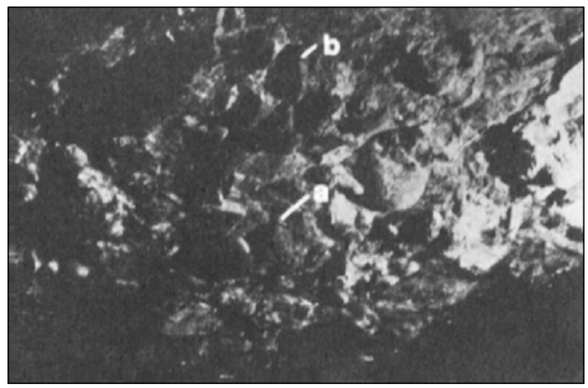

Figure 6. Oblique view of planar surface of Figure 4 showing many indistinct overlapping tracks plus two tracks of a three-toed animal coming from (a) to (b). Pointers are on the center toe of each cast. They are members of a four-track sequence. Figure 6b is 60 cm in length.

mine roof surfaces have been described in more detail (Parker and Balsley 1983, in prep.).

Sediment Above the Mine Roof

In older portions of almost all mines, “room and pillar” methods were used to extract coal. In this process, pillars of coal about 5 m square were left in place to secure the roof. Final mining activities in certain mines included the removal of alternate pillars, eventually allowing sections of the roof to fall. In this way, sedimentary features are exposed as much as 2 m above the coal surface. The significance of these rock-fall areas is that they show depositional and biological activities which occurred after the termination of the peat-forming swamp. Rocks at this level were deposited at the leading edge of the fluvial coastal plain which

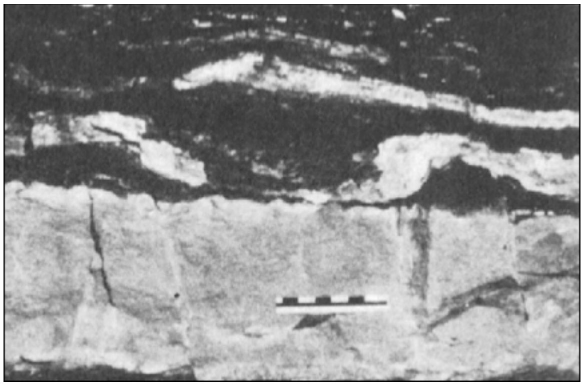

Figure 7. Close-up of roof-fall area near that shown in Figure 4. Lateral view of sediment distortion due to dinosaur footprint is evident. Scale is 16 cm long.

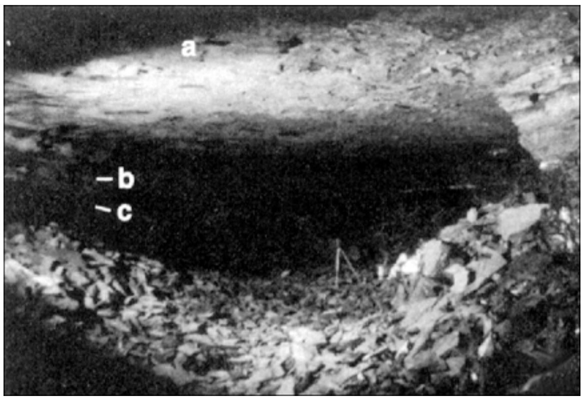

Figure 8. View of roof-fall area showing apparent smooth planar surface of lacustrine mudstone **(a)**, lateral view of sediment over coal **(b)**, top of the Castlegate A Coal **(c)** and rubble on the floor. Tripod in center is 1 m tall.

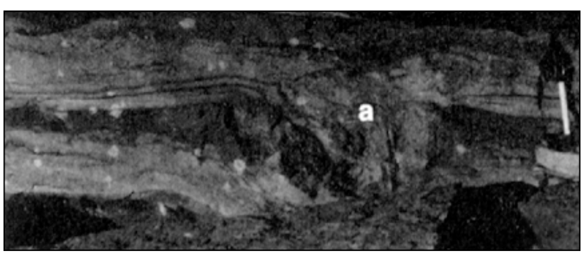

Figure 9. Lateral view of block fallen from roof in Figure 6. Distortion of bedding due to dinosaur footprint **(a)** is evident. Pen is 1.5 cm long.

prograded seaward over the thick peat blanket (Balsley and Parker 1983).

One such mine is west of Helper, Utah in the Castlegate A Coal. In this locality, the coal is covered by thin, laterally extensive, even-bedded lacustrine units, including some with well-defined laminations. Roof falls in this mine (Figs. 4, 5, 8, 12) show sedimentary features in both broad planar and lateral (side) views.

Some beds were heavily bioturbated by several dinosaur types (Fig. 6). Others have no evident tracks at all. One mudstone is covered by large polyhedral cracks indicating fluctuations in water level and subaerial exposure.

Figures 7 and 9 are lateral views of lacustrine beds where distortions of certain units can be seen. Both are vertical sections through dinosaur footprints. The animal which produced the structure in Figure 7 was walking on a peat surface (now the thin coaly layer), its foot pressing into one soft bed below. However, the dinosaur which made the distorted features in Figure 9 was walking on mud.

Occasionally, large, distinctly flat-footed footprint casts occur with a unique straight-sided preservation of the vertical walls. One such specimen is shown in both Figures 10 and 11. It extends down from the surface 28 cm, and is one of three which were in a bipedal trackway. The animal was walking on a thick, soft mud surface and produced a unique “cookie-cutter” effect by apparently placing its feet straight down and lifting them straight up.

Tail drag structures are rare in mines, although linear depressions which are interpreted as such are seen (Robert L. Rowley pers. comm.). Two depressions, each about 8 cm deep, 2.5 m in length and 0.3 m wide, are present in a lightly bioturbated unit (Fig. 12). Both are curved. Their relation to one another suggests that they were produced at the same time by the same animal. Short lateral projections on the tail seem to have been

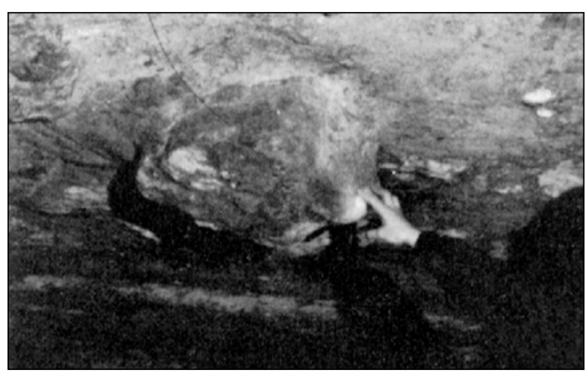

Figure 10 and 11. Two views of the same footprint cast in a roof-fall area. Its three-toed outline, flat bottom and straight vertical sides are evident. White area in Figure **11(a)** is where the next track in sequence has fallen. Arm in Figure 10 for scale (see next page).

present, making the parallel striations seen on the sides of these depressions. The infrequent occurrence of tail traces in these lakeshore muds suggests that the animals which lived here normally supported their tails above the surface.

Tracks which are different from the morphology of the rest of the footprints we have seen occur in one rock fall area (Fig. 13). They are on the recently exposed surface in Figure 8. A map has been prepared (Fig. 15), showing at least 50 of these specimens in an area 2 x 2.5 m. They were produced by a three-toed animal with a distinctly asymmetrical foot. One lateral toe is long and slender, almost 2.5 times the length of the median and opposite lateral toes. Total length from the heel to the end of the longest toe is 15 cm. No claw impressions are evident. Both left and right footprints occur. They apparently were produced by the pedes of a bipedal animal, since no footprints of any other shape or size are present. At least seven clusters of tracks occur where a single foot was being picked up, moved slightly and replaced. This shuffling gait, plus their random orientation, appears similar to tracks of extant birds as they feed on mud-dwelling organisms. Interestingly, associated with these tracks are many small 1 x 2 cm depressions and several thin (1.5 cm wide) elongate striations among the tracks, neither of which have been observed elsewhere in the lacustrine beds. Are these depressions beak or "peck" marks made in the mud by the animal as it fed?

Lockley (pers. comm. 1988) suggests that, because of the comparatively small size of these odd tracks, plus their widely separated toes, they probably are bird tracks. Currie (1981) studied several features of fossil and modern footprints, and pointed out that the angle of divergence of digits II and IV in small dinosaur tracks does not exceed 100°, while the same angle in bird tracks is greater. The angle in the Blackhawk specimens is 120°, well within that observed in birds.

Several techniques, inherent in the mining process, limit the observable roof area and in some cases destroy the specimens within the roof. The most common is white "rock dust", a powdered limestone, which is applied as a thick layer onto all freshly exposed mine surfaces in order to reduce the quantity of

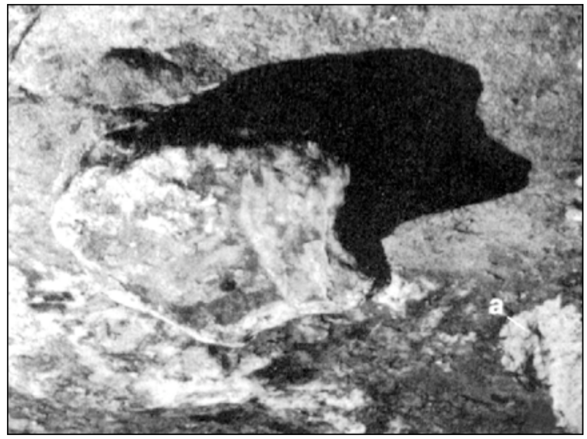

Figure 11.

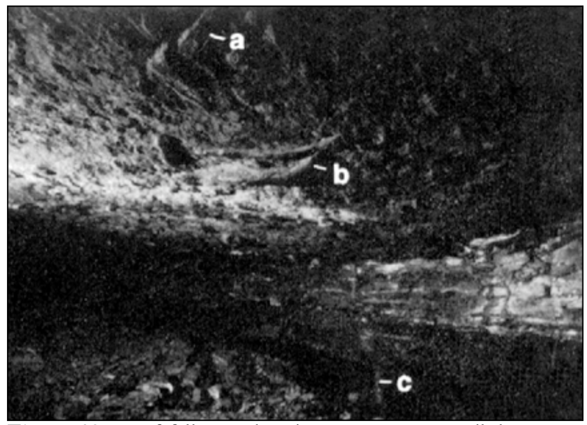

Figure 12. Roof-fall area showing two apparent tail drag features (**a** and **b**) on a shallowly bioturbated surface. The center one **(b)** is 2.5 m in length. Note vertical edge of roof fall area, the top of a mine support post **(c)** in the position where coal was removed, and rubble.

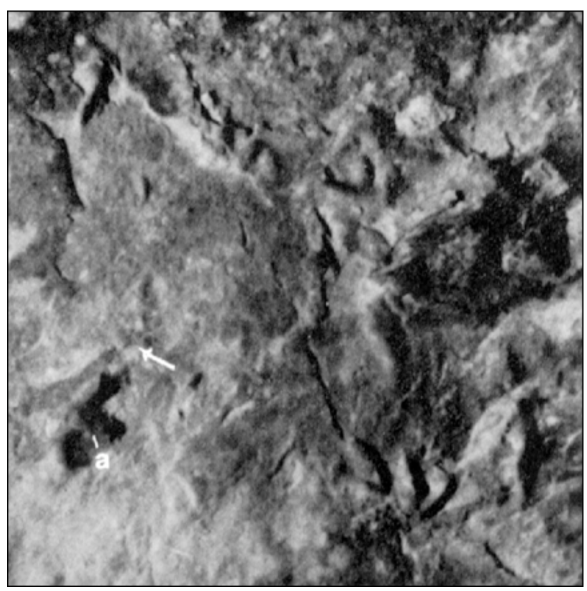

Figure 13. Several small dinosaur footprint casts which occur on the exposed surface of the roof fall area in Figure 8. Cast in lower left **(a)** shows three-toed, asymmetrical organization. End of longest toe originally extended to arrow tip. Map, Figure 15, was made from this surface.

explosive coal dust. This completely covers all roof features or distorts observation of roof topography with a "snow-blindness" effect. Secondly, "top coal", a layer of coal usually from 10 to 50 cm thick, is left in place on the roof to cover certain types of roof shales which are otherwise subject to "air slacking" (the absorption and subsequent expansion of shales to the point that they fall from the roof). Because of these problems, only about 20% of the roof surface in any mine has been visible for study. But the most serious problem to the study of mine-roof paleontology is the recent development and use of long-wall retreat mining. The equipment in this technique removes coal in long 161 m swaths in such a way that the roof is unsupported and collapses within a few hours in the "gob area" behind the support shields. This completely destroys whatever features might have been preserved in the roof rock and makes studying the areas very hazardous.

Because dinosaur footprint casts are abundant in every level of swamp development which we can see underground, why don't they appear in outcrop? We have determined that they are indeed present and common in outcrop but are rarely recognized. For one thing, in lateral view they appear to be load castings which are expected (and present) in these sediments. Additionally, they weather rapidly, destroying characteristic toe

Figure 14. Cast of three-toed footprint seen in lateral view on undersurface of ledge in outcrop exposure. Rock hammer for scale.

and metatarsal features. In fresh exposures, however, and on protected undersurfaces of ledges there are often several intriguing three-lobed structures the same size and shape as those specimens in mine roofs (Fig. 14). We believe that many of these are dinosaur footprints, *not* load casts.

It is clear that the fluvial delta and coastal plain peat-forming environments of the Upper Cretaceous of the Rocky Mountain states had a large and varied dinosaur fauna recognized mainly from their tracks. Coal mines in the Blackhawk Formation of east-central Utah provide a unique opportunity to study their diversity, behavior and paleoecology.

Acknowledgments

We are grateful to Aureal T. Cross of Michigan State University for his infectious enthusiasm, help underground and insightful comments.

References

Bass, N. W., Eby, J. B., and Campbell, M. R. 1955. Geology and mineral fuels of parts of Routt and Moffat counties, Colorado. U.S. Geol. Surv. Bull.1027-D: 143-250.

Balsley, J. K., and Parker, L. R. 1983. Cretaceous Wave dominated Delta, Barrier Island, and Submarine Fan Depositional Systems: Book Cliffs east central Utah. Amer. Assoc. Petrol. Geol. Field Guide. 279 pp.

Currie, P. J. 1981. Bird footprints from the Gething Formation (Aptian Lower Cretaceous) of northeastern British Columbia, Canada. Jour. Vert. Paleont. 1(3-4):257-264.

Lockley, M. G. 1986. Dinosaur Tracksites. Univ. Colorado Denver Geol. Dept. Mag. Spec. Issue No. 1. 56 pp.

Lockley, M. G., Young, B. H., and Carpenter, K. 1983. Hadrosaur locomotion and herding behavior: evidence from footprints in the Mesaverde Formation, Grand Mesa Coal Field, Colorado. Mountain Geol. 20:5- 13.

Osterwald, F. W., and Dunrud, C. R. 1966. Instrumentation study of coal mine bumps, Sunnyside District, Utah. Utah Geol. Min. Surv. Bull. 80:97-110.

Parker, L. R. 1976. Paleoecology of the fluvial coal-forming swamps and associated floodplain environments in the Blackhawk Formation of central Utah. Brigham Young Univ. Geol. Studies 22:99-116.

1979. Paleoecology of delta and coastal plain plant communities in the Upper Cretaceous Blackhawk Formation of Utah. Botanical Soc. Amer. Misc. Ser. Publ. 157:35.

1980. Paleoecology of palm forests in Upper Cretaceous coal-forming swamps of central Utah. Botanical Soc. Amer. Misc. Ser. 158:86-87.

1981. Paleontology of the Cretaceous coal-forming environments in the Rock Springs Formation of Wyoming. Xlll Internat. Botanical Congr. Sydney AustraIia. Abst.:204.

Parker, L. R., and Balsley, J. K. 1977. Paleoecology of the coastal margin coal-forming swamps in the Upper Cretaceous Blackhawk Formation of central Utah. Geol. Soc. Amer. Abst.:1125-1126. Seattle.

Parker, L. R., and Rowley, L. R. 1989. Dinosaur Footprints from a Coal Mine in East-Central Utah. In D.D. Gillette and M.G. Lockley (ed) Dinosaur Tracks and Traces. (Cambridge University Press, 1989) pp. 360-366.

in prep. Plant fossils and dinosaur footprints in coal mine roof surfaces.

Peterson, W. 1924. Dinosaur tracks in the roofs of coal mines. Nat. Hist. 24 (3):388-391.

Ratkevich, R. P. 1976. Dinosaurs of the Southwest. (Albuquerque: University of New Mexico Press) 115 pp.

Strevell, C. N. 1932. Dinosauropodes. (Salt Lake City: C. N. Strevell and Deseret News Press) 15 pp.

Wilson, W. D. 1969. Footprints in the sands of time. Gems and Minerals June 1969:25.

Editorial Note: The bird-like tracks illustrated in Figure 15 display morphologies consistent with the asymmetric foot of Hesperomis and its relatives.

Figure 15. Map of numerous randomly oriented three-toed footprint casts. Clusters of two or more footprints seem to have been made by shuffling. Short linear depressions may be “peck marks” of the animal as it fed. Apparent tail drag casts occur in several places. Stippled areas are rock remaining on surface.