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AN INVENTORY OF NON-AVIAN DINOSAURS FROM NATIONAL PARK SERVICE AREAS

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Abstract—Dinosaurs have captured the interest and imagination of the general public, particularly children, around the world. Paleontological resource inventories within units of the National Park Service have revealed that body and trace fossils of non-avian dinosaurs have been documented in at least 21 National Park Service areas. In addition there are two historically associated occurrences, one equivocal occurrence, two NPS areas with dinosaur tracks in building stone, and one case where fossils have been found immediately outside of a monument's boundaries. To date, body fossils of non-avian dinosaurs are documented at 14 NPS areas, may also be present at another, and are historically associated with two other parks. Dinosaur trace fossils have been documented at 17 NPS areas and are visible in building stone at two parks. Most records of NPS dinosaur fossils come from park units on the Colorado Plateau, where body fossils have been found in Upper Jurassic and Lower Cretaceous rocks at many locations, and trace fossils are widely distributed in Upper Triassic and Jurassic rocks. Two NPS units are particularly noted for their dinosaur fossils: Dinosaur National Monument (Upper Triassic through Lower Cretaceous) and Big Bend National Park (Upper Cretaceous). To date, fourteen dinosaur species have been named from fossils discovered in NPS areas, the most famous probably being the sauropod *Apatosaurus louisae*. Increasing interest in the paleontology of the parks over the past few decades has brought many of these body and trace fossils to light. Future paleontological field inventories and research will likely yield new dinosaur finds from NPS areas.

INTRODUCTION

Non-avian dinosaurs are among the most iconic extinct animals. The great size and remarkable features of perennial favorites such as *Apatosaurus*/*Brontosaurus*, *Stegosaurus*, *Triceratops*, and *Tyrannosaurus* are indelibly ingrained into Western popular culture, where they have been joined by more recent stars such as the formidable *Deinonychus* and related dromaeosaurid "raptors". Non-avian dinosaurian body and trace fossils are known from nearly two dozen National Park Service (NPS) areas. Collectively, these occurrences span the Mesozoic and include significant Triassic, Jurassic, and Cretaceous localities. Bones, teeth, and footprints of early dinosaurs are documented in Upper Triassic strata in several NPS areas in Arizona, Colorado, and Utah. Jurassic records include bones and tracks in Arizona, Colorado, Utah, and Wyoming, headlined by the iconic Douglass Quarry Wall at Dinosaur National Monument. The Cretaceous dinosaur record extends from national parks in Alaska south to Big Bend National Park in Texas, documenting the final chapter of dinosaur history up to the terminal extinction event. The historical record begins with William Clark attempting to collect a presumptive dinosaur rib in Montana in 1806 on or near the modern Lewis & Clark National Historic Trail and continues to the widespread activity of the present day.

Records of non-avian dinosaurs in NPS areas mostly come from the Colorado Plateau, with a smaller group in Alaska (Fig. 1). Dinosaur remains are distributed fairly evenly through the Late Triassic, Jurassic, and Cretaceous. The NPS record includes few instances for the Middle Jurassic, which is typical for North America as a whole, and the Campanian and Maastrichtian of the Cretaceous are relatively underrepresented due to the limited presence of the appropriate rocks in NPS areas. On the other hand, the Early Jurassic is well-represented due to extensive exposures of the Glen Canyon Group in the Colorado Plateau parks. To date, body fossils of non-avian dinosaurs are documented from 14 NPS areas, may also be present at another, and are historically associated with two others. (For convenience, "non-avian" will be omitted in the rest of this document, but all references to dinosaurs should be understood as non-avian.) Confirmed occurrences of dinosaur body fossils are known from Arches National Park (ARCH), Big Bend National Park (BIBE), Bighorn Canyon National Recreation Area (BICA), Bryce Canyon National Park (BRCA), Capitol Reef National Park (CARE), Chaco Culture National Historical Park (CHCU), Colorado National Monument (COLM), Curecanti National Recreation Area (CURE), Denali National Park and Preserve (DENA), Dinosaur National Monument (DINO), Glen Canyon National Recreation Area (GLCA), Mesa Verde National Park (MEVE), Petrified Forest National Park (PEFO), and Yellowstone National Park (YELL). Dinosaur body fossils may also be present at Katmai National Park and Preserve (KATM), are historically associated with Lewis & Clark National Historic Trail (LECL) and Springfield Armory National Historic Site (SPAR), and have been found just outside of Navajo National Monument (NAVA). Fourteen species of dinosaurs have been named from body fossils found in these parks, plus one specimen historically associated with SPAR (Table 1).

Dinosaur tracks and other trace fossils have been reported from 17 NPS areas: Aniakchak National Monument and Preserve (ANIA), ARCH, BIBE, BICA, Canyonlands National Park (CANY), CARE, COLM, DENA, DINO, GLCA, PEFO, Pipe Spring National Monument (PISP), Rainbow Bridge National Monument (RABR), Wrangell-St. Elias National Park and Preserve (WRST), Yukon-Charley Rivers National Preserve (YUCH), YELL, and Zion National Park (ZION). In addition, dinosaur tracks are visible in building stone at Gettysburg National Military Park (GETT) and Valley Forge National Historical Park (VAFO).

In historical terms, many of the discoveries of dinosaur fossils from NPS areas have occurred since 1980. Before this time, apart from a few published tracks, knowledge of NPS dinosaurs was largely confined to DINO and BIBE, and little had yet been published on the dinosaur fossils from the latter. The expanding record of NPS dinosaur fossils can be attributed to a combination of the general upswing of interest in dinosaurs and a greatly increased awareness of paleontological resources

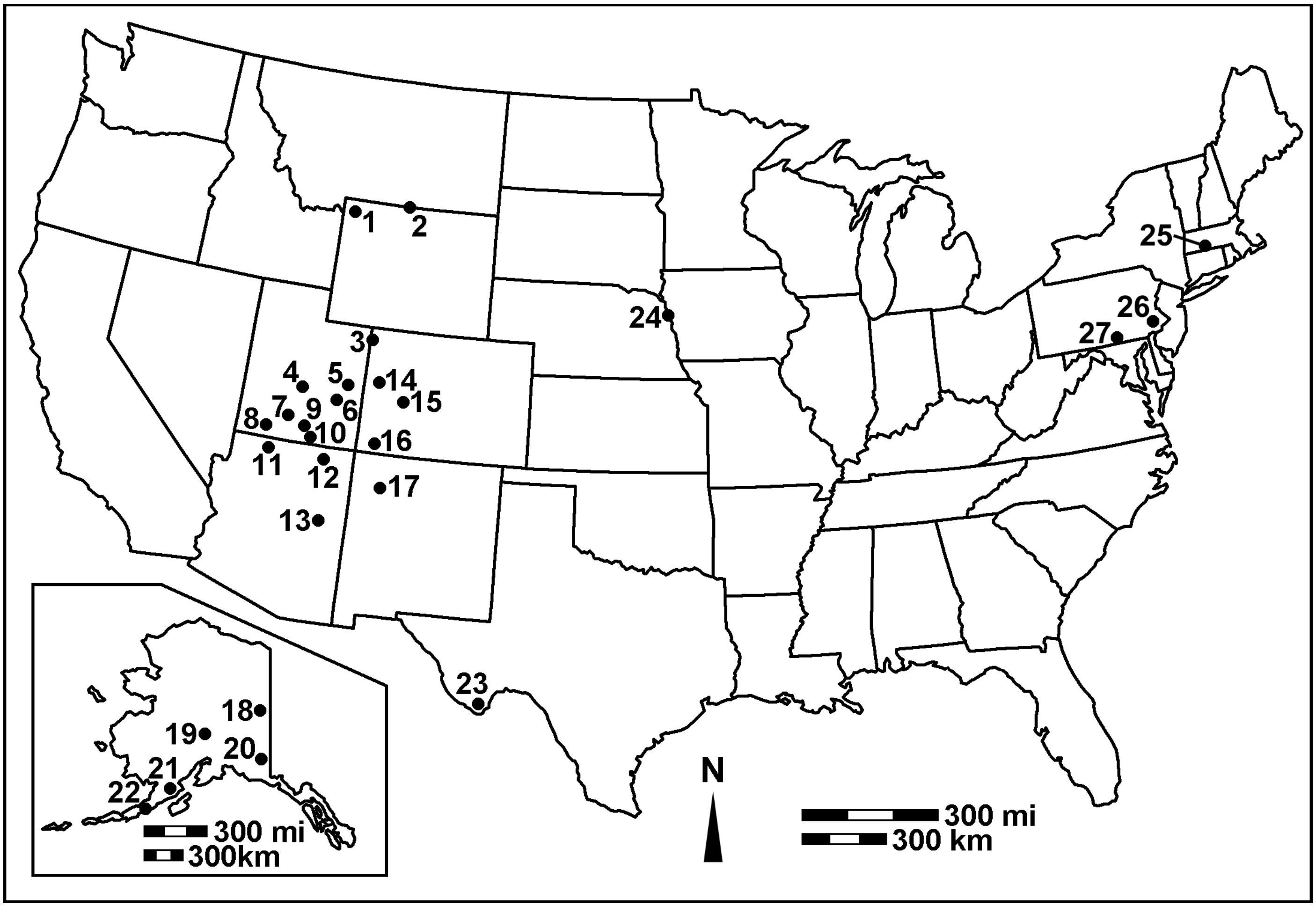

FIGURE 1. A map of National Park System units mentioned in the text. **1**, Yellowstone National Park (YELL), Idaho–Montana–Wyoming; **2**, Bighorn Canyon National Recreation Area (BICA), Montana–Wyoming; **3**, Dinosaur National Monument (DINO), Colorado–Utah; **4**, Capitol Reef National Park (CARE), Utah; **5**, Arches National Park (ARCH), Utah; **6**, Canyonlands National Park (CANY), Utah; **7**, Bryce Canyon National Park (BRCA), Utah; **8**, Zion National Park (ZION), Utah; **9**, Glen Canyon National Recreation Area (GLCA), Arizona–Utah; **10**, Rainbow Bridge National Monument (RABR), Utah; **11**, Pipe Spring National Monument (PISP), Arizona; **12**, Navajo National Monument (NAVA), Arizona; **13**, Petrified Forest National Park (PEFO), Arizona; **14**, Colorado National Monument (COLM), Colorado; **15**, Curecanti National Recreation Area (CURE), Colorado; **16**, Mesa Verde National Park (MEVE), Colorado; **17**, Chaco Culture National Historical Park (CHCU), New Mexico; **18**, Yukon-Charley Rivers National Preserve (YUCH), Alaska; **19**, Denali National Park & Preserve (DENA), Alaska; **20**, Wrangell-St. Elias National Park & Preserve (WRST), Alaska; **21**, Katmai National Park & Preserve (KATM), Alaska; **22**, Aniakchak National Monument & Preserve (ANIA), Alaska; **23**, Big Bend National Park (BIBE), Texas; **24**, Lewis & Clark National Historic Trail (LECL), multiple states; **25**, Springfield Armory National Historic Site (SPAR), Massachusetts; **26**, Valley Forge National Historical Park (VAFO), Pennsylvania; and **27**, Gettysburg National Military Park (GETT), Pennsylvania.

in the National Park System. Our knowledge of these animals in our parklands has been greatly enhanced by a number of park-specific and resource-specific paleontological resource inventories involving most of the parks in the previous lists.

The occurrences of dinosaurs in the various parks discussed below are arranged by geologic time period and then by NPS units, presented in alphabetical order. Separation by body and trace fossils was unfeasible because many parks had examples of both.

In addition to the various official units of the NPS, the NPS also administers the National Natural Landmarks (NNL) program and National Historic Landmarks (NHL) program. Among the numerous sites recognized by these programs are some connected to dinosaurs. It is beyond the scope of this document to fully document all of them here, but some notable examples include: in the NNL program, Bridger Fossil Area (MT), Cleveland-Lloyd Dinosaur Quarry (UT), Cloverly Formation Site (MT), Comb Ridge (AZ), Como Bluff (WY), Dinosaur Trackway (CT), Dinosaur Valley State Park (TX), Garden of the Gods (CO), Garden Park Fossil Area (CO), Ghost Ranch (NM), Hell Creek Fossil Area (MT), Morrison-Golden Fossil Areas (CO), Valley of Fire (NV), and West Bijou Site (CO); in the NHL program, Edward Drinker Cope House (PA), *Hadrosaurus Foulkii* Leidy Site (NJ), and Othniel Charles Marsh House (CT).

TRIASSIC DINOSAUR OCCURRENCES

Triassic dinosaur fossils are documented in eight NPS units and are primarily tracks. Most of the records are from either the Upper Triassic Chinle Formation or the overlying eolian Wingate Sandstone, which spans the Triassic–Jurassic boundary. The Chinle Formation is a heterogeneous terrestrial unit deposited across much of the American Southwest in a variety of settings, including fluvial, lacustrine, floodplain, and eolian (Stewart et al., 1972). Deposition began by at least 228 Ma, perhaps a few million years before (Dickinson and Gehrels, 2008a; Ramezani

TABLE 1. Non-avian dinosaur species named from specimens collected from localities known to be within NPS park boundaries as of May 2018, or historically associated with an NPS area in the case of *Megadactylus polyzelus* (=*Anchisaurus*).

TAXON	CITATION	PARK	FORMATION	TYPE SPECIMEN	NOTES
Agujaceratops mavericus	Lehman et al., 2017	BIBE	Aguja	TMM 43098-1	Ceratopsid
Angulomastacator daviesi	Wagner and Lehman, 2009	BIBE	Aguja	TMM 43681-1	Hadrosaurid
Bravoceratops polyphemus	Wick and Lehman, 2013	BIBE	Javelina	TMM 46015-1	Ceratopsid
Chasmosaurus mariscalensis	Lehman, 1989	BIBE	Aguja	UTEP P.37.3.086	Ceratopsid, now known as *Agujaceratops mariscalensis*
?*Gryposaurus alsatei*	Lehman et al., 2016	BIBE	Javelina	TMM 46033-1	Hadrosaurid
Richardoestesia isosceles	Sankey, 2001	BIBE	Aguja	LSUMGS 489:6238	Theropod
Texacephale langstoni	Longrich et al., 2010	BIBE	Aguja	LSUMNS 20010	Pachycephalosaurid
Abydosaurus mcintoshi	Chure et al., 2010	DINO	Cedar Mountain	DINO 16488	Brachiosaurid
Apatosaurus louisae	Holland, 1915b	DINO	Morrison	CMNH 3018	Diplodocid
Camarasaurus annae	Ellinger, 1950	DINO	Morrison	CMNH 8942	Camarasaurid, now considered a synonym of *Camarasaurus lentus*
Camptosaurus aphanoecetes	Carpenter and Wilson, 2008	DINO	Morrison	CMNH 11337	Iguanodontian, sometimes known as *Uteodon aphanoecetes*
Koparion douglassi	Chure, 1994	DINO	Morrison	DINO 3353	Theropod
Uintasaurus douglassi	Holland, 1919	DINO	Morrison	CMNH 11069	Camarasaurid, now considered a synonym of *Camarasaurus lentus*
Chindesaurus bryansmalli	Long and Murry, 1995	PEFO	Chinle	PEFO 10395	Basal dinosaur
Megadactylus polyzelus	Hitchcock Jr. (in Hitchcock, 1865)	SPAR	Portland or Longmeadow	ACM 41109	"Prosauropod", now known as *Anchisaurus polyzelus*; ICZN moved type to YPM 1883 in 2015

et al., 2014) and ended near the end of the Triassic. The Chinle Formation was followed by widespread eolian deposition, which dominated the Southwest for much of the Early Jurassic.

Arches National Park (ARCH)

Dinosaur tracks are known from the Chinle Formation at ARCH. Lockley and Gierliński (2009) described a fallen slab with at least 40 footprints attributed to the theropod ichnogenus *Grallator*. This slab is now in ARCH collections. It was found in the upper Chinle Formation (identified as the Rock Point Formation of the Chinle Group in Lockley and Gierliński, 2009; this would be the Church Rock Member of the Chinle Formation of Martz et al., 2017). Additional slabs with unpublished tracks have been found at this site at the top of the Chinle; the tracks are primarily *Grallator*, but at least one slab has *Anomoepus*-like dinosaur tracks as well (J. Foster, personal commun., 2018).

There are reports of both trace and body fossils from the overlying Wingate Sandstone within ARCH. The ages of these occurrences are not known for certain, but for convenience they will be discussed here. Madsen et al. (unpubl. report for ARCH, 2012) reported the discovery of a significant tracksite at the base of the formation in the Salt Valley part of the park, with abundant *Grallator* tracks. The tracks were found as "natural casts on the undersides of overhanging blocks". In addition to the tracks, Madsen et al. (unpubl. report for ARCH, 2012) also reported a zygapophysis of a dinosaur vertebra. It came from somewhere near the middle of the formation, but the precise level is unknown because it was found as float. This specimen may be the first dinosaurian body fossil found in the Wingate Sandstone (S. K. Madsen et al., unpubl. report for ARCH, 2012). There is a chance, though, that the specimen came from the overlying Kayenta Formation (A. Milner, personal commun., 2018).

Canyonlands National Park (CANY)

To date, there is a single record of a dinosaur fossil in the Triassic rocks of CANY: a *Grallator* track in the Church Rock Member (Rock Point Formation of Lucas et al., 1995) of the Chinle Formation, found in the Upheaval Dome area of the park (Lucas et al., 1995; Santucci et al., 1998). This track has been maintained in situ (Lucas et al., 1995). Based on the abundance and distribution of tracks in Upper Triassic and Lower Jurassic rocks in the area (see for example Hunt-Foster et al., 2016), CANY is an excellent candidate for more discoveries.

Colorado National Monument (COLM)

There are several reports of Triassic dinosaur tracks in COLM. Scott et al. (2001a) reported a site with *Grallator*-like tracks in the Chinle Formation near the east entrance of the monument; however, the fossils are reportedly in a fallen block that may have come from the overlying Wingate Sandstone instead (J. Foster, personal commun. in Tweet et al., 2012). Several other track occurrences are reported from the lower 25 m (82 ft) of the Wingate Sandstone within COLM (Fig. 2A), in the part of the formation regarded as Late Triassic in age (Lucas et al., 2006a). King et al. (2004) briefly reported five localities with a total of 79 *Grallator* tracks in interdune rocks. Trujillo et al. (unpubl. report for COLM, 2004; 2005) also briefly mentioned these tracks, and Lucas et al. (2006a) more fully documented these tracksites. By that time, six localities were known, from the Devils Kitchen and Ute Canyon areas of the monument. Of the six sites, two were in situ and the others were fallen blocks. One of the in situ sites included examples of *Grallator* and the suggested sauropodomorph ichnogenus *Eosauropus*, while the other was limited to chirothere pseudosuchian tracks (although *Grallator* tracks may also be present; J. Foster, personal commun. in Tweet et al., 2012). The four displaced block sites have tracks of *Grallator* and synapsids. Some of the larger Devil's Kitchen tracks may represent the theropod ichnogenus *Anchisauripus* (J. Foster, personal commun., 2018).

Dinosaur National Monument (DINO)

Upper Triassic dinosaur tracks are known from two geologic units at DINO. Historically, the stratigraphic nomenclature of the Upper Triassic–Lower Jurassic interval of DINO and the vicinity has varied significantly from publication to publication. A full account of this history is beyond the scope of this report; recent summaries can be found in Sprinkel et al. (2011) and Irmis et al. (2015). For reference, the nomenclature of Irmis et al. (2015) is used here, with glosses as necessary to note the terminology used in in other reports. Irmis et al. (2015) divides the rocks into the Chinle Formation (Upper Triassic) and overlying Nugget Sandstone (uppermost Triassic–Lower Jurassic), with the Chinle Formation subdivided (in ascending order) into the Gartra Member, mottled member, ocher siltstone member, and upper member (orange sandstone interval below purple interval). The upper member of the Chinle Formation is significant as the interval sometimes identified with the Bell Springs Member of the Nugget Sandstone, occasionally raised to a formation in its own right (Bell Springs Formation of Hunt et al., 1993).

The oldest dinosaur fossils at DINO come from the Chinle Formation (Lockley et al., unpubl. report for DINO, 1990, 1992; Lockley et al.,1991, 1992a; the Chinle Formation is identified as the Popo Agie or Popo Agie/Chinle Formation in these publications). Lockley et al. (1992a) reported 17 track-bearing levels at 14 sites from DINO in the "Popo Agie/Chinle Formation". Tracks identified as the *Grallator*-like theropod ichnogenus *Agialopus* were found at eight sites, all in the orange sandstone interval of the upper member (Red Siltstone Member of their usage).

At least two possible dinosaur tracks have been reported from strata low in the Nugget Sandstone in DINO. Lockley et al. (1992a) mentioned an enigmatic semi-circular to ovoid track and a poorly preserved tridactyl track at two sites in the lower 7 m (23 ft) of the Nugget Sandstone (identified as the Glen Canyon Group). These sites were also briefly discussed by Lucas et al. (2006a; their Wingate Sandstone equivalent within the Glen Canyon Group), who tentatively attributed the tridactyl tracks of the area to *Grallator* and the ovoid tracks to the suggested sauropodomorph ichnotaxon *Eosauropus*. The presence of the Triassic ichnogenera *Eosauropus* and *Brachychirotherium* (likely aetosaur or rauisuchian tracks) in this stratigraphic sequence supports a Late Triassic age (Lucas et al., 2006a).

Gettysburg National Military Park (GETT)

In situ dinosaur fossils have not been discovered at GETT to date, but dinosaur tracks are visible in building stone of the South Confederate Avenue Bridge over Plum Run, a historic structure within the park. The stone used for the bridge was quarried from a site known as the Trostle Quarry about 24 km (15 miles) northeast of GETT during the middle 1930s (Kenworthy et al., 2006). The track-bearing stone slabs were quarried from the Upper Triassic Gettysburg Formation, near but below the base of the Heidlersburg Member (Olsen and Baird, 1986); this would be within the Passaic Formation under the reorganization of Weems et al. (2016). Several stones with clearly visible dinosaur tracks were built into the bridge (Kenworthy et al., 2006). Historic archives at GETT suggest that the track-bearing blocks were selected and used on the bridge capstone to display the tracks. Ichnotaxa represented in these blocks include *Anchisauripus* (Fig. 2B), *Atreipus milfordensis*, and possibly *Otozoum* (Kenworthy et al., 2006). *Anchisauripus* tracks are interpreted as theropod tracks, and *Otozoum* is attributed to sauropodomorphs. The *Atreipus* tracks have long been interpreted as dinosaurian (Olsen and Baird, 1986), and were in fact first assigned to *Anchisauripus* and *Grallator* (Kenworthy et al., 2006), but more recent study attributes *Atreipus* to silesaurids, small quadrupedal archosaurs closely related to early dinosaurs (Lagnaoui et al., 2012; Winitch and Olsen, 2017).

The Trostle Quarry produced a second batch of track-bearing stones in July 1937 (Cleaves, 1937). Some of the tracks were displayed at GETT shortly after their discovery, and GETT superintendent James R. McConaghie and assistant historian Frederick Tilberg facilitated distribution of the track slabs to various repositories, including the Carnegie Museum of Natural History, National Museum of Natural History, and State Museum of Pennsylvania (Kenworthy et al., 2006). The GETT tracks are also discussed in Santucci and Hunt (1995), Santucci et al. (1998), Cuffey (2006), and Kenworthy and Santucci (2006). The Gettysburg Formation is considered sparsely fossiliferous, but it is present within GETT, albeit generally hidden by cover (Kenworthy et al., 2006); therefore, it is not impossible that similar tracks will one day be found in situ in GETT.

Glen Canyon National Recreation Area (GLCA)

Dinosaur tracks have been reported from the Chinle Formation and Wingate Sandstone at GLCA. Tweet et al. (2009) mentioned that there are at least three track localities in the Chinle Formation of GLCA, although only two have been described in print (Lockley et al., 1998a). Of these two vertebrate track localities, one, at Four Mile Canyon, includes silesaurid tracks (*Atreipus*) and the other, at Mike's Mesa, has tridactyl tracks, which could have been produced by a dinosaur. The Mike's Mesa site may be the same as a tracksite reported in Longwell et al. (1923) (Lockley et al., 1998a); Longwell et al. assigned their section to the overlying Wingate Sandstone.

Lockley et al. (1998a) provided brief descriptions of

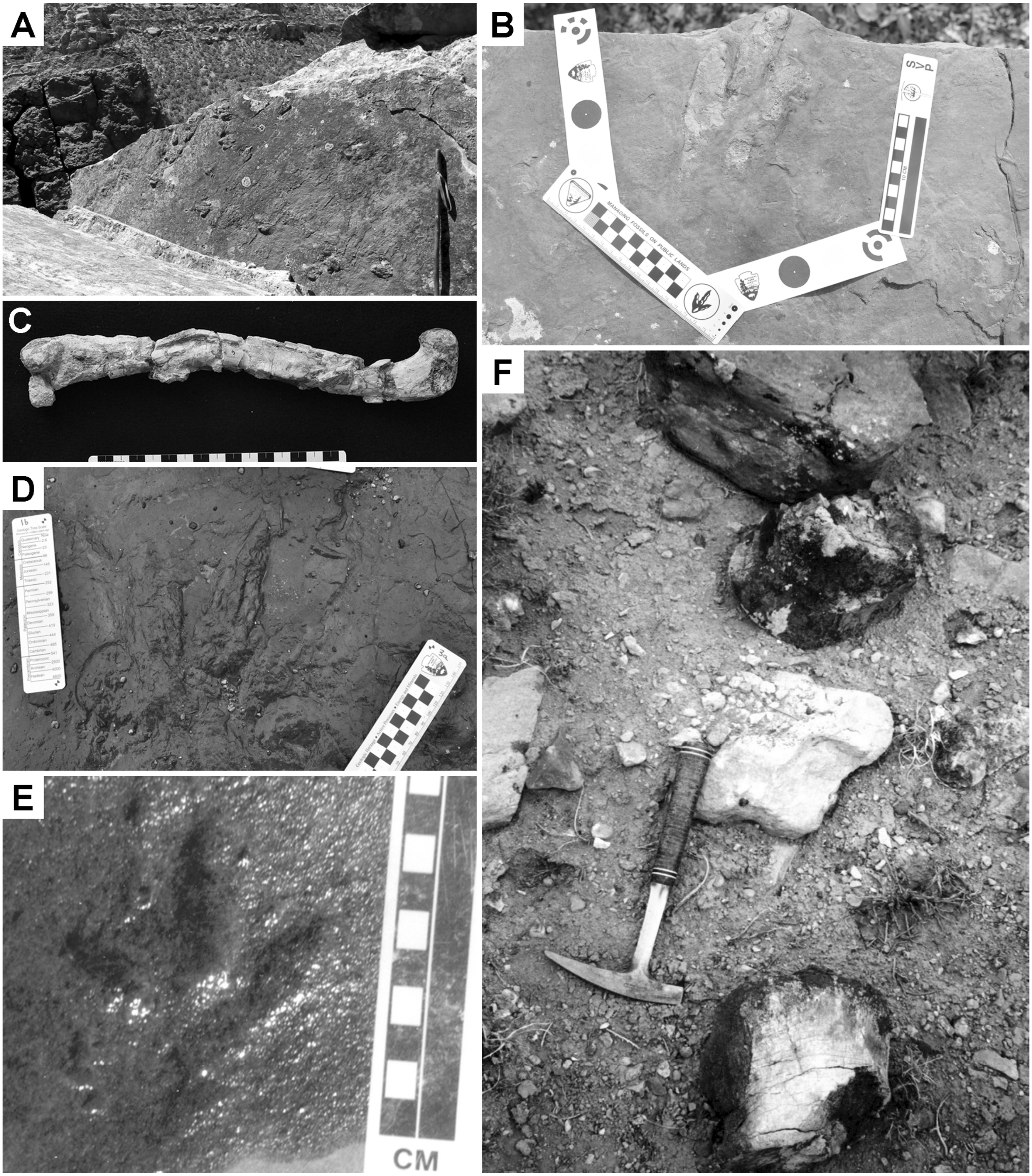

FIGURE 2. Examples of Triassic and Jurassic dinosaur fossils from NPS areas. **A,** Wingate Sandstone theropod tracks from Ute Canyon, COLM (courtesy of John Foster, Museum of Moab; photograph taken during permitted work at COLM). **B,** example of an *Anchisauripus* track in building stone at the South Confederate Avenue Bridge, GETT (VLS). **C,** *Chindesaurus* femur from PEFO (NPS). **D,** grallatorid track in building stone at VAFO (VLS). **E,** theropod track from the Moab Member of the Curtis Formation of ARCH (VLS). **F,** *Apatosaurus* caudal vertebrae at ARCH (courtesy of John Foster, Museum of Moab; photograph taken during permitted work at ARCH).

Wingate Sandstone tracksites at Lee's Ferry and the Rincon, and a third at North Wash near the recreation area. The Lee's Ferry tracksite was first reported in Riggs (1904). Riggs found six tracks at the site, all tridactyl, and collected a specimen, now FMNH (Field Museum of Natural History) P25123. Lockley et al. (1998a) assigned the tracks to *Grallator*. Riggs's specimen is the first fossil footprint collected and illustrated from the Glen Canyon area (Lockley et al., 1998a). The Rincon site, also known as the "Secor" site, is known to the boating public through its inclusion in Kelsey (1989). Tridactyl tracks are visible here (Lockley et al., 1998a). The North Wash site, less than 3 km (2 mi) outside of GLCA, was first reported by Hunt et al. (1953). Lockley et al. (1998a) revisited the site and observed four fallen blocks with tracks of cf. *Grallator sulcatus*. These Wingate Sandstone sites may be latest Triassic or earliest Jurassic; they are included under the Triassic for convenience. Photographs of additional sites are included in Delgalvis (2015); one site on the San Juan arm has numerous fallen blocks with *Grallator* tracks (A. Milner, personal commun., 2018).

Petrified Forest National Park (PEFO)

To date, the only confirmed Triassic dinosaurian body fossils in the National Park Service have come from PEFO (the Wingate Sandstone occurrence at ARCH may be Lower Jurassic). Dinosaurs are a rare component of the Chinle Formation assemblage here; Parker and Martz (2011: table 1) cited seven confirmed dinosaur specimens and an eighth probable specimen. Six of these eight are from the Petrified Forest Member, with one from the Jim Camp Wash beds of the Sonsela Member and the probable specimen from the Blue Mesa Member; all but the Blue Mesa Member occurrence are from the Revueltian biozone. The best-represented dinosaur at PEFO is a small theropod identified as *Coelophysis* sp., known from three partial skeletons from the Petrified Forest Member (UCMP 129618, PEFO 33981, and PEFO 33983) (Nesbitt et al., 2007). This form was first reported in Padian (1986). The other PEFO dinosaur identifiable to genus or species is *Chindesaurus bryansmalli*, known from a fragmentary skeleton (PEFO 10395) and other fossils (Nesbitt et al., 2007) (Fig. 2C). PEFO 10395, the holotype of *C. bryansmalli*, was collected from PEFO in 1984–1985 amid great media interest. The specimen was nicknamed "Gertie" after the iconic animated dinosaur created by pioneering cartoonist Windsor Mckay in the 1914 film "Gertie the Dinosaur". "Gertie" was erroneously reported as a prosauropod and initially suggested to be the earliest known dinosaur (e.g., Meyer, 1986). The specimen received its scientific name in Long and Murry (1995) and today is generally considered to be a herrerasaurid, although recent re-analysis indicates it was more derived (Marsh et al., 2016). Alternatively, it may be the case that *Chindesaurus* was indeed a herrerasaurid but that herrerasaurids are outside of Dinosauria (Baron and Williams, 2018). Other discussions of these occurrences can be found in Hunt et al. (1996, 1998), Hunt and Wright (1999), Irmis (2005a), and Parker and Irmis (2005).

Due to discoveries over the past few decades showing unexpected diversity of Triassic reptiles, including several examples of purported dinosaurs proving to belong to other groups, a great deal of caution is warranted when dealing with isolated Triassic bones. Therefore, it is not surprising that some of the purported dinosaur finds from PEFO have been re-evaluated as non-dinosaurian or ambiguous (Nesbitt et al., 2007). PEFO occupies a notable place in the re-assessment of Triassic dinosaurs; it yielded specimens (PEFO 33787 through 33795) that showed the purported Triassic ornithischian dinosaur *Revueltosaurus callenderi* to be a relative of the aetosaurs (Parker et al., 2005) and helped set off a re-evaluation of putative Triassic dinosaurs. In addition to dinosaurs, a proximal silesaurid femur (PEFO 34347) is known from the Blue Mesa Member in PEFO (Parker et al., 2006; Nesbitt et al., 2007; Parker and Martz, 2011).

Putative dinosaur tracks from PEFO were reported by Martin and Hasiotis (1998) and Hunt and Lucas (2006). Martin and Hasiotis (1998) interpreted two partial prints from the Newspaper Rock Bed (Hunt and Lucas, 2006) as dinosaurian, one with traces of three toes interpreted as a large theropod track, the other a less complete trace interpreted as similar to *Atreipus*. Hunt and Lucas (2006) reinterpreted the "*Atreipus*" track as an example of the crurotarsan ichnogenus *Brachychirotherium* and identified the tridactyl track as *Eubrontes*; the identity of this poorly preserved track is questionable (A. Milner, personal commun., 2018). Hunt and Lucas (2006) also reported tracks similar to the possible sauropodomorph ichnogenus *Barrancapus*.

Valley Forge National Historical Park (VAFO)

In November 2017, a volunteer at VAFO reported finding a pes and possible manus track of the dinosaur-like *Atreipus* in Triassic building stone, quarried locally and placed in a foot path in 2012. One of the authors (Vincent Santucci) visited VAFO in April 2018 and obtained photogrammetric images of several vertebrate tracks in the building stone. Aside from the *Atreipus* tracks, he also identified crurotarsan tracks (*Brachychirotherium*) and dinosaurian tracks of an unknown grallatorid (Fig. 2D).

JURASSIC DINOSAUR OCCURRENCES

Records of Jurassic dinosaurs in NPS areas are mostly from the Colorado Plateau and typically come from one of two sources: Lower Jurassic rocks of the Glen Canyon Group and correlatives, or Upper Jurassic rocks of the Morrison Formation. The Glen Canyon Group units are historically noted for a sparse record of vertebrate body fossils but a greater abundance of vertebrate tracks. The group is often divisible into the basal Wingate Sandstone and/or Moenave Formation (in part a lateral equivalent), overlying Kayenta Formation, and uppermost Navajo Sandstone (Harshbarger et al., 1957); to the north the Nugget Sandstone is equivalent to the group (Sprinkel et al., 2011). Although the Glen Canyon Group is known for eolian sandstones, fluvial deposition was significant for the Kayenta and Moenave formations (Harshbarger et al., 1957), and the Whitmore Point Member of the Moenave Formation is known for its lacustrine rocks (Tanner and Lucas, 2008; Kirkland et al., 2014). The Morrison Formation is found across much of the American West, from western Oklahoma and northern New Mexico into Montana. It is a heterogeneous terrestrial formation, deposited primarily in a combination of fluvial, floodplain, and lacustrine settings, and it features not only significant dinosaurian body fossils but also fossils of a wide range of other organisms (Foster, 2003). Morrison Formation outcrops at many NPS units were explored as part of the Morrison Formation Extinct Ecosystems Project of 1994–1997, a multidisciplinary effort to study the ecosystem of this formation in detail (Turner et al., 1996).

Arches National Park (ARCH)

Several Jurassic formations exposed in ARCH have yielded fossil evidence of dinosaurs. Aside from the Wingate Sandstone, discussed in the previous section and of ambiguous age, the oldest such unit is the overlying Lower Jurassic Kayenta Formation. At least two theropod tracks have been found in this formation within the park (Swanson et al., 2005). More notably, fragmentary bones of a *Dilophosaurus*-sized theropod have also been found. These fossils, including partial vertebrae, long bones, and other limb elements, are the first dinosaur body fossils found in the Kayenta Formation of Utah. Most Kayenta Formation body fossils come from the silty facies, found to the south in Arizona, with only rare body fossils in the northern sandy facies (S. K. Madsen et al., unpubl. report for ARCH, 2012).

Above the Kayenta Formation, few fossils have been located in the Lower Jurassic Navajo Sandstone of ARCH, but a few dinosaur tracks have recently been identified. One site has been interpreted as a playa facies of the formation in Salt Valley and has several *Grallator* tracks as well as stromatolites (S. K. Madsen et al., unpubl. report for ARCH, 2012). In spring 2018, another site was reported by ARCH staff (M. Van Scoyoc and S. Baril, personal commun., 2018). This site includes at least one sauropodomorph track (*Navahopus* or *Otozoum*).

Higher in section, the lower Upper Jurassic Moab Member of the Curtis Formation has yielded abundant fossil tracks in and around ARCH (Fig. 2E). The uppermost part of the unit, at the contact with the overlying Summerville Formation, hosts part of an extensive megatracksite (Lockley, 1991; Lockley et al., 2007). References to the tracks can be confusing because of changes in stratigraphic nomenclature or differences in application; the Moab Member was formerly assigned to the Entrada Sandstone (Doelling, 2010), and the megatracksite horizon is sometimes attributed to the basal Summerville Formation instead (Lockley, 1991). Practically all of the tracks are attributed to the large theropod ichnogenus *Megalosauripus* (Lockley and Hunt, 1995), although another type of large theropod track (*Therangospodus*) has also been identified (Lockley et al., 1998b). Smaller theropod tracks have been found lower in the Moab Member (Lockley and Hunt, 1995), including from at least eight locations just west of ARCH (Lockley et al., 2007). Tracks have been known in the Moab Member near Moab since 1936 (Lockley, 1991). Fossil footprints from near Courthouse Wash west of ARCH were described by McKnight (1940), and area tracks were examined by track specialist Roland T. Bird in 1944, but the tracks were largely forgotten for many years (Lockley, 1991). McKnight's tracks are examples of the smaller dinosaur tracks which occur lower than the megatracksite horizon (Lockley et al., 2007).

The uppermost Jurassic formation in ARCH is the Morrison Formation. Isolated dinosaur skeletal fossils have been found in this formation at a number of locations within ARCH. Some of the most significant finds include possible bones of rare Morrison ankylosaurs (Swanson et al., 2005) and fossils of an *Apatosaurus* from near the top of the formation (Foster, 2005; Swanson et al., 2005) (Fig. 2F). The *Apatosaurus* material may represent the latest Morrison Formation dinosaur known from the Colorado Plateau (Santucci and Kirkland, 2010).

Bighorn Canyon National Recreation Area (BICA)

The Middle Jurassic Gypsum Spring Formation and Upper Jurassic Morrison Formation have yielded dinosaur fossils within BICA. The Gypsum Spring Formation occurrences are entirely ichnofossils. There is one interval in the middle portion of the formation, about a meter thick, that includes multiple track-producing horizons. The tracks are all of tridactyl bipeds, at least some of which were theropods, and were preserved within microbial mat growth on tidal flats (Kvale et al., 2001). A meter above this interval is a widespread horizon with swim traces; most were left by crocodylomorphs, but some may have been produced by bipedal dinosaurs (Mickelson et al., 2005a, b, 2006).

In the Morrison Formation, dinosaur fossils include a sauropod tracksite low in the formation on the west side of Sykes Mountain (Engelmann and Hasiotis, 1999; Santucci et al., 1999), and fragmentary unidentified dinosaur bones (Santucci et al., 1999).

Canyonlands National Park (CANY)

Dinosaur tracks are known from the Kayenta Formation at CANY (Tweet et al., 2012), but are undescribed. Tweet et al. (2012) included a photograph of a tridactyl track (Fig. 3A). Ichnofossils in the Kayenta Formation at CANY are found in the upper part of the formation, just below the Navajo Sandstone (Lockley and Hunt, 1993; Santucci et al., 1998).

Capitol Reef National Park (CARE)

Dinosaurs have been reported from two Jurassic formations in CARE, but in both cases the fossils have only been mentioned in passing. Undescribed dinosaur tracks have been reported from the Kayenta Formation of CARE (Santucci et al., 1998), and dinosaur bones have been reported from the upper Salt Wash Member of the Morrison Formation (Santucci and Kirkland, 2010). Fragmentary bones of herbivorous dinosaurs are reportedly common in Salt Wash Member paleochannels at CARE (Petersen and Roylance, 1982). Some of the bone sites show evidence of vandalism (G. F. Engelmann, unpubl. report for NPS, 1999).

Colorado National Monument (COLM)

There are a number of dinosaur fossils reported from the Morrison Formation of COLM, and the monument is adjacent to historically significant paleontological localities (Tweet et al., 2012). Three members of the Morrison Formation can be distinguished in COLM, in ascending order the Tidwell, Salt Wash, and Brushy Basin members (Scott et al., 2001b). All three members have produced dinosaur fossils within the monument (Scott et al., 2001a; Trujillo et al., 2005). The monument's Morrison Formation outcrops were first surveyed by George Callison and field assistants in 1977 (G. L. Callison, unpubl. report for COLM, 1977). Additional surveys were undertaken by George Engelmann in 1985, and Engelmann and Anthony Fiorillo in 1995 (Scott et al., 2001a). Rodney Scheetz surveyed the trails in 2001, and Kelli Trujillo and field assistants surveyed again in 2004 (K. Trujillo et al., unpubl. report for COLM, 2004).

The lowest Morrison Formation dinosaur records in COLM are in the Tidwell Member. They include a tridactyl dinosaur track in the Artists Point area (Tweet et al., 2012) and a sauropod bone documented from channel sandstones of the upper Tidwell Member in the western part of the monument (Armstrong and McReynolds, 1987). Dinosaur bones are present in the Salt Wash Member (Trujillo et al., 2005), and there are also theropod, sauropod, and ornithopod tracks from this member (Foster and Lockley, 2006; Lockley and Foster, 2006). One locality has eight tracks of tridactyl dinosaurs showing a mix of walking and swimming traces. Identifiable ichnotaxa include *Dinehichnus socialis* (interpreted as an ornithopod) and the swimming trace *Characichnos*, probably in part made by the same animals in water. A probable theropod track is also present. The site is near a prolific turtle trace horizon, which is slightly higher in section (Lockley and Foster, 2006). Sauropod tracks have also been found at various horizons in the member (Foster and Lockley, 2006). Finally, dinosaur bones have been reported from the Brushy Basin Member (Trujillo et al., 2005).

Curecanti National Recreation Area (CURE)

Dinosaur bones were first found in the Morrison Formation of the Black Canyon area by uranium prospectors in the early 1950s (Jenkins, 2004), but fossils from the area of CURE and adjoining Black Canyon of the Gunnison National Park (BLCA) were not studied in detail until the 1990s. In CURE, dinosaurs and other Morrison Formation vertebrates are best known from three localities on Blue Mesa Reservoir (Koch and Zichterman, 2006; Koch et al., 2006, Foster et al., 2015). In most references to date, the sites are known as Dino Cove, Dinosaur Beach, and Northern Dinosaur Beach, but in Foster (2013) Dino Cove is the Blue Mesa *Apatosaurus* Quarry, and in Foster et al. (2015) Dinosaur Beach and Northern Dinosaur Beach are South Beach and North Beach, respectively, with an extension of North Beach identified as North Beach II. Stratigraphically, all three

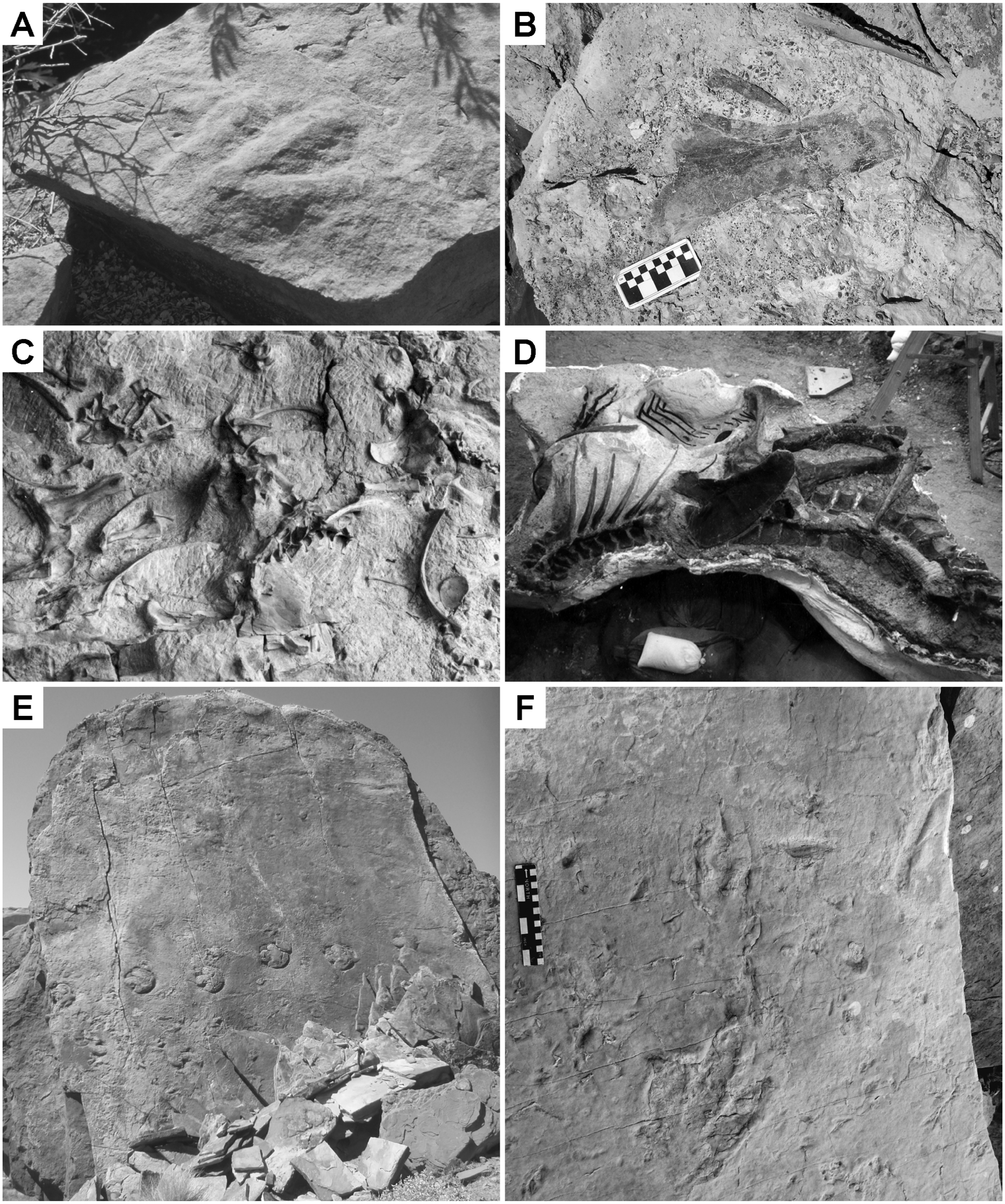

FIGURE 3. Examples of Jurassic dinosaur fossils from NPS areas. **A,** a dinosaur track from the Kayenta Formation of CANY (VLS); **B,** pieces of dinosaur bone at the Dinosaur Beach site of CURE (Jason Kenworthy/NPS); **C,** part of the Dinosaur Quarry wall as prepared today for visitors (JST); **D,** The postcranial skeleton of *Allosaurus* specimen DINO 11541, under preparation (VLS); **E,** massive block of track-bearing Navajo Sandstone at GLCA; several large theropod tracks that resemble ornithopod tracks are evident, but many other tracks are also exposed on this block (NPS); **F,** slab at GLCA featuring three theropod tracks: a larger track in the lower right and two smaller tracks with metatarsal impressions in the upper half, from a crouching theropod (photo by David Slauf/St. George Dinosaur Site, courtesy of Andrew R. C. Milner).

appear to be in the Brushy Basin Member, with the two "beach" sites slightly lower in section than Dino Cove (Koch et al., 2006). The faunal assemblage of the sites includes theropods (*Allosaurus* sp., *Ceratosaurus* sp., and indeterminate theropods), sauropods (*Apatosaurus* sp., *Camarasaurus* sp., *Diplodocus* sp., and indeterminate sauropods), *Stegosaurus* sp., possibly a hypsilophodont-grade ornithischian, and indeterminate dinosaurs, as well as goniopholidids, mammals, indeterminate reptiles, and possibly turtles and pterosaurs (Foster et al., 2015)

Dino Cove was discovered in the mid-1990s. It is best known for yielding a partial associated skeleton of *Apatosaurus*, apparently deposited as a floating carcass by a flood and later scavenged (Fiorillo and May, 1996; Fiorillo et al., 1996). *Allosaurus* and *Stegosaurus* bones have also been reported from Dino Cove (Koch et al., 2006), although the former was not included in Foster et al. (2015). Foster (2013) mentioned and illustrated a *Stegosaurus* caudal centrum and a more complete *Stegosaurus* caudal vertebra (MWC 5525) from the site. Zircon samples were collected from neighboring rocks stratigraphically equivalent to the base of the Dino Cove site (F. Frost, personal commun., 2018), and U-Pb dating resulted in an age of 151 ± 0.5 Ma (K. Chamberlain, unpubl. report for CURE, 2015).

Dinosaur Beach/South Beach (Fig. 3B) has yielded generally fragmentary remains, including fossils Koch et al. (2006) attributed to *Allosaurus* and *Camarasaurus*, and a vertebra identified as possibly from *Stegosaurus* in Tweet et al. (2012), but which proved to be a distal sauropod caudal vertebra after further preparation (J. Foster, personal commun., 2018). Only an indeterminate sauropod caudal centrum and the tibia of a small bipedal dinosaur were reported from this site in Foster et al. (2015). Northern Dinosaur Beach/North Beach also has yielded generally fragmentary fossils, but of a more diverse assemblage (Koch et al., 2006), including *Allosaurus*, *Camarasaurus*, *Ceratosaurus*, *Diplodocus*, indeterminate theropods, indeterminate sauropods, what may be a hypsilophodont-grade ornithischian, and indeterminate dinosaurs. (Foster et al., 2015).

Dinosaur National Monument (DINO)

Three Jurassic units within DINO are known to have produced dinosaur fossils in the monument: the Lower Jurassic portion of the Nugget Sandstone, the Middle Jurassic Carmel Formation, and the Upper Jurassic Morrison Formation.

Numerous tracksites have been reported from the eolian upper Nugget Sandstone within DINO. Lockley (2011) reported on a group of 13 track-bearing horizons at three sections from the vicinity of the monument's visitor center. The horizons ranged from about 35 m (115 ft) to about 8 m (26 ft) below the overlying Carmel Formation. Five of the track-bearing surfaces were mapped and were found to include approximately 260 dinosaur tracks from 125 trackways. The majority of tracks were identified as theropod tracks, but there were at least 20 trackways of the sauropodomorph ichnogenus *Otozoum*. On one horizon are several parallel *Otozoum* trackways, suggesting possible gregarious behavior of the trackmakers (Lockley, 2011). These tracks are also briefly discussed in Gregson et al. (2010). Near DINO, the Saints and Sinners Quarry in the Nugget Sandstone has yielded skeletal remains of at least 20 individuals of an undescribed coelophysoid dinosaur (Chure et al., 2014).

The Middle Jurassic Carmel Formation, of mixed terrestrial and marine origin (Rigby, 1964), has equivocal records of dinosaur tracks at DINO. Loope and Simpson (1992) mentioned the presence of reptile tracks just below the Entrada Sandstone of DINO, based on a personal communication. Untermann and Untermann (1954) observed tridactyl and tetradactyl tracks near the southwestern part of DINO. These tracks are probably on BLM land, but there are other tracks in fluvial beds within the monument (D. Sprinkel, personal commun., 2012 in Tweet et al., 2012).

Although the Upper Cretaceous dinosaur fossils at BIBE are garnering an increasing amount of attention, DINO is still the face of NPS dinosaurs, and the face of dinosaurs within DINO is the world-renowned Dinosaur Quarry (also known as the Carnegie Quarry or Douglass Quarry), within the Morrison Formation. Dinosaur fossils have also been found at other Morrison Formation sites in the monument. The following discussion is largely adapted from Tweet et al. (2012). The first prospecting for dinosaur fossils in the DINO area predates the quarry by nearly 40 years. Othniel Charles Marsh, who would later become famous for his work on dinosaurs of the Morrison Formation in Colorado and Wyoming, collected a theropod tooth from the Morrison Formation just beyond what would become the northwestern boundary of DINO in 1870 (Marsh, 1871; Bilbey and Hall, 1999; Chure, 2000a, 2000b). The tooth probably pertains to *Allosaurus* (Chure, 2000b), and represents the second recorded dinosaur discovery from Utah, the first to be published, and the first record of theropods from the state (Bilbey and Hall, 1999).

The Dinosaur Quarry site was discovered August 17, 1909 by Carnegie Museum of Natural History (CM or CMNH) paleontologist Earl Douglass. Douglass would not only lead excavations at the site, but envisioned the in situ fossil relief concept that became the monument's feature attraction (Chure and McIntosh, 1990; Carpenter, 2018). The first fossils he found were eight articulated tail vertebrae of an *Apatosaurus*, which are now recognized as part of the holotype of *Apatosaurus louisae* (CM 3018) on display at the Carnegie Museum in Pittsburgh. Between 1909 and 1922, museum personnel extracted more than 320,000 kg (700,000 lbs.) of fossils from the Dinosaur Quarry, mostly from dinosaurs, but also from turtles and crocodylomorphs (Chure and McIntosh, 1990). Carnegie Museum officials began to worry that the site would be claimed by speculators or attract competition, so they filed a claim on the land for its mineral rights. This was denied on the grounds that fossils were not strictly minerals (Chure and McIntosh, 1990; Elder, 1990). First Assistant Secretary of the Interior Andrieus A. Jones, sympathetic to the efforts to protect the site, independently set into motion an alternative plan for protection: designation of the site as a National Monument under the Antiquities Act of 1906. On October 4, 1915, President Woodrow Wilson signed Dinosaur National Monument into existence, much to the surprise of Douglass and Carnegie Museum director William Holland. After a brief initial period of wariness, the Carnegie Museum continued operations for several more years (Carpenter, 2018).

1922 was the last year of excavation for the Carnegie Museum (Chure and McIntosh, 1990; Elder, 1999). The Carnegie field crews were followed in 1923 by the National Museum of Natural History (USNM) under the supervision of Charles Gilmore, who would eventually describe several notable finds from the quarry (e.g., Gilmore, 1925a, 1925b, 1932, 1936), and the University of Utah (UUVP, UMNH, or NHMU). Both institutions collected 33 crates of fossils, with the USNM collection including a skeleton of *Diplodocus*, and the University of Utah collection including an *Allosaurus*, which was on display before being sent back to DINO in the early 1980s (Chure and McIntosh, 1990). The University of Michigan received a permit to excavate in 1924 but did not act on it (Carpenter, 2013). With such large quantities of fossils already collected, it is understandable that Douglass faced skepticism when he proposed that an unexcavated section be prepared to show bones in situ, prepared in relief. Although there was interest in developing the site, difficulties in obtaining funding stymied its development until the 1950s (Carpenter 2018).

Very little paleontological fieldwork was undertaken at DINO between 1925 and 1952, although some non-paleontological excavation work was done at the quarry at the suggestion of

American Museum of Natural History paleontologist Barnum Brown (Chure and McIntosh, 1990; Elder, 1999). This work was performed between 1933 and 1938 by laborers from the Civil Works Administration, then the Transient Relief Service, and finally the Works Progress Administration (Chure and McIntosh, 1990). DINO expanded greatly in 1938, from the original quarry site to an area including Split Mountain Gorge and canyonlands of the Green and Yampa rivers (Carpenter, 2018). The quarry once again became active in 1953, when Douglass' plan was brought back to life as part of the wider Mission 66 initiative (Elder, 1999). Work to expose bones on the quarry face began under the direction of park paleontologist Theodore White. Any doubts about whether scientifically important specimens were still present were answered with White's publication (White, 1958) on a new partial skull of *Camarasaurus* (Chure and McIntosh, 1990), the same year the visitor center was dedicated. In the end, over 1,400 bones were prepared for viewing on the quarry face (Elder, 1999) (Fig. 3C). The in situ bone relief display concept was adopted by several other heavily fossiliferous sites, such as Berlin-Ichthyosaur State Park in Nevada, the Mammoth Site in South Dakota, and the Dashanpu Dinosaur Museum in China (Chure and McIntosh, 1990). The DINO visitor center had to be closed in the first decade of the 2000s due to structural damage brought on by underlying bentonitic shrink-swell clays (Chure, 2010), and a new facility opened at the quarry in October 2011 (Carpenter, 2013).

Paleontological work in the Morrison Formation of DINO began to go beyond Dinosaur Quarry in the 1980s. Surveying of DINO's Morrison Formation took place in the 1980s and 1990s. A preliminary survey in 1984 found more than 100 fossil localities, including what would become the two very productive vertebrate microsites in Rainbow Park. A more extensive survey began in 1989, and within two field seasons over 260 localities had been documented. More than half of the localities had dinosaur bone, usually scrappy. The survey found that the Salt Wash Member had abundant fossils in its sandstone beds, but the material was limited to wood and dinosaur bone. The overlying Brushy Basin Member had much more diverse fossils, in sandstone and finer beds (Engelmann, 1992).

One of the best theropod specimens discovered and collected at the monument (DINO 11541) (Fig. 3D) was found in the Salt Wash Member in 1990 by George Engelmann (Chure, 2000a). Initially headless, its skull was located in 1996 by Ray Jones using a shielded gamma scintillation detector (Jones et al., 1998; Chure, 2000a). This specimen has been reported as representing a new species of *Allosaurus* (Chure, 2000a). A year later, a partial skeleton of an embryonic *Camptosaurus* was found high in the formation by Scott Madsen (Chure et al., 1994). Reinvestigation of old material has also yielded important discoveries, such as a partial skeleton of the rare theropod *Marshosaurus* that was collected in 1912 but not studied until the 1990s (Chure et al., 1997).

Dinosaurs reported from DINO include the theropods *Allosaurus* (two species), *Ceratosaurus*, *Koparion*, *Marshosaurus*, *Torvosaurus*, and an unnamed possible troodontid; the sauropods *Apatosaurus*, *Barosaurus*, *Camarasaurus*, *Diplodocus*, and possibly *Haplocanthosaurus*; the stegosaurid *Stegosaurus*; the ornithopods *Camptosaurus* and *Dryosaurus* (Foster, 2003; Gregson et al., 2010); and dinosaur eggshell (Bray and Hirsch, 1998). There are also reports of undescribed unusual theropods, currently only documented in abstracts (Chure et al., 1993; Chure, 1995). Aside from Dinosaur Quarry, several microsites within DINO have proven to contain diverse vertebrate assemblages, including Rainbow Park Microsite DNM 94, Rainbow Park Microsite DNM 96 (Foster, 2003), and DNM 375 (Engelmann and Callison, 1998). Locality-level taxonomic lists for the Morrison Formation dinosaurs can be found in Turner and Peterson (1999), and similar compilations for all vertebrates can be found in Foster (2003).

Dinosaur Quarry, in the Brushy Basin Member (Lawton, 1977; Fiorillo, 1994), is famous for the abundance, variety, and preservation quality of its fossils (Untermann and Untermann, 1949; Gregson et al., 2010). The age of the quarry is thought to be slightly younger than 150.91 ± 0.43 Ma (recalibrated from 148.98 ± 0.42 Ma), in the Tithonian (Trujillo and Kowallis, 2015). Some 5,000 bones have been found at the quarry. It covers an area of 1,700 m^2 (18,300 ft^2), giving a density of 2.9 bones/m^2 (0.27 bones/ft^2) (Dodson et al., 1980). The paleoenvironmental setting was most likely a braided river system, perhaps like the Platte River, with flow to the south (not west to east, as is sometimes thought) (Carpenter, 2013). The fossil accumulation is interpreted as the result of three or four closely-spaced depositional events (Lawton, 1977; Fiorillo, 1994). Deposition occurred during brief periods of high flow, with short transportation distances for the bones (Lawton, 1977). It has been suggested that the remains represent attritional and non-catastrophic mass mortality from lengthy droughts (Carpenter, 2010, 2013). Some of the bones feature biogenic damage, in some cases perhaps microbial or algal in origin, in others from osteophagous or boring insects. However, insect damage is not abundant or necessarily from dermestid beetles, as sometimes reported. Soft-tissue impressions are known but few examples exist (Carpenter, 2013).

Dinosaurs from the Dinosaur Quarry include the following (minimum number of individuals in parenthesis): *Ceratosaurus* (1); *Torvosaurus* (1); *Allosaurus* (8, including 3 juveniles); *Diplodocus* (29, including 14 juveniles); *Apatosaurus* (16, including 4 juveniles and 1 hatchling); *Barosaurus* (5); *Camarasaurus* (22, including 6 juveniles); ?*Haplocanthosaurus* (2); *Stegosaurus* (14, including 3 juveniles); *Dryosaurus* (4, including 2 juveniles); and *Camptosaurus* (8, including 3 juveniles) (Foster, 2003, with correction for *Camptosaurus* after Carpenter and Wilson, 2008; this is not exhaustive because of the wide dispersal of quarry specimens, as noted in Carpenter, 2013). Diplodocid taxonomy is currently in flux, but although there is some question about species, the three classic genera *Apatosaurus*, *Barosaurus*, and *Diplodocus* are still considered present (Tschopp et al., 2015). Sauropods are often found as segments of a skeleton (White, 1964). *Stegosaurus*, while common (White, 1964), is found primarily as disarticulated specimens (Carpenter, 2013).

Two of the best-known specimens from the quarry are CM 11338, a nearly complete and articulated juvenile specimen of *Camarasaurus lentus* (Gilmore, 1925a), and CM 3018, the nearly complete holotype skeleton of *Apatosaurus louisae*, which is one of the defining specimens of this genus thanks to the extensive monograph by Charles Gilmore (Gilmore, 1936). This specimen is part of the *Apatosaurus* skull controversy because of CM 11162, a skull found near it. Holland thought that this skull was potentially that of CM 3018, which would give *Apatosaurus* a slender *Diplodocus*-like skull (Holland, 1915a, 1924a), in opposition to the prevailing opinion that *Apatosaurus* had a squarish *Camarasaurus*-like skull. Gilmore (1936) dismissed Holland in part because he thought that Holland had gotten CM 11162 confused with CM 11161, a smaller *Diplodocus* skull found farther away in the quarry (and which Holland had described earlier [Holland, 1924a] as *Diplodocus longus*). Thus, Gilmore thought that the skull near CM 3018 was the smaller skull CM 11161, which could not have belonged to the large skeleton. It later became apparent that Gilmore was the mistaken party, and CM 11162 is indeed the probable skull of CM 3018 (McIntosh and Berman, 1975; Berman and McIntosh, 1978).

Other notable specimens from the quarry include: juvenile specimens such as a baby *Dryosaurus* (Carpenter, 1994; originally described as a specimen of *Laosaurus gracilis* in Gilmore, 1925b), juvenile *Barosaurus* (Melstrom et al., 2016; Hanik et al., 2017), and a juvenile *Stegosaurus* (Galton, 1982); thirteen dinosaur skulls, from *Allosaurus* (two), *Apatosaurus* (one), *Camarasaurus* (five), *Diplodocus* (three), and *Dryosaurus* (two) (Chure and McIntosh, 1990; Gregson et al., 2010); and what may be the best specimens of *Dryosaurus* and *Camptosaurus* (Chure and McIntosh, 1990).

Two microvertebrate sites, now known as Rainbow Park Microsites DNM 94 and 96 (Turner and Peterson, 1999; Foster, 2003), were discovered in Rainbow Park by Robert West in 1984 (Chure and Engelmann, 1989). These localities are within the upper Brushy Basin Member, with DNM 94 lower than DNM 96 (Turner and Peterson, 1999). DNM 94 represents a mud slurry deposit and DNM 96 represents quiet water deposition (Chure and Engelmann, 1989). Dinosaurs reported from DNM 94 include *Allosaurus*, *Koparion* (Foster, 2003), an unnamed troodontid apparently distinct from *Koparion* (Turner and Peterson, 1999), *Diplodocus*, *Camarasaurus*, *Stegosaurus*, *Camptosaurus*, and *Dryosaurus* (Foster, 2003). Dinosaurs reported from DNM 96 include *Camarasaurus* and *Stegosaurus* (Foster, 2003).

Five dinosaur taxa have been named from the Morrison Formation of DINO (Table 1). In order of publication, they are:

- The sauropod *Apatosaurus louisae*, based on CM 3018 from Dinosaur Quarry (Holland, 1915b; Gilmore, 1936);
- The sauropod *Uintasaurus douglassi*, based on CM 11069 from Dinosaur Quarry (Holland, 1919, 1924b; now considered a synonym of *Camarasaurus lentus*);
- The sauropod *Camarasaurus annae*, based on CM 8942 from Dinosaur Quarry (Ellinger, 1950; now considered a synonym of *C. lentus*);
- The possible troodontid theropod *Koparion douglassi*, based on DINO 3353 from Rainbow Park Microsite DNM 94 (Chure, 1994);
- And the ornithopod *Camptosaurus aphanoecetes*, based on CM 11337 from Dinosaur Quarry (Carpenter and Wilson, 2008, originally described in Gilmore, 1925b as a specimen of *C. medius*; *Uteodon* of McDonald, 2011, but see Carpenter and Lamanna, 2015).

In addition, as mentioned above, an unofficially named species of *Allosaurus* is represented by an excellent skull and skeleton (DINO 11541) discovered in Salt Wash Member beds at DINO (site DNM 116) (Chure, 2000a).

The early years of collection in the area now within DINO (1909–1924) produced about 20 specimens that were complete enough to mount for display (Chure and McIntosh, 1990). Several museums exhibit original or cast specimens from DINO, including: the American Museum of Natural History (AMNH) in New York City (Norell et al., 1995); the Carnegie Museum of Natural History (CM or CMNH) in Pittsburgh (Chure and McIntosh, 1990); the Denver Museum of Nature and Science (DMNS, previously the Denver Museum of Natural History/DMNH) (Chure and McIntosh, 1990); the Royal Ontario Museum (ROM) in Toronto (Anonymous, 2007); the Smithsonian Institution's National Museum of Natural History (USNM) in Washington, D.C. (Chure and McIntosh, 1990); and the University of Nebraska State Museum (UNSM) in Lincoln (McIntosh, 1981).

The AMNH has a rearing mount of *Barosaurus* cast from DINO specimens obtained via the CM, the USNM, and the University of Utah (specimen AMNH FR 6341; Norell et al., 1995). The CM displays DINO fossils of the theropods *Allosaurus* and *Marshosaurus*, the sauropods *Apatosaurus*, *Camarasaurus*, and *Diplodocus*, *Stegosaurus*, and the ornithopods *Camptosaurus* and *Dryosaurus* (McIntosh, 1981; Chure, 2010). The DMNS has a *Diplodocus* obtained via the CM (DMNH 1494; Stokes, 1949; Markman, 1961). The ROM acquired a partial DINO *Barosaurus* skeleton in 1962 from the CM and put it on exhibition in 2007 (ROM 3670; Anonymous, 2007). The UNSM has a *Stegosaurus* mount based on fossils collected by the CM from DINO (CM 11372 or UNSM 53192; McIntosh, 1981). The USNM's mounted specimens include two significant sauropods, a *Diplodocus* (USNM 10865; Gilmore 1932; Stokes, 1949) and a *Camarasaurus* with a circuitous history (USNM 13786; Lay, 2016). The University of Utah formerly exhibited an *Allosaurus* from DINO, but it was transferred back to DINO with the bulk of their collection from the monument, and the skull is now on display at the monument (Chure and McIntosh, 1990); this specimen, historically UUVP 6000 or UU 6000, is now DINO 2560. A skeleton of *Apatosaurus* was sent to the Natural History Museum of Los Angeles County (LACM), in Los Angeles (LACM 52844; McIntosh and Berman, 1975; Tschopp et al., 2015), but the museum no longer has DINO fossils on display (Chure and McIntosh, 1990). Another noteworthy specimen returned to DINO, in this case from the USNM, is the *Camarasaurus* braincase described in White (1958) (DINO 28; Chure, 1981). The AMNH and CM also have mountable skeletons in storage (Chure and McIntosh, 1990).

Glen Canyon National Recreation Area (GLCA)

Dinosaur tracks are found extensively in several Jurassic formations at GLCA. Beginning above the Upper Triassic–Lower Jurassic Wingate Sandstone, which was discussed under the Triassic, the lowest completely Jurassic unit is the Kayenta Formation. The Kayenta Formation and overlying Navajo Sandstone are often exposed near the water level at Lake Powell, and lacustrine processes have accelerated shoreline erosion (Lockley et al., 2014). In addition, recent low water levels have exposed many tracksites that were not observed before Lake Powell filled (Santucci and Kirkland, 2010). These factors, combined with the vast areas of geologic exposures that have only been lightly explored by trained observers, make the Lower Jurassic tracks of GLCA a dynamic area of study. Documentation of the fossil tracks was sporadic (Edwards, 1967; Stokes, 1978; Gilland, 1979) until the 1990s (Lockley et al., 1992b, 1998a). The first published collation of GLCA tracksites, Lockley et al. (1998a), reported 19 tracksites in either the Kayenta Formation or Navajo Sandstone within GLCA. Dozens more tracksites were documented over the next 20 years, as reported in Lockley et al. (2014), and it can be safely assumed that many more fossil track localities remain to be discovered, as illustrated in Delgalvis (2015). Many sites were discovered during the drought years of 2004 and 2005. One of the most notable tracksites, designated the John Wesley Powell Track Block, is an enormous block of Navajo Sandstone with more than 80 tracks of dinosaurs and other animals, dominated by *Grallator* tracks (Santucci et al., 2012) (Fig. 3E). This block preserves an interesting feature where large theropod tracks have been flattened and resemble ornithopod tracks (Milner et al., 2016). Another site, discovered in 2004, features rare footprints and metatarsal impressions of a crouching theropod (Fig. 3F). The traces were illustrated and briefly discussed in Gierliński et al. (2009). A more detailed description is in preparation (A. Milner, personal commun., 2018).

Fossil dinosaur tracks and other vertebrate tracks are particularly abundant in the transitional stratigraphic zone between the Kayenta Formation and Navajo Sandstone. Deposition of the transition appears to have been under pluvial conditions that promoted playa lake settings (Lockley et al., 2014). According to Lockley et al. (2014), the most abundant dinosaurian ichnogenera in the Kayenta–Navajo interval are *Grallator* and *Eubrontes*, representing small and large theropods. Tracks of ornithischians (*Anomoepus* and *Moyenisauropus*) and sauropodomorphs (*Otozoum*) are also present.

The dinosaur tracksites at GLCA have occasionally attracted vandalism, such as an *Otozoum* tracksite where caulking traces remain from unauthorized casting (Santucci and Kirkland, 2010). The management challenges facing these fossil tracksites at GLCA led to the selection of the national recreation area as the prototype for paleontological resource monitoring for the National Park Service (Santucci et al., 2009; Kirkland et al., 2011).

Above the Kayenta–Navajo interval, the Middle Jurassic Entrada Sandstone is generally poorly fossiliferous, but some stratigraphic horizons with theropod tracks at GLCA have been reassigned from the Navajo Sandstone to the Entrada Sandstone (Lockley et al., 2005).

The Upper Jurassic Morrison Formation, as noted, is best known for its body fossils, but it also preserves trace fossils. A locality in the vicinity of Bullfrog in GLCA, low in the formation, includes several sauropod tracks with skin impressions (Lockley et al., 1998a; Tidwell Member of the Summerville Formation of their usage). Fragments of dinosaur bones are also known in the recreation area (Anderson et al., 2010).

Katmai National Park and Preserve (KATM)

Fiorillo et al. (2004) reported a large bone fragment from the Upper Jurassic Naknek Formation within KATM. The bone, showing evidence of ancient fluvial transport, was tentatively attributed to a dinosaur due to its robustness. If indeed dinosaurian, it is the first reported Jurassic dinosaur body fossil from Alaska.

Navajo National Monument (NAVA)

Dinosaur fossils have not been reported from within the boundaries of NAVA to date, but the Navajo Sandstone has produced multiple tracksites within about 16 km (10 mi) of NAVA's three administrative units (Tweet et al., 2009), and the monument's museum collection includes a *Eubrontes* footprint and an ornithischian footprint (Hunt et al., 2005; Santucci et al., 2006). Hunt et al. (2005) described the ornithischian track as similar to "*Dinepodus*", an otherwise unknown name that appears to be a typographical error for the ichnogenus *Dinehichnus* (M. Lockley and A. Milner, personal commun., 2018), also an ornithischian ichnotaxon (Lockley et al., 1998c). The track in question may be a poorly preserved *Eubrontes*, however (A. Milner, personal commun., 2018).

Curiously, of the handful of partial tetrapod skeletons found in the Navajo Sandstone, five were found near NAVA's units, including three dinosaur specimens. The type specimen of the small theropod *Segisaurus halli* was found about 1.6 km (1 mi) north of the Keet Seel Ruin unit in 1933 (Camp, 1936; Carrano et al., 2005). A partial sauropodomorph skeleton was found about 4 km (2.5 mi) east of Inscription House Lodge (Brady, 1935a, 1935b, 1936). Finally, another sauropodomorph specimen was found near the Betatakin Ruin unit (Galton, 1971). Although both sauropodomorph specimens had been assigned to *Ammosaurus* (now *Anchisaurus*), they are now considered undetermined sauropodomorphs (Yates, 2004; Irmis, 2005b).

Pipe Spring National Monument (PISP)

Dinosaur tracks have been found in the Navajo Sandstone at PISP (Fig. 4A). The first report was made by Stokes (1988), who published a photograph of a natural track cast which was on display at the monument. Roger Cuffey was following up on the report in 1995 when he was shown three additional in situ tracks by PISP personnel, near the visitor center, about 2 m (7 ft) above the base of the Navajo Sandstone. These tracks are fairly large, measuring 30 cm (12 in) in length along the middle toe and 30 cm (12 in) in width across the two toes flanking it. Two of the tracks are essentially side-by-side, with a third 2.7 m (8 ft) away and on approximately the same line. Cuffey et al. (1997, 1998) found them to be most like the ichnogenus *Eubrontes*. Hunt et al. (2005) noted that these three tracks are unusual in that the two lateral toes are almost as long as the middle toe, instead of being substantially shorter. They also described the Stokes track as resembling Late Triassic tracks assigned, probably incorrectly, to *Pseudotetrasauropus*, a tetradactyl track often preserved as a tridactyl underprint.

Rainbow Bridge National Monument (RABR)

There is at least one dinosaur track in the Kayenta Formation sandstones at RABR (Fig. 4B). This track is visible at the bridge viewing area (Chidsey et al., 2010). It is a heavily weathered track identified as *Eubrontes* (Lockley et al., 1998a). Lockley et al. (1998a) reported that a small number of such tracks were present at RABR, but Chidsey et al. (2010) only mentioned the track in the viewing area, and RABR volunteer Wally Wedel also reported a single track (Tweet et al., 2009); perhaps any other tracks have eroded to the point of being unrecognizable. The RABR track(s) may have been referenced in an older report: fossil tracks were reported by Hall (1934) from Chinle rocks in the RABR area, but Hall did not provide more specific locality information (Lockley et al., 1998a; Santucci and Kirkland, 2010). These tracks were discovered during the University of California Rainbow Bridge–Monument Valley Expedition of 1933 (Hall, 1934).

Springfield Armory National Historic Site (SPAR)

In dinosaur paleontology, Springfield Armory is noted as the locality where the original type specimen of *Anchisaurus polyzelus* was discovered. This specimen is reposited at Amherst College as ACM 41109 (AM 41/109 in some sources). The circumstances surrounding this discovery have been documented in several publications since the late 1990s (Santucci, 1998a; Tweet et al., 2010; Tweet and Santucci, 2011). To briefly summarize, the *Anchisaurus* specimen was discovered during blasting operations for improvements to the Water Shops of the armory at Mill Pond in 1855. The Water Shops are not part of the modern historic site, but they are part of the history that the historic site commemorates, and SPAR staff interpret the history of the Water Shops (Tweet and Santucci, 2011). The bones were mostly dispersed before excavation superintendent William Smith intervened. The military superintendent of the armory, General James S. Whitney, ordered further investigation of the discovery, so Smith recovered what he could and sent the fossils to Edward B. Hitchcock (Hitchcock, 1858; Tweet and Santucci, 2011). Hitchcock, best known for his work on the fossil footprints of the Connecticut River Valley, issued brief descriptions (Hitchcock, 1855, 1858), and his son Edward Jr. gave the specimen the name *Megadactylus polyzelus* (Hitchcock, 1865).

The Springfield Armory dinosaur, ACM 41109, includes eleven dorsal and caudal vertebrae, a partial scapula, a partial right forearm and nearly complete right manus, a partial left hindlimb, and two fused partial ischia. This early discovery is considered one of the most complete dinosaur specimens known before the exploration of the great fossil beds of the American West during the later decades of the nineteenth century. Both sides of the "Bone Wars" addressed the specimen (Cope, 1870a, 1870b; Marsh, 1882, 1885), but it was Marsh who gave it its present name after determining that "*Megadactylus*" was already in use. His first choice for a replacement, *Amphisaurus*, also proved preoccupied, necessitating a further substitution (*Anchisaurus*; Marsh, 1885). Marsh eventually named several other taxa of similar animals based on partial skeletons from the Buckland (or Wolcott) Quarry in Manchester, Connecticut: *A. colurus* (Marsh, 1891; later *Yaleosaurus* Huene, 1932), *A. major* (Marsh, 1889; later *Ammosaurus* Marsh, 1891), and *A. solus* (Marsh, 1892). These species and genera have since been synonymized with *A. polyzelus* (Galton, 1971, 1976; Galton and Cluver, 1976; Yates, 2004, 2010; Fedak and Galton, 2007).

Since the publication of Tweet and Santucci (2011), there

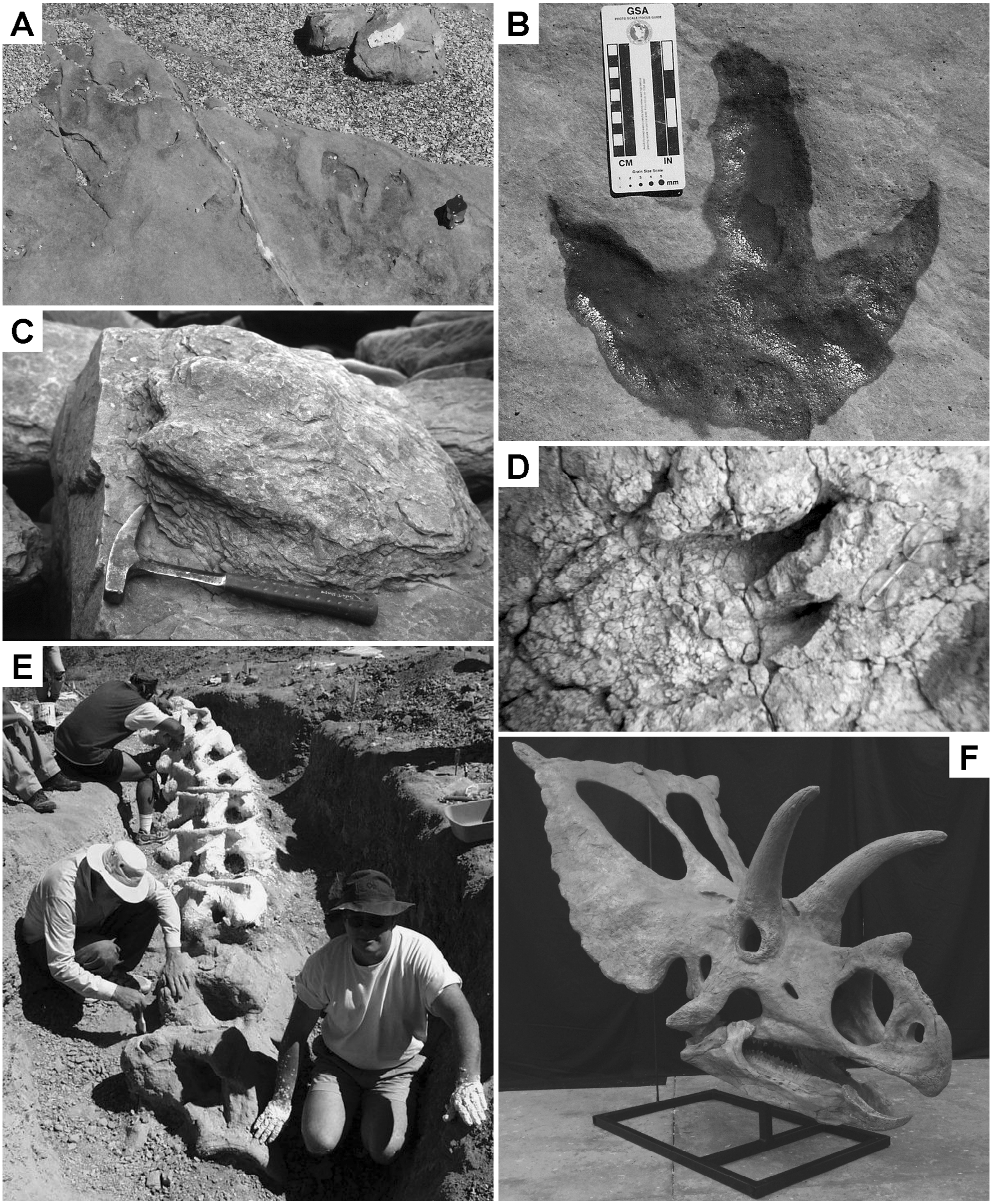

FIGURE 4. Examples of Jurassic and Cretaceous dinosaur fossils from NPS areas. **A,** pair of tracks in the Navajo Sandstone of PISP, with hand lens for scale (VLS); **B,** *Eubrontes* track visible in the Kayenta Formation of RABR (VLS); **C,** hadrosaur footprint found in the Chignik Formation of ANIA (Anthony Fiorillo); **D,** didactyl footprint in the Cedar Mountain Formation of ARCH attributed to a large dromaeosaurid, with glasses for scale (VLS); **E,** excavation of an *Alamosaurus* neck (BIBE 45854) by a crew from the University of Texas at Dallas (NPS); **F,** reconstructed holotype skull of *Bravoceratops polyphemus* (TMM 46015-1) (Gaston Design Inc., courtesy Robert Gaston).

has been a further significant development in the story of ACM 41109. In 2015, the International Commission on Zoological Nomenclature (ICZN) designated YPM 1883, the holotype of Marsh's *Anchisaurus colurus*, as the neotype of *Megadactylus polyzelus*, on the argument that ACM 41109 was non-diagnostic (ICZN, 2015; case 3561).

There has also been some discussion of the stratigraphic nomenclature. At the time Tweet and Santucci (2011) was published, the formation that produced ACM 41109 was known as the Portland Formation. More recently, Weems et al. (2016) proposed a revised stratigraphic nomenclature for the Newark Supergroup. For the Portland Formation, they raised the formation to a group and divided it into the Boonton Formation and overlying Longmeadow Sandstone, with the Mount Toby Conglomerate laterally intertonguing with the formations. The age of these sedimentary rocks is given as late Hettangian to early Sinemurian. Specimens of *Anchisaurus* are reported as coming from the upper half of the Portland Formation (Olsen et al., 2003), and the Water Shops site has sometimes been attributed to the Longmeadow Sandstone (e.g., Galton, 1976). Therefore, ACM 41109 would presumably be from the Longmeadow Sandstone under the stratigraphy of Weems et al. (2016).

Yellowstone National Park (YELL)

One of the most northwestern occurrences of dinosaur fossils in the Morrison Formation is from YELL: Ruppel (1972) reported fragments of a dinosaur limb bone in this unit on Stellaria Creek in the northwestern part of the park.

Zion National Park (ZION)

Lower Jurassic dinosaur tracks have been reported from three formations in ZION. In ascending order these track-bearing units are the Moenave, Kayenta, and Navajo Sandstone formations. Both the Dinosaur Canyon Member and overlying Whitmore Point Member of the Moenave Formation have yielded dinosaur tracks in the park, including examples of *Eubrontes* and *Grallator*. Greenish-gray dolomitic beds have been particularly productive (D. D. DeBlieux et al., unpubl. report for ZION, 2005; DeBlieux et al., 2006). There are also small bird-like tracks (Smith and Santucci, 2001). The Moenave Formation spans the latest Triassic and earliest Jurassic (Kirkland et al., 2014; Suarez et al., 2017), although it is not known if it also includes the end-Triassic extinction event due to the paucity of fossils in the Dinosaur Canyon Member (Kirkland et al., 2014). In the absence of any characteristic Upper Triassic ichnotaxa (Kirkland et al., 2014), the formation is included here as Jurassic.

The Kayenta Formation of ZION is noted for its abundant tracks, with dozens of documented track localities. This formation has the highest concentration of fossils of any of the park's formations (DeBlieux et al., 2006). The ichnotaxa *Eubrontes* and *Grallator* are the most abundant ichnotaxa (Santucci and Kirkland, 2010). Several tracksites have been selected for monitoring (Clites and Santucci, 2012). Between the Moenave Formation and the main body of the Kayenta Formation (unnamed silty facies; Milner et al., 2011; Kirkland et al., 2014) is the Springdale Sandstone, currently designated as the basal member of the Kayenta Formation but historically assigned to the Moenave Formation (Biek et al., 2010). Numerous dinosaur tracksites have been found at the top of the member, with *Eubrontes* particularly common (DeBlieux et al., 2006). Among the tracksites in the upper Springdale Sandstone Member at the park is a locality interpreted as showing three theropods traveling together (Smith et al., 2002). Another tracksite has ornithopod-like footprints (Smith and Santucci, 2001). The Springdale tracksites are part of a megatracksite found in southern Utah and northern Arizona (Lucas and Tanner, 2006; Milner and Spears, 2007). Other descriptions of the Kayenta Formation tracks can be found in Santucci et al. (1998), Smith and Santucci (1999), and Santucci et al. (2006).

A few tracksites have been found in the overlying Navajo Sandstone in ZION. Dinosaur footprints have been observed along the trail to Observation Point, and tracks of several types of animals are visible on a fallen Navajo Sandstone boulder near Parunuweap Canyon (DeBlieux et al., 2005, 2006; Santucci et al., 2006; Santucci and Kirkland, 2010). A photograph of the boulder shows two types of tracks from tridactyl bipeds and tracks from a quadruped (Tweet et al., 2012). Tracks may actually be more abundant, but circumstances are unfavorable for finding them because they are found on bedding planes, which occur at the tops of cliffs and on fallen blocks. Even where a plane is exposed, there must be some erosion to make the tracks stand out (DeBlieux et al., 2005).

CRETACEOUS DINOSAUR OCCURENCES

The Cretaceous dinosaur record of the NPS is not as easy to simplify as the Triassic or Jurassic records. Geographically, the Colorado Plateau is not as dominant, and two of the most significant sources of Cretaceous dinosaur fossils in the NPS are BIBE and DENA, distant from the plateau. Stratigraphically, the Cretaceous record is not dominated by a handful of stratigraphic units, unlike the Triassic and Jurassic. Most of the dinosaur-producing Lower Cretaceous strata belong to heterogeneous terrestrial units broadly comparable to the Morrison Formation (e.g., the Cedar Mountain Formation and lateral equivalent Burro Canyon Formation). Toward the end of the Early Cretaceous, the first advance of the Western Interior Seaway marked the onset of several cycles of marine advance and retreat, illustrated by a variety of epicontinental marine, transitional, and coastal terrestrial formations. Dinosaur fossils are largely confined to the more terrestrial formations, although there are exceptions, such as the *Nothronychus* skeleton found in the marine Tropic Shale just outside of GLCA in Utah. Near the end of the Cretaceous the seaway largely retreated, leaving behind broad plains with the rising mountains of the Laramide Orogeny to the west. The Lower Cretaceous terrestrial and Lower–Upper Cretaceous alternating intervals are well-represented in the NPS, but the terminal Cretaceous terrestrial interval is largely confined to BIBE.

Aniakchak National Park and Preserve (ANIA)

Tracks interpreted as a hadrosaur footprint and two manus prints have been published from the Chignik Formation in the Aniakchak Bay area of ANIA (Fig. 4C). This formation is late Campanian–early Maastrichtian in age, and transitions from predominantly shallow marine to nearshore marine lower in section to predominantly terrestrial higher up. The dinosaur tracks were found in a terrestrial facies (Fiorillo and Parrish, 2004). Unpublished tracks were reported by Fiorillo in Kenworthy and Santucci (2003), but these may be the manus impressions because only the footprint had been published at that time (Fiorillo, 2002). These tracks appear to be the "tip of the iceberg"; Fiorillo et al. (2017) reported in an abstract that more than 30 track sites have been found at ANIA. Tracks from hadrosaurs (juveniles to adults) were most common (*Hadrosauropodus* per McCarthy et al., 2017), with rare ankylosaur tracks also present.

Arches National Park (ARCH)

Dinosaur fossils in the Cretaceous rocks of ARCH come from the Lower Cretaceous Cedar Mountain Formation. This terrestrial formation is divided into three members in and around the park, in ascending order the Yellow Cat, Poison Strip Sandstone, and Ruby Ranch members (Santucci and Kirkland, 2010). The Yellow Cat and Ruby Ranch members have yielded dinosaur body and trace fossils within ARCH, and all three members have produced significant fossils in the vicinity of the park.

Swanson et al. (2005) reported one fossiliferous Yellow Cat Member locality within ARCH, which produced sauropod bones. The Yellow Cat Member is abundantly fossiliferous just outside of the park, especially to the north and west. It was named for Yellow Cat Flat, which was administered as part of ARCH until 1971 (Santucci and Kirkland, 2010). Several notable Yellow Cat Member localities are within a few km (less than approximately 10 km) of ARCH, including the Dalton Wells, Doelling's Bowl, Gaston, and Stikes quarries, producing assemblages including small theropods, the large dromaeosaurid *Utahraptor*, brachiosaurid and turiasaurian sauropods, the ankylosaur *Gastonia*, and multiple iguanodontian taxa (Kirkland and Madsen, 2007; Kirkland et al., 2016). Fossil tracks have also been discovered in and near ARCH, including iguanodontian tracks (Kirkland et al., 1997) and bird tracks (Wright et al., 2007).

The overlying Poison Strip Sandstone Member has not yielded dinosaur fossils within ARCH to date, but fossils of a giant *Gastonia*-like ankylosaur have been found about 5 km (3 mi) west of ARCH (Bodily, 1969; Santucci and Kirkland, 2010).

Exposures of the Ruby Ranch Member in ARCH have yielded dinosaur tracks at several horizons. One notable site is in the lower part of the member in the vicinity of Delicate Arch. Lockley et al. (2004) identified two major track horizons and a third, less defined higher level at this site. The lowest assemblage has two types of theropod tracks and faint sauropod tracks, as well as some unusual traces. The latter may be invertebrate traces, pterosaur or bird feeding traces, or inorganic marks (Wright et al., 2007; Martin et al., 2014). The upper well-defined assemblage is a trampled layer with seven distinct trackmakers: three varieties of tridactyl theropods, a didactyl theropod possibly the size of *Utahraptor* (Fig. 4D), a sauropod, a probable ornithopod, and a probable ankylosaur (Lockley et al., 2004). Madsen et al. (unpubl. report for ARCH, 2012) reported a new dromaeosaurid track at the Delicate Arch tracksite. Madsen et al. (unpubl. report for ARCH, 2012) also reported an additional dinosaur track horizon near the middle of the Ruby Ranch Member. The tracks, sandstone natural casts in a carbonaceous mudstone, are interpreted as primarily iguanodontian tracks, but some may be sauropod tracks. The track-producing interval of the area is part of the eastern margin of a lacustrine sequence (S. K. Madsen et al., unpubl. report for 2012). Nearby but northwest of ARCH, the Mill Canyon Dinosaur Tracksite was established for a significant tracksite in the Ruby Ranch Member, where at least 240 tracks at several sites have been observed, representing theropods, sauropods, and ornithopods (Kirkland et al., 2016).

Big Bend National Park (BIBE)

As DINO has the best record of Jurassic dinosaur body fossils in the NPS, BIBE has the best record of Cretaceous NPS dinosaur body fossils. Three successive Upper Cretaceous formations have produced dinosaur fossils within BIBE, in ascending order the Aguja, Javelina, and Black Peaks formations (Wick and Corrick, 2015; note that changes in stratigraphic nomenclature can make it difficult to translate usage from publication to publication). Together, these three formations provide information on southern North American dinosaurs of the Late Cretaceous, complementing the record in Colorado, the Dakotas, Montana, Utah, Wyoming, Alberta, and Saskatchewan. The formations at BIBE also span more time than many of the other well-known sources of Late Cretaceous dinosaurs in North America, covering a period beginning before 80 Ma and continuing beyond the Cretaceous–Paleogene boundary at 66 Ma. Dating is not as firm in these units as it is for other formations, though, and there are internal hiatuses (Fowler, 2017). Dinosaurs are most abundant in the Aguja and Javelina formations; at the family level the two formations have much the same dinosaurs as are seen to the north, such as tyrannosaurids, dromaeosaurids, nodosaurids, pachycephalosaurids, ceratopsids, and hadrosaurids. Several unique genera and species are present in BIBE, though, and the park is also a source of fossils of the titanosaurian sauropod *Alamosaurus*, which as of June 2018 is the only named latest Cretaceous sauropod of North America.

The following historical paragraphs are primarily drawn from Wick and Corrick (2015). The first identification of dinosaurs from what is now BIBE appears to be in Udden (1907). Udden sent bones he found in the "Rattlesnake Beds" (=Aguja Formation) to Samuel Wendell Williston of the University of Chicago. Williston identified teeth of *Dryptosaurus* (presumably a tyrannosaurid), a partial tibia perhaps from a ceratopsid, and limb bones and vertebrae attributed to the hadrosaurid *Claosaurus* (at the time used primarily for what is now known as *Edmontosaurus annectens*), as well as fossils of turtles and a large crocodilian (likely *Deinosuchus*). Although Williston encouraged further collection and research, paleontology was not pursued in the area until the 1930s, during the state park and Civilian Conservation Corps (CCC) period of BIBE.

In 1936, NPS geologists Charles Gould and Ross A. Maxwell prepared a small geological museum at the Chisos Basin CCC headquarters, including dinosaur fossils. Unfortunately, this museum was lost in a fire with the rest of the CCC barracks on Christmas Eve, 1941. In 1938, separate field parties working for what is now the Centennial Museum of the University of Texas at El Paso (UTEP) and the University of Oklahoma made collections from what is now BIBE. The El Paso party, led by William Strain and Ray Miller, utilized the assistance of the Works Progress Administration (WPA), and were intent on collecting a mountable dinosaur skeleton for the museum. The field party collected hundreds of dinosaur fossils from the Aguja Formation near Talley Mountain during 1938 and 1939, and their work is reflected in the names of three quarries (WPA 1, 2, and 3). Unfortunately, no mountable skeletons were found due to the disarticulated nature of the fossils. It was not until the 1980s that the UTEP fossils began to be formally described. In particular, the WPA 1 collection included bonebed material of a new ceratopsid, *Agujaceratops mariscalensis* (originally described as *Chasmosaurus mariscalensis* in Lehman, 1989).

The University of Oklahoma party arrived after the Texas party had staked their claims and had to work in more marginal areas. They were not as successful, but the expedition is of historical note as the beginning of Wann Langston Jr's long association with the area that would soon be designated as BIBE. As an instructor at Texas Tech University, Langston returned in 1947 and collected dinosaur bones including an *Alamosaurus* femur. Beginning in the 1960s, when he was affiliated with the University of Texas at Austin, he made nearly annual trips to BIBE. The resulting vertebrate fossil collections are at the university's Texas Memorial Museum (TMM).

Paleontologists from the American Museum of Natural History and the Smithsonian's National Museum of Natural History followed in the 1940s, with the most notable specimen being the holotype of the giant crocodilian *Phobosuchus riograndensis* (Colbert and Bird, 1954; =*Deinosuchus*), secured from the Aguja Formation by Barnum Brown and Roland T. Bird for the AMNH. In 1944, BIBE was formally established as a unit of the National Park Service from the former state park.

Interest in the park's Cretaceous fossils increased in the 1970s. At the beginning of the decade, University of Texas–Austin student Douglas Lawson made several notable discoveries, including fossils of the giant pterosaur *Quetzalcoatlus* (Lawson, 1975a, 1975b), *Tyrannosaurus* ("*T. vannus*" of Lawson, 1972), and the ceratopsid *Torosaurus utahensis* (Lawson, 1976), all from the Javelina Formation ("lower third of the Tornillo Group" of Lawson's usage). At about the same time, Judith Schiebout began working on BIBE microfossils. Although dinosaurs were not the focus, her work and the work of her students at Louisiana

State University (LSU) have been important for documenting the animals, particularly mammals, that lived alongside the dinosaurs of BIBE, as well as the geology of the park's upper Cretaceous–Paleogene rocks (e.g., Schiebout, 1970, 1973, 1974; Standhardt, 1986; Sankey, 1998, 2001, 2008, 2010; Sankey and Gose 2001; Sankey et al., 2005). In 1979, Thomas Lehman, another UT–Austin student, began working on the WPA collections, which led to his description of *Chasmosaurus mariscalensis* (Lehman, 1989) and a discussion of provincialism in dinosaurs (Lehman, 1987, 1997, 2001). Kyle Davies provided the first description of the WPA hadrosaur material (Davies, 1983). Work to date at BIBE was summarized in an unpublished field trip guidebook for the 1989 SVP meeting at Austin (Busbey and Lehman, 1989).

Increasing activity at the park since around 1990 makes a concise summary unfeasible. A selection of highlights includes:

- The discovery of a largely complete ceratopsid skull in 1991 by a University of Chicago group. It was described as *C. mariscalensis* by Forster et al. (1993), and later given its own species, *Agujaceratops mavericus* (Lehman et al., 2017);
- A series of papers by Julia Sankey, one of Judith Schiebout's students, beginning with her dissertation (Sankey, 1998); some publications of particular interest for dinosaurs with Sankey as lead author or coauthor include Sankey (2001), Sankey et al. (2005), the description of BIBE dinosaur eggshell fragments in Welsh and Sankey (2008), and the description of the pachycephalosaurid *Texacephale langstoni* in Longrich et al. (2010);
- Ongoing work on the hadrosaurids of BIBE, building on Davies (1983), including Jonathan Wagner's 2001 thesis and the new taxa *Angulomastacator daviesi* (Wagner and Lehman, 2009) and ?*Gryposaurus alsatei* (Lehman et al., 2016);
- Work carried out by NPS staff, including Donald Corrick and Steven Wick, which has produced numerous new specimens and rediscovered historic quarries. Perhaps the most notable discovery to date is the ceratopsid *Bravoceratops polyphemus* (Wick and Lehman, 2013). Another area of interest has been the park's tyrannosaurs (Lehman and Wick, 2012; Wick, 2014);
- Finally, the titanosaur *Alamosaurus* has been the recipient of a great deal of interest, with a string of recent publications (Coulson, 1998; Lehman and Coulson, 2002; Woodward and Lehman, 2009; Fronimos, 2010; Wick and Lehman, 2014; Fronimos and Lehman, 2014; Tykoski and Fiorillo, 2017). One notable specimen, an articulated series of nine cervicals (BIBE 45854) (Fig. 4E), is on display at the Perot Museum of Nature and Science. It can be seen there by itself and (in cast form) as part of a skeletal mount, which also includes casts of another BIBE specimen, TMM 41541-1 (Tykoski and Fiorillo, 2017).

The Aguja Formation was deposited during the middle and late Campanian (Fowler, 2017). It is a complex unit with several members and a variety of facies, from nearshore marine to deltaic to fluvial and marsh (Wick and Corrick, 2015). Accounting for superseded terminology, both biological and geological, the Aguja Formation of BIBE has yielded the following dinosaur taxa: a gracile tyrannosaurid (Lehman and Wick, 2012); ornithomimids (Longrich et al., 2010); a caenagnathid (Longrich et al., 2010); small theropods of the poorly understood *Paronychodon* and *Richardoestesia* lineages, including *Richardoestesia isosceles* (Standhardt, 1986; Sankey, 2001; Sankey et al., 2005); the dromaeosaurid *Saurornitholestes* (Sankey, 2001; Sankey et al., 2005); an undescribed small theropod (Fortner, 2015); a nodosaurid (Longrich et al., 2010); a possible ankylosaurid (Standhardt, 1986); the pachycephalosaurid *Texacephale langstoni* (Longrich et al., 2010; "*Troodon*" teeth of Sankey, 1998 and other publications were redescribed as pachycephalosaurid in Sankey, 2001); two chasmosaurine ceratopsid species, *Agujaceratops mariscalensis* and the more recent *A. mavericus* (Lehman et al., 2017); a hypsilophodont-grade ornithopod (Davies, 1983); and at least two hadrosaurids, *Kritosaurus* cf. *K. navajovius* (Davies, 1983) and the lambeosaurine *Angulomastacator daviesi* (Wagner and Lehman, 2009). In addition, dinosaurian trace fossils from the Aguja Formation in BIBE include eggshells (Welsh and Sankey, 2008) and herbivorous dinosaur coprolites (Baghai-Riding and DiBenedetto, 2001).

The Javelina Formation was deposited during the Maastrichtian and perhaps the latest Campanian, although precise dates have proven elusive (Fowler, 2017). It is a fluvial-floodplain unit, more terrestrial than the Aguja Formation, but not as fossiliferous (Wick and Corrick, 2015). A smaller dinosaurian fauna has been reported from this formation in the park, including: a large tyrannosaurid, similar to or conspecific with *Tyrannosaurus rex* (Lawson, 1976; Wick, 2014; informal "*Tyrannosaurus vannus*" of Lawson, 1972); the dromaeosaurid *Saurornitholestes* (Sankey et al., 2005); a troodontid (Wick and Corrick, 2015); the titanosaurian sauropod *Alamosaurus* (numerous publications; recently Fronimos and Lehman, 2014 and Wick and Lehman, 2014); two species of chasmosaurine ceratopsids, *Bravoceratops polyphemus* (Wick and Lehman, 2013) and *Torosaurus utahensis* (Lawson, 1976; Hunt and Lehman, 2008); and at least three hadrosaurid taxa (Lehman et al., 2016), including ?*Gryposaurus alsatei*, *Kritosaurus* sp. (cf. *Edmontosaurus* sp. of Davies, 1983), and a *Saurolophus*-like form.

The Black Peaks Formation was deposited during the late Maastrichtian and Paleocene. Dating of this unit has proven difficult, in part because of conflicting stratigraphic interpretations (Fowler, 2017). This formation is dominated by floodplain strata, sometimes with well-developed paleosols, and the occasional fluvial bed (Wick and Corrick, 2015). Few dinosaur fossils have been described from the Black Peaks Formation, but some of the park's *Alamosaurus* specimens come from this unit (Lehman and Coulson, 2002; Tykoski and Fiorillo, 2017), as well as a tyrannosaurid tooth (Wick, 2014).

Seven dinosaur taxa have been named from BIBE specimens (Table 1). In chronological order of description, they are:

- The ceratopsid *Chasmosaurus mariscalensis*, based on UTEP P.37.3.086 from WPA Quarry 1 (Lehman, 1989; given new generic name *Agujaceratops* in Lucas et al., 2006b);
- The small theropod *Richardoestesia isosceles*, based on LSUMGS 489:6238 from LSUMG 489 at Talley Mountain (Sankey, 2001);
- The hadrosaurid *Angulomastacator daviesi*, based on TMM 43681-1 from TMM 43681 (Wagner and Lehman, 2009);
- The pachycephalosaurid *Texacephale langstoni*, based on LSUMNS 20010 from WPA Quarry 1 (Longrich et al., 2010);
- The ceratopsid *Bravoceratops polyphemus*, based on TMM 46015-1 (Fig. 4F) from TMM 46015 ("Hippiewalk") (Wick and Lehman, 2013);
- The hadrosaurid ?*Gryposaurus alsatei*, based on TMM 46033-1 from TMM 46033 ("Rough Run Amphitheater") (Lehman et al., 2016);
- And the ceratopsid *Agujaceratops mavericus*, based on TMM 43098-1 from TMM 43098 at Rattlesnake Mountain (Lehman et al., 2017).

All of these taxa are from the Aguja Formation except *Bravoceratops polyphemus*, which is based on material from the Javelina Formation (although Fowler, 2017 suggested that *Agujaceratops mavericus* is actually from the Javelina Formation).

Bryce Canyon National Park (BRCA)

Two Upper Cretaceous stratigraphic units are known to have yielded dinosaur fossils within BRCA: the John Henry Member of the Straight Cliffs Formation (upper Coniacian through Santonian) and the Wahweap Formation (middle Campanian). To date, relatively little has been published on the dinosaurian fossils of the park, unlike elasmobranchs (Kirkland et al., 2013), small amphibians and squamates (Munk, 1998; Gardner et al., 2013; Nydam, 2013; Roček et al., 2010, 2013), and mammals (Eaton, 2013).

Undescribed dinosaur remains have been found in the Upper Cretaceous Straight Cliffs Formation at BRCA, including teeth from the John Henry Member (Tweet et al., 2012), a mixed marine-nonmarine unit (Eaton and Cifelli, 1988). Park records indicate a handful of sites in the John Henry Member with material specifically identified as dinosaurian, some identified as hadrosaur. Santucci and Kirkland (2010) included a photo of a hadrosaur jaw fragment. Given the Coniacian–Santonian age of the John Henry Member, the remains are more likely those of basal hadrosauromorphs than true hadrosaurids. Two more complete hadrosauromorph specimens have been found just east of BRCA in the basal John Henry Member and underlying Smoky Hollow Member (Santucci and Kirkland, 2010), which may clarify the identity of the BRCA specimens. A specimen in BRCA collections formerly identified as a mammoth tooth is actually a piece of hadrosaurid jaw (Fig. 5A).

BRCA is noted for its Upper Cretaceous microvertebrate record. The first microvertebrate locality from BRCA to be described in print was UMNH VP (Natural History Museum of Utah, formerly Utah Museum of Natural History) loc. 77, a Wahweap Formation locality within Campbell Canyon (Munk, 1998). Dinosaurs reported from this site include indeterminate theropods, hadrosaurs, and possible ankylosaurs (Eaton et al., 1998). UMNH VP 77 has also produced fossils of chondrichthyans (Kirkland et al., 2013), osteichthyans (Eaton et al., 1998), anurans (Roček et al., 2010), salamanders, chelonians, lizards, crocodilians (Eaton et al., 1998), multituberculates, and marsupials (Eaton et al., 1998; Eaton, 2013). This site was also briefly discussed in Eaton (1999).

Capitol Reef National Park (CARE)

Dinosaur bone fragments have been found as float at Cedar Mountain Formation exposures within CARE. Bones are more common in the vicinity; the formation only crops out over a small area in the park (J. I. Kirkland et al., unpubl. report for CARE, 2014).

Chaco Culture National Historical Park (CHCU)

The Menefee Formation, an Upper Cretaceous deltaic and coastal plain unit, has produced fossils of several types of dinosaurs. Between 2005 and 2017 paleontological resource inventories at CHCU have located remains of theropods and ornithischians, the latter including probable hadrosaurid fossils and potential ceratopsid fossils (Varela, 2013, 2014, unpubl. report for CHCU, 2017).

Colorado National Monument (COLM)

Cretaceous dinosaur remains are reportedly common in fallen blocks of the Burro Canyon Formation at COLM (Trujillo et al., 2005). Two of the localities were originally reported as in the Morrison Formation (K. Trujillo et al., unpubl. report for COLM, 2004); the Burro Canyon Formation can be difficult to distinguish from the Brushy Basin Member of the Morrison Formation (Ekren and Houser, 1959). The Burro Canyon Formation is regarded as a lateral correlative of the Cedar Mountain Formation (Dickinson and Gehrels, 2008b).

Denali National Park and Preserve (DENA)

Abundant dinosaur tracks have been found in the Cantwell Formation of DENA (Fig. 5B), sometimes with exceptional preservation (Fig. 5C). The lower Cantwell Formation has an outstanding Upper Cretaceous polar continental record (Brease et al., 2009), with abundant trace and paleobotanical fossils (Santucci et al., 2011). Dinosaur tracks were first discovered at the park in 2005 (Santucci et al., 2011), and the first few sites were reported in 2006 (Fiorillo et al., 2006a, 2006b). Additional early finds were briefly described in Fiorillo et al. (2007). Since the initial discoveries, extensive occurrences of dinosaur tracks have been located. Tracks of avian and non-avian dinosaurs, along with those of pterosaurs and other taxa, are found as true tracks, natural casts, and underprints, sometimes isolated and weathered, sometimes as part of extensively trampled surfaces (P. Druckenmiller, personal commun., 2018). The assemblage includes theropods (non-avian and avian), hadrosaurs, and ceratopsians (Fiorillo et al., 2014a). Some of the published finds include:

- A footprint described as possibly therizinosaurian and attributed to the ichnogenus *Saurexallopus*, (Fiorillo and Adams, 2012). If it indeed represents a therizinosaur, it would be the northernmost occurrence and the first record of the group in Alaska (Fiorillo and Adams, 2012). However, this attribution to a therizinosaurian has been questioned (P. Druckenmiller, personal commun., 2018), and Gierliński and Lockley (2013) have identified other *Saurexallopus* tracks as oviraptorosaurian;
- Examples of two distinct types of small to medium theropod tracks, including one identified as *Eubrontes* and a type interpreted as the didactyl *Menglongipus*, representing a dromaeosaurid or troodontid. Together with the *Saurexallopus* track they show the presence of at least three theropod taxa (Fiorillo et al., 2014a). Didactyl deinonychosaurian tracks are also reported by from DENA by Druckenmiller et al. (2017);
- A site with thousands of tracks, mostly hadrosaurid, that appears to represent the movement of a multigenerational hadrosaur herd (Fiorillo et al., 2014b);
- And handprints (manus) and footprints (pes) attributed to a juvenile hadrosaur, providing evidence of facultative quadrupedalism in juvenile hadrosaurs as well as adults (Fiorillo and Tykoski, 2016).

Significant unpublished sites are the subject of ongoing study, yielding trackways of ceratopsids and hadrosaurids, as well as various avian and non-avian theropods (P. Druckenmiller, personal commun., 2018). The lower Cantwell Formation of DENA has also yielded several ichnotaxa of avian dinosaurs, representing birds ranging in size from sparrows to herons (Fiorillo et al., 2011), and pterosaur tracks (Fiorillo et al., 2009).

The first dinosaurian body fossils from the Cantwell Formation of DENA were discovered July 2016 and include four fragments of larger bones, among them an ossified tendon. These remains may be from hadrosaurids (Anonymous, 2016). Patrick Druckenmiller (personal commun., 2018) reported that up to six fragments, including two unambiguously hadrosaurid ossified tendons, had been discovered in DENA as of January 2018.

Dinosaur National Monument (DINO)

The Cedar Mountain Formation at DINO has recently yielded significant dinosaur remains. The best-known site in the monument is a sauropod bonebed (DNM 16) discovered near the Dinosaur Quarry. This site has yielded four skulls of the *Brachiosaurus*-like sauropod *Abydosaurus mcintoshi*, including the holotype specimen (DINO 16488) (Fig. 5D). The site also includes many sauropod postcranial bones that probably belong to the same species (Chure et al., 2010). Based on left femora, bones of at least seven sauropods have been found, and the size range of the bones indicates the presence of juveniles, subadults, and possibly adults or large subadults (Holmes, 2017). Holmes (2017) regarded the site as showing contemporaneous deaths of the sauropods and rapid burial in a distributive fluvial system. The only other dinosaur remains from the quarry are a few small theropod teeth, although fragmentary remains (MCZ 2404) of

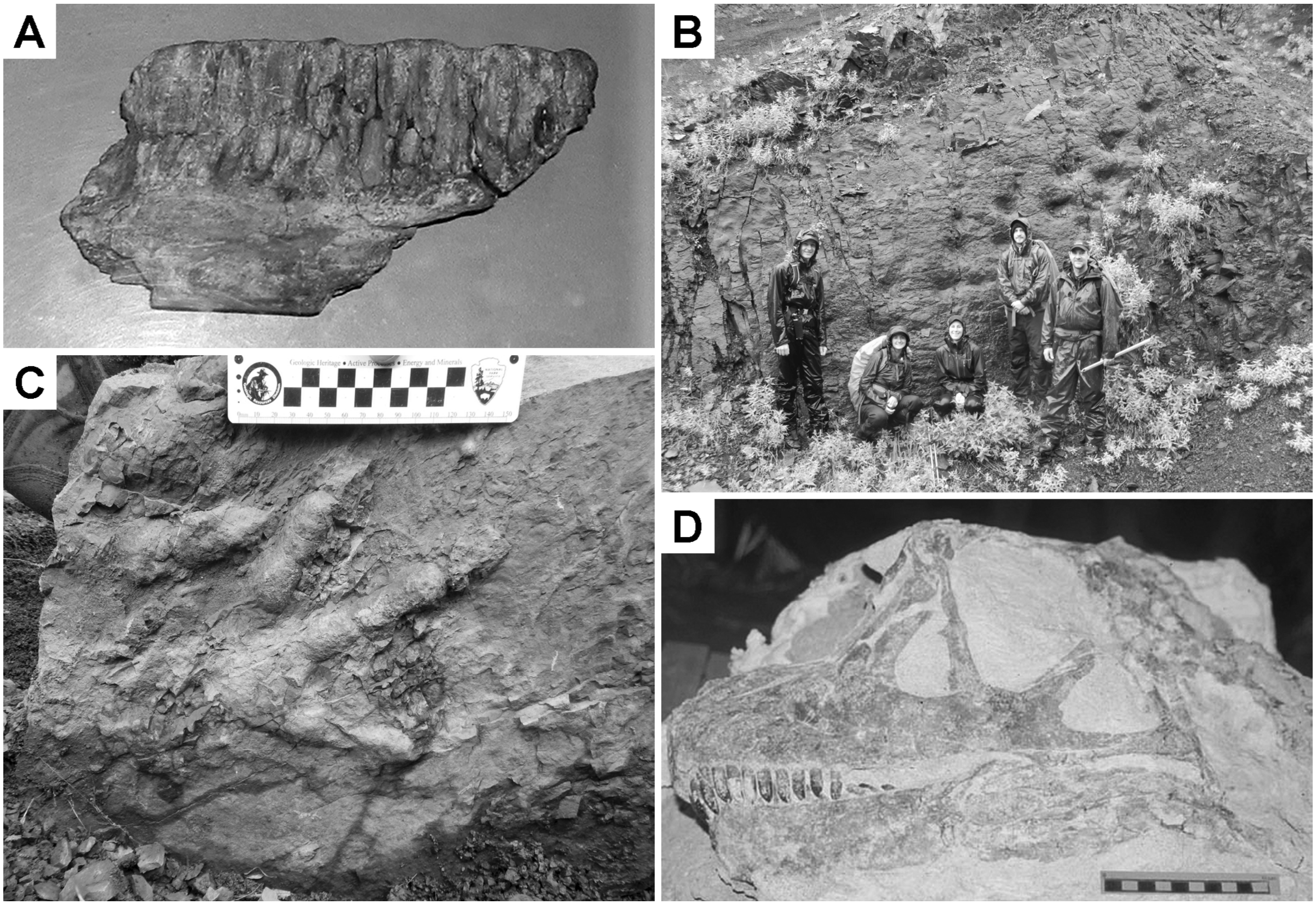

FIGURE 5. Examples of Cretaceous dinosaur fossils from NPS areas. **A,** piece of hadrosaur jaw in BRCA collections formerly misidentified as a mammoth tooth (Jason Kenworthy/NPS); **B,** ornithopod (hadrosaur?) trackway on near-vertically inclined beds of the Cretaceous Cantwell Formation. University of Alaska field crew for scale (courtesy of Patrick Druckenmiller, University of Alaska Museum); **C,** theropod footprint (natural cast) from a recently discovered track site in the Denali backcountry. Some of the Denali footprints show incredible detail including claw impressions, digital pads and even skin impressions (courtesy of Patrick Druckenmiller, University of Alaska Museum); and **D,** holotype skull of *Abydosaurus mcintoshi* (DINO 16488) from DINO (NPS).

a small theropod collected some decades before the quarry was established may come from the site (Holmes, 2017). It is not clear if MCZ 2404 is the same as an undescribed dromaeosaurid mentioned in Chure et al. (2007) and attributed to DNM 16 by Kirkland et al. (2016), although Chure et al. (2007) reported two individuals. The material cited by Chure et al. (2007), including a femur, astragalus, and dorsal vertebra, does fit with bones reported for MCZ 2404 by Holmes (2017). In addition, an iguanodont (cf. *Tenontosaurus*) has been found just outside of the monument's boundary (Kirkland et al., 2016). At this time, the Cedar Mountain Formation of DINO has not been formally divided into members, as has been done to the southwest, but Kirkland et al. (2016) assigned DNM 16 to the upper Ruby Ranch Member transitional facies. A recent thesis (Holmes, 2017) assigned DNM 16 to the Naturita Formation instead, on the grounds that the rocks are part of a facies that more properly belongs to the overlying Naturita Formation.

Glen Canyon National Recreation Area (GLCA)

Dinosaurs have not yet been reported from the Cretaceous of GLCA, but the holotype and only known specimen of the therizinosaur *Nothronychus graffami* was discovered in the marine Upper Cretaceous Tropic Shale just outside the boundary of the recreation area (Zanno et al., 2009; Albright et al., 2013).

Lewis & Clark National Historic Trail (LECL)

As with SPAR, there is a record associated with the events LECL was established to commemorate, but not necessarily within the legislative boundaries of the NPS unit. On July 25, 1806, during the return trip of the expedition, William Clark spotted a fossil in the vicinity of Pompey's Pillar, Montana:

> "…I employed my self in getting pieces of the rib of a fish which was Semented within the face of the rock this rib is (about 3) inches in Secumpherence about the middle it is 3 feet in length tho a part of the end appears to have broken off (the fallen rock is near the water--the face of the rock where rib is is perpend[icula]r - 4 i[nch] s lengthwise, a little barb projects I have several pieces of this rib the bone is neither decayed nor petrified but very rotten. the part which I could not get out may be seen, it is about 6 or 7 Miles below Pompys Tower in the face of the Lar[boar]d [north] Clift about 20 feet above the water" (Clark quoted in Simpson, 1942; Simpson's annotations in brackets, original spelling retained).

Clark's pieces have not been relocated, so it is not certain that the rib was dinosaurian, but it was likely from the terrestrial Hell Creek Formation, which has produced dinosaur fossils of the proper size (Colbert, 1984). If dinosaurian, it would be the first documented dinosaur fossil from the Rocky Mountain West (Breithaupt, 1999).

Mesa Verde National Park (MEVE)

Fragmentary dinosaur bones have been found in the Cliff House Sandstone of MEVE (Harrison et al., 2017), a regressive Upper Cretaceous nearshore unit better known as containing the preferred settings for building cliff dwellings at Mesa Verde (Griffitts, 1990).

Wrangell-St. Elias National Park and Preserve (WRST)

Dinosaur tracks were first reported from an unnamed Cretaceous unit in the Nutzotin Basin of northeastern WRST in Fiorillo et al. (2010) and were more fully described in Fiorillo et al. (2012). Two specimens have been reported. One is approximately 9 cm (4 in) long by 7 cm (3 in) wide and is attributed to a theropod (DMNH 2008-06-01). The other is approximately 22 cm (9 in) long and 26 cm (10 in) wide, and is attributed to an ornithopod, probably a hadrosaurid (DMNH 2008-06-02). They were found along with more abundant paleobotanical remains in sandstone and shale beds within a dominantly conglomeratic unit, interpreted as latest Cretaceous in age (Fiorillo et al., 2012). More recent unpublished work suggests these units are of Early to middle Cretaceous age (P. Druckenmiller, personal commun. 2018). Fiorillo et al. (2012) described the two specimens as undertracks. They are fairly obscure and difficult to interpret from the illustrations, and their identity as tracks is not universally accepted (P. Druckenmiller, personal commun., 2018).

Yellowstone National Park (YELL)

There are two records of dinosaur fossils from Upper Cretaceous rocks of YELL. The Harebell Formation, a Maastrichtian-age unit (Harris et al., 1996), has yielded a tyrannosaurid (“Deinodontidae”) tooth within YELL (Love, 1973; Love and Keefer, 1975). More recently, Santucci (1998b) reported dinosaur eggshell from Cretaceous rocks at Mount Everts. Almost all of the rocks of Mount Everts are Upper Cretaceous, and per the mapping of Ruppel (1972), the most likely candidates by areal extent are the Eagle Sandstone, Everts Formation, and Landslide Creek Formation.

Yukon-Charley Rivers National Preserve (YUCH)

Fiorillo et al. (2014c) reported a possible hadrosaurid track from rocks on Washington Creek within YUCH. The geologic unit (“TKs”) is an unnamed fluvial formation, probably deposited primarily by braided streams, and it spans the Late Cretaceous through early Paleogene. Detrital zircon ages suggest the tracksite is Campanian or Maastrichtian in age. Fiorillo et al. (2014c) interpreted the specimen, DMNH 2010-06001, as a hadrosaurid track, but as with the WRST specimens, this specimen is difficult to interpret from the figures.

IMPLICATIONS AND CONCLUSIONS

The record of non-avian dinosaurs in NPS areas is robust and growing. Ongoing exploration and study have the potential to add much information to the knowledge base. New finds and re-evaluation of old finds offer opportunities for education and interpretation featuring these popular prehistoric animals. Of course, with increased knowledge and publicity have come increasing management issues, particularly prevention and mitigation of vandalism and unauthorized collecting. In addition to specific incidents mentioned above, there has also been theft and vandalism at sites in BIBE (Wick and Corrick, 2015), COLM (Scott et al., 2001a), and DINO (Anonymous, 2014). The passage of the Paleontological Resources Preservation Act is intended to enhance protection of these and other non-renewable fossils of the National Park Service and other federal lands. Going forward, it is hoped that new research, new exploration, new management tools and procedures, and park interpretation and education based around these fossils will continue to add to the story of America’s paleontological heritage.

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