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VULPES VULPES (RED FOX) REMAINS FROM STANTON'S CAVE, GRAND CANYON NATIONAL PARK, ARIZONA

Mary C. Carpenter[1] and Jim I. Mead[2,C]

ABSTRACT

Stanton's Cave is a large solutional cavern in the eastern region of Grand Canyon National Park, Arizona. The cave is best known to Quaternary paleontologists for its abundant Late Pleistocene and early Holocene fossil remains of mammals, birds, and Archaic artifacts. Re-examination of the fossil vertebrate collection, housed at the Grand Canyon Museum Collections, has resulted in re-identification of two fox dentaries (GRCA 76272) that were originally published as *Urocyon cinereoargenteus* (gray fox). Morphometric and morphological comparisons presented here find the dentaries diagnostic to *Vulpes vulpes* (red fox) and not the gray fox. The remains are the first record of *Vulpes vulpes* from the Grand Canyon and may be the first fossil evidence of the species from Arizona.

INTRODUCTION

Stanton's Cave (elevation 927 m) at 44 m above the Colorado River in the eastern Colorado River corridor of the Grand Canyon (Grand Canyon National Park, GRCA), Arizona, is well known to Quaternary paleontologists and archaeologists for its numerous Late Pleistocene taxa such as the extinct Harrington's mountain goat (*Oreamnos harringtoni*), the extant bighorn sheep (*Ovis canadensis*), the extinct Merriam's teratorn (*Teratornis merriami*), and the extirpated but now reintroduced California condor (*Gymnogyps californianus*), along with unassociated archaeological split twig figurines that date to the middle to late Holocene (Mead, 1981; Euler, 1984; Rea and Hargrave, 1984). Excavation of the cave sediments in the late 1960s and early 1970s was under the direction of Dr. Robert C. Euler (deceased) who undertook archaeological and paleontological assessment of the deposits (Euler, 1984). Among the hundreds of skeletal specimens reported were two dentaries (lower jaws, GRCA 76272) identified as gray fox (*Urocyon cinereoargenteus*) (Olsen and Olsen, 1984). Re-examination of the two dentaries determined that the gray fox specimens were misidentified. Here we present the reanalysis of these specimens.

Three species of foxes live in Arizona today. The gray fox and kit fox (*Vulpes macrotis*) are relatively common, though of the two, the kit fox has a more restricted range (Cockrum, 1960; Hoffmeister, 1986). The red fox (*Vulpes vulpes*) is uncommon in Arizona, with all of its records occurring in the extreme northeastern corner of the state, within Apache and Navajo Counties (Hoffmeister, 1986). In a study of extant red foxes in this region, Mikesic and LaRue (2003) maintain that the red fox is more common than previously thought, at least in their study area of the Navajo Reservation in northeastern Arizona. However, they also state that the southern and western limits of the red fox in Arizona are unknown. Only the gray fox is known to occur today within or adjacent to the Grand Canyon (Bailey, 1935; Hoffmeister, 1971, 1986).

MATERIALS AND METHODS

The two fox dentaries from Stanton's Cave are curated by the National Park Service at GRCA and are stored in a field bag labeled, "From Packrat Nest (consolidated) adjacent to fig. [split twig figurine ?] find F.S. [Field Specimen] #13 in upper end of Antechamber #1. Depth of bone ca. 10-20 cm. June 18/19 [1969], L. Powers."

There was no direct radiometric age available for the fox specimens. The "post-Pleistocene levels above 20 cm in depth" is the only evidence for an age for the dentaries (Olsen and Olsen, 1984:52; see also Euler, 1984). However, packrats (*Neotoma* spp.; woodrats) are well known to collect plants, dung, bones, and other assorted small objects from their surroundings, no matter the age, and incorporate these items into their middens (nest debris accumulations). Phillips (1984) notes just such an event in Rampart Cave (western Grand Canyon), where a dung ball of the extinct Shasta ground sloth (*Nothrotheriops*) was recovered from a Holocene-age packrat midden, yet the specimen radiocarbon dated to the latest Pleistocene. Olsen and Olsen (1984:49) discuss various taphonomic factors affecting the composition of the Stanton's Cave deposits, stating, "In all probability, the majority of bone displacement may be attributed to bioturbation, primarily on the part of the wood rat (*Neotoma* sp. indet.)." Thus, it is plausible for the two fox specimens to be older than the depth association suggests. Traces of muscle tissue attached to the dentaries could be used for future radiocarbon dating.

Fossils cataloged as GRCA 76272 consist of an incomplete left dentary and an incomplete right dentary that clearly belong to one individual. Because of this, only one dentary was used for measurements (Fig. 1). Dentaries were

[1]Badlands National Park, Interior, SD 57750
[2]The Mammoth Site, Hot Springs, SD 57747, and Desert Laboratory on Tumamoc Hill, University of Arizona, Tucson, AZ 85745
[C]Corresponding author: jmead@mammothsite.org

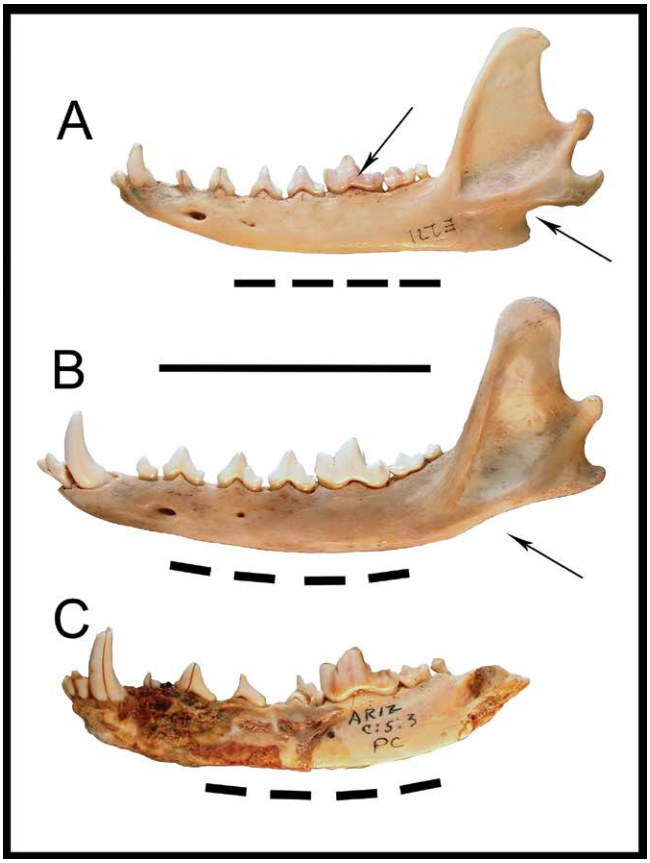

Figure 1. Left dentaries of foxes in labial view. A) modern Urocyon cinereoargenteus (gray fox), note the presence of notch in postero-ventral end of horizontal ramus (arrow), the straight ventral edge (dashed line), and the arrow to the m1 locating the protostylid (see text); B) modern *Vulpes vulpes* (red fox), note absence of postero-ventral notch (arrow versus that in A) and curved ventral edge (dashed line); C) GRCA 76272, note same characters exhibited in Vulpes vulpes and lack of characters exhibited in *Urocyon cinereoargenteus* (A).

Table 1. Alveolar length (mm) of the lower p1-m3. Comparing GRCA 76272 from Stanton's Cave, Grand Canyon, with modern fox specimens housed at the Mammoth Site, Hot Springs, South Dakota and Gray Fossil Site, East Tennessee State University, Tennessee.

Taxon	n=	Measurement
GRCA 76272	1	56.30
Vulpes vulpes (red fox)	5	54.87–64.57
Urocyon cinereoargenteus (gray fox)	6	43.67–51.00
Vulpes macrotis (kit fox)	5	42.75–47.53
Vulpes velox (swift fox)	1	49.37
Alopex lagopus (Arctic fox)	1	48.22

compared to modern specimens (now housed at the Mammoth Site, Hot Springs, SD; and the Gray Fossil Site, East Tennessee State University, TN) of five extant fox species: kit fox, gray fox, red fox, swift fox (*Vulpes velox*), and Arctic fox (*Alopex*) (Table 1, Fig. 1; taxonomy as used by Mercure et al., 1993).

The features used here to separate the gray fox from the red fox and other species are: 1) measurements of the alveolar length (mm) from the anterior alveolar edge of the lower first premolar (p1) through to the posterior alveolar edge of the lower third molar (m3); 2) the presence or absence of a distinctive notch in the postero-ventral end of the horizontal ramus (postero-ventral notch) (Fig. 1; see Tedford et al., 1995); 3) the curve or straightness of the ventral surface of the horizontal ramus (Fig. 1); and 4) the presence or absence of the protostylid on the postero-labial edge of the m1 protoconid (Fig. 1; Tedford et al., 1995; character 29) .

RESULTS

Measurements were taken of five species and compared to GRCA 76272 (Table 1). The dentaries of the kit, swift, and arctic foxes are characteristically smaller than that of the red fox and GRCA 76272 (Table 1). Measurement of GRCA 76272 is within the size range of red fox and is distinctly larger than that of the gray fox, smaller species of *Vulpes*, and *Alopex* (Table 1).

The GRCA 76272 dentary (Fig. 1C) is broken posteriorly, so the area where a postero-ventral notch would occur (as on *Urocyon*; Fig 1A) is not fully exhibited. However, the horizontal ramus continues far enough to prove no existence of a postero-ventral notch that is the characteristic in *Vulpes* spp. and *Alopex*.

On *Urocyon,* the ventral surface of the horizontal ramus is relatively straight antero-posteriorly until interrupted by the postero-ventral notch (Fig. 1A). This ventral surface of the horizontal ramus is conspicuously curved on species of *Vulpes* and *Alopex* (Fig. 1B) and the fossil specimen (Fig. 1C).

Urocyon has a protostylid on the posterolabial edge of the m1 protoconid (Fig. 1A), whereas *Vulpes* and the fossil specimen do not (Tedford et al., 1995; character 29).

Thus, given the four criteria mentioned above, GRCA 76272 is identified as a red fox and not *Urocyon*.

DISCUSSION

Kurtén and Anderson (1980) reported the red fox as an apparent late immigrant to North America, with no record antedating the Sangamonian Interglacial (greater than about 110,000 years old), except possibly in the far north (Alaska, Canada). More recent genetic work has revealed new information on the immigration of the red fox in North America (Aubry et al., 2009; Sacks et al., 2010, Statham et al., 2012). Their data suggest that the red fox first reached North America from Asia after dispersing across Beringia during a phase of the Illinoian Glaciation (Marine Isotope Stage 6, MIS), and during the following nearly 30,000 year-long Sangamonian Interglacial (approximately MIS 5e), it likely dispersed further south into the USA. During the continental Wisconsinan Glaciation (MIS 3 and 4) red fox populations separated in the far north from those further south resulting in two isolated populations, thus equating to a Holarctic

clade and a Nearctic clade. The Holarctic clade was isolated in unglaciated portions of Alaska, the Yukon, and further west within Beringia. The Nearctic clade became isolated south of the ice sheets in the contiguous USA in forested western mountains, grasslands, and in the eastern region (Aubry et al., 2009; Statham et al., 2012).

The red fox has been documented in the fossil record from Late Pleistocene shoreline deposits of Lake Bonneville, Utah, in the eastern Great Basin (Nelson and Madsen, 1986), and in more than 25 late Rancholabrean-age sites from Arkansas, California, Colorado, Idaho, Missouri, New Mexico, Tennessee, Texas, Virginia, and Wyoming (Kurtén and Anderson, 1980; Harris, 1985; Harris, 2016). Despite this wide distribution, the fossil red fox has remained relatively unknown in the greater Southwest and into Sonora, Mexico (Mead et al., 2005; Harris, 2016).

CONCLUSIONS

Originally identified as *Urocyon cinereoargenteus* (gray fox) (Olsen and Olsen, 1984), morphometric and morphological data (Table 1, Fig. 1) presented here demonstrate that the two dentaries (GRCA 76262) from Stanton's Cave, eastern Grand Canyon belong to the red fox (*Vulpes vulpes*), not the gray fox. This finding is a significant addition to the paleobiological record of the Grand Canyon region, as well as that of Arizona. While the modern gray fox is common in the region today, the extant red fox is limited to the extreme northeastern portion of Arizona (Hoffmeister, 1986; Mikesic and LaRue, 2003) and is not known from the Grand Canyon (Mead et al., 2005). Although the fossil red fox has been documented from surrounding states and other regions in the greater Southwest (Kurtén and Anderson, 1980; Harris, 1985; Nelson and Madsen, Jr., 1986; Harris, 2016), the Late Pleistocene record in Arizona appears to be lacking this fox. Knowing this, we recommend that radiocarbon analysis be conducted on GRCA 76262. Although the two red fox dentaries could prove to be of the Late Pleistocene, we hypothesize that they will be middle to late Holocene in age. However, these specimens do represent the first record of red fox remains from the Grand Canyon and may be the first Pleistocene reported from Arizona.

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