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MIOCENE AND PLIOCENE VERTEBRATES FROM ARIZONA

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Abstract—We present an overview of the Miocene and Pliocene vertebrates of Arizona, spanning the time period from about 2 to 20 Ma. The best known Miocene faunas are Wellton and Anderson Mine from the late Arikareean or Hemingfordian North American land-mammal "age" (NALMA); Milk Creek Formation sites from the Clarendonian NALMA; and Camel Canyon, Redington, White Cone, and Wikieup representing the Hemphillian NALMA. The Wellton fauna is composed of the small camelid *Stenomylus* and the heteromyid rodent *Mookomys*, and the Anderson Mine fauna contains the rhinoceros *Diceratherium* and the camelid *Oxydactylus*. The protolabidine camelids *Protolabis coartatus* and *Michenia yavapaiensis* and borophagine canids *Carpocyon robustus* and *Epicyon haydeni* indicate a Clarendonian age (9.0-12.5 Ma) for sites in the Milk Creek Formation (e.g., Milk Creek Quarry, Manzanita Quarry). White Cone in the Bidahochi Formation and Redington in the Quiburis Formation both contain diverse small mammal faunas of late Hemphillian age (4.9-7.0 Ma). Wikieup from the Big Sandy Formation and Camel Canyon from the Quiburis Formation are also late Hemphillian in age based on biostratigraphy and magnetostratigraphy.

Pliocene vertebrates (Blancan NALMA) are well known from Arizona, with more than 15 faunas spanning much of the Blancan (1.8-4.9 Ma). Many of these faunas have been dated by a combination of biostratigraphy and magnetostratigraphy. Small mammals are better known from Arizona Blancan sites than are large mammals. The best known early Blancan (2.7-4.9 Ma) faunas are (from oldest to youngest): Verde, Benson, Clarkdale, Bear Springs, Duncan, and Country Club. The best known late Blancan faunas (1.8-2.7 Ma) are (from oldest to youngest): Wolf Ranch, 111 Ranch, Pearson Mesa, San Simon, California Wash, and Curtis Ranch. The Verde and Clarkdale faunas from the Verde Formation in central Arizona are primarily composed of small mammals. Verde is the oldest Blancan fauna in the state (4.3-4.8 Ma). The Bear Springs fauna from the Safford basin and the Duncan and Country Club faunas from the Duncan basin are derived from strata of the Gila Group in southeastern Arizona, and date to the latter part of the early Blancan (~3.0-3.6 Ma). The Blancan faunas from the St. David Formation in the San Pedro River Valley in southeastern Arizona have played a key role in understanding the biochronology of Blancan faunas throughout North America, comprising one of the first sequences of superposed vertebrate faunas in North America to be dated using magnetostratigraphy and mammalian biostratigraphy. The early Blancan Benson fauna (~3.3 Ma) is the oldest in this sequence of faunas, whereas late Blancan faunas include Wolf Ranch (~2.7 Ma), and California Wash and Curtis Ranch (2.0-2.2 Ma). The late Blancan in North America is defined by the first appearance of mammals of South American origin that participated in the Great American Biotic Interchange. Wolf Ranch occurs in the uppermost Gauss Chron (~2.7 Ma) and documents the earliest North American record of the porcupine *Erethizon*, a member of the Interchange fauna. The 111 Ranch fauna from the Safford Basin provides perhaps the best documented first appearance datum for the Interchange fauna in temperate North America. Two Interchange mammals, the glyptodont *Glyptotherium* and the capybara *Neochoerus*, occur in the uppermost Gauss Chron in the 111 Ranch section, just below the Gauss/Matuyama boundary at 2.58 Ma. The geochronology of the 111 Ranch and Wolf Ranch faunas is important in dating the onset of the Interchange in temperate North America at about 2.7 Ma.

Keywords: Neogene, Miocene, Pliocene, vertebrate, mammal, Arizona, Arikareean, Hemingfordian, Clarendonian, Blancan, Irvingtonian, Great American Biotic Interchange

INTRODUCTION

We review the published literature on Miocene and Pliocene vertebrate faunas from Arizona. The only unpublished fossils we discuss result from recent field work by RSW and colleagues on Pliocene (Blancan) faunas from 111 Ranch, San Simon (Artesia Road, Tanque), and Bear Springs in Graham County and by GSM on late Blancan faunas from the Duncan Basin in Greenlee County. We concentrate on mammals because most of the published literature is on that group; however, we do mention other vertebrates where known, especially birds (e.g., Bickart, 1990). Miocene vertebrate faunas from Arizona are not as well known as Miocene faunas from neighboring states (e.g., California and New Mexico), although there is extensive unpublished material of large mammals from the Miocene of Arizona housed in the Frick (AMNH) and University of Arizona (UALP) collections (e.g., Milk Creek Formation sites, Wikieup, Redington, Camel Canyon). Some of the best known and well-dated Blancan faunas in North America are from Arizona, including Benson and Curtis Ranch (Gidley, 1922, 1926; Gazin, 1942; Johnson et al., 1975), Wolf Ranch (Harrison, 1978), 111 Ranch (Galusha et al., 1984; Tomida, 1987), Duncan (Tomida, 1987), Pearson Mesa (Tomida, 1987; Morgan and Lucas, 2000, 2003), and Verde (Czaplewski, 1987a, 1990).

The majority of Miocene and Pliocene vertebrate fossils from Arizona are housed in five museum collections: University of Arizona Laboratory of Paleontology (UALP), Tucson, Arizona; Mesa Southwest Museum (MSM), Mesa, Arizona; Museum of Northern Arizona (MNA), Flagstaff, Arizona; American Museum

of Natural History, including the Frick Collection(AMNH), New York; and U.S. National Museum of Natural History, Smithsonian Institution (USNM), Washington, DC. Other abbreviations used in the text are NALMA (North American Land Mammal Age), GABI (Great American Biotic Interchange, also shortened to "the Interchange"), and GPTS (Geomagnetic Polarity Timescale).

MIOCENE FAUNAS

Early Miocene (late Arikareean and Hemingfordian) vertebrates from Arizona are scarce, whereas several diverse medial and late Miocene (Clarendonian and Hemphillian) vertebrate faunas are known. Lindsay and Tessman (1974) first noted the widespread occurrence of Miocene vertebrate faunas in Arizona, although several Miocene faunas and fossils had been mentioned previously. Our intention is to update Lindsay and Tessman (1974) based on papers published in the past 30 years. We concentrate on faunas and taxonomic groups described in the literature, and only briefly mention the large unpublished samples of Miocene mammals represented in museum collections, especially AMNH and UALP.

The Taylor gravel pit fauna, located north of Taylor, in Navajo County in east-central Arizona, was regarded as late Miocene (Hemphillian) in age by Lindsay and Tessman (1974) based on the presence of a gomphotheriid proboscidean and "*Pliohippus*." However, further study of the Taylor fauna by Madden (1986) indicated the presence of two proboscideans restricted to the Pleistocene, an advanced species of the gomphothere *Stegomastodon*, *S. barbouri*, and the mammoth, *Mammuthus imperator*. The association of *Stegomastodon* and *Mammuthus* indicates an early Irvingtonian (early Pleistocene) age for the Taylor fauna (Madden, 1986). This review covers only Miocene and Pliocene vertebrate faunas, and thus the Taylor gravel pit fauna is not discussed further here.

Wellton—Camelids are known from the early Miocene Wellton local fauna, located about 10 km northeast of Wellton in Yuma County, southwestern Arizona (Fig. 1, site 1). Wood (1956) and Lance and Wood (1958) identified the small stenomyline camelid *Stenomylus* from this site and assigned it an Arikareean (?) age. Frick and Taylor (1968) briefly mentioned the Wellton camelid and referred it to *Stenomylus* following Lance and Wood (1958). The stratigraphic range of *Stenomylus* is from the early Arikareean through the early Hemingfordian in western North America (Frick and Taylor, 1968). Lindsay and Tessman (1974) also identified the heteromyid rodent *Mookomys* from Wellton.

Anderson Mine—Lindsay and Tessman (1974) reported the rhinocerotid *Diceratherium* and the camelid *Oxydactylus* from the early Miocene (Hemingfordian) Anderson Mine in Yavapai County, western Arizona (Fig. 1, site 2). Prothero (1998) confirmed the identification of *Diceratherium*. The Anderson Mine fauna is listed as late Arikareean or Hemingfordian in age by Janis et al. (1998), based on the first occurrence of *Oxydactylus* in the late Arikareean and the latest occurrence of *Diceratherium* in the Hemingfordian (Prothero, 1998; Tedford et al., 2004).

Milk Creek Formation sites, including Milk Creek Quarry, Manzanita Quarry, Deep Springs Quarry, Goldie's Honeypot Quarry, and Walnut Grove—There are several fossil sites of medial or late Miocene (Clarendonian) age from the Milk Creek Formation in the Walnut Grove basin, located about 25 km south of Prescott in Yavapai County, western Arizona (Lindsay and Tessman, 1974; Honey and Taylor, 1978; Fig. 1, site 3). Large collections from the Milk Creek Formation sites are housed at the AMNH and at the UALP, although many of these fossils are undescribed. Lindsay and Tessman (1974) listed a borophagine dog, rodent, two genera of horses, two genera of camelids, antilocaprid, and gomphotheriid proboscidean in the UALP collection from four localities in the Milk Creek Formation, the most diverse of which is Walnut Grove. Honey and Taylor (1978) provided the most detailed stratigraphic information on the Milk Creek Clarendonian sites. The most productive localities in the Milk Creek Formation, including Milk Creek Quarry, Manzanita Quarry, Shields Ranch Quarry, Deep Springs Quarry, and Goldie's Honeypot Quarry, occur in the upper part of the Milk Creek Formation. Most of the fossils from these quarries are housed in the AMNH collection. Honey and Taylor (1978) described large samples of the protolabidine camelids *Protolabis coartatus* and *Michenia yavapaiensis* (type locality is the Milk Creek Quarry) from the Milk Creek Formation. Wang et al. (1999) identified the borophagine canids *Carpocyon robustus* and *Epicyon haydeni* from the Milk Creek Quarry and several other sites in the Milk Creek Formation. Baskin (2004) reported an associated upper and lower dentition of the small procyonid *Bassariscus* from the Walnut Grove local fauna.

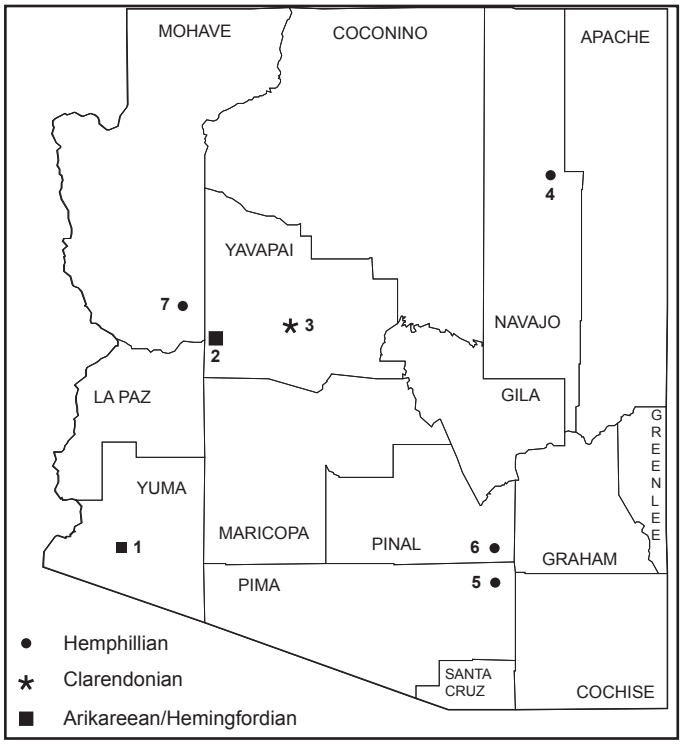

FIGURE 1. Map of Arizona showing location of key Miocene vertebrate fossil sites. **Arikareean/Hemingfordian** (squares): **1**, Wellton; **2**, Anderson Mine; **Clarendonian** (asterisk): **3**, Milk Creek Formation sites; **Hemphillian** (circles): **4**, White Cone and other sites in the Bidahochi Formation; **5**, Redington; **6**, Camel Canyon; **7**, Wikieup.

Table 1 lists the mammals from the Milk Creek Formation sites, including taxa mentioned by Lindsay and Tessman (1974), Honey and Taylor (1978), Wang et al. (1999), and Baskin (2004). This faunal list is incomplete because it does not include unpublished fossils in the AMNH and UALP collections. Lindsay and Tessman (1974), Honey and Taylor (1978), and Wang et al. (1999) considered the Milk Creek sites to be Clarendonian (9.0-12.5 Ma), but they did not refer these sites to a subdivision of the Clarendonian (i.e., early, medial, or late Clarendonian; Tedford et al., 2004).

White Cone and other Bidahochi Formation sites—The White Cone local fauna was collected from fluvial sediments in the upper member of the Bidahochi Formation at White Cone Peak on the Hopi Indian Reservation (formerly Hopi-Navajo joint-use land) in Navajo County, northeastern Arizona (Fig. 1, site 4). Several other localities in the Bidahochi Formation are on the Hopi Indian Reservation, including Keams Canyon and Jeddito. One of the first reports of Miocene vertebrates in Arizona was

Stirton's (1936) description of the beaver *Dipoides williamsi* from White Cone. Repenning et al. (1958) briefly mentioned vertebrate fossils from the Bidahochi Formation at White Cone, and Uyeno and Miller (1965) identified four species of cyprinid fish from the Bidahochi Formation. Breed (1973) reported tracks of two different types of birds from the Bidahochi Formation at the Coliseum Diatreme about 60 km north of Holbrook in Navajo County. Breed (1973) also summarized the vertebrate fauna from the Bidahochi Formation. Baskin (1978, 1979) reported 14 species of small mammals (two insectivores, one leporid, and 11 rodents; see Table 1) from White Cone, including four new species of rodents: *Perognathoides bidahochiensis*, *Bensonomys gidleyi*, *Bensonomys yazhi*, and *Paronychomys alticuspis*. The two species of the small murid rodent *Bensonomys* from White Cone are important because they provide strong evidence that South American murids ("phyllotines" or "sigmodontines") originated in North America in the Miocene prior to the Great American Biotic Interchange (Baskin, 1978; 1986). Baskin (1979) reported the presence of the extinct "wolverine" *Plesiogulo*, which Harrison (1981) identified as *P. marshalli*. White (1987) identified the leporid *Hypolagus ringoldensis*. Parmley and Peck (2002) reviewed the amphibians and reptiles from White Cone, including three toads (two species of *Bufo* and one species of *Scaphiopus*) two frogs (one species each of *Rana* and *Hyla*), two lizards (one species each of *Cnemidophorus* and *Eumeces*), and four species of colubrid snakes (one species each of *Heterodon*, *Lampropeltis*, *Pituophis*, and *Thamnophis*).

Lindsay et al. (1984) described the lithostratigraphy and magnetostratigraphy of the Bidahochi Formation at White Cone. They assigned a latest Miocene age (~5.9 Ma) to the White Cone local fauna based on the paleomagnetic section, an airfall tuff K/Ar dated at 6.7 Ma that occurs about 15 m below the fossil-bearing unit, and the biostratigraphy of the small mammal fauna (Baskin, 1979). This age places White Cone in the early late Hemphillian (Hh3; Tedford et al., 2004; Fig. 2). White Cone is similar in age to other southwestern late Hemphillian faunas, including Redington from southeastern Arizona and Coffee Ranch in the Texas Panhandle (Lindsay et al., 1984; Tedford et al., 2004).

In addition to White Cone, there are several other localities in the Bidahochi Formation in Navajo County that have produced late Miocene mammals. Harrison (1985) described and illustrated a large sample of the giant camelid *Megacamelus merriami* from the late Hemphillian Keams Canyon local fauna. Frick (1929) originally described this camel as *Megacamelus blicki*, but Harrison (1985) synonymized the species with *M. merriami*, described from the late Hemphillian Mt. Eden fauna in southern California (Frick, 1921). There are undescribed mammalian fossils from Keams Canyon in the AMNH Collection. Prothero (1998) reported the late Hemphillian rhinoceros *Teleoceras hicksi* from Jeddito. Wang et al. (1999) referred two partial dentaries to the borophagine canid *Epicyon haydeni* from President Wilson Springs in the Jeddito Valley. Wang et al. (1999) considered this site to be Clarendonian in age based on the presence of *E. haydeni*, whereas all other faunas in the Bidahochi Formation are late Hemphillian. Baskin (1998) recognized *E. haydeni* from several early Hemphillian faunas.

Redington—The Redington local fauna is derived from the lower member of the Quiburis Formation in the San Pedro Valley northeast of Tucson in Pima County, southeastern Arizona (Fig. 1, site 5). Ted Galusha of the Frick Laboratory first collected fossils in the Redington area from 1954-1965. Field crews from the UALP continued work at Redington after 1971, in particular, screenwashing for microvertebrates (Jacobs, 1977). The Redington local fauna includes three main fossil quarries, Old Cabin Quarry, Redington Quarry, and San Pedro Valley Quarry (Jacobs, 1977). The Old Cabin Quarry is often listed as a separate locality. Lindsay and Tessman (1974) published the first preliminary vertebrate faunal list from

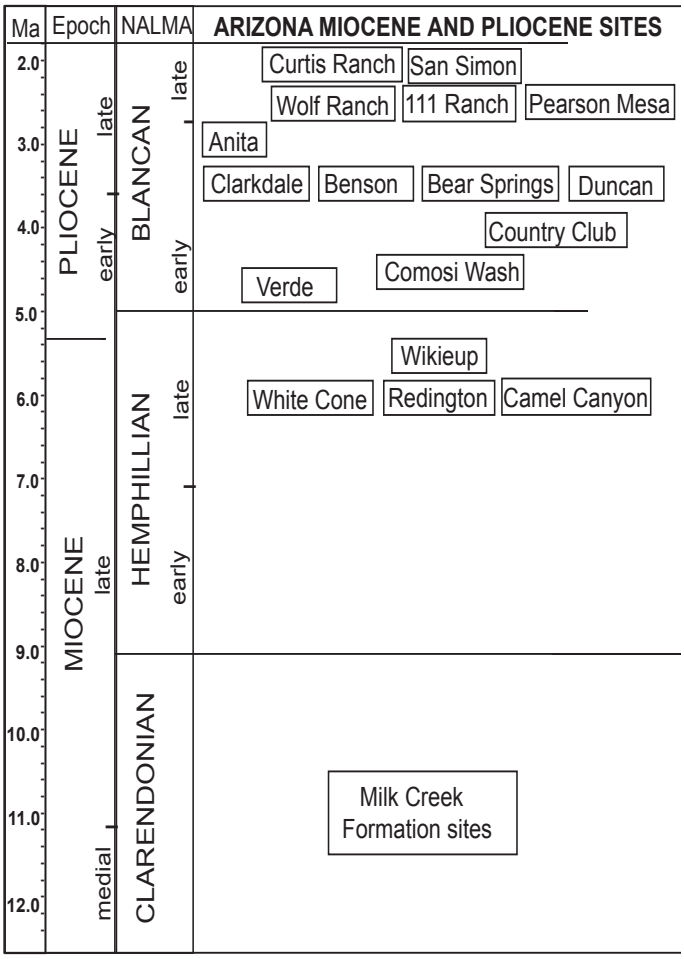

FIGURE 2. Correlation chart of key Miocene and Pliocene vertebrate fossil sites from Arizona. The age of sites is shown relative to the time scale (years in Ma) and North American land mammal ages.

Redington (they called it the Bingham Ranch site). Jacobs (1977) reported ten taxa of rodents from Redington, including three new genera and six new species: *Ronquillomys wilsoni*, *Perognathus henryredfieldi*, ?*Copemys vasquezi*, *Galushamys redingtonensis*, *Paronychomys lemredfieldi*, and *Paronychomys tuttlei*. Harrison (1981) referred several specimens from the Old Cabin Quarry and Redington Quarry to her new species of "wolverine," *Plesiogulo lindsayi*. Harrison (1985) reported the large camelid *Megatylopus*. White (1987) identified three species of the archaeolagine leporid *Hypolagus*, *H. edensis*, *H. tedfordi*, and *H. vetus*. Czaplewski (1993) tentatively referred several teeth from the Old Cabin Quarry to the vespertilionid bat *Eptesicus*. Old Cabin Quarry is also the type locality of the borophagine canid *Borophagus parvus* (Wang et al., 1999). MacFadden and Carranza-Castañeda (2002) mentioned a large quarry sample of the horse *Dinohippus* cf. *D. interpolatus* from Redington.

The list of carnivores, perissodactyls, and artiodactyls from Redington was compiled in part by Richard Tedford and Beryl Taylor based on unpublished material in the AMNH collection (Lindsay, 1978; Lindsay et al., 1984; Table 1). Lindsay et al. (1984) assigned an early late Hemphillian age (Hh3; ~5.9 Ma; Fig. 2) to the Redington local fauna based on the paleomagnetic stratigraphy of the Quiburis Formation and the biostratigraphy of the mammalian fauna (Jacobs, 1977).

Camel Canyon—The Camel Canyon local fauna is from the Quiburis Formation in the San Pedro Valley near Mammoth in southeastern Pinal County, about 15 km north of the Redington

TABLE 1. Miocene mammals from Arizona. The genera and/or species of mammals reported from Miocene vertebrate faunas (Arikareean, Hemingfordian, Clarendonian, and Hemphillian NALMA) in Arizona are listed, along with the faunas from which they are known. Within families, genera and species are listed in alphabetical order. Taxa identified only to the family level are not included in this list. Presence is indicated by "X", type locality of species indicated by "X*", questionable identification by "X?" (identified with "?" or "cf." in original publication), absence by "--". Faunal lists were taken from the published literature on the various sites, cited under the individual site accounts in the text.

	Arikareean/Hemingfordian		Clarendonian	late Hemphillian			
Taxon	Wellton	Anderson Mine	Milk Creek Fm. Sites	White Cone/ Bidahochi Fm.[1]	Redington	Camel Canyon	Wikieup
Insectivora							
Soricidae							
Notiosorex sp.	--	--	--	X	--	--	--
Talpidae							
Domninoides sp.	--	--	--	X?	--	--	--
Chiroptera							
Eptesicus sp.	--	--	--	--	X?	--	--
Carnivora							
Mustelidae							
Cernicitis sp.	--	--	--	X	--	--	--
Martes sp.	--	--	--	--	X	--	X
Martes (*Plionictis*) sp.	--	--	--	X	--	--	--
Plesiogulo lindsayi	--	--	--	--	X	--	X*
Plesiogulo marshalli	--	--	--	X	--	--	--
Pliogale furlongi	--	--	--	--	--	--	X
Pliotaxidea cf. *P. nevadensis*	--	--	--	--	X?	--	X
Procyonidae							
Bassariscus sp.	--	--	X	--	--	X	X
Procyon sp.	--	--	--	X?	--	--	--
Canidae							
Borophagus parvus	--	--	--	--	X*	--	X
"*Canis*" sp.	--	--	--	--	X	--	--
Carpocyon robustus	--	--	X	--	--	--	--
Epicyon haydeni	--	--	X	X	--	--	--
Eucyon davisi	--	--	--	--	--	--	X
Vulpes stenognathus	--	--	--	--	--	--	X
Ursidae							
Agriotherium gregorii	--	--	--	--	--	--	X
Agriotherium sp.	--	--	--	--	X	X	--
Felidae							
Adelphailurus kansensis	--	--	--	--	--	--	X[2]
"*Felis*" sp.	--	--	--	--	X	--	--
Machairodus coloradensis	--	--	--	--	--	--	X
Nimravides sp.	--	--	--	X	--	--	--
Pseudaelurus sp.	--	--	--	X	--	--	X
Lagomorpha							
Leporidae							
Hypolagus edensis	--	--	--	--	X	--	--
Hypolagus ringoldensis	--	--	--	X	--	--	--
Hypolagus tedfordi	--	--	--	--	X	--	X
Hypolagus vetus	--	--	--	--	X	--	--
Rodentia							
Mylagaulidae							
Mylgaulus monodon	--	--	--	X?	--	--	--
Sciuridae							
Spermophilus sp.	--	--	--	X	--	--	--
Castoridae							
Dipoides williamsi	--	--	--	X*	--	--	--

TABLE 1 (Cont)

Taxon	Arikareean/Hemingfordian		Clarendonian	late Hemphillian			
	Wellton	Anderson Mine	Milk Creek Fm. Sites	White Cone/ Bidahochi Fm.[1]	Redington	Camel Canyon	Wikieup
Eomyidae							
Ronquillomys wilsoni	--	--	--	--	X*	--	--
Heteromyidae							
Mookomys sp.	X	--	--	--	--	--	--
Perognathus henryredfieldi	--	--	--	--	X*	--	--
Perognathus mclaughlini	--	--	--	--	X	--	--
Perognathus sp.	--	--	--	X	--	--	--
Perognathoides bidahochiensis	--	--	--	X*	--	--	--
Prodipodmys kansensis	--	--	--	--	X	--	--
Muridae							
Bensonomys gidleyi	--	--	--	X*	--	--	--
Bensonomys yazhi	--	--	--	X*	--	--	--
?*Copemys vasquezi*	--	--	--	--	X*	--	--
Copemys sp.	--	--	--	X	--	--	--
Galushamys redingtonensis	--	--	--	--	X*	--	--
Paronychomys alticuspis	--	--	--	X*	--	--	--
Paronychomys lemredfieldi	--	--	--	--	X*	--	--
Paronychomys tuttlei	--	--	--	--	X*	--	--
Perissodactyla							
Equidae							
Dinohippus cf. *D. interpolatus*	--	--	--	--	X	X	--
"*Merychippus*"	--	--	X	--	--	--	--
Onohippidium galushai	--	--	--	--	--	--	X*
"*Pliohippus*"	--	--	X	--	--	--	--
Rhinocerotidae							
Diceratherium sp.	--	X	--	--	--	--	--
Teleoceras hicksi	--	--	--	X	--	--	--
Artiodactyla							
Camelidae							
"*Hemiauchenia*" sp.[3]	--	--	--	--	X	X	--
Megacamelus merriami	--	--	--	X	--	--	--
Megatylopus matthewi	--	--	--	--	--	--	X
Megatylopus sp.	--	--	--	--	X	X	--
Michenia yavapaiensis	--	--	X*	--	--	--	--
Oxydactylus sp.	--	X	--	--	--	--	--
Pleiolama vera[4]	--	--	--	--	--	--	X
Protolabis coartatus	--	--	X	--	--	--	--
Stenomylus sp.	X	--	--	--	--	--	--
Antilocapridae							
Cosoryx cerroensis	--	--	X?	--	--	--	--
Hayoceros sp.	--	--	--	--	X?	--	--
Illingoceros sp.	--	--	--	--	--	--	X?
Spenophalos nevadanus	--	--	--	--	--	--	X
Texoceros minorei	--	--	--	X	--	--	--
Texoceros sp.	--	--	--	--	X	X	X
Proboscidea							
Mammutidae							
Mammut sp.	--	--	--	--	--	X?	--

[1]Includes species from the White Cone local fauna and several species from other localities in the Bidahochi Formation of similar age, including Keams Canyon, Jeddito, and President Wilson Springs.
[2]According to Harrison (1983), there are two species of *Adelphailurus* from Wikieup.
[3]Some camelids identified as *Hemiauchenia* from Redington and Camel Canyon may belong to the recently described genus *Pleiolama* (Webb and Meachen, 2004). They are here identified as "*Hemiauchenia*" pending re-examination.
[4]*Hemiauchenia vera* was recently transferred to the new genus *Pleiolama* by Webb and Meachen (2004).

localities (Fig. 1, site 6). Fossils were first discovered at Camel Canyon in 1941 by Frick Laboratory field parties. Camel Canyon is not as well known as Redington because this site lacks the extensive small mammal fauna present at Redington (Jacobs, 1977). The list of large mammals from Camel Canyon was compiled by Richard Tedford and Beryl Taylor based on the AMNH collection (Lindsay, 1978; Lindsay et al., 1984; Table 1). Harrison (1985) reported *Megatylopus*. Lindsay et al. (1984) described the paleomagnetic stratigraphy of the Camel Canyon section of the Quiburis Formation and also obtained a fission-track date of 6.6 Ma near the base of the section. Magnetostratigraphy, the fission-track date, and biostratigraphy support a latest Miocene age of about 5.6 Ma for the Camel Canyon fauna (latest Hemphillian, Hh4; Lindsay et al., 1984; Fig. 2).

Wikieup—The Wikieup local fauna is derived from the Big Sandy Formation about 12 km south of Wikieup in Mohave County, western Arizona (Fig. 1, site 7). Wikieup is one of the best known Miocene vertebrate faunas from Arizona (MacFadden et al., 1979; Lindsay et al., 1984; Bickart, 1990). Field crews from the Frick Laboratory collected large samples of vertebrate fossils at Wikieup from 1938-1941 and again from 1955 to 1963. The two main fossil concentrations that comprise the Wikieup local fauna, the Clay Bank Quarry and Bird Bone Quarry, are located within 100 m of one another (MacFadden and Skinner, 1979). MacFadden and Skinner (1979) described the one-toed horse *Onohippidium galushai* based on a large sample from Wikieup, including skulls, jaws, and postcranial elements. The presence of *Onohippidium* is important because this is the oldest record of this genus, which is otherwise restricted to Pliocene and Pleistocene faunas in South America (MacFadden and Skinner, 1979). Wikieup is the type locality for *Plesiogulo lindsayi*, also known from Redington (Harrison, 1981). Bickart (1990) reviewed the extensive avifauna from Wikieup, including 38 species of birds in 13 families, comprising one of the largest North American Miocene avifaunas. Bickart (1990) described six new species: the swan *Cygnus mariae*, the geese *Anser arenosus*, *Anser arizonae*, and *Branta woolfendeni*, the stilt *Himantopus olsoni*, and the crow *Corvus galushai*.

MacFadden et al. (1979) reviewed the biostratigraphy and magnetostratigraphy of Wikieup. They also obtained a fission-track date of 5.5 Ma on a volcanic tuff that underlies the Clay Bank and Bird Bone quarries. The magnetostratigraphy and fission-track date constrain the age of the Wikieup local fauna to the very early Pliocene between 5.1 and 5.3 Ma. A late Hemphillian age is indicated by the biostratigraphy of the extensive mammalian fauna (Fig. 2). Lindsay et al. (1984) also regarded Wikieup as late Hemphillian but assigned this fauna a slightly older age of 5.6 Ma (latest Miocene).

PLIOCENE FAUNAS

Pliocene vertebrate faunas from Arizona are both more numerous and better studied than are Miocene faunas (Fig. 3). Most of these Pliocene sites are located in river valleys in southeastern Arizona, including the San Pedro River Valley south of Benson in Cochise County, the San Simon River Valley and Gila River Valley near Safford in Graham County, and the Gila River Valley near Duncan in Greenlee County. There are also several Pliocene faunas from the Verde River Valley in Yavapai County, central Arizona. All Arizona Pliocene vertebrate faunas are assigned to the Blancan NALMA.

Verde—Czaplewski (1987a, 1990) described the Verde local fauna from the Verde Formation near House Mountain east of Cornville, Yavapai County, central Arizona (Fig. 3, site 8). The Verde Formation consists of a sequence of Miocene and Pliocene fluvial and lacustrine sediments located in the Verde River Valley. The Verde local fauna is derived from two sites in the Verde

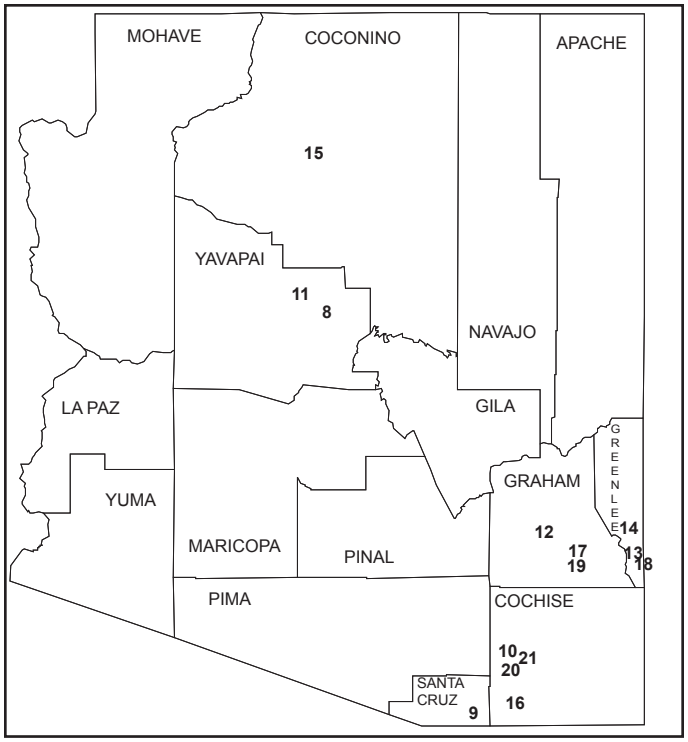

FIGURE 3. Map of Arizona showing location of key Pliocene (Blancan) vertebrate fossil sites. **8**, Verde; **9**, Comosi Wash; **10**, Benson; **11**, Clarkdale; **12**, Bear Springs; **13**, Duncan; **14**, Country Club; **15**, Anita; **16**, Wolf Ranch; **17**, 111 Ranch; **18**, Pearson Mesa; **19**, San Simon; **20**, California Wash; **21**, Curtis Ranch.

Formation separated stratigraphically by about 35 m. The Verde fauna consists mostly of small vertebrates, in particular rodents. Czaplewski (1987a) described four species of sigmodontine rodents, including two new species, *Prosigmodon holocuspis* and *Jacobsomys verdensis*. Czaplewski (1990) reviewed the entire vertebrate fauna from Verde consisting of 21 species: one salamander, one passerine bird, and 19 mammals, including two more new rodents, the small heteromyid *Perognathus strigipredus* and the woodrat *Neotoma vaughani* (Table 2). Czaplewski (1990) also mentioned the presence of mammal tracks from two other sites in the Verde Formation, including cat, tapir, camel, and proboscidean. These tracks were briefly described by McGregor and Schur (1994).

Verde is the oldest Blancan vertebrate fauna currently known from Arizona, on the basis of both biostratigraphy and geochronology. Rodents from Verde that are typical of the early Blancan include the geomyid *Geomys minor*, the heteromyid *Prodipodmys idahoensis*, the sigmodontine *Prosigmodon holocuspis*, and the arvicoline *Ogmodontomys* (=*Mimomys*) *poaphagus*. Based on a study of the magnetostratigraphy of the Verde Formation (Bressler and Butler, 1978), the two Verde fossil sites occur in the Gilbert Chron between the top of the Sidufjall Subchron (4.80 Ma) and the base of the Cochiti Subchron (4.29 Ma). These ages are based on the revised ages for the subchron boundaries within the Gilbert Chron (Berggren et al., 1995), and are somewhat older than the ages originally proposed for this portion of the Verde Formation (Bressler and Butler, 1978; Czaplewski, 1990). The combination of biostratigraphy and magnetostratigraphy places the Verde local fauna in the very early Blancan, between about 4.3 and 4.8 Ma (see correlation chart in Fig. 2).

Comosi Wash—The UALP has a collection of early Blancan mammals from Comosi Wash, a small tributary of the Santa Cruz River in the San Raphael Valley, located about 20 km southeast of Patagonia, Santa Cruz County, southeastern Arizona (Fig. 3,

site 9). The only published description of the Comosi Wash site (Quinn, 1958) was based on information provided by John Lance, who discovered this site in the 1950s. The site has not been worked since that time. The Comosi Wash local fauna was collected from a small pocket of red silty sandstone about 1 m thick in the bank of Comosi Wash. Lindsay and Tessman (1974) and Lindsay (1978) provided a list of the mammals from Comosi Wash. Quinn (1958) described a new species of horse from this site, *Equus* (*Asinus*) *pons*, based on a partial skull and mandibles with complete dentitions and a complete metacarpal and metatarsal. Repenning (1962) reported the giant marmot *Paenemarmota barbouri* on the basis of a pair of mandibles, one of which was illustrated. An antilocaprid is represented by the anterior half of the right ramus with incisors, p2 and p3. Although Lindsay (1978) identified this as *Capromeryx*, it is too large to be *Capromeryx* and seems closer in size to specimens of *Texoceros* from Redington. Berta (1981) identified two upper premolars of *Chasmaporthetes*, which Kurtén and Werdelin (1988) later referred to *C. ossifragus*. Repenning (1962) and Kurtén and Anderson (1980) noted that, despite their rarity, *Chasmaporthetes* and *Paenemarmota* often co-occur in Blancan sites, possibly related to some unknown paleoecological factor such as a predator-prey relationship between these two genera. Both *Chasmaporthetes* and *Paenemarmota* are restricted to Blancan faunas. The camelid from Comosi is *Pleiolama vera*, a species typical of late Hemphillian and early Blancan faunas. Until recently, this species was referred to the genus *Hemiauchenia*, but Webb and Meachen (2004) transferred *vera* to their new genus *Pleiolama*. The absence of South American Interchange mammals, as well as the presence of *P. vera*, suggests that the Comosi Wash fauna is early Blancan in age (~3.0-4.9 Ma). No other biostratigraphic or geochronologic data are currently available that would help constrain the age of the Comosi Wash local fauna. Further work at this site is clearly warranted.

Benson—A series of Blancan sites from the St. David Formation occurs in the San Pedro Valley south of Benson in Cochise County, southeastern Arizona. The early Blancan Benson fauna and late Blancan Wolf Ranch and Curtis Ranch faunas (see below) are the best known (Gidley, 1922, 1926; Gazin, 1942; Harrison, 1978), whereas the remainder of the sites have appeared in the literature primarily in faunal lists (Lindsay and Tessman, 1974; Johnson et al., 1975; Lindsay, 1978, 1984). Several of the lesser known Blancan sites from the San Pedro Valley (e.g., McRae Wash, Mendevil Ranch, Cal Tech) are briefly discussed at the end of this section under "Other Pliocene sites." The Benson site (also known as Post Ranch, e.g. Gray, 1967; Johnson et al., 1975) is located about 3 km south of Benson on the west side of the San Pedro River (Fig. 3, site 10). The Benson fauna occurs in the middle member of the St. David Formation (Gray, 1967).

Benson is one of the best known and most thoroughly documented Blancan sites in Arizona. Gidley (1922) described the rodents and lagomorphs , including nine new species of rodents (Table 2). Gidley (1926) described the proboscidean *Anancus bensonensis* based on a partial skull. Frick (1933) tentatively referred additional material to *A. bensonensis*, including a crushed skull with both M3s, a pair of mandibles with both m3s, and several immature dentitions. Osborn (1936) transferred *A. bensonensis* to the genus *Cordillerion*, together with the species *C. edensis* from the late Hemphillian of California. *Cordillerion* is now considered a synonym of *Cuvieronius*, and *Cordillerion edensis* has been included in *Rhynchotherium* as *R. edense* (Lambert and Shoshani, 1998). Kurtén and Anderson (1980) synonymized *A. bensonensis* with *Stegomastodon mirificus*, whereas Lindsay (1984) referred this species to a fourth different genus as *Cuvieronius bensonensis*. Osborn (1936) noted that the tetralophodont M3 in the type skull of *A. bensonensis* is not typical of *Stegomastodon*, which normally has five or more lophs on M3. Pending a thorough study of this species, we list it as "*Anancus*" *bensonensis* in Table 2, with the understanding that *Anancus* is almost certainly not the correct generic assignment.

Gilmore (1922) described a new species of mud turtle, *Kinosternon arizonense*, from Benson, and Wetmore (1924) reviewed the avifauna. Gazin (1942) reviewed the mammalian fauna, including new material he collected in 1936. Gazin described a new species of lagomorph, *Sylvilagus*? *bensonensis*, which Downey (1968) later transferred to the new genus *Aluralagus*. Downey (1968) also reported three other lagomorphs, *Nekrolagus*? sp., *Hypolagus* cf. *H. limnetus*, and *Notolagus* cf. *N. velox*. Brattstrom (1955) described the herpetofauna, including salamander, toad, lizard, and kinosternid turtle. Berta (1981) identified a mandible of the hyaenid *Chasmaporthetes johnstoni*. The Benson hyaenid was subsequently referred to *C. ossifragus* by Kurtén and Werdelin (1988), who synonymized *C. johnstoni* with *C. ossifragus*. White (1991) described and illustrated several specimens of the leporine lagomorph *Aluralagus bensonensis*. Wang et al. (1999) identified two specimens of the borophagine canid *Borophagus diversidens*, a mandible from the "Post Ranch Fauna, Carnivore Site" and a mandible from the "Three and One-half Mile Section" near Benson. The current faunal list from Benson includes 46 species (Lindsay, 1984): one frog, one salamander, four turtles, one lizard, 12 birds, and 27 mammals (see Table 2 for list of mammals).

In a paper on the magnetic polarity stratigraphy of Pliocene vertebrate faunas from the San Pedro Valley, Johnson et al. (1975) discussed the geochronology and biostratigraphy of the Benson fauna and more than 10 other vertebrate faunas that occur stratigraphically higher in the St. David Formation in the vicinity of Benson, Arizona. The San Pedro Valley provided one of the first areas where magnetic polarity stratigraphy was used in a terrestrial sedimentary sequence to help understand the geochronology of a series of superposed vertebrate faunas (Johnson et al., 1975; Lindsay et al., 1975). Magnetostratigraphy has since become a standard tool for geochronological studies of Cenzoic vertebrate-bearing strata in the southwesten United States and elsewhere. Benson (=Post Ranch locality of Johnson et al., 1975) is the oldest Blancan vertebrate fauna in the St. David Formation in the San Pedro Valley, occurring in the lowermost normally-magnetized magnetozone in the Gauss Chron, just below the Mammoth Subchron. Johnson et al. (1975) assigned an age of 3.1 Ma to the Benson fauna based on the age of the base of the Mammoth Subchron, which at that time was placed at 3.08 Ma. Refinement of the geomagnetic polarity timescale (GPTS) now places the base of the Mammoth Subchron at 3.33 Ma and the boundary between the Gauss and Gilbert chrons at 3.58 Ma (Berggren et al., 1995). Thus, the age of the Benson fauna is between 3.3 and 3.6 Ma, probably closer to 3.3 Ma based on its occurrence just below the Mammoth Subchron (Johnson et al., 1975; Lindsay et al., 1990; Fig. 2). Biostratigraphic data from Benson support an early Blancan age, including some of the earliest known appearances of the rodents *Sigmodon medius* and *Bensonomys arizonae*, the leporid *Aluralagus*, and the hyaenid *Chasmaporthetes*. An early Blancan age is also supported by the absence of South American Interchange mammals, which first occur higher in the San Pedro Valley sequence at Wolf Ranch at about 2.7 Ma.

Clarkdale—The Clarkdale local fauna is derived from the uppermost strata of the Verde Formation northwest of Clarkdale, Yavapai County, central Arizona (Fig. 3, site, 11). Czaplewski (1987b) described the Clarkdale fauna primarily from fossils collected in a quarry operated by the Phoenix Cement Company. The most complete fossil is a skull with both tusks and associated mandible of the gomphothere *Stegomastodon* cf. *S. mirificus* (Agenbroad et al., 1998). Most of the fossils from this site are microvertebrates recovered by screenwashing about 200 kg of

TABLE 2. Pliocene mammals from Arizona. The genera and/or species of mammals reported from the best known Pliocene (Blancan NALMA) vertebrate faunas in Arizona are listed, along with the faunas or sites from which they are known. Within families, genera and species are listed in alphabetical order. Only taxa identified to the generic or specific levels are listed here; identifications at the family level (e.g., Soricidae, Antilocapridae, etc.) are not included. Sites are listed from the oldest on the left (Verde) to the youngest on the right (Curtis Ranch). Presence is indicated by "X", type locality of species by "X*", questionable identification by "X?" (identified with "?" or "cf." in original publication), absence by "--".Faunal lists were taken from the published literature on the various sites, cited under the individual site accounts in the text, except for recent additions to the faunal lists for 111 Ranch and San Simon by RSW and for Pearson Mesa by GSM.

		Early Blancan							Late Blancan					
Taxon	**Verde**	**Comosi Wash**	**Benson**	**Clarkdale**	**Bear Springs**	**Duncan**	**Country Club**	**Anita**	**Wolf Ranch**	**111 Ranch**	**Pearson Mesa**	**San Simon[1]**	**California Wash**	**Curtis Ranch**
Xenarthra														
Megalonychidae														
Megalonyx leptostomus	--	--	--	--	--	--	X?	--	--	X	--	--	--	--
Mylodontidae														
Glossotherium chapadmalense	--	--	--	--	--	--	--	--	--	X	X	--	--	--
Glyptodontidae														
Glyptotherium arizonae	--	--	--	--	--	--	--	--	--	--	--	--	X	X*
Glyptotherium texanum	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Glyptotherium sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Insectivora														
Soricidae														
Notiosorex sp.	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Sorex taylori	--	--	--	--	--	--	--	--	--	--	--	--	X	--
Sorex sp.	--	--	--	--	--	X	--	--	X	--	--	--	--	--
Chiroptera														
Vespertilionidae														
Antrozous pallidus	--	--	--	--	--	--	--	--	X	--	--	--	--	--
Lasiurus blossevillii	X?	--	--	--	--	--	--	--	--	--	--	--	--	--
Myotis sp.	--	--	--	X	--	--	--	--	--	X	--	--	--	--
Simonycteris stocki	--	--	--	--	--	--	--	--	--	--	--	--	--	X*
Carnivora														
Canidae														
Borophagus diversidens	--	--	X	--	X	--	--	--	--	X	--	X	--	--
Canis edwardii	--	--	--	--	--	--	--	X	--	X	--	X	--	X*
Canis latrans	--	--	--	--	--	--	--	X?	--	--	--	--	--	--
Canis lepophagus	--	--	--	--	X?[2]	--	--	--	--	X	--	--	--	--
Canis new sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Canis sp.	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Urocyon sp.	--	X?	--	--	--	--	--	--	--	X	--	--	--	--
Mustelidae														
Ferinestrix sp.	--	--	--	--	--	--	--	--	--	X?	--	--	--	--
Mustela sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Satherium sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Spilogale pedroensis	--	--	--	--	--	--	--	--	--	--	--	--	--	X*
Spilogale rexroadi	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Taxidea taxus	--	--	--	--	--	--	--	X	--	--	--	--	--	--
Taxidea sp.	--	--	--	--	X	--	X	--	--	--	--	X	--	--
Trigonictis cooki	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Trigonictis macrodon	--	--	--	--	X	--	--	--	--	X	--	--	--	--
Procyonidae														
Bassariscus sp.	X	--	--	--	--	--	--	--	--	X?	--	--	--	--
Procyon sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Ursidae														
Arctodus sp.	--	--	--	--	--	--	--	--	--	X	--	X	--	--
Tremarctos sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Plionarctos harroldorum	--	--	--	--	X?	--	--	--	--	--	--	--	--	--
Hyaenidae														
Chasmaporthetes ossifragus	--	X	X	--	--	X	--	X*	--	X	--	--	--	--

[1] San Simon includes the San Simon Power Line fauna of Tomida (1987), as well as several additional localities in this same general vicinity, including the Central and Southern Whitlock Mountain and Whitlock Oil Well collecting areas of Galusha and two new areas discovered during recent work by RSW and colleagues, Artesia and Tanque Road .

[2] The *Canis* from Bear Springs has been identified as either *C. lepophagus* or *C. ferox*.

TABLE 2. (Continued)

Taxon	Early Blancan								Late Blancan					
	Verde Wash	Comosi	Benson	Clarkdale	Bear Springs	Duncan	Country Club	Anita	Wolf Ranch	111 Ranch	Pearson Mesa	San Simon[1]	California Wash	Curtis Ranch
Felidae														
"*Felis*" sp.[3]	--	--	X	--	--	X	--	--	--	--	X	--	--	X
Homotherium sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Lynx sp.	--	X	--	--	X	--	--	--	--	X	--	--	--	--
Miracinonyx sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Puma lacustris	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Smilodon gracilis	--	--	--	--	X	--	--	--	--	--	--	--	--	--
Xenosmilus sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
small felid, n. sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Lagomorpha														
Leporidae														
Alilepus wilsoni	--	--	--	--	--	--	--	--	--	--	--	X*	--	--
?*Alilepus browni*	--	--	--	--	--	--	--	X*	--	--	--	--	--	--
Aluralagus bensonensis	--	--	X*	--	--	--	--	--	--	--	--	--	--	--
Aluralagus virginiae	--	--	--	--	--	--	--	--	--	--	--	X	--	X*
Alurlagus sp.	--	--	--	X?	--	--	--	--	--	--	--	--	--	--
Aztlanolagus agilis	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Hypolagus arizonensis	--	--	--	--	--	--	--	--	--	X*	--	--	--	--
Hypolagus edensis	--	--	X?	--	--	--	--	--	--	--	--	--	--	--
Hypolagus sp.	--	--	--	X	--	X	--	--	--	--	--	--	--	--
Lepus benjamini	--	--	--	--	--	--	--	X*	--	--	--	--	--	--
Lepus townsendi	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Lepus sp.	--	--	--	--	X	--	--	--	--	--	--	--	--	--
Nekrolagus progressus	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Notolagus lepusculus	--	--	--	--	--	--	X	--	X?	--	--	--	--	--
Notolagus velox	--	--	X?	--	--	--	--	--	--	--	--	--	--	--
Sylvilagus cunicularius	--	--	--	--	--	--	--	--	--	X	--	X	--	X?
Sylvilagus floridanus	--	--	--	--	--	--	--	--	--	--	--	--	--	X?
Sylvilagus hibbardi	--	--	--	--	--	--	--	--	X	--	--	X	--	--
Sylvilagus sp.	--	--	--	--	--	--	--	--	--	--	--	--	X	--
Rodentia														
Sciuridae														
Marmota arizonae	--	--	--	--	--	--	--	X*	--	--	--	--	--	--
Marmota sp.	--	--	--	X?	--	--	--	--	--	--	--	--	--	--
Paenemarmota barbouri	--	X	--	--	--	--	--	--	--	--	--	--	--	--
Spermophilus bensoni	--	--	X*	--	--	--	--	--	X	X?	--	X?	X	--
Spermophilus cochisei	--	--	--	--	--	--	--	--	--	--	--	--	--	X*
Spermophilus tuitus	--	--	--	--	--	--	--	X*	--	--	--	--	--	--
Spermophilus sp.	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Castoridae														
Castor sp.	--	--	--	--	--	--	--	--	--	X	--	X	--	X
Geomyidae														
Geomys minor	X	--	X*	--	--	--	--	--	X	--	--	--	--	--
Geomys persimilis	--	--	--	--	--	X?	--	--	X	X?	X?	X?	X	X*
Geomys sp.	--	--	--	X	X	--	X	--	--	--	--	--	--	--
Cratogeomys bensoni	--	--	X*	--	--	--	--	--	--	--	--	--	--	--
Cratogeomys sansimonensis	--	--	--	--	--	--	--	--	--	--	--	X*	--	--
Heteromyidae (continued on next page)														
Dipodomys gidleyi	--	--	--	--	--	--	--	--	--	X	--	--	--	X*
Dipodomys hibbardi	--	--	--	--	--	--	--	--	--	X	--	X	--	--
Perognathus gidleyi	--	--	--	--	--	X	--	--	X	X	--	--	--	--
Perognathus pearlettensis	--	--	--	--	--	--	--	--	X	--	--	--	--	--
Perognathus strigipredus	X*	--	--	--	--	--	--	--	--	--	--	--	--	--
Perognathus sp.[4]	X[5]	--	X	X	--	--	--	--	--	--	--	--	X	X

[3] Small cats from the Pliocene of Arizona generally have been identified in the literature as "*Felis*." However, mammalogists separate the living species of cats previously referred to *Felis* into a number of different genera. Although it is likely that most of the Arizona Pliocene records of small cats pertain to the genus *Lynx*, we here retain these records in the genus *Felis*, with quotation marks.

[4] All small pocket mice in the family Heteromyidae are here placed in the genus *Perognathus*, although mammalogists separate the various species previously referred to this genus into two genera, *Perognathus* and *Chaetodipus*. Since all species of *Perognathus* listed here are extinct and the original authors did not specify to which of these two genera (or subgenera) the extinct species belonged, we use the genus *Pergonathus* in the broad sense (*sensu lato*) to include species now referred to either *Perognathus* or *Chaetodipus*.

[5] Czaplewski (1990) identified three species of *Perognathus* from Verde, *P. strigipredus*, *Perognathus* species A, and *Perognathus* species B. This "X" actually represents two species.

TABLE 2. (Continued)

Taxon	Early Blancan								Late Blancan					
	Verde	Comosi Wash	Benson	Clarkdale	Bear Springs	Duncan	Country Club	Anita	Wolf Ranch	111 Ranch	Pearson Mesa	San Simon[1]	California Wash	Curtis Ranch
Heteromyidae (continued from previous page)														
Prodipodomys idahoensis	X	--	--	--	--	--	--	--	X	--	--	--	X	--
Prodipodomys minor	--	--	X*	--	--	--	--	--	X	--	--	--	--	--
Prodipodomys sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Muridae														
Arvicolinae														
Mictomys vetus	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Mictomys sp.	--	--	--	--	--	--	--	--	--	--	--	--	X	--
Ogmodontomys poaphagus	X	--	--	--	--	--	--	--	--	--	--	--	--	--
Ondatra idahoensis	--	--	--	--	--	--	--	--	--	X	--	--	X	X
Ophiomys taylori	--	--	--	--	--	X?	--	--	--	--	--	--	--	--
Pliophenacomys primaevus	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Pliophenacomys sp.	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Pliopotamys meadensis	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Pliopotamys sp.	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Sigmodontinae														
Baiomys brachygnathus	--	--	--	--	--	--	--	--	X	X?	--	--	--	X*
Baiomys minimus	--	--	X*	--	--	X	--	--	X	--	--	--	--	--
Bensonomys arizonae	X	--	X*	X	--	--	--	--	X	X	--	--	X	X
Bensonomys elachys	--	--	--	X?	--	--	--	--	--	--	--	--	--	--
Bensonomys sp.	--	--	--	--	--	X	--	--	--	--	--	--	--	--
Copemys sp.	X	--	--	--	--	--	--	--	--	--	--	--	--	--
Jacobsomys verdensis	X*	--	--	--	--	--	--	--	--	--	--	--	--	--
Neotoma fossilis	--	--	X*	--	--	X	--	--	--	--	--	--	--	--
Neotoma quadriplicata	--	--	--	--	--	--	X	--	--	--	--	--	--	--
Neotoma taylori	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Neotoma vaughani	X*	--	--	--	--	--	--	--	--	--	--	--	--	--
Neotoma sp.	--	--	--	X	--	--	--	X	X	--	--	--	--	--
Onychomys bensoni	X	--	X*	--	--	--	--	--	X	--	--	--	--	--
Onychomys pedroensis	--	--	--	--	--	--	--	--	--	X	--	--	--	X*
Peromyscus hagermanensis	--	--	--	X?	--	X	--	--	--	X	--	--	--	--
Peromyscus sp.	--	--	X	--	--	--	X	--	X	--	--	--	--	X
Prosigmodon holocuspis	X*	--	--	--	--	--	--	--	--	--	--	--	--	--
Reithrodontomys galushai	--	--	--	--	--	--	--	--	--	X*	--	--	--	--
Reithrodontomys rexroadensis	--	--	--	--	--	X	--	--	--	X	--	--	--	--
Reithrodontomys wetmorei	X?	--	--	--	--	--	--	--	--	--	--	--	--	--
Reithrodontomys sp.	--	--	--	X	--	--	--	--	--	--	--	--	--	--
Repomys arizonensis	--	--	--	--	--	--	--	--	--	X*	--	--	--	--
Repomys panacaensis	--	--	--	X?	--	--	--	--	--	--	--	--	--	--
Sigmodon curtisi	--	--	--	--	--	--	--	--	X	--	--	--	X	X*
Sigmodon medius[6]	X	--	X*	X	--	X	X	--	X	X	--	--	--	--
Sigmodon minor[6]	--	--	--	--	--	--	--	--	--	--	--	--	X	X*
Sigmodon sp.	--	--	--	--	X	--	--	--	--	--	--	X	--	--
Erethizontidae														
Erethizon bathygnathum	--	--	--	--	--	--	--	--	X	--	--	--	--	--
Hydrochaeridae														
Neochoerus dichroplax	--	--	--	--	--	--	--	--	--	X*	--	--	--	--
Perissodactyla														
Equidae														
Equus calobatus	--	--	--	--	--	--	--	--	--	X?[7]	--	--	--	--
Equus cumminsii	--	--	--	--	--	--	--	--	--	X?[7]	X?	--	--	--
Equus pons	--	X*	--	--	--	--	--	--	--	--	--	--	--	--
Equus scotti	--	--	--	--	--	--	--	--	--	--	X	--	--	--
Equus simplicidens	--	--	--	--	--	--	--	--	X	X?[7]	X	--	--	--
Equus sp.[8]	--	--	X	X	X	X	X	X[9]	--	--	--	X	X	X
Nannippus peninsulatus	--	--	X	X	X	X	--	--	X	X	X	--	--	--

TABLE 2. (Continued)

Taxon	Early Blancan								Late Blancan					
	Verde	Comosi Wash	Benson	Clarkdale	Bear Springs	Duncan	Country Club	Anita	Wolf Ranch	111 Ranch	Pearson Mesa	San Simon[1]	California Wash	Curtis Ranch
Tapiridae														
Tapirus sp.	--	--	--	--	--	--	--	--	--	X	--	X	--	--
Artiodactyla														
Tayassuidae														
Platygonus bicalcaratus	--	--	--	--	--	--	--	--	--	--	X	--	--	--
Platygonus sp.	--	--	X	--	X	X	--	X	--	X	--	X	--	X
Camelidae														
Blancocamelus sp.	--	--	--	--	--	--	--	--	--	X	--	--	--	--
Camelops traviswhitei	--	--	--	--	--	--	--	--	--	X	X?	--	--	--
Camelops sp.	--	X	X	--	X	X	--	--	X?	--	--	X	X	X
Gigantocamelus sp.[10]	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Hemiauchenia blancoensis	--	--	--	--	--	--	--	--	--	X	X	X	--	--
Hemiauchenia new sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Hemiauchenia sp.	--	--	X	--	X	X	X	X	--	--	--	--	--	X
Megatylopus cochrani	--	--	--	--	--	--	--	--	--	--	--	X?	--	--
Megatylopus gigas	--	--	--	--	X	--	--	--	--	--	--	--	--	--
Megatylopus sp.	--	--	--	--	--	--	--	X	--	--	--	--	--	--
Pleiolama vera[11]	--	X	--	--	X	--	--	--	--	--	--	--	--	--
Cervidae														
Bretzia sp.	--	--	--	--	--	--	--	--	--	--	--	X?	--	--
Odocoileus sp.	--	--	X	--	--	X	--	--	X	--	--	X	--	X?
cervid new sp.	--	--	--	--	--	--	--	--	--	--	--	X	--	--
Antilocapridae														
Capromeryx arizonensis	--	--	--	--	--	--	--	--	--	X*	--	X	--	X
Capromeryx sp.	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Tetrameryx sp.	--	--	--	--	--	X	--	--	--	X?	--	--	--	--
Texoceros sp.	--	X?	--	--	--	--	--	--	--	--	--	--	--	--
Proboscidea														
Gomphotheriidae														
"*Anancus*" *bensonensis*[12]	--	--	X*	--	--	--	--	--	--	--	--	--	X	--
Cuvieronius sp.	--	--	--	--	X	--	--	--	--	X	--	--	--	--
Rhynchotherium sp.	--	--	--	--	X?	--	--	--	--	X	--	--	--	--
Stegomastodon mirificus	--	--	--	X	--	X?	--	--	X	--	--	--	--	X
Stegomastodon primitivus	--	--	--	--	--	--	--	--	--	--	X	--	--	--

[6] Many authors have synonymized *Sigmodon medius* and *S. minor* as *S. minor*, the latter name having priority (e.g., Martin et al., 2000). However, there does appear to be a species (subspecies?) of *Sigmodon* from several localities, including the type locality, Curtis Ranch, that is distinctly smaller than typical *S. medius*, and this smaller cotton rat is here listed *as S. minor*.

[7] The horses from 111 Ranch are currently under study by Eric Scott. He cautions that the identifications listed here are based largely on size and are subject to change based on further study of the material.

[8] Most previous publications on Arizona Blancan sites identify the one-toed horses as *Equus*, with no species identification. It is important to recognize that more than one species of *Equus* could be represented at sites where "*Equus* sp." is listed.

[9] Hay (1921) identified two species of *Equus* from Anita, *E. giganteus* and *E. occidentalis*. Both of these species are typical of Pleistocene faunas, whereas the Anita fauna is clearly Blancan. Based on the size of the teeth there are two species of *Equus* present at Anita, but the species-level identification of these horses requires further study.

[10] Giant Blancan camelids previously referred to *Titanotylopus* are here referred to *Gigantocamelus* following Harrison (1985).

[11] *Hemiauchenia vera* was recently transferred to the new genus *Pleiolama* by Webb and Meachen (2004).

[12] The gompthotheriid proboscidean listed here as "*Anancus*" *bensonensis* is almost certainly referable to a another genus, although it is as yet unclear to which genus this species belongs.

greenish clay removed from the plaster jacket that contained the *Stegomastodon* skull (Czaplewski, 1987b). The vertebrate fauna consists of 28 species (from Czaplewski, 1987b) : a cyprinid fish, a salamander, the giant tortoise *Hesperotestudo*, an emydid turtle, the lizard cf. *Crotaphytus* sp., the snake *Thamnophis* sp., the turkey *Meleagris* sp., and 21 mammals (see Table 2 for list of mammals). The rocks of the upper Verde Formation are poorly magnetized and thus did not yield a magnetostratigraphy that could be correlated with the GPTS (Bressler and Butler, 1978). The mammalian biostratigraphy from Clarkdale, in particular the rodents *Pliopotamys meadensis*, *Peromyscus* cf. *P. hagermanensis*, and *Repomys* cf. *R. panacaensis*, as well as the absence of South American immigrants, indicates a late early (=medial) Blancan age between 2.7 and 3.5 Ma (Czaplewski, 1987b; Fig. 2).

Bear Springs—The Bear Springs fauna, including Red Knolls, Pima, and Matthews Wash, is derived from strata of the Gila Group located south of Pima, Graham County, southeastern Arizona (Fig. 3, site 12). Howard Scott Gentry, working for Childs Frick, made the first collections from Matthews Wash and Pima in 1937. Ted Galusha made extensive collections for the Frick Laboratory in the winter of 1937 and 1938. Bear Springs is not well known but contains an important vertebrate assemblage of early Blancan age. Lindsay and Tessman (1974) first listed fossils from Bear Springs, including a kinosternid turtle, bird, horse, peccary, camel, and gomphothere (*Rhynchotherium*?). Lindsay (1978) listed a snake, *Lynx*, and *Equus* from this fauna as well. Tomida (1987) provided the most complete mammalian faunal list, consisting of 12 species, most of which are large mammals identified only to genus (Table 2). Small mammals are rare but include fragmentary specimens of *Geomys* and *Sigmodon* (Tomida, 1987). Brattstrom (1955) identified the water snake *Natrix* (=*Nerodia*) from Red Knolls. Ray et al. (1981) reported two specimens of the Blancan mustelid *Trigonictis macrodon*, a partial maxilla with three teeth from Matthews Wash and an edentulous mandibular ramus from Bear Springs Flat. Wang et al. (1999) identified a partial mandible of *Borophagus diversidens* from Pima. The presence of *Trigonictis*, *Borophagus*, and *Nannippus peninsulatus* confirms a Blancan age for the Bear Springs fauna. Lindsay et al. (1984) established the *Nannippus* extinction datum at about 2.2 Ma; however, there appear to be no Blancan sites in Arizona younger than the Gauss/Matuyama boundary (2.58 Ma) that contain *Nannippus* (Galusha et al., 1984). Two taxa reported here suggest an early Blancan age. The small tremarctine bear *Plionarctos* (mentioned from this locality in Hunt, 1998 as *P. edensis*; Fig. 4M) and a new record of the lamine camelid *Pleiolama* (=*Hemiauchenia*) *vera* (Figs. 4D-F). are typical late Hemphillian forms, but are also known from several early Blancan faunas. *P. edensis* occurs in a Blancan fauna from Riverside County in southern California (Hunt, 1998) and Tedford and Martin (2001) described *P. harroldorum* from the early Blancan Taunton fauna in Washington. The presence of *Smilodon gracilis* constitutes either an anamolously early record, or indicates the presence of younger sediments in the Bear Springs area. The absence of South American mammals further suggests an early Blancan age. Several representative fossils from Bear Springs are illustrated in Figure 4, including *Plionarctos harroldorum* and *Pleiolama vera*. The paleomagnetic stratigraphy from Bear Springs shows a long normal polarity zone that Tomida (1987) correlated with either the lowermost normal zone of the Gauss Chron (3.33-3.58 Ma) or the uppermost normal zone of the Gauss (2.58-3.04 Ma). Ongoing studies of Bear Springs fossils in the AMNH, MSM, and UALP collections should permit a more precise age assignment of this fauna within the early Blancan.

Duncan—The Duncan fauna is derived from strata of the Gila Group near the town of Duncan in the Duncan basin, Greenlee County, southeastern Arizona (Fig. 3, site 13). C. H. Falkenbach of the Frick Laboratory first collected fossils in the Duncan area in 1932. Ted Galusha of the Frick Laboratory collected fossils along the Gila River in the Duncan area in 1938-1939 and again in 1953-1954. Lindsay and Tessman (1974) first listed the vertebrate fauna from Duncan, including a tortoise, a bird, the pocket gopher *Geomys*, and the horses *Nannippus* and *Equus*. Tedford (1981) briefly summarized the fauna based on the AMNH collection. Tomida (1987) listed 25 species of mammals in the AMNH and UALP collections (Table 2), and described the small mammal fauna of 14 species in detail. Tomida (1987) noted that several of the rodents, including *Baiomys minimus*, *Sigmodon medius*, *Neotoma* (*Paraneotoma*) *fossilis*, and *Ophiomys taylori*, are typical of medial Blancan (=late early) Blancan faunas. Duncan shares the first three of these species with the early Blancan Benson fauna. The presence of *Nannippus peninsulatus* is significant because this small three-toed horse is unknown from faunas younger than the Gauss/Matuyama boundary (2.58 Ma) in Arizona (Galusha et al., 1984). Emslie and Czaplewski (1999) described a new species of eagle, *Amplibuteo concordatus*, based on specimens from Florida and Duncan. The paleomagnetic stratigraphy of the Duncan section (Tomida, 1987) shows a lower zone of normal polarity and an upper zone of reversed polarity, with most of the fossil sites occurring just below and above this polarity reversal. Tomida (1987) placed the Duncan fauna in the Gauss Chron, but was unable to determine if the upper reversed zone represented the Mammoth Subchron (3.22-3.33 Ma) or the Kaena Subchron (3.04-3.11 Ma). The biostratigraphy and magnetostratigraphy indicate an early Blancan age for the Duncan fauna (~3.0-3.4 Ma), similar to Benson which it closely resembles (Fig. 2).

Country Club—The Country Club fauna is derived from strata of the Gila Group about 25 km north of Duncan on the east side of the Gila River in the Duncan basin, Greenlee County, southeastern Arizona (Fig. 3, site 14). The Country Club fauna consists of 11 species of mammals, mostly small taxa (Tomida, 1987). The most age-diagnostic mammals are the leporid *Notolagus lepusculus* and the woodrat *Neotoma* (*Paraneotoma*) *quadriplicata*, both of which are known from the Rexroad fauna in Kansas (Tomida, 1987). The megalonychid ground sloth *Megalonyx* cf. *M. leptostomus* is one of the more interesting records of large mammals. Although uncommon, *M. leptostomus* is widespread in both early and late Blancan faunas. The magnetostratigraphy of the Country Club section (Tomida, 1987) shows a zone of reversed polarity at the base of the section containing most of the fossil sites, overlain by a zone of normal polarity, with a reversed zone at the top of the section. Tomida (1987) correlated the section with the uppermost Gilbert Chron through the Mammoth Subchron (~3.2-3.8 Ma; Fig. 2), an age range that also correlates well with the biostratigraphy of the small mammals suggesting an early to medial Blancan age (Tomida, 1987).

Anita—The Anita local fauna (Fig. 3, site 15) was derived from an unnamed fissure deposit formed in the Permian Kaibab Limestone in the Val Verde copper mine near Anita in Coconino County, northern Arizona (Hay, 1921). The fossils were collected by B. C. Bicknell in 1901 and Barnum Brown in 1904. Fossils from Anita are housed in the USNM and AMNH collections. Hay (1921) reported 15 species of mammals (Table 2), including eight new species (generic and specific names are those proposed by Hay, 1921; see below for current taxonomy): the hyena *Chasmaporthetes ossifragus*, the badger *Taxidea robusta*, the camels *Procamelus coconinensis* and *Procamelus longurio*, the rodents *Marmota arizonae* and *Citellus tuitus*, and the rabbits *Brachylagus browni* and *Lepus benjamini*. The taxonomic status of several of these species is now considered questionable. Hay (1921) also reported seven other species of mammals (Table 2; the "?" after several species names are from Hay, 1921): the canids *Canis nubilus*? and *C. latrans*?, the

horses *Equus giganteus* and *E. occidentalis*, the tayassuid *Mylohyus*, the pronghorn *Antilocapra americana*?, and the woodrat *Neotoma cinerea*.

Hay (1921) based his description of *Chasmaporthetes ossifragus* on two very incomplete dentary fragments with a partial tooth and two other teeth represented only by roots. Berta (1981) confirmed that the type of *C. ossifragus* from Anita was indeed a true hyaenid and referred additional material to *C. ossifragus* from late Blancan sites in Florida. Kurtén and Werdelin (1988) referred all North American hyaenids to *C. ossifragus*. Kurtén and Anderson (1980) synonymized *Taxidea robusta*, known from Anita by a partial ulna with robust proportions, with the living badger *T. taxus*. The Anita camelids clearly do not belong to the Miocene genus *Procamelus*, to which Hay (1921) originally referred them. Honey et al. (1998) referred *Procamelus coconinensis*, described from a partial upper molar and complete proximal phalanx, to the giant camelid *Megatylopus*, and *Procamelus longurio*, described from an incomplete metatarsal, several proximal phalanges, and an axis vertebra, to the smaller lamine *Hemiauchenia*, which we here confirm as *H. blancoensis*. Kurtén and Anderson (1980) retained Hay's species names for the marmot *Marmota arizonae*, the ground squirrel *Spermophilus* (=*Citellus*) *tuitus*, and the leporid *Lepus benjamini*. White (1991) tentatively referred *Brachylagus browni* to the genus *Alilepus* as ?*Alilepus browni*. White (1991) reported specimens of Blancan *Lepus* from only two sites, Borchers, Kansas and Big Springs, Nebraska. White (1991) apparently excluded *L. benjamini* from his analysis because he considered the Anita fauna to be Irvingtonian in age, and his study did not include Pleistocene leporids. Lindsay and Tessman (1974) listed the giant marmot *Paenemarmota*, although Repenning (1962) noted that this genus did not occur at Anita. Kurtén and Anderson (1980) stated that *Paenemarmota* was mistakenly identified from Anita, and as such it is not listed in Table 2.

Among the mammals Hay (1921) identified from Anita but did not describe as new are several taxa that are probably misidentified. The two species of *Equus*, *E. giganteus* and *E. occidentalis*, are primarily known from late Pleistocene faunas. A partial radius-ulna was referred to the tayassuid *Mylohyus*, which is mainly an eastern form. The westernmost records of this genus are from Nebraska, Kansas, Oklahoma, and Texas (Kurtén and Anderson, 1980). Although a tayassuid partial postcranial element is probably not identifiable to genus, it is much more likely that this bone belongs to *Platygonus*, the typical peccary in southwestern Plio-Pleistocene faunas. The living pronghorn *Antilocapra americana* was reported on the basis of a single proximal phalanx; however, this element is almost certainly not diagnostic at the generic or specific level. Hay (1921) tentatively identified two canids, *Canis nubilus* and *C. latrans*. Nowak (1979) restudied Hay's canid material, identifying three species of *Canis*. He referred two mandibles to the wolf-like species *Canis edwardii*, one mandible to the somewhat larger ancestral dire wolf *C. armbrusteri*, and a tibia and canine to the coyote *C. latrans*. Nowak (1979) regarded Anita as early Irvingtonian in age based on the presence of *Canis armbrusteri*, which is restricted to Irvingtonian faunas, and the extant coyote *C. latrans*, unknown prior to the Irvingtonian. However, the identification of *C. latrans* from Anita is questionable because it is based on non-diagnostic fossils, a partial tibia and an upper canine. *C. edwardii* first appeared in the late Blancan at San Simon and Curtis Ranch (type locality), but is also known from several early Irvingtonian sites in Florida (Berta, 1995). Hay (1921) referred a woodrat mandible to a living species, *Neotoma cinerea*, the bushy-tailed woodrat; however, Kurtén and Anderson (1980) listed no records of this species older than late Rancholabrean.

Hay (1921) considered the Anita local fauna to be early Pleistocene in age. Nowak (1979) also suggested an early Pleistocene (early Irvingtonian) age based on the presence of *Canis armbrusteri*, which first appears in the early Irvingtonian. Lindsay and Tessman (1974) regarded Anita as early Blancan. Kurtén and Anderson (1980) suggested a late Blancan age based on the co-occurrence of the lagomorphs *Hypolagus* and *Lepus*. Both Dice (1929) and Dawson (1958) referred Hay's lagomorph species *Brachylagus browni* to *Hypolagus*, a genus that went extinct in the late Blancan. White (1991) tentatively referred *browni* to *Alilepus* and gave the geologic range of *Alilepus* as Clarendonian through late Blancan, although he regarded Anita (including ?*A. browni*) to be Irvingtonian. The presence of *Chasmaporthetes* and *Megatylopus* would seem to confirm a Blancan age, although this would require a range extension into the Blancan for *Canis armbrusteri*, if this species is correctly identified. The lack of Interchange mammals argues for an early Blancan age. The rodents *Marmota*, *Spermophilus*, and *Neotoma* are represented by well-preserved partial skulls or mandibles that should help clarify the age of this fauna. The entire Anita fauna needs to be restudied, especially the horses, canids, and rodents.

Wolf Ranch—The Wolf Ranch local fauna occurs in silts and clays of the St. David Formation in Oro Verde Arroyo west of the San Pedro River, about 50 km south of Benson and 25 km east of Sierra Vista, Cochise County, southeastern Arizona (Fig. 3, site 16). Wolf Ranch is the southernmost Blancan locality in the San Pedro Valley (Johnson et al., 1975; Lindsay, 1978). Harrison (1978) identified 21 species of mammals from the late Blancan Wolf Ranch fauna, including 17 species of small mammals and four large mammals (the horses *Nannippus peninsulatus* and *Equus simplicidens*, the camelid *Camelops*, and the gomphothere *Stegomastodon*). One of the most biostratigraphically-significant mammals is a porcupine, identified from an upper molar that Harrison (1978) referred to *Coendou stirtoni*. Frazier (1981) reidentified this tooth as *Erethizon bathygnathum* in his review of North American fossil Erethizontidae, a South American caviomorph rodent family that participated in the Great American Biotic Interchange (GABI). The late Blancan is defined in part on the first appearance South American mammals in the southwestern United States (Woodburne and Swisher, 1995). The tooth of *Erethizon* from Wolf Ranch represents the earliest record of this genus in North America. The rodent *Sigmodon curtisi* is typical of late Blancan faunas. The presence of *Sylvilagus hibbardi* also suggests a late Blancan age, as the earliest record of *Sylvilagus* is late Blancan (White, 1991). The bat identified as *Simonycteris stocki* (Harrison, 1978) has since been reidentifed as *Antrozous pallidus* (Czaplewski, 1993).

The magnetic polarity stratigraphy of the San Pedro Valley sequence of the St. David Formation places the Wolf Ranch local fauna very high in the uppermost normally-magnetized zone of the Gauss Chron, just below the Gauss/Matuyama boundary at 2.58 Ma (Johnson et al., 1975; Lindsay et al., 1990; revised age for GPTS from Berggren et al., 1995). At Wolf Ranch and several other sites in Arizona (111 Ranch and Pearson Mesa), magnetostratigraphy indicates that South American Interchange mammals first appeared in the uppermost Gauss Chron very near the Gauss/Matuyama boundary (Johnson et al., 1975; Galusha et al., 1984; Tomida, 1987). Thus, the onset of the GABI in the southwestern United States, which also defines the beginning of the late Blancan, has been placed at about 2.7 Ma (Woodburne and Swisher, 1995). The combination of biostratigraphy and magnetostratigraphy places the age of the Wolf Ranch local fauna between 2.6 and 3.0 Ma (Fig. 2), probably closer to the younger end of this age range.

111 Ranch—The 111 Ranch Fauna is derived from strata of the Gila Group informally termed the "111 Ranch beds," exposed on the flanks of Dry Mountain about 25-30 km southeast of Safford in the Safford basin, Graham County, southeastern Arizona (Fig. 3, site 17). For the purposes of this paper, we include in the 111

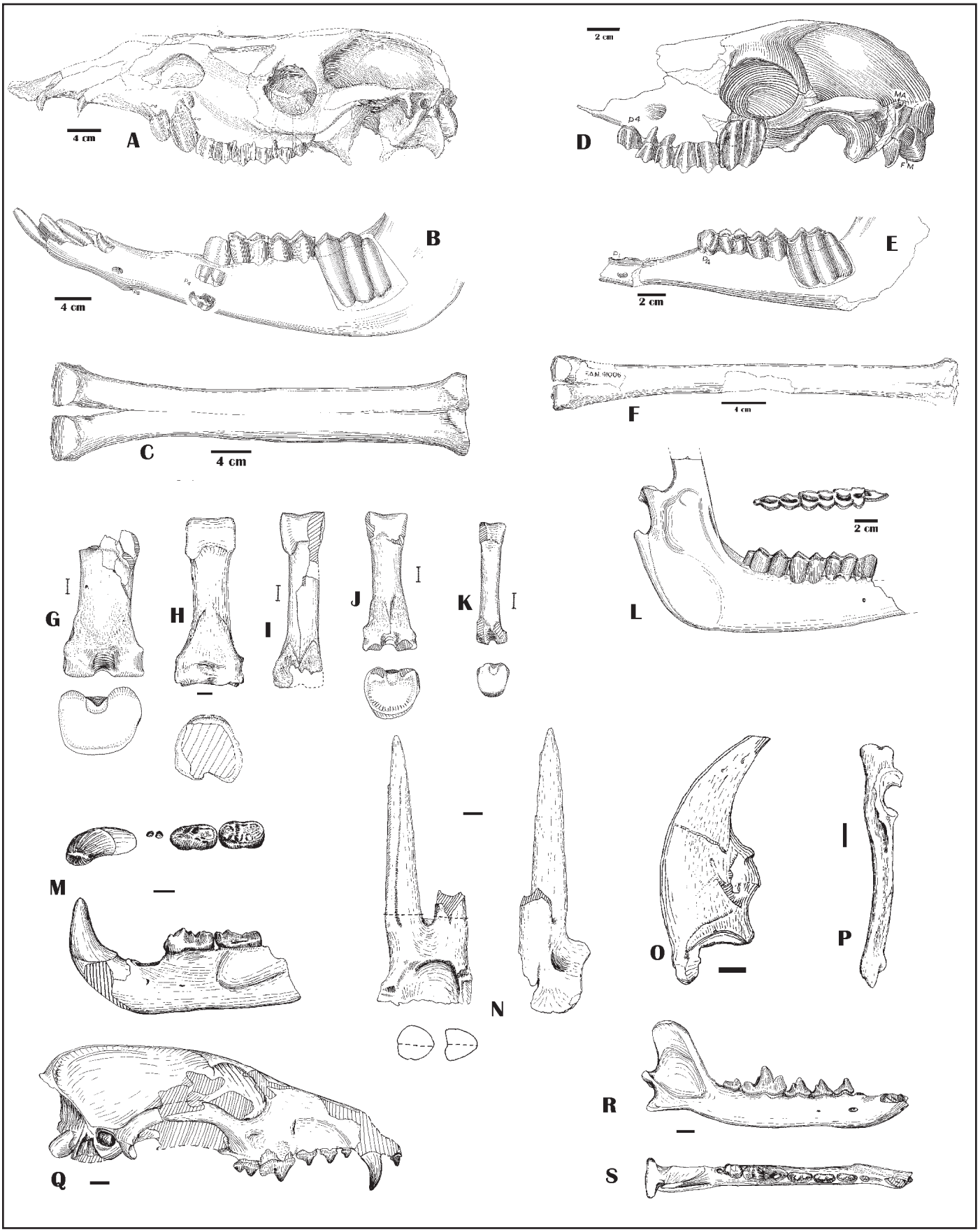

FIGURE 4. Representative vertebrates from the 111 Ranch, Bear Springs, San Simon, and Curtis Ranch faunas, Blancan, Arizona. See opposite page for full caption.

Ranch fauna fossils from near Frye Mesa in sediments overlying the Bear Springs beds, and fossils from the southwestern flank of Dry Mountain as far south as the northern half of section 4, that is, we have included Galusha's Northern Whitlock Mountain locality. The composite stratigraphic section of the Gila Group in the 111 Ranch area consists of about 100 m of fossiliferous fluvial and lacustrine sediments (Galusha et al., 1984). Pliocene vertebrates were first found in the vicinity of 111 Ranch by Knechtel in 1933 (Knechtel, 1936, 1938). Gazin collected fossils at 111 Ranch for the USNM in 1936. Ted Galusha of the Frick Laboratory made large collections from 111 Ranch between 1937 and 1978. Guy Hazen also made small collections for the Frick Laboratory in 1943 and 1944. John Lance and field parties from the University of Arizona began collecting fossils in this area in the 1950s and early 1960s, designating two faunas, the Blancan Flat Tire local fauna and Irvingtonian Tusker local fauna (Lance, 1958, 1960; Wood; 1960, 1962). Lindsay and Tessman (1974) listed the vertebrates from the Flat Tire and Tusker local faunas. In a comprehensive study of the biostratigraphy and magnetostratigraphy of the 111 Ranch area, Galusha et al. (1984) confirmed that all of the sites in this vicinity studied by previous authors are late Blancan in age, and they combined these previously named sites as the 111 Ranch fauna (including Dry Mountain, Flat Tire, and Tusker). Yukimitsu Tomida and UALP field parties screenwashed sediments from several rich microvertebrate sites in the 111 Ranch area in the late 1970s and early 1980s (Tomida, 1987). Beginning in 1997 and continuing to the present, field parties from the MSM, International Wildlife Museum in Tucson, and the BLM in Safford, have been collecting in the 111 Ranch area. Field work at 111 Ranch and vicinity over more than 70 years has resulted in a large and diverse vertebrate fauna that is still being actively collected and studied.

Galusha et al. (1984) and Tomida (1987) provided the most current published mammalian faunal lists from 111 Ranch. Recent work by RSW and colleagues has added several more mammals to the fauna (Table 2), and ongoing work by a number of specialists will undoubtedly add others. Galusha et al. (1984) listed 41 mammals and provided stratigraphic ranges for most of these taxa. Mammalian biostratigraphy and magnetostratigraphy confirm that the 111 Ranch fauna is entirely Blancan in age, primarily late Blancan (~2.4-2.7 Ma; Fig. 2). However the lowermost portion of the 111 Ranch section (lower 30 m) is probably late early Blancan in age (~2.7-3.0 Ma), as this part of the section consists of normally-magnetized sediments from the upper Gauss Chron and lacks Interchange mammals. Two Interchange mammals have their first appearance in the 111 Ranch section in the uppermost Gauss Chron, just below the Gauss/Matuyama boundary (2.58 Ma), which occurs at about the 160 ft (49 m) level of the section (Galusha et al., 1984). The glyptodont *Glyptotherium texanum* first appears at the 95 ft (29 m) level in the stratigraphic section and the capybara *Neochoerus dichroplax* appears slightly higher at the 110 ft (33 m) level (Galusha et al., 1984). In this portion of the section, these two Interchange mammals co-occur with the three-toed horse *Nannippus peninsulatus* (listed as *N. phlegon* in Galusha et al., 1984 and Tomida, 1987). We follow MacFadden (1984) for use of *N. peninsulatus*. *N. peninsulatus* does not occur in strata younger than the Gauss/Matuyama boundary in Arizona, including 111 Ranch, although this horse does occur in the lower Matuyama Chron in the Blanco local fauna in Texas (Lindsay et al., 1975). Other typical Blancan mammalian genera from 111 Ranch include *Borophagus*, *Chasmaporthetes*, *Gigantocamelus*, and *Rhynchotherium*. See Figure 4 for illustrations of several large mammal fossils from 111 Ranch, including *Camelops traviswhitei* (Fig. 4A-D), *Blancocamelus meadei* (Fig. 4I), and *Megalonyx leptostomus* (Fig. 4O).

Tomida (1987) reviewed the small mammal fauna based primarily on two rich microvertebrate quarries, one at about the 40 m level of the section, in the uppermost Gauss Chron, and the second at the 85 m level, in the lower Matuyama Chron. The small mammals include at least 27 species: a soricid, a vespertilionid bat, 4 lagomorphs, and 21 rodents (Table 2). Tomida (1987) described two new species of murid rodents, *Reithrodontomys galushai* and *Repomys arizonensis*. An important bird fauna is under study by David Steadman. Combined with material from the San Simon fauna (correlated with the uppermost portions of the 111 Ranch section), the 111 Ranch avifauna is represented by at least 24 species (D. Steadman, pers. comm., 2005).

In addition to papers by Galusha et al. (1984) and Tomida (1987), a number of taxonomic studies have mentioned fossils from 111 Ranch. We use the locality or faunal names as published by the original authors, all of which are now included in the 111 Ranch fauna following Galusha et al. (1984). Skinner (1942) described the antilocaprid *Capromeryx arizonensis* from Dry Mountain. Downey (1962) reviewed the Leporidae from the Tusker local fauna, including a new species, *Hypolagus arizonensis*. Ahearn and Lance (1980) described a new species of capybara *Neochoerus dichroplax* based on a large sample from Dry Mountain. Some confusion surrounds this species of capybara because Mones (1980) described the same fossil sample from Dry Mountain under a second name, *Neochoerus lancei*. Mones (1981) confirmed that Ahearn and Lance's (1980) name *N. dichroplax* has priority over his *N. lancei*, which was described later that same year. Gillette and Ray (1981) described and illustrated three carapaces, a skull, and a nearly complete postcranial skeleton of the glyptodont *Glypotherium texanum* from the Tusker local fauna. The *Glyptotherium* sample from 111 Ranch is among the most complete material of glyptodonts known from North America (Gillette and Ray, 1981). Berta (1981) identified a metatarsal of the hyaenid *Chasmaporthetes* from Dry Mountain. White (1987) described and illustrated several p3s of the archaeolagine lagomorph *Hypolagus arizonensis* from 111 Ranch and White (1991) identified two species of leporine lagomorphs, *Aluralagus virginiae* and *Sylvilagus* cf. *S. cunicularius*. Winkler and Tomida (1988) identified the small leporid *Aztlanolagus agilis*. Wang et al. (1999) reported a mandible of the borophagine canid *Borophagus diversidens* from Dry Mountain. Emslie and Czaplewski (1999) referred a partial skeleton to their new species of extinct eagle, *Aquila bivia*. Studies are currently in progress on various vertebrate groups from 111 Ranch, including reptiles and amphibians (R. McCord), birds (D. Steadman), Xenarthra (D. Gillette, G. McDonald), Chiroptera (G. Morgan, N Czaplewski), Perissodactyla (E. Scott), Carnivora (R. White, G. McDonald, K. Seymour), Artiodactyla (J. Mead, R. White), Rodentia (E. Lindsay), and Lagomorpha (C. Ramos Baxter).

111 Ranch is one of the best-documented Blancan vertebrate faunas in North America, particularly with regard to geochronology. The combination of a diverse mammalian fauna, including

FIGURE 4 (Opposite page). Representative vertebrates from the 111 Ranch, Bear Springs, San Simon, and Curtis Ranch faunas, Blancan, Arizona. Scale bar where not labeled is 1 centimeter, others as indicated. **A**, **B**, **C**, *Camelops traviswhitei*, FAM 41020, 111 Ranch, skull, mandible, and metacarpal. **D**, **E**, **F**, *Pleiolama* (=*Hemiauchenia*) *vera*, FAM 41001, Bear Springs, skull, mandible and metacarpal. **G**: *Megatylopus* cf. *M. cochrani*, MSM P4454, San Simon, proximal phalanx. **H**, *Camelops traviswhitei*, UALP 1637, Curtis Ranch, proximal phalanx. **I**, *Blancocamelus meadei*, UALP 16375, 111 Ranch, proximal phalanx. **J**, *Hemiauchenia blancoensis*, MSM P3865, San Simon, proximal phalanx. **K**, *Hemiauchenia* sp., MSM P4048, San Simon, proximal phalanx. **L**, *Hemiauchenia blancoensis*, MSM P4024, San Simon, mandible. **M**, *Plionarctos harroldorum*, FAM 95593, Bear Springs; mandible. **N**, *Capromeryx arizonensis*, MSM P4824, San Simon, horncore. **O**, *Megalonyx leptostomus*, USNM 521075, 111 Ranch, distal phalanx. **P**, *Taxidea* sp., UALP 15713, 111 Ranch, ulna. **Q**, **R**, **S**, *Canis edwardii*, UALP 23402, San Simon, skull and mandible.

both large and small mammals, detailed biostratigraphic data, and magnetostratigraphy (Galusha et al., 1984; Tomida, 1987), has allowed a level of chronologic precision at 111 Ranch that is unavailable in most other sites of similar age. Perhaps most importantly, 111 Ranch has attained primary importance in establishing the chronology of the Great American Biotic Interchange in temperate North America, specifically the onset of the primary pulse of the Interchange in the late Pliocene. The records of the South American immigrants *Glyptotherium* and *Neochoerus* from 111 Ranch are among the oldest occurrences of these two genera in temperate North America, occurring in strata of the uppermost Gauss Chron, slightly older than 2.6 Ma. The beginning of the late Blancan is defined by the first appearance of South American mammals in temperate North America, a definition based at least in part on the geochronology of the 111 Ranch fauna (e.g., Galusha et al., 1984; Woodburne and Swisher, 1995). The date of 2.7 Ma has been widely cited as the boundary between the early and late Blancan. A third Interchange mammal, the mylodontid sloth *Glossotherium chapadmalense*, occurs slightly higher in the 111 Ranch section, at about the level of the Gauss/Matuyama boundary. The association in the 111 Ranch section of three South American immigrants (*Glyptotherium*, *Neochoerus*, *Glossotherium*) with typical North American Blancan mammals (e.g., *Borophagus*, *Gigantocamelus*, *Hypolagus*, *Nannippus*, *Rhynchotherium*) defines a restricted biostratigraphic interval in the early part of the late Blancan, after the beginning of the Interchange (~2.7 Ma) and before the extinction of these characteristic Blancan genera (~2.2 Ma, the *Nannippus* extinction datum of Lindsay et al., 1984).

Pearson Mesa—Exposures of Gila Group strata on Pearson Mesa south of the Gila River in the Duncan basin along the Arizona-New Mexico border have produced a diverse assemblage of late Blancan vertebrates, the Pearson Mesa local fauna (Fig. 3, site 18). Most of Pearson Mesa is located in Hidalgo County in southwestern New Mexico, but the westernmost point of the mesa extends into Greenlee County in southeastern Arizona. Because the stratigraphic units that produce the Pearson Mesa local fauna are continuous across the state line, all species recovered from this fauna are listed in Table 2, even though several of the species are currently known only from sites on the New Mexico side of the border. Tomida (1987) first mentioned fossil mammals from Pearson Mesa and obtained data on the magnetic stratigraphy of the Pearson Mesa section. Morgan and Lucas (2000, 2003) discussed the Pearson Mesa local fauna in more detail based on field work conducted by New Mexico Museum of Natural History field crews between 1998 and 2002. The stratigraphic section consists of about 65 m of sandstones, mudstones, and sedimentary breccias referred to the Gila Group. The lower 15 m of the section contains the Pearson Mesa local fauna of late Blancan age, whereas the latest Blancan Virden local fauna (discussed below under "Other Pliocene sites") occurs in the upper 20 m of the section. The Pearson Mesa local fauna consists of 16 species of vertebrates (Morgan and Lucas, 2000, 2003): the land tortoise *Gopherus*, a large and a small species of the land tortoise *Hesperotestudo*, the box turtle *Terrapene*, a heron, and 11 species of mammals (Table 2). For biostratigraphic correlation, the most significant mammals are *Nannippus peninsulatus* and the mylodontid ground sloth *Glossotherium chapadmalense*, found in association at the Pearson Mesa Horse Quarry, an in-place concentration of fossils low in the Pearson Mesa section. The presence of *Nannippus* indicates an age greater than 2.2 Ma (Lindsay et al., 1984). *Glossotherium* is a South American immigrant that does not appear in temperate North American faunas until the beginning of the GABI in the late Blancan, indicating an age of 2.7 Ma or younger. The co-occurrence of *Nannippus* and *Glossotherium* restricts the age of the Pearson Mesa fauna to 2.2-2.7 Ma (Fig. 2). A paleomagnetic section (Tomida, 1987) demonstrates that the Pearson Mesa local fauna occurs in normally-magnetized strata in the upper Gauss Chron, above the Kaena Subchron (younger than 3.04 Ma) and below the Gauss/Matuyama boundary (older than 2.58 Ma). Combining the biostratigraphic and magnetostratigraphic data would seem to tightly constrain the age of the Pearson Mesa fauna between 2.7 Ma (earliest appearance of *Glossotherium*) and 2.6 Ma (Gauss/Matuyama boundary).

San Simon—The San Simon Power Line fauna (Tomida, 1987) was derived from Gila Group strata in the Safford basin, about 30 km southeast of Safford and about 10 km south of 111 Ranch, Graham County, southeastern Arizona (Fig. 3, site 19). The San Simon Power Line fauna, discovered in 1975, was recovered from a rather limited area and from a stratigraphic section about 15 m thick (Tomida 1987). For purposes of this paper, we have added several nearby sites to this fauna, including the Central and Southern Whitlock Mountain and the Whitlock Oil Well collecting areas of Galusha, as well as two new areas discovered in recent work by RSW and colleagues, the Artesia Fauna (Bell et al., 2004) and the Tanque Road Fauna. Artesia and Tanque Road are both located on the west side of the San Simon River and seem to be the same age as the Power Line fauna on the basis of the contained fossils. To reflect the inclusion of several additional sites in the fauna, we have changed the name from the San Simon Power Line (Tomida, 1987) to the more inclusive San Simon Fauna. Tomida (1987) reported 17 species of mammals (Table 2) and described the small mammal fauna in detail, including a new species of geomyid, *Cratogeomys sansimonensis* (originally regarded as a subgenus of *Pappogeomys*). Among the large mammals, *Tremarctos* is known, and the short-faced bear *Arctodus* is a rare occurrence. Additional new records include the canid *Borophagus diversidens*, the beaver *Castor*, the tapir *Tapirus*, the cervid cf. *Bretzia*, and an undescribed species of cervid. Tomida (1987) thought the glyptodont from San Simon was possibly a transitional form between the late Blancan species *Glyptotherium texanum* and the latest Blancan and early Irvingtonian *G. arizonae*. The antilocaprid *Capromeryx arizonensis* from these sites also suggests a late Blancan age. The leporid *Aluralagus virginiae* (referred to *Hypolagus* by Tomida, 1987) is known from San Simon and two other sites, Curtis Ranch (type locality) and Mesilla Basin Fauna B in New Mexico (Vanderhill, 1986), both of which are latest Blancan in age. White (1991) described a new species of leporid, *Alilepus wilsoni*, based on two mandibles and an isolated p3 from San Simon. See Figure 4 for illustrations of several large mammal fossils from San Simon, including *Megatylopus* cf. *M. cochrani* (Fig. 4G), *Hemiauchenia blancoensis* (Figs. 4J, 4L), *Capromeryx arizonensis* (Fig. 4N), and *Canis edwardii* (Figs. 4Q-S).

The presence of *Aluralagus virginiae* and a possible transitional form of *Glyptotherium*, along with the absence of *Nannippus*, led Tomida (1987) to assign a late Blancan age to the San Simon Power Line fauna. This correlation suggests the San Simon fauna is equivalent to the upper part of the 111 Ranch section, younger than Wolf Ranch and somewhat older than Curtis Ranch, probably between 2.1 and 2.4 Ma. The presence of *Borophagus* confirms an age no younger than late Blancan (~2.2 Ma), whereas the absence of *Nannippus* suggests these sites are above the Gauss/Matayama boundary. The lack of *Nannippus* is considered significant in view of the extensive collections from these sites. Unlike other sites in the Safford and Duncan basins, Tomida (1987) was not able to obtain a reliable magnetostratigraphic correlation for the San Simon Power Line fauna. We suggest a late (but not latest) Blancan age for the San Simon fauna, probably between 2.2 and 2.4 Ma (Fig. 2).

California Wash—The California Wash site is located in the San Pedro Valley about 15 km south of Benson on the west side of the San Pedro River, Cochise County, southeastern Arizona (Fig. 3, site 20). The California Wash local fauna occurs in the upper

part of the St. David Formation, above the stratigraphic level of Benson and Wolf Ranch and just below the level of Curtis Ranch. Most of the published information on California Wash comes from papers on the magnetostratigraphy and biostratigraphy of the San Pedro Valley sequence (Johnson et al., 1975; Lindsay, 1984; Lindsay et al., 1990). The most comprehensive faunal list is in Lindsay's (1984) review of fossils from the San Pedro Valley, and includes 32 species of vertebrates: a fish, a salamander, 2 frogs, 2 toads, a turtle, 4 lizards, 6 snakes, and 15 mammals. The fauna is dominated by small vertebrates, and has one of the most diverse herpetofaunas of any Blancan site in Arizona. The only large mammals are *Glyptotherium arizonae*, *Equus*, *Camelops*, and the gomphothere "*Anancus*" *bensonensis*. California Wash is similar to the latest Blancan Curtis Ranch fauna in the presence of *Glyptotherium arizonae* and the rodents *Ondatra idahoensis* and *Sigmodon curtisi*, and the absence of *Nannippus*. This site represents the earliest occurrence of both *Ondatra* and the *Sylvilagus* in the San Pedro Valley Sequence. Magnetostratigraphy (Johnson et al., 1975; Lindsay et al., 1990) places California Wash in the lower reversely-magnetized zone of the Matuyama Chron, above the Gauss/Matuyama boundary and below the base of the Olduvai Subchron (1.95 Ma). California Wash almost certainly belongs in the younger portion of this age range, as this site is underlain by the Huckleberry Ridge ash dated at 2.0 Ma (Lindsay et al., 1990). California Wash and Curtis Ranch are similar in age, the former site is slightly older (latest Blancan, about 2.0 Ma).

Curtis Ranch—The youngest Pliocene fauna in the San Pedro Valley sequence is Curtis Ranch, located about 20 km southeast of Benson on the east side of the San Pedro River, Cochise County, southeastern Arizona (Fig. 3, site 21). Curtis Ranch and the nearby Benson fauna were among the first Blancan faunas discovered in Arizona. The earliest collections from Curtis Ranch were by J. W. Gidley in 1921 and 1924 and by C. L. Gazin in 1928 and 1936. Gidley (1922) presented a faunal list and described the rodents and lagomorphs, including six new species of rodents: *Spermophilus cochisei*, *Geomys persimilis*, *Baiomys brachygnathus*, *Onychomys pedroensis*, *Sigmodon curtisi*, and *S. minor*. Gidley (1926) described a new species of glyptodont, *Glyptotherium arizonae*, and gomphothere, *Stegomastodon arizonae*. Gazin (1942) updated the faunal list and described two new carnivores, the wolf-like canid *Canis edwardii* and the skunk *Spilogale pedroensis*. The most current vertebrate faunal lists for Curtis Ranch (Table 2) are by Lindsay and Tessman (1974) and Lindsay (1984). Notable additions in those two papers are: two turtles, *Kinosternon flavescens* and *Terrapene* cf. *T. ornata*; three snakes, *Coluber*, *Lampropeltis*, and *Nerodia*; and three rodents, the beaver *Castor*, the mouse *Bensonomys arizonae*, and *Ondatra idahoensis*.

Several authors have included fossils from Curtis Ranch in taxonomic reviews of various vertebrate groups. Wetmore (1924) described the dove *Columba micula*. Stirton (1931) described a partial bat skull as the new species *Simonycteris stocki*. Wood (1935) named the extinct kangaroo rat *Dipodomys gidleyi*. Frick (1937) described a partial antilocaprid horn core as a new species *Capromeryx gidleyi*, which we here refer to *C. arizonensis*, as *C. gidleyi* is both a *nomen dubium* and *nomen oblitum*. Brattstrom (1955) reported a salamander and six reptiles, including a new species of snake, *Lampropeltis intermedius*. Downey (1970) described a new species of leporid, *Aluralagus virginiae*. In their review of North American glyptodonts, Gillette and Ray (1981) described and illustrated several carapaces of *Glyptotherium arizonae* from Curtis Ranch, the type locality of this species.

Most papers on Curtis Ranch have considered this fauna to be early Pleistocene (early Irvingtonian) in age. However, Lindsay et al. (1990) pointed out that Curtis Ranch lacks genera of mammals typical of the Irvingtonian, most importantly *Mammuthus* and *Microtus*, and they suggested this fauna was more accurately placed in the latest Blancan. The magnetostratigraphy of the San Pedro Valley sequence (Johnson et al., 1975; Lindsay et al., 1990) placed Curtis Ranch in reversely-magnetized sediments of the uppermost portion of the lower Matuyama Chron, just prior to the Olduvai Subchron (base of Olduvai is 1.95 Ma, after Berggren et al., 1995), indicating a latest Blancan age (~2.0 Ma). The lagomorph *Aluralagus virginiae*, originally described from Curtis Ranch (Downey, 1970), is known from only two other faunas, San Simon (listed as *Hypolagus virginiae* in Tomida, 1987) and Mesilla Basin Fauna B in New Mexico (Vanderhill, 1986), both of which are considered very late Blancan. *Ondatra idahoensis* is also typical of very late Blancan faunas, including Grand View, Idaho (type locality), Borchers, Kansas, and Inglis 1A, Florida (Morgan and Hulbert, 1995; Bell et al., 2004). *Canis edwardii* and *Glyptotherium arizonae* are characteristic of latest Blancan and early Irvingtonian faunas. A number of typical Blancan mammals that disappeared by about 2.2 Ma, including *Nannippus*, *Borophagus*, and *Rhynchotherium* (Lindsay et al., 1984), are absent from Curtis Ranch. These genera are present in the somewhat older late Blancan 111 Ranch fauna. Curtis Ranch dates to the latest Pliocene, after the extinction of many typical Blancan mammals at 2.2 Ma and before the appearance of *Mammuthus* in the early Pleistocene at about 1.6 Ma. Biostratigraphy and magnetostratigraphy constrain the age of the Curtis Ranch fauna to the latest Blancan, between 2.0 and 2.2 Ma (Fig. 2).

Other Pliocene sites—There are several additional Blancan faunas from Arizona that have produced smaller but nonetheless important faunas. As discussed above, a series of Blancan faunas occurs in the St. David Formation in the San Pedro Valley south of Benson in Cochise County, southeastern Arizona (Johnson et al., 1975; Lindsay et al., 1990). The best known of these faunas, Benson, Wolf Ranch, California Wash, and Curtis Ranch, are described above. However, quite a few other smaller faunas occur in the stratigraphic intervals between these larger faunas, including (from oldest to youngest), Mendevil Ranch, Bonanza, Honey's Hummock, McRae Wash, Horsey Green Bed, Cal Tech, and Johnson Pocket. The Prospect fauna occurs somewhat higher in the section than Curtis Ranch. Johnson et al. (1975) provided mammalian faunal lists for these sites, only two of which, Mendevil Ranch and McRae Wash, have more than 10 species of mammals. Both of these faunas occur in normally-magnetized sediments of the Gauss Chron (Johnson et al., 1975; Lindsay et al., 1990). Mendevil Ranch occurs between the top of the Mammoth Subchron (3.22 Ma) and the bottom of the Kaena Subchron (3.11 Ma) and McRae Wash between the top of the Kaena Subchron (3.04 Ma) and the Gauss/Matuyama boundary (2.58 Ma). Mendevil Ranch (~3.1-3.2 Ma) is the second oldest Blancan fauna in the San Pedro Valley sequence and shares a number of age-diagnostic mammals with the Benson fauna (from Johnson et al., 1975), including the rodents *Geomys minor*, *Cratogeomys bensoni*, *Prodipodomys minor*, *Baiomys minimus*, *Bensonomys arizonae*, *Onychomys bensoni*, *Neotoma fossilis*, and *Sigmodon medius*, and the horse *Nannippus peninsulatus*. McRae Wash (~2.8-3.0 Ma) occurs below the stratigraphic level of Wolf Ranch (~2.7 Ma) and also shares a number of species with Benson, including *Spermophilus bensoni*, *Cratogeomys bensoni*, *Prodipodomys minor*, *Baiomys minimus*, *Bensonomys arizonae*, *Sigmodon medius*, and *Nannippus peninsulatus*. Czaplewski (1993) identified the large molossid bat *Eumops* cf. *E. perotis* from McRae Wash. *Eumops* appears to be of South American origin and may have been an early participant in the Interchange (Czaplewski et al., 2003). The Cal Tech site occurs in reversely-magnetized sediments of the lowermost Matuyama Chron (~2.5 Ma), just above the Gauss/Matuyama boundary. Cal Tech is above the stratigraphic level of Wolf Ranch and lower in the section than California Wash and

Curtis Ranch. Five species of mammals are known from this site (Lindsay, 1984), including the gomphothere *Stegomastodon arizonae* and the capybara *Neochoerus*, a species of South American origin that participated in the Interchange. Prospect is the only fauna in the San Pedro Valley sequence that occurs above the Olduvai, and has been considered Irvingtonian in age (Johnson et al., 1975). However, Bell et al. (2004) have suggested placing the Blancan/Irvingtonian boundary much later, around 1.35 Ma, which would put the Prospect fauna in the late Blancan. The absence of *Mammuthus* from Prospect further supports a late Blancan age. The *Capromeryx* from Prospect seems to be slightly more advanced than specimens from older late Blancan faunas (111 Ranch, Curtis Ranch), but not as advanced as those from Irvingtonian sites such as Hay Springs (work in progress by RSW).

Tomida (1987) mentioned several Blancan sites derived from Gila Group strata on the east side of the Gila River between the Duncan and Country Club faunas. These include the "Duncan Nada" (AMNH) and "Sand Wash" (UALP) sites located in Sand Wash just north of Duncan and the "11 Mile Wash" site (AMNH) located about 7 km south of the Country Club area. *Nannippus peninsulatus* and several species of *Equus* are known from the Sand Wash sites. Tedford (1981) and Tomida (1987) mentioned a partial skeleton of the small mylodontid ground sloth *Glossotherium chapadmalense* from 11 Mile Wash. The sloth skeleton supposedly was collected at about the same elevation and stratigraphic interval as the nearby Country Club fauna (Tomida, 1987). *Glossotherium* is a member of the Interchange fauna suggesting a late Blancan age (less than 2.7 Ma), which is considerably younger than the age of the Country Club fauna (~3.2-3.8 Ma) based on biostratigraphy and magnetostratigraphy (Tomida, 1987). However, the *Glossotherium* skeleton is an isolated occurrence lacking both associated fauna and paleomagnetic data. Several explanations for the apparent age discrepancy are possible: (1) the skeleton could be older than other known occurrences of *Glossotherium*, indicating that the Interchange began earlier in the southwestern United States than previously thought; (2) the Country Club fauna might be younger than previously thought, extending into the lowermost Matuyama Chron (younger than 2.6 Ma), although this would require an upward range extension for several species of mammals otherwise restricted to the early Blancan; or (3) the exact locality where the 11 Mile Wash sloth was collected is unclear (Tomida, 1987, gave the locality within two ¼ sections), and therefore it is possible the sloth skeleton was collected from a stratigraphic unit higher in the section than the Country Club fauna.

Miller (1990) described a skull and associated mandibles of the proboscidean *Rhynchotherium falconeri* from Pliocene sediments of the Gila Group on a private ranch east of the Gila River near Sheldon in Greenlee County, southeastern Arizona, about 5 km west of the New Mexico line. This is one of the most complete known associated skull and jaws of the gomphotheriid *Rhynchotherium*. Characters typical of *Rhynchotherium* include the torsion or spiralling of the upper tusks with enamel bands, the strongly downturned mandibular symphysis (deflected at about a 65° angle), and the presence of lower tusks with fluted grooves. This specimen of *Rhynchotherium* is an isolated occurrence and thus its age is problematic; however, Gila Group strata in this vicinity contain almost exclusively Blancan vertebrates, including the Duncan, Country Club, and Pearson Mesa faunas.

The Virden local fauna occurs in Gila Group strata on Pearson Mesa south of the Gila River in the Duncan basin along the Arizona-New Mexico border, in the same general area as the Pearson Mesa local fauna discussed above but about 30 m higher in the stratigraphic section (Morgan and Lucas, 2000, 2003). Pearson Mesa straddles the border between Greenlee County in Arizona and Hidalgo County in New Mexico. The Virden local fauna is an assemblage of species derived from several sites in each state located at the same stratigraphic level. The land tortoise *Hesperotestudo* and several species of large mammals are known from Virden, including *Glyptotherium arizonae*, the coyote-like canid *Canis lepophagus*, *Equus scotti*, and a small undescribed species of *Hemiauchenia*, as well as the cotton rat *Sigmodon minor*. This fauna differs significantly from the underlying Pearson Mesa local fauna; the only taxa these faunas share are the tortoise and *Equus scotti*. *Glyptotherium arizonae* occurs in several latest Blancan and early Irvingtonian faunas in the southwestern United States, including Curtis Ranch (Gidley, 1926; Gillette and Ray, 1981; Morgan and Lucas, 2000), but is absent from the underlying Pearson Mesa fauna. *Canis lepophagus* is restricted to Blancan faunas, including 111 Ranch (Galusha et al., 1984), and the small species of *Hemiauchenia* is known primarily from latest Blancan faunas in Florida (Morgan and Hulbert, 1995), but also occurs at San Simon. Blancan cotton rats previously identified as *Sigmodon minor* and *S. medius* are now generally referred to *S. minor* (Martin et al., 2000). However, specimens from Curtis Ranch, as well as Virden and the De Soto Shell Pit in Florida, are significantly smaller than typical *S. medius* from older Blancan sites. This dwarfed lineage of cotton rats seems to occur only in latest Blancan faunas. The association of these four mammals indicates a latest Blancan age (1.8-2.2 Ma) for the Virden local fauna; *C. lepophagus,* the small *Hemiauchenia*, and *S. minor* are unknown from the Irvingtonian and *G. arizonae* is found in at least two other southwestern latest Blancan faunas (Curtis Ranch and Mesilla Basin Fauna B, New Mexico). There is a published paleomagnetic section from Pearson Mesa (Tomida, 1987), but there are no samples from the upper 20 m of the section that produced the Virden local fauna.

The Snowflake fauna from southern Navajo County in east-central Arizona was regarded as late Blancan by Lindsay and Tessman (1974) but contains no genera of mammals restricted to the Blancan. They listed *Castor*, *Sigmodon*, *Equus*, and Camelidae from Snowflake, along with fish. All three of these genera of mammals are also known from the Pleistocene. The Blancan age of the Snowflake fauna is here considered tentative, although the species of *Sigmodon* in this fauna may help to further constrain its age.

DISCUSSION

Two key factors characterize the history of the collection and study of Miocene and Pliocene vertebrate faunas from Arizona, the significance of biostratigraphy and geochronology and the importance placed on small mammals. The careful stratigraphic documentation of fossil mammal collections was a hallmark of the collectors for the Frick Laboratory, and one of its greatest practitioners was Ted Galusha, who made notable contributions to the Neogene vertebrate paleontology of Arizona and New Mexico. Galusha collected large samples of Miocene and Pliocene vertebrates in Arizona, perhaps none more significant than the collections from 111 Ranch. From the 1970s through the 1990s, Everett Lindsay and his graduate students at the University of Arizona continued this study of the biostratigraphy of Late Cenozoic mammal faunas in Arizona, and also implemented new geochronologic techniques including magnetostratigraphy and radioisotopic dating of volcanic rocks. Lindsay also emphasized the importance of collecting and studying microvertebrates. The study of several Miocene and Pliocene small mammal faunas from Arizona were the direct result of graduate research by Lindsay's students, including the late Hemphillian Redington (Jacobs, 1977) and White Cone (Baskin, 1978, 1979) faunas and the Blancan faunas from Wolf Ranch (Harrison, 1978) and the Duncan and Safford basins (Tomida, 1987).

Paleomagnetic stratigraphy, radioisotopic dates, the biostra-

tigraphy of large mammals, the presence of two microvertebrate quarries, and the occurrence of Interchange mammals of South American origin has led to the recognition of 111 Ranch as one of the most important faunas in North America for documenting the onset of the GABI (Galusha et al., 1984; Tomida, 1987). Two mammalian genera of South American origin, the glyptodont *Glyptotherium* and the capybara *Neochoerus*, first appear in the 111 Ranch section in the uppermost Gauss Chron in strata somewhat older than the Gauss/Matuyama boundary (2.58 Ma). Although Interchange mammals are known from the upper Gauss Chron in several other sites in the southwestern United States (see below), none of these sites are as well documented geochronologically as is 111 Ranch.

The boundary between the early and late Blancan at ~2.7 Ma is currently defined by the earliest appearance of Interchange mammals in the southwestern United States, a date based in part on the occurrence of *Glyptotherium* and *Neochoerus* in the uppermost Gauss Chron at 111 Ranch (e.g., Woodburne and Swisher, 1995). Other southwestern faunas that have a combination of biostratigraphic and magnetostratigraphic data establishing the presence of Interchange mammals in the upper Gauss Chron (i.e., >2.58 Ma) are Wolf Ranch with the earliest record of the porcupine *Erethizon* (Harrison, 1978; Johnson et al., 1975; Lindsay et al., 1990); Mesilla Basin Fauna A in southern New Mexico (Vanderhill, 1986) and Cita Canyon in the Texas Panhandle (Lindsay et al., 1975) with *Glyptotherium*; and three sites with the ground sloth *Glossotherium*, Pearson Mesa, Arizona/New Mexico (Morgan and Lucas, 2000, 2003), Cita Canyon, Texas (Lindsay et al., 1975), and Donnelly Ranch, Colorado (Hager, 1974). These records of *Glossotherium* are slightly older than the 111 Ranch record of that genus, which occurs at about the level of the Gauss/Matuyama boundary (Galusha et al., 1984). None of these early Interchange sites in the southwestern United States are found in association with dated volcanic rocks that occur stratigraphically below the earliest appearance of Interchange mammals, which might further constrain the age for the beginning of the GABI. At 111 Ranch and Wolf Ranch, Interchange mammals appear just below the Gauss/Matuyama boundary in long well-dated sections. The age of the other four sites (Pearson Mesa, Mesilla Basin Fauna A, Cita Canyon, Donnelly Ranch) cannot be dated more precisely than upper Gauss Chron, between 3.04 Ma (top of the Kaena Subchron) and 2.58 Ma (Gauss/Matuyama boundary).

The numerous Blancan faunas derived from the St. David Formation in the San Pedro Valley in southeastern Arizona were the basis for the first published sequence in the terrestrial vertebrate record of North America in which paleomagnetic stratigraphy was used in conjunction with mammalian biostratigraphy to help determine the relative ages of superposed faunas (Johnson et al., 1975). MacFadden et al. (1979) studied the magnetostratigraphy and biostratigraphy of the late Hemphillian Wikieup local fauna from the Big Sandy Formation in west-central Arizona. Lindsay et al. (1984) used magnetostratigraphy and biostratigraphy to date several additional late Hemphillian faunas from Arizona: Redington and Camel Canyon from the Quiburis Formation in the San Pedro Valley and White Cone from the Bidahochi Formation in northeastern Arizona. Tomida (1987) studied the magnetostratigraphy and small mammal biostratigraphy of Blancan faunas in the Safford and Duncan basins, including Bear Springs, 111 Ranch, San Simon, Duncan, Country Club, and Pearson Mesa. Czaplewski (1990) used the biostratigraphy of small mammals and magnetostratigraphy (Bressler and Butler, 1978) to correlate the early Blancan vertebrate fauna from the Verde Formation in central Arizona. The biostratigraphic and geochronologic data from Miocene and Pliocene sites in Arizona has been used for the continent-wide correlation of certain critical immigration events and geochronologic boundaries (Galusha et al, 1984; Lindsay et al., 1984; Woodburne and Swisher, 1995; Bell et al., 2004; Tedford et al., 2004).

Much work remains to be done on the Miocene and Pliocene vertebrates of Arizona. Although the small mammals from several late Miocene (late Hemphillian) faunas have been thoroughly described, including Redington (Jacobs, 1977) and White Cone (Baskin, 1978, 1979), there are no comprehensive faunal studies of large mammals (Carnivora, Perissodactyla, Artiodactyla, and Proboscidea) from Arizona Miocene faunas and few taxonomic studies. Faunal lists of large mammals exist for most sites (Table 1), including the Clarendonian Milk Creek Formation sites (Lindsay and Tessman, 1974), and the late Hemphillian Camel Canyon, Redington, White Cone, and Wikieup faunas (MacFadden et al., 1979; Lindsay et al., 1984). Blancan small mammal faunas from Arizona are well known and occur in all 14 sites listed in Table 2, although Comosi Wash and Pearson Mesa have only a single species of rodent each. Many Arizona Blancan small mammal faunas have been described including: Anita (Hay, 1921); Benson and Curtis Ranch (Gidley, 1922; Gazin, 1942); Wolf Ranch (Harrison, 1978); Duncan, Country Club, 111 Ranch, and San Simon (Tomida, 1987); and Verde and Clarkdale (Czaplewski, 1987a, 1987b, 1990). The large mammals from most of these same faunas are in need of further study.

Beginning in the early 20th century and continuing to the present, there have been a number of significant contributions on Miocene and Pliocene vertebrates from Arizona. Although additional field work is certainly necessary, much can be learned by studying the extensive fossil collections already housed in museums, particularly the Frick collections in the AMNH and the UALP. Further study of various groups of both large and small mammals from the Clarendonian, Hemphillian, and Blancan will help provide a better understanding of the taxonomy, biostratigraphy, biogeography, and paleoecology of Arizona vertebrate faunas over the last 12 million years.

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