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FOSSIL MAMMALS AND THE EARLY EOCENE AGE OF THE SAN JOSE FORMATION, SAN JUAN BASIN, NEW MEXICO

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Abstract—Fossil mammals from the San Jose Formation in the San Juan Basin are the only means by which an age can be assigned to the San Jose Formation. These mammals indicate an early Eocene (middle Wasatchian, Lysitean) age for the entire San Jose Formation except its basal strata, which have not produced age-diagnostic fossils. Selected, age-diagnostic fossil mammals from the San Jose Formation are illustrated here.

INTRODUCTION

The San Jose Formation in the San Juan Basin of northwestern New Mexico and southwestern Colorado (Fig. 1) is as much as 590 m thick and has an outcrop area of 8500 km^2, making it the most extensively exposed Laramide sedimentary unit in New Mexico (Baltz, 1967; Smith et al., 1985; Smith, 1988; Smith and Lucas, 1991). It was deposited by high-energy, low-sinuosity streams with extensive, muddy floodplains and contains diverse vertebrate fossil assemblages that have been known for almost 120 years (Lucas, 1977; Lucas et al., 1981). Indeed, the only means by which the age of the San Jose Formation has been determined is by its vertebrate fossils, specifically its fossil mammals. Here, we review the age of the San Jose Formation based on fossil mammals. NMMNH refers to the New Mexico Museum of Natural History, Albuquerque.

MAMMALIAN BIOCHRONOLOGY

The North American land-mammal "ages"

Cenozoic time in western North America has been calibrated by a sequence of North American land-mammal "ages" (NALMAs) since the work of Wood et al. (1941). NALMAs, as originally conceived by Wood et al. (1941), are based on "type faunas," not on stratotype sections. Thus, they are not stage-ages in the formal stratigraphic sense, but are biochronologic units sensu Williams (1902), that is, intervals of geologic time during which particular types of mammals lived. In a sense, the "type faunas" of the NALMAs could be viewed as assemblage zones, and each NALMA as the time equivalent to each assemblage zone, just as a biochron (biochronological unit) can be viewed as the time equivalent to a zone (biostratigraphic unit). Most vertebrate paleontologists, however, prefer not to be constrained too closely by the stratigraphic distribution of the mammalian fossils that represent each NALMA. Instead, they base age determinations on a less precise, and more abstract, biochronological concept of an aggregate "fauna" (coeval mammals) even if stratigraphic ranges demonstrate some lack of synchroneity among the mammals of a NALMA. Such concepts, particularly a failure to pursue stratotypical definitions of NALMAs, has reduced their precision in correlation. Yet, despite this, NALMAs continue to provide a robust framework for the correlation of the nonmarine mammal-bearing Cenozoic strata of western North America.

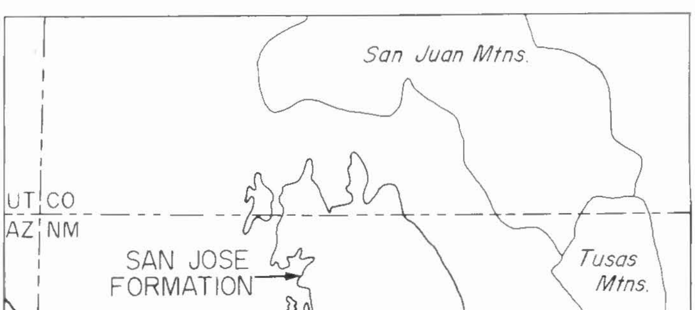

FIGURE 1. Location map of San Jose Formation (after Smith and Lucas, 1991).

Wasatchian NALMA

The fossil mammals from the San Jose Formation have long been assigned a Wasatchian age. Wood et al. (1941, p. 9) based the Wasatchian "on at least the upper part of the Wasatch group of southwestern Wyoming." They made specific reference to the Wasatchian mammal faunas of the Wind River and Bighorn basins of Wyoming as the type faunas of the Wasatchian NALMA.

Correlation of the Wasatchian land-mammal "age" with the global standard chronostratigraphic scale indicates it straddles the Paleocene-Eocene boundary (Fig. 2). This correlation is based on a well-established biochronology that indicates the French Sparnacian Stage is late

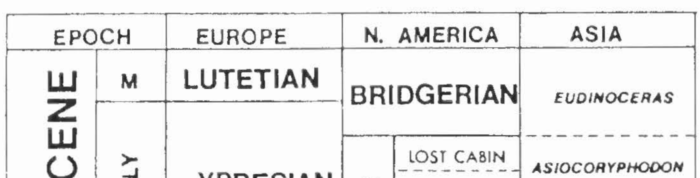

FIGURE 2. Intercontinental correlation of the Wasatchian and adjacent NALMAs (from Lucas, 1984a).

Paleocene, not early Eocene as believed by some previous workers (e.g., Gingerich, 1976; Rose, 1981). In the mixed marine-nonmarine facies of the London-Belgian-Paris basin of western Europe, the beginning of Eocene time, the base of the Ypresian, is approximated by the base of the London Clay (= Argile d'Ypres). French Sparnacian mammal faunas are equivalent to pre-London Clay mammals in Great Britain, a correlation supported by dinoflagellates (Costa et al., 1978). Fossil mammals indicate the Sparnacian is correlative with much of the Clarkforkian and the early Wasatchian (Lucas, 1984a). Thus, the Paleocene-Eocene boundary is not in the Clarkforkian, but in the Wasatchian, a conclusion also supported by palynological correlations (Wing, 1982).

FOSSIL MAMMALS FROM THE SAN JOSE FORMATION

Lucas et al. (1981, table 1) last provided a comprehensive listing of the fossil mammals from the San Jose Formation. A variety of new taxa and taxonomic modifications relevant to this list have appeared since 1981, but most need not concern us here because they do not affect age determinations based on fossil mammals. Fossil mammals are found in the Regina and Tapicitos Members of the San Jose Formation (Fig. 3).

The early Eocene mammals from the San Jose Formation represent the orders Marsupialia, Edentata, Creodonta, Carnivora, Proteutheria, Taeniodonta, Tillodontia, Pantodonta, Insectivora, Leptictida, Pantolestida, Primates, Rodentia, "Condylarthra," Perissodactyla and Artiodactyla. Characteristic Wasatchian taxa include the pantodont *Coryphodon molestus* (Fig. 4A), the taeniodont *Ectoganus gliriformis* (Fig. 4B–C), the creodont *Oxyaena* (Fig. 4D–E), the rodent *Paramys wortmani* (Fig. 4F–G), the carnivore *Didymictis* (Fig. 4H–I), the "condylarths" *Meniscotherium chamense* (Fig. 5A) and *Hyopsodus miticulus* (Fig. 5M–N), the perissodactyls *Hyracotherium tapirinum* (Fig. 5B, H–I), *Heptodon* (Fig. 5C) and *Xenicohippus* (Fig. 5F–G) and the artiocadtyls *Diacodexis secans* (Fig. 5D–E, J) and *Bunophorus macropternus* (Fig. 5K–L).

CORRELATION OF THE SAN JOSE FORMATION

The correlation of the San Jose Formation with other late Laramide deposits in western North America presented here (Fig. 6) relies heavily on the *Coryphodon*-based biostratigraphy developed by Lucas (1984a, b, c). Through the work of Gingerich (e.g., 1976, 1980, 1989), Bown (1979, 1980), Schankler (1980) and Rose (1981), the biostratigraphy of the Clarkforkian-Wasatchian interval of the Polecat Bench and Willwood Formations in the Clark's Fork and Bighorn Basins, Wyoming and Montana is the most detailed mammalian biostratigraphy of this time interval in the world. Various biostratigraphic schemes have been used in these rocks (Schankler, 1980; Bown and Schankler, 1982). For the Wasatchian, we employ the terms Gray Bull, Lysite and Lost Cabin in the Bighorn Basin and other basins as Van Houten (1945) used them (Schankler, 1980). Their equivalence to other biostratigraphic terms is readily understood from Schankler (1980, fig. 1) and Fig. 6 of this paper.

Thus, the distribution of *Coryphodon* species in the Bighorn and Clark's Fork Basins is considered by us to form the principal reference section for the correlation of other *Coryphodon*-bearing deposits in North America. However, before the distribution of *Coryphodon* species in the Clark's Fork and Bighorn Basins can be freely applied to the correlation of these other deposits, the following qualifications need to be considered:

1. Very few of the identifiable *Coryphodon* specimens from the Clark's Fork and Bighorn Basins can be precisely placed in the stratigraphic sequence. This is because only a minority of the specimens have been placed into the published locality schemes. Also, only a minority of the specimens placed into these schemes have come from localities that have been located in measured stratigraphic sections. Nevertheless, many specimens not in the published locality schemes, and many of the specimens in these schemes that are from imprecisely located sites, are accompanied by supplementary locality data that support the biostratigraphic ranges depicted here (Fig. 6).
2. The single, located occurrence of *C. subquadratus* in the Clarkforkian should not be considered to exemplify the entire stratigraphic range of this species, especially since some occurrences in the Wasatch Formation in southwestern Wyoming are arguably of early Wasatchian (Gray Bull) age.
3. Although *C. molestus* does not occur in the Lost Cabin of the Bighorn Basin, it does occur in the Lost Cabin Member of the Wind River Formation in the Wind River Basin. Therefore, we consider *C. molestus* to be a taxon compatible with a Lost Cabin age assignment.

Three species of *Coryphodon*—*C. simus*, *C. molestus* and *C. lobatus*—are present in the Regina Member of the San Jose Formation in the San Juan Basin (Lucas, 1984a, b, c). Analysis of the large Almagre

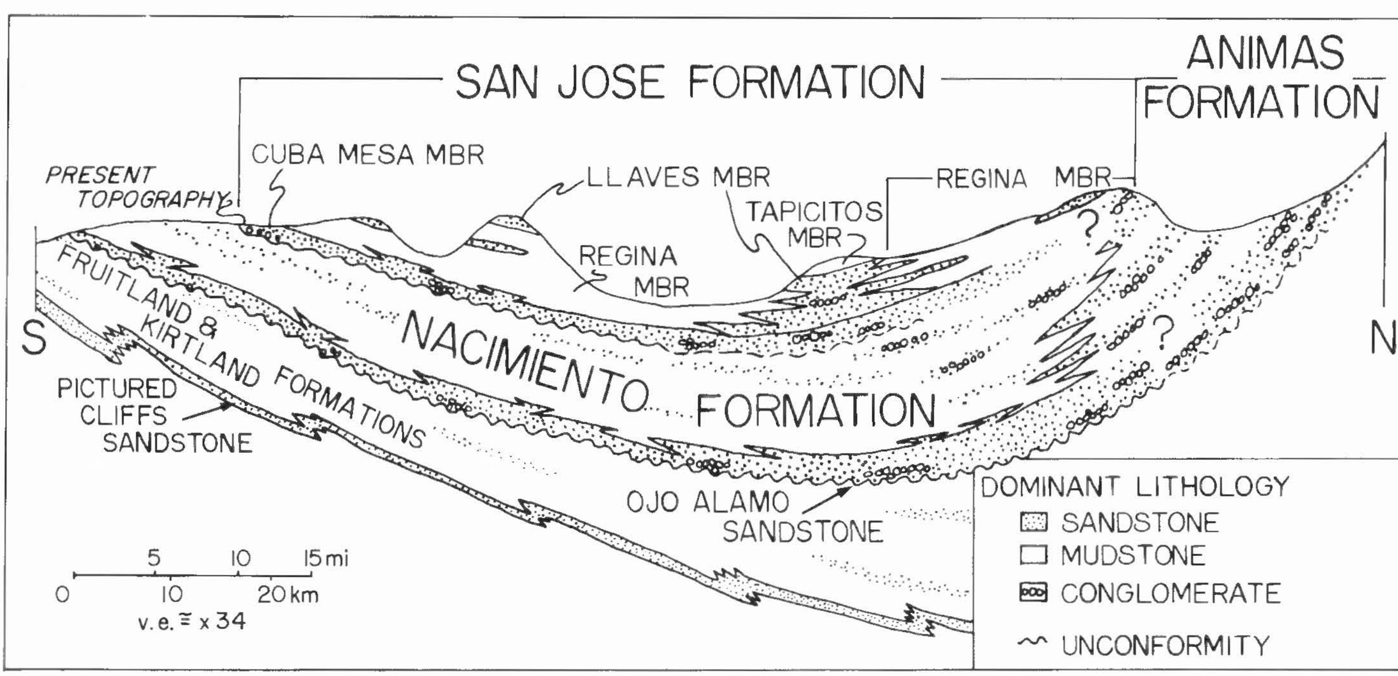

FIGURE 3. Diagrammatic north-south cross section showing the physical stratigraphy of the uppermost Cretaceous and lower Tertiary strata in the San Juan Basin (from Smith and Lucas, 1991). Early Eocene mammals are present in the Regina and Tapicitos Members of the San Jose Formation.

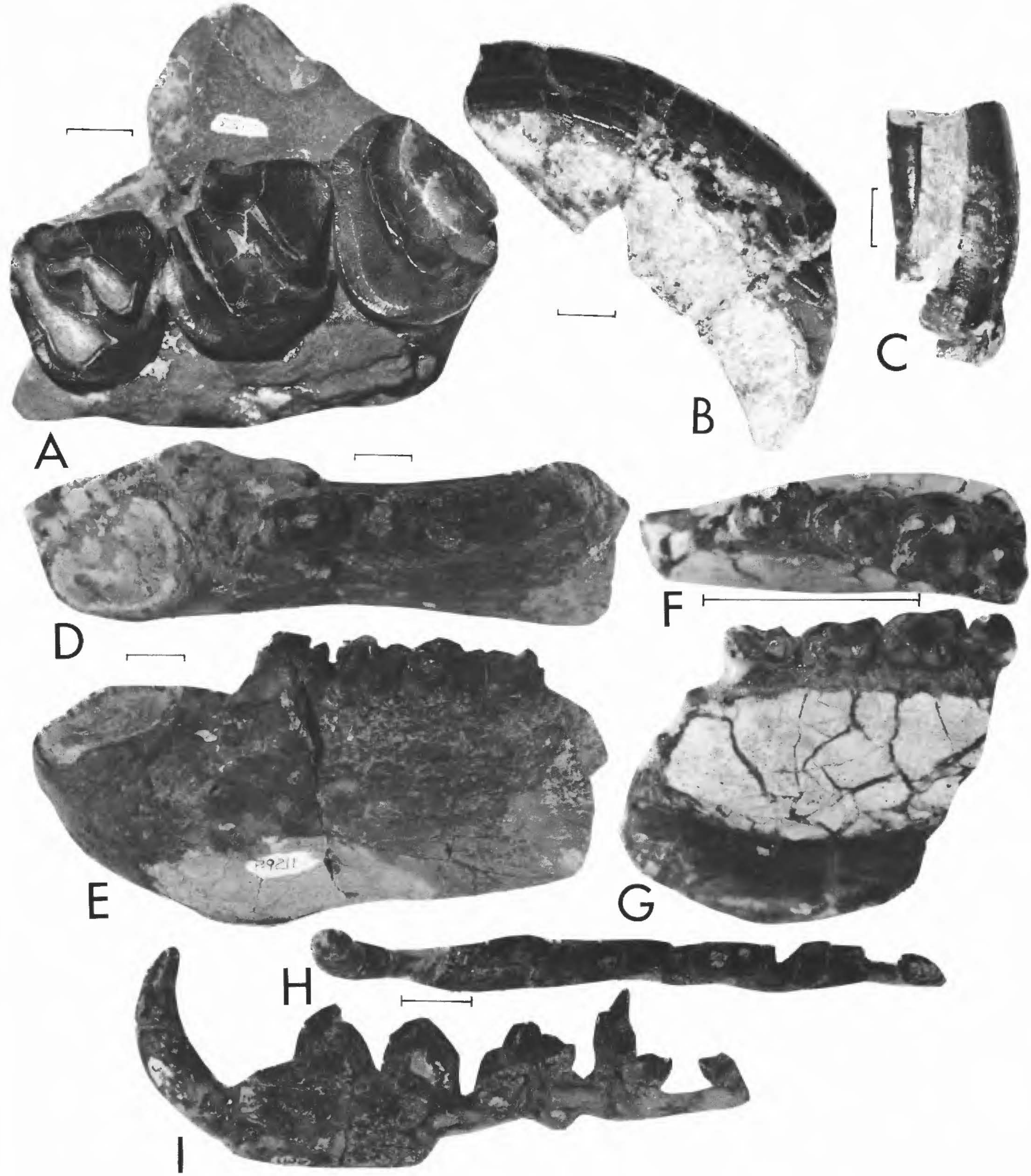

FIGURE 4. Selected fossil mammals from the San Jose Formation. A, *Coryphodon molestus*, NMMNH P-J153, left M^{1-3}, occlusal view. B–C, *Ectoganus gliriformis*, NMMNH P-J8, lateral view of tusk (B) and premolar (C). D–E, *Oxyaena* sp., NMMNH P-9211, left dentary fragment with C root and P_4–M_3, occlusal (D) and labial (E) views. F–G, *Paramys wortmani*, NMMNH P-9785, right dentary fragment with P_4–M_2, occlusal (F) and lingual (G) views. H–I, *Didymictis* sp., NMMNH P-9121, right dentary fragment with C and P_3–M_2, occlusal (H) and lingual (I) views. All bar scales are 1 cm long.

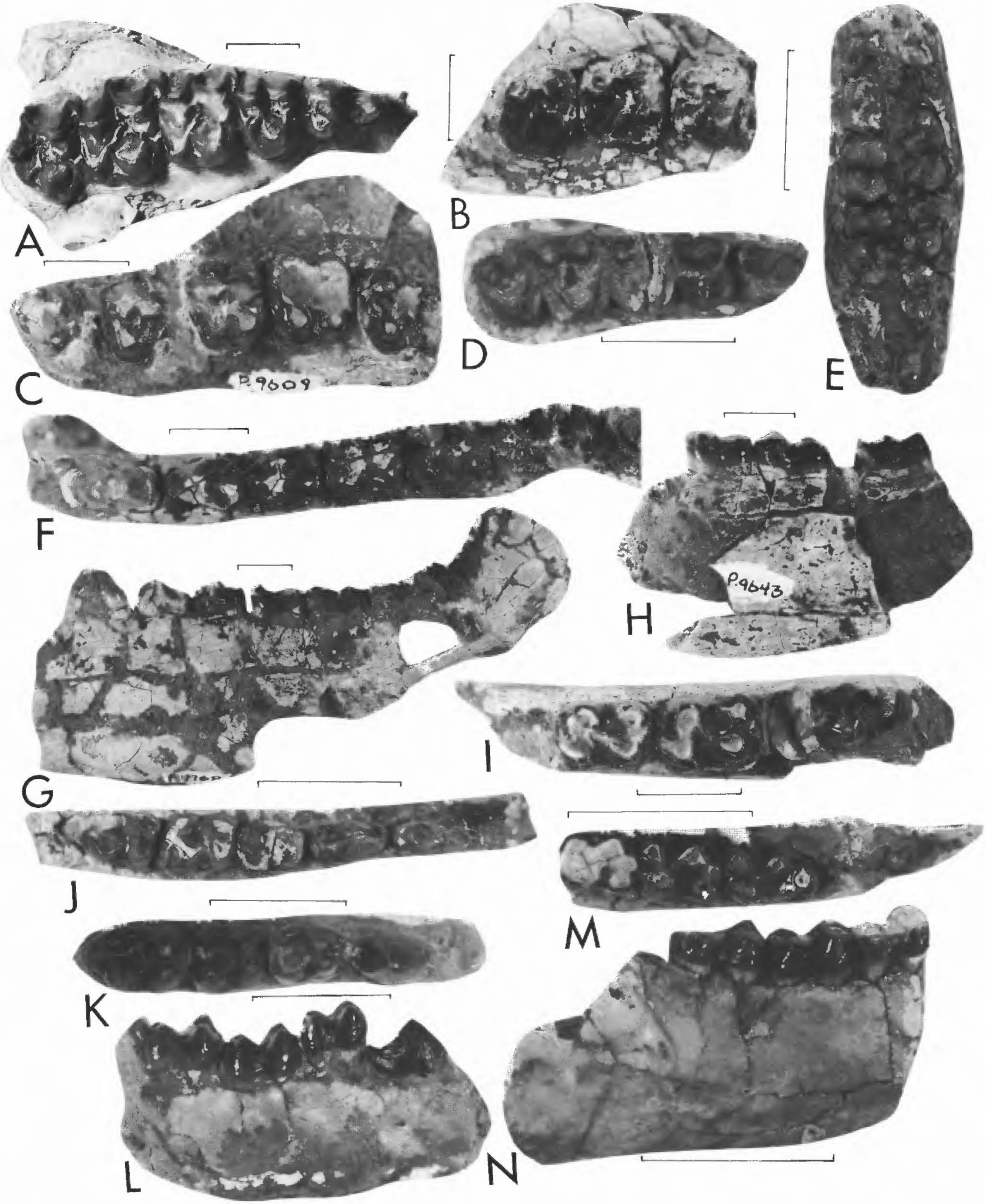

FIGURE 5. Selected fossil mammals from the San Jose Formation. A, *Meniscotherium chamense*, NMMNH P-3621, right P^2–M^3, occlusal view. B, *Hyracotherium tapirinum*, NMMNH P-9393, right M^{1-3}, occlusal view. C, *Heptodon* sp., NMMNH P-9609, left P^3–M^3, occlusal view. D–E, *Diacodexis secans*, NMMNH P-9161, right P^3–M^3, occlusal view (D) and NMMNH P-9112, right and left dentary fragments with P_4–M_3, occlusal view (E). F–G, *Xenicohippus* sp., NMMNH P-9768, left dentary fragment with P_2–M_3, occlusal (F) and labial (G) views. H–I, *Hyracotherium tapirinum*, NMMNH P-9643, left dentary fragment with M_{1-3}, labial (H) and occlusal (I) views. J, *Diacodexis secans*, NMMNH P-9101, right dentary fragment with P_3–M_3, occlusal view. K–L, *Bunophorus macropternus*, NMMNH P-9103, right dentary fragment with P_4–M_3, occlusal (K) and labial (L) views. M–N, *Hyopsodus miticulus*, NMMNH P-9150, right dentary fragment with M_{1-3}, occlusal (M) and labial (N) views. All bar scales are 1 cm long.

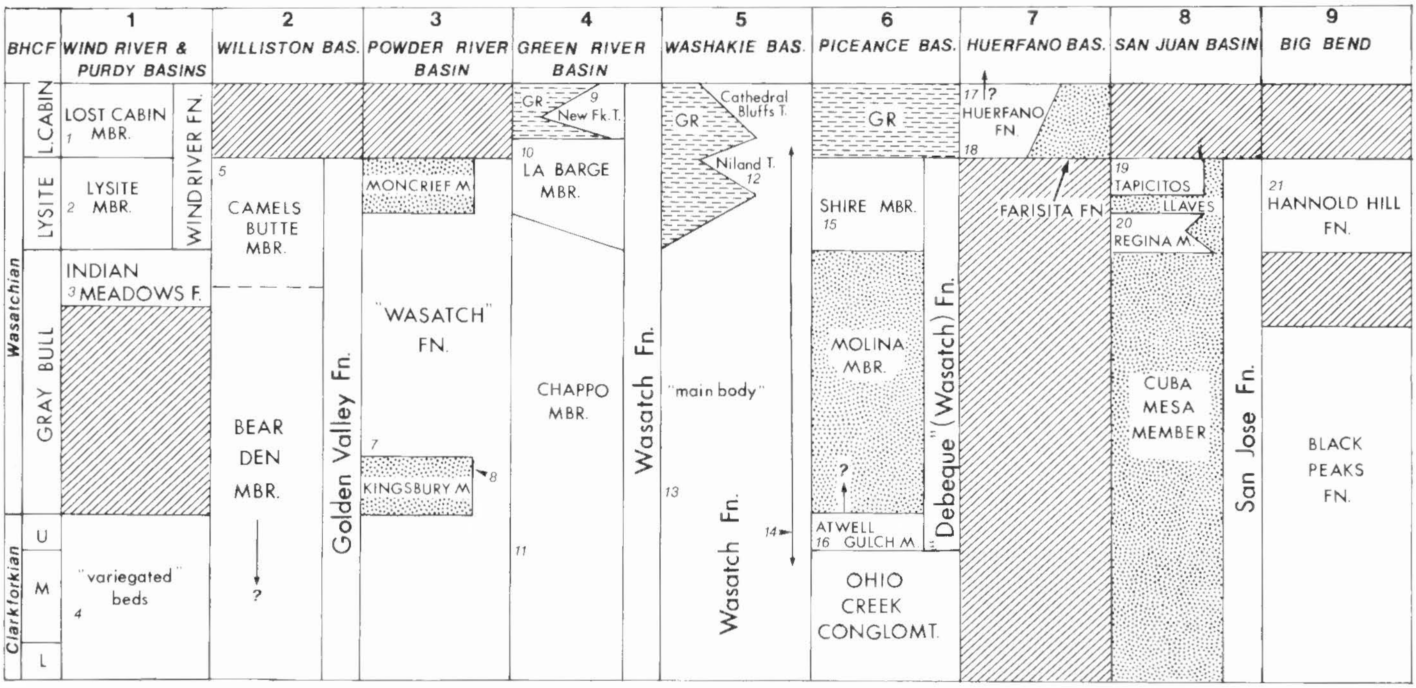

FIGURE 6. Correlation of North American *Coryphodon*—producing deposits. Major local faunas/*Coryphodon* species occurrences are: 1 = Lost Cabin fauna(s): *C. molestus* and *C. lobatus;* 2 = Lysite fauna(s): *C. molestus* and *C. lobatus;* 3 = *C. molestus;* 4 = *C. proterus*?; 5 = *C. molestus;* 7 = *C. eocaenus* from Powder River local fauna; 8 = *C. eocaenus*?; 9 = *C. molestus* from New Fork Tongue faunas; 10 = *C. molestus;* 11 = *C. proterus;* 12 = Dad local fauna: *C. molestus;* 13 = Four Mile fauna: *C. lobatus;* 14 = Bitter Creek faunal levels (various *Coryphodon* species); 15 = *C. molestus* and *C. lobatus;* 16 = *C. eocaenus;* 17 = AMNH locality II: *C. molestus;* 18 = AMNH locality VI: *C. molestus;* 19 = Largo local fauna: *C. molestus;* 20 = Almagre local fauna: *C. molestus. C. simus* and *C. lobatus;* 21 = *C. molestus*. The biostratigraphic subdivisions from the Bighorn-Clark's Fork Basins (BHCF) are indicated on the left.

local fauna from this unit (Lucas et al., 1981) suggests a Lysite age, consistent with the *Coryphodon* species present. The Largo local fauna, from the Tapicitos Member of the San Jose Formation (above the Regina Member) contains *C. molestus,* and this is consistent with a Lysite age assignment as well (Lucas et al., 1981). It should be noted that although *C. simus* is restricted to the Regina Member, this species is so derived that it is arguably post–Gray Bull. A more refined biostratigraphy of the San Jose Formation is needed, one that will place the various faunal horizons now lumped into two local faunas into a rigorous stratigraphic framework.

The only other *Coryphodon*—bearing strata in New Mexico are the lower part of the Galisteo Formation. Robinson (1957), Lucas and Kues (1979) and Lucas (1982) reported specimens of *Coryphodon* from the lower part of the Galisteo Formation near Cerrillos in north-central New Mexico. However, these specimens are too fragmentary to allow a species-level identification. The small Wasatchian Cerrillos local fauna includes *Ectoganus* and *Hyracotherium* sp., *Hyopsodus powellianus,* cf. *Homogalax protapirinus* and *Hyracotherium* sp. and probably is of Lysite age (Schoch, 1981; Lucas, 1982).

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