Reports

Cretaceous Mammals from Montana

Abstract. *A series of Cretaceous mammal faunas, beginning with standard late Cretaceous faunas and continuing with three of Paleocene aspect, are summarized. Four families (Eucosmodontidae, Taeniolabididae, Leptictidae, Arctocyonidae) and one order (Condylarthra) of Tertiary mammals are extended into the Cretaceous. New genera* Cimexomys, Stygimys, Procerberus, *and* Protungulatum *are described, as is a small species of* Catopsalis. *The skeleton of a multituberculate is restored and multituberculate classification is revised.*

A series of late Cretaceous vertebrate faunas, of unusual aspect, were discovered in the summers of 1962, 1963, and 1964 at and near Bug Creek, Montana (*1*). In the first 10 weeks of field work, about 26,000 mammal teeth, some 1,000 mammal jaw fragments, hundreds of mammalian postcranial elements and numerous remains of fish, amphibians, and reptiles (including unweathered teeth of seven species of dinosaurs) were recovered from the richest of these localities, Bug Creek Anthills.

The Bug Creek Anthills local fauna is the earliest and lowest of three newly discovered distinct Cretaceous mammal faunas, present in the Hell Creek Formation of western McCone County, that are transitional in community structure from characteristic, previously known, late Cretaceous faunas to those of the early Paleocene. They contain the earliest North American species of four families previously thought to be restricted to the Early Tertiary.

The Bug Creek Anthills local fauna occurs in a crossbedded stream channel within the upper one-third of the Hell Creek Formation. The base of the channel is 80 feet (24 m) below the Z coal bed, which is the formal mapping boundary of the Cretaceous system and the Paleocene series. The *Triceratops* zone extends up to this coal bed, which is the base of the overlying lower Paleocene Tullock Formation (*2*). Nearby mammal faunas occurring below the horizon of this local fauna are of typical late Cretaceous aspect.

Previously known North American late Cretaceous mammalian faunas are characterized by an abundance of ptilodontid multituberculates, an equally abundant suite of didelphid marsupials, and a much smaller number of primitive placental mammals which are currently referred to the order Insectivora (*3, 4*). These are associated with a characteristic suite of dinosaurs. The earliest Tertiary faunas (those of the Puercan Provincial Age) are characterized by an absence of dinosaurs, a rarity of marsupials, the presence of eucosmodontid and usually taeniolabidid multituberculates, and a dominance of placental mammals of several orders.

Mammals collected previously from the Hell Creek Formation were found in the same stratigraphic horizons as the Bug Creek fauna and in lower horizons, but they are of typical late Cretaceous aspect (*5*). The upper part of the Hell Creek Formation, including the Bug Creek Anthills horizon, is characterized by a distinct and progressive reduction in the relative abundance of dinosaurs, the progressive loss of typical Cretaceous mammal species, and by the zone of overlap of some species of fossil plants characteristic of the lower two-thirds of the Hell Creek Formation and some characteristic of the overlying Paleocene Tullock Formation (*6*).

The principal mammal localities (see Fig. 1) of standard Late Cretaceous facies in this area are Brownie Butte (BB), 65 feet below the Tullock Formation, in section 31, Township 21 North, Range 37 East; Mammal Hill (MH), approximately 100 ($\pm$20) feet below the Tullock Formation in sect. 4, T 21 N, R 37 E; Crooked Creek (CC), of uncertain precise horizon in sect. 36, T 22 N, R 39 E, from which most of the previously described Hell Creek mammals came; McKenna Hollow (MKH), 120 feet below the Tullock Formation in sect. 4, T 24 N, R 43 E; and Ken's Saddle (KS), 100 feet below the Tullock Formation, on Bug Creek, in sect. 8, T 22 N, R 43 E.

The three Late Cretaceous localities of Paleocene aspect are Bug Creek Anthills (BCA), 80 feet below the Tullock Formation in the west half of sect. 9, T 22 N, R 43 E; Bug Creek West (BCW), 60 feet below the Tullock Formation in the northeast quarter of sect. 17, T 22 N, R 43 E; and Harbicht Hill (HH), 40 feet below the Tullock Formation in sect. 32, T 25 N, R 43 E.

Bug Creek Anthills is the most fossiliferous of these localities. A plane table survey suggests that 2×10^6 cubic feet (5.6×10^4 m^3) is a minimum estimate of the fossiliferous matrix at this locality. The fossil density approximates 8 mammal teeth or jaws per kilogram of matrix. The bones are generally broken, but uncrushed, and the matrix can easily be concentrated by dry or wet screening.

The fossil collections from the Bug Creek Anthills locality are mixtures of three contemporary communities. One of these is the usual aquatic and semiaquatic Cretaceous and early Tertiary community of gar-pike, bowfin, sturgeon, ray, crocodile, alligator, champsosaur, turtle, salamander, frog, and aquatic bird species (*7*). Two terrestrial vertebrate communities are represented in very unequal proportions. The less abundantly represented community, a distal community in Shotwell's sense (*8*), is the well-known late Cretaceous assemblage of dinosaurs, lizards, didelphid opossums, and ptilodontid multituberculate mammals, best known from the Lance Formation of Wyoming. The second or proximal community is dominated by previously undescribed species whose descendants are characteristic species of the early Paleocene Puercan Provincial Age.

On the basis of the grade of evolution of these species, the Bug Creek Anthills local fauna was deposited about as long before the early Puerco fauna ("*Ectoconus* zone") of New Mexico as that was before the Torrejon fauna. In addition to the above

Cretaceous mammal localities, a mollusc-bearing channel sand 116 feet above the base of the Tullock Formation in the southwest quarter of sect. 36, T 23 N, R 43 W has produced, among others, the following early Paleocene mammals, *Taeniolabis taoensis,* and *Anisonchus* cf. *gillianus*. In view of the low concentration of mammal fossils and the high concentration of shell debris this locality has been named Purgatory Hill (PH). The early Paleocene (*Taeniolabis* biozone) aspect of the mammals from this locality suggests that the Tullock Formation encompasses the entire Puercan Provincial Age.

Table 1 shows the list of Cretaceous mammal species known from this area, with the approximate percentage of the total number of mammal specimens for each species present at Bug Creek Anthills, and the minimum number of individuals represented for each species at the other localities. The large quantity of material from Bug Creek Anthills has made the determination of minimum number of individuals at Bug Creek Anthills difficult. Since each species possesses about ten types of identifiable teeth, the percentage values should be roughly comparable to the minimum number of individuals (*9*).

Subclass Allotheria
Order Multituberculata
Suborder Ptilodontoidea (Simpson 1927) new rank
Ectypodidae, new family

The new family Ectypodidae is proposed to include a central stock of small members of the Ptilodontoidea, and consists of *Cimexomys* new genus, *Mesodma* Jepsen 1940, *Neoplagiaulax* Lemoine 1882, *Parectypodus* Jepsen 1930, and several undescribed genera in the complex of species presently referred to *Ectypodus* Matthew and Granger 1921.

The lateral profile of P^4 (see *10*) is normally close to an isosceles triangle with the posterior edge shorter. The ratio between lengths of P_4 and M_1 normally ranges from 1.4 to 2.0. The lateral profile of P_4 is arcuate, the anterior portion of the profile is curved, the highest point on the profile occurs in mid-length and is above the line of cusps of M_1 and M_2. These small multituberculate mammals are more common and usually pose a more difficult taxonomic problem at the species level than other mammals in any fauna. They apparently filled roles in community structures analogous to those of modern mice.

Cimexomys, new genus

Type: *Cimexomys minor* new species.
Diagnosis: Very small ectypodid multituberculate, with dental formula $\frac{?\ ?\ ?\ ?}{1\text{-}0\text{-}2\text{-}2}$; P_3 peglike; P_4 with rounded anterior edge, no ridges descending from first or last of eight or nine serrations, last two serrations developed as distinct cusps. Lateral profile of P_4 high and arcuate. Height of first serration of P_4 (above base of notch for P_3) 38 percent of total length. M_1 with cusp formula 6 : 4; M^1 with cusp formula 5 : 6 : 1.
Etymology: *Cimex*, Latin for bug, in reference to the type locality; *mys* mouse or small gnawing mammal.

Cimexomys minor, new species

Type: S.P.S.M. 62-2115 left mandible with P_3, P_4, and alveoli for I, M_1, and M_2.
Type locality: Bug Creek Anthills.
Known distribution: Hell Creek Formation, Montana (BB, KS, BCA, BCW); Lance Formation, Wyoming.
Diagnosis: The length P_4–M_2 is 6.5 mm; P_4 with eight serrations (Fig. 2).
Etymology: Minor is in reference to the extremely small size of this species.
Discussion: Clemens, in his study on the Lance mammals (*4*), noted the existence of a number of small M^1's at the lower limit of size for *Mesodma formosa* (Marsh). These M^1's have a much shorter internal row of cusps than is usual or characteristic for the Ptilodontidae. Bearing in mind the confusion resulting from Marsh's original description of the Lance mam-

Table 1. Minimum numbers of individuals of mammal species from the Hell Creek formation, listed by locality.

Taxa	Locality							
	BB	MH	CC	MKH	KS	BCA*	BCW	HH
Allotheria (multituberculate mammals)								
Ptilodontoidea								
Ectypodidae								
Cimexomys minor n. gen. and sp.	1				3	1.07	5	
Cimexomys n. sp.								3
Mesodma formosa (Marsh)	1			1	2	8.56	28	
Mesodma thompsoni Clemens	1		1	1	4	34.26	43	12
Ptilodontidae								
Cimolodon nitidus Marsh	1		1		1	0.13	1	
Essonodon browni Simpson			1		1	0.05		
Taeniolabidoidea								
Cimolomyidae								
Cimolomys gracilis Marsh					1	0.05		
Meniscoessus borealis Simpson	2	2		1	2	0.86	1	1
Eucosmodontidae								
Stygimys kuszmauli n. gen. and sp.						25.70	9	
Stygimys gratus (Jepsen)								15
(undescribed genus and species)							1	5
Taeniolabididae								
Catopsalis joyneri n. sp.						3.85	2	3
Metatheria (marsupial mammals)								
Didelphidae								
Didelphodon vorax Marsh		2	1	2	1	0.05		
Alphadon marshi Simpson						0.02		
Pediomys elegans Marsh	1				2	0.45	1	
Pediomys hatcheri (Osborn)	1		1		2	0.24	1	
Pediomys sp.		1	1		1	0.30	1	
(undescribed genus and species)	2					0.10	1	
Eutheria (placental mammals)								
Insectivora								
Palaeoryctidae								
Cimolestes incisus Marsh						0.10		
?Erinaceoidea								
Gypsonictops hypoconus Simpson	1				1	0.10		
Gypsonictops petersoni (Simpson)						0.50	4	
Leptictidae								
Procerberus formicarum n. gen. and sp.						7.07	2	3
Condylarthra								
Arctocyonidae								
Protungulatum donnae n. gen. and sp.						16.70	5	
Protungulatum cf. *P. donnae*								3
Protungulatum n. sp. O.							3	
Protungulatum n. sp. S.								4
?*Protungulatum* n. sp. H.								3
Protungulatum n. sp. E.								2

* Figures for BCA are percentages of 6000 individual teeth and jaw fragments.

mals, Clemens chose not to define a species on the basis of these isolated teeth and to refer them questionably to *Mesodma*. The discovery of jaws bearing teeth of this size at Bug Creek Anthills makes it possible to define this genus and species in a fairly satisfactory fashion. The only species present at Bug Creek which can be confused with *Cimexomys minor* is the slightly larger *Mesodma formosa*, which has more serrations on P_4 and more and smaller cusps on the molars. While definitely a ptilodontoid, *Cimexomys* seems to represent a late surviving primitive form.

A second and larger species is known from Harbicht Hill, Hell Creek Formation, and the Mantua Lentil, Polecat Bench Formation, Wyoming (P.U. 14999) (*11*).

Mesodma thompsoni Clemens 1964

The rich concentration and excellent preservation of bones from the Bug Creek Anthills locality has made possible the identification of isolated mammalian postcranial elements. Specifically identified postcranial elements of multituberculate mammals have been known primarily from partial skeletons of *Ptilodus montanus; Eucosmodon* sp. and *Djadochtatherium matthewi* Simpson (*12*). By utilizing data on size, frequency, and morphology, Dennis Deischl and one of us (R.E.S.) have been able to identify isolated limb, girdle, and vertebral elements of the five most common species of multituberculates at Bug Creek Anthills (*13*). This study permitted a composite skeletal restoration of *Mesodma thompsoni*, the most common North American late Cretaceous mammal (Fig. 3), the first such reconstruction for any Mesozoic mammal, and the first for any member of the longest-lived order of mammals known, the Multituberculata. By trial articulations of the limb bones, the ranges of movements of the limb bones have been defined for this species. In a vertical transverse plane, the shaft of the femur can rotate from a position slightly below horizontal to a vertical position. The knee has a range of movement from 120° to 40° for the included angle between femur and tibia, in contrast to the maximum included angle of 90° suggested for *Eucosmodon* sp. (*14*). The movement of the humerus is apparently in the same plane as the blade of the scapula. The elbow has a range of movement of from 45° to 120° for the angle between the shafts of the humerus and the ulna. Movement of the ulna in this and all other studied species of multituberculates is restricted to a single plane by the shapes of the trochlea and semilunar notch.

Suborder Taeniolabidoidea (Granger and Simpson 1929) new rank

The new discoveries at Bug Creek Anthills show that the taeniolabidids and eucosmodontids are more similar to each other than either are to ptilodontids. Thus it is necessary to define a new suborder to unite them. This suborder also includes one other named but undescribed family, the Cimolomyidae (Marsh 1889) with two included genera, *Meniscoessus* Cope 1882 and *Cimolomys* Marsh 1889. The suborder Taeniolabidoidea may be defined as including multituberculates in which the enamel of the lower incisor is restricted to the ventro-lateral surface of the tooth, producing a self-sharpening tooth similar to that of rodents. The shearing premolars are reduced in proportion to the molars in all included genera except *Eucosmodon*.

Catopsalis, Meniscoessus, Cimolo-

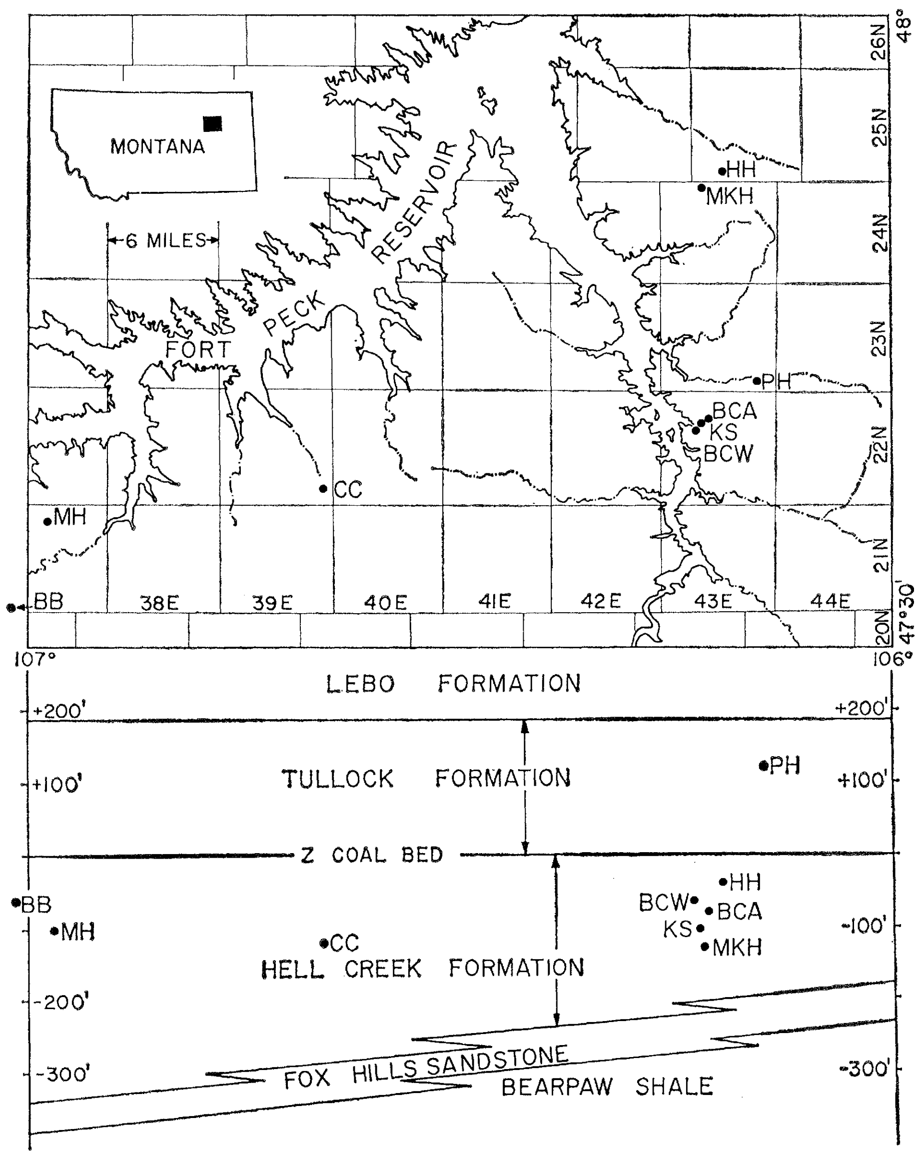


Fig. 1. Map of the Fort Peck Region, Montana, showing the locations of the mammals collected from the Hell Creek and Tullock Formations. The horizons in which the mammals are found are indicated in the stratigraphic cross-section of the area. (*HH*, Harbicht Hill; *MKH*, McKenna Hollow; *PH*, Purgatory Hill; *BCA*, Bug Creek Anthills; *KS*, Ken's Saddle; *BCW*, Bug Creek West; *CC*, Crooked Creek; *MH*, Mammal Hill; *BB*, Brownie Butte).

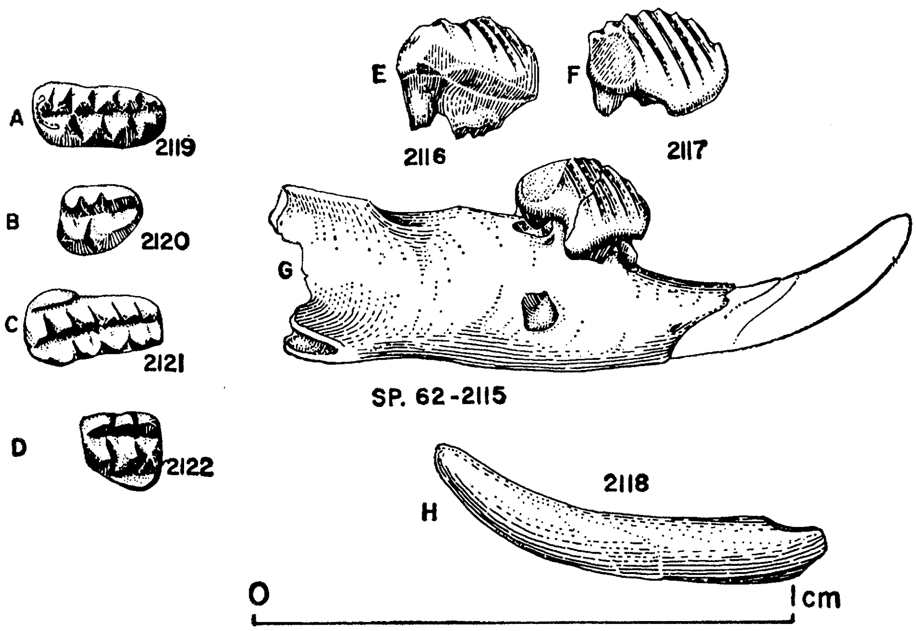


Fig. 2. Teeth and right lower jaw of *Cimexomys minor*, new genus and species. *A*, Left M_1; *B*, right M_2; *C*, left M^1; *D*, left M^2; all in occlusal views. *E*, Worn left P_4, lingual view; *F*, unworn right P_4, labial view; *G*, right lower jaw with P_3, worn P_4, and I restored from *H*, left lower incisor (S.P.S.M. 62-2118).

mys, Stygimys, and an undescribed eucosmodontid known principally from Harbicht Hill, are the only known North American Cretaceous taeniolabidoids. The gnawing specialization is less advanced in *Meniscoessus* (?and *Cimolomys*) than in the others. These are apparently the most efficient mammalian herbivores of the Cretaceous of North America.

Family Eucosmodontidae (Jepsen 1940) new rank
Stygimys, new genus

Type: *Stygimys kuszmauli* new species, known from the Hell Creek Formation of Montana. The referred species are *Eucosmodon teilhardi* Granger and Simpson 1929 from the Nacimiento Formation of New Mexico, *Parectypodus jepseni* Simpson 1935 (=*Eucosmodon sparsus* Simpson 1937) from the Lebo Formation of Montana and perhaps the Rock Bench Quarry beds of the Polecat Bench Formation, and *Eucosmodon gratus* Jepsen 1930 from the Mantua Lentil of the Polecat Bench Formation of Wyoming.

Known distribution: Late Cretaceous to Mid Paleocene, western North America.

Diagnosis: A genus of medium sized Eucosmodontidae. Dental formula $\frac{2\text{-}0\text{-}4\text{-}2}{1\text{-}0\text{-}1\text{-}2}$; P^1, P^2, P^3, single rooted. Lower incisor more compressed laterally than in *Eucosmodon*. Posterior portion of profile of P_4 relatively straight and continuous with crest of M_1 and M_2, anterior portion of P_4 profile circular or parabolic. Ratio length of P_4 to length of M_1 approximately 1.1. Infraorbital canal relatively large. Zygomatic arch originates opposite P^1 and P^2.

Etymology: A rodent-like mammal from the Hell Creek (Styx) Formation.

Discussion: This genus differs from *Eucosmodon* in several significant features. Perhaps the most obvious is the dental formula: P^1 is present in *Stygimys* and absent in *Eucosmodon*. The lateral profile of P_4 differs significantly in the two genera; it is J- or pothook-shaped in *Stygimys* and arcuate in *Eucosmodon*. The roots of P_4 are subequal in size and the anterior root is curved forward in the present genus in contrast to *Eucosmodon*, where the anterior root is straight and of normal proportions and the posterior root has become antero-posteriorly elongate. The ratio between the lengths of P_4 and M_1 is about 1.9 in *Eucosmodon*, about 1.1 in *Stygimys*. The height to width ratio of the lower incisors is greater in *Stygimys* than in *Eucosmodon*, and the lateral profile of the incisor is relatively more curved. In *Eucosmodon molestus* (A.M.N.H. 16534) and in *Eucosmodon americanus* (K.U. 9401), the zygomatic arch originates opposite P^3 and P^4, there is a large maxillary portion of the snout anterior to the zygoma, and the infraorbital canal is both relatively and absolutely smaller than in the present genus.

The lower jaw of *Stygimys* shows two prominent masseteric crests. The

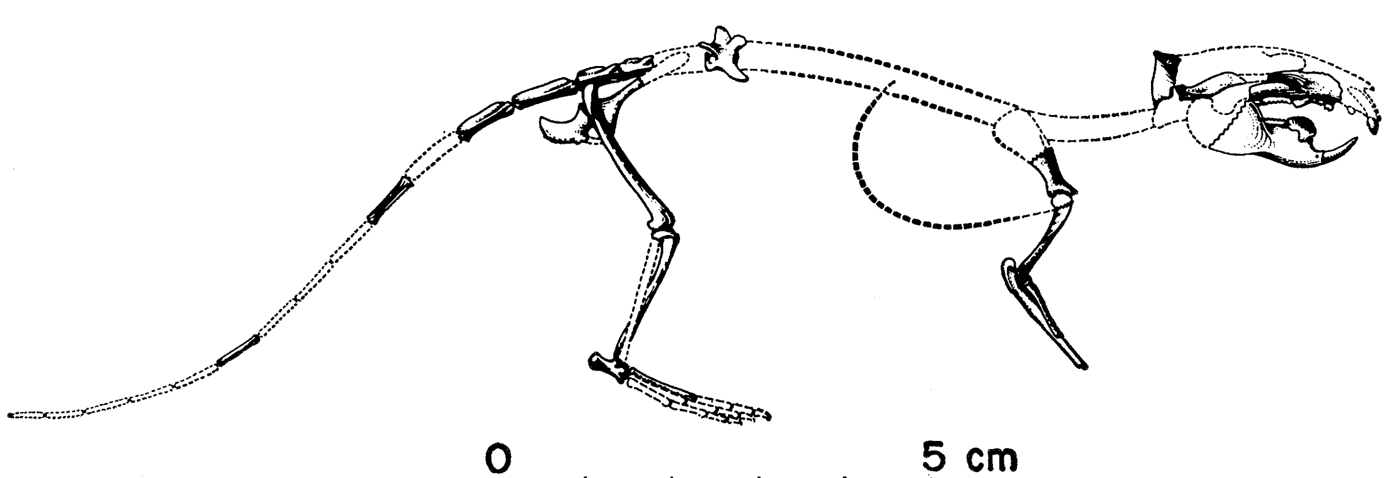


Fig. 3. Skeletal restoration of *Mesodma thompsoni* Clemens.

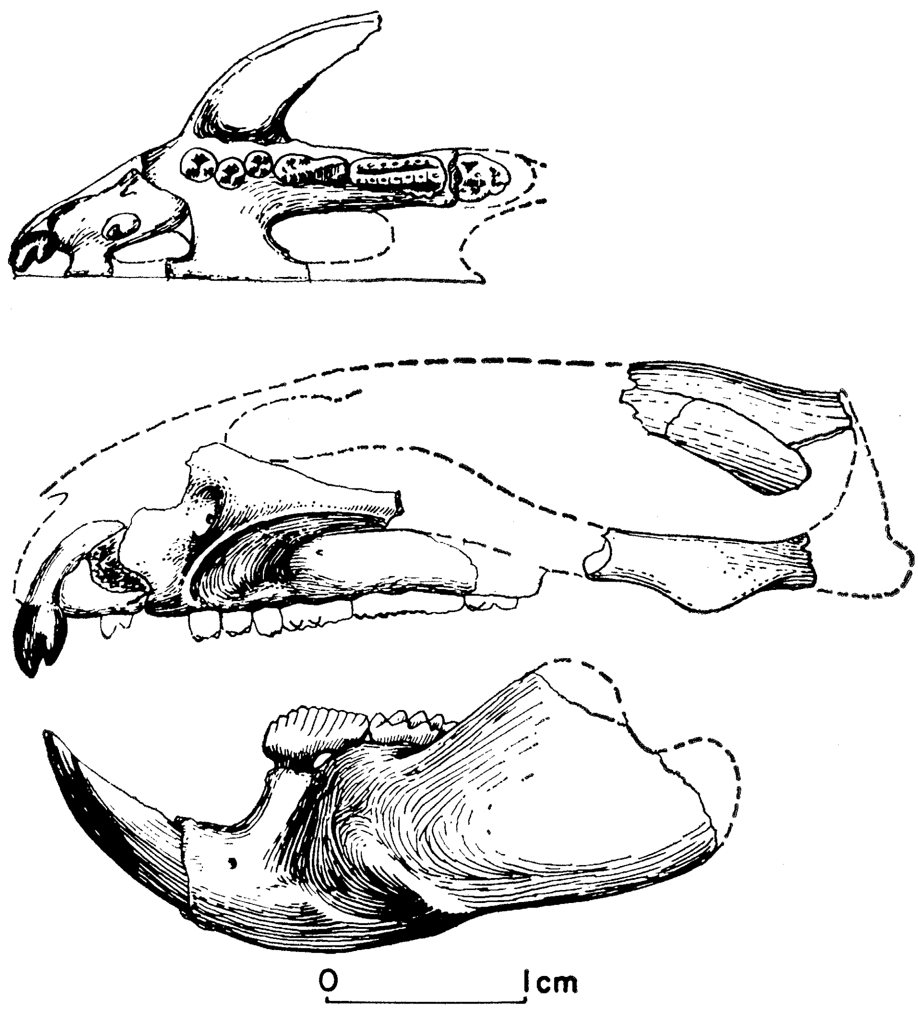


Fig. 4. Skull restoration of *Stygimys kuszmauli*, new genus and species, based on U.M.V.P. 1480, left premaxilla; 1481 to 1483, maxillae with P^3 and P^4; 1477, left squamosal; 1476, fused parietals; 1478, 1479, and 1485, lower jaws with I and P_4; and 1487 to 1492, isolated teeth.

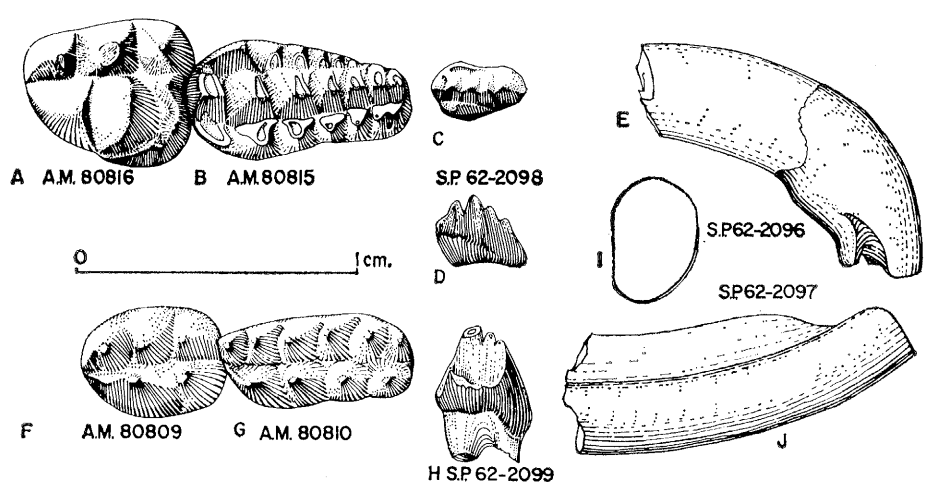


Fig. 5. Teeth of *Catopsalis joyneri*, new species. *A*, Left M^2 and *B*, left M^1 in occlusal views; *C*, occlusal and *D*, lingual views of right P^4; *E*, labial view of right I^1; *F*, left M_2 and *G*, left M_1 in occlusal views; *H*, right P_4; *I*, cross section and *J*, labial view of right I_1.

superficial masseter originates on the zygomatic process of the maxilla and inserts on the more forward crest, the deep masseter inserts on the more posterior crest and probably extended, at least partially, through the infraorbital foramen to originate on the facial portion of the maxilla. This modification parallels that of the hystricomorph and caviamorph rodents.

The second upper incisor is located medial to the line of molars and premolars, a position otherwise known only in *Meniscoessus* and *Djadochtatherium* but probable for *Catopsalis* as well.

Djadochtatherium matthewi Simpson 1925, reported from the late Cretaceous Djadochta Formation of Mongolia, resembles *Stygimys* more closely than it does any other multituberculate and may be transferred to the Eucosmodontidae. *Djadochtatherium* has a *Stygimys*-like palate, the wear on the incisors is of a type characteristic only of the Eucosmodontidae, and the ratio of the length of P_4 to the length of M_1 is similar to that of *Stygimys*. *Djadochtatherium* is more primitive than other Eucosmodontidae in having doubly rooted anterior upper premolars.

Stygimys kuszmauli, new species

Type: U.M.V.P. 1478, left lower jaw fragment with I and alveoli for P_4 and M_1.

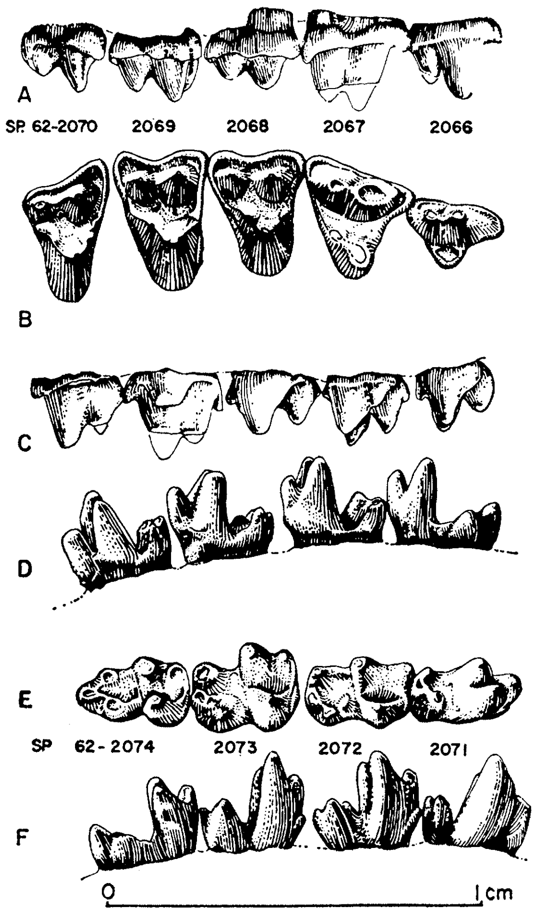
Known distribution: Late Cretaceous Hell Creek Formation; Bug Creek Anthills (type locality), and Bug Creek West.

Etymology: This species is named for Mr. Eugene Kuszmaul of Fort Peck, Montana.

Diagnosis: This is the smallest described species of the genus. Length P_4, 4.6 ± .3 mm (standard deviation of sample); 11 serrations (Fig. 4). The specimens of *Stygimys* from Harbicht Hill are larger than those from Bug Creek Anthills and can be referred to *Stygimys gratus* (Jepsen 1930), previously known only from the early Paleocene Mantua Lentil of Wyoming.

Family Taeniolabididae
Catopsalis joyneri, new species

Type: U.M.V.P. 1494, right maxilla with complete palate, M^1, roots of P^4, alveoli of P^3 and M^2.



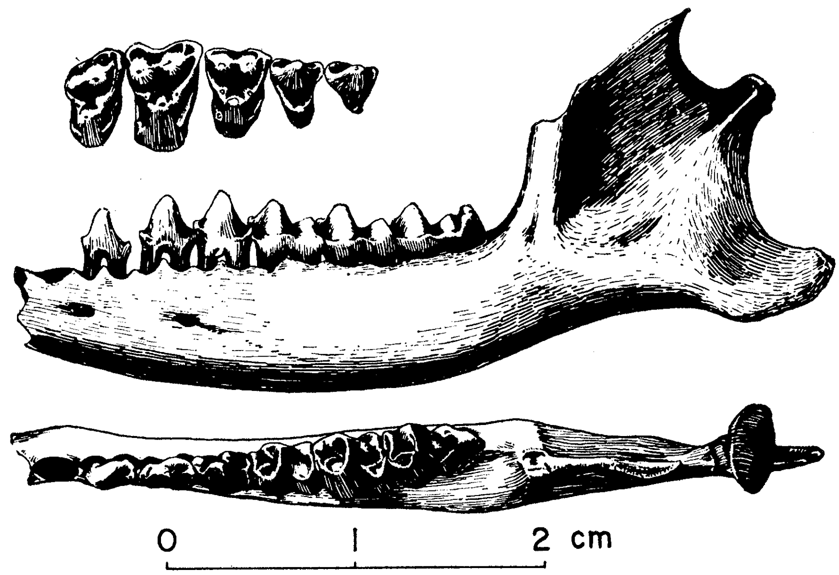


Fig. 6 (left). Isolated teeth of *Procerberus formicarum*, new genus and species. *A*, Labial, *B*, occlusal, and *C*, lingual views of S.P.S.M. 62-2066 to 62-2070, P^3–M^3; *D*, lingual, *E*, occlusal, and *F*, labial views of S.P.S.M. 62-2071 to 62-2074, P_4–M_3. Fig. 7 (above). (Top) Occlusal view of P^3–M^3; S.P.S.M. 62-2061 to 62-2065, isolated right upper teeth referred to *P. donnae.* (Center and bottom) Labial and occlusal views of S.P.S.M. 62-2028, left mandible with P_2–M_3, holotype of *Protungulatum donnae*, new genus and species.

Type locality: Bug Creek Anthills, also known from Bug Creek West and Harbicht Hill, Late Cretaceous Hell Creek Formation, Montana.

Diagnosis: Smallest and earliest known species of the genus. P_4 length 3.5 mm, two-rooted with 3 cusplike serrations, typically with shear-wear facet on labial face. M_1 length 7.0 mm, cusp formula 5 : 4; M_2 length 5.5 mm, cusp formula 3 : 2. P^4 length 3.3 mm, cusp formula 1 : 5 : 1, morphology of P^4 intermediate between that of *Meniscoessus borealis* and *Taeniolabis taoensis.* M^1 length 8.1 mm, cusp formula 7 : 8 : 8; M^2 length 5.2 mm, cusp formula 1 : 3 : 3. Molar cusps subcrescentic. Lower incisor gliriform with constant curvature and limited enamel band (Fig. 5).

Etymology: Name given in honor of Newell F. Joyner, one of the discoverers of Bug Creek Anthills.

Discussion: This is the largest of the common species of multituberculates from Bug Creek Anthills. It is the first Cretaceous species of this family to be found and is morphologically ancestral to the later species of this family. It is most similar to *Meniscoessus*, among other late Cretaceous genera, and is of similar size, but a number of crossing specializations suggest neither is ancestral to the other: *Meniscoessus* possesses a more primitive shearing P_4 and the cusp shape of the molars is more advanced; *Catopsalis* has a more degenerate P_4 and more primitive molar cusp arrangement in both form and count. The two genera probably share close common ancestry.

Subclass Theria
Order Insectivora
Family Leptictidae
Procerberinae, new subfamily

Diagnosis: Leptictids with postcingulum of upper molars no larger than precingulum, upper molars and especially P^4 not very transverse, lingual cingula and conules absent on upper premolars, paraconid of lower molars large and lingual.

Procerberus formicarum, new genus and species

Type of *P. formicarum*: U.M.V.P. 1460, lower jaw fragment with P_3, P_4, and M_1.

Known distribution: Bug Creek Anthills (type locality), Bug Creek West, and Harbicht Hill local faunas, Late Cretaceous Hell Creek Formation, McCone County, Montana. A second species of *Procerberus* occurs at Purgatory Hill, Tullock Formation, early Paleocene.

Generic and specific diagnosis: Small, palaeoryctid-like leptictids. Interradicular crests absent on all teeth. Upper molars not very transverse, lingual cingula very small, paracone and metacone connate for at least half the lingual height of the paracone, conules small and without centrally-directed wings. P^{3-4} submolariform, with shearing metacrista but no lingual cingula; conules very weak or absent. Lower molars with large and lingual paraconid, protoconid not higher than metaconid, trigonid of moderate height. P_4 submolariform, narrow, with anterior paraconid and weak paralophid; metaconid slightly more posterior than protoconid. P_3 simple, with paraconid and one-cusped talonid. Combined length M^{1-3}, 7.4 ± 0.2 mm (standard deviation of sample); combined length M_{1-3}, 8.7 ± 0.2 mm. (see Fig. 6).

Discussion: *Procerberus* has been compared in detail with all described groups of early placental mammals, and is in a morphologically central position among the highly divergent families Arctocyonidae, Stylinodontidae, Leptictidae, Erinaceidae, Pantolestidae, and Palaeoryctidae (including Deltatherididae) and the primates. Notable similarities are present also to all other Paleocene placentals not derived from one of these taxa. The central position of *Procerberus* suggests, but does not prove, that a semimolariform P^4 and P_4 were primitive for most or all placental mammals.

Procerberus is referred to the Leptictidae mainly because its total morphology is more nearly duplicated by leptictids than by any other group, but partly because of a few apparent leptictid specializations and the virtual lack of specializations characteristic of other placental families. The P_4 is in particular very similar to that of the early Eocene leptictid *Palaeictops tauricinerei* and to an undescribed middle Paleocene species related to this. The only characters that can with any assurance be claimed as leptictid specializations are the moderately narrow stylar shelf on the upper molars (wider than in most placentals, however), the absence of a central paraconule wing, the slightly larger lingual cingula than in primitive Palaeoryctidae, and part of the reduced transverseness of the upper molars. None of these specializations (or even their combination) is unique to the Leptictidae, but they are elsewhere found only in groups less similar to *Procerberus*. Eventual reference of *Procerberus* to the Palaeoryctidae or even the Pantolestidae or Erinaceoidea is not completely excluded by present information, but its formal classification is of less importance than its unique combination of relatively simple molars with relatively complex posterior premolars, and its many similarities to the most primitive members of several orders of mammals.

Order Condylarthra (15)
Family Arctocyonidae
?Subfamily Oxyclaeninae
Protungulatum donnae, new genus and species

Type: S.P.S.M. 62-2028, left mandible with P_2–M_3, type of *P. donnae*.

Generic diagnosis: Small arctocyonids which are most similar to *Oxyclaenus*. P^{3-4} with a relatively narrow paracone; P^3 with a small protocone; P^4 with a prominent pointed protocone, and usually a trace of a metacone. M^2_2 wider transversely than M^1_1. Prominent labial cingula on P^3–M^3; prominent lingual cingula on M^{1-3}. Upper molars relatively transverse; hypocone absent or a weak swelling on the postcingulum; apex of protocone nearly half the distance to the labial border of the tooth. P_4 submolariform, with tall protoconid, large but low paraconid, and moderately large metaconid; talonid simple. Lower molars with short and relatively narrow talonids, usually with an incomplete lingual border; lingual cingula are absent and labial cingula are weak; paraconid moderately large and lingual. M_3 narrower than M_2 and with projecting hypoconulid. Cusps on all teeth high for an arctocyonid; enamel not wrinkled except sometimes on cingula.

Specific diagnosis: Size rather small; combined length M^{1-3}, 9.9 ± 0.4 mm (standard deviation of sample); combined length M_{1-3}, 12.0 ± 0.4 mm. Middle of protocone lobe of P^4 without crest and not markedly inflated. Conules of upper molars relatively close to each other; no commissure between lingual cingula. P_1 one- or two-rooted. Trigonids of lower molars relatively high, cusps moderately separated (Fig. 7). Named for Miss Donna Beckman of Ft. Peck, Montana.

Discussion: *Protungulatum donnae* is presently the oldest genus and the oldest known species of ungulates. Five additional species, that can be referred to this genus or to closely related genera, are now known from the Cretaceous, and one occurs at Purgatory Hill; these will be described later. No earlier placental mammal that could have given rise directly to *Protungulatum* is known. The contemporary *Procerberus formicarum* is approximately structurally ancestral. Nothing in the known anatomy of *P. donnae*, dental or otherwise, precludes it from being an ultimate ancestor in the real rather than structural sense for the various orders of ungulates. The low stratigraphic occurrence lends credence to this view, which may nevertheless be drastically altered by future discoveries. In particular, this species is distinctly removed from all other known Cretaceous eutherians and must have had some earlier ancestors, whose morphology is not completely predictable at present. Considering the limited state of knowledge of Late Cretaceous mammals of the balance of the world, we cannot assume they were restricted to North America.

Protungulatum donnae is most closely similar to the oxyclaenine arctocyonids (usually placed in the order Carnivora), but it also shows very close similarities to primitive early Paleocene genera belonging to the Hyopsodontidae and to the subfamily Anisonchinae of the Periptychidae, both of the order Condylarthra. It forms a very satisfactory annectant type between these taxa and its familial allocation is therefore somewhat arbitrary and subject to discussion. This legitimate and expected discussion should not be allowed to obscure the real community of origin of these families.

The bulbous form and many other similarities of both upper and lower premolars, and the near identity of the lower molars of *Conacodon cophater* and *Oxyacodon agapetillus*, suggest that the latest common ancestor of the anisonchines and the hyopsodontids was rather different from any known arctocyonid; it would probably be called a hyopsodontid. Nevertheless, *Protungulatum* or some closely related Cretaceous genus probably was ancestral to this hypothetical form.

It is in the upper molars that anisonchines depart most radically from the more primitive patterns of oxyclaenines and hyopsodontids. The apex of the protocone has shifted onto the labial half of the tooth, quite close to the less-shifted conules. Wear on the protone is almost or entirely on its labial surface. In arctocyonids and hyopsodontids the protocone wear is from the apex, in or near the occlusal plane.

The upper molars of *Protungulatum* have a typically oxyclaenine wear pattern. However, these teeth are more transverse than the upper molars of Puercan or later arctocyonids. The additional width is present partly on the lingual slope of the protocone, as in anisonchines; also as in this group, the paracone and metacone, and paraconule and metaconule, are closer to each other. Again as in anisonchines, the hypocone (when present) is considerably lingual to the apex of the protocone. Although *Protungulatum donnae* may not have given rise to the anisonchines and hyopsodontids, it is very probable that it or a closely related taxon did so.

More comprehensive reports, in which other new species will be described, are in preparation.

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References and Notes

1. The site was discovered by Newell F. Joyner, Regional Museum Curator, National Park Service, Omaha, Nebraska, and the families of Donald C. Beckman and Eugene Kuszmaul of Ft. Peck, Montana. Collections have so far been made by or for the St. Paul Science Museum (S.P.S.M.), The American Museum of Natural History (A.M.N.H.), and Minnesota (U.M.V.P.), Harvard, Princeton (P.U.), Kansas (K.U.), Yale, Montana State, and Nebraska Universities. Similar but slightly later Cretaceous mammals, now at A.M.N.H., were first found in this region in 1938 by Darwin Harbicht, then of Ft. Peck, and an untraced Mr. Moseley. It was while searching for their locality (now named Harbicht Hill) that we were led to the Bug Creek site.
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10. The abbreviations I, C, P, and M refer to incisors, canines, premolars, and molars, respectively.
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16. This investigation was supported in part by a Boese postdoctoral fellowship from Columbia University, a NATO Postdoctoral Fellowship, and NSF grant GB-1798 to L. V. V., and by grants from the Louis A. and Maud W. Hill Family Foundation of St. Paul, from the graduate school of the University of Minnesota, and NSF grant GB-894 to R. E. S. We thank M. C. McKenna, W. A. Clemens, E. L. Simons, G. L. Jepsen, and G. E. Lewis for the loan of specimens, and McKenna and Clemens for comments on the manuscript. We also thank Mr. Donald C. Beckman and family, Mr. Eugene Kuszmaul, and Mr. Richard Eriksen of Ft. Peck, for telling us of the localities BCA and BCW, for donation of specimens, and for many other courtesies; Dr. W. F. Nelson for the drawings of *Protungulatum* and *Stygimys*, and Miss Sarah Babb for the other drawings.

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Stratospheric Tapping by Intense Convective Storms: Implication for Public Health in the United States

Abstract. *The observation of a cloud-free vortex in the top of a violent convective storm over Oklahoma suggests a mechanism whereby large quantities of air may be brought directly from the lower stratosphere to the lower troposphere in the central part of such storms. That this mechanism, in combination with the torrential rains frequently generated by these systems, is capable of producing radioactive "hot spots" on the ground is pointed out. Climatological considerations and observations of accumulated strontium-90 in soils support the hypothesis that the Plains States are peculiarly subject to heavy contamination compared to other middle-latitude areas because of this mechanism.*

List *et al.* (*1*) report a "cause-and-effect relationship between the penetration of thunderstorms into high concentrations of nuclear debris in the lower stratosphere and the subsequent amount of iodine-131 in milk." I write primarily to point out a possible mechanism, on the basis of observations made in May 1962, for direct tapping of debris from the lower-stratosphere reservoir. It should, however, be clear that torrential rains are fully capable of concentrating the debris contained by tropospheric air by the selfsame convergent-flow mechanism that serves to concentrate water substance locally to form such rains. Therefore I do not wish to enter into controversy (*2*) as to the source of the observed iodine-131 contamination of milk.

Basically, the scavenging of stratospheric debris by rain is a logistics problem which requires that certain conditions be fulfilled in succession:

1) The radioactive particles must become attached to or contained in raindrops.

2) They must at some time be brought into close proximity to adequate water substance as vapor, liquid, or ice.

3) There must be an active mixing process between (i) the stratospheric (hence dry) air that contains the radioactive particles; and (ii) tropospheric air which contains sufficient water substance to produce rain.

4) The particles to be scavenged must have size and mass appropriate for the envisioned collection process. (i) For diffusive collection by cloud droplets they must be of size comparable to the stratospheric aerosol *but* they must then be associated with the cloud droplets for an extended time, and in a part of the cloud which converges toward the rain generating region. (ii) For impact collection by raindrops (washout), they must be very large, by 10 to 50 times, compared to the stratospheric aerosol.

For the production of rain, the flux of moist low-level air through a horizontally convergent system requiring uplift, condensation, and storage of condensed water in a cloud mass is necessary. All such flow systems in nature are characterized by a divergence of the processed air above the level of water storage. To the extent that the generation of rain characterizes a developing and strengthening cyclonic storm, the divergence aloft must remove a larger mass of air from the storm center than that which low-level convergence brings in. The tops of most rain-producing storm systems are therefore in the divergent flow, and cloud particles present at these levels are not likely to become associated with the precipitation particles. They are rather more likely to move away from the raining system aloft and evaporate downstream, leaving behind aggregated nuclei suitable for the generation of rain in a subsequent storm.

In particular, convective storms are characterized by horizontal divergence in their tops, which is more or less proportional to the intensity of their development. Since only the most intense are expected to penetrate the lower stratosphere, these are particularly divergent in their uppermost levels. Stratospheric debris collected by the cloud particles that penetrate to these levels is therefore not well located for incorporation in the rain produced at, and falling from, the lower portions of the storm.

Several mechanisms have been pro-