turn, by sedimentary rocks as old as Early Devonian. Thus, paleontologic data indicate an orogenic episode between Early Cambrian and Early Devonian, an interval that includes most of the isotopic dates of this area. This episode has been termed the Ross Orogeny (*7*).

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The Earliest Primates

Abstract. *The known range of the Primates is extended down from the middle Paleocene to the early Paleocene and late Cretaceous by a new genus and two new species from Montana,* Purgatorius unio *and* P. ceratops. *These species approach condylarths and leptictid and erinaceoid insectivores in structure.* Purgatorius *is referred to a new subfamily, Purgatoriinae, of the Paromomyidae, but is probably not the stem primate. The fauna of Purgatory Hill indicates a late early Paleocene age.*

Although 10 genera and 11 species of primates are known from the middle Paleocene (*1–3*), none have been reported from earlier horizons. Field work in 1964 in eastern Montana by a party from the University of Minnesota has resulted in the discovery of six primate teeth from the early Paleocene Purgatory Hill local fauna (*4*) in the Tullock Formation and one tooth from the latest Cretaceous Harbicht Hill local fauna (*4*) in the Hell Creek Formation. These teeth represent two species of a new genus. The Cretaceous species was contemporaneous with at least six species of dinosaurs and in fact was recovered from the same stream channel sand as was a main part of the mounted skeleton of *Triceratops* in the American Museum of Natural History (A.M.N.H. No. 5033).

Family Paromomyidae
Purgatoriinae, new subfamily

Diagnosis: Primitive paromomyids; trigonids of lower molars relatively high, posterior wall of trigonid nearly vertical (except *Mckennatherium*), paraconid distinct, hypoconulid of M_3 relatively unexpanded (except *Plesiolestes*); upper molars transverse, protocone-hypocone crest weak or moderate, metaconule strong, posterior slope of protocone-metastyle crest relatively vertical, angle in labial view on crest between paracone and metacone less than 90 degrees; P^4 (when known) with strong metacone.

Included genera: *Purgatorius, Mckennatherium* (*3*), *Plesiolestes, Palenochtha, Palaechthon.*

Discussion: We tentatively recognize the Paromomyidae as a family distinct from the Anaptomorphidae (which is not clearly distinct from the Omomyidae). We follow McKenna (*5*) and the rules of nomenclature in using the name Paromomyidae rather than Phenacolemuridae. *Phenacolemur* and its ancestor *Paromomys* are markedly divergent from the genera listed above, and distinction at the subfamily level seems warranted. We include *Paromomys* and *Phenacolemur* in the Paromomyinae.

Purgatorius, new genus

Type species: *Purgatorius unio*, new species.

Diagnosis: Purgatoriines with relatively wide stylar shelf on upper molars, only a weak vertical swelling between protocone apex and lingual end of posterolingual cingulum, a distinct concavity between the lingual and labial posterior cingula, relatively strong anterolingual cingulum and protocone-metastyle crest, and sharp conule wings; talonid somewhat (M_2) or considerably (M_3) narrower than trigonid, M_3 distinctly longer than M_2, hypoconulid of M_3 not expanded into third lobe, hypoconulid of M_2 reduced, hypoconid relatively low, paraconid relatively small and not distinct from paralophid; P_4 relatively narrow, with weak paraconid, no metaconid, and basined talonid with two cusps (*6*).

Etymology: From Purgatory Hill,

Table 1. Tentative faunal list for Purgatory Hill local fauna. Symbols: + indicates a record later than any previously reported; — indicates a record earlier than any previously reported. Identifications of nonmammals are by R. Estes. Abbreviations: sp. indet., species indeterminate; sp. unident., species unidentified; n. sp., new species; n. gen., new genus.

Fauna	Minimum number of individuals (*10*)	Total number of specimens
Chondrichthyes		
Isuridae, sp. indet.		
Dasyatidae, sp. unident.		
+cf. *Ischyrhiza avonicola* (*11*)		
Osteichythyes		
Acipenser sp.		
Kindleia fragosa		
+*Lepisosteus occidentalis*		
?Pycnodonta, sp. indet.		
Perciformes, sp. indet.		
Teleostei, sp. indet.		
Amphibia		
+*Scapherpeton tectum*		
Lisserpeton bairdi (*12*)		
+*Opisthotriton kayi* (*11*)		
+*Prodesmodon copei* (*11*)		
Reptilia		
Baenidae, sp. indet.		
+*Compsemys victa*		
Trionyx sp.		
Champsosaurus sp.		
Leidyosuchus sp.		
+*Brachychampsa* sp.		
Multituberculata		
Taeniolabis taoensis	1	1
Stygimys n. sp. (*4*)	1	6
—*Parectypodus* n. sp.	4	7
—*Neoplagiaulax* n. sp.	4	7
+*Mesodma formosa*	2	5
+*Mesodma* cf. *M. ambigua*	1	2
+*Kimbetohia* n. sp.	6	6
+*Cimexomys minor* (*4*)	1	2
Marsupialia		
—*Peradectes* n. sp.	1	1
Insectivora		
+*Procerberus* n. sp. (*4*)	2	4
—*Palaeictops* n. sp.	1	5
—Mixodectidae, n. gen. and sp., cf. *Palaeoryctes* (*13*)	1	3
—Microsyopidae or Mixodectidae, n. gen. and sp.	2	5
Palaeoryctidae, n. gen. and sp.		
cf. *Palaeoryctes* (*13*)	1	3
—cf. *Gelastops* n. sp.	1	2
about 3 other species		
—Primates		
Purgatorius unio, n. gen. and sp.	2	6
Condylarthra		
+*Protungulatum* n. sp. (*4*)	3	22
Oxyclaenus n. sp.	2	9
Oxyclaenus pugnax (*14*)	1	3
—*Tricentes* n. sp. (*15*)	2	10
+*Eoconodon* n. sp.	1	6
Anisonchus oligistus	2	6
+cf. *Hemithlaeus* n. sp.	1	1

with analogy to *Tetonius, Absarokius*, and other genera.

Purgatorius unio, new species (Fig. 1)

Type: University of Minnesota (U.M.) No. V.P.1597, right $M^{?2}$.

Referred specimens: U.M. Nos. V.P.-1652 (right $M^{?2}$), 1504 (right $M_{?2}$), 1506 (left M_3), 1616 (left P_4), and perhaps 1596 (right $M^{?1}$, eroded).

Locality: Early Paleocene Purgatory Hill local fauna, Tullock Formation, McCone County, Montana (*4*).

Diagnosis: Differs from *P. ceratops* in M_2 (one specimen each species) as follows: talonid relatively broader and longer, paraconid less anterior, posterior slope of metaconid moderately bulbous, groove between hypoconulid and entoconid slightly shallower, posterior cingulum from hypoconulid slightly weaker. Transverse width type $M^{?2}$, 2.85 mm; transverse width referred $M^{?2}$, 2.95 mm; length $M_{?2}$, 1.85 mm; M_3, 2.20 mm; trigonid width $M_{?2}$, 1.50 mm; M_3, 1.40 mm; length P_4, 1.60 mm; talonid width P_4, 1.10 mm.

Etymology: *Unio*, a genus of pelecypods, with reference to the clam bed in which *P. unio* was found.

Purgatorius ceratops, new species (Fig. 1)

Type and only known specimen: U.M. No. V.P.1547, right $M_{?2}$.

Locality: Latest Cretaceous Harbicht Hill local fauna, Hell Creek Formation, McCone County, Montana (*4*).

Diagnosis: See *P. unio*. Length $M_{?2}$, 1.85 mm; trigonid width $M_{?2}$, 1.52 mm. Generic separation from *P. unio* is possible but not now warranted.

Etymology: *Ceratops*, a genus of dinosaurs, with reference to the contemporaneity of *P. ceratops* with *Triceratops*.

Although in all or nearly all known characters *Purgatorius* is more primitive (*Procerberus*-like; see *4*) than other purgatoriine and nonpurgatoriine primates, this is not as true with respect to *Mckennatherium*. In at least the following characters *Mckennatherium* seems more primitive than *Purgatorius*: larger paraconid, less bulbous cusps, more vertical lateral walls of trigonid, higher trigonid, hypoconulid distinct on M_2. While it therefore seems unlikely that *Purgatorius* is the stem primate, we suspect that some unknown purgatoriine was ancestral to all other primates (*7*).

Among nonprimates *Purgatorius* has been compared most closely with the primitive erinaceoid *Leptacodon tener*, the apatemyid *Jepsenella*, the leptictid *Procerberus*, the arctocyonid *Protungulatum*, and an undescribed Puercan species of the hyposodont *Promioclaenus*. A community of origin with condylarths cannot be excluded, but many of the similarities of primitive condylarths to *Purgatorius* are not shared with *Mckennatherium* and may be of independent acquisition. There is no indication of special affinity to apatemyids. Erinaceoids may not have originated from leptictids by the time of the first appearance of *Purgatorius*, and the evidence is inadequate to decide which group is closer to primates.

A provisional faunal list for Purgatory Hill is given in Table 1. The fauna indicates an age equivalent to that of the Wagonroad local fuana (*8*) of Utah, or late early Paleocene (late Puercan) in at least provincial usage (*9*).

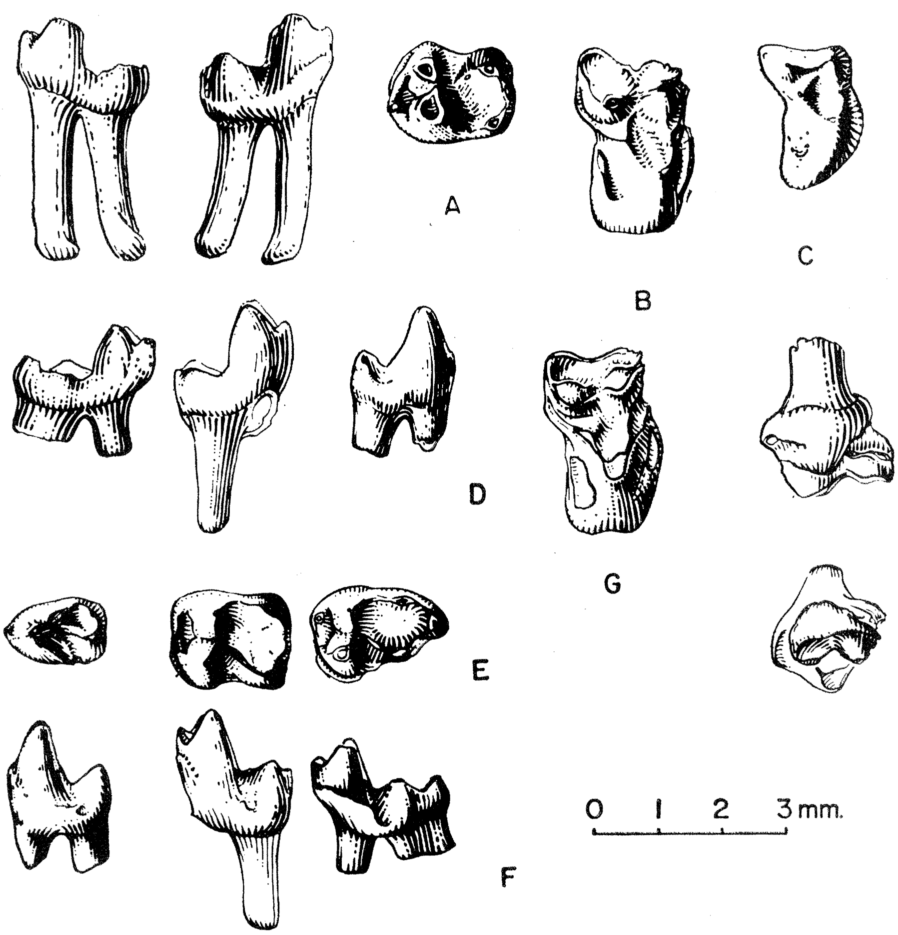

Fig. 1. Isolated teeth of *Purgatorius*, new genus. (*A*) *Purgatorius ceratops*, new species, right M_2 (type) in lingual, labial, and occlusal views. (*B–G*) *Purgatorius unio*, new species; (*B*) right M^2 (type), occlusal view; (*C*) eroded right M^1, questionably referred; (*D*) lingual, (*E*) occlusal, and (*F*) labial views of left P_4, right M_2 (reversed), and left M_3; (*G*) right M^2 (referred) in occlusal, lingual, and labial views.

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Inst. Misc. Collect. 136 (1958) No. 1, p. 1; and E. L. Simons (*1*).
8. C. L. Gazin, *Proc. U.S. Nat. Mus.* **91**, 1 (1941).
9. We thank R. Estes for permission to include his identifications of the nonmammalian vertebrates of Purgatory Hill and S. Babb for the drawings. Investigation supported in part by NSF grant GB-1798 to L.V. and by NSF grant GB-2213 to R.E.S.
10. Use of minimum number of individuals always tends to overrepresent the relative frequency of species with one or a few specimens; use of total number of specimens has a greater error variance only if elements of the same individual are prevalent. Such overrepresentation of single individuals can be tested by a comparison of the calculated minimum number of individuals for each species with that expected on the basis of random sampling of the same number of elements each from a different individual, and then combining the probabilities. In the present case no overrepresentation is shown but the numbers are small. The number of identifiable parts is comparable among the mammals except for the multituberculates, where it is smaller. Minimum number was estimated using tooth homology, side of mouth and attrition.
11. R. Estes, *Univ. Calif. (Berkeley) Publications Geol. Sci.* **49**, 1 (1964).
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13. This genus also occurs in the early Tiffanian of the Bison basin, Wyoming.
14. *Chriacus pugnax* is referable to *Oxyclaenus* by parts now known, as is *C. antiquus*.
15. *Tricentes crassicollidens*, the type species of *Tricentes*, is a synonym of *"Chriacus" truncatus*. The other species of *Tricentes* are referable to *Mimotricentes*, and *Tricentes* is a genus distinct from *Chriacus* and is a senior synonym of *Epichriacus, Metachriacus*, and possibly *Prothryptacodon*.

8 July 1965

Strontium and Magnesium in Water and in Crassostrea Calcite

Abstract. *Distribution of magnesium and strontium was determined between waters and calcites secreted by the oyster species* Crassostrea virginica *and* C. rhizophorae *in natural habitats at eight localities, from Maine to Puerto Rico. The concentration of strontium in the calcite shells increases with increasing temperature in the range 13° to 25°C, and also with increasing Sr^{++}/Ca^{++} molal ratio in the water. The concentration of magnesium in the shells increases irregularly with temperature, and it is apparently independent of the Mg^{++}/Ca^{++} ratio in the water. The greater variation with temperature in the distribution factor for magnesium may be related to genetic differences between semi-isolated populations.*

A number of investigators in recent years studied various aspects of the occurrence of minor elements in the calcareous skeletons of marine invertebrates, such as general patterns of the distribution of minor elements in Recent and fossil phyla, and correlation of the concentration of minor elements in the skeletons with taxonomic level, geologic age, mean annual temperatures, and salinities (*1*). I report here my study of the composition of a biogenic carbonate as a function of more narrowly defined environmental conditions.

In order to relate a biogenic calcite of composition $(Ca_{1-x-y}Mg_xSr_y)CO_3$ to the environmental conditions under which it was formed, at least the following factors must be considered: (i) location of magnesium and strontium in calcite; (ii) change in the composition of calcite, in terms of the mole fractions N_{MgCO_3} and N_{SrCO_3}, with changes in temperature and water composition; (iii) possible effects of such inherent genetic differences as may exist between animal groups (such as between individuals or between subspecies) which secrete shells of comparable composition.

X-ray diffraction measurements (*2–4*) show that in biogenic carbonates $MgCO_3$ and $SrCO_3$ are in solid solution with $CaCO_3$. However, up to approximately 10 percent of the total $MgCO_3$ may be present in noncrystalline form in some high-magnesian algal and echinoid calcites (*4*), and some strontium has been reported to occur in a similar state in an aragonitic gastropod shell (*3*).

In order to determine the distribution of strontium and magnesium between biogenic calcite and water under natural conditions, the following has been done: water samples and temperature readings were taken in the upper 0.6 m of water for 5 to 10 months at approximately monthly intervals at the localities listed in Table 1 (*5*). At the end of the sampling period I collected live specimens of the American oyster, *Crassostrea virginica*, at seven North American localities, and *C. rhizophorae* in Puerto Rico. The linear growth of the shell takes place by increments at the ventral margin; therefore, the ventral portions of the shells, secreted within the sampling period, were treated with Clorox to remove organic matter, and were subsequently analyzed for magnesium and strontium (calcium was found by subtraction). The bulk of the secreted material is the inner calcitic layer of the shell, insofar as the outer prismatic layer in oysters is developed only discontinuously and very poorly (*6*). However, since the rates of growth under natural conditions are not known accurately, the correspondence between the last grown increment and the entire sampling time may not be exact. This uncertainty is likely to be reflected in some of the scatter of the points in Figs. 2 and 3.

Calcium and magnesium in sea water were determined by volumetric titration with disodium dihydrogen(ethylenedinitrilo)tetraacetate, with Metab (Fisher Scientific Co.) as indicator. Strontium was determined by x-ray fluorescence spectrometry, with reproducibility of about ±6 percent, in evaporated residues of 50 ml of the

Table 1. Sampling localities, water and temperature sampling periods, size of *Crassostrea* samples used for analysis, and depth of sample collection.

Locality, lat. N, long. W	Sampling period	Sample size (specimens)	Water depth (m)
Boothbay Harbor, 43°50.6′, 69°38.5′	May to Sept. 1964	8	1
Great Bay, 43°07.8′, 70°53.1′	June 1963	10	2
Pond Point, 41°11.7′, 73°01.2′	May to Sept. 1964	3	8
Franklin City, 38°00.4′, 75°23.2′	May to Oct. 1964	6	Intertidal
Beaufort Inlet, 34°43.4′, 76°40.8′	May to Oct. 1964	5	<1
Newport River, 34°45.1′, 76°41.4′	May to Oct. 1964	4	<1
Pass Marianne, 30°14′, 89°15′	July 1964 to March 1965	8	3
Aransas Bay, 28°03.5′, 96°57.5′	May 1964 to Feb. 1965	6	1
Magueyes Island, 17°58′, 67°03′	June 1964 to March 1965	8	Intertidal mangrove