across kink-band boundaries and that (ii) [010] was the axis of external rotation in the kink-band boundaries. Inversion to clinoenstatite in highly deformed parts of the enstatite grains was observed by Turner *et al.* (*5*). Inversion to clinoenstatite in kink bands and also in lamellae parallel to (100) was produced in the present experiments.

Diopside. Diopside in a eucrite gabbro and bright green diopside in the peridotite nodule deformed at 700°C to 850°C, when viewed in incident light, showed broad discontinuous twins parallel to (001) and narrow slip (or twin) traces parallel to (100). In thin section, lamellar twinning on (100) is seen to occur on a fine scale. In the undeformed diopside of the peridotite, exsolution lamellae or twins parallel to (100) are rare, and therefore the lamellar twinning observed must have been produced experimentally. Twinning elements determined by universal stage measurements in both polished and thin sections are $K_1 = (100)$, the composition plane; $\eta_1 = [001]$, the twin axis; $K_2 = (001)$; and $\eta_2 = [100]$. It is not possible to determine whether slip on (100), as invoked by Griggs *et al.* (*6*) to account for large external rotations, and the absence of internal rotation of (100) exsolution lamellae in kinked diopside may have occurred in addition to twinning on (100) in my experiments. However, such rotation of the untwinned lattice as I have observed, although in accord with inhomogeneous slip on the system $T = (100)$, $t = [001]$, may be accounted for entirely by variation in the density or spacing of the (100) twin lamellae within the crystal (Fig. 4).

Basal twins (Fig. 4) have been produced experimentally in diopside by other workers (*6*), and the twinning elements deduced are in agreement with those determined in the present work. The composition plane is (001), the twin axis $= [100]$, and (100) twin lamellae remain parallel to (100) in the twinned lattice after rotation by the basal twin gliding. The twinning elements are, therefore, $K_1 = (001)$, $\eta_1 = [100]$, $K_2 = (100)$, and $\eta_2 = [001]$.

Kyanite. Slip traces are parallel to (100), and well-developed kink bands (Fig. 1, right) in which external rotation takes place about [010] serve to define the slip direction as [001] (Fig. 3). The slip system so determined confirms the early observations of Mügge (*7*). No mechanical twins were produced experimentally. However, the kink bands which also occur in naturally deformed kyanite superficially resemble twins and may be mistaken for them, as Mügge (*7*) pointed out.

Although it is premature to draw any broad conclusions about the relation between glide mechanisms and crystal structure of the silicates in general, some structural control of the glide elements in the crystals studied is apparent. (i) For the three minerals—olivine, enstatite, and kyanite—for which translation gliding could be demonstrated, the choice of glide plane is such that the strong silicon-oxygen bonds remain unbroken. In olivine and kyanite more than one such plane exists (*8*) but in the enstatite structure, (100), the slip plane is the only planar surface which satisfies this criterion. (ii) Within the glide plane, for each mineral, the glide direction is that direction for which the Burgers vector for a unit edge dislocation in the plane is least, thereby minimizing the length of a unit translation during slip. In olivine and kyanite the slip directions, [001], are also parallel to close-packed rows of oxygen atoms; in enstatite, one-third of the oxygens in the slip plane are close-packed in the slip direction.

The similarity between the structural arrangement of enstatite and diopside on the (100) face makes it probable that $T = (100)$, $t = [001]$ would be the easy glide system in diopside also. Twin gliding on (100) in the direction [001] has been demonstrated here, and the likelihood of translation glide on the same system, as suggested by Griggs *et al.* (*6*), is supported by these structural considerations.

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22 July 1965

Potassium-Argon Age from a Granite at Mount Wilbur, Queen Maud Range, Antarctica

Abstract. *The basement complex of the Robert Scott Glacier area, Queen Maud Range, Antarctica, consists of a complex suite of metasedimentary and metavolcanic rocks intruded by light gray biotite granite. Brown biotite from a granite at Mount Wilbur was dated by the potassium-argon method at 470 ± 14 million years; this age coincides closely with many other ages from granitic rocks in the Transantarctic Mountains.*

Intrusive igneous rocks, mostly light gray biotite granite, are exposed extensively in the Robert Scott Glacier area, Queen Maud Range, Antarctica (Fig. 1). They make up the entire basement in the southern part of the area, while in the north they intrude thick sequences of metasedimentary rocks. The general geology of this area has been described (*1*).

Some of the oldest rocks exposed in the area are metagraywackes with a thickness estimated to exceed 3000 m; the beds dip vertically and strike parallel with the mountain front. The metagraywackes have been metamorphosed to the greenschist facies and are restricted to the LaGorce Mountains where they are intruded by the typical gray granite of this area.

North of the Watson Escarpment in the area of the Leverett Glacier the gray granite intrudes thick, more gently dipping, slightly metamorphosed carbonates, sandstones, and rhyolites. These beds of the Leverett group contain thin beds of carbonate rich in trilobite fragments that appear to be of Cambrian age. The carbonate beds are more than

1500 m thick and occur only in this one area.

The granitic rocks were examined in greatest detail in the area around the head of the Robert Scott Glacier, near Mount Wilbur. Typically, these rocks are covered by sedimentary rocks ranging in thickness from only a few meters to more than 700 m, except where the sedimentary strata have been eroded and the old erosion surface on the basement is exposed. The summits of many of the mountains lacking the sedimentary cover are gently undulating and represent the pre-Permian erosion surface.

The predominant rock type in the basement is a medium- to coarse-grained, gray biotite granite that weathers dull reddish-brown. Inclusions, some of them obviously differentiation products while others are xenoliths of metasedimentary rocks, are common in the granite. At Mount Wilbur and Mount Weaver the xenoliths are oriented with their long axes vertical or nearly so. Some of the xenoliths are more than 70 cm long, but most are less than 15 cm. The granite is cut by pegmatite dikes, the largest of which is about 1 m thick.

Mount Mooney, a few kilometers north of Mount Paine, is composed principally of coarse-grained, red biotite granite, with a few patches of gray granite. The red granite is most often present near intrusive contacts and is a facies of the gray granite. At Mount Gardiner, the red granite can be traced into the typical granite.

A K:Ar age determined (*2*) from one sample of brown biotite from a typical gray granite at Mount Wilbur (Fig. 1) is 470 $\pm$ 14 million years. Details of the analysis follow: potassium (average), 6.85 percent; K^{40}, 8.35 parts per million; Ar^{40}, 0.263 and 0.258 ppm; and $Ar^{40}:K^{40}$, 0.0312. Constants were: $\lambda\beta = 4.72 \times 10^{-10}$ per year; $\lambda e = 0.585 \times 10^{-10}$ per year; $K^{40}:K = 1.22 \times 10^{-4}$ ($\lambda\beta$ and λe are branching decay constants of K^{40}). This age closely coincides with Treves's (*3*) dates of 470 $\pm$ 36 million years (K:Ar) from biotite and 516 $\pm$ 72 million years (Rb:Sr) from a whole-rock analysis of a quartz monzonite from the Ohio Range, about 300 km to the east.

Recently, Rb:Sr ages obtained from muscovite, biotite, and microcline (*4*) from O'Brien Peak, near the convergence of the Robert Scott Glacier with the Ross Ice Shelf, were 460 $\pm$ 20, 450 $\pm$ 20, and 490 $\pm$ 20 million years, respectively. These data were interpreted to mean that the ". . . granite was intruded 490 m.y. ago and deformed 450 m.y. ago during the Ordovician" (*3*, p. 239).

A granodiorite from the Thorvald Nilsen Mountains, about 100 km northwest of Mount Wilbur, was recently dated by both the K:Ar and Rb:Sr methods (*5*). Biotite yielded 472 $\pm$ 10 million years by K:Ar and 846 $\pm$ 35 million years by Rb:Sr. This was interpreted to mean that the earlier date was the time of crystallization and the later date was a time of thermal metamorphism.

At least some of the ages of 470 million years from the Transantarctic Mountains do not necessarily reflect times of crystallization, but only of metamorphism. Other such ages do represent a time of crystallization about 470 to 520 million years ago. Paleontologic dates agree with radiogenic dates.

Metamorphic rocks containing Early Cambrian archeocyathids have been intruded by granitic rocks in some parts of the Transantarctic Mountains (*6*). The trilobite-bearing Cambrian (?) limestones near the lower part of the Robert Scott Glacier are intruded by granitic rocks, which are overlain, in

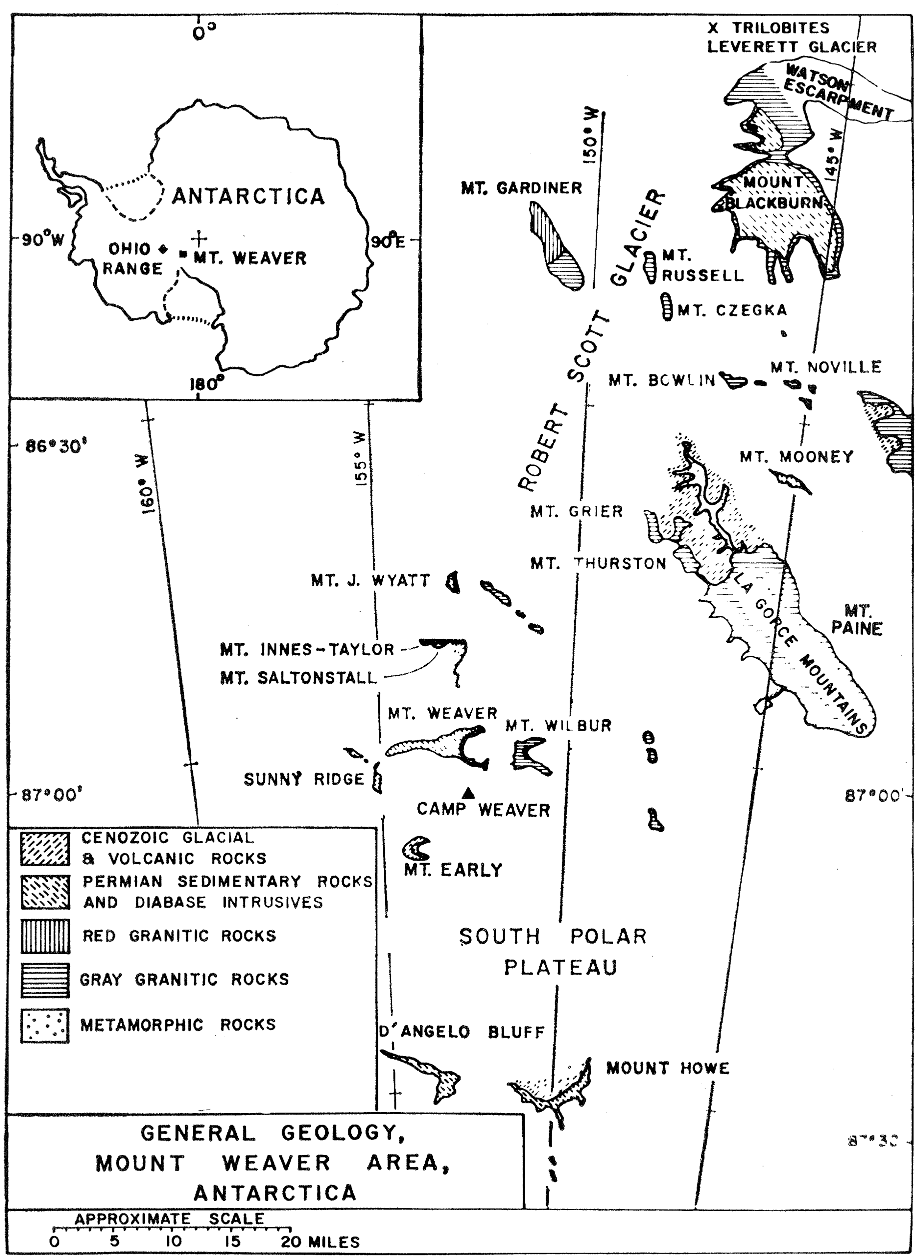

Fig. 1. Generalized geologic map of the Mount Weaver area, Queen Maud Range, Antarctica.

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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12 July 1965

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