magnitude of I_c that have been observed between cooldowns). We checked the repeatability of these data as a function of T by sweeping temperature down and up and checking that the observations remained the same. The most striking aspect of the I_c data is that, for $1 - (T/T_c) > 0.3$, the values were several times greater than the maximum depairing (*16*) currents in bulk ^{3}He-B (Fig. 3). Several calculations predict such enhancement (*11, 12, 14*). The observed quadratic growth in I_c is a feature predicted (*17*) for diffuse-scattering boundary conditions for quasiparticles. We also note that I_c seemed to fall to zero well below T_c of the bulk liquid.

The techniques and measurements reported here create several opportunities for macroscopic quantum physics research in superfluid ^{3}He. Continuous measurements of $\Delta\phi$ (using the absolute pressure calibration from the Josephson frequency relation) as demonstrated here can be used in experiments focusing on macroscopic quantum phase. Further, the detailed information on the $I(\Delta\phi)$ of a superfluid ^{3}He weak link will allow the future development of a superfluid "two-slit" interferometer. This device, which is analogous to the superconducting dc-SQUID and is sometimes called a "superfluid quantum interference gyroscope," should be a sensitive rotation sensor (*18*).

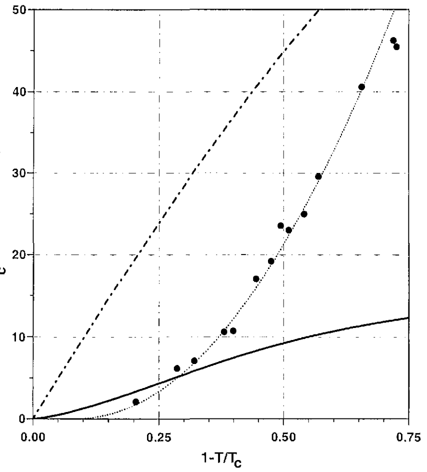

Fig. 3. The measured values of the critical current for the microaperture array weak link divided by 4225 (circles) as a function of $1 - (T/T_c)$. Here we have used the I_c that is derived from analysis of the pendulum mode; the values are consistent with those derived from the quantum oscillations. For $1 - (T/T_c) > 0.3$, the values of I_c are several times greater than the maximum depairing currents in bulk ^{3}He-B (solid line) (*16*). The predictions for a pinhole aperture (*12*) (dot-dash line) are shown for comparison. The data are best fit by $I_c = 104[1 - (T/T_{ca})]^2$ pg/s, where $T_{ca} = 0.85$ mK (dotted line). The observed quadratic growth in I_c is a feature predicted to be associated with diffuse-scattering boundary conditions for the ^{3}He quasiparticles (*17*).

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6 August 1997; accepted 7 October 1997

A Tribosphenic Mammal from the Mesozoic of Australia

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A small, well-preserved dentary of a tribosphenic mammal with the most posterior premolar and all three molars in place has been found in Aptian (Early Cretaceous) rocks of southeastern Australia. In most respects, dental and mandibular anatomy of the specimen is similar to that of primitive placental mammals. With the possible exception of a single tooth reported as Eocene in age, terrestrial placentals are otherwise unknown in Australia until the Pliocene. This possible Australian placental is similar in age to *Prokennalestes* from the late Aptian/early Albian Khoboor Beds of Mongolia, the oldest currently accepted member of the infraclass Placentalia.

The known Cretaceous fossil record of placental mammals comes primarily from three areas: Mongolia, Middle Asia (Uzbekistan, Kazakhstan, and Tajikistan), and the Western Interior of North America. In addition, single genera have been described from India and Baja, California, and single teeth have been reported from France and Mississippi (Fig. 1). Except for the Mongolian *Prokennalestes* and Uzbekistani *Bobolestes*, all are Late Cretaceous in age. This record, based on about 2 dozen genera, is meager compared with that of Cenozoic placentals. In a roughly comparable time span, there are literally thousands of Cenozoic placental genera known.

Because Mesozoic tribosphenic mammals were unknown on all Southern Hemisphere continents in 1986, in that year Jóse Bonaparte proposed that subsequent to the end of the Jurassic, the Gondwanan mammalian fauna had evolved completed isolated from faunas on the northern continents until the end of the Cretaceous or the beginning of the Paleocene (*1*). According to Bonaparte, during this period of isolation, marsupials and placentals arose from more primitive tribosphenic or near tribosphenic mammals in Laurasia. According to this hypothesis, tribosphenic mammals of any kind reached South America for the first time near the Cretaceous-Tertiary boundary, from North America. From South America, marsupials then dispersed across Antarctica to Australia.

The concept of the complete isolation of the Gondwana continents from tribosphenic mammals until the end of the Cretaceous was first challenged with the an-

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nouncement in 1991 of *Tribotherium africanum* in the ?Berriasian (Early Cretaceous) Anoual assemblage of Morocco (*2*). *Tribotherium africanum* is a primitive tribosphenic mammal that has characteristics typical of neither marsupials nor placentals (*2*). Subsequently, a possible placental mammal was reported from the ?Cenomanian-Campanian (Late Cretaceous) of Brazil (*3*).

Here we describe a tribosphenic mammal from Aptian rocks of Australia (Fig. 2): subclass Theria Parker and Haswell, 1897; infraclass Placentalia? Owen 1837; order Ausktribosphenida ord. nov.; family Ausktribosphenidae fam. nov.; *Ausktribosphenos* gen. nov.; type species *Ausktribosphenos nyktos* sp. nov.

Aukstribosphenos nyktos is unlike the Monotremata (*4*–*6*) in having (i) a paraconid on M_1; (ii) all molar trigonids relatively anteroposteriorly expanded; (iii) a well-developed tribosphenic wear pattern on the lower molars, particularly in the talonid basin (Fig. 3); (iv) a P_5 with three trigonid cusps and a trigonid sub equal in size to that on the M_1; and (v) in lacking an internal coronoid process. The absence of a masseteric canal and masseteric foramen differentiates *A. nyktos* from all monotremes except for *Tachyglossus aculeata* with its highly reduced dentary.

Aukstribosphenos nyktos differs from the Aegialodontidae (*7*) (i) in having more anteroposteriorly compressed molar trigonids and (ii) in lacking a distal metacristid on M_{1-3} (*8*). It can be distinguished from the Pappotheriidae (*7*) in having (i) lower cusps on the molar trigonids and (ii) the talonid width broader than the trigonid width on M_1. *Aukstribosphenos nyktos* can be differentiated from both the Marsupialia and the Deltatheroida (*9*) in that (i) the most posterior lower premolar has all three trigonid cusps well developed; (ii) there are three, rather than four, lower molars and at least four, rather than three, lower premolars; and (iii) except for phascolarctids (koalas), there is no inflected angle on the dentary. It can be further distinguished from the Marsupialia in the absence of a posterolabial cingulum on M_{1-3}, and from the Deltatheroida in having (i) strong, well-developed talonids, (ii) strong precingulids, and (iii) paraconids lower than metaconids on M_{1-3}.

Aukstribosphenos nyktos is unlike all other Placentalia, including *Prokennalestes*, in having (i) a remnant of the surangular facet, (ii) a hypoconulid located close to entoconid on the lower molars, and (iii) a crest on M_{1-2} linking the hypoconulid and metaconid buccal to the entoconid, which is separately linked to the metaconid (*10*). In addition, it is distinguished from all other Placentalia, except *Prokennalestes*, by the presence of (i) remnants of a Meckelian groove and (ii) a coronoid bone on the lingual side of the dentary (*10*). On the other hand, *A. nyktos* is similar to many more advanced placentals, but differs from *Prokennalestes*, in having (i) a much smaller M_3 relative to M_{1-2}; (ii) lower trigonid cusps on M_{1-3} relative to tooth length; (iii) the presence of four, double-rooted lower premolars instead of five; (iv) the presence of a single-, rather than double-rooted, C_1 or the presence of a single-, rather than double-rooted, P_1 (*11*); (v) the absence of a protruding angular process on the dentary (*12*); and (vi) the lack of a labial mandibular foramen.

Etymology: *Ausktribosphenos*, "the Australian Cretaceous tribosphenic mammal"; *Ausktribosphenos nyktos* sp. nov. Holotype: (Monash Science Centre) MSC 007 (Fig. 2); found by N. Barton on 8 March 1997. Diagnosis: that of the genus until other species are described. Type locality, stratigraphic unit, and age: Shore platform at Flat Rocks, Bunarong Marine Park, Victoria, Australia, 38°39′40 ± 02″S, 145°40′52 ± 03″E (World Geodetic Standard 1984), Wonthaggi Formation, Strzelecki Group, Aptian (*13*) (Fig. 4). Etymology: *nyktos*, "night."

The most anterior alveolus on the dentary is either that of the C_1, in which case four premolars were present, or a single-rooted P_1 in a jaw where five premolars occurred. The small size of this alveolus relative to those immediately behind it supports the identification of it as a premolar, rather than a canine. For descriptive purposes, this most anterior alveolus is regarded as that of P_1. The dentary is broken just anterior to the P_1 alveolus, and the opening of the dental canal can be seen on the broken vertical surface, the dental canal having been traced in an x-ray image forward from the opening of the mandibular foramen in the coronoid area. A partition anterior to the P_1 alveolus appears to be thicker than those between any two alveoli for the same premolar. This supports the identification of the P_1 alveolus as that of a single-rooted tooth rather than the posterior one of a double-rooted tooth.

Despite the dentary being preserved posterior to a point somewhat anterior to the P_1, there is not a single mental foramen visible. Likewise, no labial mandibular foramen is evident in the mandibular fossa.

The length and width of the P_5 are 1.4 and 1.2 mm. There is no hint of a talonid-like structure on this tooth. If a cuspule were present near the middle of the postcingulid, it was destroyed when the rock in which the specimen was preserved was broken open. If it were present, it would have been quite small, because the loss in that area of the tooth would be no more than one- or two-tenths of a millimeter.

The form of the P_5 of *A. nyktos* is unusual, but not unknown in placentals. Some erinaceids have a well-developed trigonid and merely a postcingulum, instead of a full-fledged talonid, on the most posterior lower premolar (*14*). The length and trigonid and talonid widths of the M_1 are 1.6, 1.4, and 1.7 mm. Although there

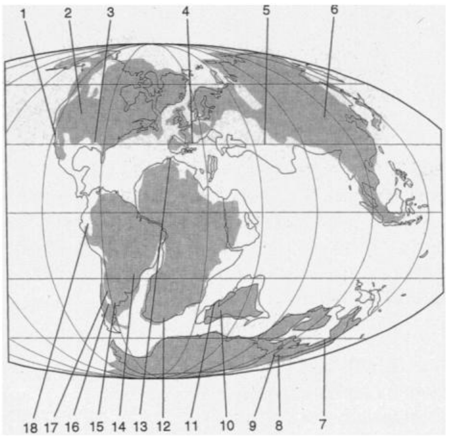

Fig. 1. 1 to 6, 8, 10, 14: sites or regions with Cretaceous placental mammals; 7, 9, 11, 12, 13, 15 to 18: Cretaceous mammal sites or regions in Gondwana with no recognized placentals. Paleogeographic map of land surfaces during the Aptian, late Early Cretaceous, 115 million years ago. Mollweide projection (*28*). 1. Baja, California. *Gallolestes*, Campanian (*29*). 2. Western Interior of North America. *Avitotherium*, *Batodon*, *Cimolestes*, *Gypsonictops*, *Paranyctoides*, *Telacodon*, Campanian-Maastrichtian (*30*). 3. Mississippi. Tooth fragment, Santonian (*31*). 4. France. Champ-Garimond, Tooth, Campanian (*32*). 5. Middle Asia (Uzbekistan, Kazakhstan, and Tajikistan). *Alymlestes*, *Aspanlestes*, *Beleutinus*, *Bobolestes*, *Buklaklestes*, *Cretasorex?*, *Daulestes*, *Khuduklestes*, *Kumsuperus*, *Otlestes*, *Oxlestes*, *Sailestes*, *Sorlestes*, *Taslestes*, *?Zalambdalestes*, and *Zhelestes*, Latest Albian-Coniacian (*33*). 6. Mongolia. *Prokennalestes*, ?Late Aptian/Early Albian (*19*). *Asioryctes*, *Barunlestes*, *Kennalestes*, *Zalambdalestes*, ?Campanian-?Maastrichtian (*34*). 7. Australia. Lightning Ridge, Middle Albian (*6*). 8. Australia. Flat Rocks, *Ausktribosphenos*, Aptian. 9. Australia. Dinosaur Cove, monotreme humerus, MSC 011, Albian (*35*). 10. India. *Deccanolestes*, Maastrichtian (*36*). 11. Madagascar. Mahajanga Basin, Campanian? (*37*). 12. South Africa. Kirkwood, Portlandian-Early Valanginian (*38*) 13. Morocco. Anoual, ?Berriasian (*2*). 14. Brazil. São Paulo State, Adamantina Formation, ?Cenomanian-Campanian (*3*). 15. Argentina. Río Negro Province, Los Alamitos Fauna, Campanian (*39*). 16. Argentina. Río Negro Province, Anacleto Member, Río Colorado Formation, Campanian-Maastrichtian (*40*). 17. Argentina. Neuquén Province, La Amarga Formation, Neocomian (*41*). 18. Peru. Upper Santonian–Campanian (*42*).

is a definite notch present in the paracristid, there is no sign of a true carnassial notch in this structure. The metacristid is too damaged in the expected area of a notch to ascertain if a true carnassial notch was present.

The M_2 is 1.8 mm long. This tooth is slightly smaller and the corresponding cusps slightly lower than those on M_1. Aside from a few other differences noted in the balance of this paragraph, the two teeth are much alike. A prominent cristid (uc1, unnamed cristid 1) (Fig. 3A) descends on the posterior side of the metaconid and extends toward a similar entocristid directed forward from the entoconid. Unnamed cristid 1 is not a distal metacristid (8), because it is not even remotely close to the cristid obliqua. Lingual to the entocristid and subparallel to it is a second, higher cristid (uc2) (Fig. 3A) extending forward from the entoconid along the lingual margin of the tooth. Along the length of this cristid are one or two small cuspules, the one at the anterior end being the most distinct. Between these two cristids, extending in parallel forward from the entoconid, is a small basin partially cut off from the rest of the talonid basin. The same pattern may have been present on M_1, but has been obliterated by wear. The hypocristid is preserved on the M_2, being much lower than the hypoconulid and convex posteriorly in occlusal view. Extending forward into the talonid basin from the hypoconulid is an arcuate cristid (uc3) (Fig. 3A) that parallels the base of the entoconid, continuing to a point where it joins the posterior cristid from the metaconid and the entocristid from the entoconid. Uc3 is a unique feature of *A. nyktos*. This autapomorphy alone forms the basis for the recognition of the Order Ausktribosphenida. Uc3 appears to have also been present on M_1 but was heavily damaged when the rock in which the fossil was preserved was broken open.

The length and trigonid and talonid widths of the M_3 are 1.2, 0.9, and 0.9 mm. This is the one tooth of the holotype that is completely undamaged. With broad talonid basins on the lower molars that show evidence of wear on the labial side of the entoconid (Crompton's wear facet 6) and

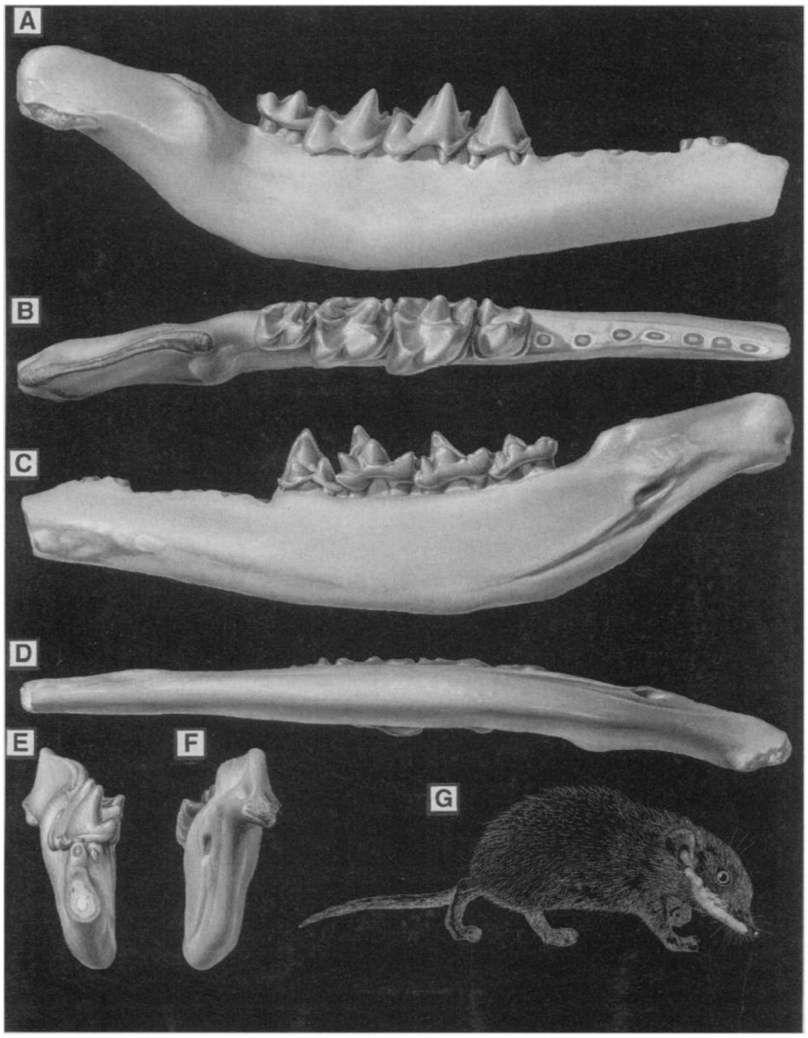

Fig. 2. Holotype of *A. nyktos*, MSC 007. Maximum length of specimen, 16 mm. (**A**) Labial view. (**B**) Occlusal view. (**C**) Lingual view. (**D**) Ventral view. (**E**) Anterior view. (**F**) Posterior view. (**G**) Holotype of *A. nyktos* superimposed on a restoration of what the living animal (size ~8.5 cm) might have looked like. A stereo figure of *A. nyktos* is available at www.sciencemag.org/feature/data/972804.shl and will be published in 1998 in the *Records of the Queen Victoria Museum* No. 106. [Technical art by P. Trusler, reconstruction by D. Gelt]

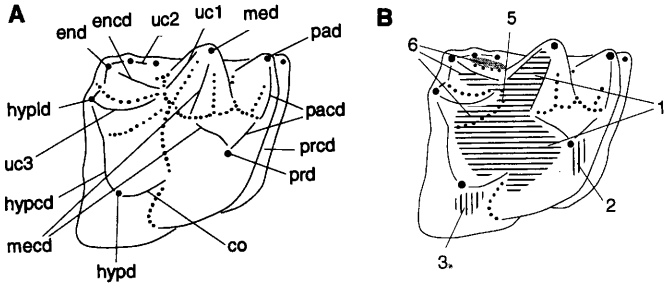

Fig. 3. (**A**) Generalized lower molar of *A. nyktos*. Abbreviations: co, cristid obliqua; encd, entocristid; end, entoconid; hypld, hypoconulid; hypcd, hypocristid; hypd, hypoconid; mecd, metacristid; med, metaconid; pad, paraconid; pacd, paracristid; prcd, precingulid; prd, protoconid; uc1, unnamed cristid 1; uc2, unnamed cristid 2; uc3, unnamed cristid 3. (**B**) Restoration of the wear surfaces on the lower molars of *A. nyktos*. See (*15*) for discussion.

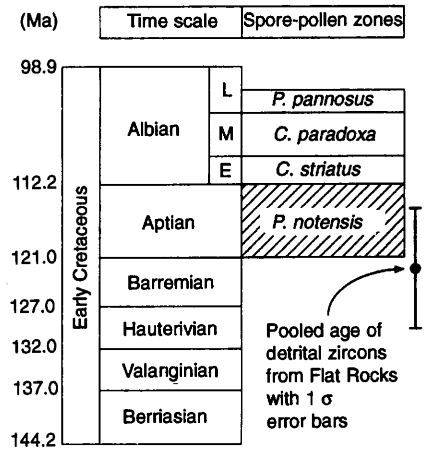

Fig. 4. Age of the Flat Rocks vertebrate fossil site (hatched) relative to the geologic time scale (*26*). Spore-pollen zones modified after Helby *et al.* (*24*).

lingual side of the cristid obliqua, *A. nyktos* appears to have had a prominent protocone on its upper molars and, therefore, can be considered a tribosphenic mammal (Fig. 3) (*15*). In this regard, it is quite unlike the Australian Early Cretaceous monotreme *Steropodon galmani*, where wear in the talonid region of the lower molars is confined to the labial side of the cristid obliqua, Crompton's wear facets 3 and 4 (*16*). Among tribosphenids, as indicated in the diagnoses, *A. nyktos* is not a deltatheroid (*9*), a marsupial, or a tribothere (*7*). Those diagnostic features, coupled with a postcanine dental formula unknown, other than in placentals and highly characteristic of them (*17*), P1-4 or P1-5 and M1-3 are the bases for regarding *A. nyktos* as a placental.

Except for the presence of a remnant of the Meckelian groove and a vestigal coronoid bone, features it shares with the undoubted placental *Prokennalestes* (*10*, *18*), together with the presence of a remnant of the surangular facet, *A. nyktos* has features expected in a rather advanced Cretaceous placental mammal. These features include the marked reduction in the size of the M_3 relative to M_{1-2}, reduced height of the molar trigonids relative to tooth length, greater width of the M_1 talonid than the trigonid, and possible reduction of the premolar number to four or a most anterior of five premolars being a single-rooted rather than double-rooted tooth.

The lack of an angular process on the dentary is not a feature that unites *A. nyktos* with the monotremes. Well-developed dentary angles are present in the only two species of monotreme with functional teeth where the posterior part of the jaw is known: *Obdurodon insignis* and *Obdurodon dicksoni*, as well as in the living echidna, *Tachyglossus aculeata* (*4*, *5*). Although most specimens of the platypus, *Ornithorhynchus anatinus*, lack an angular process on the dentary, individuals are known that have them (*4*). On the basis of the published evidence, there appear to be two additional differences—the number of premolars and the number of molar roots—separating *A. nyktos* from the monotremes. However, there is an edentulous mandible from Lightning Ridge, probably referable to the monotreme *Steropodon galmani* (Australian Museum) AM F97263 which, like *A. nyktos*, has more than two premolars, and the molars have only two roots. The latter feature can also be seen on the holotype of *S. galmani*.

A primitive feature among therians, with or without an angular process on the dentary, is the presence of a pronounced concavity in the ventral profile of that bone ventral to the masseteric fossa (*12*). In contrast, *A. nyktos* has a convex ventral profile in that area, as is the case with advanced placentals, which also lack an angular process on the dentary (*12*).

It has been suggested that during the Cretaceous there was much evolutionary experimentation among tribosphenic mammals. Lineages may have evolved within that plexus that were neither marsupials nor placentals, and the tribosphenic condition may even have arisen independently in the marsupials and placentals (*2*, *17*, *19*). The Deltatheroida have been interpreted in this way, being regarded as a sister group of the Marsupialia; combined, they form the Metatheria (*9*). The Deltatheroida have features, such as the location of the three principal talonid cusps on the lower molars, suggestive of placentals, as well as other character states that associate them with marsupials. In an analogous manner, *A. nyktos*, with its unique lingual molar talonid morphology, may prove to be the sister group of the Placentalia rather than a member of that group sensu stricto. Or *A. nyktos* may represent yet another group of mammals that evolved the tribosphenic condition independently of all previously recognized ones that did. At this stage, the one part of the Cretaceous radiation of tribosphenic mammals from which *A. nyktos* can be confidently excluded is the Metatheria. Thus, on the basis of the features of *A. nyktos* suggestive of the placentals, coupled with an absence of any features that link it with other tribosphenic groups to the exclusion of placentals, it is here provisionally referred to the Placentalia.

Because of this discovery of a possible placental mammal from the Australian Early Cretaceous, it is now plausible that both placentals and marsupials may ultimately be found to have then been widespread on all the land masses of Earth in the Late Mesozoic (*20*). The fossil record of Australian terrestrial mammals for the late Cenozoic is accurate enough to conclude that nonvolant placentals were not present in the mid-Tertiary, rodents having entered the continent by the Pliocene (*21*). A placental presence in the Aptian means that the group would have become extinct in Australia at least once and then reentered the continent at the end of the Tertiary. Coexistence with marsupials during their earlier presence in Australia has not yet been incontrovertibly documented (*22*).

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13. Palynological examination of five mudstone samples collected from a 7-m-thick floodplain sequence immediately underlying the type locality of *A. nyktos* indicates the site is *Pilosisporites notensis* Zone (Aptian) in age. This age determination is based on the presence of the spore *Pilosisporites notensis* in one of the samples examined. This spore makes its first appearance in Australia at the base of the Aptian (*23*) and continues up into the Albian (*24*). The site is not Albian in age because none of the samples examined contained any spore or pollen species that make stratigraphically younger first appearances within the overlying *Crybelosporites striatus*, *Coptospora paradoxa*, or *Phimopollenites pannosus* spore-pollen zones, all of them of Albian age. The Aptian age determination for the type locality is supported by the fission track dating of detrital zircons obtained from volcaniclastic sandstone 50 cm above the bone-bearing conglomerate. The 21 zircons dated yield a pooled age of 122.5 ± 8 million years (Ma) (1σ) with a chi-squared probability of 99.7%. The pooled age represents the age of the source volcanic rocks because vitrinite reflectance measurements of coalified plant fragments from the site indicate the sediments have not experienced burial temperatures greater than 77°C. This is well below the partial annealing temperature for zircon (200°C), which indicates they have not been thermally annealed. This interpretation substantiates an earlier fission track study by Green (*25*) on detrital zircon from similar volcaniclastic sandstones of *Crybelosporites striatus* Zone age in the Otway Basin, ∼130 km to the west of Flat Rocks. Green (*25*) obtained a pooled fission track age that overlapped its chronobiostratigraphic age, suggesting that the lag time between eruption, erosion, transport, and deposition was probably on the order of a few million years. The pooled age for Flat Rocks, therefore, suggests that the site is probably situated close to the base of the Aptian, which ranges, according to the time scale of Gradstein *et al.* (*26*), from 121 to 112.5 Ma.
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where it is equally strong. Although presumably these latter wear surfaces are homologous with wear surfaces 5 and 1, respectively, of Crompton, there are no evident boundaries between them. Some evidence of wear surface 2 may be present on the anterior slope of the protoconid of M$_1$, but there is only the slightest evidence of wear surface 3 and none of wear surface 4 on the anterior and posterior sides, respectively, of the hypoconid. This distribution of wear facets might be expected of a fully tribosphenic mammal in which the unknown upper molars had prominent protocones with major wear surfaces on their tips together with their anterior and posterior slopes. In addition, these upper molars had well-developed wear surfaces on the paracrista (wear surface 1a of Crompton) or preparaconule crista (wear surface 1b of Crompton), or both. Unlike M$_{1-2}$, the M$_3$ is not damaged. Wear facets 1, 5, and 6 of Crompton are present but more subdued than on M$_{1-2}$. There is no sign of wear facets 2-4 on M$_3$.

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43. T.H.R and P.V.-R. acknowledge the long-term support of the Committee for Research and Exploration of the National Geographic Society. We thank J. Archibald, J. Bonaparte, W. Clemens, A. Crompton, F. Goin, J. Hopson, Z. Kielan-Jaworowska, D. W. Krause, J. Lillegraven, M. McKenna, R. Pascual, D. Sigogneau-Russell, R. Sloan, F. Szalay, L. Van Valen, M. Woodburne, and two anonymous reviewers for helpful commentary on this manuscript and F. Coffa, C. de Groot, A. Dyer, D. Gelt, R. Jackson, P. Littlefield, S. Morton, I. Stewart, and P. Trusler for technical assistance.

27 May 1997; accepted 9 October 1997

Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed

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Stream channel erosion has long been suspected as the major contributor to long-term sediment yield from urbanizing watersheds. For San Diego Creek in southern California, measurements from 1983 to 1993 showed that stream channel erosion furnished 10^5 megagrams per year of sediment, or about two-thirds of the total sediment yield. Thus, because channel erosion can be a major source of sediment yield from urbanizing areas, channel stabilization should be a priority in managing sediment yield.

Stream channel erosion can be the major source of sediment in urbanizing watersheds, with deleterious downstream effects (*1*). Increased storm runoff and stream channel changes resulting from urbanization have long been a concern, and work over the past three decades suggests that the relative contribution of long-term channel erosion to downstream sediment yield is substantial (*2–4*). However, the lack of hard data prompted the National Research Council to designate long-term channel erosion rates and sediment budgets for urbanizing watersheds as priority research needs (*5*). Additionally, much less is known about the geomorphologic effects of urbanization in arid regions than in humid regions (*6*). In most arid urban areas, irrigation increases antecedent soil moisture in vegetated areas, further increasing storm runoff. Moreover, urban development may, within the basin, displace rather than replace irrigated agriculture, so that agricultural impacts remain. Here I present data from an urbanizing basin in southern California and examine the role of channel erosion in augmenting sediment yield.

San Diego Creek, which drains a 288-km^2 basin in Orange County, California (Fig. 1), supplies sediment to Newport Bay, which is considered to be one of the primary estuarine wildlife habitats in the state. Urbanization has been rapid (Fig. 1) and is typical of many areas in the United States, especially the Southwest. A federal Clean Water Act study of the basin in 1981 concluded that the sediment sources were agriculture, steep foothills, and construction. Channel erosion was considered unimportant (*7*).

I began a long-term study of channel changes in the San Diego Creek watershed after a brief geomorphologic analysis (*8*) of the area in 1981 suggested that erosion from the largely earthen channel system could be a major contributor of sediment. An initial channel study using historical methods and aerial photogrammetry indicated that from the late 1930s to the early 1980s channel erosion supplied more than one-fourth of all sediment yield, but there were many uncertainties, especially regarding total sediment yield from the basin (*9*). Starting in 1983, I surveyed and installed 196 monumented (more or less permanently marked) channel cross-sections (profiles) at intervals along earthen channels of all types and sizes (Fig. 1). Over time, some profiles were invalidated by disturbance, and problems of property accessibility delayed or prevented measurements in some places. Thus, profiles had to be monitored annually, and new profiles were added as required throughout the decade (*10*). As a cooperator in the study, Orange County annually surveyed the downstream zones of sediment accumulation—trunk channels and in-channel sedi-

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