cause drainages are graded with respect to the old (Miocene?) surface upon which the Watauga and New rivers flow northward. Immediately south of Boone Fork lies the edge of the Blue Ridge escarpment. The Johns River and other actively downcutting south-flowing tributaries to the Catawba River have been denuding the eastern face of Grandfather Mountain, perhaps destroying completely the evidence of glaciation. Even at Boone Fork it appears likely that the remaining evidence will be lost by erosion within a few hundred years.

Whether or not further proof of alpine glaciation is discovered in the higher elevations of the southern Appalachian Mountains of North Carolina and Tennessee, the Boone Fork occurrence has important implications (*18*). Evidence of alpine glaciation in northern North Carolina suggests a glacial origin for abundant polished and striated boulders in the southeastern states. This alternative to the action of river ice was offered by Wentworth (*12*) but has been ignored by later investigators. The existence of periglacial features reported in the southern and central Appalachian Mountains, the Piedmont, and the Atlantic coastal plain are strongly supported. A periglacial origin for the Carolina Bays is brought into focus (*4, 19*). The paleoclimatic and paleobotanical maps of the southern Appalachian area must include local Pleistocene glacial conditions, along with the tundra and boreal conditions suggested by some workers (*3, 4, 10, 15*). Finally, the genus of "warm-water walruses" (*Trichechodon*), suggested by Pleistocene fossils from the southern Atlantic states (*11*), is more likely the ordinary circumboreal genus (*Odobenus*). These Arctic animals probably migrated with the cold water that flowed farther south during glacial maxima, as evidenced by the ostracod studies of Hazel (*20*).

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## Rates of Late Cenozoic Uplift, Baldwin Hills, Los Angeles, California

Abstract. *Radiocarbon ages for the marine late Pleistocene stratigraphic units of the Baldwin Hills are 36,200 ± 2,750 years and 28,450 ± 2,600 years, respectively, defining the termination of marine deposition in this area of the Los Angeles Basin at less than 28,000 years ago. Faunas of the older sample suggest that water depths were about 100 meters at the time of deposition. Shoaling of waters by deposition resulted in very shallow marine to nonmarine conditions about 28,000 years ago. The average rates of uplift for the past 36,000 years have been between 0.5 and 0.8 meter per 100 years.*

A report on ground rupture in the Baldwin Hills (Fig. 1) has pointed to little or no regional uplift in the area during the past half-century (*1*). Other workers have calculated recent rates of uplift of as much as ~0.9 m per 100 years for the same area (*2*). We have evidence that there has been more than 178 m of uplift in the Baldwin Hills within the past 36,000 years, which likely resulted from alternating episodes of uplift and quiescence. The past half-century or so may be one of the stable intervals.

A late Pleistocene phase of marine deposition, in the area of the Baldwin Hills, is dated at 36,200 ± 2,750 years ago [sample I-4867 (*3*)]. The sample contains marine mollusks and foraminiferans; it is from the west side of La Cienega Boulevard, west of the trace of the Newport-Inglewood fault; and it was collected at an elevation of about 78 m on the central graben of the hills. Fossil species of this sample have living representatives largely to the north of Point Conception. These modern representatives include species that are definitive of water depths of about 100 m or more, but not as deep as 200 m (*4*). Thus, about 36,000 years ago this fossil horizon, now at an elevation of about 78 m above present sea level, was forming at water depths of about 100 m; sea level at that time has been interpreted as being about the same as its present level for the Atlantic coast and as much as 100 m below its present level in other areas (*5*). Using these maximum and minimum values for sea level at that time, we calculate the amount of uplift in the past 36,000 years as a minimum of 178 m and a maximum of 278 m. The approximate average rate of uplift in that time ranges from 0.5 to as much as 0.8 m per 100 years, depending on the position of sea level.

An early phase of late Pleistocene shallow marine to nonmarine deposition in the central Los Angeles Basin is represented by littoral or fluviatile deposits and deposits of coalescing alluvial fans building southward from the Santa Monica Mountains. Deposits of a similar character containing clasts similar to the Santa Monica slate were exposed by trenching to a depth of 3.66 m in the summit of the hills, just south of the Baldwin Hills Reservoir at an elevation of about 145 m above sea level. Carbonized wood fragments (sample I-4766) collected from a brown sand bed exposed in the trench, have a radiocarbon age of 28,450 ± 2,600 years (*6*). This sample, now at an elevation of about 145 m, represents a time when there was active sedimentation at or near sea level; there is a general correspondence of data indicating that sea level was 15 or 20 m below its present level about 28,000 years ago (*5*). Thus, an uplift of 160 to 165 m is indicated for about the past 28,000 years, and represents a rate of 0.57 to 0.59 m per 100 years.

The transition from marine to nonmarine conditions between about 36,000 and 28,000 years ago or less involved shoaling of the sea in the basin by more than 100 m in about 8,000 years. This was likely due to a combination of sedimentation, uplift, and a slight decrease in sea level (*5*). We suggest that active sedimentation terminated in the area of the Baldwin Hills proper somewhat less than 28,000 years ago and that the uplift, producing the topographic expression of the Baldwin Hills, commenced after the formation of the sand beds near the summit of the hills. The modern topographic expression of the Baldwin Hills is viewed as the current manifestation of structural activity along the Newport-Inglewood fault zone, which was active during Pliocene to Holocene time (*7*).

The late Pleistocene sequence in the Baldwin Hills finds its counterparts in the Rancho La Brea tar pits of the Los Angeles Basin, just a few kilometers to the north of the Baldwin Hills uplift (Fig. 1). In the tar pits there is a lower marine unit (unit D) with a shallow warm-water molluscan fauna lying beneath freshwater deposits (unit E); the latter contains the well-known vertebrates of the late Pleistocene (*8*). We suggest that this Pleistocene marine fauna of unit D is likely near the northern margin of the waning late Pleistocene sea that occupied the Los Angeles Basin. The somewhat warmer character of the marine fauna there is due in part to shallower marine conditions, and it may also coincide more specifically with the warmer paleoclimatic cycle that reached a peak between 30,000 and 35,000 years ago (*9*). Thus, the Rancho La Brea vertebrate fossils in the overlying nonmarine beds should be younger than 28,000 years. This is corroborated by a maximum radiocarbon date of 21,400 ± 560 years ago, which was obtained from amino acids derived from collagens in the bones of the vertebrates following removal of the tar (*10*).

Clearly, the Baldwin Hills, one of the uplifts along the Newport-Inglewood fault zone, or the Newport-Inglewood zone of faults and folds (*7*), was a site of effective marine deposition until about 28,000 years ago or less. The topographic character of the Baldwin Hills has developed in less than 28,000 years; some other domal uplifts along the Newport-Inglewood trend may be as recent in their development.

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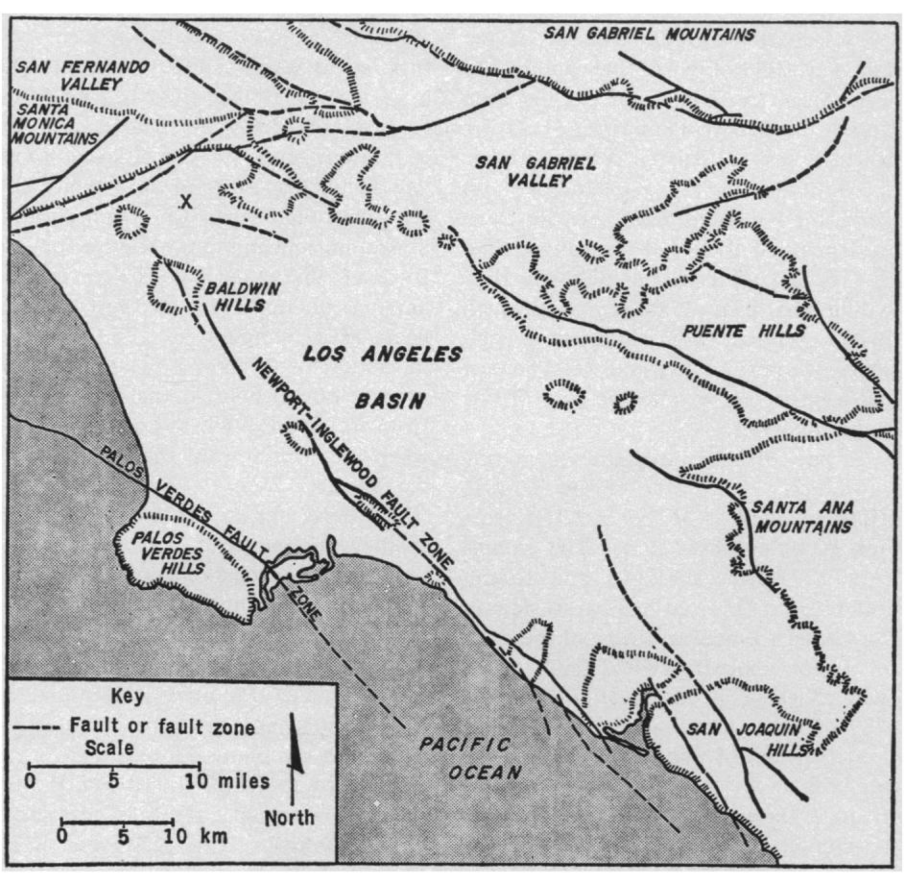


Fig. 1. Generalized location map for the Los Angeles Basin. The topography of the Baldwin Hills is only approximately coincident with the structural figure. The location of the La Brea tar pits is shown by X. [Adapted from Yerkes *et al.* (*11*) and Castle (*12*)]

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3. Sample I-4867 (age 36,200 ± 2,750 years; Isotopes, Inc.) consists of shells of mollusks from a siltstone and sand section, locally called the San Pedro formation. The sample is from beds exposed at the western abutment to an underpass beneath La Cienega Boulevard, 671 m north of Slauson Avenue (33°59′38″N, 118°22′05″W; elevation 77.775 m). It was collected in February 1970 by T. L. Wright, Standard Oil of California.
4. Species of sample I-4867 indicating depths of about 100 to 200 m include the foraminifers *Globorotalia pachyderma* (Ehrenberg), *Islandiella californica* (Galloway and Wissler), *Nonionella globosa* Ishiwada, and *Uvigerina juncea* Cushman and Todd, and the mollusks *Acila castrensis* (Hinds) and *Cardita ventricosa* Gould. See G. J. Anderson, *Micropaleontology* **9**, 305 (1963); T. Uchio, *Spec. Publ. Cushman Found. Foramin. Res. No. 5* (1960); O. L. Bandy, *J. Paleontol.* **32**, 703 (1958); J. A. Cushman and H. B. Gray, *Spec. Publ. Cushman Lab. Foramin. Res. No. 19* (1946); W. P. Woodring, M. N. Bramlette, W. S. W. Kew, *U.S. Geol. Surv. Prof. Pap. 207* (1946).
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## Sediments of Deep Canadian Shield Lakes: Observations of Gross Structure and Biological Significance

Abstract. *Sediments of deep Canadian shield lakes have a firm mud-water interface and an intricately structured, oxygenated surface. Surface relief is not uniform, but is broken by small ridges and upright chironomid tubes. The sedimentary material behaves like a weak jelly and becomes flocculent only when violently disturbed. Sculpins were observed to rest on and, when startled, to hide in the oxygenated layers. Sequestering of nutrients in the bottom sediments is enhanced by the structuring of the substrate surface below 10 meters, and may inhibit nutrient recycling at overturn.*

The sediments of deep small lakes are often so weak in structure that echo sounders barely record a trace at their surface. It is often difficult to determine the precise level at which a weight touches "bottom." When dredges return the material to the surface and it is held in aquariums, it takes months to settle even partially. For these and other reasons, it has been conjectured that the deep sediments are in a state of semisuspension, and that they are loosely flocculent, with no true interface. Mortimer (*1*) suggested that "near the bottom there generally exists an undulating detritus or silt layer containing organic complexes . . ." and this suggestion was repeated by Mortimer (*2*) and later by Milbrink (*3*). They and others have assumed that this upper "semisuspended" or "flocculent" layer of the sediments is a source of nutrients returned to the lake waters at turnover. So little is known of the nature of the sediments, however, that biologists and limnologists have sometimes used uncomplimentary words to describe them in conversation. My observations suggest that these assumptions are inappropriate in Canadian shield lakes.

Observations were made primarily in two lakes in Algonquin Park, Ontario. One was a large (6000 ha) oligotrophic lake [Lake Opeongo (*4*)] which stratifies in the summer, but turns over in fall. The maximum depth is 48 m. The shoreline is forested and the terrain is hilly. The action of a dredge in various sediment types was observed in shallow water by divers. The weaker the structure of the material, the deeper the dredge bit before coming to a stop. It was, therefore, a matter of conjecture how far into the "semisuspended" substrate of deep water the dredge sank before stopping and being subsequently triggered.

Gross examination of this deep-water sedimentary material revealed a high percentage of organic debris, including insect wings and decomposing wood. But in most areas the prominent and recognizable item was chironomid tubes, which imparted a pelletlike appearance to the material. A fine glacial silt forms the basic inorganic matrix. Microscopic examination indicated high abundances of diatoms (both Pennatae and Centricae) with lesser abundances of pollen grains such as pine and ragweed. Loss on ignition was 27 percent. (Other sediments from lakes in Algonquin Park lose up to 60 percent on ignition, whereas sediments from southern Ontario nonshield lakes lose 10 to 20 percent on ignition.)

To determine the depth to which dredges sank into this sediment we followed them down using scuba to depths of 35 m. At this depth and temperature (5.1°C), standard quarter-inch (6-mm) wet suits allowed exposure times of about 10 to 15 minutes with only a limited loss of objectivity. No weights were necessary to maintain neutral buoyancy at 33 to 35 m. Hand lights were necessary below about 22 m, and useful below 15 m. We found that it was impractical to overstay the no-decompression limits.

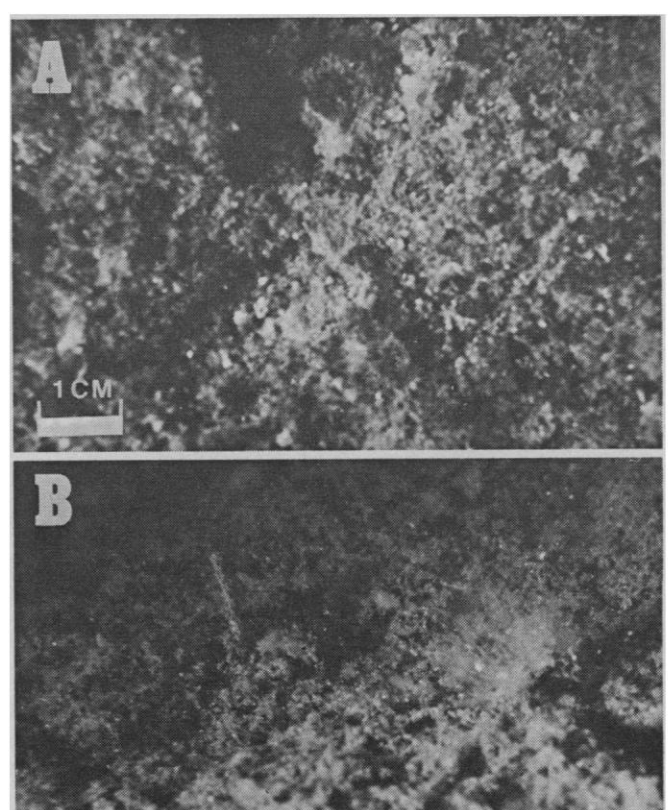


Fig. 1. (A) Photograph of the hole and ejecta left when a sculpin (*Cottus cognatus*) dived through the surface of the bottom sediments of Lake Opeongo in an apparent attempt to escape from divers. (B) Detail of bottom sediments of Lake Opeongo at a depth of 33 m, showing chironomid tubes and a fungal mat.