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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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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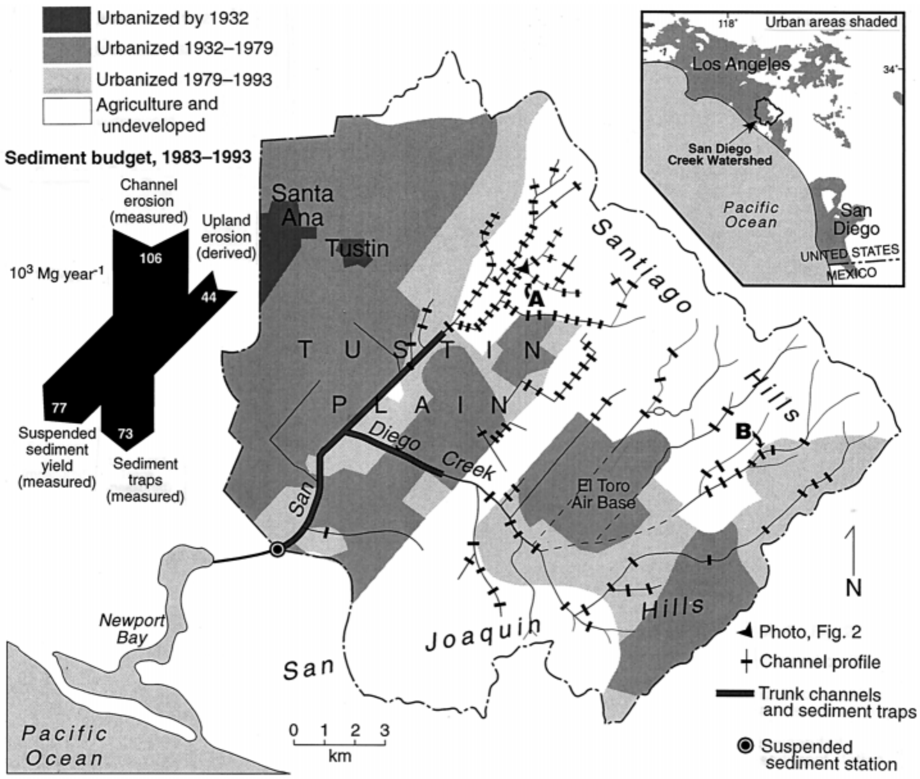

Fig. 1. San Diego Creek, showing the earthen stream channel network and the expansion of urban land, 1932–93. Paved channels and channels lying upstream from reservoirs were not included in the study. The cross-sectional channel profiles shown are those remaining in 1993. Sediment yield is that measured at the station plus accretion in the trunk channels and sediment traps. Inset is the sediment budget (balance). A and B indicate the profiles shown in Fig. 3.

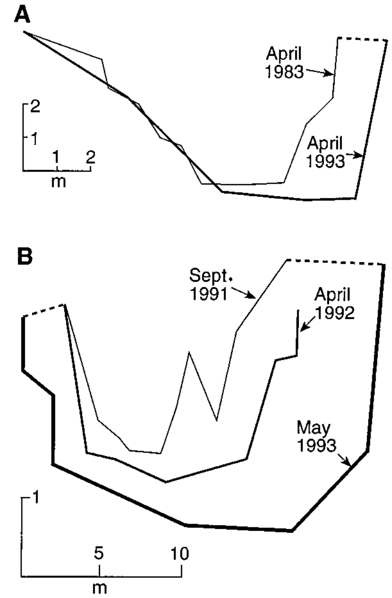

Fig. 3. Surveyed stream channel profiles. (**A**) Hicks Canyon Wash profile 6, 1983 and 1993 (Fig. 2). The rate of erosion at this profile was 0.47 m^3 year^{-1} per meter of channel. At a bulk specific gravity of 1.44, this would be 0.7 Mg m^{-1} year^{-1}, a local erosion rate that was slightly less than the decadal mean for this type of channel. (**B**) Extreme erosion of Borrego Canyon Wash profile 3, directly downstream from an urbanizing area during the wet years of 1992–1993. The rate of erosion was about 20 m^3 m^{-1} year^{-1} or about 29 Mg year^{-1} per meter of channel. This reach has since been stabilized. See Fig. 1 for locations.

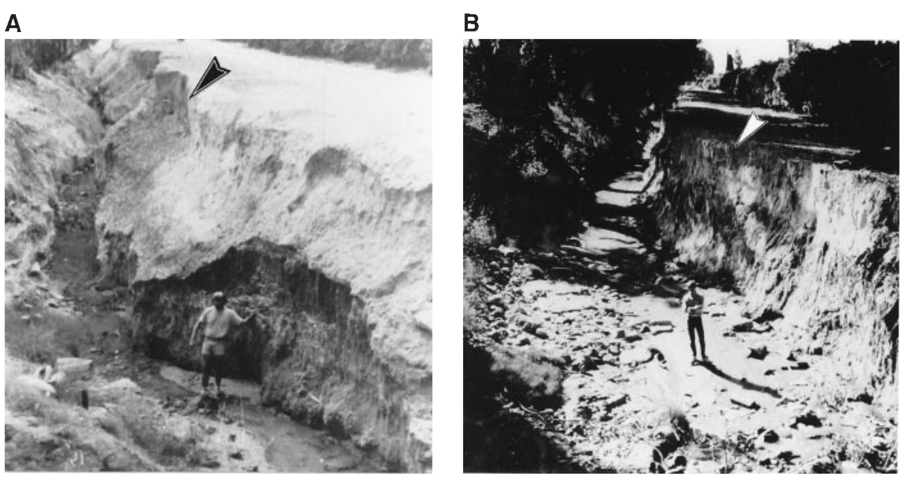

Fig. 2. An example of stream channel erosion in Hicks Canyon Wash, looking southeast at the confluence with Rattlesnake Canyon Wash (Fig. 1). (**A**) 1979. (**B**) 1993. A person stands at approximately the same location in both photographs. Note the retreat of the cut bank to the right. Arrows mark the location of surveyed profiles in 1983 and 1993 (Fig. 3).

ment traps (Fig. 1)—and kept an account of all sediment removed. The county also maintained a full-time suspended sediment measuring station about 2 km upstream of Newport Bay (Fig. 1).

All 108 usable profiles remaining in 1993 were resurveyed. The results indicated that the net average rate of channel erosion was 106×10^3 Mg year^{-1} between 1983 and 1993. Time-lapse photography (Fig. 2) and the survey results (Fig. 3) give graphic evidence of channel enlargement. During the same period, net accretion in the trunk channels and sediment traps was 73×10^3 Mg year^{-1}; and suspended sediment yield at the station was 77×10^3 Mg year^{-1}, constituting a total sediment sink and efflux of 150×10^3 Mg year^{-1}(see sediment budget, Fig. 1). Thus, channel erosion accounted for about two-thirds of the measured sediment yield from San Diego Creek. Average erosion rates show few signs of declining, and new development may locally accelerate channel erosion (Fig. 3B). Hence, amelioration of channel erosion is an appropriate management strategy for sediment control, but little had been done by 1993.

The usually perceived problem with stream channel erosion is that it has deleterious downstream effects in streams, lakes, and estuaries. However, the erosional process itself is also problematic because channel enlargement is often lateral, thus removing substantial areas of valuable urban land; damaging parkland, bridges, and other infrastructure; and making channels unsightly (*2*, *4*) (Fig. 2).

The process of sediment loss in urbanizing basins is analogous to the formation of arroyos that occurred in the Southwest in the late 18th and early 19th centuries (*12*). However, rather than grazing or climatic change, the present cause is the greater magnitude and frequency of peak stream flow in response to impervious urban surfaces. This study joins a growing literature on the role of sediment storage in general; and, in particular, shows that sediment storage loss from stream channel erosion over varied geographic regions can be a major source of sediment yield (*13*). In such cases, sediment yield per unit area can actually increase with basin area rather than decrease, as is commonly perceived.

Suspended sediment measuring stations in sand-bed channels can underestimate total sediment loads (*14*), and this may be the case for San Diego Creek. If substantial, the additional sediment yield could relegate channel erosion to a somewhat smaller proportion of total sediment yield but probably no less than half. Erosion of earthen channels will remain a substantial source of sediment yield from urban stream systems until proper ameliorative measures are taken.

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Adatom Pairing Structures for Ge on Si(100): The Initial Stage of Island Formation

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With the use of scanning tunneling microscopy, it is shown that germanium atoms adsorbed on the (100) surface of silicon near room temperature form chainlike structures that are tilted from the substrate dimer bond direction and that consist of two-atom units arranged in adjoining substrate troughs. These units are distinctly different from surface dimers. They may provide the link missing in our understanding of the elementary processes in epitaxial film growth: the step between monomer adsorption and the initial formation of two-dimensional growth islands.

Because of its importance in microelectronics and its unique properties, the (100) surface of silicon has been extensively investigated. Driven by the capability of the scanning tunneling microscope (STM) to view this surface easily with atomic resolution, Si(100) in particular has been used as a model to understand the atomistic mechanisms of film growth (*1*). For both Si and Ge deposition, early stages of growth at low temperatures produce many stable adsorbed dimers (called ad-dimers), that is, two atoms that clearly remain bound to each other for extended times, as well as rows of many such ad-dimers (called islands) (*2*, *3*). Following classical nucleation theory, in which growth occurs by the addition of atoms to a "critical nucleus" (*4*), it was postulated that Si or Ge monomers deposited on the Si(100) surface diffuse to form ad-dimers and that the ad-dimer is the stable nucleus from which all subsequent larger growth structures (such as the ad-dimer row islands) evolve by addition of further monomers (*2*). Intermediate structures ("diluted-dimer islands"), in which alternate ad-dimers in ad-dimer row islands are missing (*5*) and in which the remaining ad-dimers are rotated (*6*), are thought to arise from individual ad-dimers and to represent an early growth stage (*5*, *7*). Yet this evolution from single ad-dimer to any of the larger structures has not been observable, despite the intrinsic ability of the STM to do so. Hence, a critical element of understanding is missing: the atomistic pathway from the initial adsorbed monomers to the existence of stable ad-dimer row islands. The role of the ad-dimer as the essential element in this pathway has so far not been questioned.

In this report, we describe high-resolution STM observations of structures formed during the initial growth of Ge on Si(100)(2×1) near room temperature, in which the Ge atoms exist as two-atom units that are distinctly different electronically and structurally from any dimer in or on the surface. We show that they provide a physically reasonable link between monomer adsorption and diluted-dimer island formation. We suggest that, at least at low temperatures, ad-dimers are not part of the nucleation-growth pathway.

The experiments were performed on Si(100) with a high-quality 2×1 surface and a defect density of <0.5%, in an STM outfitted with an evaporation source from

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