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SEDIMENT YIELD VARIATIONS IN THE NORTHERN SANTA LUCIA MOUNTAINS

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Sediment Yield Variations in the Northern Santa Lucia Mountains

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Sediment yields in the northern Santa Lucia Mountains affect channel stability and flood inundation levels along the larger streams, riparian vegetation and aquatic habitat associated with the streams, beach sand supply, and the supply of sand available for transport into the deepsea canyon network just offshore. Sediment yields vary considerably over space and time in this region. Understanding this variability is one key to usefully reconstructing events of the recent past and anticipating channel, beach, and offshore dynamics likely to occur in the near future.

Knowledge of sediment yields and transport rates are based on a limited number of measurements of sediment transport (c.f., Matthews, 1989; Hecht and Napolitano, 1995); on progressive measurements of sedimentation rates in three reservoirs (see Figure 1, from Woyshner and Hecht, 2000); and on miscellaneous observations developed by biologists and engineers in the course of evaluating instream habitat and channel stability or flooding potential. Until recently, absence of data and analysis would have precluded developing even initial assessments of sediment yields.

Sediment originating in the northern Santa Lucia Mountains is transported subequally as suspended and bedload sediment (Kondolf, 1982), in contrast to other many other Central Coast streams, where bedload is frequently 10 percent or less of the material delivered from large watersheds. The predominantly granitic or crystalline-metamorphic parent rock often weathers to relatively coarse sands, normally transported by rolling or saltating along the bed. One recent analysis of portions of the sediment retained in San Clemente Reservoir on the Carmel River (Moffatt and Nichol, 1996) indicates that about 95 percent of the material is sand, primarily coarser than 0.25 millimeters.

Spatial Variability

Data to date show much more temporal variability, which masks sub-regional or basin-by-basin tendencies. In keeping with patterns observed elsewhere in the world, the sub-arid portion of the region, where mean annual rainfall is less than 20 inches (600 mm.), appears to yield more sediment per unit area than the sub-humid areas (20 to 40 inches of mean annual precipitation) based on the limited information presently available. One important mechanism for the apparently higher rates in the drier areas is mobilization of sediment stored in valley fills by incision of the larger streams into the adjoining alluvium (Williams and Matthews, 1983; Hampson, 1997). Higher local relief in the wetter areas also contributes to yields from the headwaters. It is difficult to distinguish the effects of climate from those of grazing or other land-use practices, which tend to affect the drier areas to a greater degree.

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Underlying geologic materials strongly affect the mechanisms – and presumably the rates – of erosion. About one-quarter of the northern Santa Lucia Mountains are underlain by Tertiary sandstones and shales (including Monterey Shales), or by Mesozoic Franciscan and Great Valley Assemblages. Since little is known directly about yields from these substrates (Hampson, 1997; Matthews, 1989), rates and processes may be best inferred from adjoining areas with similar erosional influences (Brown, 1973, Hecht and Enkeboll, 1981, Hecht and Kittleson, 1997 for the Tertiary sediments; Brown and Jackson, 1973; Knott, 1976; Hecht, 1983 for the older rocks).

Short-Term Variability

Both rates and processes of sediment delivery vary episodically in the northern Santa Lucia Mountains. Sediment yields following large wildfires, in particular, can abruptly alter sediment yields and result in fundamental changes in the processes which move sediment (c.f., Cleveland, 1973, 1977; Jackson, 1977; Hecht, 1993). Sedimentation in Los Padres Reservoir during the winter following the Marble-Cone fire of 1977 effectively doubled the long-term rate of reservoir filling (Hecht, 1981). Following the same fire, Arroyo Seco aggraded nine feet at the Green Bridge upstream of Greenfield, with the bed gradually being exhumed during the following 4 to 6 years (Roberts and others, 1984); farther downstream, non-cohesive banks of the Salinas River were destabilized during the following 10 years. The pulse of suspended sediment generated by this fire was several times larger than that moved by the record storms of January and February 1969, two of the regional floods of record. Smaller – but still geomorphically-significant -- episodic events generating large volumes of sediment have been attributed to large regional storms, landsliding associated (Fig. 1) with large-scale grading and channel incision and instability (Kondolf, 1982; Williams and Matthews, 1983; Matthews, 1989; Hampson, 1997; Woyshner and Hecht, 2000).

It is difficult to evaluate sediment yields (or sediment storage) in the streams of the northern Santa Lucia Mountains without knowing the recent local history of fire, floods and other episodes. For example, the March 1995 storm fundamentally altered sediment delivery and channel stability on several regional streams, such as Cachagua Creek (Kondolf, 1995), while incision events which altered the entire Carmel River corridor downstream occurred on Tularcitos Creek during 1983 and 1998. At Big Sur, debris flows following fires have complemented overbank flooding during 1995, which left atypical vegetation washed in from the watershed growing on the floodplain downstream from the mountain front (Jeff Norman, pers. comm.).

Episodic variability is sometimes caused and extended by two or more discrete unusual events occurring concurrently, or nearly so. The high rates of sediment yield following the Marble-Cone fire are likely related to a very large buildup in fuel loadings caused by a record snowstorm in January 1974 (Griffith, 1978). The numerous hardwood limbs which broke off during this event had been thoroughly dried in time for the July and August 1977 fire by a hard drought during 1976 and 1977 – at Big Sur, the driest and third-driest years in a century of measuring rainfall. The winter 1978 fire/fill episode resulted from the sequential occurrence of snow, then drought, then lightning.

Whether eroded during isolated or compound episodes, sediment can be rapidly removed from source areas and delivered to the lower alluvial reaches of the master stream or to the near-shore environment following episodic events. Factors promoting quick recovery of the sedimentary system and related instream and riparian habitat values are rapid curtailment of the source of sediment (such as after a fire by regrowth) and/or maintenance of terrestrial channel stability downstream. 'Soft', non-cohesive banks may retreat during the rapid delivery of sediment, adding substantial volumes from bank or bed storage to the event-related yields from far upstream. The additive yields of sediment from these 'primary' and 'secondary' sources can result in large accumulations of sediment in the lower alluvial reaches or on the adjoining continental shelf over a period of a few years, potentially generating density currents in the marine environment. It may be that depositional sequences in the offshore canyons or abyssal plain are most likely to be generated or preserved following episodic events in the high-relief setting of the northern Santa Lucia Mountains.

Valley-Filling Events

The geological evidence points to a number of periods of valley-filling aggradation throughout the northern Santa Lucia Mountains. Multiple river terraces are visible at heights of 1000 feet (300 m) or more along the larger streams, such as the Carmel and Big and Little Sur Rivers. The terraces appear to be remnants of once-continuous and presumably coeval surfaces, now discontinuous and partially buried beneath cones or slopes of colluvial deposition.

Kondolf (1982) shows that the flood of 1911, perhaps in combination with a smaller event in 1914, left deposits which now form much of the floor of Carmel Valley. The flood(s) resulted in sedimentation of typically 2 to 20 feet thick over much of the eastern half of the valley. No subsequent events have even approached the level, magnitude, or extent of deposition. The river terraces visible high above the present-day valley floors may be eroded relics of comparable depositional epicycles in the past.

River terraces and alluvial benches or fans are often ascribed to climatic change, typically to the drying stages of the fluctuations prevailing throughout the Quaternary. Conventional thinking is that the higher rates of erosion prevailing in drier climate lead to accelerated erosion of the weathering which occurred during the wetter stade. This mechanism may or may not play a significant role in the incidence of valley-filling events. It might be held that this epicycle followed a period of protracted drying from the preceding glacial maximum, circa 15000 bp, when the Monterey Bay region was clearly colder and wetter, locally supporting Sitka spruce woodlands (c.f., Adams, 1975). It is also possible that the valley-filling epicycles are associated simply with peaks in sediment supply. Such peaks might be created by discrete events (such as massive erosion following fires, or failures during earthquakes). They may also be an artifact of the rapid rise of the mountains. Very large sediment loads might be generated by temporary obstructions of the main channel (such as the debris flows described by Cleveland in 1973), rapid erosion of large point bars or the previous generation(s) of terraces as the rivers erode beneath the riparian trees which hold such features in place in less tectonically-dynamic settings, or by large failures of soils and regolith as the river undercuts metastabale slopes not previously-attacked for many years (c.f., Kondolf, 1995).

Many homes and extensive public improvements have been built on deposits of the 1911/1914 floods in Carmel Valley. The scale of such valley-filling epicycles should be better known, if only in deference to their public safety implications. They also have a significant, little-understood role in the regional sediment budget when considered at the geologic time scale. Although perhaps better known from Southern California or the Wasatch Front, the causes and implications of valley-filling events in a rapidly-uplifting areas merit consideration and evaluation in many aspects of local geological investigations.

Conclusions

Sediment yields in the northern Santa Lucia Mountains are variable spatially, with underlying geology, rainfall and relief as significant influences. Sediment yields in this region vary even more over both the short term and geologic time frame. The sedimentary record preserved in reservoirs and Quaternary stream terraces helps in understanding accumulation in the lower valleys and near-offshore environments during the recent geologic past. The episodes which generate sediment yields in this high-relief setting may aid in understanding (and be better understood through) the turbidites and other high-energy deposits recorded in the Jurassic and Cretaceous rock record preserved along this coast.

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