TECTONIC EVOLUTION OF SUBMARINE CANYONS ALONG THE CALIFORNIA CONTINENTAL Margin

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ABSTRACT: The development of submarine canyons along active-plate margins commonly is influenced by tectonic processes. Recent studies of submarine canyons along the transform margin of western North America show that the origin and subsequent evolution of many canyons are correlative with plate motion and plate-margin deformation. Elements of canyon morphology such as bends and meanders commonly are controlled by faults and folds that are relatable to the structural fabric of the continental shelf and slope. Some canyon heads that appear to be displaced from their lower reaches are explainable as the result of movement along strike-slip faults associated with the plate margin.

Many submarine canyons along the California margin are not associated with large rivers and thus may owe their origins either to pre-Holocene fluvial or structural processes. Some modern canyons appear to be associated with pre-Pleistocene ancestral canyons. Because of both vertical and horizontal tectonic movements during the past 20 Ma, some California submarine canyons have been repeatedly filled and exhumed; the most recent exhumation began during the latest lowstand of sea level and continues today.

Canyons that today have their upper reaches on the continental shelf are often structurally controlled. For example, detailed studies of the Ascension-Monterey Submarine Canyon system in Monterey Bay suggest that several smaller canyons on the outer shelf and upper slope have been displaced northward from the headward part of Monterey Canyon by right slip along offshore faults of the Palo Colorado-San Gregorio, Ascension, and Monterey Bay fault zones. Many other canyons on the California margin have developed along, or had their courses abruptly altered by, structural zones, owing either to canyon cutting along a zone of weakness or to fault displacement. Mass wasting associated with zones of faulting and slumping, which may have been seismically induced, also may affect canyons. Clearly, submarine canyons along the California margin commonly owe their origin and morphologic development to influences other than fluvial erosion during sea-level lowstands. A chief influence has been the San Andreas fault system.

INTRODUCTION

Many different hypotheses for the origin of submarine canyons evolved during the 60 years before the popularization of plate-tectonic theory. For example, Spencer (1898, 1903) emphasized the role of glaciation, Smith (1902) stressed ocean currents, and Davis (1934) suggested that canyons are scoured by outflowing bottom currents or wave buildup. Daly (1936) and Kuenen (1937) proposed that canyons are cut by turbidity currents, Johnson (1939) that artesian sapping has a role, and Bucher (1940) that thermal circulations are agents of submarine-canyon cutting. Most of these authors sought a single process to explain the origin of submarine canyons. Some more mobilistic concepts, such as continental uplift, as proposed by Hull (1912), and diastrophism, as proposed by Wegener (1924) and de Andrade (1937), were attributed possible roles in the origin of submarine canyons. The role of geologic structure in the development of submarine canyons was discussed by Shepard (1937, 1938b, c, 1957), Shepard and Emery (1941, 1946), Emery (1960), and Shepard and Dill (1966), and Starke and Howard (1968) subsequently suggested that submarine canyons are polygenetic in origin and illustrated this concept in their discussion of Monterey Canyon. However, before the advent of global tectonics and sea-floor-spreading theory, submarine canyons were thought to be formed primarily by fluvial processes, and most canyons to have been cut by subaerial erosion during times of Pleistocene lowstands of sea level (Shepard and Emery, 1941).}

Nearly 60 submarine canyons cut the continental margin of California. Many (28) of these are known to be associated with structures that suggest that their origin and/or development was influenced by geologic structure (Shepard, 1937, 1938c, 1939; Shepard and Emery, 1941, 1946). Other canyons are suspected of being structurally controlled, on the basis of their morphology; but, pending further investigation to determine their origin, the role of tectonics in their evolution remains unclear.

The continental margin of California is mostly situated along the active, obliquely convergent transform boundary between the Pacific and North American crustal plates (Fig. 1). This boundary is defined by the San Andreas fault system, a zone of strike- and oblique-slip faults that ranges in width from 50 to 350 km and extends for more than 1,100 km along most of the length of California (Fig. 1). Since its inception during middle Miocene time (20 Ma), more than 300 km of right-lateral displacement have occurred along the San Andreas fault system (Turner and others, 1970; Matthews, 1973; Huffman and others, 1973).

Submarine canyons were formed, filled, and exhumed along the tectonically unstable margin of California throughout the Neogene. Many canyons owe their origin and subsequent modification to Neogene tectonism, and some appear to have been displaced from their point of origin by right slip along the San Andreas fault system. Uplift and subsidence due to wrenching within this fault system can add yet another element of complexity to canyon history. Thus, active canyons along the California margin commonly have been modified considerably by sedimentary and deformational processes since their formation.

Profound differences exist between canyons formed on active-plate margins and those formed on passive margins. Submarine canyons on the passive margin of the Eastern United States commonly are straight, except for meandering lower-slope channels. By contrast, submarine canyons of the Western United States, especially those along the