toward the southwest and west-northwest respectively, with minor lateral feed from the north.

This flysch sequence was deposited primarily by turbidity currents in an elongate trough supplied from a northerly volcanic source area. In the absence of a confining basement seaward of the flysch deposits, the original depositional basin is interpreted as an oceanic trench. These trench deposits were deformed initially in a semilithified state with the development of axial-plane slaty cleavage. Fold axes parallel the existing continental shelf edge, trending northeast and west-northwest in the outer Shumagin and Sanak Islands, respectively. Folds are overturned seaward predominantly, axial surfaces dipping landward. Locally units may be described as broken formations, though no mélanges are observed. The style of this early folding is consistent with, but not diagnostic of, gravity gliding. Alternatively, the rocks may have been deformed by underthrusting at the trench inner wall. At strain rates of $10^{-13}$ to $10^{-14}$/sec (calculated assuming underthrusting), the trench sediments may have undergone "strain hardening" from increasing internal grain friction and cementation during dewatering.

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## SEDIMENTS AND STRUCTURE OF CONTINENTAL MARGIN, CENTRAL VENEZUELA

The continental margin of central Venezuela is a borderland similar to the area off California. Major east-west faults separate tilted crustal blocks which form horsts and grabens. Gravity gliding on these blocks has developed folds and secondary faults. The shelf east of Margarita Island is a shallow terrace topographically, but seismic profiles show an underlying system of sediment-filled horsts and grabens. The Antilles arc can be traced from Grenada to Testigos Island and on through Margarita and Tortuga Islands.

Sediment-size distribution is related to bathymetry. Sands are restricted to the Tortuga-Margarita rise and the broad terrace east of Margarita. These sands are high in carbonate content and have abundant glauconite. They are mainly relict sediments that were reworked during lower sea level of the last glacial episode. Silts and clays cover the continental slope, Cariaco basin, and the inner shelf between Cumaná and Cape Codero, marking deeper areas of the sea floor and areas where only fine sediments are available.

Sand composition also is related to bathymetry west of Margarita. The Tortuga-Margarita Rise sediments are reef-related material. The rest of the shelf is dominated by a benthonic Foraminifera-Mollusca shell-fragment facies. The continental slope and Cariaco basin sands consist of planktonic Foraminifera. The eastern terrace sands are more complex. Reworked detrital sands surround Margarita. Around Testigos and in the south, there is a reef debris facies. Except for a pellet facies north of Araya Peninsula and Carupano, the rest of the area has a benthonic Foraminifera-shell-fragment facies.

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## SEDIMENTARY AND TECTONIC HISTORY OF OUACHITA MOUNTAINS

The Ouachita Mountains of Oklahoma and Arkansas contain Paleozoic flysch-like geosynclinal rocks exposed by elongated east-west folds and thrust faults. Approximately 5,000 ft of Cambrian to Devonian flysch consists predominantly of dark slates and cherts, comprising a classical "starved trough" succession. Minor incursions of mature sands, apparently from the North American craton, invaded the trough at three different intervals. The succeeding Carboniferous, almost 40,000 ft thick, consists of proximal and distal turbidite sandstones, black shales, and minor interlayered wildflysch and volcanic ash. Sedimentary structures indicate southwestward, westward, and northwestward sand dispersal. Sandstone compositions suggest a cratonic, quartz-rich provenance as well as a feldspathic, lithic extracontinental source.

The tectonic setting may well have been due to oceanic crust spreading northwestward, plunging under continental crust, and creating an island-arc-trench-subduction zone whose present location is overlapped by post-Paleozoic rocks. Northwest of the trench, a complex of slope, rise, and abyssal sediments formed upon the depressed outer margin of continental crust. East of the Ouachitas, continent-continent collision caused suturing of Africa and North America, which created source materials that were subsequently emplaced as a westward-building subsea cone during the Carboniferous. In the Ouachita area, continued subduction finally created a series of uplifted tectonic lands resulting in northward sliding of the sedimentary succession as continentward-directed folds and thrust sheets. Subsequent stress-field orientation changed so that the area then became dormant.

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## STRUCTURE, SEDIMENTATION, AND PALEOENVIRONMENTS OF NORTHERN CAPITAN REEF COMPLEX, NEW MEXICO AND WEST TEXAS

The Capitan Reef complex may be subdivided into western, northern, and eastern segments by major differences in structure and sedimentation. The western segment is characterized by a barrier "stratigraphic" reef and simple shelf folds paralleling the basin-shelf margin. In contrast, the northern segment has current-oriented mounds formed by shelf beds draped over biohermal cores that extend at approximately right angles to the basin-shelf margin, and shelf domes of irregular orientation superimposed on larger structures and distributed at random in the shelf. Test drilling suggests that primarily detrital and recrystallized dolomite and dolomitic limestone lie between the current-oriented mounds in what are interpreted as ancient Capitan channels. The current-oriented mounds of the Capitan shelf and tidal-current ridges of the Great Bahama Bank have some similarities: (1) both are on an innermost shelf margin facing a deep basin or oceanic tongue, and (2) the long structural axes of both appear to have been determined by prevailing marine-currents. Shelfward from the tidal-current ridges of the Bahama Banks are moundlike accumulations of sand, which are similar in shape to the Capitan shelf domes. The Bahama mounds and tidal-current ridges were formed by marine-current deposition of oolites and carbonate detritus, whereas the Capitan current-oriented mounds and shelf domes were probably formed by marine-current deposition of carbonate detritus and by organic biohermal growth. The channels between current-oriented mounds probably provided a ready passageway for Permian marine currents and allowed a large influx of quartzose clastics into the Delaware basin.

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## LATERAL VARIATIONS OF CLAY MINERALS IN DELTAIC SEDIMENTS OF COLVILLE AND ADJACENT RIVERS, NORTH SLOPE, ALASKA

The less than 2-micron fraction of deltaic sediments of the central North Slope, Arctic Alaska, were analyzed by X-ray diffraction. In almost all samples illite is the predominant clay mineral; smectite, chlorite, and kaolinite are present in minor amounts. In the Colville Delta, there is a notable increase in the illite/smectite ratio and a decrease in the smectite/kaolinite ratio from the fluvial channels to the saline fluviomarine and marine regions adjacent to the estuarine mouth. These changes in clay mineral assemblages presumably are due to reconstitution in the saline environment, through $K^+$ adsorption and/or cation exchange, of either degraded illites or mixed-layered illite-smectite derived from nonsaline fluvial channels. This conclusion is supported by results of laboratory studies conducted on fresh and brackish water clays with seawater. The observed environmental variations in clay mineral assemblages may have important implications on paleogeographic interpretations.

There are two clay-mineral zones in the shallow-marine facies of the deltaic complex. Clays west of Oliktok Point have markedly lower illite/smectite and illite/kaolinite ratios than clays east of the Point. These lateral variations probably are related to differences in clay-mineral sources rather than depositional environments.

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CONTINENTAL-MARGIN SEDIMENTATION OF EOCENE TEJON FORMATION, WESTERN TEHACHAPI AND SAN EMIGDIO MOUNTAINS, CALIFORNIA

The Tejon Formation was deposited from early to late Eocene time in a variety of shallow-to-deep marine environments along the western margin of the North American continent. It crops out in east-west-trending mountain ranges along the southern margin of the Great Valley of California. These ranges offer the only exposures of Eocene rocks underlying the Valley on the north. On the basis of new megafaunal data, deposition of the Tejon commenced in the early Eocene with the Uvas Conglomerate Member, a shallow-marine basal conglomerate and sandstone that rests unconformably on pre-Tertiary crystalline basement rocks. The Uvas records a slow transgression of the sea from west to east. It grades upward into the Liveoak Shale Member, consisting of shales, siltstones, and thinly bedded, fine-grained sandstones. The Liveoak was deposited seaward of the Uvas in middle and late Eocene time; it grades laterally eastward into shallow-marine sandstones and conglomerates and laterally westward into hemipelagic foraminiferal shales. The Metralla Sandstone Member was deposited by the westward-retreating, late Eocene sea. It is a locally conglomeratic, shallow-marine sandstone that overlies the Uvas in the easternmost part of the area, and the Liveoak in all other areas. It grades laterally westward into thinly interbedded, fine-grained sandstones and shales deposited in deeper water, and farther west into the hemipelagic shale facies of the Liveoak. The Reed Canyon Siltstone Member, the uppermost member of the Tejon Formation, discontinuously overlies the Metralla and was deposited during the late Eocene in shallow-marine environments, including probably lagoonal areas behind barrier islands. Thus, the Tejon Formation records an advancing and retreating shoreline across a narrow continental shelf, bordered on the east by alluvial plains and on the west by an irregular continental borderland containing deep-sea basins in which submarine fans were being deposited.

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SEDIMENTATION AND TECTONICS IN EARLY TERTIARY CONTINENTAL BORDERLAND OF CENTRAL CALIFORNIA

The most prominent Eocene paleogeographic elements of central California were the Sierran continental landmass on the east and the Salinian continental borderland on the west, both underlain by granitic crust and separated by a trough-shaped, deep-marine area underlain by oceanic crust. These linear elements trended approximately north-south, parallel with the edge of the continent. Erosion of the Sierran area yielded clastic detritus that was transported westward and deposited in successive fluvial, near-shore, shallow-marine, and deep-marine environments. The Salinian borderland, which probably had been detached from the Sierran landmass by pre-Eocene right-lateral faulting along its eastern edge, consisted of irregular island uplands interspersed with deep marine basins. Detritus eroded from these islands was deposited as submarine fans within the borderland basins and on the sea floor on the east and west. Microfossils indicate deposition in basins of bathyal to abyssal depths and unrestricted access to the ocean. The early Tertiary submarine-fan deposits are similar throughout the central Coast Ranges, and contain assemblages of proximal and distal turbidites, deep-sea conglomerates, grain-flow deposits, and hemipelagic shales. They differ from most modern deep-sea fan deposits and typical flysch sequences in that they are very thick, limited in areal extent, and consist mostly of coarse clastic detritus. The conglomerates contain coarse clasts, including boulders, and have very thick, irregular bedding. Proximal sandstones consist of Bouma *ae* to *abcde* sequences that are very thickly bedded and amalgamated, poorly graded to ungraded, commonly structureless, and contain large mudstone rip-up clasts and dish structures. Distal sandstones contain more complete Bouma sequences, a greater variety of sedimentary structures, and are graded. The borderland region was tectonically active during sedimentation, so that island source areas and depositional basins formed and changed abruptly. Submarine fan sedimentation was rapid, but the supply of sediment was probably not continuous for long periods of time. Paleocurrent directions are varied, reflecting the irregular distribution of source areas and depositional basins.

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DETERMINATION OF SOME PALEOHYDRAULIC PARAMETERS

New river measurements combined with existing laboratory evidence show that, in a river reach where traction motion as well as net sediment deposition take place, the mean applied bed shear stress is equal to the critical shear stress required to move particles of median bed material size. Consequently, application of Shields' relation between shear stress and material size permits the determination of mean applied shear stress at an ancient depositional site from the grain-size distribution of the sediment. Furthermore, by applying laboratory values for the friction factor, determined for the appropriate bed configuration, we can calculate the paleoflow velocity by the Darcy-Weisbach relation. This method for the determination of paleoflow velocity is generally applicable to any sedimentary deposit if a reasonable estimate of the friction factor can be made.

For rock units containing climbing ripple cross-lamination, we can go one step farther and determine the rate at which the sediments were accumulated. The rate of bedload transport has a known functional relation to the mean velocity of the overlying column of water as determined in the first part of this study.

Very high rates of sedimentation are found to exist in nature. Late Pleistocene deltaic sediments in the Truckee Canyon of Nevada, locally contain climbing ripple cross-laminated units indicating a local rate of aggradation of 0.1 mm/sec or 36 cm/hr.

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SAND-DISPERSION PATTERNS PRODUCED BY WAVE-CURRENT AND TIDAL-CURRENT INTERACTIONS IN NEARSHORE ZONE

In mesotidal nearshore zones, patterns of sedimentation commonly are dependent on the characteristics of the interactions between wave surge and tidal flow. Sedimentary processes associated with waves alone or with tidal currents alone are generally insufficient for explaining the distributions, orientations, textures, and structures of bedforms in zones exhibiting wave-surge/tidal-current interactions. The resultant forces produced by the interaction of wave surge and tidal currents generally