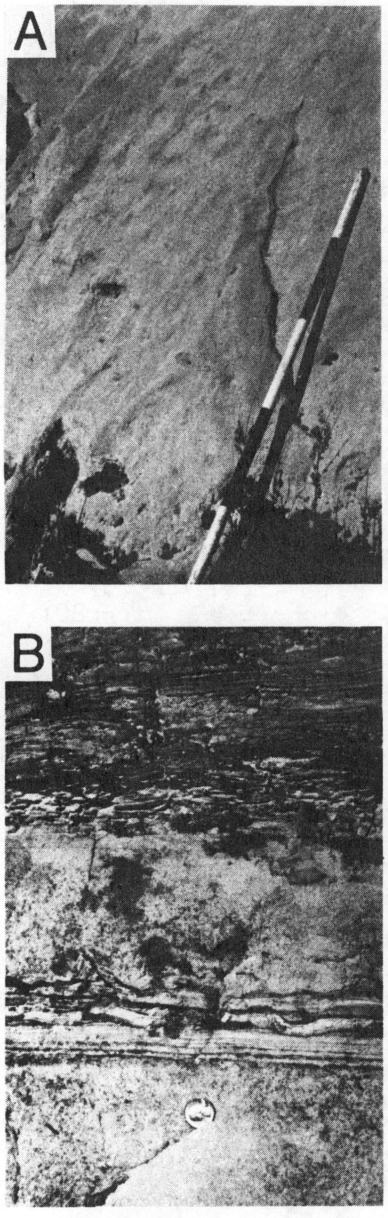

Figure 16. Close-ups of outcrops of outer shelf to slope channel facies shown in Figure 15. A) Base of lower amalgamated sandstone with a few scattered ripup clasts; scale is 1.5 m. B) Base of upper medium sandstone body grading into laminated fine sandstone with flame structures. Above the flame structures, the fine sandstone grades into laminated very fine sandstone containing small channels filled with coarser material; coin is 2.4 cm in diameter.

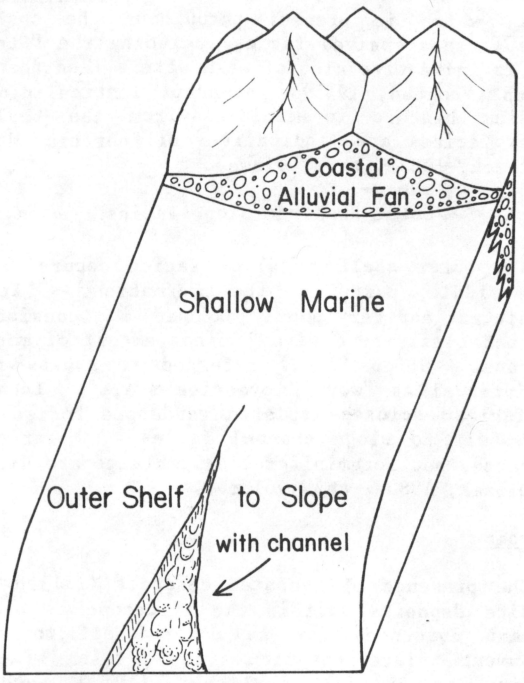

Figure 17. Depositional model of the Eocene Llajas Formation.

PALEOENVIRONMENTAL SUMMARY

The late early through early middle Eocene Llajas Formation of the Simi Valley area represents a transitional alluvial to marine system. In a vertical sequence, most of the formation is transgressive (retrogradational) in that shallower deposits are overlain by deeper-water deposits. Based on regional paleogeographic analyses (Howell, 1975; Nilsen and McKee, 1979), the shoreline was probably oriented in a north-south direction with a highland to the east. Topography most likely resembled modern high-relief areas along the west coast of Baja, California. Gravelly and sandy alluvial-fan deposits accumulated along the shoreline (Fig. 17). Source rocks were probably nearby Paleocene deposits. During storms, braided rivers of the alluvial-fan system carried coarse sediment into the transgressing sea. Shoreline deposits consisted of gravel interfingering with well laminated, well sorted, Ophiomorpha-burrowed sands containing abundant, mostly fragmented shells of shallow-marine mollusks.

Just offshore from these rivers, sedimentation was rapid in the shallow-marine environment, and sand build up caused shoaling conditions. The shallow-marine (transgressive) deposits were predominantly laminated sands alternating with bioturbated sands. The laminated sands represent storm-influenced stratification, and the bioturbated sands represent inter-storm activity of burrowing organisms. Well preserved indigenous shallow-marine molluscan and benthic foraminiferal assemblages were present but were largely confined to surge-channel deposits. In more seaward areas, the deeper the water the less amount of laminated sands and the more amount of bioturbated sands. Where such shallow-marine deposits graded into the outer shelf to slope environment, sediments consisted mostly of bioturbated silty sands and the invertebrate remains show less signs of reworking. One layer, the "Stewart bed", contains an essentially in situ megafaunal assemblage that consists predominantly of carnivore and herbivore gastropods and shallow-burrowing bivalves. Extant genera of the "Stewart bed", as well as the previously mentioned indigenous molluscan assemblages, most commonly occur today in warm temperate to tropical seas less than 80 m depth.

Deposits which formed in the outer shelf to slope area consisted of bioturbated siltstone.

Molluscan remains were scarce, but benthic foraminiferal assemblages are diverse and indicative of the slope environment. Locally, these deposits were incised by turbidity currents. The resulting small-scale channels were subsequently filled with amalgamated turbidite sandstone with minor amounts of gravel containing displaced shallow-marine mollusks.

The uppermost part of the formation represents a regressive (progradational) event in which the outer shelf to slope channel-fill deposits and enclosing outer shelf to slope deposits were covered by shallower deposits. Where such outer shelf to slope deposits graded into these shallower deposits, sediments consisted of bioturbated silts and silty sands. Shallow-marine mollusk and benthic foraminiferal taxa are similar to those found where the transgressive shallow-marine deposits grade into the outer shelf to slope deposits.

The regressive cycle is incomplete due to truncation by erosion prior to the deposition of the overlying nonmarine early late Eocene through Oligocene Sespe Formation.

ACKNOWLEDGEMENTS

Acknowledgement is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research under grant number PRF 11472-B2. I am grateful to G. Boyle, G. Haigh, W. Haigh, D. Poe, and R. Turley for allowing access to the area.

I also wish to thank M. H. Link and T. H. Nilsen for their comments in the field. L. R. Saul helped greatly in the documentation of the early Eocene molluscan fauna of the Llajas Formation. M. Filewicz and M. Hill shared their calcareous nannofossil data, and I. P. Colburn shared his knowledge of the geology of the Devil Canyon area. Numerous California State University, Northridge students assisted in the field work. M. V. Filewicz reviewed the manuscript.

REFERENCES CITED

Allen, J. R. L., 1973, Physical processes of sedimentation: London, Allen and Unwin, 248 p.

Bouma, A. H., 1962, Sedimentology of some flysch deposits: Amsterdam, Elsevier, 168 p.

California Oil and Gas Fields, 1961, Part 2-Los Angeles-Ventura Basins and central coastal regions: California Division of Oil and Gas, Maps and Data Sheets.

Clark, B. L., 1921, The stratigraphic and faunal relationships of the Meganos Group, middle Eocene of California: Journal of Geology, v. 29, p. 125-165.

_____, 1926, The Domengine horizon, middle Eocene of California: University of California, Publications in Geological Sciences, v. 16, p. 99-118.

_____, and Vokes, 1936, Summary of marine Eocene sequence of western North America: Geological Society of America, Bulletin, v. 47, p. 851-878.

Cooper, J. D., Colburn, I. P., and Sundberg, F. A., 1982, Upper Cretaceous environmental stratigraphy and field trip stops, Silverado Canyon area, in Bottjer, D. J., Colburn, I. P., and Cooper, J. D., eds., Late Cretaceous depositional environments and paleogeography, Santa Ana Mountains, southern California, Pacific Section, Society Economic Paleontologists and Mineralogists, Fall Field Trip Guidebook, p. 11-23.

Craig, G. Y., and Hallam, A., 1963, Size-frequency and growth-ring analyses of Mytilus edulis and Cardium edule, and their palaeoecological significance: Palaentology, v. 6, p. 731-750.

Cushman, J. A., and McMasters, H. H., 1936, Middle Eocene Foraminifera from the Llajas Formation, Ventura County, California: Journal of Paleontology, v. 10, p. 497-517.

Dott, R. H., Jr., and Bird, K. J., 1979, Sand transport through channels across an Eocene shelf and slope in southwestern Oregon, U.S.A., in Doyle, L. J., and Pilkey, O. H., Jr., eds., Geology of continental slopes: Society of Economic Paleontologists and Mineralogists, Special Publication Number 27, p. 327-342.

Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Hemphill, 182 p.

Goldring, R., and Bridges, P., 1973, Sublittoral sheet sandstones: Journal of Sedimentary Petrology, v. 43, p. 736-747.

Golz, D. J., 1976, Eocene Artiodactyla of southern California: Natural History Museum of Los Angeles County, Science Bulletin No. 26, 85 p.

Holmes, A., 1965, Principles of physical geology: New York, Ronald Press Company, 1288 p.

Howard, J. D., 1971, Comparison of the beach-to-offshore sequence in modern and ancient sediments, in Howard, J. D., Valentine, J. W., and Warme, J. E., eds., Recent advances in paleoecology and ichnology: American Geological Institute, Short Course, p. 148-183.

_____, 1972, Trace fossils as criteria for recognizing shorelines in the stratigraphic record, in Rigby, J. K., and Hamblin, W. K., eds., Society of Economic Paleontologists and Mineralogists, Special Publication Number 12, p. 215-225.

_____, and Reineck, H. E., 1972, Physical and biogenic sedimentary structures of the nearshore shelf: Senckenbergiana Maritima, v. 4, p. 81-123.

_____,and_____, 1981, Depositional facies of high-energy beach-to-offshore sequence: comparison with low-energy sequence: American Association of Petroleum Geologists, Bulletin, v. 65, p. 807-830.

Howell, D. G., 1975, Middle Eocene paleogeography of southern California, in Weaver, D. W., Hornaday, G. R., and Tipton, A., eds., Conference on future energy horizons of the Pacific Coast, Paleogene Symposium and Selected Technical Papers: Pacific Sections, American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Annual Meeting, p. 272-293.

_____, and Link, M. H., 1979, Eocene conglomerate sedimentology and basin analysis, San Diego and the southern California Borderland: Journal of Sedimentary Petrology, v. 49, p. 517-540.

Janes, S. D., 1976, Geology and paleontology of the Santa Susana Shale, Simi Valley, California: University of California Los Angeles, Unpublished Master of Science thesis, 33 p.

Keen, A. M., 1971, Sea shells of tropical west America (marine mollusks from Baja California to Peru): Stanford, Stanford University Press, 1064 p.

_____, and Coan, E., 1974, Marine molluscan genera of western North America -- an illustrated key: Stanford, Stanford University Press, 208 p.

Kew, W. S. W., 1919, Structure and oil resources of the Simi Valley, southern California: United States Geological Survey, Bulletin 691-Part 2, p. 323-347.

_____, 1924, Geology and oil resources of a part of Los Angeles and Ventura Counties, California: United States Geological Survey, Bulletin 753, 202 p.

Kira, T., 1965, Shells of the western Pacific in color: Osaka, Hoikusha, v. 1, 224 p.

Kumar, N., and Sanders, J. E., 1976, Characteristics of shoreface storm deposits: modern and ancient examples: Journal of Sedimentary Petrology, v. 46, p. 145-162.

Laiming, B., 1940a, Some foraminiferal correlations in the Eocene of San Joaquin Valley, California: Sixth Pacific Science Congress, Proceedings, v. 2, p. 535-568.

_____, 1940b, Foraminiferal correlations in Eocene of San Joaquin Valley, California: American Association of Petroleum Geologists, Bulletin, v. 24, p. 1923-1939.

_____, 1943, Eocene foraminiferal correlations in California: California Division of Mines, Bulletin 118, p. 193-198.

Link, M. H., Peterson, G. L., and Abbott, P. L., 1979, Eocene depositional systems, San Diego, California, in Abbott, P. L., ed., Eocene depositional systems, San Diego: Pacific Section, Society of Economic Paleontologists and Mineralogists, Field Trip Guide, Geological Society of America Annual Meeting, p. 1-7.

Mallory, V. S., 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Tulsa, American Association of Petroleum Geologists, 416 p.

McGowen, J. H., 1970, Gum Hollow fan delta, Nueces Bay, Texas: University of Texas, Bureau of Economic Geology, Report of Investigations Number 69, 91 p.

McMasters, J. H., 1933, Eocene Llajas Formation, Ventura County, California: Geological Society of America, Bulletin (abstract), v. 44, p. 217-218.

Merriam, C. W., 1941, Fossil Turritellas from the Pacific Coast region of North America: University of California, Publications in Geological Sciences, v. 26, p. 1-214.

_____, and Turner, F. E., 1937, The Capay middle Eocene of northern California: University of California, Publications in Geological Sciences, v. 24, p. 91-114.

Morris, P., 1966, A field guide to shells of the Pacific Coast and Hawaii: Boston, Houghton Mifflin, 297 p.

Mutti, E. and Lucchi, F. R., 1972, Le torbiditi dell' Apennino settentrionale: introduzione all' analisi di facies: Memorie della Societa Geological Italinan, v. 11, p. 161-199. (Translated by Nilsen, T. H., 1978, American Geological Institude Reprint Series 3).

Nagle, H. E., and Parker, E. S., 1971, Future oil and gas potential of onshore Ventura Basin, California, in Cram, I. H., ed., Future petroleum provinces of the United States--their geology and potential: American Association of Petroleum Geologists, Memoir 15, p. 254-297.

Nagle, J. S., 1967, Wave and current orientation of shells: Journal of Sedimentary Petrology, v. 37, p. 1124-1138.

Nelson, R. N., 1925, A contribution of the paleontology of the Martinez Eocene of California: University of California, Publications in Geological Sciences, v. 15, p. 397-466.

Nilsen, T. H., 1982, Alluvial fan deposits, in Scholle, P. A., and Spearing, D., eds., Sandstone depositional environments: American Association of Petroleum Geologists, Memoir 31, p. 49-86.

_____, and McKee, E. H., 1979, Paleogene paleogeography of the western United States, in Armentrout, J. M., Cole, M. R., and Terbest, H., Jr., eds., Cenozoic paleogeography of the western United States: Pacific Section, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 3, p. 257-276.

Perlmutter, M. A., 1979, Recognition of storm produced layering in the Ten Thousand Islands region of southwest Florida: Geological Society of America, Abstracts for Annual Meeting, v. 11, p. 493-494.

Poore, R. Z., 1980, Age and correlation of California Paleogene benthic foraminiferal stages: United States Geological Survey, Professional Paper 1162-C, 8 p.

Reineck, H., E., and Singh, I. B., 1975, Depositional sedimentary environments: Berlin, Springer-Verlag, 439 p.

Sage, O., Jr., 1973, Paleocene geography of the Los Angeles region, in Kovach, R. L., and Nur, A., eds., Proceedings of the Conference on Tectonic Problems of the San Andreas Fault System: Stanford University Publications in Geological Sciences, v. 13, p. 348-357.

Sanders, J. E., and Kumar, N., 1975, Evidence of shoreface retreat and in-place"drowining" during Holocene submergence of barriers, shelf off Fire Island, New York: Geological Society of America, Bulletin, v. 86, p. 65-76.

Schenck, H. G., 1931, Cephalopods of the genus Aturia from western North America: University of California, Publications in Geologlical Sciences, v. 19, p. 435-490.

Schymiczek, H. B., 1983a, Benthic Foraminifera and paleobathymetry of the Eocene Llajas Formation, southwestern Santa Susana Mountains, California: California State University, Northridge, Unpublished Master of Science thesis, 76 p.

_____, 1983b, Depositional environments and petroleum occurrence, the Eocene Llajas Formation, southwestern Santa Susana Mountains, California. Pacific Sections, American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Annual Meeting, (abstract).

Squires, R. L., 1981, A transitional alluvial to marine sequence: the Eocene Llajas Formation, southern California: Journal of Sedimentary Petrology, v. 51, p. 923-938.

_____, 1983, New mollusks from the lower middle Eocene Llajas Formation, southern California: Journal of Paleontology, v. 57, p. 354-362.

_____, in press, Molluscan paleontology and biostratigraphy of the Eocene Llajas Formation, Simi Valley, California: Natural History Museum of Los Angeles County, Contributions in Science.

Stipp, T. F., 1943, Simi oil field, in Geologic formations and economic development of the oil and gas fields of California: California Division of Mines, Bulletin 118, pt. 3, p. 415-425.

Tudor, R. B., 1963, Las Llajas Oil Field: California Division of Oil and Gas, Summary of Operations of California Oil Fields, v. 49, p. 53-57.

Vaughan, T. W., 1945, American Paleocene and Eocene larger Foraminifera: Geological Society of America, Memoir 9, pt. 1, 175 p.

Vokes, H. E., 1939, Molluscan faunas of the Domengine and Arroyo Hondo Formations of the California Eocene: Annals of the New York Academy of Sciences, v. 38, p. 1-246.

Waring, C. A., 1914, Eocene horizons of California: Journal of Geology, v. 22, p. 782-785.