of this belt. A large area toward the northwest subsided as much as 6 feet.

Submarine landslides destroyed the waterfronts of Seward, Whittier, and Valdez. Landslides generated sea waves, and tsunamis caused additional damage.

In Anchorage, the jarring action of the earthquake liquefied sensitive sand and clay zones, causing large landslides which destroyed residential and downtown business areas. Long-period surface waves caused extensive damage to many large buildings. Detailed geological and soils studies have not been completed by government agencies and consulting firms. Recommendations have been made for future land use and for stabilization of two major slides by a gravel buttress and an underground sand-pile buttress.

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NEW FORAMINIFERAL ZONATION, UPPER MESOZOIC, SACRAMENTO VALLEY, CALIFORNIA

Six new foraminiferal zones have been established in the upper Mesozoic of the Scaramento Valley, California, as the result of detailed micropaleontological work in conjunction with several reconnaissance field mapping projects. The letter designations I, J-1, J-2, K, L, and M are proposed for these microfaunal zones. These designations are a downward continuation of the Upper Cretaceous zones of Goudkoff, who established the A through H Zones in 1945. The rocks on which this new zonation is based range in age from lower Early Cretaceous, Cenomanian stage, through Late Jurassic, Tithonian stage. Micropaleontological work is essential for mapping of this thick clastic sequence, because of the gross lithologic similarity and the lenticular, disconnected, and time-transgressive nature of the coarse clastic marker beds. This study covers a 150 mile ± section along the regional strike of the outcrop along the western side of the Sacramento Valley, and also extends into the Redding area on the northeastern side of the valley.

Over 600 species, many of them new, and approximately 100 genera, including some new, were checklisted or recorded from more than 30 outcrop and well sections in the area. The new zones have been correlated approximately with the European stage classification. The I, J-1, and J-2 Zones range from Cenomanian to Aptian on the basis of both planktonic and benthonic Foraminifera; the K, L, and M Zones range from Barremian to Tithonian on the basis of cosmopolitan benthonic species. Correlations also were made between microfossil localities and northern California megafossil localities which have been equated with the European standard section.

Specific criteria for identification of the H Zone were not established by Goudkoff, but detailed study permits both identification and biofacies differentiation within it. The abundant and varied microfaunas of the "Middle" Cretaceous have made it possible to distinguish the I from the J Zones, separate the closely related J-1 and J-2, and divide the J-1 into three sub-Zones. The K, L, and M Zones are more difficult to differentiate, because of the absence of planktonics and the predominance of many similar *Nodosariidae*. The M Zone probably can be subdivided if more comprehensive work is done.

There is no faunal indication in the outcrop section of any unconformity between the Upper and Lower Cretaceous. Many species range through both Albian and Cenomanian sediments, without apparent interruption.

BILLMAN, HAROLD G., Union Oil Co. of California

REVIEW OF TERTIARY STRATIGRAPHY AND FORAMINIFERAL ZONATIONS OF WESTERN WASHINGTON STATE

Tertiary marine sediments and volcanic rocks ranging in age from early Eocene to late Miocene, or possible Pliocene, are present in southwestern Washington State. Total thickness of these rocks is more than 50,000 feet.

The Eocene history of the area is characterized by widespread vulcanism. Sedimentary rocks definitely dated as early Eocene have not been found in southwestern Washington. Middle Eocene rocks are represented by volcanics and interbedded sediments of the Crescent Formation and typically contain *Amphistegina californía* and *Asterigerina crassiformis*. Upper Eocene rocks are represented by the marine Raging River Formation and the non-marine Puget Group in the eastern part of the area. To the southwest, equivalents of these formations range from marine to non-marine facies and are mapped as McIntosh, Northcraft, Skookumchuck, and Cowlitz Formations. Further west, upper Eocene rocks are wholly marine and are mapped as the Cowlitz Formation. Total thickness of middle and upper Eocene rocks is at least 15,000 feet. Foraminiferal zones equivalent to Laiming's B Zones and B-1-A, A-2, and A-1 Zones of the California Eocene can be identified.

In early Oligocene time, regional subsidence, accompanied by notable pyroclastic vulcanism, took place and Oligocene rocks are characteristically tuffaceous.

Rocks assigned an Oligocene age have a maximum thickness of 9,000 feet in southwestern Washington and comprise the Lincoln Formation. Two lithologic members usually are distinguished: a lower basaltic sandstone member and an upper tuffaceous siltstone member. Three foraminiferal zones are recognized and are correlated with the Refugian and Zemorrian stages of California.

In early Miocene time, deposition continued uninterrupted in the same basins that were receiving Oligocene sediments. In middle Miocene time widespread diastrophic activity was accompanied by withdrawal of the seas from southwestern Washington, except along the present Pacific Ocean front and a deep embayment in the Grays Harbor-Montesano area.

In the Chehalis basin, Miocene sediments consist of 2,000 feet of wholly non-marine rocks comprising the Astoria (?) Formation (early Miocene) and Wilkes Formation (late Miocene).

In the Grays Harbor-Montesano basin, lower and middle Miocene rocks consist of an estimated 6,000 feet of marine sediments mapped as the Astoria Formation. The Astoria Formation is subdivided informally into three lithologic units which are assigned an early and middle Miocene age, equivalent to the Saucesian, Relizian, and possibly Luisian stages of California.

At Ocean City, sediments notably different from the typical Astoria Formation are correlated tentatively with the lower portion of the Astoria Formation.

Marine sediments of late Miocene to questionably Pliocene age occur only in the Grays Harbor-Montesano basin and the Pacific Ocean coastal strip. In the Grays Harbor-Montesano basin, these rocks are mapped as Montesano Formation and consist of 2,500 feet of marine conglomerate, sandstone, and siltstone containing Foraminifera which indicate a late Miocene age equivalent to the Mohnian and Delmontian stages of California. Along the Pacific Coast, in the vicinity of Ocean City, sediments of equivalent age are represented by up to 6,000 feet of sediments informally denominated the Ocean City and Quillayute Formations. A late Miocene age for these rocks is supported by the presence of *Rotalia garveyensis*, *Uvigerina hootsi*, and *Pulvinulinella gyroidinaformis*.

BOWEN, OLIVER E., California Div. of Mines and Geology

Stratigraphy, Structure, and Oil Possibilities in Monterey and Salinas Quadrangles, California

The 7,900-foot-thick Cenozoic section in Monterey and Salinas Quadrangles, northern Santa Lucia Mountains, lies on Mesozoic granite and Paleozoic (?) Sur Series schist. Age of the 1,100-foot-thick Carmelo Formation is confirmed by new micro- and megafossil material. Eocene and Oligocene rocks are missing from the section. An 850-foot-thick middle Miocene sandstone-conglomerate formation of two members, containing a typical Temblor fauna, is assigned new member and formation names. Conformably above it is the Monterey Formation consisting of three mappable members: a lowermost Luisian sandstone, up to 200 feet thick; a Luisian through Mohnian siliceous shale, 2,000 feet thick; and an uppermost Delmontian diatomite, up to 800 feet thick. A 60-foot-thick olivine basalt lies between the Monterey and underlying Temblor-age formations, dating this volcanism as middle Miocene. Conformably overlying the Monterey Formation is the Santa Margarita Formation, up to 1,600 feet thick.

Choice of the Monterey vicinity as the type locality of the Monterey Formation was unfortunate because the section there is not typical of the Monterey Formation in well-known localities elsewhere in California, either in age, thickness, or completeness. A few miles east of the type section, the shale and diatomite members of the Monterey Formation begin to interfinger with the Santa Margarita Formation and the entire Miocene section grades into sandstone against the Sierra de Salinas.

Overlapping the Miocene and basement units is the Plio-Pleistocene Paso Robles Formation, up to 500 feet thick, and several thin younger Quaternary units.

The structural pattern is essentially a series of northwest-trending open folds punctuated by the development of three horsts. Several Miocene units are warped over the noses of these horsts. The sense of movement on the northwest-trending faults is normal and strike-slip; thrusting was not identified.

The best possibilities for oil are possible fault-stratigraphic traps along the western side of the Salinas Valley, northeast of the projection of the King City fault.

BROOKS, RICHARD L., Richfield Oil Corp.

Review of Biostratigraphy of Los Angeles Basin

The Los Angeles basin contains a thick sedimentary sequence, mainly of late Miocene and Pliocene age. Sedimentary rocks from Cretaceous through Oligocene age crop out in places along the fringe of the basin, but these strata have not been encountered in the central portion of the basin.

A rich foraminiferal assemblage makes it possible to subdivide the Miocene and Pliocene into a number of stages and zones.

Luisian fauna, generally the oldest encountered within the basin, is indicated by *Valvulineria californica* and *Anomalina salinasensis*.

Strata of the overlying late Miocene, lower Mohnian stage, contain the marker fossils *Bulimina uvigerinaformis*, *Bolivina modeloensis*, and *Epistominella gyroidinaformis*.

The upper Mohnian fauna is recognized by the presence of *Cassidulinella renulinaformis* and *Bolivina hughesi*.

The upper Miocene Delmontian stage has fauna similar to the early Pliocene Repettian stage, but contains the marker *Rotalia garveyensis* and abundant Radiolaria.

The Pliocene is divided into three stages, these being—from oldest to youngest—Repettian, Venturian, and Wheelerian.

The Repettian stage is divided into 18 zones. Typical Repettian forms are: *Ellipsonodosaria verneuili*, *Karreriella milleri*, *Bulimina rostrata*, and *Nonion pompilioides*.

The Venturian stage has the markers *Bulimina subacuminata* and *Bolivina sinuata*.

Fauna of the Wheelerian stage includes *Uvigerina peregrina*, *Epistominella pacifica* and *Bolivina interjuncta*.

The early Pleistocene guide fossils include *Cassidulina limbata* and *C. tortuosa*.

The late Pleistocene fauna has the forms *Elphidium poeyanum* and *Elphidiella hannai*.

Water depth during Luisian time was about ±1,500 feet. Water depth increased at a fairly steady rate, through the Miocene and early Pliocene, until a maximum depth of about ±5,000 feet was reached during mid-Repettian time. The water depth then slowly decreased through late Repettian and sharply decreased during the Venturian. Wheelerian water depths commenced at ±2,000 feet and ended at ±1,000 feet. The basin was filled by the close of Pleistocene time.

The main production in the basin is from strata of Repettian age. This is followed by production from the late Miocene. Rocks of other ages produce relatively minor amounts of oil.

BURG, KENNETH E., Geophysical Service, Inc.

Geological Value of Digital Processing in Highly Explored Areas

Effective and economic use of seismic methods in highly explored areas requires a different approach to the exploration problem than that used in less developed areas. In highly explored areas the subsurface structure and stratigraphy generally are well known and the exploration objective is the extension of known areas, search for new productive zones, or establishment of deeper production. Thus the seismic method must be capable of much greater resolution and accuracy, and ambiguities caused by multiple reflections and other signal-like events must be eliminated.

The Digital Seismic Exploration System, consisting of digitally recording and processing of seismic data to achieve specific objectives, is uniquely applicable in highly explored areas. Effective utilization of the system requires a step-by-step approach to the exploration problem: (1) the exploration objective must be defined in seismic terms; (2) the ability of digital technology to solve the problem must be evaluated; (3) the exploration system, consisting of special digital data collection techniques and sophisticated data-reduction processes by digital computers, must be designed; and (4) close coordination of geologist and geophysicist is required to evaluate continuously the achievement of the exploration objective and to make necessary modifications in the system to achieve the objective in a better way.

The application of these principles to the solution of a