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GEOLOGIC CROSS SECTION ACROSS THE CONTINENTAL MARGIN OF SOUTHWESTERN WASHINGTON

By

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The geologic cross section A-A" is located across the continental margin of southwestern Washington near latitude 46°50'N. The section extends westward from longitude 123°30' in the Coast Range and terminates on the continental shelf near longitude 124°40' (fig. 1). Onshore it includes the subsurface data from the Sharples-Weyerhauser, Clemons No. 1 well; Continental Oil Company, Hogan Estate No. 1 well, and their core hole RA-1747; offshore the section passes through Shell Oil Company, P-0155 well.

The geologic data used to construct the cross section are from detailed geologic mapping by Gower and Pease (1965) in the Montesano quadrangle and reconnaissance studies in parts of the Aberdeen quadrangle by Gower (written commun., 1966). Inasmuch as detailed geologic mapping is not available for the Aberdeen and adjacent Grayland quadrangles (fig. 1), the western part of the onland portion of the cross section is highly interpretative. The magnetic anomalies shown on maps prepared by Henderson and others (1958a, 1958b) were helpful in interpretating the structure of the lower and middle Eocene volcanics west of the coastline. Offshore data used in constructing the continental shelf part of cross section A-A' are based upon an interpretation of a 24-channel seismic-reflection profile (fig. 2) and subsurface information in Shell Oil Company, P-0155 test well, which lies along the line of section.

The time-stratigraphic units shown on the offshore part of the cross section are based upon the correlation of acoustical units on the seismic profile with biostratigraphic units established by a study of Foraminifera from the Shell well by Weldon Rau (written commun., 1978). The segment of the cross section that extends east of our 24-channel profile (fig. 2) to the coastline is based in part on a single-channel profile collected by Silver (1972) and a poor quality single-channel profile collected by the writers which extends Silver's profile eastward into Grays Harbor (fig. 1). The single-channel profile in Grays Harbor, north of the cross section, is the basis for the interpretation of the shallow structure shown on the section in the Grayland quadrangle where the Tertiary rocks are mantled by uplifted Pleistocene estuarine and terrace deposits.

In constructing the geologic cross section (fig. 3) at true scale, the contacts between formational or acoustical units were converted to nonmigrated depths based upon depth-velocity data derived from an analysis of the sonic log taken in Shell Oil Company, P-0155 test well. The unit symbols used in the cross section for time-stratigraphic units

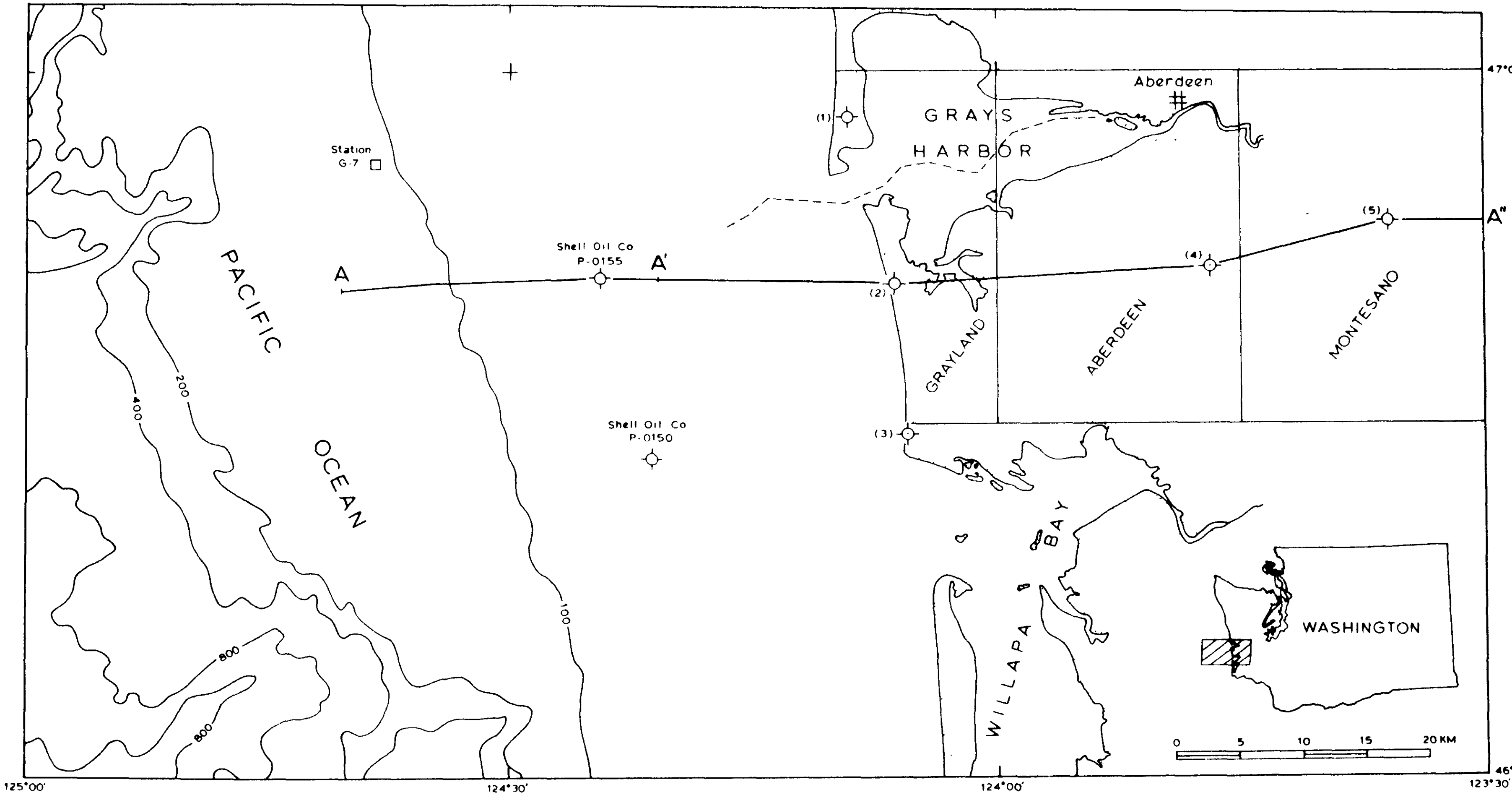


Figure 1.--Index map of the continental margin of southwestern Washington showing the location of geologic cross section A-A". Offshore the map shows the location of USGS 24-channel seismic-reflection profile A-A', seismic refraction station G-7 of Shor and others (1968), and Shell Oil Company's P-0150 and P-0155 offshore exploratory wells. The dashed line extending from the inner shelf into Grays Harbor is the trackline of the single-channel profile referred to in the report. The onshore wells shown on the map include: (1) Sunshine Mining Company, Minard No. 1, (2) Continental Oil Company core hole RA-1747, (3) Union Oil Company of California, Smith No. 1, (4) Continental Oil Company, Hogan Estate No. 1, and (5) Sharples-Weyerhauser, No. 1. Bathymetric contours in meters.

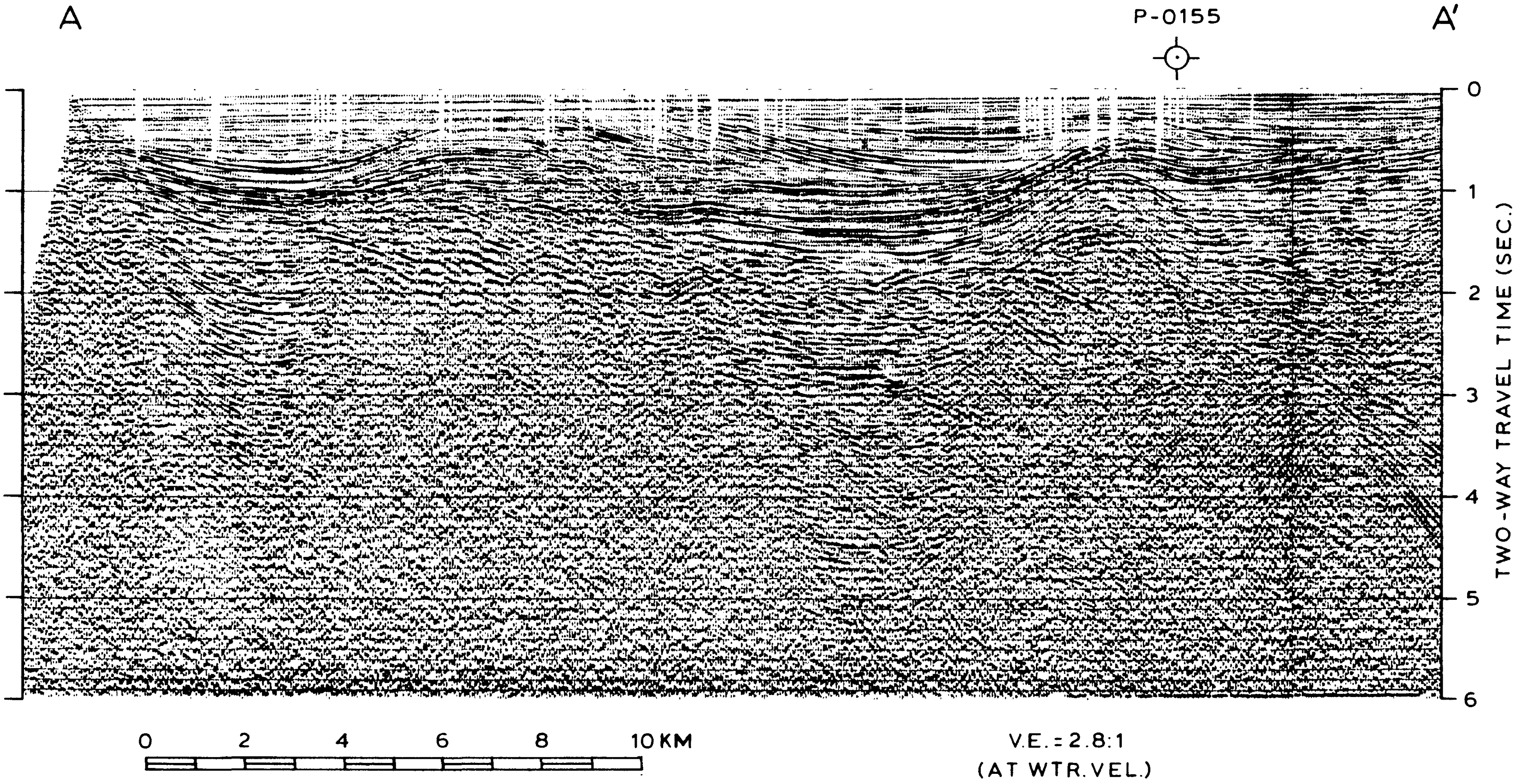


Figure 2.--Twenty-four channel seismic-reflection profile A-A' collected aboard U.S. Geological Survey R/V S. P. LEE.

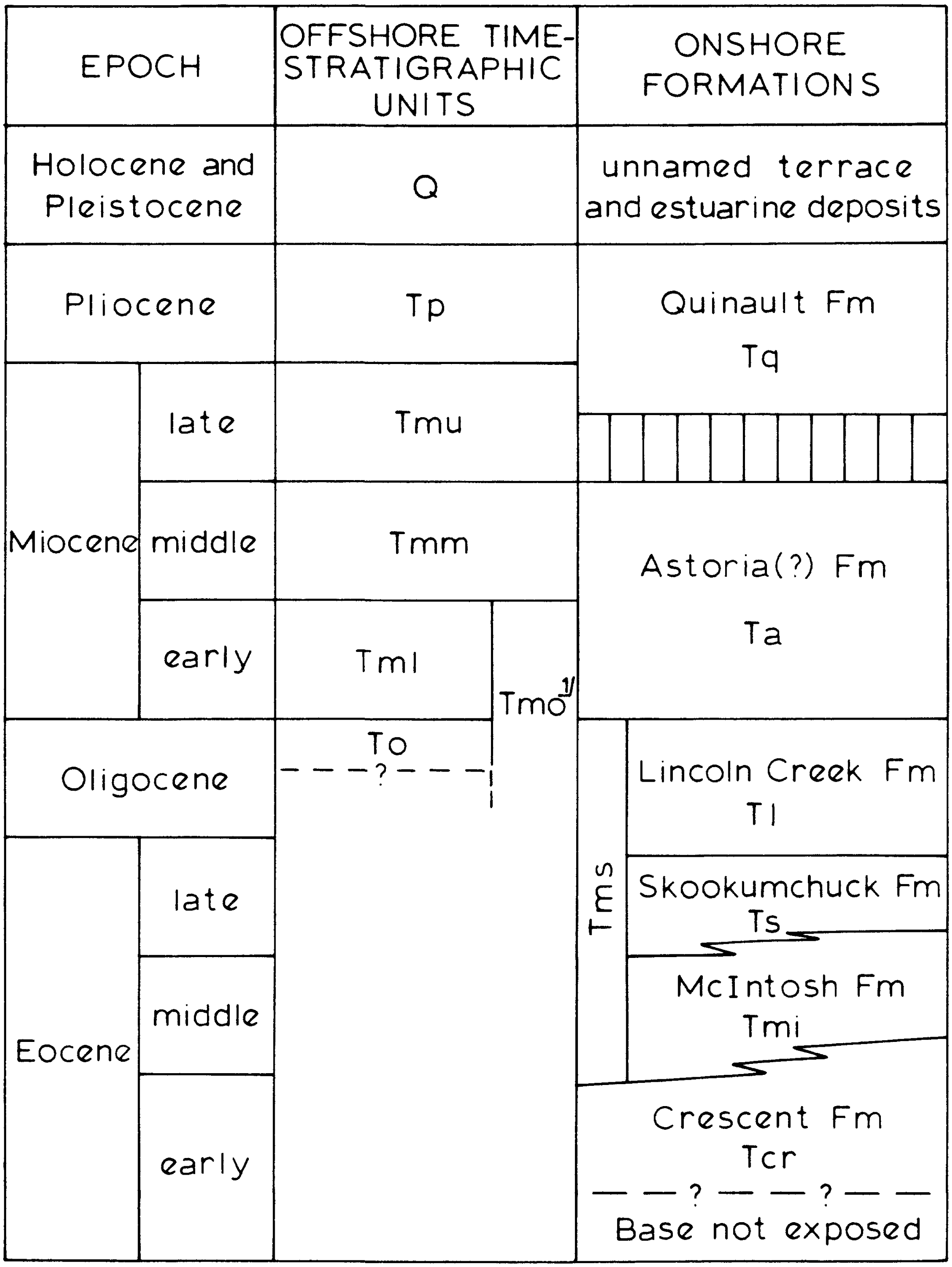
on the continental shelf and for the onshore formations are shown in figure 4.

The multichannel seismic-reflection profile was obtained using a tuned array of 5 airguns totaling 1326 in^3 as a sound source. The recording system consisted of a 24-channel streamer 2400 m long and a GUS (Global Universal Science) model 4300 digital recording instrument. Records were sampled at a 2-millisecond rate and later processed at a 4-millisecond rate. Also collected were single-channel and high-resolution seismic reflection profiles, and magnetic and gravity data. Navigational control for the survey was by satellite fixes augmented by doppler-sonar dead reckoning. The 24-channel seismic-reflection and magnetic data along profile A-A' were published by Snavely and Wagner (1982).

Based upon the writers' interpretation of the offshore and onshore tectonic framework of the southwestern Washington continental margin, two major tectonostratigraphic terranes are inferred to exist above the subducted Pacific (Farallon) plate. Thrust fault B, whose surface trace apparently lies only several kilometers west of the coastline, forms the interface between these two terranes (fig. 3). West of thrust fault B, on the continental shelf, deformed Oligocene and younger strata overlie an oceanic crust of probable Miocene age (not shown on section). Magnetic anomaly 5, which is about 10 m.y. old (Vine, 1968), extends about 75 km east of the base of the continental slope off Washington (National Oceanographic and Atmospheric Administration, 1974). East of thrust fault B Miocene(?) oceanic crust, and the melange that overlies it (unit Tmo), is inferred to underthrust the lower to middle Eocene pillow basalt and breccia of the Crescent Formation (unit Tcr) which has been interpreted as ridge basalts and associated oceanic islands.

The onland structures are interpreted to be controlled by imbricate offsets of the Eocene volcanic crust in the upper plate of thrust fault B which forms the western boundary of the Crescent Formation (fig. 3). The pillow lavas and breccia mapped by Wells (1979) at Cape Disappointment, about 64 km south of the cross section, and basalts that have been penetrated in several test wells drilled near the coast between Cape Disappointment and Grays Harbor (Rau and McFarland, 1982), are considered part of the upper plate of thrust fault B. Structures like those mapped by Gower and Pease (1965) in the Montesano quadrangle are interpreted as resulting from offsets of Crescent basalts by eastward-dipping thrust faults that splay off thrust fault B above the downgoing Pacific plate. The thrust faults that offset the Crescent basalts are expressed in the overlying Tertiary sedimentary rocks as narrow, generally asymmetric, westward verging anticlines that are separated by broad synclines (fig. 3). These thrust faults cut strata as young as middle Miocene which in places are steeply dipping or overturned to the west (Gower and Pease, 1965; Pease and Hoover, 1957).

The writers suggest that a "thin-skin" type of tectonic framework may extend as far east as the Centralia-Chehalis coal district, located about 50 km to the east of the cross section A-A". There, Snavely and



1/ Hoh rock assemblage of Rau (1973, 1975).

Figure 4.--Chart showing symbols used for offshore time-stratigraphic units based upon biostratigraphy in Shell Oil Company well P-0155 and comparable symbols used for onshore formations shown in cross section A-A".

others (1958) mapped a series of northwest-trending asymmetric folds that are commonly cut by high-angle reverse faults along their steep western limbs. Blocks of Crescent basalt that are interpreted to have been uplifted along the eastward-dipping thrust faults in the upper plate of fault B are expressed by positive magnetic anomalies on maps prepared by Henderson and others (1958a, 1958b). North-trending moderate to steep linear gradients on these magnetic maps are inferred to mark the west edges of the blocks bounded by thrust faults B and C shown on the cross section (fig. 3).

The geologic framework of the Washington shelf is interpreted to consist of a thick sequence of late Oligocene to Quaternary strata that overlies an irregular acoustical basement consisting of melange and broken formation of late Oligocene to middle Miocene age (fig. 3). Sparse faunas from a locally sheared siltstone and sandstone sequence in the lower part of the Shell Oil Company, P-0155 well, indicate that the well bottomed in strata of probable late Oligocene age. Based upon an increase in the number of shear zones with depth in the well, the lower 3000 feet (1000 m) penetrated may represent a transitional zone from less sheared late Oligocene strata into melange. In outcrops, and in test wells drilled near the Washington coast, the melange comprises a tectonostratigraphic unit of sheared siltstone of late Oligocene to middle Miocene age that contains tectonic inclusions of sandstone and less common basalt. This melange is referred to as the Hoh rock assemblage by Rau (1973, 1975); Rau and McFarland (1982). In cross section A-A', the sedimentary sequence above the melange is structurally complex and is characterized by a series of landward-dipping (eastward) imbricate thrust faults and attendant compressional folds. In places, the Oligocene and Miocene melange forms diapiric uplifts that deform or pierce younger strata (fig. 3). The thinning of post-middle Miocene strata over these diapirs indicate that they have been growing structures from middle Miocene through Holocene time. Seismic-reflection profiles elsewhere on the Oregon and Washington shelves indicate that some diapirs are presently growing, as they deform and breach Holocene sediments.

Where large blocks have been uplifted along thrust faults, or uplifted by diapirism, gravity appears to have played an important role in structuring the strata on the continental shelf. Our interpretation of the structure near the western end of cross section A-A' presumes that the large faulted block of supposed late Oligocene strata (unit To) was initally uplifted along eastward-dipping thrust fault A. Subsequent to this uplift, it is speculated that the upper part of the block slid eastward off this structural high and overrode middle Miocene strata. Although juxtaposition of older over younger strata could also occur as a result of thrusting, the seismic reflection data suggests that gravitational sliding is the more likely explanation at this locality. Similar inverse stratigraphic relationships have been encountered in several test wells drilled near the coast north of Grays Harbor. For example, in the lower part of the Sunshine Mining Company and Cascade Natural Gas, Rayonier No. 1-A well, strata of Oligocene, upper Eocene, and middle Miocene were penetrated in that order going downhole (Rau and McFarland, 1982).

Critical to our interpretation of the tectonic framework on the Washington continental margin is the validity of thrust fault B which in our model has a low eastward dip and emplaces Eocene basalt over younger melanged sedimentary rocks. Two test wells drilled north and south of cross section A-A" bear upon this interpretation. Continental Oil Company core hole RA-1747 on the line of section (fig. 3) apparently bottomed in the middle to lower Eocene Crescent basalt at about 1450 feet (442 m) (McFarland, 1981), however, two test wells drilled north and south of the cross section drilled into sheared siltstone and sandstone beneath these volcanic rocks. Union Oil Company of California, Smith No. 1 well, drilled 11.5 km south of the cross section, penetrated 3400 feet (1035 m) of sheared strata, referred to as the "Hoh rock assemblage" by Rau and McFarland (1982), and Sunshine Mining Company, Minard No. 1 well, drilled 14 km north of the cross section (fig. 1), encountered 1400 feet (425 m) of similarly deformed strata in the lower plate. Although paleontological evidence is lacking to date the deformed strata beneath the Crescent(?) basalt in these wells, the writers speculate that the sheared rocks which lie below thrust fault B represent Oligocene and Miocene melange (Hoh rock assemblage).

If the depth to the top of the upper Miocene oceanic crust on the abyssal plain west of cross section A-A" is projected as a straight line to intersect the top of the oceanic crust at station G-7 of Shor and others (1968) (fig. 3), a melange wedge of about 7 km thick presumably would be present above the projected top of the oceanic crust on the inner shelf. Although the upper part of the melange wedge that forms the acoustical basement on the seismic profile (fig. 2) is probably of late Oligocene to middle Miocene age, there is no direct evidence as to the age of the lower part of the melange unit. We speculate that melange of Eocene age formed during the period of middle to late Eocene subduction (Snavely and others, 1980), may exist above the Miocene(?) oceanic crust and below the Oligo-Miocene melange on the inner shelf. If, a pre-upper Eocene melange wedge actually exists, melange of this unit would have been deformed during both the mid-late Eocene and late middle Miocene periods of plate convergence.

The tectonic and stratigraphic framework of the southwestern Washington continental margin shown along cross section A-A" is highly interpretative and should be considered a working model that, undoubtedly, will be revised as new data becomes available. A modest amount of new geologic and geophysical data in the coastal zone would eliminate many of the problems that arose in constructing the cross section as these new data would place constraints on the interpretation of the structural style of the Tertiary sequence.

Onshore seismic-reflection profiles extending eastward from the coast would provide significant information on the down-dip configuration of thrust fault B and determine if a low velocity zone of sedimentary rocks underlies the Crescent basalts in the upper plate. These profiles would also indicate the thickness and structure of the Tertiary strata that overlie the Crescent Formation between thrust fault B and C. An offshore refraction profile would provide important data on the thickness of the melange wedge that overlies the Miocene(?) oceanic crust and location of the trace of thrust fault B on the inner shelf. Velocity models based upon these refraction profiles would also provide data on the amount of eastward dip of the Miocene(?) oceanic crust.

Detailed gravity and magnetic surveys near the coast would provide additional information needed to model the thickness and distribution of the Crescent Formation and the Tertiary strata that overlie these basalts or that may be present at depth beneath them.

Detailed geologic mapping needs to be undertaken in the Grayland and Aberdeen quadrangles in order to establish the Tertiary structural and stratigraphic framework of this important segment of the coastal zone. This mapping is required to provide a more perceptive interpretation of any new geophysical data collected in this part of southwest Washington.

Acknowledgments

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