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Tertiary Volcanic and Intrusive Rocks on the Oregon and Washington Continental Shelf

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ABSTRACT

Three major basaltic volcanic units form a significant part of the Tertiary sequence in western Oregon and Washington and in places these rocks extend onto the continental shelf. Identification of the type of volcanic rock encountered in the subsurface is important in petroleum exploration. For example, the Paleocene to lower middle Eocene oceanic basalts are the geologic as well as the economic basement rocks. In contrast, the upper Eocene alkalic basalts and the middle Miocene basalts are underlain by thick sequences of siltstone and sandstone that are potential source beds and reservoir rocks for petroleum.

The most critical evidence for the recognition of a particular basalt unit is the age of the superjacent or interbedded strata. However, most basalts can be identified by petrographic studies and chemical analyses. Although the recognition of a specific type or age of volcanic rock from drill cuttings or cores is difficult using a handlens or binocular microscope, each of the three volcanic sequences has several physical characteristics that are useful in their identification.

INTRODUCTION

Three major episodes of volcanism form major chapters in the Tertiary history of western Washington and Oregon. The volcanic rocks form a significant part of the stratigraphic section, and in places these rocks extend onto the continental shelf (fig. 1). The proper identification of the type of volcanic rock encountered in the subsurface is an important factor in petroleum exploration in this region. For example, the Paleocene to lower middle Eocene oceanic basalts form the basement rocks in western Oregon and Washington and constitute the economic basement. In contrast, the upper Eocene alkalic basalts are underlain by a thick sequence of middle and upper Eocene siltstone and sandstone, which contain potential source beds and reservoir rocks for petroleum. The youngest basalt flows of middle Miocene age are underlain by as much as 3,000 meters of strata that include organic-rich siltstone that are potential source beds and sandstone units that are potential reservoir rocks. Also, middle Miocene basalt sills cross cut older strata and thus provide a minimum age for the strata they intrude. A detailed knowledge of the stratigraphic position, physical characteristics, and petrochemistry of the surface outcrops of these igneous rocks is required in order to identify them from cores and cuttings obtained from petroleum exploration wells.

Recognition of a specific type or age of volcanic rock from drill cuttings or sidewall cores is often difficult, as individual volcanic sequences vary in physical characteristics and chemistry. In addition, alteration of

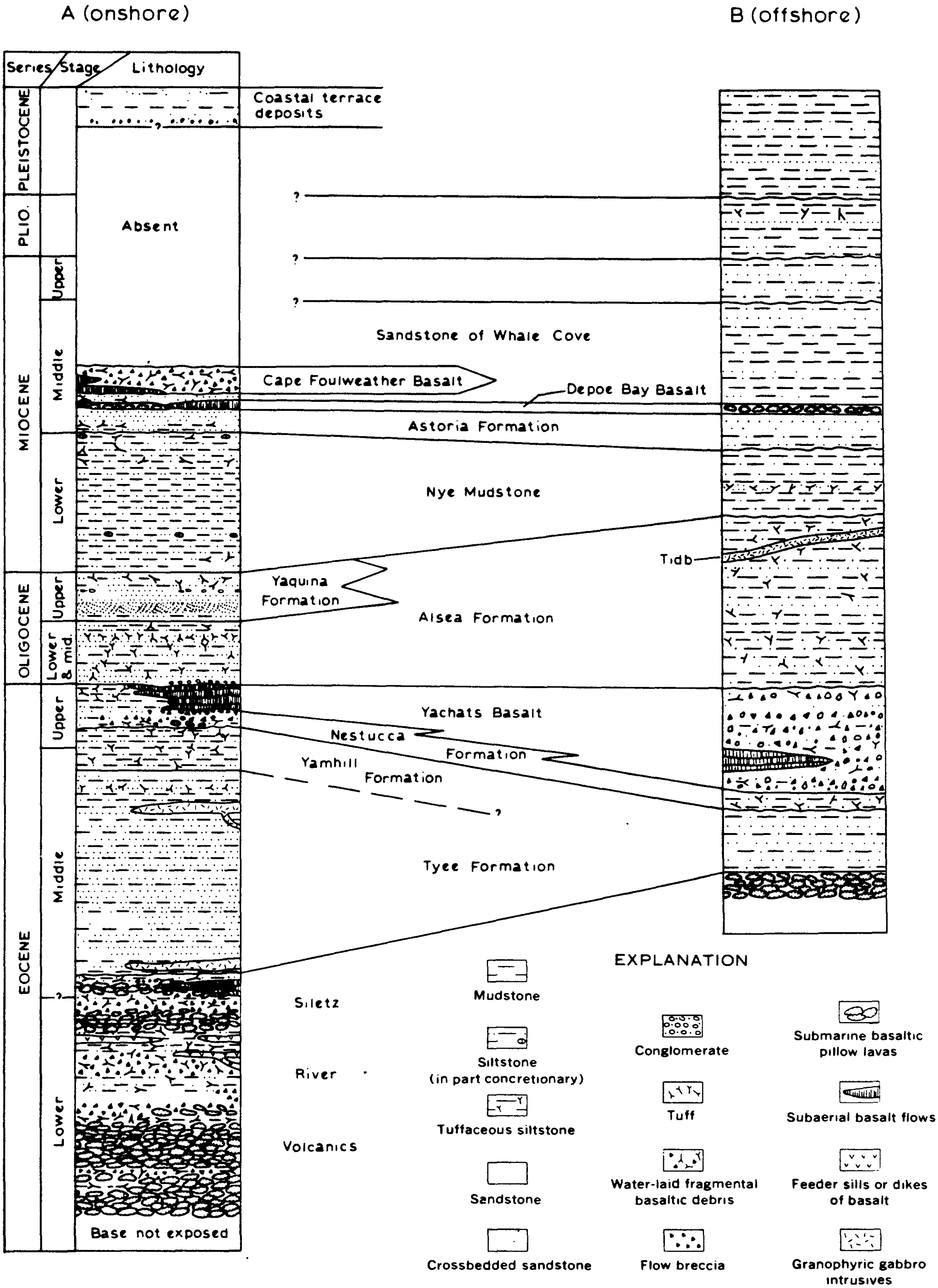

Figure 1.--Generalized composite stratigraphic section, central Oregon continental margin. Column A, based on geologic mapping by Snavely and others, 1976a, b, c; column B based on units penetrated in Standard-Union Nautilus test well (Braislin and others, 1971) and interpretation of 24-channel seismic profile (Snavely and others, 1980). No vertical scale indicated.

basalts by hydrothermal action commonly destroys the phenocrystic minerals and alters the glass to various clay minerals. Even in isolated outcrops, it can be difficult to identify with certainty an altered pillow lava of early Eocene age from a submarine flow of late Eocene age, or a fine-grained upper Eocene basalt from a fine-grained middle Miocene basalt flow or sill.

Unquestionably, but not surprisingly, the most critical evidence for the age of a particular basalt unit is the age of the superjacent or interbedded strata. However, there are useful lithologic criteria that make it possible to distinguish between various volcanic units even in hand samples or small fragments, although the success rate may be as low as 50 percent. Petrographic studies of thin sections or grain mounts greatly improve these odds, as many of the phenocrystic minerals, which are difficult to identify with a handlens or binocular microscope, are easily recognized with a petrographic microscope.

The following discussion of the Paleocene to lower middle Eocene, upper Eocene, and middle Miocene basaltic volcanic rocks includes data that necessarily may not be germane to specific needs for identifying these units in offshore exploratory wells. However, these data are included in this report for those who may wish to study in more detail the onshore volcanic sequences. The Oligocene intrusive rocks exposed in the Oregon Coast Range (MacLeod and Snavely, 1973) are not discussed as they probably do not extend as far west as the continental shelf.

PALEOCENE TO LOWER MIDDLE EOCENE BASALT

Distribution

These volcanic rocks consist primarily of oceanic basalts and form the basement rocks in western Oregon and Washington and on the inner shelf of Oregon (plate 1). These pillow lavas and breccias, with minor sedimentary interbeds, are referred to the lower part of the Umpqua Formation (Diller, 1898) or the volcanic member of the Roseburg Formation (of Baldwin, 1974) in the southern Oregon Coast Range, the Siletz River Volcanics (Snavely and Baldwin, 1948; Snavely and others, 1968) in the central and northern Oregon Coast Range, and the Crescent Formation (Pease and Hoover, 1957; Wagner, 1967; Wells, 1981) in the Washington Coast Range and in the Olympic Mountains (Arnold, 1906; Brown and others, 1960).

Of this older sequence, only the basalts equivalent to the Roseburg and Siletz River Formations of Oregon occur on the outer continental shelf (plate 1). The Crescent basalts are restricted to a narrow thrust-faulted block along the southwestern Washington Coast (Snavely and Wagner, 1983). The Crescent basalts are also known to underlie the Prometheus High (Shouldice, 1971; MacLeod and others, 1977) in Canadian waters along the south side of Vancouver Island and probably extend southeastward and are present offshore between Point of the Arches and Cape Flattery (plate 1). Although most of the Washington continental shelf is probably underlain by post-mid-Oligocene strata, large submarine slide blocks of Crescent basalt may occur in places within an upper Oligocene to upper middle Miocene melange and broken formation--the so-called Hoh Assemblage of Rau (1980).

Stratigraphic Relations

Since the Paleocene to lower middle Eocene basalts represent ocean-ridge basalts capped by a chain of seamounts and oceanic islands, the age of the strata that overlie these basalts range from early Eocene (Penutian and Bulitian) in basins marginal to the islands to upper Ulatisian where strata onlap the ocean-island constructional highs. Microfossils of Paleocene age are known only from siltstone interbeds in pillow lavas in the Roseburg area, but basalts of this age probably are not present on the Oregon shelf. David Bukry (written commun., 1977) assigns nannofossils from siltstone interbeds in the Roseburg basalts to his Discoaster multiradiatus Zone, Campylosphaera eodela Subzone of late Paleocene age. Coccoliths from limy interbeds in the Crescent basalts of the Olympic Peninsula are assigned to his Discoaster lodoensis Zone of early Eocene age and indicates an abyssal depositional environment.

Checklists of Foraminifera and phytoplankton occurring in the siltstone member of the Umpqua Formation that overlies the oceanic basalts in exploratory wells drilled in the southern Oregon continental margin are contained in a biostratigraphic correlation chart by Snavely and others (1982). Also, Rau (1981) presents a brief synthesis of faunal characteristics for his foraminiferal zones in western Washington and Oregon that includes siltstone that overlies the Eocene oceanic basalts.

Physical Character

Pillow lava and breccia most commonly are dark-greenish-gray aphanitic to fine-grained amygdaloidal basalt. The lava is composed mainly of closely packed ellipsoidal pillows that are commonly radially jointed and are 1-2 meters in diameter. The chilled margins of the pillows, originally basaltic glass, are now waxy, greenish-black clay minerals. Smectite clay minerals, produced by submarine weathering, commonly fill vesicles in the lavas and occur as alteration products of interstitial basaltic glass in the groundmass. These clays give fresh rock a blue-green color that rapidly oxidizes to greenish-black upon exposure to air. Slickensided and polished fracture surfaces are common in rocks that contain a high clay content. Zeolite minerals and calcite are also common as amygdules and veinlets, and form the cementing material in breccias.

In thin sections the basalt is holocrystalline to hypocrystalline and commonly with intersertal or vitrophyric textures. Some rocks are slightly porphyritic with essentially equal proportions of augite and plagioclase forming as much as 85 percent of the more crystalline rocks. For a detailed description of the mineralogy of these basalts, the reader is referred to Snavely and others (1968).

Chemical Analyses

The oceanic basalts are interpreted to represent two major petrochemical units, a lower unit (spreading ridge basalt), a submarine tholeiitic suite of Paleocene to early Eocene age, and an upper unit (oceanic islands and seamounts) of submarine and subaerial alkalic and porphyritic basalt of late early Eocene and earliest middle Eocene age. The chemistry of these two units is generally typical of other oceanic basalt units that crop out in western Oregon and Washington and those that would be encountered in offshore Oregon

(Snavely and others, 1968).

Table 1, column 1, shows analyses of representative samples of the lower unit and table 1, column 2, shows analyses of samples of the upper unit, both from the Siletz River Volcanics.

Paleomagnetic Data

Paleomagnetic studies, noteably by Simpson and Cox (1977), Magill and others (1981), and Wells (1982), indicate that the Eocene oceanic basalts have been rotated clockwise. The Siletz River Volcanics in the Oregon Coast Range have a paleomagnetically determined clockwise rotation of about 75°; whereas, similar rocks in the Washington Coast Range have more moderate rotations of about 30°. Because the change in the amount of clockwise rotation occurs near the Columbia River, one would speculate that an old tectonic boundary separating two microplates may occur at the river, and that the larger 75° rotation would also characterize the Eocene oceanic basalts on the Oregon continental shelf.

Isotopic Age

Reliable isotopic ages are difficult to obtain as much of the Eocene oceanic basalt is altered and argon loss probably has occurred in these rocks. Radiometric ages for the Coast Range basalts range from 49-62 MA, and according to Duncan (1982) are oldest at the northern Olympic Peninsula and southern Oregon Coast Range. However, it is possible that the north-south age progression of K/Ar dates is the result of a sampling bias in long-lived volcanic piles, but the author agrees that the oldest exposed oceanic basement rocks occur in the Roseburg area of the southern Oregon Coast Range.

UPPER EOCENE VOLCANIC ROCKS

Distribution

Thick accumulations of chiefly subaerial basalts were erupted from three major centers along coastal Oregon at Cape Perpetua, Cascade Head, and in the Tillamook Highlands. The basalts at Cape Perpetua and Cascade Head are about 700 meters thick and of late Eocene age, whereas in the Tillamook Highlands they are more than 2,000 meters thick and range in age from early late Eocene to late Eocene. These upper Eocene basalts have been encountered in several of the offshore exploration wells and occur over a broad area of the central part of the Oregon continental shelf (table 2; and plate 2). Based upon field studies, these volcanic rocks were erupted near the strandline of a late Eocene sea and grade rapidly westward from subaerial flows to breccia, conglomerate, and basaltic sandstone near the present coastline. Probably most of the upper Eocene volcanic rocks that occur on the shelf are tuff-breccia, lapilli-tuff, and basaltic sandstone and conglomerate eroded off the onshore volcanic highs. Subsurface data from the Union Grebe P-093, Shell P-087, and Standard Nautilus P-0103 support the conclusion that upper Eocene basalts are largely fragmental in nature in offshore areas (table 2).

	Lower and early middle Eocene		Upper Eocene		Middle Miocene	
	Siletz River Volcanics		Basalt of Yachats	Basalt of Cascade Head	Depoe Bay Basalt	Cape Foulweather Basalt
	1	2	3	4	5	6
SiO_2	49.0	48.2	51.4	47.1	55.7	51.9
Al_2O_3	14.5	16.0	17.6	15.5	14.0	13.9
$FeO+Fe_2O_3$	11.6	12.0	10.9	12.0	12.3	14.5
MgO	8.3	6.1	3.6	6.6	3.6	4.1
CaO	12.2	7.4	8.7	10.3	7.1	7.9
Na_2O	2.3	4.3	3.6	3.0	3.3	3.0
K_2O	0.17	1.9	1.0	1.3	1.4	1.0
TiO_2	1.6	3.3	2.6	3.3	2.0	3.0
P_2O_5	0.19	0.20	0.16	0.23	0.21	0.22
MnO	0.19	0.20	0.16	0.23	0.21	0.22
Number of analyses	3	9	20	12	8	11

1. Tholeiitic basalt from lower part of Siletz River Volcanics (Snavely and others, 1968, Table 3).

2. Alkalic basalt from upper part of Siletz River Volcanics (Snavely and others, 1968, Table 7, cols. 14 and 15, and Table 8, cols. 1-3 and 4a-7a.

3. Basalt near Yachats, Waldport, Tidewater, and Mapleton quadrangles (Snavely and others, 1969, Table 1).

4. Basalt near Cascade Head, Hebo quadrangle (Snavely and others, 1969, Table 1).

5. Depoe Bay Basalt, northwestern Oregon (Snavely and others, 1973, Table 2).

6. Cape Foulweather Basalt, northwestern Oregon (Snavely and others, 1973, Table 2).

Table 1. Average chemical composition of volcanic rocks in the central part of the Oregon Coast Range (averages recalculated water-free).

Number on figs. 2, 3 and 5	Company and Name of Well	Year Drilled	Location		Total Depth ft.	Tertiary Rocks Penetrated	Remarks
			Latitude	Longitude			
1	Pan American P-141	1967	47° 39.7'	124° 47.5'	10,368	Pliocene - late Oligocene(?)	Bottomed in melange
2	Union Tidelands State #2	1964	47° 3.2'	124° 12.8'	5,073	Pliocene - middle Miocene	Bottomed in melange and broken formation
3	Shell Oil 1ET P-0155	1967	46° 51.2	124° 24.5'	11,162	Pliocene(?) - late Oligocene(?)	Bottomed in melange
4	Shell Oil and Pan American P-0150	1966	46° 43.5'	124° 21.3'	13,179	Pliocene - late Oligocene(?)	Bottomed in melange
5	Shell Oil P-075 1 ET	1966	46° 9.1'	124° 24.5'	10,160	Pliocene(?) to middle Eocene(?)	Bottomed in Crescent(?) basalt
6	Shell Oil P-072 1 ET	1965-1966	46° 2.8'	124° 29.9'	8,219	Pliocene to late Oligocene(?)	Bottomed in melange
7	Standard Oil - Nautilus #1, P-0103	1965	44° 51.5'	124° 16.7'	12,628	Pliocene to late(?) Eocene	Cut Depoe Bay flow and sill; bottomed in late(?) Eocene breccia
8	Union Oil Grebe P-093	1966	44° 29.8'	124° 24.9'	10,010	Pliocene(?) to early(?) Eocene	Cut Depoe Bay sill and late Eocene tuff-breccia; bottomed in Siletz River Volcanics(?)
9	Shell Oil Well 1 ET-2 ET P-087	1965	44° 13.3'	124° 28.2'	8,353	Pliocene to early (?) Eocene	Penetrated late Eocene tuff-breccia; bottomed in early(?) Eocene basalt
10	Union-Fulmar P-0130	1966	44° 3.6'	124° 38.8'	12,221	Pliocene to early Eocene	Bottomed in cemented sandstone
11	Pan American Well No. 1, P-0112	1967	43° 14.8'	124° 35.6'	6,146	Pliocene to early Eocene	Bottomed in cemented sandstone

Table 2. Significant data on exploratory test wells drilled on the Oregon-Washington OCS

Stratigraphic Relations

The Yachats Basalt (Snavely and others, 1974) in the Cape Perpetua area are underlain by and grade laterally northward into thin-bedded tuffaceous siltstone of the upper Eocene (upper Narizian) Nestucca Formation. The basalts at Cascade Head also have a similar stratigraphic relationship to the Nestucca Formation. The upper contact of both these volcanic piles is marked by thick deposits of boulder and cobble conglomerate and shallow-water basaltic sandstone of late Eocene (Refugian) age. The Tillamook Volcanics also are overlain by thick beds of conglomerate and basaltic sandstone of late Eocene age, but the lower part of the Tillamook sequence is in part submarine and intertongues southward with siltstone of the Yamhill Formation of early late Eocene (lower Narizian) age. The relationship between the Yachats, Cascade Head, and Tillamook Volcanics and associated sedimentary rock is shown diagrammatically in figure 2.

Physical Character

The upper Eocene basalts are chiefly of subaerial origin with individual aphyric to very porphyritic flows of about 5-10 meters thick, commonly with brick-red oxidized and scoriaceous upper surfaces and a rubbly breccia base. Platy flow structures parallel to the flow contacts are common. The upper Eocene basalts are cut by numerous basaltic to andesitic dikes 1/4-3 meters thick that are commonly porphyritic with large phenocrysts of plagioclase and/or augite. Abundant vesicles and amygdules occur in blocks in breccia and also are common in the lower parts of many flows.

In northern Oregon, the lower part of the Tillamook Volcanics is of submarine origin and consists of pillow lavas and breccia with interbedded basaltic sandstone and lapilli tuff. Elsewhere pillow lavas are uncommon, but are found along the coast near Heceta Head where subaerial flows of the Yachats Basalt entered the sea. At Cascade Head 100-200 meters of volcanic breccia occur at the base of the sequence where it overlies the Nestucca Formation, but the remainder of the pile is largely subaerial flows with minor lapilli-tuff interbeds. Aerodynamically shaped bombs occur in some near-vent tuff breccia at Cascade Head and at Cape Perpetua.

The bulk of the upper Eocene volcanic rocks are basalts, but grade in composition to include basaltic andesite, andesite, and minor amounts of rhyodacite. Most of the rocks are porphyritic with phenocrysts of plagioclase (labradorite) and less commonly augite and olivine. The fine-grained groundmass is composed of plagioclase, augite, opaque minerals, and glass or its clay alteration product. Calcite, zeolite minerals, and quartz occur locally in amygdules in flows, and as cement in breccias.

Chemical Analyses

Chemical analyses of these upper Eocene volcanic rocks typically contain 50 percent SiO_2 and are characterized by high alumina, alkali, titania, and phosphate content. Table 1, columns 3 and 4, shows the variations in chemical analyses of the Yachats and Cascade Head basalts (Snavely and others, 1974) that are typical of the Tillamook Volcanics.

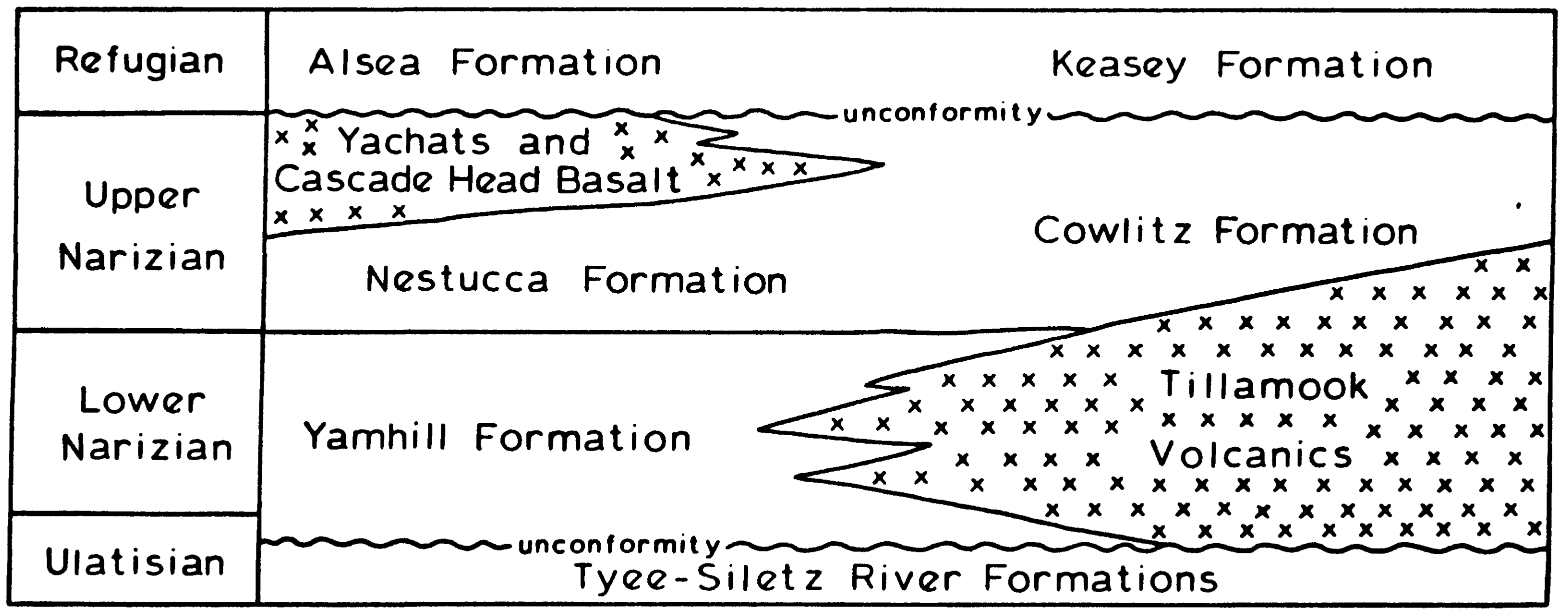

Figure 2. Diagram showing relationship between sedimentary units on the Tillamook Volcanics and the Yachats and the Cascade Head Basalts.

Paleomagnetic Data

Paleomagnetic studies by Simpson and Cox (1977) and Magill and others (1981) indicate that the upper Eocene basalts have been rotated in a clockwise direction. This rotation ranges from about 55° in the Yachats Basalt to 45° in the Tillamook Volcanics. These rotations are less than those in the lower 30-35° rotation for the lower Eocene oceanic basalts in southwestern Washington. This change in the amount of clockwise rotation, generally near the Columbia River, indicates that the Oregon Coast Range terrane was subjected to a different tectonic history than the Washington Coast Range, probably in response to interactions between the Pacific plate and the newly accreted Coast Range terrane.

Isotopic Age

Isotopic ages on whole rock and on feldspar separated from the upper Eocene basalts display a wide range of values, ranging from 44 to 22 MA, with many dates clustered around 30 MA. In view of the stratigraphic positions of these basalts within strata of late Eocene age, the younger dates are spurious and undoubtedly reflect argon loss from the rock. Possibly some of the upper Eocene basalts had their isotopic "clock" reset during a period of low-grade metamorphism resulting from the intrusion in the Oregon Coast Range of extensive sills of ferrogabbro dated at 30 MA.

MIDDLE MIOCENE BASALT

Distribution

Two periods of middle Miocene basaltic volcanism and associated intrusive activity occurred in coastal western Oregon and Washington. In Oregon these rocks extend onto the continental shelf (plate 3). These flows and breccias were erupted from coastal vents marked by dikes and sills of the same composition as the extrusive rocks. The oldest of the two units was named the Depoe Bay Basalt and the youngest, the Cape Foulweather Basalt (Snavely and others, 1973). These two basalt units are separated by 150 meters of massive arkosic sandstone and thin-bedded siltstone informally referred to as the sandstone of Whale Cove (fig. 1). Pillow lava and thick sills of the Depoe Bay Basalt are the most widespread middle Miocene igneous rocks on the continental shelf (plate 3). The Cape Foulweather breccias, and less common flows, probably only extend for a few kilometers beyond their local centers along the present coast. Although Depoe Bay pillow lavas extended as far west as Standard Oil Company's Nautilus P-0103 well, about 18 km west of the shoreline, probably most of the Depoe Bay type basalt on the continental shelf occurs as sills. These sills intrude strata as old as late Eocene in Union Oil Company's Grebe P-093 well (Snavely and others, 1983), but probably most of the sills occur in strata of Oligocene and middle Miocene age, as do many of the thick Depoe Bay Basalt sills exposed at Cape Falcon and Tillamook Head and elsewhere along the Oregon coast (figs. 2 and 10 in Snavely and others, 1973). On seismic-reflection profiles (fig. 3), these sills are readily recognized, for in places they cross-cut strata and have a high acoustic impedance (reflectivity).

Although sills and dikes of middle Miocene age occur near the Washington Coast (plate 3), these intrusives probably do not extend onto the continental shelf. This conclusion is supported by the fact that no igneous rocks were

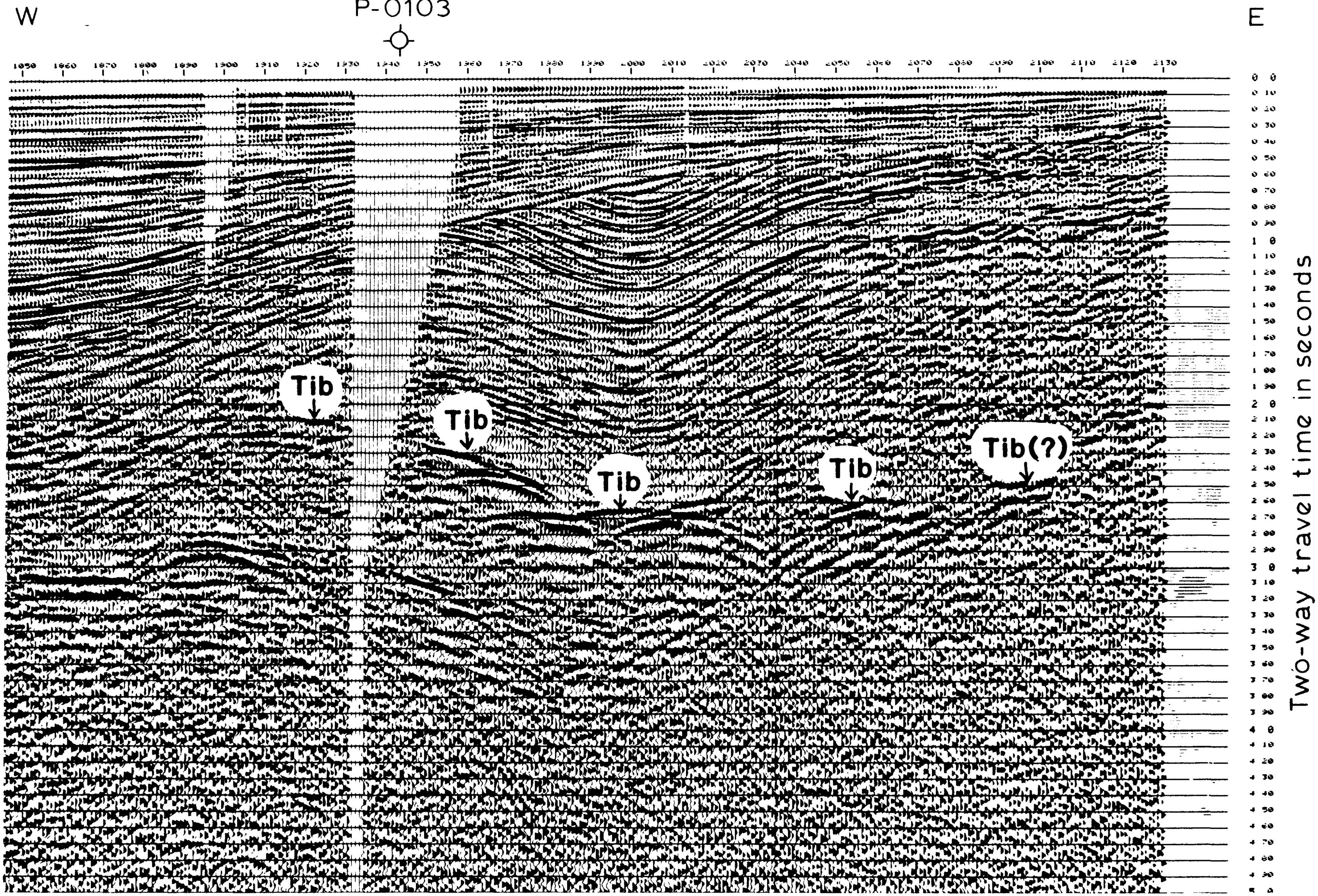

Figure 3.--Multichannel seismic-reflection profile (USGS, Lee 76-5) showing typical high acoustic impedance (reflectivity) of middle Miocene basalt sill (Tib). Note that acoustical unit cross-cuts folded strata. Standard Oil test well P-0103 penetrated Depoe Bay Basalt (Tib) sill at about 8,000 ft. See Snavely and others (1980) for geologic interpretation of seismic profile.

encountered in the four deep test wells drilled on the Washington shelf (plate 3 and table 2, wells No. 1-4).

Stratigraphic Relations

In coastal Oregon, the pillow lava flows of Depoe Bay Basalt unconformably overlie the Astoria Formation of middle Miocene age (Saucesian) and are overlain by the sandstone of Whale Cove also of Saucesian age (fig. 1). The Cape Foulweather Basalt unconformably overlies the sandstone of Whale Cove and offshore is overlain by siltstone and sandstone of middle Miocene (Relizian) age. Commonly occurring foraminiferal species in the Astoria Formation are listed by Rau (1981, p. 81) and in Snavely and others (1969, p. 41).

Physical Character

The Depoe Bay Basalt consists of submarine pillow lava and breccia, subaerial flows, and dikes and sills and irregular intrusive bodies. The pillows have black glassy borders 2 to 5 cm thick; some show ropy (pahoehoe) surfaces. The basalt is medium to dark gray and aphanitic to fine grained and has a glassy appearance when unweathered. Well-crystallized rocks contain a glassy silicic residuum and chlorophaeite. In places blebs of olive-green chlorophaeite occur in freshly broken basalt; they rapidly turn a dusty black color when exposed to air.

The Cape Foulweather Basalt consists largely of fragmental rocks such as tuff-breccia with blocks typically 2 to 15 cm in diameter. The blocks consist of massive vesicular or amygdaloidal basalt, bombs, and broken pieces of spatter. Numerous dikes cut the extrusive units in local centers such as at Cape Foulweather and some of these dikes feed breccia units higher in the pile. Aprons of water-laid lapilli tuff occur marginally to the eruptive centers and may represent littoral cones. Near former vent areas, these tuffs may have been transported by density currents on the inner shelf. Carbonized wood occurs in considerable quantity in the lapilli tuff units.

Unlike the Depoe Bay Basalt, the Cape Foulweather Basalt contains ubiquitous, but sparce, large plagiclase phenocrysts. The presence of these phenocrysts serves to distinguish this unit from the nonporphyritic Depoe Bay Basalt. Zeolite minerals, calcite, and quartz locally occur in amygdules and veinlets in the matrix of breccia.

Chemical Analyses

Chemical analyses from the Depoe Bay Basalt and the Cape Foulweather Basalt indicate that each has a distinct and uniform composition (table 1, cols. 5 and 6). The Depoe Bay Basalt is characterized by high SiO_2 content and is chemically equivalent to the Yakima petrographic type [now Grande Ronde Basalt] of the Columbia Plateau. The Cape Foulweather Basalt has a high content of total iron, TiO_2, and P_2O_5 and is equivalent to the late-Yakima petrographic type [now Frenchman Springs Member of the Wanapum Basalt] of the plateau (Snavely and others, 1973).

Paleomagnetic Data

Paleomagnetic studies by Magill and others (1982), and Wells and others

(1983) show that Coast Range Miocene volcanics have rotated 15° to 20° clockwise when compared to Columbia Plateau lavas. The rotation increases to the west and suggests dextral shear during oblique subduction along the coast may be responsible for the rotation.

Isotopic Age

A few dates are available for the Depoe Bay Basalt, but none are available for the Cape Foulweather Basalt. Depoe Bay Basalt from the Mt. Hebo sill has a K/Ar date of 16 ± 0.65 MA (Snavely and others, 1973). Turner (1970) reports K/Ar dates of 14.5 ± 1.0 MA, and 15.2 ± 0.6 MA for Depoe Bay Basalt at Cape Meares, and 14 ± 2.7 MA for basalt from near Ecola State Park. Recent K/Ar dates determined by Leda Beth Pickthorn (written commun., 1983) for a Depoe Bay sill that cuts the upper Eocene basalt at Cascade Head was 15.1 ± 0.4 MA, and a sill that cuts the lower Eocene Siletz River Volcanics in the Little Nestucca River had a K/Ar date of 15.0 ± 0.5 MA.

SUMMARY

Volcanic rocks form important parts of the Tertiary sequence of western Oregon and Washington. In exploration drilling programs, it is important to be able to identify which of the three volcanic rock types are being penetrated by the drill; for example, the Paleocene to lower middle Eocene oceanic basalts are the economic and geologic basement, but the upper Eocene and middle Miocene basalts overlie thick sequences of siltstone and sandstone that are potential source beds and reservoir rocks for petroleum.

In most cases, it is difficult to recognize a particular volcanic unit by examining well cuttings with a handlens or binocular microscope. However, thin section studies of mounted cuttings greatly improve one's success in the identification process. Listed below are a few criteria that may be useful in identifying various volcanic units from core samples or well cuttings using a handlens or binocular microscope:

1. Paleocene to early middle Eocene basalt

    Abundant white veins and amygdules that include zeolite minerals and calcite and minor quartz

    Basalt is mildly tectonized, fractures are common and have slickensided surfaces

    Appearance is waxy greenish-black due to alteration of basaltic glass to clay minerals

    Generally a fine-grained dark-greenish-gray basalt with a felted appearance

    Commonly aphyric to microphyric; augite is the most apparent phenocryst in most flows especially near the top of the sequence

    Lack of red oxidized material

2. Late Eocene

Aphyric to commonly porphyritic with large phenocrysts of plagioclase and/or augite, generally noticeably fresher and less tectonized than basement basalts

Commonly contains brick-red scoria derived from upper parts of subaerial flows; grains of scoria also found in basaltic sandstone that overlies the basalt

Rock generally is a lighter shade of gray to gray-green due to increase in silica and alkalis in basaltic andesite and andesite; more silicic dacite may be found locally; platy flow structure is common in this sequence

3. Middle Miocene

Usually black, unaltered dense basalts with glassy appearance

Fine-grained and lacks phenocrysts, except for Cape Foulweather basalt, which sometimes has sparse large (1-2 cm), clear plagioclase phenocrysts

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