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SCHEMATIC FENCE DIAGRAM OF THE SOUTHERN TYEE BASIN, OREGON COAST RANGE,

SHOWING STRATIGRAPHIC RELATIONSHIPS OF EXPLORATION WELLS TO SURFACE MEASURED SECTIONS

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Notice

The Oregon Department of Geology and Mineral Industries is publishing this report because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, text and figures submitted by the authors have not been edited by the staff of the Oregon Department of Geology and Mineral Industries.

Plate 1

Schematic Fence Diagram
of the Southern Tyee Basin, Oregon Coast Range,
Showing Stratigraphic Relationships
of Exploration Wells to Surface Measured Sections

Folded Separately

Plate 1 Errata

In column #4, the Weyerhaeuser F-1 well was spudded near the top of the Tyee Mountain Member. The strata shown in column #4 above the Tyee Mountain Member were measured in a nearby creek.

In Fig. 2 in column labeled "Calcareous Nannofossils" for zone CP-12, a and b were inadvertently transposed. Subzone CP-12a is older than subzone CP-12b.

In Table II, Kellog should be spelled Kellogg.

In Table II, LaVern Creek should read "LaVerne County Park."

Geologic interpretation of the Schematic Fence Diagram of the Southern Tyee Basin, Oregon Coast Range (Plate 1)

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INTRODUCTION

As part of the final phase of a 5-year program established by the Oregon Department of Geology and Mineral Industries (DOGAMI) to assess the hydrocarbon potential of the Eocene southern Tyee basin (Fig. A), a fence diagram was constructed from 24 composite measured sections and 11 oil and gas exploration wells (Plate 1). The 3,000- to 17,000-ft thick sections were measured from outcrops on the western and eastern flanks of the basin and correlated to the wells which are located in the southern, central and northern parts of the basin.

The positions of the composite sections and wells are shown on the index map (Fig. 1 on Plate 1). The names of the sections and wells are tabulated on Plate 1. Correlation of units between sections and wells on the fence diagram is based on stratigraphic position, lithology, examination of well cuttings, ages of strata as indicated by microfossils (foraminifers and coccoliths) (Fig. 2 on Plate 1) and molluscan fossils, wireline logs, seismic reflection profiles between wells, and measured sections. These correlations are supplemented by geologic mapping and field studies by Ewart Baldwin and his graduate students at the University of Oregon, by C. M. Molenaar (USGS), by G. L. Black (DOGAMI), by A. R. Niem (OSU), and by R.E. Wells (USGS). Additional detailed stratigraphic sections, interpretation of wireline logs, and paleontological data for biostratigraphic control are provided in the doctoral thesis of Ryu (in prep.) and master's thesis of Weatherby (1991).

Niem and Niem (1990) compiled geologic mapping of the basin that existed prior to this program. They also made a preliminary interpretation of oil and gas data that they tabulated from various sources. Furthermore, they prepared an overview of the geologic history and stratigraphy of the basin. A revised geologic map of the Tyee basin (Black and others, in press) and a geologic report on the oil and gas potential of the basin (Niem and others, in prep.) will be published in the near future. The revised map and report on oil and gas potential should be used in conjunction with this fence diagram in interpreting the surface and subsurface stratigraphic relationships in this basin.

FENCE DIAGRAM CONSTRUCTION

The solid vertical line forming each column of the fence diagram (Plate 1) represents a composite measured section or logged interval (in exploration wells). A dashed vertical line in any column represents the probable extension of the thickness of units inferred from thicknesses measured in adjacent sections and/or from nearby geologic mapping. Each column is numbered prominently, and the corresponding names of wells and measured sections are shown in Tables I and II on Plate 1. The symbol # preceding a number denotes an exploration well.

The solid line connecting the top of the stratigraphic section from one column to another represents the present land surface; it is exaggerated in places so that the reader can more clearly see the stratigraphic relationships in adjacent panels. Dashed horizontal lines represent lateral continuation of rock units, now eroded away between measured sections and/or wells.

The vertical scale in all sections is 1 inch equals 1,000 feet. However, the horizontal scale varies in order to fit the diagram onto standard width paper. Because the horizontal scale varies, we have indicated the number of miles between adjacent measured sections and/or wells on the diagram. The distances between columns are shown to scale on the index map (Fig. 1 on Plate 1).

DEFINITION AND LOCATION

The southern Tyee basin includes an area of approximately 4800 sq miles from Powers and Agness on the south to Roseburg and Glide on the southeast and Florence and Cottage Grove on the northwest and northeast, respectively (Fig. A). The basin extends another 80 miles north of the study area to the vicinity of Dolph, northeast of Lincoln City. The southern part of the basin appears to have the greatest oil and gas potential. The southern Tyee basin is part of the Oregon Coast Range geologic province but overlaps the northern boundary of the Klamath Mountains geologic province (Fig. A).

Within the southern Tyee basin are two superimposed basins with different trends and geologic and tectonic histories. The older northeast-southwest-trending Paleocene to early Eocene Umpqua basin has two subbasins: (1) the Sutherlin-Myrtle Point subbasin, filled with turbidite sandstone and mudstone, and (2) the Smith River subbasin to the north which contains dominantly deep-marine mudstone. These subbasins are separated by the Umpqua arch (Fig. A). Superimposed on the Umpqua basin is the late early to middle Eocene Tyee forearc basin (Chan, 1982; Heller and Ryberg, 1983) which trends north-south. Generally, strata in the Umpqua basin are more structurally deformed than the Tyee forearc strata. The more gently deformed middle Eocene Tyee strata are preserved in the broad synclinal low of the southern Oregon Coast Range. The underlying Sutherlin-Myrtle Point subbasin and part of the Umpqua arch are exposed on the eastern and western flanks of the southern Oregon Coast Range. The Tyee forearc basin is bordered on the west by the upper Eocene Coos Bay basin (Fig. A). Upper Eocene to Miocene Western Cascade calc-alkaline volcanic arc rocks unconformably overlie the eastern boundary of both the Tyee forearc basin and the Umpqua basin.

MODIFICATIONS TO THE STRATIGRAPHIC NOMENCLATURE OF THE TYEE BASIN

The stratigraphic framework on which this fence diagram is based builds upon elements from Baldwin (1974), Baldwin and Perttu (1989), and Molenaar (1985), upon field work completed for this project, and upon new mapping by Black (1990; 1993), Black and others (in press), and R. E. Wells and others (in prep.) (see Figs. 2 and 3 on Plate 1). Stratigraphic changes include:

1. The White Tail Ridge Member, Camas Valley Member, Bushnell Rock Member, and Tenmile Member of Baldwin (1974) and Baldwin and Perttu (1989) are raised informally to formation rank within the Umpqua Group.
2. Several new informal units are recognized. They are: (a) the Slater Creek sandstone member of the Bushnell Rock formation and (b) Berry Creek, Remote, and Coquille River members, and Rasler Creek tongue (from oldest to youngest) of the White Tail

Ridge formation. Proposed type and reference sections of these new informal units are established by Ryu (in prep.); the map distribution of these units will be shown on the geologic map by Black and others (in press).

3. We drop Baldwin's (1974) and Baldwin and Perttu's (1989) Lookingglass, Flournoy, and Roseburg formations and Olalla Creek Member of the Lookingglass Formation due to confusing stratigraphic and mapping relationships between the eastern and western flanks of the basin (for further discussion see Molenaar, 1985; Niem and Niem, 1990; Black and others, in press; Ryu, in prep.). We retain the Tyee Formation and its constituent members (the Tyee Mountain, Hubbard Creek, and Baughman members of Baldwin, 1974 and Baldwin and Perttu, 1989), the Elkton Formation, and the Bateman Formation because these units can be mapped and correlated throughout the basin.

In the southern part of the Umpqua basin, Paleocene and Eocene turbidite lithic sandstone, mudstone, and polymictic conglomerate (derived from the Klamath Mountains) interfinger with thick pillow basalt flows and breccias, basaltic lapilli tuff and tuffaceous mudstone, and associated diabase sills and dikes of the upper part of the Siletz River Volcanics (the Roseburg volcanics of Baldwin, 1974; see Fig. 3 on Plate 1). Following the usage of Wells and others (in prep.), we informally use the name Bushnell Rock formation for the thick-bedded polymictic conglomerate and pebbly, coarse-grained, lithic sandstone and apply the name undifferentiated Umpqua Group to the thin- to medium-bedded, lithic, turbidite sandstone and mudstone that are locally interstratified with and that overlie these volcanic rocks. In the northern part of the Umpqua basin where the Bushnell Rock and White Tail Ridge formations pinch out, the name undifferentiated Umpqua Group is also applied to deep-marine lithic turbidites and mudstone that overlie the Siletz River Volcanics. (Note the pinchout of White Tail Ridge formation units between column 12 and column 16 in the eastern part of the basin and the pinchout of these units between columns 7 and 17 in the western part of the basin).

On the fence diagram, facies variations within the undifferentiated Umpqua Group are indicated by lithologic symbols. We recognize thick-bedded, pebbly sandstone-dominated inner and middle submarine fan facies, thin- to medium-bedded turbidite outer fan facies, and basinal and slope mudstone facies. More detailed mapping is required, however, before these facies can be elevated to member status.

The depositional environment is also indicated for each member or formation shown on the fence diagram. For example, the Bushnell Rock formation is composed of fanglomerate, beach, and submarine fan facies.

The changes in group, formation, and member status and the new names of units used in this report are informal. The new names, however, have been reserved with the U.S. Geological Survey Geologic Names Committee. When the new map by Black and others (in press) is published, we intend to formalize the new names.

The following discussion should be used with the fence diagram (Plate 1) in full view.

BASEMENT ROCKS

Two basement rock units form the bottom of most measured sections or exploration wells (columns) in the fence diagram. These units are: (1) the older accreted Mesozoic terranes of the Klamath Mountains (Blake and others, 1985; Niem and Niem, 1990) (columns 1 through 10), and (2) the Paleocene to lower Eocene Siletz River Volcanics of the southern Oregon Coast Range (formerly the Roseburg volcanics of Baldwin, 1974) in the central, northern, and southeastern parts of the diagram (columns 10, 13, 14, 15, 18, 21, 22, and 23; wells #1, #2, #4, #5, #7, and #10).

ACCRETED MESOZOIC TERRANES

Nomenclature and Lithology

The igneous, sedimentary, and metamorphic rocks that comprise the Klamath Mountains of southwestern Oregon have been interpreted as a series of thrust-bounded terranes (Dott, 1971; Blake, 1984; Blake and others, 1985; Roure and Blanchet, 1983; Roure and others, 1986). The accreted Mesozoic terranes in the area of the fence diagram are dominated by the Sixes River terrane of Blake (1984) and Blake and others (1985). This terrane is a mélange dominated by intensively sheared, deep-marine dark gray mudstone containing fractured and highly faulted phacoidal blocks and broken formation. The tectonic blocks and broken formation are composed of thin- to thick-bedded, well-indurated, quartzo-feldspathic and lithic turbidite sandstone and thin-bedded, carbonaceous, gray mudstone. Some quartz-chert conglomerate and polymictic conglomerate also occur. In addition, this terrane includes scattered, exotic tectonic blocks of greenstone, blueschist, meta-gabbro, diabase, diorite and microtonalite, red and green radiolarian cherts, metatuff, eclogite, and limestone (Whitsett Limestone of Diller, 1898; Niem and Niem, 1990). The limestone blocks are tens to hundreds of feet long and thick. They are incorporated in a mélange of sheared mudstone and turbidite sandstone with scattered small blocks of red radiolarian chert and greenstone. Limestone blocks are composed of shallow-marine, massive, red algal-stromatoporoid boundstone, floatstone, oolitic to intraclast grainstone, and deep-marine, thin, rhythmically bedded micrite (planktonic foraminiferal wackestone), gray chert, and carbonaceous mudstone (Niem, unpublished data).

Age and Contact Relationships

The Sixes River terrane is considered by Blake (1984) and Blake and others (1985) to be Upper Jurassic (Tithonian to Hauterivian) and middle to Upper Cretaceous (Albian to Cenomanian; see Fig. 2 on Plate 1). Near Bushnell Rock, a klippe of Sixes River mélange (bottom of column 10) contains small blocks of fresh microtonalite that Mobil Oil Corporation K-Ar dated (whole rock) as 147.4 ± 5.4 Ma and 174.5 ± 4.5 Ma, or Jurassic (unpublished data from Mobil courtesy of Bill Seeley). The tectonic blocks of Whitsett limestone contain Lower and middle Cretaceous foraminifers (Albian to Aptian; Bill Sliter, USGS, 1986, pers. commun.).

The Sixes River terrane is overthrust by Jurassic and Triassic island arc and ophiolite terranes (Blake, 1984; Roure and Blanchet, 1983; Roure and others, 1986). In turn, the Sixes River terrane has been thrust over the Paleocene-lower Eocene Siletz River Volcanics and undifferentiated Umpqua Group of the southern Oregon Coast Range (Carayon, 1984; Carayon and others, 1984; Niem and Niem, 1990; Wells, in prep.; Black and others, in press) (e.g., columns 9 and 10). For example, in columns 9, 10, and #16 of the fence diagram (Plate 1), note the thrust relationship of pre-Tertiary Klamath terranes over lower Eocene Siletz River Volcanics.

The Wildlife Safari Fault (Fig. A) has been mapped as a high-angle right-lateral strike-slip fault (Ramp, 1972; Baldwin, 1974; Ryberg, 1984) and more recently as a thrust fault with some right-lateral oblique slip (Wells, in prep.). Small klippen of Mesozoic terrane rocks in thrust fault contact with the Siletz River Volcanics also occur north of the Wildlife Safari fault (Carayon, 1984; Niem and Niem, 1990). Thrust faulting and accretion appear to have been accomplished in the Paleocene to early Eocene prior to deposition of the Tenmile formation. Baldwin (1974) and Baldwin and Beaulieu (1973) alternatively mapped many of these thrust faults as high-angle normal and reverse faults which juxtapose Klamath Mountain terranes (Mesozoic basement) against Siletz River Volcanics (Tertiary basement) and Umpqua Group strata. Baldwin (1984) offered the alternative interpretation that the small outliers or "klippen" of pre-Tertiary rocks surrounded by Tertiary rocks in the southern Oregon Coast Range are olistostromal or slump blocks that slid into the Umpqua flysch basin during the early Eocene.

The pre-Tertiary terranes in the northern Klamath Mountains are regionally truncated by an angular unconformity which is overlain by conglomerate and lithic sandstone of the Bushnell Rock and younger formations (columns 1, 3, 5, 6, 7, 8, 9, and 10).

SILETZ RIVER VOLCANICS

Nomenclature

The basaltic basement rocks of the central and southern Oregon Coast Range have been assigned to several formations over the years. Diller (1898), on his pioneering map of the Roseburg quadrangle, included a thick pile of Eocene basalts and sedimentary interbeds as part of his Umpqua Formation. Baldwin (1974) and Baldwin and Beaulieu (1973) subsequently raised the Umpqua Formation to group status. The lowermost part of the Umpqua Group was renamed the Roseburg Formation. The lower member of the Roseburg Formation contained the basalts (see Fig. 3 on Plate 1). Basalts and sedimentary rocks exposed along the North Umpqua River were designated as the type section of the Roseburg Formation.

In the central Coast Range, the Siletz River Volcanics were named by Snavely and Baldwin (1948) for a thick sequence of lower Eocene tholeiitic pillow lavas, submarine breccias, and capping alkalic subaerial flows exposed along the Siletz River.

Snavely and others (1968) noted the chemical and petrologic similarity between the Siletz River Volcanics and the basalts in Diller's (1898) Umpqua Formation. In 1985, Molenaar assigned the Eocene volcanic rocks of the southern Coast Range to the Siletz River Volcanics. Furthermore, the recently published geologic map of Oregon (Walker and MacLeod, 1991) refers to these basalts in the southern Oregon Coast Range as the Siletz River Volcanics.

There is ongoing discussion whether to call the Eocene mafic lavas in the southern Oregon Coast Range Roseburg Formation (Baldwin, 1974) or Siletz River Volcanics (Molenaar, 1985). Exposures of the type Siletz River Volcanics and the Eocene volcanics in the southern Coast Range are physically separated by many miles, which supports applying two names. However, the Eocene volcanic rocks in the southern Tyee basin are geochemically, petrographically, and lithologically similar to the type Siletz River Volcanics (Pyle, 1988). In addition, geophysical studies indicate that the basalts of the two areas are continuous in the subsurface (Snavely and Wagner, 1963).

The basalts in the southern Tyee basin appear to be, in part, older than the type Siletz River Volcanics (Duncan, 1982). Also, unlike the basaltic lavas in the type area, they are locally interbedded with thick sequences of extrabasinal sedimentary rocks (Baldwin, 1974; Ryberg, 1984; Niem and Niem, 1990; R. Wells, 1992, pers. commun.). We prefer to assign the thick, mappable interbeds of interfingering sedimentary rock to sedimentary formations (e.g., undifferentiated Umpqua Group and Bushnell Rock formation) rather than include them in an igneous unit. This follows the convention set by Swanson and others (1979) on the Columbia Plateau of southeastern Washington and northeastern Oregon. When defining the middle Miocene Columbia River Basalt Group, they restricted the igneous unit name to the widespread tholeiitic lavas and associated basaltic pyroclastics. They excluded the locally thick sedimentary interbeds, which they assigned to other formations (e.g., Ellensburg Group of eastern Washington). In addition, the Columbia River Basalt Group has been further subdivided into members and formations on the basis of geochemistry and magnetostratigraphy (Reidel and Hooper, 1989). In the future with additional mapping, magnetostratigraphy, petrography, and geochemical analyses, the Siletz River Volcanics of the Roseburg-Myrtle Point-Drain area of the southern Oregon Coast Range may be similarly subdivided.

Lithology

The Paleocene to lower Eocene Siletz River Volcanics of western Oregon have been interpreted as an early Tertiary oceanic crust and seamount province accreted to the North American continent (Snavely and others, 1968; Simpson and Cox, 1977; Dickinson, 1979; Heller and Ryberg, 1983; Snavely, 1987; Niem and others, 1992).

In the southern Tyee basin, this unit (Roseburg basalts of Baldwin, 1974) consists of a thick sequence of tholeiitic pillow lavas veined with calcite and zeolites. The pillow lavas are interbedded with and overlapped by palagonitized basaltic breccia and local highly undersaturated alkalic subaerial flows (Pyle, 1988). The pillow lava and breccia sequence also includes subordinate beds of moderately indurated, dark gray, basaltic, tuffaceous mudstone, lapilli tuff, and hyaloclastites (R. E. Wells, 1992, pers. commun.). Associated diabase sills are most numerous near thrusts and near the upper contact with strata of the Umpqua Group (e.g., Glide section [column 14]; R. E. Wells, 1992, pers. commun.).

Several subaerial flows, consisting of amygdaloidal, columnar jointed, plagioclase- and augite-phyric to finely crystalline basalt, containing abundant zeolite-filled vesicles in flow top breccias and red oxidized paleosols, are exposed in basalt quarries in the Drain anticline near the settlement of Drain (near column 22). Pyle (1988) noted also that pillow lava-dominated sections are more common in the Roseburg and Sugarloaf Mountain (i.e., Remote) areas in the south whereas subaerial alkalic (or differentiated) flows, basaltic breccias, and hyaloclastics are more abundant in the northern part of the basin (i.e., the Drain area). He suggested that the northern volcanics represent a differentiated seamount(s) or Hawaiian-like shield volcano(es).

Thickness and Distribution

Geophysical studies indicate that the Siletz River Volcanics are at least 25 km thick in the central Oregon Coast Range (Trehu, 1993, pers. commun.; Trehu and others, 1992). These rocks represent economic basement. Based on exploration wells and outcrops, these volcanics can be traced throughout the Tyee basin (see columns #10, 23, 14, #7, 15, 18, #4, #5, #2, and #1). For example, Mobil's Sutherlin well (#7 on Plate 1) in the southeastern part of the Tyee basin penetrated more than 8,900 ft of Siletz River Volcanics. Amoco's Weyerhaeuser B-1 well in the central part of the basin (#5 on Plate 1) drilled more than 4,400 ft of pillow lavas and breccias. In the northeastern part of the basin, Florida Exploration's Harris 1-4 well (#2 on Plate 1) encountered more than 3,700 ft of mafic volcanics; and in the northwestern part of the basin, the bottom 1,700 ft of the Long Bell well (#1 on Plate 1) are basalt. A partial representative section of more than 5,300 feet of continuously exposed, unfaulted, homoclinally dipping pillow lavas and basaltic breccia containing a few thin sedimentary interbeds was measured along the North Umpqua River (base of the Glide section, column 14 on Plate 1; secs. 16, 17, and 18, T. 26 S., R. 4 W.).

Locally, a thick carapace of basaltic breccia and tuffs overlies the pillow lavas. In the Sutherlin (#7), B-1 (#5), Harris 1-4 (#2), and Long Bell (#1) wells, the thickness of breccia encountered is more than 2,500 ft, 1,400 ft, 1,800 ft, and 1,300 ft, respectively.

Geophysical Expression and Basin Topography

A network of multi-channel seismic reflection profiles (unpublished data courtesy of Mobil Corp. and Weyerhaeuser-Amoco Production Co.) extends from the southeastern part of the basin (i.e., well #7) to the central and northern parts of the basin (wells #4, #5, #1, and #2). On these records, the Siletz River volcanic basement appears as numerous subparallel, gently inclined, strong and weak reflectors that can be traced for miles (Peter Hales, Weyerhaeuser, 1990, pers. commun.). The reflectors approximately outline several broadly folded, coalescing shield volcanoes or elongate oceanic island and seamount volcanic edifices, named the Umpqua arch in this report (Fig. A and Plate 1). A petrographic study of cuttings from Mobil's Sutherlin well (#7) and from Amoco's Weyerhaeuser F-1 and B-1 wells (#4 and #5) shows that the shallowest of the gently inclined, continuous reflectors within the Siletz River Volcanics are alternating layers of soft palagonitized breccia, lapilli tuff, and minor mudstone interbeds and hard, dense, pillow basalt flows (unpublished Amoco-Weyerhaeuser report). However, there is a regionally traceable seismic reflector within the Siletz River Volcanics that has not been penetrated by drilling and that does not crop out (Peter Hales, 1993, written commun.). The reflector was a drilling objective in both Amoco's Weyerhaeuser B-1 and Mobil's Sutherlin wildcats, but both wells stopped <500 ft short of penetrating it. The seismic reflector may indicate a transition back to sedimentary rocks (Peter Hales, 1993, written commun.).

The early Eocene volcanic highs that form the Umpqua arch are also recognizable as a series of elongate, *en echelon*, northeast-southwest trending magnetic anomalies and gravity highs. These anomalies can be traced on unpublished gravity and magnetic maps (from Mobil Oil Corp. and Amoco Production Co.-Weyerhaeuser) from mapped anticlines cored with Siletz River Volcanics on the eastern flank of the basin (e.g., Drain, Jack Creek, and Red Hill anticlines on maps of Hoover, 1963 and Niem and Niem, 1990) southwestward beneath the middle Eocene Tyee forearc strata preserved in the central part of the basin. The volcanics crop out again in the cores of faulted anticlines on the southwestern flank of the basin at Sugarloaf Mountain between Remote and Myrtle Point (Fig. A).

The Umpqua arch is centered in the subsurface near the Amoco-Weyerhaeuser F-1 and B-1 wells (#4 and #5) and in measured sections 18 and 21 (Plate 1). The Florida Exploration Harris 1-4 well (#2) penetrated the Tyee Formation and a thin section of Umpqua Group strata and abruptly encountered Siletz River volcanic basement in the northernmost of these buried "anticlinal" or oceanic volcanic highs in the eastern part of the basin.

The arch affects the geometry of the overlying undifferentiated Umpqua Group strata. For example, field maps (Baldwin, 1974; Black and others, in press), seismic reflection profiles (Peter Hales, 1989, pers. commun.) and measured sections and wells (e.g., column 15 and wells #7 and #8) show that south of the arch several thousand feet of Klamath Mountains-derived, lithic turbidite sandstone and bathyal mudstone of the undifferentiated Umpqua Group are preserved in a depositional low herein named the Sutherlin-Myrtle Point subbasin (Fig. A). These submarine fan strata onlap the arch to the north, thinning rapidly to < 200 ft of bathyal mudstone on the axis of the arch (columns 18 and 21). Some locally derived, shallow-marine basaltic sandstone unconformably overlies subaerial Siletz River lavas, reflecting erosion of volcanic islands on the arch prior to thermal(?) subsidence and slow burial by bathyal mudstone. On the north side of the arch, the undifferentiated Umpqua sedimentary section again rapidly thickens to more than 3,000 ft of deep-marine mudstone in the Long Bell well (#1 on Plate 1). This thickening perhaps reflects a separate, more distal depositional low, herein called the Smith River subbasin (Plate 1 and Fig. A). The extent of the Smith River subbasin is unclear because it is buried by the north-south trending Tyee forearc basin. However, well logs and seismic reflection profiles indicate that the strata thin to the southeast (e.g., 700 ft of Umpqua mudstone in the Harris 1-4 well [#2]) and to the south (e.g., in the Sawyer Rapids well [#3]) and thicken to the northwest and north.

The Sutherlin-Myrtle Point subbasin was a syntectonic marginal basin or trench that has been subsequently shortened by imbricate thrusts (e.g., the Bonanza fault zone on Fig. A) during late-early Eocene subduction (Heller and Ryberg, 1983; see Fig. Ba). Lower Eocene undifferentiated Umpqua Group strata that comprise the northeast-southwest-trending Sutherlin-Myrtle Point subbasin crop out in the Roseburg-Sutherlin area on the east and in the Myrtle Point-Coquille-Blue Ridge Mountain-Sugarloaf Mountain area on the southwest. Younger middle Eocene units (largely Tyee Formation) bury the locally more deformed Umpqua strata in the center of the basin. The southern boundary of the Sutherlin-Myrtle Point subbasin is unclear, but it extended as far south as Agness on the Rogue River (column 1, Plate 1; Fig. A).

Contact Relationships

The basal contact of the Siletz River Volcanics is not exposed in the Oregon Coast Range. The upper contact of the unit is both depositional and tectonic. Siletz River basalts interfinger with and are locally unconformable with overlying undifferentiated Umpqua Group strata and the Bushnell Rock formation in the southern Oregon Coast Range (Molenaar, 1985; Figs. 2 and 3 on Plate 1).

In the Roseburg-Glide-Sutherlin area (in the southeastern part of the basin; Fig. A and Plate 1), for example, pillow lavas, basaltic breccias, and tuffs of the Siletz River Volcanics interfinger with mappable lenses and beds (tens to hundreds of feet thick) of polymictic conglomerate, debris flow deposits, and thick-bedded, pebbly lithic sandstone of the lower Bushnell Rock formation (e.g., Glide section, column 14; Baldwin, 1974; Ryberg, 1984; Wells and others, 1984; Wells and others [in prep.]). These deep-marine conglomerates and turbidite sandstones were derived from metamorphic, igneous, and sedimentary rocks of the Mesozoic Klamath Mountains. Some interbeds within the volcanics are deep-marine, thin- to medium-bedded, graded, coarse-grained, lithic turbidite sandstone, mudstone, and minor conglomerate lenses of the lower undifferentiated Umpqua Group (lower part of column 10 and column 23).

Mapping and seismic reflection profiles show that the Siletz River Volcanics are also commonly in fault contact with Bushnell Rock formation conglomerate and the Umpqua Group and with the pre-Tertiary rocks of the northern Klamath Mountains (Baldwin, 1974; Baldwin and Beaulieu, 1975; Ryberg, 1984; Wells and others, in prep.; Amoco and Mobil unpublished maps and seismic reflection profiles). Wells and others (in prep.) and Ryberg (1984) have shown by mapping that the Siletz River Volcanics have been repeated against overlying units by at least four major northwestward-verging imbricate thrusts. These faults occur between the Glide section (column 14), Melrose section (column 13), and the Sutherlin well (#7) and comprise the Bonanza fault zone (Fig. A; Baldwin, 1964; Ryberg, 1984; Niem and Niem, 1990; Wells, 1992, pers. commun.; Niem, unpub. mapping).

The Siletz River Volcanics and lower Umpqua Group strata are overlain with local angular unconformity by syntectonic strata of the upper Bushnell Rock formation, Tenmile formation, and middle to upper Umpqua Group (e.g., columns 9 and 10) (Heller and Ryberg, 1983; Fig. B).

Age

Duncan (1982) reported five whole rock K-Ar dates for the Siletz River Volcanics that crop out in the Drain area and in the Coquille-Myrtle Point-Remote area (Fig. 1 on Plate 1). The dates range from 62.1 ± 1.0 Ma to 59.2 ± 2.8 Ma. These absolute dates correlate to lower to upper Paleocene (Ynezian foraminiferal stage; Fig. 2 on Plate 1). K-Ar dates of surface samples from these areas analyzed by Mobil Oil Corporation range from 47.2 Ma to 56.5 Ma (unpublished data, courtesy of Bill Seeley). No systematic regional progression of age is obvious from these K/Ar dates over this relatively small area. There is much overlap, but the youngest dates are clustered in the Drain-Jack Creek-Dickinson Mountain area.

Duncan (1982) calculated a whole rock K-Ar age of 52.7 ± 0.7 Ma (or early Eocene) for Siletz River Volcanics near the bottom of Mobil's Sutherlin well (total depth 13,177 ft; well #7 on Plate 1). However, he believes that argon loss possibly as a result of late stage burial metamorphism is responsible for this anomalously young date. The $^{40}Ar/^{39}Ar$ analysis of the same sample yielded an older isochron age of 63.9 ± 1.9 Ma that Duncan feels is more reliable. The $^{40}Ar/^{39}Ar$ date is closer to the oldest dates of outcrop samples. Mobil Oil Corp. also determined K-Ar dates of 58.2 and 56.9 ± 1.5 Ma for Siletz River Volcanics in Mobil's Sutherlin well (#7) at depths of 11,340 to 11,350 ft, respectively (unpublished data, courtesy of Bill Seeley). Questionable Upper Cretaceous K-Ar ages reported for the Siletz River Volcanics include: 69 Ma near Bushnell Rock (Carayon, 1984) and 73.9 Ma near Coquille (Mobil, unpublished data).

Along the North Umpqua River near Glide (column 14, Plate 1) (secs. 17 and 18, T 26 S., R. 4 W.), a thin mudstone interbed (<3 ft) within the upper part of the Siletz River pillow basalts contains a foraminiferal assemblage of lowest Eocene age (Bulitian stage; or D stage of Almgren and others, 1988; McKeel, 1990, written commun.) (Fig. 2 on Plate 1). In the Scott No. 1 well at depths of 1,420 ft and 1,920 ft (#10 on Plate 1), deep-marine mudstone of the Umpqua Group overlying the volcanics and Bushnell Rock conglomerate yielded lower Paleocene(?) foraminiferal assemblages (McKeel, 1990, written commun.). Paleocene foraminiferal ages also were reported from interbeds in Mobil's Sutherlin well (unpublished Amoco data, courtesy of Weyerhaeuser Co.). In summary, these paleontological and isotopic dates indicate a Paleocene to early Eocene age for the Siletz River Volcanics.

TECTONIC SETTING OF SILETZ RIVER VOLCANICS AND KLAMATH MOUNTAIN TERRANES

The tectonic relationship of the Oregon Coast Range Siletz River Volcanics to the Klamath Mountains pre-Tertiary terranes is an important factor in planning oil and gas drilling in the Tyee basin (see Niem and others, in prep.). Different strategies are needed depending on whether the boundary between these two geologic provinces is a fault contact or an angular unconformity.

Several ideas have been put forward for the origin of these rocks. The thickness and range of compositions (from tholeiitic basalts to alkalic basalts) of the Siletz River Volcanics have led some researchers to interpret these lavas as a remnant block of the Farallon Plate (Snavely and others, 1968; MacLeod and Snavely, 1973; Simpson and Cox, 1977; Dickinson, 1979; Heller and Ryberg, 1983). Based on major and trace element geochemistry and an apparent progression to younger K-Ar ages in the northern Oregon and southern Washington Coast Ranges, Duncan (1982) and Pyle and Duncan (1992) suggested that the oceanic islands and seamounts of the Siletz River Volcanics were created at an oceanic spreading ridge centered over a Yellowstone hotspot in northwestern Oregon-southwestern Washington.

There are also questions as to whether the basalts were erupted in place or elsewhere. Some geologists have suggested that the volcanics in the southern Oregon Coast Range were accreted to the North American continent by oblique underthrusting or subduction beneath the northern border of the Klamath Mountain terrane in the late early Eocene (Snavely, 1984, 1987; Wells and others, 1984; Heller and Ryberg, 1983; Perttu and Benson, 1980; Baldwin and Perttu, 1980; Niem and others, 1992a). In this model, the Wildlife Safari Fault represents the main tectonic suture or boundary between the Mesozoic Klamath terrane and the Tertiary Siletz River Volcanics oceanic crust (Fig. A). North of the Wildlife Safari fault, a series of imbricate thrusts, the Bonanza fault zone of Baldwin (1964) and Ryberg (1984), trends generally northeast-southwest. The intensity of thrusting decreases to the north, away from the suture. Seismic reflection profiles (Peter Hales, Weyerhaeuser, 1990, pers. commun.) and geologic mapping by E. M. Baldwin and his graduate students (1960-1970), by Ryberg (1984), and by Black and others (in press) show that the northeast-southwest-trending Bonanza fault zone continues southwestward (column 11) beneath the overlying Tyee forearc sequence (see panel between columns 7 and 17; Fig. A).

Only a few thrusts of the Bonanza fault zone are shown schematically on the structurally simplified fence diagram (e.g., between columns 11, 12, and 13, between columns 7 and 17, between columns 14 and #7, and between columns #7 and #8). The diagram would have become too complicated to be readily useful if a more complete depiction of the faulting had been attempted. The panels between columns are not palinspastic reconstructions; the sections are shown in their relative positions after middle Eocene thrusting, folding, and possible later renewed oblique-slip to normal and reverse faulting during the Neogene.

Wells and others (1984), however, suggested that the Siletz River Volcanics were erupted in place. They pointed out that the Siletz River Volcanics are locally interbedded with extrabasinal Bushnell Rock formation and Umpqua Group strata that were derived from the Mesozoic terranes of the northern Klamath Mountains. Therefore, rather than being formed at a distant spreading ridge, the volcanics were erupted in place along a rifted continental margin (Snavely, 1987), perhaps at a spreading ridge or above a hotspot. One possibility is that the tholeiitic submarine lavas were erupted in a rifted basin or half-graben on possible extended Klamath Mountain Mesozoic crust along normal or oblique-slip faults that stepped down to the north into the basin (R. Wells, 1992, pers. commun.). Some earlier map interpretations (for example, Hicks, 1964; Cornell, 1971; Baldwin, 1974; Baldwin and Beaulieu, 1973) showed pre-Tertiary rocks of the Klamath Mountains unconformably beneath the Siletz River Volcanics. High-angle normal and reverse faults juxtaposed Siletz River Volcanics against pre-Tertiary rocks. In this model, sediments shed into the deep-marine basin from nearby uplifted blocks of the Klamath Mountains interfingered with the erupting lavas.

The lavas would have partly covered accreted Mesozoic terranes and formed a broad complex of overlapping submarine shield volcanoes and oceanic islands (some are subaerial flows). Mobil's Sutherlin well, for example, penetrated more than 6,500 ft of submarine breccia and pillow lavas before encountering 2,500 ft of subaerial vesicular lavas with red oxidized zones in the bottom of the well (Bill Seeley, Mobil, 1990, pers. commun.). This lower 2,500 ft might indicate the presence of another shield volcano; but based on trace element and rare earth geochemistry of samples throughout the Mobil well, Pyle (1988) recognized no major chemical variations or differentiation that might be expected in the growth of coalescing shield volcanoes.

This rifting episode probably was followed by plate reorganization and/or plate rotation in the late early Eocene (Wells and others, 1984). This reorganization resulted in less oblique subduction and more head-on collision that slowly cut off the mafic oceanic volcanism and further depressed the Klamath Mountain terrane (North American crust). Bushnell Rock conglomerate and Tenmile slope and turbidite strata were deposited over a local angular unconformity across both the Mesozoic Klamath Mountain terranes and the Siletz River Volcanic oceanic crust (columns 1 to 9). During subsequent subduction in the late early Eocene, underthrusting on faults (e.g., Wildlife Safari, Canyonville, and Powers faults, Fig. A; Ryberg, 1984) created a classical, imbricate-thrust "trench fill" or subduction complex of Bushnell Rock submarine channel-fanglomerates and overlying undifferentiated Umpqua Group-Tenmile formation turbidite fan strata (Fig. Ba). These strata now overlie the older, deformed Siletz River Volcanics, Paleocene-earliest Eocene strata, and Klamath Mountain tectonic terranes.

Ongoing field work by R. E. Wells and U.S. Geological Survey personnel is striving to define the tectonic framework and early Tertiary development of this suture zone and the accompanying oceanic basalt volcanism. This team of investigators hopes to determine if this boundary is a rifted continental margin, an accreted and partially subducted oceanic Siletz River Volcanics and trench fill, or a combination of both. The tectonic and depositional settings at this basin margin could affect exploration drilling strategies in the basin.

STRATIGRAPHY OF SEDIMENTARY UNITS

This section discusses the stratigraphy of the 20,000-ft thick Eocene sedimentary section that overlies the basement rocks of the southern Oregon Coast Range. Several formations and members comprise this section (Figs. 2 and 3 on Plate 1). From oldest to youngest these are: (1) Bushnell Rock formation and Slater Creek member; (2) undifferentiated Umpqua Group; (3) Tenmile formation; (4) White Tail Ridge formation including Berry Creek, Remote, and Coquille River members and Rasler Creek tongue; (5) Camas Valley formation; (6) Tyee Formation with Tyee Mountain, Hubbard Creek, and Baughman members; (7) Elkton Formation (and laterally equivalent Lorane Shale); and (8) Bateman and Spencer formations. Discussion of each formation includes nomenclature, lithology, thickness and distribution, age, contact relationships. The depositional environment of some units is also mentioned.

BUSHNELL ROCK FORMATION

Nomenclature

The Bushnell Rock member of the Lookingglass Formation was named by Baldwin (1974) for exposures at Bushnell Rock, a 2,033-ft high mountain 2 miles northwest of the settlement of Tenmile and approximately 1 mile southeast of Reston. Baldwin did not describe a type section in the Bushnell Rock area. We have measured a section, suitable as a type section, along the Tenmile to Reston road in sec. 25, T. 28 S., R. 8 W. (Plate 1, column 10; Ryu, in prep.). Other reference sections are the Slater Creek, Twelvemile Creek, and Glide measured sections (columns 8, 9, and 14, respectively). We have informally raised the Bushnell Rock to formation status because there are mappable facies or members within the unit (Black and others, in press). Foremost of these is the sandstone-dominated Slater Creek member. The type section for this member occurs along the logging road and in Slater Creek in secs. 20 and 29, T. 30 S., R. 9 W.

Thickness and Distribution

The Bushnell Rock formation crops out only in the southern part of the basin where the thickness of the unit ranges from 250 ft to 4,000 ft (e.g., Plate 1, columns 1, 2, 5, 6, 8, 9, 10, 13, 14, and 23). This unit also was penetrated in two exploration wells; i.e., the Great Discovery well (#17) and the Scott well (#10).

The formation is thickest and coarsest in the southern and southeastern parts of the basin in the Slater Creek and Twelvemile Creek sections (columns 9 and 8), in the Reston Road section (column 10), in the Glide section (column 14), and in the Scott well (#10). The unit thins and fines to the west and southwest (i.e., toward columns 7, 6, 5, 4, 3, 2, and 1) and pinches out entirely before reaching the LaVerne section (column 17) on the northwestern flank of the basin. Also, the formation is absent in the northern and western parts of the basin. It was not penetrated in Mobil's Sutherlin well (#7), in Amoco's Weyerhaeuser B-1 and F-1 wells (#5 and #4), or in General Petroleum's Long Bell well (#1) and is missing in the Allegany section (column 18). The unit also is missing in the Elkton section (column 21), in the Metz Hill section (column 15), in the Interstate-5 section (column 22), and in Florida Exploration's Harris 1-4 well (#2).

Lithology and Depositional Setting

The Bushnell Rock formation consists of thick- to very thick-bedded, pebble-cobble-boulder polymictic conglomerate and subordinate, poorly sorted, dark gray lithic sandstone. The conglomerate is poorly sorted and commonly in framework-support. Clasts are subangular to subrounded. The lithic sandstone is typically coarse- to very coarse-grained. Subordinate lithologies include thin to medium beds of red and gray mudstone, fine-grained lithic sandstone, and siltstone. This well-indurated unit forms barren to grass-covered, precipitous cliffs that are tens to hundreds of feet high.

Four lithofacies are recognized within the formation: (1) fanglomerate and fan delta facies; (2) deep-marine conglomerate and sandstone; (3) very thick-bedded, fine-grained sandstone of the Slater Creek member; and (4) beach and shallow-marine coarse-grained sandstone.

On the fence diagram, we have used different lithologic symbols and labels to indicate various depositional facies within the Bushnell Rock formation.

Fanglomerate and Fan Delta Facies: The fanglomerate facies occurs in the south-central part of the basin (the main depocenter) (columns 8, #17, 9, #16, and 10). This lithofacies forms the lower half of the formation and consists of reddish brown, thick- to very thick-bedded, polymictic pebble-cobble-boulder conglomerate; disorganized conglomerate (debris flow deposits); and subordinate lenses of massive, pebbly, very coarse- to coarse-grained lithic sandstone. The pebbles and cobbles in these poorly sorted conglomerates are subrounded to angular, and the texture ranges from framework support to sand matrix support. Some organized conglomerates display imbrication and are channelized. Intervals of thin-bedded, trough cross-bedded to ripple-laminated, fine- to medium-grained, lithic sandstone are minor. Some red to maroon mudstone interbeds are as much as 25 ft thick. A subordinate fan delta facies composed of cross-bedded, pebbly, fine- to medium-grained, moderately sorted lithic sandstone interfingers with the upper part of the fanglomerate facies in columns 8, 9, and 10. This fan delta sequence contains scattered molds and casts of disarticulated mollusks and carbonized leaf and wood fragments.

The thickness of the fanglomerate facies rapidly pinches and swells from a few hundred feet to 2,400 ft over a lateral distance of several miles (e.g., between columns 9 and 10). Clasts in the conglomerate and debris flow deposits are up to 3 ft in diameter. Clast lithologies are dominantly graywacke, chert and quartz conglomerate, vein quartz, quartzite, phyllite, greenstone, granitic intrusive rocks, and intermediate to mafic volcanic rocks. Many clasts were derived from the Mesozoic Klamath Mountain terrains that were uplifted and exposed along the Canyonville fault scarp (Perttu, 1976; Kugler, 1979; Heller and Ryberg, 1983; Ryberg, 1984) adjacent to the Slater Creek section (column 8) and Twelvemile Creek section (column 9). A probable depositional setting is a series of coalescing temperate alluvial fans or bajadas at the mouths of several canyons that drained the nearby rugged Klamath Mountain uplands. These alluvial fans prograded into the sea as fan deltas in the warm, humid temperate or semi-tropical climate of the early Eocene (Kugler, 1979; Ryberg, 1984).

Deep-marine Conglomerate and Sandstone Facies: The deep-marine facies is as much as 1,000 ft thick and comprises the upper one-third to one-half of the Bushnell Rock formation. These poorly sorted units were deposited as submarine canyon or upper submarine fan valley fills as sea level rose and inundated the fanglomerate-fan delta shoreline. In the Twelvemile Creek section (column 9) and in the Bushnell Rock type section (column 10), thick, cliff-forming, very coarse-grained fanglomerates and mollusk-bearing pebbly sandstone fan delta facies are gradationally overlain by a thick sequence of deep-marine conglomerate and very coarse-grained lithic sandstone. This overlying lithofacies includes thick- to very thick-bedded to amalgamated, medium gray disorganized debris flow deposits and graded and reverse graded polymictic pebble-cobble-boulder conglomerate. Very coarse-grained, poorly sorted pebbly lithic sandstone comprises a subordinate component. Beds of medium gray, deep-marine mudstone are thin and minor.

The deep-marine unit is the dominant facies in the southeastern part of the basin (columns 14, 23, and #10). A thick (1,600-ft) section of submarine channel basaltic and polymictic conglomerate, matrix-supported boulder-cobble debris flow deposits, and graded, thick- to very thick-bedded, poorly sorted, pebbly very coarse-grained lithic sandstone overlies and interfingers with the Siletz River Volcanics in the Glide section (column 14) and in the Scott well (#10). Thin dark gray mudstone interbeds also are present. Although these Bushnell Rock conglomerates and sandstones appear as isolated outcrops in this section and in the well, we show a dashed tentative correlation line between the Bushnell Rock submarine facies in the Glide section (column 14) and the deep-marine conglomerate facies in the upper part of the type section (column 10) based on general compositional and lithologic similarities, stratigraphic position, and mapping of discontinuous outcrops of Bushnell Rock (e.g., column 23) along the Wildlife Safari fault by Wells and others (in prep.).

The Bushnell Rock formation may consist of separate, coalescing alluvial fans and fan deltas that were isolated from submarine valley-fill facies. For example, in the southeastern part of the basin (e.g., column 14), the conglomerates and debris flow deposits in the basal part of the Bushnell Rock formation that interfinger with Siletz River Volcanics contain abundant, locally derived basalt clasts. Polymictic conglomerate with metamorphic, vein quartz, granite, and intermediate volcanic clasts becomes more abundant up-section. At Twelvemile Creek (column 9) and in the type section (column 10), nearly all clasts (such as quartz, chert, diorite, greenstone, and graywacke) were derived from the Klamath Mountains. In the Twelvemile Creek section, the unit overlies with angular unconformity pre-Tertiary Klamath Mountain terranes. At the type section, the Bushnell Rock formation unconformably overlies both a klippe of pre-Tertiary rocks and the Siletz River Volcanics. Ryberg (1984) also recognized separate fan deltas and submarine fan systems within the Bushnell Rock formation. Also see discussion below of conglomerate lenses in the Tenmile formation that are lithologically similar to the Bushnell Rock formation conglomerates.

Very Thick-bedded, Fine-grained Sandstone of the Slater Creek Member: The fan delta facies interfingers with and is locally overlain by the Slater Creek member in the proposed type section at Slater Creek (column 8), at the top of the Glide section (column 14), and in the Great Discovery well (#17). This local, 2,100-ft thick sequence consists dominantly of very thick-bedded to amalgamated, well-indurated, lithic feldspathic sandstone with a few thin lenses of polymictic pebble conglomerate in the lower part of the unit. Sandstone beds are gray-green, uniformly fine-grained, and structureless to faintly wavy laminated. Some beds contain mudstone rip-ups and fragments of carbonized wood and leaves.

This facies is thought to be shallow-marine based on sparse molds, casts, and shell fragments of molluscan fossils. Foraminifers recovered from scattered thin mudstone beds between sandstone beds indicate "estuarine"(?) depositional conditions (McKeel, 1989, written commun.).

In the upper part of the unit, the very thick- to thick-bedded Slater Creek sandstone rhythmically alternates with thin-bedded, medium gray mudstone. The sandstone contains mudstone rip-ups as much as 1 ft long. Upper and lower contacts of sandstone beds are sharp. The bedding style and lithologic characteristics are typical of turbidite facies B of Mutti and Ricci Lucchi (1972) and Walker and Mutti (1973); therefore, some of the unit may be deep-marine.

The lateral stratigraphic relationship of the Slater Creek member at Slater Creek (column 8) and in well #17 to the submarine channel conglomerate facies at Twelvemile Creek (column 9) and Reston Road (column 10) is unclear. The submarine channel conglomerate facies which overlies the fanglomerate-fan delta facies at Twelvemile Creek appears to grade upward into alternating thin and medium beds of graded, coarse- to very coarse-grained lithic turbidite sandstone and mudstone of the Tenmile formation. However, in the Slater Creek section, the very thick-bedded, fine-grained, quartzo-feldspathic sandstone of the Slater Creek member overlies the fanglomerate-fan delta facies and is, in turn, overlain with angular unconformity by pebble-boulder conglomerate of the Remote member of the White Tail Ridge formation (column 8). Laterally, the type Slater Creek sandstone member may also overlie and interfinger with the submarine or deep-marine channel conglomerate between Twelvemile Creek and well #17 (as drawn on the fence diagram). Alternatively, the deep-water submarine channel facies at Twelvemile Creek (column 9) may erosionally cut into and overlie the Slater Creek sandstone. The mapped relationship between the two facies (between columns 8 and 9) is unclear at this time (G. L. Black, 1992, pers. commun.).

A thin (<100 ft) section of thick-bedded, fine-grained, mollusk-bearing, shallow-marine(?) "Slater Creek" sandstone facies gradationally overlies deep-water Bushnell Rock submarine polymictic conglomerate at Glide (column 14). This supports the first stratigraphic interpretation above.

Beach and High-energy Shallow-Marine Facies: The Slater Creek member and fanglomerate facies of the Bushnell Rock formation (column 8) fine and thin rapidly to the south and west to <250 ft of shallow-marine, mollusk-bearing, medium- to thick-bedded and locally planar and trough cross-bedded, pebbly, lithic sandstone (columns 1, 3, 5, 6, and 7). The sandstone is well-cemented, fine- to coarse-grained, and moderately well-sorted. Some sandstone beds contain subrounded to well-rounded, moderately sorted, fine to medium pebbles (quartz, volcanic, and metamorphic) in thin layers and in cross-beds. These beds are similar to the high-energy beach facies described by Leithhold and Bourgeois (1984) in the middle Miocene Floras Lake Formation of southwestern Oregon and in the beach deposits described by Clifton (1973).

The beach facies fines upward from pebbly, cross-bedded, lithic sandstone to dominantly shelfal, very coarse- to coarse-grained, lithic sandstone. This thin sequence of Bushnell Rock shallow-marine, mollusk-bearing conglomerate and coarse-grained lithic sandstone overlies pre-Tertiary Klamath Mountain rocks with angular unconformity. It is conformably overlain by bioturbated to laminated deep-marine mudstone, thin-bedded, lithic, turbidite sandstone, and isolated channels filled with polymictic conglomerate. Similar channel conglomerate and thick-bedded lithic sandstone occur within the thin-bedded mudstone and turbidite sandstone in Tenmile formation (e.g., column 6).

Age and Contact Relationships

The Bushnell Rock formation contains early Eocene molluscan fossils and is overlain by the Tenmile formation which contains foraminiferal assemblages that indicate an early Eocene age (Penutian foraminiferal stage; D. McKeel, 1991, written commun.).

The unit unconformably overlies both pre-Tertiary Klamath Mountain terranes (e.g., column 9) and Paleocene to early Eocene Siletz River Volcanics (e.g., column 14).

The base of the unit also locally interfingers with the Siletz River Volcanics. In the lower part of the Scott well (#10), several hundred feet of conglomerate and pebbly lithic sandstone of the Bushnell Rock formation both overlie and underlie 600 ft of Siletz River pillow lavas (based on driller's logs, cores, well cuttings, and wireline logs). Between the towns of Glide and Wilbur, the deep-marine conglomerate facies is interbedded with and overlies pillow lavas and breccias of the Siletz River Volcanics (Wells and Waters, 1934; R. E. Wells, 1992, pers. commun.). This formation is conformably overlain by deep-marine (slope) mudstone and thin lithic turbidite sandstone beds of the Tenmile formation.

Syntectonic Bushnell Rock fanglomerate, fan delta, and submarine channel conglomerate prograded northward from the uplifted Klamath Mountains source area, crossing the tectonic suture into the subducting basin. Bushnell Rock conglomerate extends northward as deep-marine channels or canyon fills and upper fan valley sequences that cut into and interfinger with Siletz River Volcanics (e.g., columns 13 and 14). The conglomerate is overlain by hundreds to thousands of feet of middle and outer submarine fan deposits (rhythmically bedded turbidite lithic sandstone and mudstone) and upper slope and basinal mudstone of the Tenmile formation (e.g., well #10; Fig. B).

Bushnell Rock formation conglomerate and Tenmile formation strata have been repeated by thrust faulting in the upper part of the Scott well (#10). Based on the wellsite geologist's description, we have interpreted the cores at 965 ft and 1,400 ft as Tenmile formation. The conglomerate shallower than 965 ft appears to be an overlying thrust plate of Bushnell Rock formation conglomerate. The sequence of strata in the Scott well, therefore, probably represents the subsurface continuation of the northeast-southwest-trending Bonanza fault zone mapped by Ryberg (1984), Niem and Niem (1990), Black and others (in press), and Wells and others (in prep.; Fig. A). Many oil and gas shows have been reported in the fractures in these cores (i.e., in driller's logs).

UNDIFFERENTIATED UMPQUA GROUP

Nomenclature

The Umpqua Formation was named by Diller (1898) for a thick sequence of conglomerate, sandstone, and mudstone that occurs stratigraphically above the pillow basalts and beneath the Tyee Formation. Baldwin (1974) raised the Umpqua Formation to group rank and subdivided the Umpqua Group into three formations and five members (Fig. 3 on Plate 1). The formations from oldest to youngest are: the Roseburg, Lookingglass, and Flournoy formations.

Baldwin (1974) further subdivided his lowermost unit, the Roseburg Formation, into two mappable members: the Roseburg volcanics and the Roseburg sedimentary rocks. Roseburg Formation sedimentary rocks largely overlie but locally interfinger with the basement Roseburg Formation volcanics.

Molenaar (1985) suggested a different scheme for subdividing the Umpqua Formation of Diller (1898). He proposed: (1) dropping the name Roseburg Formation volcanics in favor of Siletz River Volcanics; (2) retaining the name Umpqua Formation for the thick sequence of sedimentary rocks occurring between the basement volcanics and the Tyee Formation; (3) discarding the Lookingglass and Flournoy formations of Baldwin (1974); (4) combining the Olalla Creek Member of the Lookingglass Formation and the White Tail Ridge Member of the Flournoy Formation into one member, which he called the White Tail Ridge member of the Umpqua Formation; and (5) dividing the Umpqua Formation into four members, the Bushnell Rock, Tenmile, White Tail Ridge, and Camas Valley members (Fig. 3 on Plate 1). In Molenaar's interpretation, the Bushnell Rock, Tenmile, White Tail Ridge, and Camas Valley members are largely conformable facies of the laterally equivalent undifferentiated Umpqua Formation. The Umpqua Formation overlies (commonly with angular unconformity) and locally interfingers with the Siletz River Volcanics. Where the individual members pinch out, the term Umpqua Formation is used.

As mentioned above in the discussion of the nomenclature of the Siletz River Volcanics, we prefer to include sedimentary rocks in sedimentary formations and igneous rocks in igneous units. Since our Umpqua Group does not include the Eocene basalts, our Umpqua Group is not identical to Diller's (1898) Umpqua Formation.

Baldwin (1974) and Baldwin and Beaulieu (1973) maintained that, because of tectonic events, there are three regional unconformities in their Umpqua Group. These occur, from oldest to youngest: (1) between the highly deformed Roseburg sedimentary and volcanic rocks of their Roseburg Formation and the overlying Bushnell Rock, Tenmile, and Olalla Creek members of the Lookingglass Formation; (2) between the Olalla Creek Member of the Lookingglass Formation and the White Tail Ridge Member of the Flournoy Formation; and (3) between the Flournoy and Tyee formations (see Figs. 2 and 3 on Plate 1).

Our studies and recent geologic mapping by others (e.g., Black, 1990, 1993; Wells and others, in prep.) in the area show that there is a local angular unconformity between the Umpqua Group and the Siletz River Volcanics and between the Umpqua Group and the overlying Tyee Formation, as Baldwin (1974) interpreted. However, we also recognize that there are interfingering facies relationships between the members and between the Umpqua Group and the Siletz River Volcanics, as Molenaar (1985) suggested. These local unconformities imply synchronous tectonic deformation and deposition of the Umpqua Group units as Heller and Ryberg (1983) interpreted (see Fig. B). After consultation with other geologists mapping in the basin (Molenaar, Wells, and Black, 1990-93, pers. communs.) and because the North American Stratigraphic Code allows local unconformities between formations and members within a group (North American Commission on Stratigraphic Nomenclature, 1983), we have subdivided the Eocene in the southern Oregon Coast Range in the following manner: (1) the Umpqua Formation of Diller (1898) is raised to group rank, as suggested by Baldwin (1974); (2) the name Siletz River Volcanics is given to the volcanic rocks at the base of the section, as suggested by Molenaar (1985); (3) the Umpqua Group is split into four formations, the Bushnell Rock, Tenmile, White Tail Ridge, and Camas Valley formations. This usage follows the suggestion of Molenaar (1985), but raises his members to formation rank; and (4) where the individual formations named above cannot be reliably mapped, and where lower Eocene strata interfinger with the Siletz River Volcanics, we use the name undifferentiated Umpqua Group.

Lithology and Depositional Environment

Using the turbidite facies nomenclature and depositional environment interpretation of these facies of Mutti and Ricci Lucchi (1972) and Walker and Mutti (1973), the undifferentiated Umpqua Group consists of stacked, deep-marine inner, middle, and outer submarine fan turbidite sandstone sequences and basinal mudstone facies. These facies were deposited in a trench or marginal basin setting (Heller and Ryberg, 1983; Ryberg, 1984; Niem and Niem, 1990). Some of these subfacies are shown on the fence diagram (Plate 1) but are not formally named as members. That step awaits more detailed regional mapping of the units (see Black and others, in press; Wells and others, in prep.). A preliminary distribution of these deep-sea fan and basinal facies is illustrated by Ryberg (1984) which was then compiled on a larger scale map by Niem and Niem (1990).

The informal facies are: (1) Facies C and D, medium- to thick-bedded, rhythmic turbidite sandstone and mudstone; (2) Facies B and C, thick- to very thick-bedded, amalgamated sandstone and pebbly sandstone with mudstone partings; (3) Facies D and G, thin- to very thin-bedded turbidite sandstone and mudstone and thick mudstone; and (4) Facies G, thin, condensed section of basinal mudstone.

Facies C and D and Facies G: In the Metz Hill section (column 15), 1,250 ft of medium- to thick-bedded, rhythmic, lithic turbidite sandstone and dark gray mudstone of the Umpqua Group (mid-fan facies C and D of Mutti and Ricci Lucchi, 1972) overlie a thicker sequence (3,700 ft) of laminated to structureless, dark gray mudstone (basinal facies G of Mutti and Ricci Lucchi, 1972). Turbidite sandstones are medium- to coarse-grained and medium gray in color. The basinal mudstone is interbedded with minor, 100- to 200-ft sequences of thin- to very thin-bedded, fine-grained outer fan (facies D) and basinal, graded, lithic, turbidite sandstone beds. This sequence of facies reflects progradation of a mid-submarine fan facies over an outer fan facies. Turbidites in the middle-outer fan facies (C and D) display Bouma sequences bcd and abce (including graded bedding) and mudstone rip-ups. They are even-bedded and have sharp basal contacts and gradational upper contacts. Some contain flutes, grooves, and bounce-marks and burrows on the base of beds. A few thickening-upward cycles from facies D to C and amalgamation of sandstone beds occur. Sandstones are well-indurated, dark medium gray, lithic wackes composed largely of metamorphic and volcanic rock detritus derived from the Klamath Mountains (Galloway, 1974; Heller and Ryberg, 1983; Ryberg, 1984). Benthonic foraminifers from the interbedded mudstone indicate bathyal water depths (Thoms, 1965, 1975; Miles, 1977; D. McKeel, 1991, written commun.).

The tightly cemented, lithic, mid-fan turbidite facies can be tentatively correlated with thicker sequences of thin-bedded, lithic, turbidite sandstone beds (outer fan turbidite facies D) in the Union Liles well to the west (column #8 on Plate 1). There is probably some duplication within the turbidite sequence in this well owing to thrust faulting as indicated by repetition of strata that contain foraminifers of the B-4/C stages of Almgren and others (1988) (McKeel, 1991, written commun.; see queried thrust fault in #8). These mid-fan facies may also correlate to turbidite facies in Mobil's Sutherlin well (column #7) and to the Sutherlin Creek measured section (column 24). The mid-fan facies (C and D) is overlain by thick, massive slope mudstone that contains B-1 stage foraminifers (Fig. 2 on Plate 1) in the Metz Hill section along Interstate-5 (column 15).

Facies B and C: In the Sutherlin well and Sutherlin Creek section are medium- to thick-bedded, poorly sorted, graded, medium- to coarse-grained lithic turbidite sandstone beds with thin, rhythmically interbedded mudstone of outer to middle fan facies D of Mutti and Ricci Lucchi (1972). These strata thicken and coarsen upward to a 600-ft thick sequence of burrowed, thick- to very thick-bedded to amalgamated, structureless sandstone and locally pebbly, poorly sorted sandstone (Bouma aa sequences) with thin mudstone partings. The sequence is typical of the channelized middle to upper fan facies of Walker and Mutti (1973).

This sandstone-dominated unit in the Sutherlin Creek section (column 24) can be tentatively traced westward on field maps for several miles along strike in the thrust plate to Woodruff Mountain (between columns 12 and 16; Niem and Niem, 1990; Black and others, in press; Wells and others, in prep.) where similar well-indurated, pebbly lithic sandstone beds with thin mudstone partings are exposed (Wells, 1992, pers. commun.). The structureless sandstone beds at Woodruff Mountain, however, are thicker bedded, amalgamated, and coarser grained and contain lenses of organized and disorganized pebble conglomerate. These features are typical of mid-fan channels and upper submarine fan channel facies (facies B_2, A_1, and A_2 of Walker and Mutti, 1973). This lower Eocene folded and thrust-faulted, thick-bedded unit disappears southwestward unconformably beneath the Tyee escarpment (Fig. A).

This mid- to upper-fan unit may also be exposed on the west flank of the Coast Range syncline in the Big Creek and East Fork of the Coquille River area, northwest of the town of Remote (Plate 1, between columns 7 and 17; Black, 1992, pers. commun.; Black and others, in press; Niem and Niem, 1990). These tightly cemented, massive to very thick-bedded, coarse-grained to pebbly, lithic, dirty sandstone beds of facies B could be a reservoir target for exploration beneath the Tyee forearc basin strata, if fracture porosity resulting from folding and thrust faulting has been developed. Some seeps of thermogenic gas were noted by Mobil Oil Corporation geologists (Bill Seeley, 1991, pers. commun.) along thrust faults and in drag-folded medium- to thick-bedded facies C and D sandstones in the Bonanza fault zone along the Umpqua River (Niem and Niem, 1990; Niem and others, in prep.).

This coarse-grained, inner to middle fan turbidite sequence in the Sutherlin Creek section (column 24), in the Mobil well (#7), and at Woodruff Mountain may the lateral facies equivalent of the submarine fan valley conglomerate or channeled upper fan system of the Bushnell Rock conglomerate in the southern and southeastern part of the basin (Ryberg, 1984). See the Glide section (column 14), Glory Hole well (column #9), and the Scott well (column #10).

Facies D and G: Measured sections combined with seismic reflection profiles and mapping (Black and others, in press; Niem and Niem, 1990) show that the very thick sequence of outer fan facies (facies D) and thick basinal mudstone (facies G) in the Sutherlin-Myrtle Point subbasin rapidly thins northward to <200 ft of laminated to massive, concretionary mudstone (facies G) on the Umpqua arch (e.g., column 15 to columns 22 and 21). This thin interval of mudstone also occurs on the arch in Amoco's Weyerhaeuser B-1 well (column #5) and Weyerhaeuser F-1 well (column #4), in the Allegany section on the west flank of the basin (column 18), and in the Drain area (column 21). This unit is also present in the Scott Valley area along Interstate-5 (column 22) and in Florida Exploration's Harris 1-4 well (#2) on the northeast flank of the basin. This thin stratigraphic sequence represents a condensed section developed on a paleotopographic high. It contains a vertical sequence of foraminiferal assemblages (referrable to the C to B-1 stages; D. McKeel, 1991, written commun.) (Plate 1, Fig.

2) identical to the vertical sequence of foraminiferal stages in the very thick (>4,000 ft) turbidite fan and mudstone that comprise the Myrtle Point-Sutherlin subbasin.

In the base of these condensed sections are approximately 100 ft of tightly cemented (zeolites and calcite), basaltic sandstone and lenses of moderately to poorly sorted, basalt pebble conglomerate. These strata were deposited around the anticlinal highs of subaerial amygdaloidal Siletz River Volcanics in the Drain, Red Hill-Dickinson Mountain, and Jack Creek areas on the Umpqua arch (Hoover, 1963; columns 21, 22, and 15) and could be expected in the subsurface in these areas.

Thickness and Distribution

The thickness of the undifferentiated Umpqua Group varies greatly from >4,000 ft in the Sutherlin-Myrtle Point subbasin (e.g., column 15) and 3,000 ft in the Smith River subbasin (e.g., well #1) to <200 ft on the Umpqua arch (e.g., column 21). The thickest part (4,000 ft) of the Umpqua Group turbidite fan facies is preserved in the southeastern part of the Tyee basin (i.e., columns #7, #8, and 15). A thick section of undifferentiated Umpqua Group turbidites in the southwestern part of the Sutherlin-Myrtle Point subbasin was not measured due to structural complexities (G. L. Black, 1992, pers. commun.) and time constraints (e.g., area between Remote, Powers, Myrtle Point, and LaVerne County Park). Undoubtedly, the thickness is similar to that in the Metz Hill area (see Niem and Niem, 1990; Black and others, in press).

Another well, the Great Discovery well (column #17), in the southern part of the fence diagram bottomed in a thick deep-marine (bathyal) mudstone (Umpqua Group?) beneath Bushnell Rock conglomerate. This mudstone does not crop out. Foraminifers recovered from well cuttings are lowest Eocene (Bulitian Stage or D stage of Almgren and others, 1988; McKeel, 1991, written commun.; Fig. 2 on Plate 1). The unit is age correlative to and possibly a facies equivalent of thin turbidites and mudstone in the lower part of the Umpqua Group that is interstratified with the thick sequences of pillow lavas of Siletz River Volcanics at Glide (column 14; McKeel, 1991, written commun.).

Presumably Siletz River Volcanics and/or pre-Tertiary Klamath Mountain terranes lie below the thick mudstone unit (see queried thrust interpretation at #17 on Plate 1). The stratigraphic units that overlie the mudstone in the well are correlative to the Bushnell Rock formation, Slater Creek member, and Remote member of the White Tail Ridge formation that crop out nearby. A few miles south of the well along Slater and Twelvemile creeks (columns 8 and 9), pre-Tertiary Sixes River terrane is overlain with angular unconformity by Bushnell Rock fanglomerate. The 600 ft thick Umpqua Group(?) mudstone in the bottom of the Great Discovery well is missing in both of these well-exposed sections.

At least two explanations are possible: either (1) the Bushnell Rock conglomerate in the well unconformably overlies a locally preserved thick sequence of older, unexposed Umpqua Group mudstone that, in turn, overlies the two thrust-faulted, juxtaposed basement units (see interpretation shown on Plate 1 at well #17); or (2) a high-angle right-lateral or oblique-slip fault occurs between the measured sections of columns 8 and 9 and the Great Discovery well (column #17). This fault would juxtapose basement rocks to the south against the locally preserved overlying 600-ft thick lower Umpqua(?) mudstone unit to the north. This postulated basement fault is now buried beneath the angular unconformities of the Bushnell Rock conglomerate and the Remote member of the White Tail Ridge formation.

Age, Correlation, and Contact Relationships

The age of the undifferentiated Umpqua Group is early Eocene or Penutian (Fig. 2 on Plate 1; Miles, 1977). Foraminiferal stages range from C in the lower basinal mudstone facies (e.g., Metz Hill, column 15) to B-4 in the middle- and outer-fan turbidite facies (e.g., Metz Hill) to B-1 in the overlying thick basinal mudstone facies (McKeel, 1991, written commun.). This sequence of foraminiferal ages from C to B-4 to B-1 and overall similar lithology (thin-bedded lithic turbidites and mudstone) is also repeated in the type area of the Tenmile formation (column 10), suggesting an age and lithologic correlation (McKeel, 1991, written commun.; Molenaar, 1985). Mudstone bearing B-1 foraminifers also occurs in the Camas Valley formation which is dominated by massive mudstone and may also be an age and lithologic correlative of the upper undifferentiated Umpqua Group section at Metz Hill (column 15) and the condensed section at the Jack Creek anticline (column 21) and in wells #4 and #5 (see Fig. 2 on Plate 1).

Undifferentiated Umpqua Group strata conformably overlie and interfinger with the upper part of the Siletz River Volcanics (e.g., columns 14, 23, 13, and 10; see also discussion in Contact Relationships section for Siletz River Volcanics). The upper contact is discussed in the sections on the Camas Valley and White Tail Ridge formations.

TENMILE FORMATION

Nomenclature

The Tenmile formation was originally defined as a member of the Lookingglass Formation by Baldwin (1974; Fig. 3 on Plate 1). The type area is Tenmile Valley (sec. 31, T. 28 S., R. 7 W.), 11 miles southwest of Roseburg. Baldwin (1974) did not measure a type section. We measured a possible type section along Suicide Creek (column 10) and reference sections along Tenmile Creek and a logging road along Twelvemile Creek (column 9; for more details see Ryu, in prep.). Molenaar (1985) interpreted the Tenmile formation as a lithologic and age equivalent of his lower Umpqua Formation (our Umpqua Group). He dropped the name Lookingglass Formation. We informally raise the unit to formation status within the Umpqua Group and drop the name Lookingglass Formation as well.

Thickness, Distribution, and Lithology

The 3,000-ft thick, deep-marine Tenmile formation is widespread in the southern, southeastern, and eastern part of the basin (columns 1, 2, 3, 5, 6, 7, 9, 10, 13, 14, #16, and #9). The unit consists of thick sequences of thin-bedded turbidites alternating with thick sequences of deep-marine mudstone. The turbidite sequences are as much as 1,500 ft of rhythmically alternating beds of medium gray, thin to very thin lithic sandstone and dark gray mudstone. The sandstone/mudstone ratios in these sequences range from 1:1 to 2:1 (note dot-dash pattern on Plate 1). Mudstone sequences are up to 1,400 ft of deep-marine, laminated to massive, foraminifer-bearing, medium dark gray mudstone.

Sandstones in the Tenmile formation are well-indurated, even-bedded, poorly sorted, and medium- to coarse-grained. Graded bedding, parallel to convolute bedding (i.e., Bouma sequences ae and bcde), and mudstone rip-ups are common. Sandstone beds also have sharp basal contacts and gradational upper contacts with the overlying mudstone. The soles of some beds have flute and groove marks. These features are typical of turbidite facies D of Mutti and Ricci Lucchi (1972). Miles (1977) and McKeel (1991, written commun.) interpreted the benthonic foraminiferal assemblage from the intervening mudstone beds as indicative of mainly bathyal water depths.

The facies D sandstone sequences of the Tenmile formation generally occur above thick sequences of massive to laminated hemipelagic slope mudstone which overlie deep-marine submarine channel facies of the Bushnell Rock formation (columns 9 and 10). Locally, facies D sandstone sequences are overlain by 500 ft of upper slope to outer shelf, mollusk-bearing massive mudstone-siltstone, suggesting a gradual shallowing of the basin (e.g., columns 9, 10, and #16). The thin-bedded turbidite sequences also pinch out to the northwest and north (e.g., column 10 to column 11 and column 7 to column 17).

In the southernmost part of the basin there is some indication of shallowing of the basin. Here, lower to middle slope, thin-bedded turbidite sandstone and mudstone (facies D) in the Tenmile formation appear to be discontinuous lenticular deposits that grade laterally to upper slope and outer shelf, massive, mollusk-bearing mudstone. Locally, these deep-marine, thin-bedded slope turbidites overlie the beach and high-energy shallow-marine facies of the Bushnell Rock formation and are associated with several hundred foot thick sequences of polymictic conglomerate channels. There are at least three such isolated, filled slope channels (columns 1, 2, 3, 5, 6, and 7) which are described below.

Turbidite Subfacies A_1, A_2, and B_2: The channel fills within the Tenmile formation consist of thick-bedded, very poorly to poorly sorted, polymictic, normal and reverse graded pebble-cobble-boulder conglomerate and very coarse-grained, graded, pebbly lithic sandstone. The conglomerates are in framework- and sandy matrix-support (i.e., debris flow deposits). There are thin intervals of dark gray mudstone. Mudstone rip-ups in the thick pebbly sandstone beds are locally abundant due to channel scour-and-fill. Some Bouma aa and bc sequences occur. These features are typical of the deep-marine organized and disorganized conglomerate facies (A_1 and A_2) and the massive pebbly sandstone facies (B_2 to A_4) of Walker and Mutti (1973).

Each of the three isolated channel fills is dominated by very poorly sorted, well rounded to subrounded cobbles and boulders of distinctive composition. The size and lithologies of the clasts indicate very proximal Klamath Mountain source rocks such as abundant granodiorite and amphibolites (Agness, column 1), granodiorite (up to 20-ft diameter boulders at Agness Pass, column 2), and rounded, white calcareous concretions (Rasler Creek, column 6).

The distinctive lithologic assemblage in each indicates that there were at least three separate fans or deep-water submarine channels. For example, in the Rasler Creek section (column 6), the beach and high-energy shallow-marine facies of the Bushnell Rock formation is overlain by 200 ft of massive mudstone, thin-bedded turbidite sandstone, and silty sandstone of the Tenmile formation. This is overlain by 500 ft of normal and reverse graded conglomerate and thick-bedded pebbly sandstone. This thick conglomerate sequence occurs within a lens of thin-bedded, coarse-grained, lithic turbidite sandstone and mudstone that grades both vertically and laterally into Tenmile slope mudstone and thin-bedded turbidites.

These channel fills have many lithologic features similar to the Bushnell Rock conglomerates, except that they occur within the Tenmile formation whereas the Bushnell Rock conglomerates directly overlie pre-Tertiary rocks or Siletz River Volcanics. The channel fill conglomerates could be late-stage sedimentological tongues of Bushnell Rock conglomerate within the Tenmile formation. These channel fills are too small and discontinuous to show as such on small-scale maps (Black, 1992, pers. commun.) and therefore are included in the Tenmile formation. However, the thick channelized debris flow deposit in the Agness and Agness Pass sections (columns 1 and 2) (some boulders 3 to 4 ft in diameter) may be part of submarine channel fills and may be mapped in the Bushnell Rock formation (Black and others, in press).

Age, Contact Relationships, and Correlation

Abundant foraminiferal assemblages indicate that the Tenmile formation is early Eocene (Penutian) in age (Thoms, 1965, 1975; Miles, 1977). The lower part of the unit is equated to the C foraminiferal stage, and the upper part of the unit is referrable to the younger B-4 foraminiferal stage of Laiming (described by Almgren and others, 1988; McKeel, 1991, written commun.; Fig. 2 on Plate 1).

Based on similar vertical sequences of foraminiferal assemblages, most of the Tenmile formation would equate in age to the lower and middle part of the undifferentiated Umpqua Group (McKeel, 1989-92, pers. commun.). These undifferentiated Umpqua Group rocks have in the past been mapped as Roseburg Formation (Baldwin, 1974; Niem and Niem, 1990). That is, the thick basal mudstone in all sections contains foraminifers indicative of the C stage; the rhythmically thin-bedded turbidite sequences in the middle of the section contain B-4 foraminifers, and mudstone higher in the section contains B-1 foraminifers (McKeel, 1990, written commun.).

The Tenmile formation appears to be largely a slope facies, in part equivalent to outer submarine fan and basinal mudstone facies of the undifferentiated Umpqua Group farther north in the Sutherlin-Myrtle Point subbasin. It can be differentiated from the lithologically similar, rhythmically bedded, locally more deformed turbidites of the age-equivalent (C to B-1 foraminiferal stage, Fig. 2 on Plate 1) undifferentiated Umpqua Group only in the southern part of the basin. In this area, the formation gradationally overlies the Bushnell Rock formation and is conformably overlain by the Berry Creek member of the White Tail Ridge formation or is unconformably overlain by the Remote member of the White Tail Ridge formation (columns #16, 9, 10, 13, 14 and columns 17, 7, 6, 5, 2, and 1).

Farther north (e.g., columns 18, 15, #7 and #8), however, where the White Tail Ridge and Bushnell Rock formations pinch out, Tenmile formation slope turbidites and mudstone cannot be readily differentiated from lithologically similar and age-equivalent rocks of the undifferentiated Umpqua Group (Black and Molenaar, 1989-92, pers. commun.; Fig. 3 on Plate 1).

Baldwin (1974) and Baldwin and Perttu (1989), on the other hand, consider the Tenmile formation to be a younger, less deformed unit than their "underlying" Roseburg Formation (our undifferentiated Umpqua Group). This may be true for the lowermost Umpqua Group strata that are interbedded with the Siletz River Volcanics (i.e., which may be in part D stage of Almgren and others, 1988; McKeel, 1989, pers. commun.). However, recent mapping by Black and others (in press) and Wells and others (in prep.) and relative age and stratigraphic relationships in this study suggest that the Tenmile formation is, in part, syntectonic, like the Bushnell Rock formation (Heller and Ryberg, 1983). That is, in the southern part of the basin, Tenmile formation strata locally overlie an unconformity on older Umpqua Group strata and the Siletz River Volcanics. Farther northward, Tenmile formation strata interfinger with younger (C, B-4 to B-1 stage) turbidites and mudstone of the undifferentiated Umpqua Group. This interfingering relationship supports the interpretation of Molenaar (1985).

WHITE TAIL RIDGE FORMATION

Nomenclature

The White Tail Ridge formation described in this report combines Baldwin's (1974) Olalla Creek Member of the Lookingglass Formation and his White Tail Ridge Member of the Flournoy Formation into a single unit. The Olalla Creek Member was the uppermost of three members of his Lookingglass Formation (Baldwin, 1974). Although he did not designate a type section for this member, he mentioned that these strata may be seen along Olalla Creek (i.e., secs. 7 and 8, T. 30 S., R. 7 W.). Baldwin (1974) defined his White Tail Ridge Member as the basal member of the Flournoy Formation.

The Flournoy Formation included the White Tail Ridge Member and the Camas Valley Member (Fig. 3 on Plate 1). He named the Flournoy Formation for strata in upper Lookingglass Creek (since renamed Morgan Creek) in Flournoy Valley (i.e., in secs. 32 and 33, T. 27 S., R. 7 W.).

Baldwin (1974) recognized an unconformity that separated the White Tail Ridge Member from the underlying Olalla Creek Member of the Lookingglass Formation (see Fig. 3 on Plate 1). He interpreted this unconformity to be regional in extent and to represent a period of deformation. Molenaar (1985) concluded that this unconformity is not regional and that the White Tail Ridge Member cannot be distinguished from the Olalla Creek Member on the basis of lithology. Therefore, he proposed dropping the name Olalla Creek Member and combining the strata of the two members into a single member that he called the White Tail Ridge member of the Umpqua Formation. Black (1990, 1993), Black and others (in press), and Wells (1992, pers. commun.) in recent mapping also could not differentiate the fluvial and shallow-marine facies of the Olalla Creek Member from similar facies in the White Tail Ridge Member. Therefore, following the suggestion of Molenaar (1985), they also decided to abandon the name Olalla Creek Member and to map these lithologies as one unit that Black and others (in press) upgrade to the White Tail Ridge formation of the Umpqua Group.

In examining and measuring the original type sections and several reference sections of the Olalla Creek and White Tail Ridge members of Baldwin (1974), we found the several fluvial and shallow-marine lithofacies (as mapped by Baldwin, 1974, Baldwin and Beaulieu, 1973, and Niem and Niem, 1990) to be so similar that choosing the same mappable contact everywhere between the two members was difficult. Therefore, we concur with the mapping decision of Black (DOGAMI) and Wells (USGS) to combine these units into one unit of formation rank, thereby creating the White Tail Ridge formation (Figs. 2 and 3 on Plate 1). In the opinion of Black (1991-1993, pers. communications), the greater deformation of strata mapped by Baldwin (1974) in the Olalla Creek Member is local and reflects proximity of these strata to major faults. Both Olalla Creek and White Tail Ridge strata mapped by Baldwin and his students appear to be more gently deformed farther from the faults. Therefore, the apparent local angular discordance of strike and dip between the two units does not reflect a regional angular unconformity (Black, 1990; Black, 1992, pers. commun.).

Thickness, Age, and Distribution

A maximum total thickness of the White Tail Ridge formation measured in this study is 3,500 ft. The formation occurs only in the southern part of the Tyee basin (columns 1, 2, 3, 4, 5, 6, 7, 17, 8, 9, 10, 11, 12, 13, and 14). The age of this unit is early to early middle Eocene (planktonic foraminiferal Zone P10; Penutian-Ulatisian benthonic foraminiferal stage) as indicated by foraminiferal assemblages (McKeel, 1991, written commun.), mollusks (E. J. Moore, 1991, written commun.), and coccoliths (CP-11; Bukry and Snavely, 1988).

Previous unpublished mapping by Molenaar (written commun.), measured sections, and mapping by Black and others (in press) show that the fluvial-deltaic sandstone-dominated facies of the White Tail Ridge formation fines northward into massive outer shelf-slope mudstone of the undifferentiated Umpqua Group which contains similar foraminiferal assemblages of the B-1 stage of Almgren and others (1988) (McKeel, 1991, written commun.). This lateral gradation is depicted on the fence diagram near Melrose between columns 12 and 16 (Plate 1) on the east flank of the basin and in the Dora-Allegany area on the west flank of the basin between columns 7 and 17). Age-equivalent (B-1 foraminiferal stage) Umpqua mudstone also occurs at the top of the Metz Hill section (column 15) (McKeel, 1991, written commun.).

Where best developed, the White Tail Ridge formation consists of four facies. These facies are named, from oldest to youngest: the Berry Creek member (shallow-marine), Remote member (nonmarine), Coquille River member (delta front), and Rasler Creek tongue (shallow-marine). Ryu (in prep.) describes proposed type sections and reference sections for each of these units. Black and others (in press) shows the distribution of these members. In the southernmost part of the basin (i.e., columns 1 and 2), the members can not be differentiated owing to facies changes to a thick, homogeneous deltaic-fluvial facies. Therefore, the unit in this area is mapped (Black, 1992, pers. commun.) and referred to (in this text) as undifferentiated White Tail Ridge formation.

Baldwin and Perttu (1989), Black (1990, 1993), and Black and others (in press) have mapped two lobes of White Tail Ridge formation which thicken and thin abruptly in the Camas Valley 15-minute quadrangle. The rapid changes in thickness appear to be a result of deposition in lows within the Sutherlin-Myrtle Point subbasin. These intrabasinal lows were separated by a northeast-southwest-trending paleotopographic ridge which we call the Reston high (Plate 1). The high was formed in the early Eocene by uplift and deformation of older units (i.e., Siletz River Volcanics, lower undifferentiated Umpqua Group, Bushnell Rock formation, and Tenmile formation) along the Reston thrust fault. This fault is part of the Bonanza fault zone, that was apparently active prior to and possibly during deposition of the lowermost White Tail Ridge formation.

In the lobe north of the Reston high, White Tail Ridge shallow-marine sandstone gradually fines northward to a thin sequence of bioturbated silty sandstone north of Melrose (i.e., between columns 12 and 16) and LaVerne County Park (between columns 17 and 18). The bioturbated silty sandstone then grades northward into an outer shelf-slope mudstone (with B-1 foraminifers) of undifferentiated Umpqua Group (e.g., in columns 16 and 18; Molenaar, 1985, pers. communs., 1989-92).

Recent field mapping and reconnaissance study in the Bonanza fault zone by R. E. Wells (1992, pers. commun.) and C. M. Molenaar (1991-92, pers. communs.) show that the distal, thin (<100 ft), bioturbated, mollusk-bearing silty sandstone facies of the White Tail Ridge formation (Coquille River member) is locally infolded with Tenmile formation and undifferentiated Umpqua Group lithic turbidites and mudstones (previously mapped as Roseburg sedimentary rocks by Baldwin, 1974; Niem and Niem, 1990).

The individual members of the White Tail Ridge formation are described below.

Berry Creek Member

Nomenclature: This unit is informally named for a series of exposures (suitable for a type section) along an unnamed logging road in sections 22, 23, and 27 in T. 29 S., R. 8 W., half a mile east of Berry Creek. Reference sections are at Coal Creek (column 4), near Remote (column 7), and in the Glide section (column 14) along the North Umpqua River and Oregon Highway 138 (see details in Ryu, in prep.).

Lithology and Depositional Environment: The Berry Creek member is dominantly mollusk-bearing, bioturbated and hummocky bedded pebbly sandstone in thickening- and coarsening-upward sequences. Each sequence is 60 to 100 ft thick. The sandstone is moderately sorted, fine- to medium-grained, and lithic arkosic in composition. It is medium-gray to yellow-brown and thick- to very thick-bedded or amalgamated and becomes pebbly and cross-bedded in the thickening-upward cycles. Pebbles are subrounded and consist of quartz, metamorphic, intermediate and mafic volcanics, and chert. Subordinate, thin to very thin, even beds of less resistant, dark medium gray mudstone interstratified with the sandstone are more common in the lower part of the sequences. Bed contacts are sharp. Lithology, bedding styles, and sequence of sedimentary structures in the thickening-upward cycles (i.e., hummocky bedded to parallel laminated to cross ripple-laminated to trough cross-bedded sandstone) indicate that the Berry Creek member was deposited in wave-dominated shoreline or deltaic environments (Ryu, in prep.).

Thickness and Distribution: The Berry Creek member is thickest in the Glide section (1,400 ft) and, before erosion, was probably once continuous along the southern margin of the basin (Plate 1). In other sections, the thickness of the unit ranges from approx. 200 ft (in column 3) to 800 ft (in column #16). Geologic mapping in the Camas Valley quadrangle (Black, 1993) shows that the Berry Creek member is not present over the pre-existing northeast-southwest-trending Reston high (Black, 1991, 1993; Black and others, in prep.; e.g., columns 12 to 11, column #16 to column 10, column 14 to 10, and column 7 to 17).

Age and Fossils: Berry Creek member strata contain both thin lenses and scattered broken and articulated pelecypods and gastropods in assemblages that are referrable to the early Eocene (E. J. Moore, 1991, pers. communication). The unit overlies and underlies units that have been dated as early Eocene by coccoliths, planktonic foraminifers, and mollusks (i.e., Tenmile formation, Coquille River member; Bukry and Snavely, 1988; Miles, 1977; McKeel, 1991, written commun.).

Contact Relationships: The member laterally interfingers with and conformably overlies massive neritic mudstone that comprises the upper 500 ft of the Tenmile formation (e.g., column 13 to column #9 to column 11). However, at Remote (column 7) a 12° angular unconformity separates the Berry Creek member from the underlying Tenmile formation (Molenaar, 1993, written commun.). The top of the Berry Creek member has locally been eroded and truncated by the fluvial facies of the overlying Remote member (e.g., column 9 to column #17). An unconformity exists between the two members toward the Reston high (e.g., column #16 to column 10 and column 12 to column 11).

Remote Member

Nomenclature: The Remote member is named informally for exposures along Oregon Highway 42 and in the stream bed and banks of the Middle Fork of the Coquille River, 0.5 mile west of the settlement of Remote (secs. 29, 32, and 33, T. 29 S., R. 10 W.; Fig. 1 on Plate 1). Reference sections are at columns 8 and 9 (Slater Creek, Twelvemile Creek, and Oregon Highway 42; Ryu, in prep.). This member is also well exposed in the Glide section (column 14) along the North Umpqua River and in the Rasler Creek section (column 6).

Lithology and Depositional Environment: The Remote member consists of ridge-forming, multi-stacked sequences 20 to 200 ft thick of cross-bedded, very coarse-grained pebbly lithic arkosic sandstone, gray-green mudstone, and locally thick, non-marine fluvial to distributary channel pebble-cobble polymictic conglomerate. Clast sizes and bed thicknesses in these sequences typically fine and thin upward. Typical of braided river deposits, the conglomerate is cross-bedded and occurs in channelized to lenticular, amalgamated beds. The predominant lithology, however, is pebbly coarse- to very coarse-grained, quartzose to lithic arkosic sandstone and 20- to 150-ft thick intervals of massive, light green-gray, root-mottled overbank or floodplain mudstone and thin coals (Kugler, 1979). Sandstone beds are channelized and contain lenses of pebbles and large-scale planar and trough cross-bedding. Some ripple-lamination and parallel lamination also occur. These lithologies, which are typical of low gradient, highly sinuous or meandering river deposits, are a few hundred feet thick. In the section along Oregon Highway 42 near the town of Remote (column 7), Molenaar (1993, written commun.) has found alternating or intertonguing beds of marine and non-marine sandstone. Marine sandstone beds contain the fossil mollusks *Venericardia* and *Turritella*.

The lower conglomerate-dominated facies is coarsest in the Slater Creek-Twelvemile Creek area (i.e., columns 8, 9, and #17). This fluvial facies consists of very poorly sorted, framework-supported, subrounded to subangular cobbles and boulders. A few beds contain clasts that are several feet in diameter and are in matrix-support (i.e., debris flow deposits). Some organized conglomerates display imbrication and scour-and-filled channels. These strata have a coarse sand matrix of quartz and lithic clasts. Molds of tree limbs are 1 to 3 ft long, and a few carbonized logs several feet long are preserved in the pebbly sandstone higher in the section along old Highway 42. Rounded to subrounded, fine to very coarse pebbles are abundant in these polymictic conglomerates and pebbly sandstones. Pebble compositions include multi-colored cherts, graywacke, quartzite, mafic and intermediate volcanic rocks, mudstone and fine pebble chert-quartz conglomerate. These lithologies are typical of detritus derived from Klamath Mountain terranes (Koler, 1979; Kugler, 1979; Ryberg, 1984).

Thickness and Distribution: The thickness of the Remote member, as well as the grain size, varies rapidly laterally. The local fluvial conglomerate facies is thickest (approx. 2,500 ft) in the Twelvemile Creek section (column 9). Generally, the unit thins to the north and northwest (e.g., column 7 to 17, column 10 to 17, and column 12 to 16) and is not found in the Amoco Weyerhaeuser B-1 or F-1 wells (columns #5 and #4). Field mapping by Black (1990, 1993; 1992, pers. commun.; Black and others, in press) shows that this fluvial unit thins and pinches out onto the Reston high (i.e., column 10 to 11 and column 12 to 11).

The conglomerate-dominated facies of the Remote member in the Twelvemile Creek-Slater Creek area (columns 8, 9, and #17) fines laterally to the southwest, north, and northwest (i.e., column 8 to 7, 6, 4, and 3 and column 9 to 10) to pebbly cross-bedded sandstone and thick green-gray mudstone and thin coal interbeds. For example, strata in the Agness Pass section (column 2) that are laterally equivalent to the Remote member in the Slater Creek section (column 8) are 1,500 ft thick. The lithologies at Agness Pass include fining-upward sequences of coarse-grained pebbly, cross-bedded, fluvial-tidal, subarkosic sandstone and thick overbank green-gray mudstone facies with abundant subbituminous coals. The fluvial sandstone and overbank mudstone in the Agness Pass area interfinger with and are overlain by thickening- and coarsening-upward, shallow-marine delta front hummocky bedded and bioturbated sandstone. The fluvial and overbank facies are also interbedded with thinning- and fining-upward tidal flat sequences of well-laminated, oyster-bearing, accretionary bank mudstone, coals, and thin mollusk-bearing bioturbated siltstone of the undifferentiated White Tail Ridge formation. These uppermost facies are probably equivalent to the Coquille River member and Rasler Creek tongue (see below).

In the southeastern corner of the basin near Glide (column 14), a thick fluvial, pebbly, cross-bedded sandstone and overbank coal-bearing facies of the Remote member also overlies a thick interval of a shallowing-upward delta front facies of the Berry Creek member. These fluvial sandstone facies of the Remote member were probably once continuous across the basin to the western and southwestern flanks but have been subsequently eroded (note dashed lines between columns 13 and 14).

Contact Relationships: The basal contact of the Remote member is locally an erosional unconformity. The rivers that deposited the Remote member incised into and locally truncated hundreds of feet of Berry Creek member in the southern part of the study area (see columns 6, 7, 8, 9, 10, 13, 14, #16, and #17). At some localities, the Remote member abruptly overlies neritic outer shelf mudstone of the Tenmile formation (e.g., near the Reston high along Oregon Highway 42 [column 10]). The upper contact of the unit interfingers with and laterally grades into delta front and shallow-marine sandstone of the overlying Coquille River member.

Coquille River Member

Nomenclature: The Coquille River member is named informally for a sequence of sedimentary rocks that is well-exposed along Oregon Highway 42 (column 9) and in the Middle Fork of the Coquille River, southwest of the town of Camas Valley (sec. 36, T. 29 S., R. 9 W., and sec. 2, T. 30 S., R. 9 W.). Reference sections occur at columns 7 (Remote), 10 (Shield Creek), 12 (Lookingglass Road and Callahan Road), and 13 (Cow Hollow and Melrose) (see Ryu, in prep., for more details).

Lithology and Composition: The Coquille River member is a wave-dominated delta front facies that consists of shoaling-upward sequences (60 to 125 ft thick) of mollusk-bearing, bioturbated to hummocky bedded, arkosic (quartzo-feldspathic) sandstone. The sandstone is fine- to medium-grained, moderately sorted, and medium- to thick-bedded. There are also many fining- and thinning-upward sequences of thick to very thick, massive to cross-bedded, arkosic sandstone beds overlain by subordinate medium gray, oyster-bearing lagoonal or estuarine mudstone, bioturbated mollusk-bearing siltstone-sandstone, and numerous subbituminous coals (1 to 8 ft thick). The coals are also well-exposed in the Remote section (column 7).

Thickness and Distribution: The Coquille River member is thickest in the Reston Road section (column 10) and in the Uranium Ziedrich well (#16) where it is 1,200 to 1,600 ft thick. The member thins rapidly and pinches out to the north and northwest (e.g., column 12 to 16 and column 10 to 17). Although the underlying Remote and Berry Creek members lap onto and pinch out against the Reston high, the Coquille River member thins to a few tens of feet over this buried paleotopographic high (see also discussion of distribution of White Tail Ridge formation). For example, mapping by Black (1993) and Black and others (in press) and this study show that the Camas Valley formation mudstone that overlies the Coquille River member shows little or no change in thickness over the ridge (column 11; Black, 1992, pers. commun.). Therefore, both intrabasinal lows had probably been filled with non-marine strata of the Remote member and delta front sandstone of the lower Coquille River member prior to burial of the high by the upper Coquille River member and the Camas Valley formation.

In the southeastern part of the basin, there is only a thin (100 ft) section of mollusk-bearing, bioturbated Coquille River strata preserved in the Glide section (column 14).

The Berry Creek, Remote, and Coquille River members are truncated by the Canyonville right-lateral strike-slip fault (Ryberg, 1984) and by the Wildlife Safari oblique-slip and thrust fault (e.g., between columns 9 and #16; see Niem and Niem, 1990; Ryberg, 1984).

Contact Relationships: The basal contact of the Coquille River member interfingers with the underlying Remote member. Northward and northwestward, where the Remote member pinches out, the Coquille River member conformably overlies massive mudstone of the Tenmile formation (e.g., column 12 to 16 and column 10 to 17). The upper contact of the unit with the overlying Camas Valley formation mudstone also is generally an interfingering relationship (e.g., column 12 to 11).

In the Glide section (column 14), the base of the Coquille River member is a bioturbated, mollusk-bearing, fine-grained arkosic sandstone that abruptly overlies a 5-ft coal bed at the top of the Remote member. Numerous 1 to 2-ft long sand-filled *Thalassinoides* burrows (1 to 2 inches in diameter) extend from the Coquille River sandstone down into the underlying coal bed. The upper contact is sharp with the overlying mollusk-rich, massive, neritic mudstone of the Camas Valley formation.

Rasler Creek Tongue

Nomenclature and Distribution: The Rasler Creek tongue of the White Tail Ridge formation is informally named for exposures along the logging road that parallels the upper reaches of Rasler Creek in secs. 23, 24, and 25, T. 30 S., R. 11 W. (suitable as a type section). More accessible reference sections are on Skull Ridge near Bingham Creek (column 9) and along Oregon Highway 42 (column 7; sec. 14, T. 30 S., R. 9 W.) where Lake Creek joins the Middle Fork of the Coquille River (see also Ryu, in prep.). We use the term tongue for this unit, following the North American Stratigraphic Code (1983) for a lithologically mappable unit of one formation that extends into and pinches out in a laterally correlative formation.

This sandstone-dominated tongue is largely confined and pinches out within the mudstone of the Camas Valley formation (e.g., column 6 to 7). For example, detailed field mapping in the Reston and Camas Valley 7½-minute quadrangles by Black (1990, 1993) and Black and others (in press) shows that this local progradational sandy unit pinches out into silty mudstone of the upper Camas Valley formation immediately northwest of Remote and south of Reston (between columns 7 and 17 and between columns 9 and 10). Black (1993) initially included this sandstone unit in the mudstone-dominated Camas Valley formation. However, recent reconnaissance mapping by Black (1992, pers. commun.) in the Powers-Agness Pass area (columns 5, 4, 3, and 2) shows that this tongue and the lithologically similar Coquille River member, grade laterally into a thick sequence of shallow-marine sandstone, lower delta plain-estuarine coals, and oyster-bearing mudstone of the undifferentiated White Tail Ridge formation. The Camas Valley formation, which separates the Coquille River member and the Rasler Creek tongue to the north, pinches in the southern part of the basin (columns 2, 3, and 4). In sections where Camas Valley formation is missing, it is difficult to separate the two members (Black, 1992, pers. commun.). Therefore, we use the term undifferentiated White Tail Ridge formation in the southern part of the basin.

Lithology, Thickness, and Depositional Environment: The Rasler Creek tongue consists of several thickening-upward sequences of moderately indurated bioturbated and hummocky bedded shoreface sandstone with rare coal beds and thin gray mudstone beds. The sandstone is fine- to medium-grained, moderately sorted, and lithic arkosic in composition.

The unit, which is as much as 500 ft thick, crops out in the Remote-Powers-Rasler Creek-Sand Rock Mountain areas, along Skull Ridge, and along Oregon Highway 42 (columns 4, 6, 7, and 9). The Rasler Creek tongue represents a wave-dominated delta front and delta-coastal plain that prograded onto the muddy middle to outer shelf. Hummocky bedding, scattered broken molluscan shells, and lack of extensive bioturbation are indicators of strong wave energy on a shallow marine shelf (Dott and Bourgeois, 1982).

Contact Relationships and Age: The sandstone-dominated tongue displays a conformable, gradational contact with the overlying mudstone of the Camas Valley formation. The tongue is lower Eocene based on overlying and underlying lower Eocene microfauna (Penutian foraminifers and CP-11 coccoliths) in the Camas Valley formation (Miles, 1977; McKeel, 1991, written commun.; Bukry and Snavely, 1988).

CAMAS VALLEY FORMATION

Nomenclature

In this report, the Camas Valley Member of the Flournoy Formation of Baldwin (1974) and Baldwin and Perttu (1989) is raised informally to formation rank. Baldwin (1974) designated the outcrops along upper Lookingglass Creek (since renamed Morgan Creek) in the Reston 7½-min. quadrangle as the type section of the Flournoy Formation and named the Camas Valley Member for exposures in Camas Valley.

Lithology

The Camas Valley formation is the uppermost formation in the Umpqua Group (Figs. 2 and 3 on Plate 1). It is predominantly massive or structureless, non-micaceous or micro-micaceous, dark gray mudstone. The unit contains numerous spheroidal to ellipsoidal calcareous concretions. There also are abundant articulated as well as scattered broken mollusks and benthonic foraminifers (Moore, 1991, written commun.; Thoms, 1965; McKeel, 1991, written commun.). This unit includes a few thin fine-grained sandstone beds. In the LaVerne section (column 17), 50 to 75 ft of fossiliferous, pebbly volcanogenic sandstone occurs about 200 ft below the base of the Tyee Formation. These coarse basaltic clastics were probably eroded from a paleotopographic high of Siletz River Volcanics, such as Blue Ridge that is approximately 2 miles west-northwest of the LaVerne section (Molenaar, 1993, written commun.). Thick mudstone of the Camas Valley formation forms a broad valley and gentle slopes between the sandstone ridges of the White Tail Ridge formation and the steep escarpment of the Tyee Formation.

Thickness, Distribution, and Seismic Expression

The Camas Valley formation is 1,500 to 1,800 ft thick (columns 6, 7, 17, 9, 10, 11, 12, 13, and 14 on Plate 1). The formation is widespread and can be mapped on both flanks of the basin (Black and others, in press). It can also be traced in the subsurface. In the southern part of the Tyee basin, this unit is separated into a thick lower part (up to 1,500 ft thick) and a thin upper part (300 ft thick or less) by the Rasler Creek tongue of the White Tail Ridge formation (columns 6, 7, and 9).

Geologic mapping (Black, 1992, pers. commun.; Black and others, in press) shows that the thick lower part rapidly thins and pinches out south of Powers (between columns 6 and 4) and grades into the undifferentiated White Tail Ridge formation. The thin upper part can be traced tentatively as far south as Agness Pass (column 2). The upper and lower units of the Camas Valley mudstone merge into one mappable unit to the north where the intervening sandstone of the Rasler Creek tongue pinches out (e.g., between columns 7 and 17 and between columns 9 and 10).

In multi-channel seismic reflection profiles, the Camas Valley mudstone and age- and lithology-equivalent strata (i.e., the upper part of the undifferentiated Umpqua Group) appears as a thin, nearly horizontal to gently dipping, acoustically transparent layer (Peter Hales, Weyerhaeuser, 1989, pers. commun.). In the central part of the basin, this acoustically transparent unit occurs beneath the Tyee Formation forearc strata and overlies more deformed, thrust-faulted and duplexed reflectors of the older units of the Umpqua Group (i.e., White Tail Ridge, Tenmile, Bushnell Rock, and lower undifferentiated Umpqua Group) and Siletz River Volcanics basement (Peter Hales, 1992, pers. commun.).

Contact Relationships and Correlation

The Camas Valley formation interfingers with and overlies the Coquille River member of the White Tail Ridge formation in the southern part of the basin (e.g., columns 6, 7, 17, 9, 10, 11, 12, 13, and 14). To the north, the Coquille River member pinches out (e.g., between columns 12 and 16 and between columns 17 and 18), and the upper and lower Camas Valley mudstone are lithologically indistinguishable from similar, gently deformed, thick, massive, age-equivalent (B-1) mudstone and claystone in the upper part of the undifferentiated Umpqua Group (e.g., columns #8, 15, and 18). In the type area, the Camas Valley formation and underlying White Tail Ridge sandstone members are gently deformed (Black, 1990; Black and others, in press) and overlie with local angular unconformity undifferentiated Umpqua Group thin-bedded turbidites and mudstone and Tenmile and Bushnell Rock formation strata (Niem and Niem, 1990; Black and others, in press). Age-equivalent mudstone in the upper part of the undifferentiated Umpqua Group that crops out in the northern and central parts of the basin (e.g., columns 18, 16, 15, 21, and 22) is, however, only slightly more deformed than the Camas Valley mudstone and cannot, with confidence, be mapped separately, particularly in wells (i.e., #1, #2, #4, #5, and #8; Molenaar, 1985; Black and others, in prep.).

The sharp upper contact of the Camas Valley formation with the overlying Tyee Mountain Member of the Tyee Formation is slightly disconformable(?) in some areas in the southern part of the basin (i.e., columns 2, 3, 4, 5, 6, 7, 17, 9, 10, and 11). This contact becomes conformable and gradational basinward (e.g., columns 11 to 12 to 16 and column 17 to 18 to #4). For example, the upper few hundred feet of the Camas Valley formation in Camas Valley (column 10) becomes increasingly laminated and micaceous with some thin turbidites. It is difficult to separate in mapping these strata from micaceous, thin- to thick-bedded lower Tyee Mountain Member mudstone and turbidite sandstone (Black, 1990, 1993; Black, 1992, pers. commun.).

Age and Fossils

Planktonic and benthonic foraminiferal assemblages from the Camas Valley formation (and laterally equivalent upper part of the undifferentiated Umpqua Group) indicate a late early Eocene age (Miles, 1977). These microfossil assemblages are typical of the B-1 foraminiferal stage of Almgren and others (1988) (McKeel, 1991, written commun.; Fig. 2 on Plate 1). The mudstone contains diverse, shallow-marine (neritic) mollusks that indicate a lower Eocene age (e.g., in the Glide section, column 14; E. J. Moore, 1991, written commun.). Coccoliths in the formation equate to the CP-11 zone of Bukry and Snavely (1988).

TYEE FORMATION

General Discussion

Nomenclature, Age, Contact Relationships, and Thickness: The Tyee Formation was named by Diller (1898) for a sequence of thick-bedded sandstone and subordinate mudstone exposed at Tyee Mountain (secs. 20, 21, and 22, T. 25 S., R. 7 W.). The 5,000 to 6,700-ft thick unit is Ulatisian (or B-1 foraminiferal stage; McKeel, 1990, written commun.) and CP-12 nannoplankton zone (Bukry and Snavely, 1988). The formation overlies with slight disconformity the Camas Valley formation and undifferentiated Umpqua Group (e.g., columns 2, 4, 5, 6, 7, 9, 10, 11, 17, and 18). However, in the central (e.g., column 12) and northern parts of the basin (e.g., columns 21, 22, #8, #5, #4, #1, and #2), the Tyee Formation may be conformable with the underlying bathyal mudstone.

Heller and Ryberg (1983) pictured the Tyee Formation as forming in the middle Eocene after accretion of the Siletz River Volcanics and Umpqua Group to the continental margin. The formation was deposited in a newly created, subsiding forearc basin behind a subduction zone located on what is now the Oregon middle-outer shelf. Subduction had commenced in this zone after the seamounts of the Siletz River Volcanics and sedimentary rocks of the Umpqua Group had clogged the earlier Eocene subduction zone (Fig. B).

Baldwin (1974) defined three members of the Tyee Formation which Baldwin and Perttu (1989) mapped in the type area (Camas Valley and Reston 7½-min. quadrangles; see also Black, 1990, 1993; Niem and Niem, 1990). From oldest to youngest, these members are: the Tyee Mountain Member, the Hubbard Creek Member, and the Baughman Member (Figs. 2 and 3 on Plate 1).

The Tyee-Flournoy Stratigraphic Problem: The type sections and several reference sections of the Tyee Formation and Flournoy Formation and their members were measured in this study (e.g., Tyee Road part of column 16, Lookingglass Road part of column 12, column 11, Lost Lake part of column 10, and Cow Hollow and Melrose parts of column 13; Ryu, in prep.).

Abundant, large mica flakes (biotite and white muscovite) are conspicuous in all three members of the Tyee Formation in the type area. In contrast, the White Tail Ridge and Camas Valley formations (originally members of Baldwin's [1974] Flournoy Formation) are overwhelmingly non-micaceous (Molenaar, 1985; Black, 1990, 1993; this study). The White Tail Ridge formation is also composed of deltaic and fluvial facies (i.e., cross-bedded, medium- to coarse-grained, mollusk-bearing, conglomerate and pebbly sandstone and coals), whereas the Tyee Mountain Member is composed of turbidites. The Camas Valley formation is dominantly structureless, concretionary, and mollusk-bearing mudstone, whereas mudstone of the type Hubbard Creek Member is well-laminated. Using these criteria, mapping by Molenaar (1985), Black (1990, 1993) and Black and others (in press) and section measurements completed for this report (Plate 1) show that the three *highly micaceous* members of the Tyee Formation are separate, widespread, mappable units that can be distinguished from the dominantly non-micaceous White Tail Ridge and Camas Valley formations.

Coarse mica flakes in a few White Tail Ridge formation sandstone beds were noted in the Berry Creek member at only one locality (the Glide section; Bill Seeley, 1991, pers. commun.). Vance (in prep.) also found consistent differences in fission track ages of zircons from non-micaceous White Tail Ridge formation sandstones in the type area and micaceous Tyee Formation sandstones. Formation calls for Vance's study are based on mapping by Black and others (in press).

The distinction between micaceous and non-micaceous units is an excellent mapping aide in the southern Tyee basin (G. L. Black and C. M. Molenaar, 1989-1992, pers. communs.). For example, the stratigraphic sequence of micaceous Tyee Mountain Member sandstone overlying non-micaceous Camas Valley formation mudstone that in turn overlies non-micaceous White Tail Ridge formation sandstone can be mapped continuously around the southern, southwestern, and southeastern flanks of the basin (Black and others, in press; columns 12, 11, 10, 9, 7, 17, 6, and 4).

Molenaar (1985) pointed out that a stratigraphic disagreement developed over the distribution of the Tyee and Flournoy formations because Baldwin (1974) and Baldwin and Beaulieu (1973) included the very thick and widespread, micaceous, turbidite sandstones on the northwestern, northern, and northeastern flanks of the basin in the Flournoy Formation (Fig. C). However, the contact between the micaceous Tyee Formation turbidites and the underlying Flournoy Formation turbidites north and northwest of Elkton has never been mapped in detail. This contact was queried, for example, on composite geologic maps of the basin by Niem and Niem (1984, 1990).

Study of the section by Molenaar (1985), recent mapping by Black and others (in press), and this study show that the micaceous turbidite strata north and northwest of Elkton are correlative to and laterally traceable into micaceous sandstone beds of the Tyee Formation at the type section at Tyee Mountain (e.g., Tyee Mountain Member; columns 16, 20, 21, 22; column 21 to #2, columns #1, #3, #5, #4, and 18). These northern "Flournoy Formation" sandstone beds are lithologically identical to the micaceous turbidite sandstone beds of the Tyee Mountain Member. Both turbidite units (i.e., the "Flournoy Formation" and the Tyee Mountain Member) also contain microfossils indicative of a similar range of age (A to B-1; Fig. 2 on Plate 1), whereas the deltaic White Tail Ridge formation and Camas Valley formation (Flournoy Formation of Baldwin, 1974) contain only B-1 foraminifers (McKeel, 1991, written commun.).

In order to end the confusion over whether the thick-bedded micaceous turbidites north and northwest of Elkton should be called Tyee or Flournoy, Molenaar (1985) suggested dropping the name Flournoy Formation. This study informally raises the members of Baldwin's (1974) Flournoy Formation (White Tail Ridge and Camas Valley members) to formation status and discards the term Flournoy Formation.

The Tyee-Flournoy Sedimentological Disagreement: A sedimentological disagreement has developed concerning the facies distribution of the Tyee and Flournoy formations. This dispute results from the lack of detailed study of the lithostratigraphic distribution of these units. Depositional models for the Tyee and Flournoy formations by Snavely and others (1964), Lovell (1969), Chan (1982), Chan and Dott (1983), Heller (1983), and Heller and Dickinson (1985) were based on the older mapping and stratigraphic terminology of Baldwin (1974) and his graduate students. The models also were synthesized from scattered, partial measured sections in the southern and northern Tyee basin (i.e., Eugene-Florence to Newport-Lincoln City area). Chan and Dott (1983) and Heller and Dickinson (1985) each suggested that three lithofacies occur regionally in both the Tyee and Flournoy formations. Chan and Dott (1983) named these, from south to north, the delta, slope, and sandy submarine fan (Fig. Da). Heller and Dickinson (1985) called them the delta and inner and outer ramp facies (Fig. Db).

Molenaar (1985), Black and others (in press), and this investigation show that the non-micaceous, clean, deltaic sandstone of the Flournoy Formation has been incorrectly mapped and correlated to mica-rich graywacke turbidites of the Tyee Formation as far north as Dolph, northeast of Lincoln City (Snavely and others, 1991) (Fig. C). Recent detailed and reconnaissance mapping by Black (1990, 1993) and Black and others (in press) and section measuring by Molenaar (1985) and this study (Fig. 3 on Plate 1) now restrict the three highly *micaceous* lithofacies (turbidite submarine fan, slope, and deltaic facies) to the Tyee Mountain Member, Hubbard Creek Member, and Baughman Member, respectively, of the Tyee Formation as first defined by Baldwin (1974).

These three vertically stacked members of the Tyee Formation are also not necessarily lateral chronostratigraphic facies of one another as originally suggested by Chan and Dott (1983) and Heller and Dickinson (1985; Figs. Da and Db). Their models were based on Walther's law of correlation of facies, which is not valid if unconformities are present in the vertical succession (Middleton, 1973). We now recognize local unconformities (i.e., sequence boundaries of Van Wagoner and others, 1990); e.g., at the base of the Baughman Member. Therefore, the three lithofacies or members of the Tyee Formation may not be chronostratigraphic facies but may instead represent distinct and separate depositional events (see discussions below on Baughman and Tyee Mountain members and sequence stratigraphy; see also Ryu and Niem, 1993).

Tyee Mountain Member

Nomenclature and Type Section: The basal unit of the Tyee Formation is the Tyee Mountain Member (Figs. 2 and 3 on Plate 1). Baldwin (1974) named this unit for Tyee Mountain, a prominent topographic ridge 8.5 miles west of Sutherlin. A section suitable as a type section is well-exposed along the Umpqua River (secs. 20, 21, and 22, T. 25 S., R. 7 W.).

Lithology and Facies: Throughout much of the southern Tyee basin, the Tyee Mountain Member consists of thousands of feet of rhythmically stratified, thick- to very thick-bedded and amalgamated, fine-grained, micaceous sandstone and thin to very thin beds of medium gray mudstone. The mudstone beds, some of which contain bathyal foraminiferal assemblages (McKeel, 1991, written commun.), are relatively minor, although some beds are 10 to 20 ft thick. The sandstone to mudstone ratio varies from 5:1 to 30:1. The sandstone beds are well-indurated, poorly sorted, lithic feldspathic graywackes that form flat-topped, stream-dissected ridges.

These sandstones contain Bouma aa and ab sequences, mudstone rip-ups (3 to 6 in long), flutes, grooves, and load casts. Sandstone beds display sharp bottom contacts with subjacent mudstone beds; gradational, laminated, micaceous, and carbonaceous upper contacts are common. These features are characteristic of turbidite facies B, C, and some D of Mutti and Ricci Lucchi (1972) and Walker and Mutti (1973). These facies form on middle and inner submarine fans (Walker, 1979).

Locally, the basal few hundred feet of the Tyee Mountain Member consists of thin- to medium-bedded, micaceous, fine-grained, outer fan turbidite sandstone and thin-bedded mudstone. The sandstone/mudstone ratio is 1:1; some graded sandstone beds contain Bouma abcd and bcd sequences and flute and groove marks. These rocks are typical of outer-fan facies D of Walker and Mutti (1973) (columns 22 and 16). Thick, poorly exposed sections of laminated micaceous mudstone containing bathyal foraminifers also occur (basinal facies G of Walker and Mutti, 1973). The thin sandstone beds gradually thicken upward to thick- to very thick-bedded and amalgamated sequences (up to several hundred feet thick) of micaceous, cliff-forming, massive, fine-grained graywacke containing Bouma aaa and abe sequences with few thin mudstone beds or partings (sandstone to mudstone ratio is 10:1 to 20:1; mid-fan turbidite facies C and D of Mutti and Ricci Lucchi, 1972; Walker and Mutti, 1973; Walker, 1979). Thus, the vertical sequence of the Tyee Mountain Member reflects progradation of a middle fan facies over an outer submarine fan or outer ramp facies. The mid-fan facies is, in turn, locally overlain by several hundred feet of well-indurated, massive, inner sandy fan slope, amalgamated, micaceous turbidite sandstone beds with mudstone-chip conglomerates, clastic dikes, and scour-and-fill structures. Some inner fan facies formed as nested feeder channels for the sandy middle fan facies (Chan and Dott, 1983; columns 16, 17, 18, 19, 20, 21, 22, #1, #2, #3, #4, and #5).

Sea Gullies Facies: In the southernmost part of the basin (columns 3, 4, 5, 6, 7, 9, and 10) the Tyee Mountain Member consists of a thin, widespread sequence (< 200 ft) of channelized, medium- to coarse-grained, micaceous feldspathic lithic wacke. These well-indurated, thick-bedded to amalgamated sandstones contain abundant mudstone rip-ups (0.5 to 5 ft in length) and thin mudstone interbeds. Some intervals of nested, cross-cutting channels and overbank deposits composed of thin-bedded, graded turbidite sandstone and mudstone occur between intervals of very thick-bedded and amalgamated sandstone.

The nested channels are lithologically similar to the "sea gullies" facies or nested channels that cut through deltaic, shelf, and slope deposits described by Dott and Bird (1979) in the middle Eocene strata referred to the Elkton Formation at Sacchi Beach on the southwest Oregon coast. Other channelized sea gullies and upper fan valley channels have been reported in the uppermost part of the thick submarine fan facies of the Tyee Mountain Member as far north as Loon Lake (Bird, 1967; column 19) and the Umpqua River near Kellogg (column 20; Chan, 1982; Chan and Dott, 1983).

These Tyee Mountain sea gullies or channels funneled clastics to the underlying, thick, elongate sandy fan system that comprises the Tyee Mountain Member in the central and northern parts of the basin (Chan and Dott, 1983; columns 16, 17, 18, 19, 20, 21, 22, #1, #2, #3, #4, and #5).

Thickness, Paleotopography, Depositional Models, and Source Areas: The thickness of the Tyee Mountain Member changes rapidly in the southern part of the basin. Recent mapping by Black (1993) and Black and others (in press) and section measuring by Molenaar (1985) and this investigation (Plate 1; Ryu, in prep.) show that the micaceous Tyee Mountain Member abruptly thickens from a few hundred feet of sea gullies facies to 5,000 to 6,700 ft of rhythmically, even bedded, inner, middle to outer sandy submarine fan or inner to outer ramp turbidite strata north of the early Eocene Reston high. On Plate 1, note the rapid thickening of the Tyee Mountain Member from column 10 to 11 to 12 to 16, 20, 21, and 22 and from columns 7 to 17 and 10 to 17, 18, and 19. This rapid thickening may reflect the continued effect of the Reston high on the submarine paleotopography of the Tyee forearc basin slope and floor during the middle Eocene (Black, 1992, pers. commun.).

Farther north, the Tyee Mountain Member middle to inner sandy fan facies was deposited over the buried Umpqua arch without appreciable change in thickness or change in facies (e.g., column 20 to 21 to #3 and column 17 to 18 to 19 to #1). The relative uniformity of thickness and facies suggests that the Smith River subbasin north of the Umpqua arch had been filled with mudstone of the undifferentiated Umpqua Group and that there was little paleotopography to affect the distribution of Tyee Mountain Member turbidite sands.

Based on new mapping (Black and others, in press) and this investigation, the Tyee Mountain Member appears to be largely a thick, elongate, sand-dominated basin-floor submarine fan (Chan, 1982; Chan and Dott, 1983) or sandy submarine ramp (Heller, 1983; Heller and Dickinson, 1985) that can be traced as far north as Dolph (Snavely and others, 1964; Lovell, 1969; Snavely and others, 1991) (Fig. Ca).

Rb/Sr ratios indicate that the very coarse muscovite flakes in the sandstones were derived from the Idaho batholith (Heller and others, 1985, 1992). Many lithic rock fragments were also eroded from the Mesozoic terranes of the Klamath Mountains to the south and from a postulated early Tertiary volcanic arc east of the basin (Snavely and others, 1964; Chan and Dott, 1983).

Contact Relationships and Age: The contact of the Tyee Mountain Member with the underlying Camas Valley formation is a disconformity(?) in the southern part of the basin (i.e., columns 3, 4, 5, 6, 7, 9, 10, 11, and 17). Basinward, the contact between the two units is conformable (i.e., north of columns 17 and 12). The lower contact is exposed in section 4, T. 28 S., R. 7 W. The upper contact with the overlying Hubbard Creek Member is a conformity and is well exposed in sec. 7, T. 25 S., R. 7 W. The Tyee Mountain Member contains abundant foraminifers and coccoliths that indicate a middle Eocene age (Ulatisian; Miles, 1977; McKeel, 1989-92, pers. and written communs.; CP-12a and CP-12b, Bukry and Snavely, 1988).

Hubbard Creek Member

Nomenclature and Type Section: The Hubbard Creek Member of the Tyee Formation was named by Baldwin (1974) for a dominantly deep-marine siltstone sequence with subordinate, thin, even-bedded sandstone that crops out along Hubbard Creek, a tributary of the Umpqua River (secs. 7, 8, and 9, T. 25 S., R. 7 W.). We measured a reference section along the Umpqua River in secs. 8 and 9, T. 24 S., R. 7 W. (Ryu, in prep.).

Lithology, Thickness, and Distribution: The slope-forming unit is predominantly dark gray, well-laminated, micaceous deep-marine foraminifer-bearing mudstone and siltstone. The 1,200-ft unit is best exposed at Burnt Ridge (column 11) where it consists of three units: (1) a lower 500-ft thick massive micaceous mudstone that contains middle to lower bathyal (slope) foraminifers (McKeel, 1991, written commun.); (2) a middle 300- to 400-ft thick nested channel facies of micaceous turbidite sandstone beds and mudstone; and (3) an upper massive, micaceous bioturbated (outer shelf to upper slope) mudstone that is 400- to 500-ft thick.

The middle unit of the Hubbard Creek at Burnt Ridge (column 11) and at China Flat (column 3) consists of a sequence of cross-cutting, 20- to 50-ft deep nested channels filled with thin- to thick-bedded turbidite sandstone beds and dark gray mudstone. Slump structures and mudstone-chip conglomerates are abundant in the base of a few channels. These nested channels are cut into micaceous lower slope mudstone of the lower unit of the Hubbard Creek and may have fed small submarine fan(s) on the slope. Alternatively, these slope channel systems could have funneled fine sand to the thick middle to outer sandy submarine fan or ramp turbidite facies in the upper part of the Tyee Mountain Member in the central and northern parts of the Tyee basin (Chan, 1982; Chan and Dott, 1983).

The overall geometry of the Hubbard Creek Member is lenticular. This unit is thickest at Burnt Ridge and at LaVerne County Park (columns 11 and 17) and is thinner and finer grained to the north and south. To the north, the thickness of the member is a uniform 400 to 600 feet (columns 16, 20, 21, 19, 18, #3, #4, and #5). It consists entirely of lower bathyal, micaceous, laminated mudstone (Black, 1991, pers. commun.; McKeel, 1991, written commun.). South of Burnt Ridge and the LaVerne section, the member also thins to 400 to 600 feet. In that part of the basin, the unit consists of dominantly laminated mudstone that contains upper bathyal to outer neritic foraminifers (McKeel, 1991, written commun.) and some thin sequences of nested channelized turbidite sandstone and mudstone in the upper part of the unit (columns 3, 4, 5, 6, and 7).

The Hubbard Creek Member can be traced and mapped continuously from the type section (column 16) along the Tyee escarpment and around the flanks of the Tyee forearc basin (Black and others, in press; columns 3, 4, 5, 6, 7, 9, 10, 11, 12, 16, 20, 21, 7 to 17, 18, and 19). The unit is correlated from measured sections to wells in the center of the basin, using seismic reflection profiles, well cuttings, and electric logs (column 19 to #3 and column #4 to #5).

Age, Paleobathymetry, and Contact Relationships: The Hubbard Creek mudstone contains benthonic foraminifers of the A-1 to B-1 stages of Almgren and others (1988) (Fig. 3 on Plate 1; McKeel, 1991, written commun.). The member conformably overlies the Tyee Mountain Member. Locally, in the southernmost part of the basin (e.g., Coal Creek and China Flat sections; columns 4 and 3), the upper contact with the overlying fluvial facies of the Baughman Member is disconformable. That is, the upper 500 ft of the Hubbard Creek (outer shelf-upper slope mudstone) which is present in the Burnt Ridge section (column 11) to the north is missing. Thick-bedded, coarse-grained, cross-bedded, fluvial sandstone and massive sandstone with mudstone-chip conglomerate (derived from erosion of the underlying Hubbard Creek Member) directly overlie nested channels of the middle Hubbard Creek. In the deeper parts of the basin, the upper contact of the laminated mudstone is conformable with deltaic-shoreface sandstone facies of the Baughman Member (see columns 17, 18, 19, 16, 20, 21, #3, #4, and #5).

At Glide (column 14) the entire Tyee Formation is missing owing to the local erosional unconformity at the base of the upper Eocene Spencer Formation. The Hubbard Creek and Baughman members also are not present in the Interstate-5 section (column 22) on the eastern margin of the basin for the same reason.

Baughman Member

Nomenclature: The youngest unit of the Tyee Formation is the Baughman Member (Figs. 2 and 3 on Plate 1). This well-indurated, resistant unit forms the precipitous cliffs of the Tyee escarpment (Fig. A) that are well-developed in the Camas Valley 7½-minute quadrangle (Black, 1993). Baldwin (1974) named the unit for a fire lookout (now abandoned) which was built on a ridge of "massively bedded sandstone" west of Hubbard Creek in sec. 35, T. 25 S., R. 8 W. Although this could be called the type area, no type section was defined. The unit is well-exposed in an easily accessible section along the Umpqua River (Tyee Road section, column 16); reference sections are the Kellogg and Waggoner Creek section (column 20) and the Elkton section (column 21).

Lithology: The predominant lithology of the Baughman Member is thick- to very thick-bedded, micaceous, cross-bedded, lithic arkosic sandstone. The sandstone is clean and well-indurated, being cemented mainly by zeolites (Chan, 1985). This sandstone is also generally coarser grained (i.e., medium- to very coarse-grained to locally pebbly) and cross-bedded unlike the fine-grained, clay-cemented turbidite sandstone beds that typify the Tyee Mountain Member. Baughman sandstone is iron-stained yellow-orange where deeply weathered; fresh exposures are medium gray. Subbituminous coal and laminated micaceous-carbonaceous siltstone comprise <5 percent of the unit.

Facies: The Baughman Member is composed mainly of two facies: deltaic and fluvial. The lower delta plain and delta front facies is more common in the center of the basin where it is overlain by the Elkton Formation (e.g., columns 20 and 21). The fluvial facies is generally restricted to the southernmost part of the basin (e.g., columns 4, 5, and 7). The deltaic facies consists of three to four thickening-upward cycles of medium- to coarse-grained, mollusk-bearing, hummocky bedded, micaceous sandstone interstratified with thin gray mudstone. Thin to medium beds of sandstone are bioturbated and contain fossil mollusks. These wave-dominated delta front strata locally grade or thicken upward to thick- and very thick-bedded and amalgamated, large-scale (up to 10 ft in amplitude) planar and trough cross-bedded, coarse- to very coarse-grained, micaceous lithic arkosic sandstone. These beds are locally pebbly and were deposited in distributary and distributary mouth environments. A few beds of lower delta plain coal and underclay (up to 3 ft thick) and overbank carbonaceous mudstone are preserved between thick beds of channelized, cross-bedded to massive, sandstone (e.g., Kellogg section, column 20). The lower delta plain sandstone units fine and thin upward to medium to thin, even beds of micaceous fine-grained sandstone that contain hummocky stratification and ripple-laminations (Dott and Bourgeois, 1982). These fine-grained beds are interstratified with thinner even beds of well-laminated mudstone. The 100- to 300-ft cycles are well-exposed in the Tyee Road section (column 16), Kellogg and Waggoner Creek section (column 20), and the Elkton section (column 21).

The fluvial facies interfingers with the deltaic facies to the south. At Powers (column 5) and in the Eden Ridge coal field area (columns 2, 3, and 4), the fluvial facies is dominantly a thick sequence of coarse- to very coarse-grained, large-scale planar cross-bedded to massive sandstone. There are also a few cross-bedded pebble-cobble conglomerate-filled channels and lenses (20 to 30 ft thick). The poorly sorted pebbles and cobbles are in framework-support and are subrounded to well-rounded. Quartzite, chert, and volcanic and metamorphic rocks are the dominant clast types.

Sandstone beds of the fluvial facies contain locally slumped blocks of overbank mudstone and mudstone-chip conglomerates preserved in channel bases. There are also abundant, thick upper delta plain, laminated to massive, carbonaceous (leaf-bearing) siltstone, thick massive light green-gray overbank mudstone, and thick coal beds (columns 2, 3, 4, 5, 6, 7, 9, 10, and 11). There are some distributary mouth, cross-bedded sandstones associated with estuarine oyster-rich and mollusk-shell-rich mudstones, bioturbated sandstone, and thinner paralic or marginal marine coals (1 to 3 ft thick) in the upper part of the dominantly fluvial sections in the southernmost part of the forearc basin.

At least four major seams of subbituminous coal (up to 8 ft thick) have been traced over twelve square miles in the Baughman Member at Eden Ridge (columns 3, 4, and 5); the reserve is estimated at more than 50 million tons (Lesher, 1914; Duell, 1957; NERCO, 1981; USBLM, 1983; Niem and Niem, 1990). The number and thickness of coal beds decrease to the north.

Reconnaissance mapping by Black (1992, pers. commun.) in the Eden Ridge area suggests that a very thick (500-ft +) sequence of overbank(?) laminated mudstone may exist between a lower, cliff-forming fluvial sandstone facies and an upper cliff-forming fluvial-deltaic sandstone facies of the Baughman Member. An alternative interpretation by A. Niem and I. Ryu is that high-angle faulting has repeated the two sandstone ridges, and the "intervening" mudstone is a repeated (upthrown) section of the marine Hubbard Creek Member.

Thickness, Distribution, and Source Area: The thickness of the Baughman Member ranges from 1,000 to 2,000 ft. The deltaic facies in the center of the basin thins from 1,000 feet to <400 ft, and the number of thickening-upward cycles decreases from four to two from the south (well #5; columns 16 to 21) to the northwest (well #3; column 19). Mapping by Black and others (in press) and section measuring by Molenaar (1985) show that the Baughman Member thins and is eroded out (i.e., "skies out") immediately north of Elkton (column 21), Loon Lake (column 19), and Green Acres (near well #3). The original thickness of the fluvial facies in the southernmost part of the basin is unknown owing to erosion and lack of an overlying unit. However, more than 2,000 ft of section have been measured in this area (e.g., column 2).

Southward thickening and coarsening of the deltaic to fluvial facies along with paleocurrent data from cross-beds indicates a southern source for the unit (Chan and Dott, 1983). However, a few coarse-grained deltaic sandstone beds containing scattered fine to coarse pebbles occur as far north as Elkton (column 21).

Contact Relationships: A local unconformity at the base of the Baughman Member is defined by a sharp irregular erosional contact with several feet of relief in road exposures (e.g., columns 3 and 4). Along the southern margin of the basin, the base of the Baughman locally consists of mudstone-chip conglomerate with a massive coarse-grained pebbly sandstone and an overlying large-scale cross-bedded or torrential foreset-bedded pebbly fluvial sandstone. These sandstones are incised into deep-marine micaceous mudstone of the Hubbard Creek Member in the southern margin of the basin (columns 2, 3, 4, 5, 6, 7, 9, 10, 11, and 17). Reconnaissance geologic mapping by Black (Black and others, in press) also shows that Baughman fluvial channels locally eroded down through the Hubbard Creek and Tyee Mountain members into the underlying Camas Valley and White Tail Ridge formations (column 2).

In the central and northern parts of the basin, the lower contact of the deltaic facies of the Baughman Member with mudstone of the Hubbard Creek Member appears to be conformable (columns 17, 18, 19, 16, 20, 21, #4, #5, and #3). The upper contact of the Baughman with the overlying Elkton Formation is gradational (columns 20, 21, #5, and #3).

ELKTON FORMATION

Nomenclature

Originally called the Elkton siltstone member of the Tyee Formation by Baldwin (1961), the unit was elevated to formation status by Thoms (1965), Bird (1967), and Lovell (1969). The Elkton Formation was named for the town of Elkton (Fig. 1 on Plate 1). Both Bird (1967) and this investigation measured a fairly well-exposed reference section along a logging road adjacent to Waggoner Creek (column 21). Additional excellent exposures occur in the Umpqua River and along the road paralleling the river west of the town of Elkton (column 21) and east of Loon Lake (see Bird, 1967).

Lithology, Thickness, and Depositional Environment

The Elkton Formation consists of 1,500 ft of slope-forming, moderately indurated, laminated, medium dark gray mudstone. The mudstone weathers to yellow-brown chips. Abundant foraminifers in these micaceous strata indicate deposition at bathyal depths (Bird, 1967; McKeel, 1989-92, written communs.).

A few miles west of the town of Elkton, the lower 500 ft of the formation is shallow-marine (neritic), dark gray, massive to laminated concretionary mudstone. This mudstone contains two 50- to 100-ft thick, thickening-upward intervals of shallow-marine, medium- to thick-bedded, micaceous, arkosic sandstone with thin mudstone beds. Elkton sandstone beds are moderately well-sorted, medium-grained, and laminated to locally hummocky bedded (column 21). Fossil crabs and mollusks have been reported from the calcareous concretions (Baldwin, 1989, pers. commun.). This sandstone is overlain by more than 1,000 ft of dark gray, laminated to massive, deep-marine (upper bathyal) foraminifer-bearing mudstone that forms the dominant lithology of the Elkton Formation (Bird, 1967). Locally, in the upper part of this deep-marine sequence are two to three nested channel sequences of moderately indurated, medium- to thick-bedded and amalgamated, micaceous quartzo-feldspathic sandstone. The sandstone is interstratified with thinner, dark gray mudstone beds (e.g., Waggoner Creek section, columns 20, #3, and #5). These turbidite sandstones are graded, laminated to massive, and carbonaceous and contain mudstone rip-ups. Nested channel fills are 100 to 200 ft thick.

Age, Contact Relationships, and Distribution

The formation is middle Eocene (upper Ulatisian-lower Narizian by Bird, 1967; A-1 of Almgren and others, 1988) (McKeel, 1991, written commun.; Fig. 2 on Plate 1). Bukry and Snavely (1988) reported that coccoliths from Elkton strata are typical of Subzone CP12b (equivalent to the upper Ulatisian-lower Narizian foraminiferal stages). This unit is conformably overlain by the Bateman Formation (Weatherby, 1991) and interfingers with the underlying Baughman Member of the Tyee Formation (columns 20 and #5; see Figs. 2 and 3 on Plate 1). The lower gradational contact is well exposed immediately west of Elkton in the south bank of the Umpqua River (column 21). Outcrops of the formation are preserved in the center of the Tyee forearc basin (see geologic maps of Niem and Niem, 1990; Black and others, in press; also see area of fence diagram enclosed by columns #3, #5, 16, 20, and 21).

LORANE SHALE

Distribution, Nomenclature, Lithology, Contact Relationships, and Age

The Lorane Shale occurs only in the northeast corner of the basin (column 22 of the fence diagram). It was named by Vokes and others (1951) and first mapped as a separate formation by Gandera (1977) in intermittent outcrops in the Lorane Valley between Cottage Grove and Eugene (largely north of this study area) where the unit is 600 ft thick. It is a dark gray, well-laminated, micaceous, deep-marine mudstone. Within the study area, only 50 ft of Lorane Shale is exposed along Interstate-5 (column 22) where it conformably overlies the Tyee Mountain Member of the Tyee Formation. The Lorane Shale is unconformably overlain by the upper Eocene Spencer Formation. The Lorane Shale is middle Eocene (coccolith zone CP-12b of Bukry and Snavely, 1988) and has been correlated to the Elkton Formation in the center of the Tyee forearc basin by Bird (1967) (Fig. 2 on Plate 1).

BATEMAN FORMATION

Nomenclature

The Bateman Formation was first mapped by Baldwin (1961). Baldwin (1974) named the unit for the Bateman fire lookout 5.5 miles west of the settlement of Tyee (sec. 5, T. 25 S., R. 8 W.). The designated type sections are along the Rader Creek and Waggoner Creek roads in the southern part of the Elkton 15-minute quadrangle (column 20). Twelve additional stratigraphic sections were measured by Weatherby (1991).

Thickness and Distribution

The formation is 1,400 to 2,500 ft thick crops. It crops out in only two areas in the center of the Tyee forearc basin (column 20; Ramp, 1972; Baldwin, 1974; Niem and Niem, 1990; Walker and MacLeod, 1991; Black and others, in press). In a recent master's thesis, Weatherby (1991) measured a 1,150-ft continuous reference section along Hedden Creek Road (secs. 3 and 9, T. 23 S., R. 8 W.).

Lithology and Depositional Environment

The Bateman Formation is dominantly delta front, distributary mouth bar, and distributary channel facies. Delta front facies are composed of coarsening- and thickening-upward cycles (100 to 200 ft thick) of thin- to thick-bedded, micaceous feldspathic wacke interstratified with subordinate, burrowed, massive mudstone and bedded to massive (bioturbated) siltstone (Weatherby, 1991, 1991b).

Individual sandstone beds are lenticular, massive, or parallel laminated to hummocky bedded. Minor graded bedding and microripple-laminations occur. Basal sandstone contacts are sharp and planar, although some display scour-and-fill structures. Laminations are enhanced by concentrations of disseminated carbonaceous plant debris and mica flakes. Disarticulated shells of *Venericardia* were reported in a few sandstone beds by Weatherby (1991). The moderately indurated delta front sandstone is generally fine-grained, moderately well-sorted, and weakly cemented by clay rims and coatings of chlorite and minor calcite. Some prodelta mudstone is present (Weatherby, 1991).

Overlying and interfingering with the delta front cycles are large-scale tabular cross-bedded to massive, medium- to coarse-grained, distributary channel and distributary mouth bar sandstones. These micaceous, lithic arkosic sandstone beds contain scoured bases, ripped-up clasts, coalified wood, and scattered lenses or lags of pebbles. The sandstone thins and fines upward to highly carbonaceous, overbank swamp and marsh siltstone. As many as five beds of subbituminous coal, all < 3 ft thick, are associated with the siltstone and mudstone (see measured sections in Weatherby, 1991). Fossil leaves and pollen reported by Baldwin (1961) and Hopkins (1967) indicate a tropical to subtropical climate. Weatherby (1991) noted long, sand-filled *Teredolites* burrows that extend into a few marginal marine coals from the overlying transgressive delta front sandstone. Root traces mottle the underclays beneath coal layers.

Paleocurrent measurements by Weatherby (1991) indicate that the Bateman delta prograded to the north-northwest. Delta front sequences are also more dominant in the northern part of the outcrop area, whereas lower delta plain, distributary channel, and interdistributary swamp and marsh deposits are more abundant in the southern part (Weatherby, 1991, 1991b). Sandstone petrography identifies a provenance to the southeast and east that consisted of andesitic Western Cascade arc rocks; metamorphic, plutonic, and sedimentary rocks of the northern Klamath Mountain terranes; and the Idaho batholith (Weatherby, 1991).

The Bateman outcrop represents an erosional remnant of a wave-dominated delta and shoreface sequence that was part of a broad, late middle to late Eocene coastal plain in western Oregon (Dott, 1966). Age-equivalent(?) or slightly younger (i.e., late Eocene, upper Narizian) wave-dominated deltas and shoreline sequences are preserved (1) to the southwest in the Coos Bay basin (i.e., Coaledo Formation: Dott, 1966; Ryberg, 1978; Chan and Dott, 1986; Orr and others, 1992), and (2) to the north-northeast in the Willamette Valley and Nehalem Basin (i.e., Spencer Formation: Hoover, 1963; Baker, 1988; and Cowlitz Formation: Berkman, 1990; Berkman and others, 1991).

Age and Contact Relationships

The Bateman Formation strata have not been well-dated by fossils, but they are inferred to be upper middle to upper Eocene. Baldwin (1974) reported a tentative upper Ulatisian age at one locality based on foraminifers examined by K. J. Bird. However, the unit gradationally overlies middle Eocene Elkton Formation mudstone (Figs. 3 and 2 on Plate 1) (Baldwin, 1974; Weatherby, 1991; column 20 and Fig. 3 on Plate 1). No upper contact is preserved due to erosion.

SPENCER FORMATION

Nomenclature

The Spencer Formation was named by Turner (1938) for a thick sequence of upper Eocene (upper Narizian) micaceous arkosic and volcaniclastic sandstones exposed in Spencer Creek southwest of Eugene, 20 miles north of this study area.

Thickness, Lithology, and Age

The Spencer Formation is composed of several hundred feet of fluvial to deltaic, medium- to thick-bedded sandstone. There also are a few thin (< 2 ft) subbituminous coal beds and thicker, laminated carbonaceous (leaf-bearing) mudstone-siltstone interbeds in the unit. The sandstone in the area of this investigation is friable, micaceous arkosic, cross-bedded, and fine-grained to very coarse-grained. Shallow-marine mollusks and carbonaceous leaves date the formation as late Eocene (Hoover, 1963; Sanborn, 1937). The unit is probably a lateral equivalent of or slightly younger than the Bateman Formation and/or is an age-equivalent of the Coaledo Formation of the Coos Bay basin (Fig. A).

Distribution and Contact Relationships

Hoover (1963) mapped a thin outcrop belt of Spencer Formation on the northeast side of the Tyee basin. The unit pinches out due to subaerial erosion and overlap by volcanic and volcaniclastic deposits of the Western Cascade Fisher Formation near Drain and Anlauf (Niem and Niem, 1990; Black and others, in press).

The Spencer Formation unconformably overlies the middle Eocene Lorane shale along Interstate-5 in the northeastern part of the study area (column 22; Gandera, 1977). In the southeastern part of the southern Tyee basin in and adjacent to the North Umpqua River, the unit unconformably overlies the lower Eocene Camas Valley formation. The thick, friable, micaceous, cross-bedded sandstone with thin coal beds in this area was previously mapped as Flournoy Formation (Baldwin, 1974; Niem and Niem, 1990). Recent maps by Walker and MacLeod (1991) and Black and others (in press), however, call these strata Spencer Formation.

OTHER UPPER EOCENE TO MIOCENE GEOLOGIC UNITS

After the Spencer and Bateman formations were deposited in the late middle Eocene and late Eocene, calcalkaline volcanism was initiated in the Western Cascade arc along the eastern border of the southern Tyee basin (Fig. A; e.g., Fisher Formation; Hoover, 1963; Baldwin and Perttu, 1980). Eruptive activity in the arc continued into the Oligocene and Miocene (Peck and others, 1964; Smith and others, 1982; Walker and MacLeod, 1991; Orr and others, 1992). Cascade lavas east of Glide (column 14), for example, yielded K-Ar ages of 38.6 Ma to 21.2 Ma or latest Eocene to early Miocene (sec. 9, T. 26 S., R. 3 W.; Mobil, unpublished data).

The Fisher Formation and other Western Cascade units (e.g., Little Butte Volcanics) consist of thousands of feet of volcanogenic deposits of basalt and basaltic andesite (Walker and MacLeod, 1991). The volcanic sequence also includes andesitic to rhyodacitic mudflow (lahar) deposits, ash-flow tuffs, and water-laid and air-fall silicic tuffs. Western Cascade basalt sills and dikes (gabbro, diabase, and norite) intruded Western Cascade volcanic units and Umpqua Group strata in the eastern part of the Tyee basin in the late Paleogene and early Neogene (Niem and Niem, 1990; Black and others, in press). For example, basalt sills (50 to 100 ft thick) occur in the White Tail Ridge formation in the Glide-Colliding Rivers State Park area (sec. 19, T. 26 S., R. 3 W.). Thin basalt sills in the Siletz River Volcanics near the bottom of Mobil's Sutherlin well (column #7; at 10,070-75 ft and 10,550-80 ft) were K-Ar dated as Oligocene or 33.9 ± 3.4 Ma to 36.8 ± 3.6 Ma (courtesy of Mobil Oil Corp., Bill Seeley, Lee High, and Neal R. Goins, 1989, pers. communs.).

In the latest Eocene (upper Narizian), 6,000 ft of deltaic sandstone, siltstone, and coals (i.e., Coaledo Formation) began to fill the newly subsiding Coos Bay basin on the western flank of the southern Tyee basin (Dott and Bird, 1979) (Fig. A). These deposits were superseded by upper Eocene to upper Miocene deep-marine, shallow-marine, and fluvial sandstone and mudstone (Baldwin and Beaulieu, 1973; Armentrout, 1980).

SEQUENCE STRATIGRAPHY

The new concepts of sequence stratigraphy can be applied to better understand the vertical and lateral facies variations of the Tyee basin sedimentary rocks. This approach will help predict the distribution and geometry of these facies (especially potential reservoir targets and source rocks for oil and gas exploration) in the subsurface. Sequence analysis involves subdividing the basin-filling sedimentary sequence into a hierarchy of genetically related and time-bounded units (e.g., parasequence, systems tract, and sequence). For further discussion of sequence stratigraphic concepts, the reader is referred to Van Wagoner and others (1990).

According to the ideal model of Van Wagoner and others (1990), each depositional sequence starts with a lowstand systems tract (LST) created by a rapid fall of relative sea level during which time much of the continental shelf is exposed (Fig. E). Rivers and canyons are locally incised into the exposed shelf and upper slope. They funnel coarse clastics downslope through sea gullies and submarine canyons via turbidity currents to deposit a growing basin-floor fan (see submarine fan on Fig. E). Small deltas formed at river mouths are perched at the shelf/slope break.

Eventually, sea level ceases to fall and a stillstand is reached. Then sea level begins to rise slowly again. As a result, the continental shelf is gradually flooded, growth of the basin-floor submarine fan ends, and the incised river valleys begin to fill or aggrade with gravel and coarse sand of braided rivers (and/or with estuarine sands; Fig. F). Slope-perched deltas continue to prograde basinward, and a shale-prone slope wedge downlaps on top of the abandoned basin-floor submarine fan (Fig. F). The shale-prone wedge (includes slope fan of Van Wagoner and others, 1990; Haq and others, 1988; Vail and others, 1984) consists of deep-marine mudstone and thin, fine-grained turbidite sandstone beds.

With a rapid relative rise in sea level, caused by increased tectonic subsidence or eustatic sea level change, the initial lowstand systems tract is buried by a transgressive systems tract (TST; Fig. G). Transgressive system tracts are characterized by deposition of a thick marine shale (defining a maximum flooding surface) across the shelf and by an associated condensed section of organic-rich facies (i.e., thin shales and glauconite or phosphate) deposited on the outer shelf and slope. With flooding, coarsening- and thickening-upward parasequences of wave- or fluvial-dominated delta front sandstone and mudstone (Figs. I, J, and K) backstep or retrograde landward (Fig. G). Ideally, the river systems shift from a braided pattern to a meandering or high sinuosity pattern (Fig. G).

Overlying the transgressive systems tract are strata representing a highstand systems tract (HST) formed when relative sea level is highest and the rate of deposition is greater than the rate of sea level rise. As a result, wave-dominated deltas with shoreface aggradational or progradational parasequence sets (composed of coarsening- and thickening-upward parasequences) build basinward onto the shelf (Fig. H). The deltaic parasequences downlap onto the condensed section (i.e., thin sequence of organic-rich mudstones), which also moves basinward as a result of relative slow sea level rise, followed by stillstand and slow relative fall in sea level. The set of facies and lithologies that represent lowstand, transgressive, and highstand systems tracts forms one depositional sequence. This depositional sequence (LST, TST, HST) may be repeated in time (Fig. M), starting a new cycle with a rapid relative fall of sea level (Fig. E).

Each depositional sequence, according to Van Wagoner and others (1990), is separated from subjacent and superjacent sequences by local unconformities (termed sequence boundaries; Figs. E, F, M). A sequence boundary between depositional sequences may be relatively conformable in the deeper marine parts of the basin. Sequence boundaries in the southern Tyee basin, for example, are commonly characterized by rapid basinward shift in facies, local unconformities (e.g., a lowstand wedge of fluvial channels that cut-and-fill into deeper marine outer shelf or slope mudstone), and abrupt change in the parasequence stacking pattern in wireline logs (Fig. M) and measured stratigraphic sections (Ryu and Niem, 1993).

Using sequence stratigraphic analysis allows us to reinterpret several lithostratigraphic units (formations and members) in the Tyee basin as unrelated unconformity bounded units. These units were previously interpreted by others as lateral facies of one another (e.g., Heller and Dickinson, 1985; Chan and Dott, 1983; Figs. Da and Db). This is an important concept in oil and gas exploration for defining reservoir geometry because some sandstone units may be totally unrelated in time (i.e., different chronostratigraphic units) to other lithologically similar sandstone or mudstone facies (Fig. N). The fence diagram (Plate 1) is largely a lithostratigraphic correlation of members and formations, although it also includes some aspects of chronostratigraphic correlation and sequence stratigraphy (see Explanation on Plate 1 and Ryu, in prep.).

Seismic and sequence stratigraphic concepts were developed mainly for passive continental margin basins (e.g., Vail and others, 1977; Van Wagoner and others, 1990; Armentrout and Perkins, 1991). In passive margin basins, eustatic sea level fluctuations are important controls in formation of lowstand, transgressive, and highstand systems tract depositional sequences. However, in tectonically active settings, development of ideal depositional sequences is complicated by tectonism. In the southern Tyee basin, for example, syndepositional tectonic activity within and adjacent to the basin interrupted formation of ideal systems tract sequences (Ryu and Niem, 1993).

We recognize four depositional sequences (I, II, III, IV) separated by sequence boundaries in the 20,000 ft of Eocene strata that overlie the Siletz River Volcanics (Fig. 3 on Plate 1; Ryu and Niem, 1993). Each depositional sequence contains part or many of the features of the three ideal systems tracts (Figs. E, F, G, and H) defined by Van Wagoner and others (1990). Some facies or features are missing. However, the model can be applied here with some modifications (Ryu, in prep.; Ryu and Niem, 1993).

Correlations within the four depositional sequences use biostratigraphy (foraminifers, coccoliths, and mollusks) and subsurface (wireline logs, seismic reflection profiles) to surface lithologic correlations between closely spaced measured sections and wells (Plate 1; Ryu, in prep.). This study was conducted in cooperation with detailed geologic mapping of the southern Tyee basin by G. L. Black (DOGAMI) and R. E. Wells and C. M. Molenaar (USGS) (see maps by Black and others, in press, and Wells and others, in prep.).

The oldest depositional sequence (Sequence I) consists of the Bushnell Rock formation, Slater Creek member of the Bushnell Rock formation, and lower parts of the Tenmile formation and undifferentiated Umpqua Group (LST); massive mudstone of the Tenmile formation and lower and middle undifferentiated Umpqua Group (TST); and Berry Creek member of the White Tail Ridge formation (HST) (Fig. 3 on Plate 1).

Sequence II consists of the Remote and Coquille River members of the White Tail Ridge formation (LST), Camas Valley formation and uppermost part of the undifferentiated Umpqua Group (TST), and the Rasler Creek tongue of the White Tail Ridge formation (HST).

Sequence III consists of the Tyee Mountain Member (LST) and Hubbard Creek Member (TST to HST) of the Tyee Formation.

Sequence IV consists of the Baughman Member (LST) of the middle Eocene Tyee Formation, Elkton Formation and Lorane Shale (TST), and Bateman-Spencer formations (HST).

SEQUENCE I

During the early Eocene there was some underthrusting and/or some oblique-slip movement along the Wildlife Safari fault and uplift of the northern Klamath Mountains (e.g., along the Canyonville fault on Fig. A; Perttu, 1976; Perttu and Benson, 1980; Ryberg, 1984). During a lowstand and rapid relative sea level fall, streams downcut valleys across these terranes (Fig. E). As sea level began to rise slowly, syntectonic fanglomerate, fan delta, and submarine canyon to inner fan facies of the Bushnell Rock formation backfilled the valleys and canyons that had been eroded into the pre-Tertiary Klamath Mountain terranes and Eocene Siletz River Volcanics (Heller and Ryberg, 1983; Fig. F; columns 8, 9, 10, 13, 14, and 23 on Plate 1). Fan deltas and submarine channels of Bushnell Rock sands, polymictic gravels, and muds probably fed basin-floor inner, middle, and outer submarine fan turbidites of the undifferentiated Umpqua Group to the north-northwest (Ryberg, 1984; this investigation). For example, basin-floor mudstone and inner, middle, and outer submarine fan turbidite strata of the lower part of the undifferentiated Umpqua Group in the Sutherlin-Myrtle Point subbasin (columns 15, 24, #8, and #7) appear to be laterally equivalent to the Bushnell Rock fan deltas and deep-sea incised valley conglomerates (e.g., column 14). Some thick- to very thick-bedded, inner fan lithic sandstones in the southwest part of the subbasin may also have been fed by the isolated, age-equivalent, deep-sea conglomerate channels in the Tenmile formation in columns 1, 2, and 6 (near Agness, Agness Pass, and Rasler Creek). A few lenses of shallow- to deep-marine basaltic sandstone were deposited locally around the oceanic islands on the Umpqua arch to the north during this time (Fig. A; columns 15, 22, and 21 on Plate 1).

Much of the overlying lower and middle Tenmile formation represents a lowstand wedge with small slope fans (Fig. F). This upper-lower Eocene slope fan wedge consists of mainly laminated to massive bathyal mudstone interstratified with thick sequences of fine-grained, lithic turbidites. These rhythmically bedded turbidite sequences (e.g., column 9) may represent outer submarine fan facies and/or small slope fans (Fig. F; Van Wagoner and others, 1990). These deep-marine Umpqua basin strata were deposited on a continental slope during a broad marine onlap or slow rise in relative sea level (i.e., a transgression) onto the subsiding northern border of the Klamath Mountains (Fig. A). The thick Eocene bathyal mudstone and thin-bedded slope turbidites of the Tenmile formation prograded or downlapped as a slope wedge over the lowstand incised Bushnell Rock canyon head or valley fill formed earlier (e.g., at Suicide Creek, column 10; Fig. F).

Deep-marine mudstone in the upper part of the undifferentiated Umpqua Group contains foraminifers of the B-4 to B-1 stages of Almgren and others (1988) (Fig. 2 on Plate 1). This mudstone in the Sutherlin-Myrtle Point subbasin (e.g., Metz Hill section, column 15) may be a basin-floor/lower slope facies equivalent to the prograding slope wedge sequences of Tenmile formation that also contain B-4 to B-1 stage foraminifers. As thin-bedded, outer or distal fan turbidite sandstones of the Tenmile formation were trapped in local subbasins on the upper to middle continental slope, thick undifferentiated Umpqua Group hemipelagic mudstone accumulated in the Myrtle Point-Sutherlin trench or marginal basin and in the Smith River subbasin to the north (Fig. A and Plate 1).

As relative sea level rose more rapidly and inundated the shelf, the upper 500 ft of the Tenmile formation, representing a transgressive systems tract (Fig. G), was deposited as shallowing-upward, massive, bioturbated outer shelf to upper slope mudstone. These strata contain neritic molluscan and foraminiferal faunas (e.g., Shield Creek, column 10; E. J. Moore, 1991, written commun.; McKeel, 1991, 1992, written commun.). Age-equivalent deep-marine mudstone of the upper undifferentiated Umpqua Group continued to accumulate in the Smith River and Sutherlin-Myrtle Point subbasins (Fig. A and columns #1, #8 and 15 on Plate 1). Contemporaneously, a thin condensed section (< 200 ft thick) of dark gray, deep-marine mudstone accumulated over the Umpqua arch (e.g., columns 21 and 18).

Capping Sequence I is the Berry Creek member of the White Tail Ridge formation. This member occurs locally in the southern parts of the basin (e.g., columns 3, 4, 9, 12, 13, 14, and #16). The member conformably overlies and is laterally equivalent to the upper neritic mudstone facies of the Tenmile formation. The unit represents a highstand systems tract wave-dominated delta (Fig. H). The Berry Creek member consists of several coarsening- and thickening-upward progradational parasequences (Figs. I, J, K, and M).

SEQUENCE II

A second depositional sequence (II) consists of a LST (the channelized, fluvial Remote member and the shallow-marine to delta front Coquille River member of the White Tail Ridge formation); a TST (thick overlying mudstone of the Camas Valley formation and equivalent upper parts of the undifferentiated Umpqua Group); and a HST (the delta front and shoreface sandstone of the Rasler Creek tongue of the White Tail Ridge formation) (Figs. 2 and 3 on Plate 1).

A local angular unconformity at the base of the Remote member indicates a late early Eocene episode of local deformation in the southern part of the Sutherlin-Myrtle Point subbasin. The compositions and large size of clasts in the Remote member also attest to uplift in the northern Klamath Mountains. The Remote member probably formed during a sea level lowstand or rapid fall in sea level. The unit filled steep gradient valley(s) that had been incised into the exposed shelf (Figs. E and F). Boulder-cobble conglomerate (with clasts that are several feet in diameter) and cross-bedded, pebbly, coarse-grained sandstone were deposited by high-gradient braided streams that drained fault blocks to the south. These coarse clastics spread into the basin unconformably over the more deformed Slater Creek sandstone member of the Bushnell Rock formation (columns 8 and #17) and over the Tenmile formation. These relationships represent the unconformable part of the sequence boundary.

The fluvial Remote member also disconformably overlie or is incised into delta front Berry Creek member sandstone of depositional sequence I (e.g., columns 4, 6, 7, 9, 14, and #16). Locally, the channels eroded through the Berry Creek member and into the upper part of the Tenmile formation (columns 10 and 11). Farther north and west, in the deeper part of the basin, the braided stream-dominated Remote member grades into a series of coarsening- and thickening-upward wave-dominated delta front parasequences (Figs. I, J, and K) and fining- and thinning-upward, coal-bearing tidal flat-lower delta plain parasequences (Fig. L) of the overlying Coquille River member. The Coquille River member gradationally overlies the upper Tenmile neritic facies, forming a conformable sequence boundary (Fig. F; Van Wagoner and others, 1990).

The overlying deep-marine Camas Valley formation reflects a transgressive systems tract (TST) within depositional sequence II (Fig. G). This unit represents a major flooding surface created during a rapid relative rise in sea level. The unit was deposited uniformly over the Reston high in the Sutherlin-Myrtle Point subbasin (column 11) and is recognized as far south as Powers and Agness Pass (e.g., columns 2, 4, and 6).

The progradational Rasler Creek tongue which extends into the Camas Valley formation consists of stacked, wave-dominated delta front parasequences (Figs. I, J, and K). One explanation for this tongue is the classical stratigraphic interpretation that a relatively short-lived event caused progradation of a shallow-water facies into a deeper water environment. When the conditions that created the prograding shallow-water facies ceased, deep-water sedimentation resumed. An alternative explanation, using sequence stratigraphy, would describe the Rasler Creek tongue as progradation of a deltaic tongue basinward onto the Camas Valley muddy shelf during a highstand (HST of Van Wagoner and others, 1990; Fig. G). In this explanation, the thin interval of uppermost Camas Valley neritic-upper slope mudstone that overlies the Rasler Creek tongue (e.g., columns 4, 6, and 7) reflects a short-lived transgression or onlap of the shelf (a TST of Van Wagoner and others, 1990; Fig. H).

A mudstone or shale overlying a sandstone at the top of a HST does not conform to the ideal sequence model. Therefore, we introduce the term *tectonism-forced transgression* (patterned after the term forced regression in a LST introduced by Posamentier and others, 1992) to refer to the conditions that deposited a mudstone at the top of a HST (Ryu, in prep.). A tectonism-forced transgression may be created when tectonism reconfigures the geometry of a basin, leading to a basinwide change in relative sea level (Ryu, in prep.). Thus, the contact between the Rasler Creek tongue and the overlying Camas Valley formation mudstone could be termed a tectonic flooding surface.

SEQUENCE III

The third depositional sequence (III) includes the Tyee Mountain and Hubbard Creek members of the Tyee Formation. These members are separated from the overlying fluvial facies of the Baughman Member by a sequence boundary or a local disconformity (Fig. 3 on Plate 1; columns 3, 4, 5, 6, 7, 9, 10, and 11). In the deeper parts of the basin, this contact is conformable (see columns 17, 18, 19, 16, 20, 21, #3, #4, and #5).

The Tyee Mountain Member is principally a lowstand basin-floor fan (Chan, 1982; Fig. Da) or submarine ramp (Heller, 1983; Van Wagoner and others, 1990; Figs. Db and E) that conformably overlies basinal mudstone facies of the Camas Valley formation (e.g., in columns 12 and 16). Locally, to the south, however, the Tyee Mountain Member consists of a series of amalgamated, micaceous turbidite sandstone beds in nested channels (e.g., columns 3, 4, and 5). This unit locally eroded into older Camas Valley formation slope/outer shelf mudstone during a sea level lowstand (Van Wagoner and others, 1990; Fig. E). The nested channels acted as a conduit to transport shelfal-deltaic, micaceous, fine-grained, lithic feldspathic sands via turbidity currents to the basin-floor fans (Bird, 1967; Chan, 1982).

The river, deltaic, and/or shelfal sand sources for the Tyee Mountain Member were subsequently eroded away prior to deposition of the overlying Baughman Member. Also all remnants of these facies in the northern Klamath Mountains have been eroded away. Alternatively, the Baughman deltaic and shelfal facies may have fed the Tyee Mountain basin floor fan via these multiple canyon heads and canyons cut into the slope (Chan and Dott, 1983; Heller and Ryberg, 1983; Figs. Da and Db). As relative sea level slowly rose, some of these canyon heads and canyons (Fig. E) were back-filled with thin nested channel sequences of amalgamated turbidite sandstone and mudstone (Fig. F).

The Hubbard Creek Member of the Tyee Formation may represent facies from a lowstand wedge (LST), a transgressive systems tract (TST), and a highstand systems tract (HST). This member consists of three units, and its overall geometry is a shale-prone wedge. Local, thin sequences of nested turbidite sandstone channels in the middle part of the 1,000 ft thick Hubbard Creek Member in the south (columns 9, 10, and 11) are incised into bathyal mudstone of the lower deep-marine unit of the Hubbard Creek. These thin, local, nested channel facies may have fed small slope fan(s) (Fig. F) and/or the Tyee Mountain Member (Chan and Dott, 1983; Heller and Dickinson, 1985).

Basinward, the correlative, thinner, 400- to 600-ft section of lower bathyal, laminated, micaceus mudstone to the north (columns 16, 20, 21, 17, 18, and 19) may represent progradation of the shale-prone wedge over the abandoned Tyee Mountain Member lowstand fan owing to drowning of the river mouth and delta (fine-grained micaceous sand sources) as relative sea level slowly rose (Fig. F).

The 400-ft-thick upper unit of the Hubbard Creek Member at Burnt Ridge (column 11) consists of outer shelf to upper slope mudstone. The unit may represent a transgressive systems tract (TST) and/or highstand systems tract (HST; Figs. G and H). Although a condensed section remains to be identified, this upper part of the member reflects a rapid sea level rise and a stillstand that may have been associated with progradation of a highstand deltaic facies (either now completely eroded away or represented by the deltaic facies of the overlying Baughman Member; Figs. G and H; Chan and Dott, 1983; Heller and Dickinson, 1985). The first model is preferred because this investigation shows that locally (e.g., at Coal Creek and China Flat, columns 3 and 4), the upper outer shelf-upper slope mudstone unit of the Hubbard Creek is in sharp erosional contact with the fluvial facies of the Baughman Member. This erosional surface represents the sequence boundary at the base of sequence IV.

SEQUENCE IV

The fourth depositional sequence consists of the Baughman Member of the Tyee Formation, the middle Eocene Elkton Formation and Lorane Shale, and the middle to upper Eocene Bateman Formation and Spencer Formation (Figs. 2 and 3 on Plate 1).

Following widespread deposition of the deep-marine Hubbard Creek slope and basinal mudstone over the lowstand Tyee Mountain Member fan in the forearc basin, a relative sea level fall resulted in progradation of the 1,000- to 2,000-ft thick Baughman fluvial system fronted by a wave-dominated delta. The Baughman deltaic facies consists of three to four cycles of forward-stepping and thickening-upward, progradational parasequences (Figs. E, F, I, J, and K; columns 16, 20, and 21).

The parasequences consist of thin- to thick-bedded, medium-grained, mollusk-bearing, hummocky bedded, bioturbated, micaceous sandstone and thin mudstone. These organized strata were probably deposited at a wave-dominated delta front. They resemble shoaling upward parasequences described by Chan and Dott (1986) for the middle to upper Eocene Coaledo Formation of the southwest Oregon coast. These shoreface deltaic strata grade upward to lower delta plain, distributary, and distributary mouth sandstone with minor subbituminous coal (Figs. I, J, and K). The coarse-grained distributary mouth strata fine or thin upward to thin hummocky beds and ripple-laminated to laminated mudstone. These 100- to 300-ft parasequences are well-exposed in the Tyee Road section (column 16), Kellogg and Waggoner Creek section (column 20) along the Umpqua River, and the Elkton section (column 21).

These features and relationships demonstrate that the Baughman delta prograded from south to north and that the fluvial facies formed during a rapid relative fall of sea level, stillstand, and a slow relative rise of sea level (Fig. F). Initially, lower Baughman rivers incised into Hubbard Creek slope mudstone, creating incised valleys across the outer shelf and upper slope in the southern part of the basin (Fig. E). As relative sea level rose slowly, the stream valleys were backfilled and aggraded with cross-bedded, coarse sand of the Baughman Member in a braided river system (Fig. F). The associated deltaic parasequences prograded farther across the former Hubbard Creek muddy shelf to the north (Figs. F and M).

The lower 500 ft of the Elkton Formation (column 21) represents an onlapping transgressive systems tract (Figs. G and M). The Elkton at this locality consists of thick, shallow-marine, outer shelf mudstone which contains two 50- to 100-ft thick thickening-upward, micaceous, mollusk-bearing sandstone parasequences. Eventually, the entire former shelf, delta, and fluvial system of the Baughman Member was covered by thick, transgressive, slope mudstone of the Elkton Formation as a result of this rapid relative rise in sea level (Fig. G). The relative rise in sea level was probably related to increased accommodation owing to subsidence and eustatic sea level rise and a slower rate of sedimentation. Some local nested channel facies may have fed small slope fans (now eroded) via turbidity currents (Fig. G; e.g., column 20).

The overlying Bateman Formation contains several prograding coarsening- and thickening-upward deltaic parasequences (Figs. H, I, J, K, and M; Weatherby, 1991). These grade and interfinger upward to distributary channel sandstones. Thin (< 2 ft thick) discontinuous, overbank coal and carbonaceous siltstone cap the stratigraphic section (Weatherby, 1991; columns 20 and #5). The formation represents a highstand systems tract of sequence IV that downlapped onto the Elkton slope mudstones during slowing of the rate of sea level rise, a stillstand, and slow fall of sea level (Fig. H).

The Bateman Formation, along with the Spencer Formation of the Willamette Valley, the Cowlitz Formation of northwestern Oregon, and the Coaledo Formation of southwestern Oregon represent a low-lying coastal plain and the final phase of major deltaic progradation in the middle to late Eocene (lower to upper Narizian) in the western Oregon forearc basin (Snavely and Wagner, 1963; Dott, 1966; Armentrout and Suek, 1985; Weatherby, 1991). Subsequently, a possible plate reorganization in the latest Eocene (Snavely, 1984; Armentrout, 1987) resulted in renewed rapid subduction, creation of a regional sequence boundary, and major eruptions of the Tertiary Western Cascade calcalkaline arc. The volcanic arc eventually blocked the major river input of extrabasinal micaceous arkosic sand derived from the Idaho batholith and eastern Oregon, eastern Washington, Idaho, and British Columbia and Montana (Buckovic, 1979; Armentrout and Franz, 1983).

Tuffaceous ashes and pyroclastics from these eruptions overwhelmed the input of arkosic mica-bearing sand and changed the character of forearc basin sedimentation in much of western Oregon (Niem and others, 1992; Niem and Niem, 1984; McKnight and others, 1992). Although the younger tuffaceous forearc sediment is not preserved in the Tyee basin, some strata overlie the Tyee Formation farther north in the Willamette Valley (e.g., Fisher Formation; Vokes and others, 1951). Upper Eocene to Miocene lavas and pyroclastics of the Western Cascade arc overlie with angular unconformity the Spencer Formation, Tyee Formation, and White Tail Ridge formation east of the study area (e.g., east of Glide; column 14). This angular unconformity represents the upper boundary of sequence IV. The overlying young volcanogenic units define the end of sedimentation in the Tyee forearc basin.

SUMMARY

In the Paleocene to early Eocene, Siletz River Volcanics (basement rocks) of the southern Oregon Coast Range were erupted as seamounts and oceanic islands along a deep-marine rifted or convergent continental margin from a spreading ridge or hot spot (Duncan, 1982; Snavely, 1984; Wells and others, 1984). Nearby uplifted Klamath Mountain Mesozoic terranes shed gravel, coarse lithic turbidite sands, and marine muds that interfingered with the pillow lavas and breccias (i.e., lower undifferentiated Umpqua Group and lower Bushnell Rock formation). Subsequent cooling and subsidence of the volcanic crust and/or partial underthrusting of the Siletz River oceanic plate (part of the Farallon plate) beneath the North American plate (represented by the northern Klamath Mountains) created the Umpqua basin. This basin presently trends northeast-southwest (Baldwin and Perttu, 1980; Heller and Ryberg, 1983).

A northeast-southwest trending volcanic edifice or archipelago of coalescing basaltic seamounts and oceanic islands formed a submarine ridge that subdivided the Umpqua basin into two subbasins: the Sutherlin-Myrtle Point trench on the south and the Smith River subbasin on the north (Fig. A). The Smith River subbasin was isolated or cut off from the supply of coarse clastics from the south by this barrier ridge of Siletz River Volcanics.

Therefore, only hemipelagic terrigenous muds of the lower Eocene undifferentiated Umpqua Group filled this subbasin (Plate 1). In contrast, the Sutherlin-Myrtle Point subbasin was inundated with thick sequences of alluvial fan, fan delta, and submarine canyon gravels, turbidite lithic sands, and deep-marine muds of the Bushnell Rock formation, undifferentiated Umpqua Group, and Tenmile formation. These siliciclastics were derived largely from the tectonically active Klamath Mountain highlands to the south (Heller and Ryberg, 1983; Ryberg, 1984).

During deposition of these strata, several phases of renewed underthrusting and/or strike-slip or oblique-slip deformation along the southern margin of the Sutherlin-Myrtle Point subbasin resulted from continued accretion of the Siletz River basaltic crust to the North American continental crust. Early Eocene oblique-slip movement on the Wildlife Safari fault and Canyonville right-lateral faults dictated the location of the coarsest fluvial gravels, alluvial fans, and fan deltas of the Bushnell Rock formation in the south-central part of the basin (Fig. A; Perttu, 1976). Lower Bushnell Rock and undifferentiated Umpqua Group polymictic conglomerate and lithic turbidite sandstone that are interbedded with Siletz River pillow basalts were deformed, folded, and faulted to a near-vertical position before and during deposition of the overlying Bushnell Rock fanglomerate, fan deltas, and submarine channels and undifferentiated Umpqua Group submarine fan facies, creating a local angular unconformity (note Lookingglass Formation of Heller and Ryberg, 1984, in Fig. Ba). Subsequent tectonic subsidence of the northern Klamath Mountain-Coast Range crust resulted in formation of slope mudstone and thin-bedded turbidites of the Tenmile formation.

Farther north, away from the tectonically active suture, a thin mudstone facies of the undifferentiated Umpqua Group (C-4 to B-1 foraminiferal stage of Almgren and others, 1988) that is laterally equivalent to the coarse-grained alluvial fan and turbidite units of the Bushnell Rock formation and Umpqua Group is relatively undeformed where it was deposited as a condensed section on the Umpqua arch. Renewed underthrusting gently deformed Bushnell Rock, Tenmile, and undifferentiated Umpqua Group turbidites and created the Reston high that formed in the Bonanza thrust fault zone (Fig. A and Plate 1). This high subdivided the Sutherlin-Myrtle Point subbasin during deposition of the deltaic Berry Creek and fluvial Remote members of the White Tail Ridge formation (Plate 1). Eventually, the Umpqua basin (Sutherlin-Myrtle Point subbasin, Umpqua arch, and Smith River subbasin; Fig. A) was inundated with lower middle Eocene slope and basinal mudstone of the upper Camas Valley formation (upper Umpqua Group). This unit, also, is gently deformed in the southernmost part of the basin.

Owing to clogging of the subduction zone by buoyant, thickened, oceanic crust of Siletz River Volcanics (e.g., Umpqua arch) in the late-early Eocene to early-middle Eocene, a new subduction zone developed to the west (at the present position on the outer continental shelf; Snavely, 1984). Behind this subduction zone, the deep, linear, Tyee forearc basin subsided across the trend of the older Umpqua basin and Siletz River Volcanics oceanic crust (Figs. A and B). More than 9,000 ft of strata of the middle Eocene Tyee, Elkton and Lorane, and Bateman formations and upper Eocene Spencer Formation filled the basin. The elongate shape of the basin constricted development of the prograding sandy submarine fan of the Tyee Mountain Member so that it does not have a radial fan geometry (Chan and Dott, 1983). The basin configuration also controlled the distribution of the deltaic Baughman Member and Bateman Formation. Mica-rich lithiclastics in the forearc basin were derived mainly from the Klamath Mountains and postulated calcalkaline volcanic arc now located to the south and southeast (Chan and Dott, 1983; Heller and Ryberg, 1983). In addition, rivers draining the Idaho batholith contributed quartz- and mica-rich detritus prior to clockwise rotation of the basin (Peterman and others, 1981; Heller and Ryberg, 1983; Heller and others, 1985; Heller and others, 1992).

The Tyee forearc basin presently trends north-south and the Umpqua basin northeast-southwest (Fig. A). However, paleomagnetic studies show that these basins have been rotated clockwise at least 67° since the middle Eocene (Simpson and Cox, 1977; Wells and Heller, 1988). Therefore, the original orientation of the Tyee forearc basin appears to have been northwest-southeast, and the underlying Umpqua basin trended north-south. Rotation of the Tyee basin, northern Klamath Mountains, and rest of western Oregon ("Willamette plate" of Magill and others, 1982) was probably caused by oblique subduction of the Juan de Fuca plate beneath the North American plate (beginning in the late Eocene). Some rotation of this microplate may be related to extension in the Basin and Range Province in southeastern Oregon and the Great Basin in the Miocene (Wells and Heller, 1988). Oblique subduction during this time also created the Coos Bay basin (late Eocene to upper Miocene strata) on the western border of the Tyee basin and gave rise to the Western Cascades calcalkaline arc on the eastern border of the basin (Fig. A).

A major episode of deformation of the Oregon Coast Range and northern Klamath Mountains took place in the late middle Miocene to Pliocene and continues locally to the present (Niem and others, 1992). Personius (1992), for example, has recognized broad arching of Quaternary river terraces in the axis of a more steeply dipping north-trending anticline developed in the underlying Tyee Formation along the Siuslaw River in the northwestern corner of the study area (east of Florence; Fig. A). Minor high-angle normal, reverse, and oblique-slip faulting and broad north-south to northeast-southwest folding were imposed on the Tyee basin architecture (Niem and Niem, 1990; Black and others, in press). This faulting and gentle folding probably resulted from east-west compression related to renewed oblique subduction of the Juan de Fuca plate (offshore) beneath the North American plate (Snavely, 1984; Niem and others, 1992; Black and others, in press).

Subsequent epeirogenic uplift and stream erosion (including entrenchment of meanders of the Umpqua and Siuslaw rivers) have deeply dissected the thick, middle to upper Eocene Tyee forearc basin sequence. These processes have also re-exposed the underlying, more highly deformed, Umpqua Group subduction complex in the Sutherlin-Myrtle Point subbasin and the Siletz River Volcanics basement on the flanks of the forearc basin. Also exhumed are Mesozoic terranes of the northern Klamath Mountains and the suture between the Mesozoic terranes and the Tertiary Coast Range (Fig. A). The long history of deformation in the southern Tyee basin and its effect on distribution of sedimentary facies will influence exploration strategies for oil and gas in these units.

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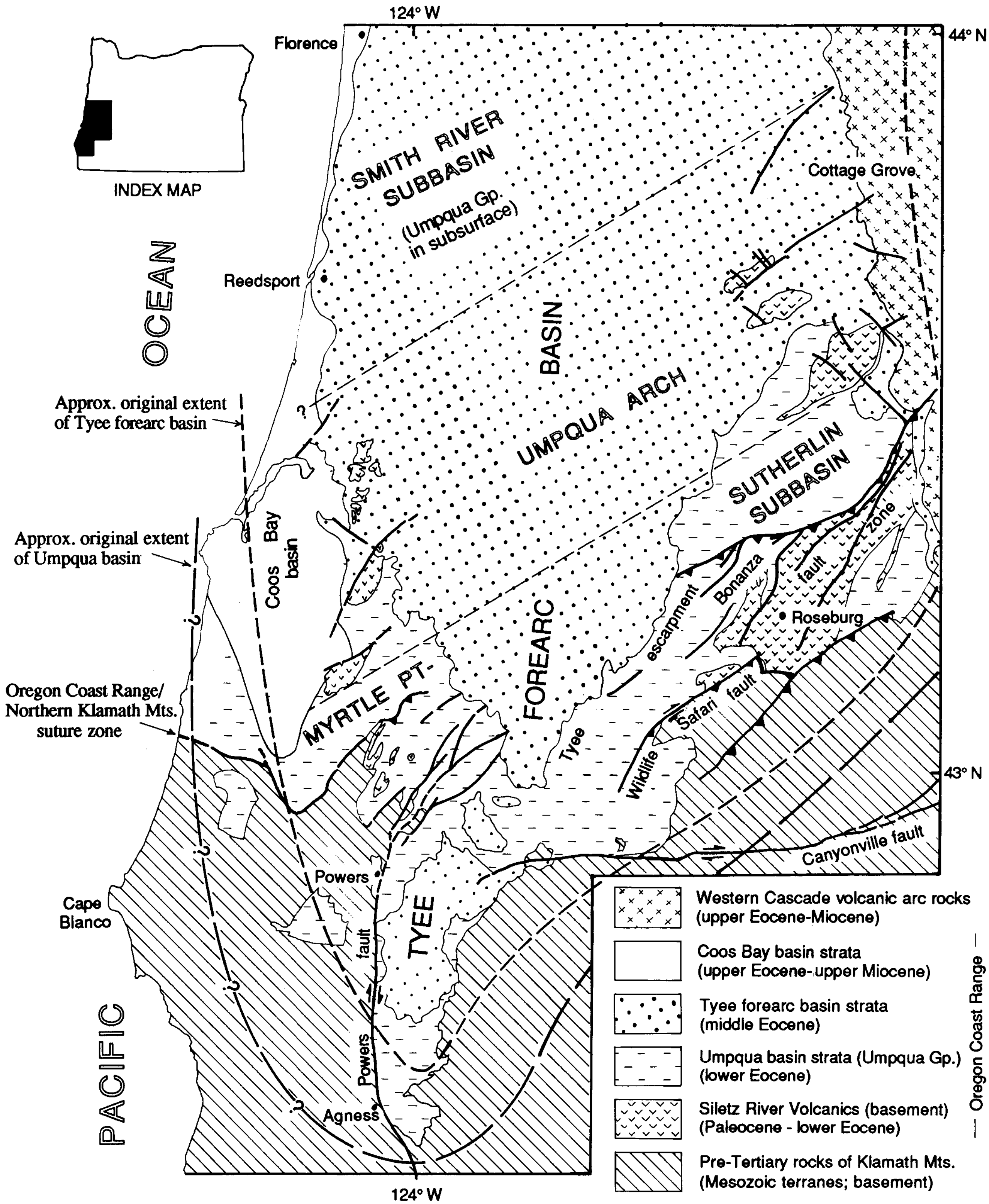


Fig. A Index map of general geology and tectonic features of the southern Tyee basin. Note the NE-SW structural trend of the Paleocene to early Eocene Umpqua subbasins (Myrtle Pt.-Sutherlin and Smith River subbasins) and Umpqua arch of Siletz River Volcanics versus the N-S trend of the superimposed middle Eocene Tyee forearc basin.

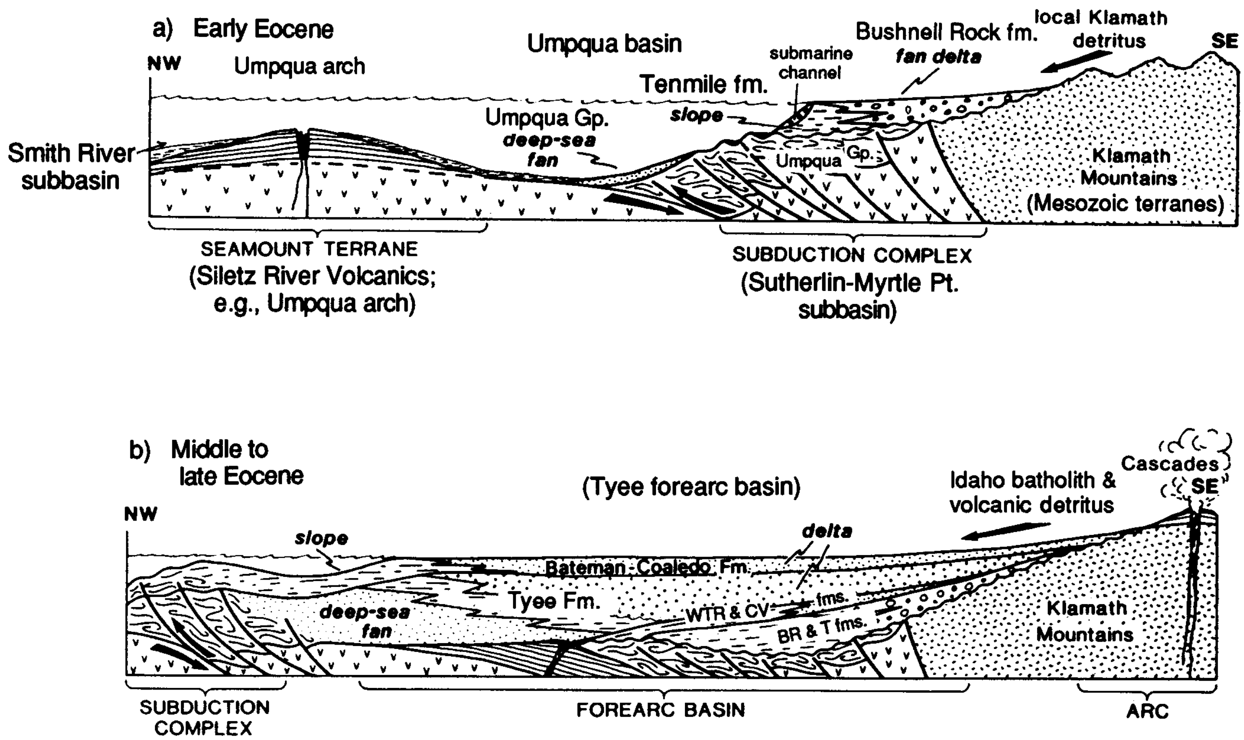


Fig. B Depotectonic setting of Eocene rock units in the southern Tyee basin (slightly modified from Heller and Ryberg, 1983). a) Early Eocene lithic deep-sea fan of the Umpqua Group (Roseburg Formation of Baldwin, 1974) and Tenmile formation slope facies fed by fan deltas of the Bushnell Rock formation. These units were simultaneously deposited and subducted (i.e., accretionary wedge with imbricate thrusts) in the subduction complex (Sutherlin-Myrtle Point subbasin). b) After accretion and clogging of the subduction zone by a thickened oceanic crust, a new subduction complex formed to the northwest. Abbreviations: WTR & CV fms. = White Tail Ridge and Camas Valley formations; BR & T fms. = Bushnell Rock and Tenmile formations. Arkosic micaceous sandstone and mudstone of the Tyee, Bateman-Coaledo, and Elkton formations accumulated in the subsequent forearc basin on top of the Umpqua basin accretionary wedge.

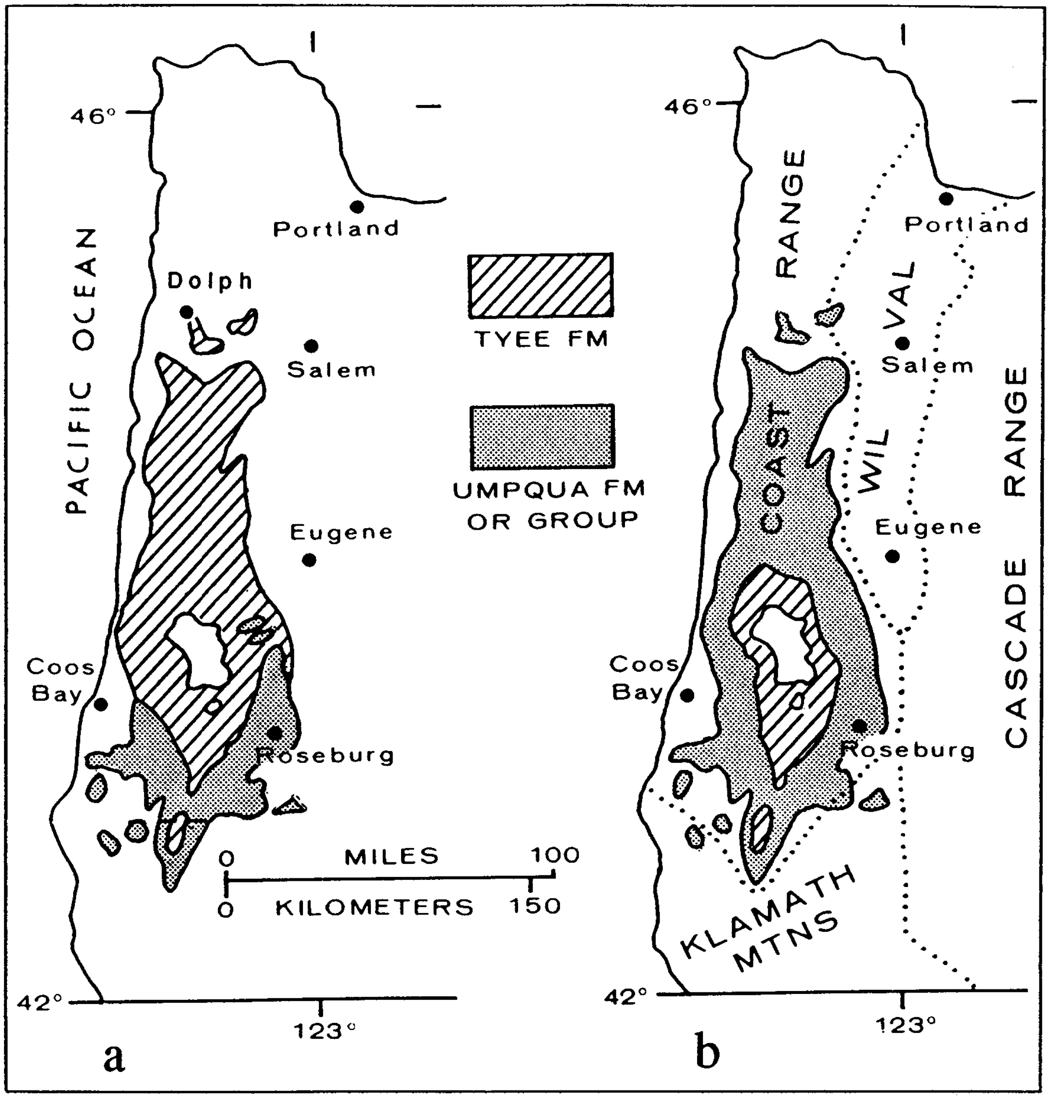
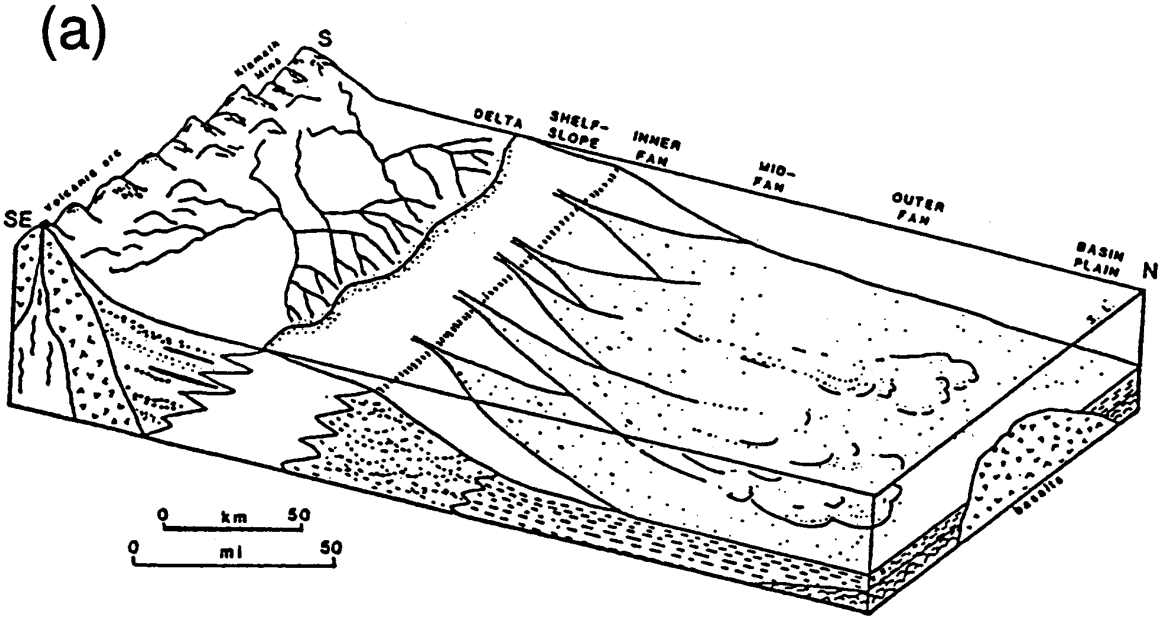
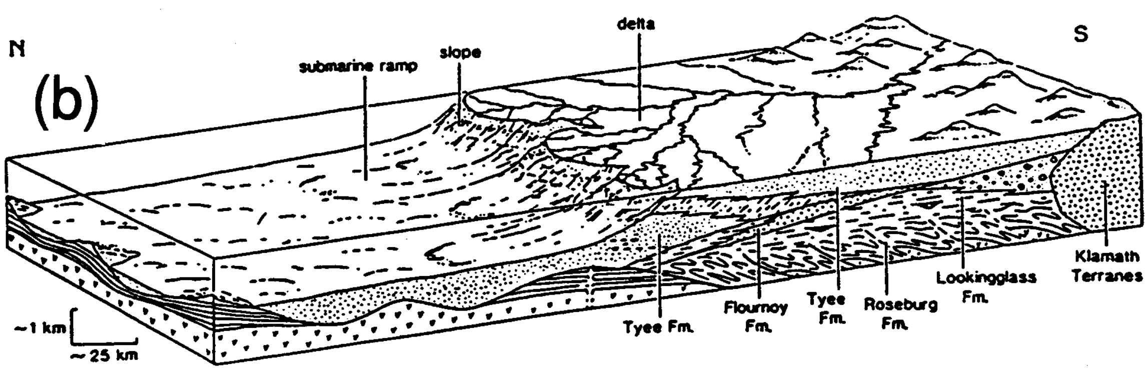


Fig. C Index map of western Oregon showing two interpretations of the distribution of the Umpqua Group (including Siletz River Volcanics in southwestern Oregon) and the Tyee Formation. Map a shows interpretation of Molenaar (1985). Map b shows interpretation of Baldwin (1974). Flournoy Formation of Baldwin (1974) (White Tail Ridge and Camas Valley formations in this report) is part of Umpqua Group. Physiographic divisions are included in map b (WIL VAL = Willamette Valley; from Molenaar, 1985). This investigation favors interpretation a.



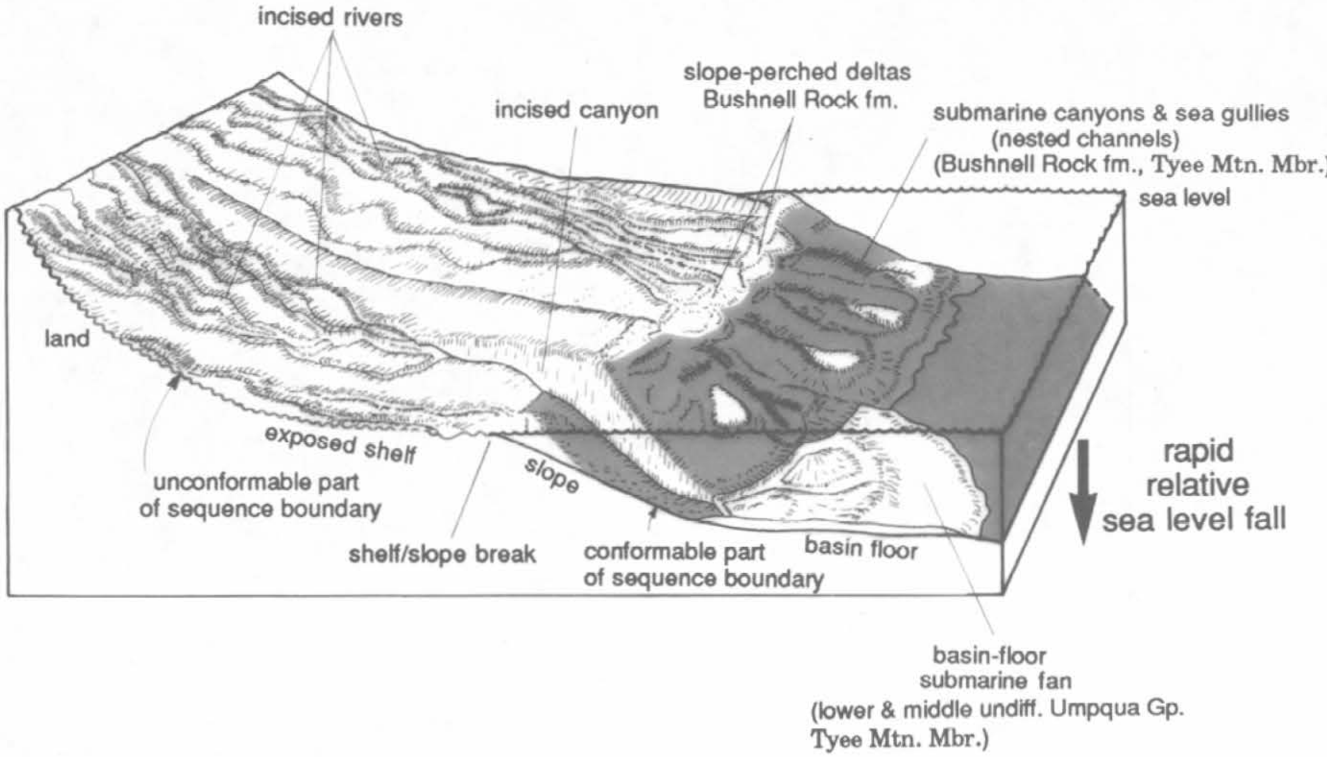
-- Early Eocene Tyee-Flournoy model for shelf sandstones in a line source cascading into deep water to form sand-rich fan deposits (from Chan and Dott, 1983).



-- Paleogeographic reconstruction of southern part of Oregon Coast Range during Eocene deposition of Tyee Formation (from Heller and Dickinson, 1985).

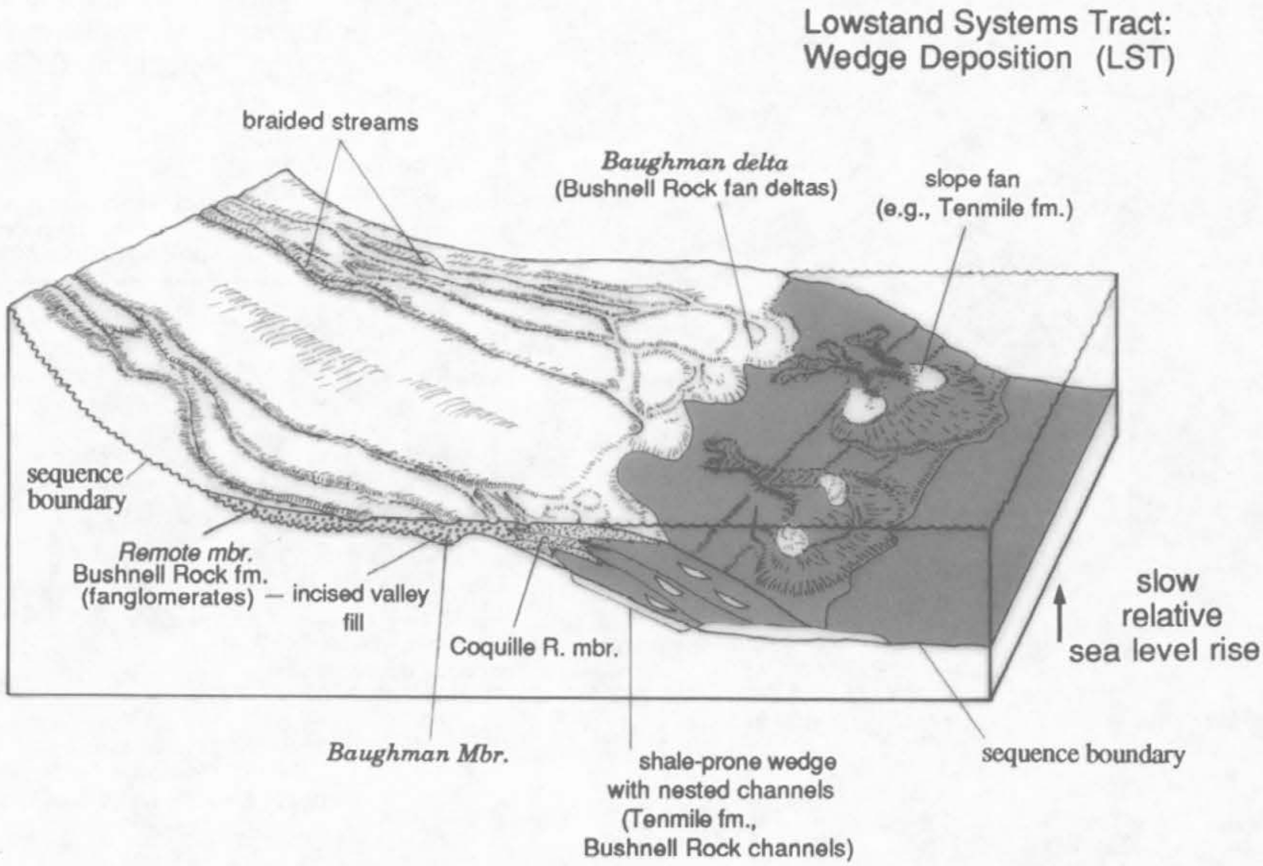
Fig. D Comparison of depositional models proposed for the Tyee-Flournoy formations of the Tyee basin. Diagram a is the sand-rich submarine fan model of Chan and Dott (1983); diagram b is the submarine ramp model of Heller and Dickinson (1985).

Formation of Sequence Boundary and Lowstand Systems Tract: Fan Deposition (LST)



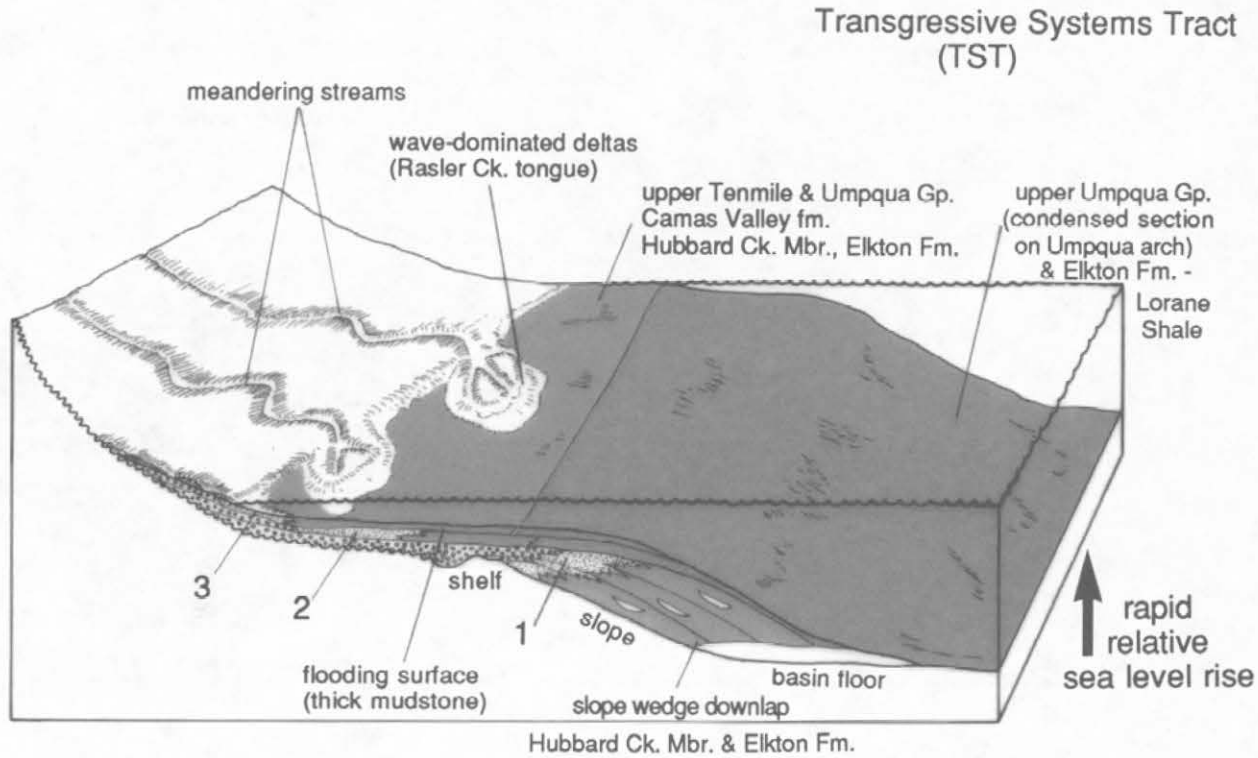
- Rate of eustatic fall exceeds rate of subsidence
- Sea level falls to shelf break; canyons are cut into the exposed shelf
- Slope-perched deltas and basin-floor submarine fans are deposited

Fig. E Formation of a sequence boundary, lowstand systems tract (LST), and lowstand basin-floor fan due to rapid relative fall of sea level as a result of a high rate of tectonic uplift and/or eustatic sea level fall (after Van Wagoner and others, 1990).



- Rate of eustatic fall and/or tectonic subsidence decreases, reaches a stillstand, and rises slowly
- Deposition of basin-floor submarine fan ceases
- Coarse-grained, braided stream or estuarine sandstones aggrade within the fluvial systems, often filling incised valleys in response to sea level rise (e.g. Bushnell Rock conglomerate)
- Fine-grained turbidites deposited on the slope form a shale-prone wedge with thin turbidite sandstone beds that downlap on top of the abandoned fan

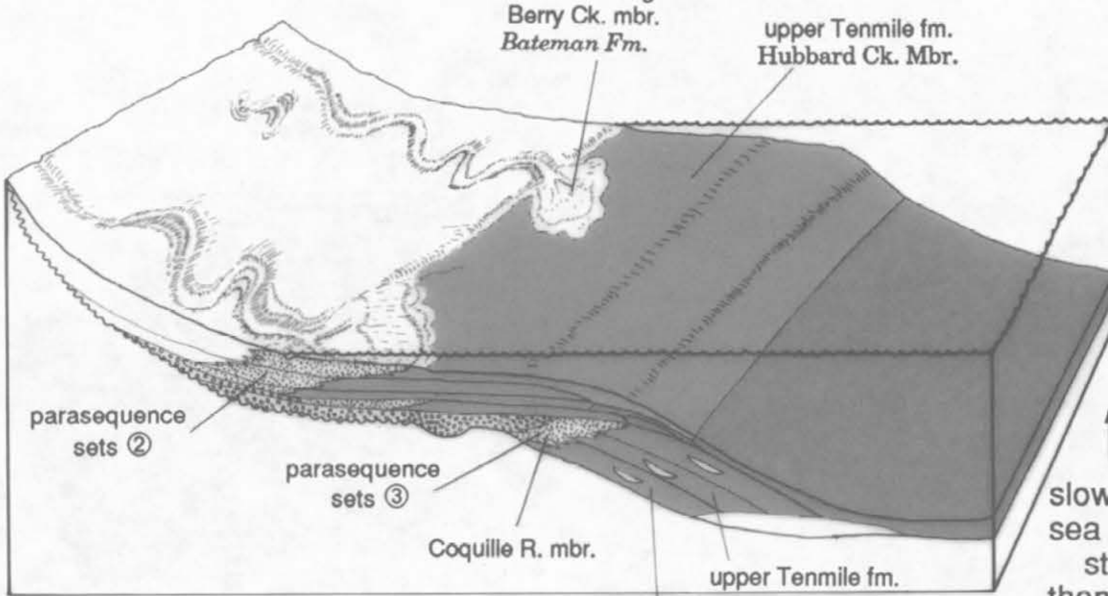
Fig. F Lowstand systems tract (LST): a lowstand slope-wedge forms as a result of a slow relative fall of sea level followed by a stillstand, and then slow relative rise of sea level (after Van Wagoner and others, 1990).



- Rate of eustatic and/or tectonic rise is at a maximum
- During brief slowdowns in rate of rise, parasequences (e.g., delta front sandstones) prograde; but overall stack in backstepping pattern (i.e., shift from position 1 to 2 to 3)
- Thin, organic-rich facies (condensed section) moves up onto the shelf
- Fluvial systems typically shift from a braided to meandering pattern

Fig. G Formation of a transgressive systems tract (TST) due to a rapid rise of sea level as a result of increased tectonic subsidence rate and/or rapid eustatic sea level rise. (modified from Van Wagoner and others, 1990)

Highstand Systems Tract (HST)



- Rate of eustatic rise is at a minimum and in the late highstand, falls slowly
- Rates of deposition greater than the rates of sea level rise, parasequences (coarsening-upward sequences of delta front sandstones) build basinward in aggradational to progradational parasequence sets of the highstand systems tract ②
- Parasequences downlap onto the condensed section ③

Fig. H Creation of a highstand systems tract (HST) by a slow relative rise, stillstand, and slow relative fall of sea level due to tectonic uplift and/or eustatic sea level drop. (modified from Van Wagoner and others, 1990)

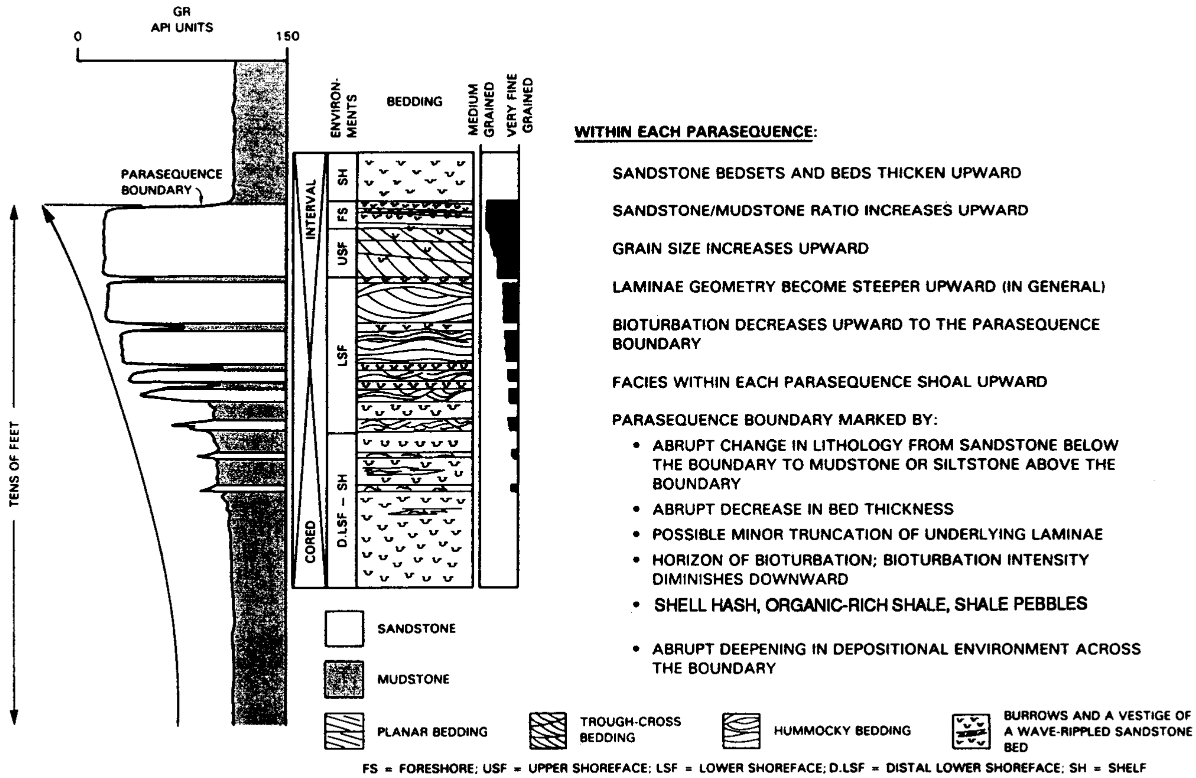


Fig. I Stratal characteristics of a coarsening-upward parasequence. This type of parasequence is interpreted to form in a beach environment on a sandy, wave- or river-dominated shoreline (from Van Wagoner and others, 1990). Typical facies in the Bateman Formation, Baughman Member of the Tyee Formation, and Coquille River and Berry Creek members of the White Tail Ridge formation.

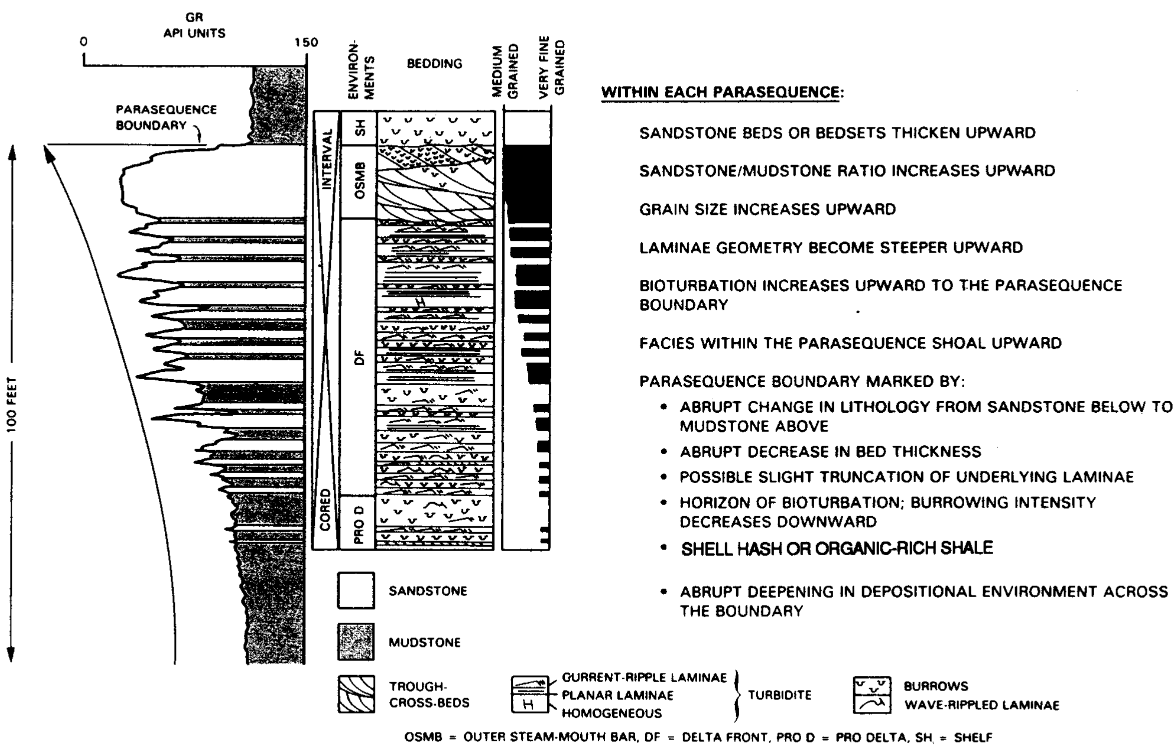


Fig. J Stratal characteristics of a coarsening-upward parasequence. This type of parasequence is interpreted to form in a deltaic environment on a sandy, river- or wave-dominated shoreline (from Van Wagoner and others, 1990). Other typical facies in the Bateman Formation, Baughman Member of the Tyee Formation, and Coquille River and Berry members and Rasler Creek tongue of the White Tail Ridge formation.

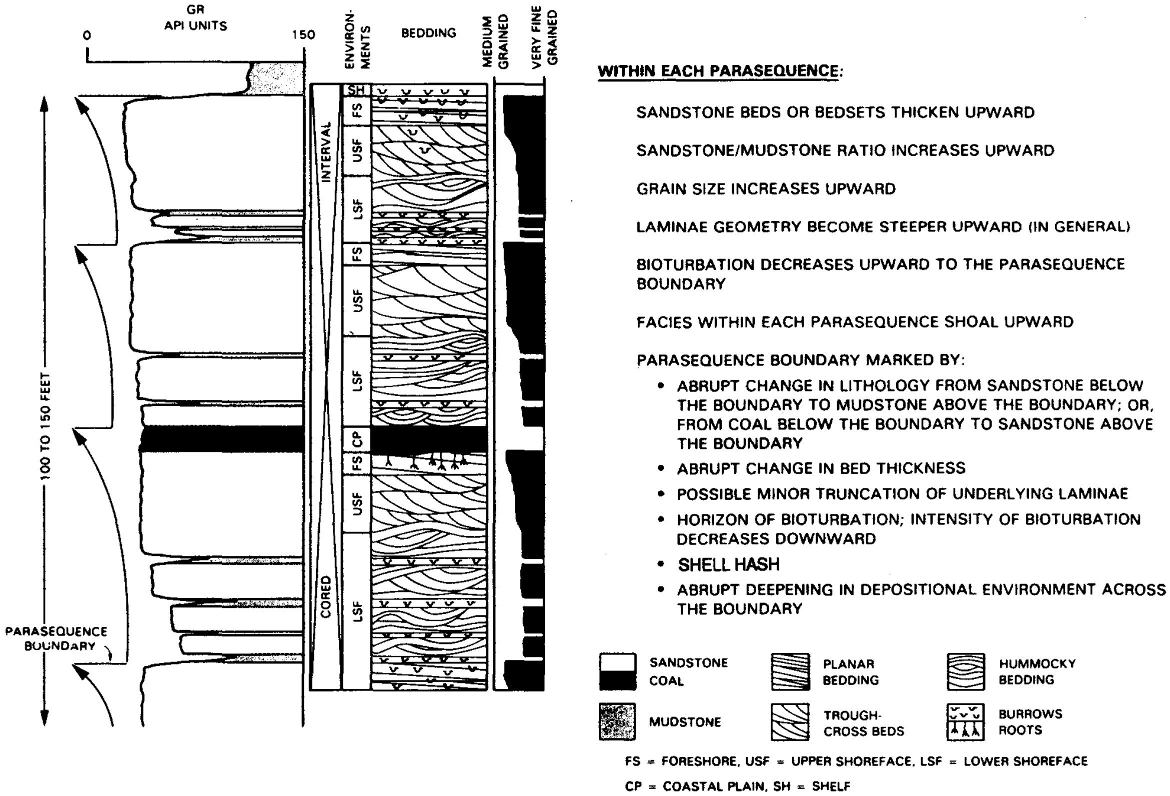


Fig. K Stratal characteristics of stacked coarsening-upward parasequences. These parasequences are interpreted to form in a beach environment on a sandy, wave- or river-dominated shoreline where the rate of deposition equals the rate of accommodation (from Van Wagoner and others, 1990). Typical third type of facies in the Spencer and Bateman formations, Baughman Member of the Tyee Formation, and Coquille River and Berry Creek members and Rasler Creek tongue of the White Tail Ridge formation.

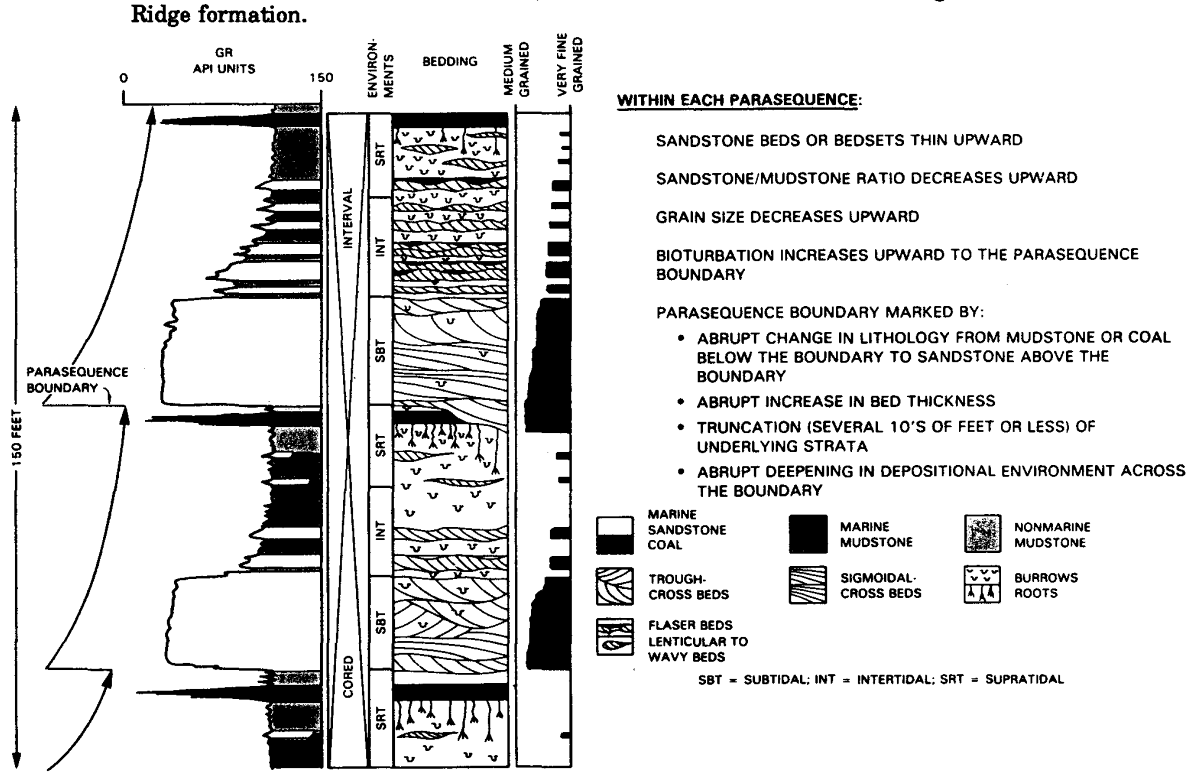


Fig. L Stratal characteristics of two fining-upward parasequences. These types of parasequences are interpreted to form in a tidal flat to subtidal environment on a muddy, tide-dominated shoreline (from Van Wagoner and others, 1990). These occur in Baughman Mbr., Coquille River mbr., and undifferentiated White Tail Ridge formation.

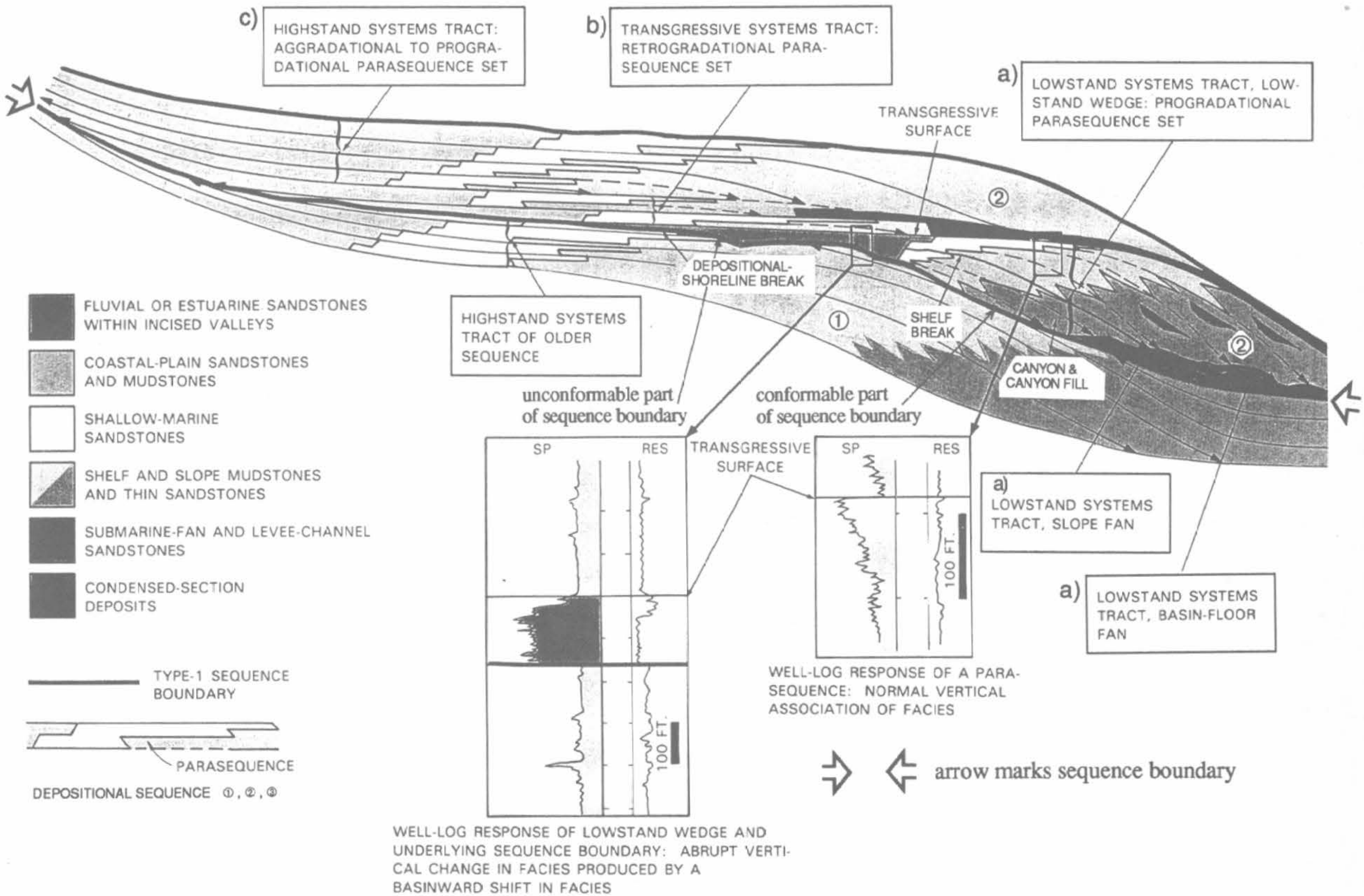


Fig. M Stratal patterns of depositional sequences formed in a basin with a shelf break (from Van Wagoner and others, 1990).

a

b

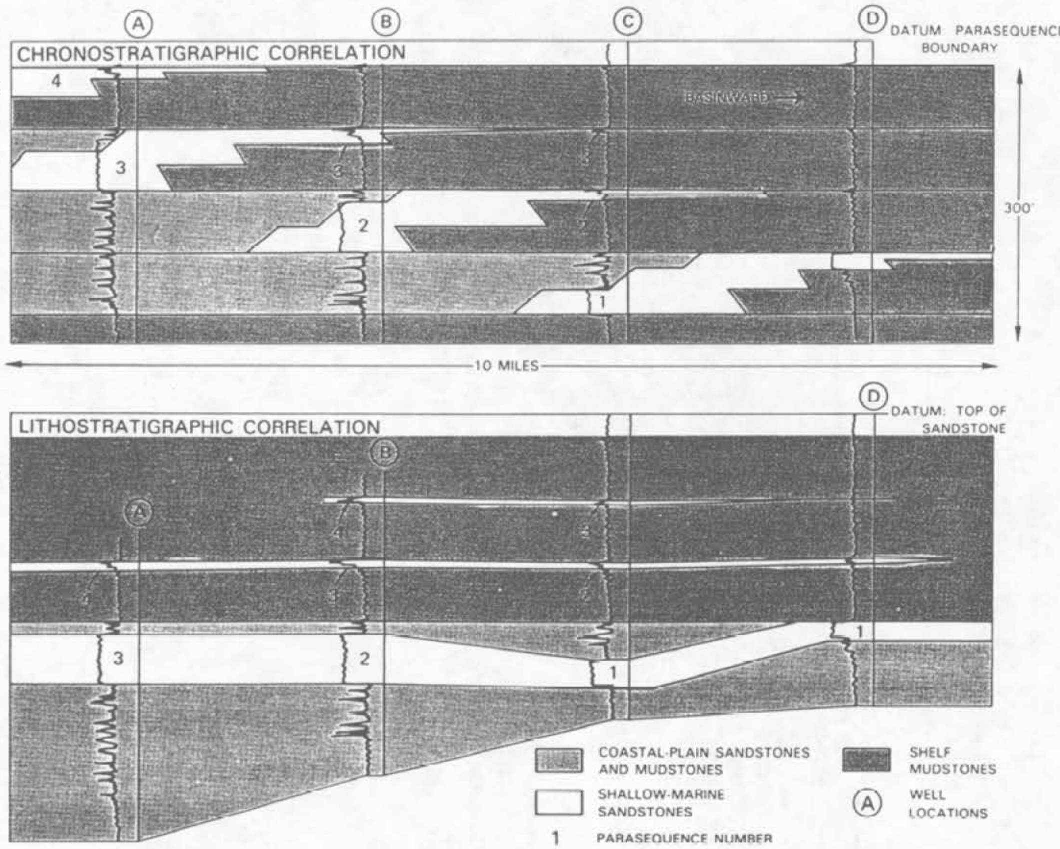


Fig. N **Comparison of (a) chronostratigraphic and (b) lithostratigraphic correlation styles; retrogradational parasequence set (from Van Wagoner and others, 1990).**
In (a) using chronostratigraphic correlation between well sections A, B, C, and D, sandstone-dominated unit 1,2,3 formed as 3 separate parasequences in time.
In contrast in (b) using lithostratigraphic correlation between well sections A, B, C, and D, sandstone unit 1,2,3 is correlated as one continuous sandstone unit.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

Plate 1

Schematic Fence Diagram of the Southern Tyee Basin, Oregon Coast Range, showing stratigraphic relationships of exploration wells to surface measured sections

by
In-Chang Ryu, Alan R. Niem, and Wendy A. Niem
(Oregon State University)

1992

OGI-18
Schematic Fence Diagram of the Southern Tyee Basin,
Oregon Coast Range, showing stratigraphic relationships of exploration wells to surface measured sections
By I. Ryu and others
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Weyerhaeuser Corporation

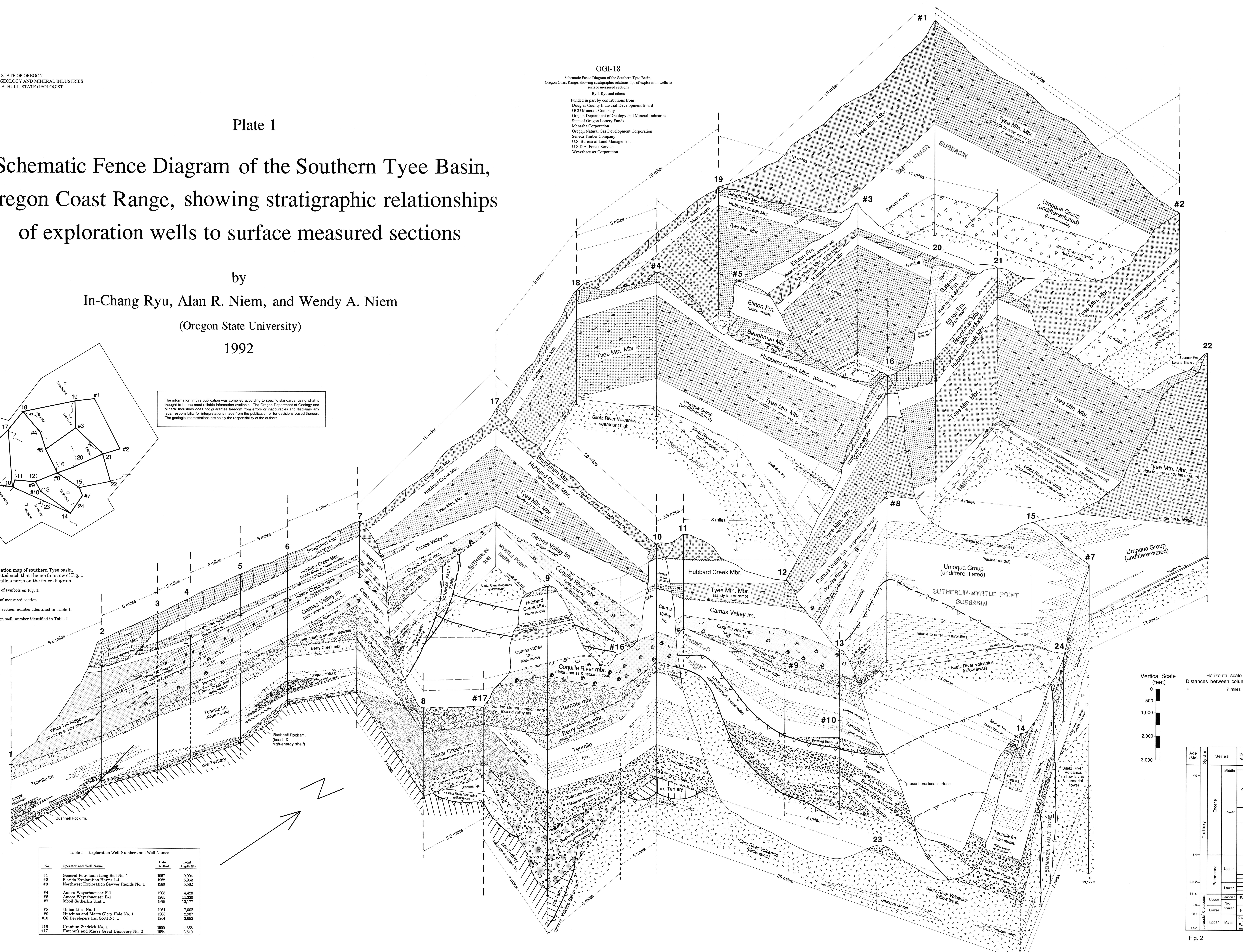

Fig. 1 Location map of southern Tyee basin, rotated such that the north arrow of Fig. 1 parallels north on the fence diagram.

Explanation of symbols on Fig. 1:
Location of measured section
3 Measured section; number identified in Table II
#4 Exploration well; number identified in Table I

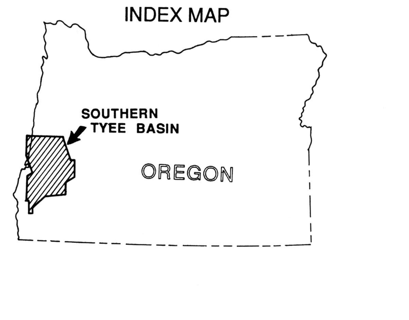

Table II List of Measured Sections and Exploration Holes that comprise the Stratigraphic Columns

Column No.	Measured Sections and Exploration Holes
1	Agness
2	Agness Pass
3	China Flat
4	Coal Creek and Sand Rock Mountain
5	Powers
6	Rasler Creek
7	Remote and Sandy Creek
8	Slater Creek
9	Twelvemile Creek, Oregon Highway 42, and Bingham Creek
10	Reston Road, Suicide Creek, Shield Creek, and Lost Lake
11	Reston Junction and Burnt Ridge
12	Glory Hole well (#9), Lookingglass Road, and Callahan Road
13	Scott well (#10), Cow Hollow, and Melrose
14	Glide
15	Metz Hill
16	Union Liles well (#8) and Tyee Road
17	LaVern Creek and Middle Creek
18	Allegany
19	Loon Lake
20	Kellog and Waggoner Creek
21	Elkton
22	I-5
23	S. Roseburg
24	Sutherlin Creek

Table I Exploration Well Numbers and Well Names

No.	Operator and Well Name	Date Drilled	Total Depth (ft)
#1	General Petroleum Long Bell No. 1	1957	9,004
#2	Florida Exploration Harris 1-4	1982	5,962
#3	Northwest Exploration Sawyer Rapids No. 1	1980	5,562
#4	Amoco Weyerhaeuser F-1	1985	4,428
#5	Amoco Weyerhaeuser B-1	1985	11,330
#7	Mobil Sutherlin Unit 1	1979	13,177
#8	Union Liles No. 1	1951	7,002
#9	Hutchins and Marrs Glory Hole No. 1	1983	2,987
#10	Oil Developers Inc. Scott No. 1	1954	3,693
#16	Uranium Ziedrich No. 1	1955	4,368
#17	Hutchins and Marrs Great Discovery No. 2	1984	3,510

EXPLANATION

Sequence IV [*1]

Bateman Formation — 2500 ft of moderately indurated, cross-bedded, micaceous arkosic sandstone; minor overbank mudstone; some coal; thickening-upward parasequences; wave-dominated delta.

Elkton Formation — 1500 ft of upper slope to basinal, laminated, medium to dark gray micaceous mudstone; some nested channels of micaceous arkosic turbidite sandstone; a few beds of shallow-marine, fossiliferous, micaceous arkosic sandstone in lower part.

Baughman Member — 1,000 to 2,000 ft of zeolite-cemented, coarse-grained, micaceous, lithic arkosic sandstone; cliff-former; some large-scale cross-bedded pebbly sandstone and conglomerate beds; fluvial- to wave-dominated delta; delta plain facies includes massive, green, overbank mudstone and abundant coal beds; delta front facies contains some oyster-bearing estuarine deposits, paralic coal, and thickening-upward parasequences of hummocky bedded bioturbated to ripple-laminated sandstone.

LOCAL UNCONFORMITY [*2]

Sequence III — **Tyee Formation**

Hubbard Creek Member — 400 to 1,000 ft of slope to basinal micaceous, laminated mudstone; minor fine-grained, arkosic micaceous sandstone and mudstone in nested turbidite channels.

Tyee Mountain Member — Well-indurated, clay-cemented, micaceous (abundant large flakes of muscovite and biotite), fine- to medium-grained, massive, lithic feldspathic sandstone (wacke) and subordinate deep-marine, dark gray mudstone; massive sandstone overlain by thin intervals of carbonaceous plant and micaceous laminae; Bouma ab sequences are common; thin, slope channel turbidite sandstones (60 to 250 ft) with mudstone-chip conglomerates to 5,000 to 6,000 ft of very thick-bedded to amalgamated inner and middle fan to thinner bedded sandstone and mudstone of outer sandy submarine fan or ramp; some mudstone rip-ups, flute and groove marks, load casts, and slumped bedding.

LOCAL UNCONFORMITY

Sequence II

Camas Valley formation — Up to 1800 ft of outer shelf and upper slope, medium gray mudstone; massive; upper few hundred feet contain some calcareous concretions and shallow-marine fossil mollusks.

White Tail Ridge formation

Rasler Creek tongue — 500 ft of moderately to well-indurated, delta front lithic arkosic sandstone; bioturbated to hummocky bedded; rare coal and thin mudstone interbeds; thickening-upward parasequences; unit occurs mainly as a tongue that extends into and pinches out into mudstone of the Camas Valley formation.

Coquille River member — 1,000 ft of delta front, moderately indurated, shell-bearing, fine- to medium- grained, bioturbated to hummocky bedded, lithic arkosic sandstone that occur in thickening-upward parasequences; some lower delta plain, thick, massive, overbank mudstone interbeds, paralic coal, and estuarine to shallow-marine bioturbated, mollusk-bearing fine-grained ss.

Remote member — 2,200 ft of moderately indurated braided fluvial pebble-cobble-boulder polymict conglomerate (filling incised valleys) to meandering river, cross-bedded, pebbly lithic arkosic sandstone channels, thick overbank green, massive mudstone, carbonaceous siltstone, and some coal.

White Tail Ridge formation (undifferentiated) — 1,400 to 4,700 ft of moderately to well-indurated delta plain, cross-bedded, channelized, lithic arkosic sandstone, distributary mouth sandstone, and thick, massive, green, overbank mudstone with abundant coal and estuarine to tidal-flat oyster-bearing sandstone and accretionary bank mudstone.

LOCAL UNCONFORMITY

Sequence I — **Umpqua Group**

Berry Creek member — 500+ ft, well-indurated delta front, hummocky bedded cross-bedded and bioturbated, mollusk-bearing, pebbly lithic arkosic sandstone and minor mudstone and conglomerate interbeds; many thickening-upward parasequences.

Tenmile formation — 3,000 ft of massive to well-bedded, very thick sequences of well-indurated, medium gray, rhythmically bedded, thin, graded, coarse-grained lithic turbidites (Bouma abcd sequence) and thin dark gray mudstone ( ) interstratified with foraminifer-bearing, upper to lower slope, dark gray mudstone; minor medium- to thick-bedded, very coarse-grained, lithic turbidites ( ); some thick lenses and channels of massive, pebbly sandstone to polymict conglomerate ( ).

Bushnell Rock formation

Slater Creek member — Up to 2,100 ft of well-indurated, shallow-marine(?), fine-grained, thick-bedded, massive to faintly laminated, lithic feldspathic sandstone and minor dark gray mudstone partings; a few fossil mollusks and minor polymict conglomerate lenses; may be deep-water turbidites(?) in part.

Up to 1,600 ft of well-indurated deep-water pebble-cobble-boulder polymict to basaltic conglomerate; thick- to very thick-bedded, graded and reverse graded; some debris flow deposits; pebbly very coarse-grained lithic sandstone, very thin dark gray laminated mudstone interbeds; locally interbedded with submarine flows and sills of Siletz River Volcanics.

Up to 2,400 ft of ridge- and cliff-forming, reddish brown, alluvial polymict fanglomerate, debris flows, poorly sorted boulder-cobble-pebble conglomerate, and cross-bedded braided river deposits of conglomeratic, coarse-grained lithic sandstone; minor massive maroon mudstone, ripple-laminated, fine-grained lithic sandstone interbeds and mollusk-bearing sandstone at top (fan delta); locally unconformable on pre-Tertiary Klamath terranes and on Siletz River Volcanics.

Less than 250 ft of nearshore, mollusk-bearing, cross-bedded, tight, moderately sorted, pebbly, medium- to coarse-grained lithic sandstone; polymict conglomerate lenses become more abundant toward the base of the unit; unconformably overlies Siletz River Volcanics.

LOCAL UNCONFORMITY

Basement rocks

Siletz River Volcanics

Volcanic breccia; basaltic siltstone and sandstone interbeds; up to 2,500 ft thick.

Basalt: pillow lavas and subaerial flows; some dark brown basaltic tuffaceous siltstone interbeds; 6,300 ft to several km thick.

Basalt/diabase sill

FAULT CONTACT

Pre-Tertiary rocks — Mesozoic Klamath Mtn. terranes (largely broken formation and mélange)

Spencer Formation — 400+ ft of friable, moderately well-sorted, thick, micaceous arkosic deltaic, fluvial, and minor shallow-marine, mollusk-bearing sandstone; a few coal beds and carbonaceous mudstone overbank deposits.

LOCAL UNCONFORMITY

Lorane Shale — 100+ ft of upper slope to basinal micaceous, laminated, medium gray mudstone.

*1 Depositional sequence; see sequence stratigraphy terminology of Van Wagoner and others (1990) and text accompanying Plate 1.

*2 Local unconformities are replaced basinward by conformities and are sequence boundaries (see terminology of Van Wagoner and others, 1990, and text accompanying Plate 1).

Umpqua Group undifferentiated (Umpqua Group: Less than 100 ft to more than 6,000 ft thick)

Basinal mudstone, gray, laminated to massive, chippy-weathering, up to 3,700 ft thick; some calcareous concretions; (condensed section where thin; e.g., less than 100 ft).

Thick, interstratified sequences of well-indurated, rhythmically bedded, thin to very thin, graded, medium gray, fine- to medium-grained lithic turbidite sandstone and dark gray mudstone; sandstone to mudstone ratio ranges from 1:1 to 1:4; some beds contain flutes, grooves, and burrows; outer submarine fan to basinal facies; up to 3,500 ft thick.

Well-indurated, medium- to thick-bedded, graded, lithic sandstone turbidites (150 to 500 ft thick intervals), rhythmically bedded; sandstone to mudstone ratio ranges from 2:1 to 5:1; burrows at base of some beds; ridge-former; mid fan lobes and channels.

Tightly cemented, very thick-bedded, amalgamated, massive to graded, ridge-forming, pebbly lithic sandstone and some lenses of polymictic conglomerate more than 700 ft thick and gray mudstone partings; some slumped bedding; inner fan and mid fan channel and inner fan valley.

Dark brown, tightly cemented basaltic sandstone (up to 100+ ft thick); massive to medium- to thick-bedded, moderately to poorly sorted; some basalt clasts contain amygdules; minor molluscan fossils; local deposit in base of condensed section of Umpqua Group overlying subaerial flows of Siletz River Volcanics; formed as shallow-marine and pocket beach(?) deposits around oceanic island headlands and sea stacks.

EXPLANATION OF SYMBOLS USED ON FENCE DIAGRAM

#1 Identification number of exploration well (refer to Table I)

2 Identification number of stratigraphic column (refer to Table II)

column — Measured stratigraphic section or well section

Projected section

Schematic present land surface

Lateral projection of member or formation prior to erosion

Formation or member boundary

Interfingering formation or member boundary

Unconformable contact

Thrust fault (teeth on upper plate)

Thrust fault with some oblique or strike-slip motion (T = toward reader; A = away from reader)

Local tectonic and subsurface features named on this diagram:
SMITH RIVER SUBBASIN
UMPQUA ARCH
Reston high
SUTHERLIN-MYRTLE POINT SUBBASIN

This fence diagram is not a palinspastic reconstruction.

Vertical Scale (feet): 0, 500, 1,000, 2,000, 3,000

Horizontal scale is variable. Distances between columns are shown by: 7 miles

TIME-ROCK CHART

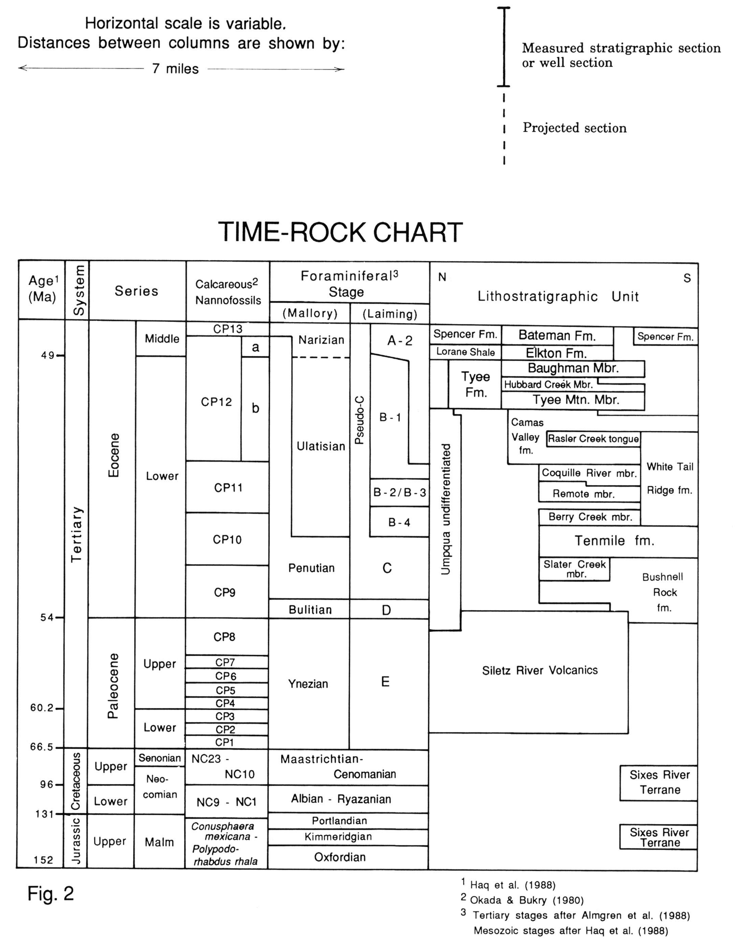

Fig. 2

STRATIGRAPHIC NOMENCLATURE

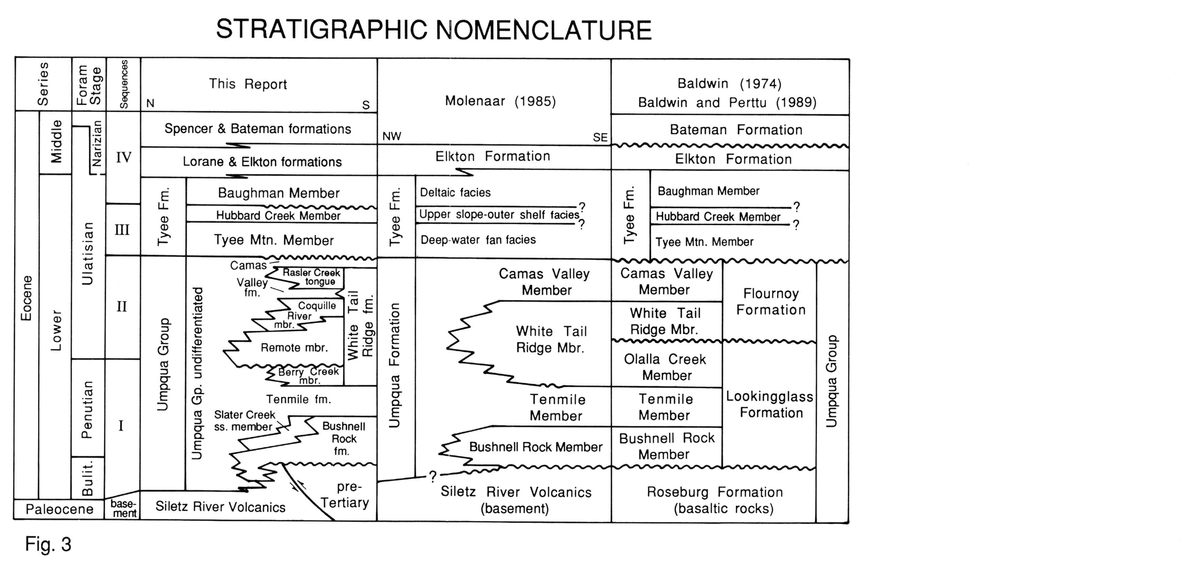

Fig. 3