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National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Lewis and Clark National Historical Park

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Lewis and Clark National Historical Park

lewi_geology.pdf

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Geologic Resources Inventory Map Document for Lewis and Clark National Historical Park

Table of Contents

Geologic Resources Inventory Map Document 1
About the NPS Geologic Resources Inventory Program 2
Map Unit List 4
Map Unit Descriptions 7
Qbs - Beach sand (Holocene) 7
Qf - Fluvial and estuarine deposits (Holocene) 7
Qal - Alluvium (Holocene) 7
Qal1 - Columbia River alluvium (Holocene) 7
Qc - Colluvium (Holocene and Pleistocene) 7
Qls - Landslide deposits (Holocene and Pleistocene) 8
Qds - Dune sand (Holocene and Pleistocene) 8
Qt - Terrace deposits (Holocene and Pleistocene) 8
Qmt - Coastal marine-terrace deposits (Pleistocene) 8
Qat - Alluvial and estuarine terrace deposits (Pleistocene) 8
Qn - Estuarine deposits of Nemah River (Pleistocene) 9
Qm - Sand of Mountain Springs (Pleistocene) 9
Tt - Troutdale Formation (Pliocene and late Miocene) 9
Columbia River Basalt Group, Yakima Basalt Subgroup, Saddle Mountains Basalt 9
Tp - Saddle Mountain Basalt, Pomona Member subaerial basalt flow (middle Miocene) 9
Tpi? - Saddle Mountain Basalt, Pomona Member, intrusive rocks(?) (middle Miocene) 9
Tiob - Olivine basalt (middle Miocene) 10
Gnat Creek formation (middle Miocene) 10
Columbia River Basalt Group, Yakima Basalt Subgroup, Wanapum Basalt 10
Tfs - Wanapum Basalt, Frenchman Springs Member, subaerial basalt flows (middle Miocene) 10
Tfsn - Wanapum Basalt, Frenchman Springs Member, interbeds (middle Miocene) 11
Tfsp - Wanapum Basalt, Frenchman Springs Member, pillow palagonite complexes (middle Miocene) 11
Tfsi - Wanapum Basalt, Frenchman Springs Member, intrusive basalt (middle Miocene) 11
Astoria Formation 11
Tab - Astoria Formation, Bald Ridge unit (middle Miocene) 11
Tac - Astoria Formation, Cannon Beach member, turbidite (middle and early Miocene) 12
Tay - Astoria Formation, Youngs Bay member, slope mudstone (middle and early Miocene) 13
Taa -Astoria Formation, Angora Peak member, shelf sandstone (middle and early Miocene) 13
Taw - Astoria Formation, Wickiup Mountain member, shelf sandstone (middle and early Miocene) 13
Tan - Astoria Formation, Naselle unit (middle and early Miocene) 14
Columbia River Basalt Group, Yakima Basalt Subgroup, Grande Ronde Basalt 14
Tgr - Grande Ronde Basalt, subaerial basalt flows (middle Miocene) 14
Tgrp - Grande Ronde Basalt, pillow palagonite complexes (middle Miocene) 14
Tgri - Grande Ronde Basalt, intrusive basalt (middle Miocene) 15
Tib - Basalt (middle Miocene) 15
Tcf - Cape Falcon conglomerate (middle Miocene) 15
Tsc - Smuggler Cove formation (early Miocene, Oligocene and late Eocene) 16
Tn - Northrup Creek formation, turbidite (early Miocene and Oligocene?) 16
Tlc - Lincoln Creek Formation (early Miocene to late Eocene) 17
Tlck - Lincoln Creek Formation, sandstone unit at Knappton (early Oligocene or late Eocene) 17

Tpb - Pittsburg Bluff Formation (Oligocene and late Eocene) ... 17
Ts - Sager Creek formation (late Eocene) ... 18
Tkj - Keasey Formation, Jewell member (late Eocene) ... 18
Th - Hamlet formation (late Eocene) ... 18
Ttv - Tillamook Volcanics (late and Middle Eocene) ... 19
Tes - Siltstone and sandstone (late and Middle Eocene) ... 19
Tsb - Siltstone at Shoalwater Bay (late and late middle Eocene) ... 19
Top - Siltstone and sandstone at O'Meara Point (late and late middle Eocene) ... 19
Tcp - Siltstone of Cliff Point (late? and middle Eocene) ... 20
Tsm - Sandstone at Mergler (middle Eocene) ... 20
Tbr - Basalt lapillli breccia and flows at Fort Columbia (middle Eocene) ... 20
Tbf - Basalt lapillli breccia and flows at Fort Columbia, pillow basalt flows (middle Eocene) ... 20
Tig - Gabbro and basalt (Eocene) ... 20
Tc - Crescent Formation (middle Eocene) ... 21
Geologic Cross Sections ... 22
GRI Source Map Citations ... 23
Astoria Basin ... 23
Astoria Basin Report ... 23
Astoria Basin Time Rock Chart ... 26
Astoria Basin Index to Geologic Mapping ... 27
Astoria Basin Map Symbols ... 28
Astoria Basin References ... 28
Cape Disappointment ... 33
Cape Disappointment Report ... 33
Cape Disappointment Correlation of Map Units ... 36
Cape Disappointment Map Location ... 37
Cape Disappointment Symbols ... 37
Cape Disappointment References ... 38
Exploration Wells ... 40
Exploration Wells Report and Chart ... 40
Exploration Wells Location ... 40
Exploration Wells Table ... 41
OGDC Release 5 ... 42
GRI Digital Data Credits ... 43

Geologic Resources Inventory Map Document

Lewis and Clark National Historical Park, Oregon and Washington

Document to Accompany Digital Geologic-GIS Data

lewi_geology.pdf

Version: 9/27/2012

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Lewis and Clark National Historical Park, Oregon and Washington (LEWI).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park

(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Lewis and Clark National Historical Park, Oregon and Washington (LEWI) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qbs - Beach sand). Units are listed from youngest to oldest. No descriptions for water or unmapped units are provided. Information about each geologic unit is also presented in the Geologic Unit Information (LEWIUNIT) table included with the GRI geology-GIS data.

Geologic Map Units

Cenozoic Era

Quaternary Period

Holocene

Qbs - Beach sand (Qbs)
Qf - Fluvial and estuarine deposits (Qf)
Qal - Alluvium (Qal)
Qal1 - Columbia River alluvium (Qal1)

Holocene and Pleistocene

Qc - Colluvium (Qc)
Qls - Landslide deposits (Qls)
Qds - Eolian dune sand (Qds)
Qt - Terrace deposits (Qt)

Pleistocene

Qmt - Coastal marine-terrace deposits (Qmt)
Qat - Alluvial and estuarine terrace deposits (Qat)
Qn - Estuarine deposits of Nemah River (Qn)
Qm - Sand of Mountain Springs (Qm)

Tertiary Period

Pliocene and Miocene

Tt - Troutdale Formation (Tt)

Miocene

Columbia River Basalt Group, Yakima Basalt Subgroup, Saddle Mountain Basalt

Tp - Saddle Mountain Basalt, Pomona Member subaerial basalt flow (Tp)
Tpi? - Saddle Mountain Basalt, Pomona Member, intrusive rocks(?) (Tpi?)

Tiob - Olivine basalt (Tiob)

Gnat Creek formation

Tg4 - Gnat Creek formation, marine deltaic sandstone
Tg3 - Gnat Creek formation, marine slope mudstone
Tg2 - Gnat Creek formation, marine slope channel sandstone
Tg1 - Gnat Creek formation, terrestrial sedimentary rocks

Columbia River Basalt Group, Yakima Basalt Subgroup, Wanapum Basalt
- Tfs - Wanapum Basalt, Frenchman Springs Member, subaerial basalt flows (Tfs)
- Tfsn - Wanapum Basalt, Frenchman Springs Member, interbeds (Tfsn)
- Tfsp - Wanapum Basalt, Frenchman Springs Member, pillow palagonite complexes (Tfsp)
- Tfsi - Wanapum Basalt, Frenchman Springs Member, intrusive basalt (Tfsi)

Astoria Formation
- Tab - Astoria Formation, Bald Ridge unit (Tab)
- Tac - Astoria Formation, Cannon Beach member, turbidite (Tac)
  - Tac3 - Astoria Formation, Cannon Beach member, mudstone
  - Tac2 - Astoria Formation, Cannon Beach member, slope mudstone
  - Tac1 - Astoria Formation, Cannon Beach member, slope channel sandstone
- Tay - Astoria Formation, Youngs Bay member, slope mudstone (Tay)
  - Tay2 - Astoria Formation, Youngs Bay member, sandstone
  - Tay1 - Astoria Formation, Youngs Bay member, sandstone
- Taa - Astoria Formation Angora Peak member, shelf sandstone (Taa)
- Taw - Astoria Formation, Wickiup Mountain member, shelf sandstone (Taw)
  - Tawu - Wickiup Mountain member, upper part, sandstone and mudstone
- Tan - Astoria Formation, Naselle unit (Tan)

Columbia River Basalt Group, Yakima Basalt Subgroup, Grande Ronde Basalt
- Tgr - Grande Ronde Basalt, subaerial basalt flows (Tgr)
- Tgrp - Grande Ronde Basalt, pillow palagonite complexes (Tgrp)
  - Tgrm - Grande Ronde Basalt, pillow palagonite complexes, mudstone interbeds
- Tgri - Grande Ronde Basalt, intrusive basalt (Tgri)
  - Tgrb - Grande Ronde Basalt, intrusive breccia

Tib - Basalt (Tib)
Tcf - Cape Falcon conglomerate (Tcf)

Miocene, Oligocene, and Eocene

Tsc - Smuggler Cove formation (Tsc)
- Tscs - Smuggler Cove formation, sandstone
- Tscm - Smuggler Cove formation, mudstone
- Tsc2 - Smuggler Cove formation, upper member
- Tscg - Smuggler Cove formation, glauconitic sandstone
- Tsc1 - Smuggler Cove formation, lower member

Tn - Northrup Creek formation, turbidite (Tn)
- Tns - Northrup Creek formation, sandstone

Tlc - Lincoln Creek Formation (Tlc)
- Tlck - Lincoln Creek Formation, sandstone unit at Knappton (Tlck)

Tpb - Pittsburg Bluff Formation (Tpb)

Eocene

Ts - Sager Creek formation (Ts)

Tkj - Keasey Formation, Jewell member (Tkj)

Th - Hamlet formation (Th)
- Thr - Hamlet formation, Roy Creek member

Ttv - Tillamook Volcanics (Ttv)

Tes - Siltstone and sandstone (Tes)
Tsb - Siltstone at Shoalwater Bay (Tsb)
Top - Siltstone and sandstone at O'Meara Point (Top)
Tcp - Siltstone of Cliff Point (Tcp)
Tsm - Sandstone at Mergler (Tsm)

Tbr - Basalt lapillli breccia and flows at Fort Columbia (Tbr)
Tbf - Basalt lapillli breccia and flows at Fort Columbia, pillow basalt flows (Tbf)

Tig - Gabbro and basalt (Tig)

Tc - Crescent Formation (Tc)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qbs - Beach sand (Holocene)

Qbs - Quaternary beach sand (Holocene)
Moderately well-sorted, fine- to medium-grained quartzo-feldspathic sands with heavy mineral laminae; also includes black winter-beach lag sand deposits up to a few meters thick of magnetite, ilmenite, and other heavy minerals (Twenhofel, 1946) locally developed on Clatsop Spit; unit includes basalt gravels of well-rounded pebbles, cobbles, and boulders around Miocene basalt headlands along southern coast of Clatsop County. *GRI Source Map ID 35633* (Astoria Basin).

Qb - Shoreline deposits (Holocene)
Unconsolidated fine to coarse sand forming beach and longitudinal dune ridges of Long Beach Peninsula; locally includes organic-rich lacustrine sand, silt, and laminated muds between dune ridges and estuarine mud and sand along eastern shoreline. *GRI Source Map ID 15326* (Cape Disappointment).

Qf - Fluvial and estuarine deposits (Holocene)

Unconsolidated clay, silt, sand, and gravel alluvium deposited along rivers and streams; also includes stabilized tidal flat deposits along the Columbia and Naselle Rivers and in Shoalwater Bay. *GRI Source Map ID 15326* (Cape Disappointment).

Qal - Alluvium (Holocene)

Unconsolidated flood-plain deposits of clay, silt, sand, and basalt gravel along and in major rivers and streams; also includes sand bars, islands, and bioturbated to laminated estuarine clay, silt, and fine sand in low-lying coastal areas in and along Columbia River, Youngs Bay, and other major river mouths. *GRI Source Map ID 35633* (Astoria Basin).

Qal1 - Columbia River alluvium (Holocene)

Recent alluvial sediments found along the Columbia River. *GRI Source Map ID 75206* (QGDC v5).

Qc - Colluvium (Holocene and Pleistocene)

Thick, structureless deposits of very poorly sorted, angular to subrounded, weathered basaltic breccias and massive basalt boulders (up to 16 m in diameter) and cobbles set in a reddish clayey matrix. Includes talus and landslide deposits around the many Miocene and Eocene basaltic breccia peaks and thick intensives. *GRI Source Map ID 35633* (Astoria Basin).

Qls - Landslide deposits (Holocene and Pleistocene)

Qls - Landslide debris (Holocene and Pleistocene)
Chaotic mixtures of weathered mudstone clasts, logs, and, less commonly, sandstone and basalt clasts supported in a weathered, sandy mud matrix; forms hummocky and slump topography throughout map area. Recently active slides shown with scarps. Also see Schlicker and others (1972) and Beaulieu (1973) for distribution. Unit also includes large (up to 200 m long) coherent glide and slump blocks of Miocene basaltic breccias and subaerial flows [**Qls (Tfs)** if Frenchman Springs Member basalt, **Qls (Tgr)** if Grande Ronde Basalt]. These blocks occur below steep Miocene basalt escarpments (e.g., Wickiup Mountain and Nicolai Mountain), where basalts overlie incompetent Tertiary mudstone units. *GRI Source Map ID 35633* (Astoria Basin).

> **Qls (Tfs)** - glide and slump blocks within the Frenchman Springs Member basalt (**Tfs**)
> **Qls (Tgr)** - glide and slump blocks within the Grand Ronde Basalt (**Tgr**)

Qls - Landslide deposits (Holocene and Pleistocene)
Large landslides of poorly sorted colluvium and coherent bedrock slump blocks; many small slides not shown on map. *GRI Source Map ID 15326* (Cape Disappointment).

Qds - Dune sand (Holocene and Pleistocene)

Active and inactive dune sands forming several prominent north-south beach ridges on Clatsop Spit. Sands are well sorted, fine grained, quartzo-feldspathic with heavy mineral laminae, and cross-bedded. Unit also includes peat and lacustrine mud deposits in and around intradune lakes. *GRI Source Map ID 35633* (Astoria Basin).

Qt - Terrace deposits (Holocene and Pleistocene)

Elevated deposits of alluvial silt, arkosic and basaltic sand, and semiconsolidated cross-bedded to medium-bedded, poorly sorted basalt gravel occurring 8 to 35 m above entrenched main drainages. Also includes elevated tidal-flat deposits along Columbia River. *GRI Source Map ID 35633* (Astoria Basin).

Qmt - Coastal marine-terrace deposits (Pleistocene)

Predominantly laminated to cross-bedded beach sand and crudely stratified, rounded basalt gravels (up to 10 m thick) with some discontinuous paleosols, mud beds, and layers of partially carbonized tree trunks and limbs. *GRI Source Map ID 35633* (Astoria Basin).

Qat - Alluvial and estuarine terrace deposits (Pleistocene)

Unconsolidated clay, silt, sand, and gravel alluvium or estuarine deposits on terraces 8-20 m above sea level; primarily along Columbia, Naselle, and Nemah Rivers. [Source Symbol Qt]. *GRI Source Map ID 15326* (Cape Disappointment).

Qn - Estuarine deposits of Nemah River (Pleistocene)

Semi-consolidated, friable, planar-laminated to cross-laminated, thin-bedded to massive mudstone and fine- to medium-grained sandstone; locally includes sandstone channel fill with quartzite gravel stringers and slump blocks of laminated sediment; on terraces up to 80 m above sea level in lower Nemah and Naselle estuaries; as mapped on Long Island it includes Pleistocene beach and dune deposits. *GRI Source Map ID 15326* (Cape Disappointment).

Qm - Sand of Mountain Springs (Pleistocene)

Semi-consolidated, laminated to massive, fine to coarse sand; commonly with yellow-orange to red iron oxide staining and characterized by planar lamination, broad gently dipping cross lamination, trough cross lamination, and localized channel fill with quartzite pebble stringers; forms hills east of town of Long Beach up to 100 m above sea level; may represent remains of an older barrier beach and dune field. *GRI Source Map ID 15326* (Cape Disappointment).

Tt - Troutdale Formation (Pliocene and late Miocene)

Semiconsolidated, light-gray, massive clayey grave deposits up to 10 m thick, containing rounded quartzite and silicic volcanic rock pebbles and cobbles. Unit occurs only as dissected terrace deposit capping hills in city of Astoria (Schlicker and others, 1972; Carter, 1976). *GRI Source Map ID 35633* (Astoria Basin).

Columbia River Basalt Group, Yakima Basalt Subgroup, Saddle Mountains Basalt

Tp - Saddle Mountain Basalt, Pomona Member subaerial basalt flow (middle Miocene)

Single subaerial porphyritic flow up to 15 m thick north of Nicolai Mountain along Columbia River. Light gray where fresh but typically deeply weathered to spheroidal blocks with orange weathering rinds. Vesicular flow displays glomeroporphyritic texture of labradorite phenocrysts (up to 20 percent) intergrown with clinopyroxene. Chemistry and reversed magnetic polarity are equivalent to that of Pomona flow of Columbia Plateau of Swanson and others (1979), Murphy (1981), and Murphy and Niem (1982). Flow is overlain by 5 m of unnamed arkosic sandstone. *GRI Source Map ID 35633* (Astoria Basin).

Tpi? - Saddle Mountain Basalt, Pomona Member, intrusive rocks(?) (middle Miocene)

Invasive sills and dikes of Pomona Member(?) basalt in southwestern part of map area. Altered, medium-gray, microgabbroic, columnar-jointed basalt with reversed magnetic polarity; basalt of unit **Tpi(?)** is chemically similar to basalt of Pomona Member flow but has an ophitic texture (Rarey and others, 1984). These intrusive rocks are petrologically equivalent to Pack Sack Lookout Basalt of Snavely and others (1973) and invade upper Eocene to middle Miocene sedimentary rocks. *GRI Source Map ID 35633* (Astoria Basin).

Tiob - Olivine basalt (middle Miocene)

Massive to crudely columnar and platy jointed, medium-grained, plagioclase-phyric olivine basalt, locally diabasic or micropegmatitic; forms large semi-concordant sill-like bodies in northeast part of map area; petrographically, chemically, and paleomagnetically similar to Pomona Member of Saddle Mountains Basalt of Columbia River Basalt Group (**Tp**) (Snavely and others, 1973; Magill and others, 1982); rocks in report area previously assigned to the basalt of Pack Sack Lookout (Snavely and others, 1973); queried south of Naselle where paleomagnetic relations are uncertain). *GRI Source Map ID 15326* (Cape Disappointment).

Gnat Creek formation (middle Miocene)

Friable, trough cross-bedded to locally bioturbated, micaceous and carbonaceous arkosic sandstone with rare lignitic coal (**Tg1, and Tg4**); intervening member (**Tg2**) of pebbly, coarse-grained arkosic sandstone and very thick-bedded, structureless, iron-stained sandstone with slumped siltstone blocks in channels cut into thicker sequence of well-laminated carbonaceous and micaceous mudstone and minor thin, graded feldspathic sandstone (**Tg3**). Total unit thickness is 200 m. Marine diatoms in units **Tg2** and **Tg3** are referrable to subzone Denticula hustedtii-D. lauta and subzone D. lauta, which are equivalent to uppermost Relizian-lower Luisian foraminiferal stages of Kleinpell (1938) (Barron, written communication, 1980, in Murphy, 1981; Murphy and Niem, 1982). Previously, this unit was informally referred to as nonmarine Pliocene sedimentary rocks (Wells and Peck, 1961), nonmarine sedimentary rocks at Clifton (Niem and Van Atta, 1973), and Clifton formation (Murphy, 1981; Murphy and Niem, 1982). The name Clifton formation is preempted, however. Gnat Creek formation unconformably overlies Frenchman Springs Member basalt and the Astoria Formation and is overlain by Pomona Member basalt. *GRI Source Map ID 35633* (Astoria Basin).

Tg4 - Gnat Creek formation, marine deltaic sandstone
Tg3 - Gnat Creek formation, marine slope mudstone
Tg2 - Gnat Creek formation, marine slope channel sandstone
Tg1 - Gnat Creek formation, terrestrial sedimentary rocks

[Gnat Creek formation name is informal usage.]

Columbia River Basalt Group, Yakima Basalt Subgroup, Wanapum Basalt

Tfs - Wanapum Basalt, Frenchman Springs Member, subaerial basalt flows (middle Miocene)

At least three subaerial flows of fine- to medium-crystalline, sparsely to abundantly plagioclase-phyric basalt and associated basal pillow breccias with total thickness of 150 m in Nicolai Mountain-Porter Ridge area. Flows have well-developed colonnades to blocky and platy fracture patterns. Two flows are sparsely plagioclase phyric, and one (Ginkgo) is abundantly plagioclase phyric. Some flows locally display intracanyon relationships. Plagioclase phenocrysts (labradorite) are up to 1.5 cm in length. Basalt is medium to dark gray when fresh; weathering produces reddish-brown color and locally forms spheroidal boulders. Flows have normal magnetic polarity. Thin interbeds of fine- to medium-grained micaceous and carbonaceous arkosic to basaltic sandstone are locally present. Some thicker (> 3 m) and more widespread interbeds are shown as unit Tfsn. *GRI Source Map ID 35633* (Astoria Basin).

Tfsn - Wanapum Basalt, Frenchman Springs Member, interbeds (middle Miocene)

Thin interbeds of fine- to medium-grained micaceous and carbonaceous arkosic to basaltic sandstone are locally present (see unit **Tfs** above) Some thicker (> 3 m) and more widespread interbeds are shown as unit **Tfsn**.

Unit also described as minor bathyal, micaceous, laminated mudstone (> 3 m thick) separates some breccias and pillow flows of unit **Tfsp** (see unit **Tfsp** below). *GRI Source Map ID 35633* (Astoria Basin).

Tfsp - Wanapum Basalt, Frenchman Springs Member, pillow palagonite complexes (middle Miocene)

Pillow palagonite complexes composed of closely packed pillow lava and isolated pillow breccias and associated autointrusive sills and dikes. In Big Creek-Wickiup Mountain area, unit **Tfsp** includes thick lava deltas of planar foresets of pillow breccia, pillow flows, and well-bedded fine and coarse hyaloclastites underlying associated subaerial flow (**Tfs**). East of Seaside, unit **Tfsp** includes some subaerial flows and arkosic sandstone. Minor bathyal, micaceous, laminated mudstone of unit **Tfsn** (> 3 m thick) separates some breccias and pillow flows. *GRI Source Map ID 35633* (Astoria Basin).

Tfsi - Wanapum Basalt, Frenchman Springs Member, intrusive basalt (middle Miocene)

Includes columnar-jointed sills, dikes, peperites, and irregularly shaped bodies that contain sparse to abundant labradorite phenocrysts. Not all intrusions are shown on map. Correlative relationships of dikes, sills, and irregularly shaped intrusions to Frenchman Springs Member pillow lavas, breccias, and subaerial flows are based on similar petrography, chemical composition, age, field relationships, and magnetic polarity (Choiniere and Swanson, 1979; Murphy, 1981; Peterson, 1984; called late Yakima by Snavely and others, 1973). These intrusive bodies probably originated as invasive flows of plateau-derived basalt of the Columbia River Basalt Group, as described by Beeson and others (1979). Units **Tfsi** and **Tfsp** have been previously called Cape Foulweather Basalt by Snavely and others (1973), Neel (1976), Tolson (1976), Coryell (1978), and others (see Sources of Data map), all of whom considered these basalts to be local in origin.

Frenchman Springs Member basalt is middle Miocene in age, based upon ages of underlying and overlying marine strata (Coryell, 1978; Murphy, 1981). Foraminifera and mollusks from interbedded mudstones northwest of Wickiup Mountain are referred to Saucesian-Relizian Stages of Kleinpell (1938) (Rau, in Coryell, 1978; Barron, written communication, 1984) and Newportian/Pillarian molluscan stages of Addicott (1976; Addicott, in Coryell, 1978). Thick sedimentary interbeds (**Tms**) occur between Grande Ronde and Frenchman Springs basalts in Nicolai Mountain area (outside of map boundary); in Wickiup Mountain area, a unit that is, in part, laterally equivalent to unit **Tms** is labeled unit **Tac3**). Elsewhere, Frenchman Springs basalt unconformably overlies or intrudes older sedimentary units. *GRI Source Map ID 35633* (Astoria Basin).

Astoria Formation

Tab - Astoria Formation, Bald Ridge unit (middle Miocene)

Thin-bedded, planar-laminated, abundantly micaceous and carbonaceous siltstone and lesser amounts of friable, very fine to coarse-grained micaceous feldspathic sandstone. Sandstone commonly occurs as graded beds, channel fills up to 15 m thick, and locally abundant clastic dikes; unit is well exposed

along logging roads on Bald Ridge 2 to 5 km southeast of the town of Naselle. Unit overlies strata containing foraminiferal assemblages referable to the Saucesian Stage of Kleinpell (1938) and is cut by sills of Grande Ronde Basalt chemistry (**Tib**), locally of middle Miocene age; unit is lateral equivalent to upper unit of Astoria Formation of Wolfe and McKee (1968) and is probably correlative in part to Youngs Bay unit of Astoria Formation in the Astoria basin of northwest Oregon (Niem and Niem, 1985). All foraminiferal age determinations by Weldon W. Rau, Washington Division of Geology and Earth Resources. *GRI Source Map ID 15326* (Cape Disappointment).

Tac - Astoria Formation, Cannon Beach member, turbidite (middle and early Miocene)

Well-bedded sequence of laminated to massive micaceous mudstone (**Tac**), with subordinate, rhythmically thin-bedded feldspathic sandstone and mudstone in lower part of unit (**Tac1**). Sandstone is fine grained, micaceous and carbonaceous, graded, micro cross-laminated to laminated (Bouma bc and cd intervals) and contains load casts and convolute bedding. Locally, there are nested channels of thin-bedded sandstone and mudstone in unit **Tac1**. Bathyal foraminiferal assemblages recovered from the mudstone are referred to Saucesian-Relizian(?) Stages of Kleinpell (1938); molluscan fossils are assigned to Newportian Stage of Addicott (1976, 1981). Previously, this member was informally called Silver Point member by Niem and Van Atta (1973), Smith (1975), Neel (1976), Cooper (1981), Wells and others (1983), and Niem and Niem (1984), but this name is preempted. Member is 200 m thick at Silver Point, thinning offshore toward outer continental shelf and thickening to a few thousand meters toward Astoria (Nelson, 1978; Cooper, 1981). Unit **Tac1** conformably overlies Angora Peak (**Taa**) and Wickiup Mountain (**Taw**) members but locally channels down into Smuggler Cove formation (**Tsc**) (Cooper, 1981).

Unit **Tac1** also includes highly carbonaceous, very well-laminated mudstone with rare, thick-bedded, graded, arkosic channeled sandstone (J-unit of Tolson, 1976). Upper part of unit **Tac2** includes very thinly laminated bathyal claystone (airplane unit of Tolson, 1976).

In northern part of map area, very well-laminated, micaceous and carbonaceous, deep-marine mudstone (**Tac2**) overlies and interfingers with Youngs Bay member (**Tay**). This unit locally contains thin lenses and beds of fine-grained arkosic sandstone and thick beds of mudstone that contain carbonized leaf imprints and Siphogenerina (foraminiferal molds and tests. Foraminifera recovered from unit equate to Saucesian-Relizian(?) Stages of Kleinpell (1938) lin Nelson, 1978, and Coryell, 1978). Diatom assemblages are no older than latest early Miocene (equivalent to Relizian foraminiferal stage; Barron, written communication, 1985).

In Wickiup Mountain-Big Creek area, thick massive micaceous and carbonaceous mudstone (**Tac3**) with subordinate cross-bedded basaltic sandstone and conglomerate and minor arkosic and glauconitic sandstone interfingers with Grande Ronde Basalt and is, in part, a lateral equivalent of unit **Tms** (interbed between Grande Ronde and Frenchman Springs basalts). This unit also equates, in part, with revised Scappoose Formation of Van Atta and Kelty (1985) in Columbia County. *GRI Source Map ID 35633* (Astoria Basin).

Tac3 - Astoria Formation, Cannon Beach member, mudstone
Tac2 - Astoria Formation, Cannon Beach member, slope mudstone
Tac1 - Astoria Formation, Cannon Beach member, slope channel sandstone

[Cannon Beach member name is informal usage.]

Tay - Astoria Formation, Youngs Bay member, slope mudstone (middle and early Miocene)

Predominantly deep-marine, laminated, carbonaceous and micaceous mudstone (**Tay**, up to 670 m thick) complexly intertongued with two thick bodies of clean, medium- to coarse-grained, friable arkosic sandstone (**Tay1** and **Tay2**) that contain large mica flakes; are commonly weathered orange yellow, iron stained, or white to medium gray (fresh); and are thick to very thick bedded. Although generally structureless, sandstones are locally laminated and carbonaceous. The lenticular sandstone bodies are up to 65 to 340 m thick, respectively (Nelson, 1978; Coryell, 1978). Mudstone (**Tay**) is medium gray when fresh and characteristically contains clastic dikes of medium-grained arkosic sandstone, bathyal foraminifera, and a few graded, thin- to medium-bedded arkosic sandstone beds. Member grades into and interfingers with Cannon Beach member (**Tac**). Unit **Tay** was informally called upper sandstone member of type Astoria Formation by Howe (1922) and Carter (1976); deep-marine Big Creek member by Cooper (1981); Pipeline member of Astoria Formation by Nelson (1978), Coryell (1978), Wells and others (1983), and Niem and Niem (1984); and, in part, post-Astoria sandstone by Dodds (1969). The names Pipeline and Big Creek have been preempted. Bathyal foraminiferal and molluscan fossils in mudstone beds are referrable to Saucesian Stage of Kleinpell (1938) (by Rau, in Nelson, 1978, and Coryell, 1978) and Newportian or Wishkahan(?) Stage of Addicott (1976). Possible Relizian foraminiferal assemblages occur in unit in the Patton 32-9 well (McKeel, written communication to Diamond Shamrock Corporation, 1982). *GRI Source Map ID 35633* (Astoria Basin).

Tay2 - Astoria Formation, Youngs Bay member, sandstone
Tay1 - Astoria Formation, Youngs Bay member, sandstone

[Youngs Bay member name is informal usage]

Taa -Astoria Formation, Angora Peak member, shelf sandstone (middle and early Miocene)

Massive to laminated, fine-grained arkosic sandstone with subordinate trough and planar cross-bedded coarse-grained volcanic sandstone; minor pumiceous-volcanic to polymict conglomerate and laminated carbonaceous mudstone with thin local subbituminous coal beds. Sandstone contains abundant shallow-water mollusks assignable to Pillarian and Newportian Stages of Addicott (1976, 1981) (Cressy, 1974; Cooper, 1981). Member is 250 m thick and unconformably overlies Smuggler Cove formation (**Tsc**). *GRI Source Map ID 35633* (Astoria Basin).

[Angora Peak member name is informal usage]

Taw - Astoria Formation, Wickiup Mountain member, shelf sandstone (middle and early Miocene)

400 m of structureless to laminated shallow-water feldspathic sandstone. Generally fine grained, locally trough cross-bedded, and fossiliferous. Sandstone is blue gray when fresh but commonly is weathered to yellowish to greenish gray. Upper part (**Tawu**) consists of friable, very fine-grained sandstone and micaceous mudstone capped by glauconitic sandstone. Member unconformably overlies Smuggler Cove formation (**Tsc**), thins to west and southwest, and contains molluscan fossils referrable to Pillarian and Newportian Stages of Addicott (1976). Member previously was informally called Big Creek member by Coryell (1978), Nelson (1978), Cooper (1981), Wells and others (1983), and Niem and Niem (1984). Member includes Tucker Creek sandstone of Nelson (1978). *GRI Source Map ID 35633* (Astoria Basin).

Tawu - Astoria Formation, Wickiup Mountain member, upper part, sandstone and mudstone

[Wickiup Mountain member name is informal usage]

Tan - Astoria Formation, Naselle unit (middle and early Miocene)

Massive-appearing, thick-bedded to massive bioturbated to wispy laminated, abundantly micaceous, carbonaceous, tuffaceous, medium-gray siltstone, sandy siltstone, and lesser fine- to medium-grained feldspathic sandstone; sandstone is locally basaltic or glauconitic; locally contains calcareous concretions. Good exposures occur in Salmon Creek east of Naselle and along logging roads east of the South Fork of the Naselle River. Contains foraminiferal assemblage referable to Saucesian Stage of Kleinpell (1938); unit is lateral equivalent to part of lower unit of Astoria Formation of Wolf and McKee (1968) and is similar in appearance and correlative in part to Wickiup Mountain unit of Astoria Formation in northwest Oregon (Niem and Niem, 1985). *GRI Source Map ID 15326* (Cape Disappointment).

Columbia River Basalt Group, Yakima Basalt Subgroup, Grande Ronde Basalt

Tgr - Grande Ronde Basalt, subaerial basalt flows (middle Miocene)

In Nicolai Mountain-Porter Ridge area, largely subaerial, columnar-jointed, dark- to light-gray, aphyric to rarely plagioclase-phyric tholeiitic basalt flows and associated basal basalt breccias and pillow lavas; unit has composite thickness of 150 m (Murphy, 1981; Goalen, in preparation). Thick, intracanyon, closely packed pillow lavas occur locally. At least seven individual flows are present: two high MgO, normal magnetic polarity flows overlie two low MgO, low Ti02, normal magnetic polarity flows. The four normal magnetic polarity flows overlie three reversed magnetic polarity flows (one low MgO, low TiO2 flow and two low MgO, high Ti02 flows) (Murphy, 1981; Goalen, in preparation). All flows belong to N2 and R2 magnetozones. Unit includes minor 2- to 20-m-thick interbeds of thin-bedded, fine-grained, arkosic to coarse-grained basaltic sandstone. Subaerial basalt flows (15 to 35 m thick) contain well-developed colonnades, entablatures, multiple flow lobes, and locally reddish-color oxidized vesicular flow tops. Magnetic polarity and major- and trace-element chemistry are equivalent to the Grande Ronde Basalt of the Columbia Plateau (Yakima Basalt of Waters, 1961, and Snavely and others, 1973; Grande Ronde Basalt of Choiniere and Swanson, 1979; Swanson and others, 1979; and Murphy, 1981) and the Willamette Valley (Anderson, 1978; Beeson and Moran, 1979). *GRI Source Map ID 35633* (Astoria Basin).

Tgrp - Grande Ronde Basalt, pillow palagonite complexes (middle Miocene)

Largely thick, blocky to palagonitic, isolated pillow breccias and subordinate, closely packed submarine pillow lavas up to 650 m thick (e.g., Angora Peak, Onion Peak, Sugarloaf, Elk Mountain, Humbug Mountain, and Saddle Mountain). Includes thick lava deltas composed of planar foresets of pillow breccias, well-bedded palagonitized hyaloclastites, and debris flows associated with thin, capping subaerial flows (as on Wickiup Ridge and in Big Creek). Breccias are cemented by zeolites, calcite, and montmorillonite clays. Minor laminated micaceous and carbonaceous medium-gray mudstone, channelized pebble-boulder conglomerate, and subordinate thin, graded, arkosic to basaltic sandstone interbeds. Some of the more extensive mudstone interbeds (**Tgrm**, up to 15 m thick) are shown on map. Mudstone interbeds contain bathyal foraminifera, diatoms, and mollusks assignable to Saucesian-Relizian Stages of Kleinpell (1938) and to Newportian Stage of Addicott (1976) (Neel, 1976; Murphy, 1981). Unit Tgrp contains same high and low Mg0 and Ti02 chemical subtypes with normal and reversed magnetic polarities as described for unit Tgr, above. Unit Tgrp has been previously called Depoe Bay Basalt by Snavely and others (1973), Cressy (1974), Smith (1975), Neel (1976), Tolson (1976), Penoyer (1977), Coryell (1978), Murphy (1981), and others (see Sources of Data map). Unit **Tgrp** complexly interfingers with unit **Tgr** and unconformably overlies units **Taa**, **Taw**, **Tsc**, and **Tn**. *GRI Source Map ID*

35633 (Astoria Basin).

Tgrm - Grande Ronde Basalt, pillow palagonite complexes, mudstone interbeds

Tgri - Grande Ronde Basalt, intrusive basalt (middle Miocene)

Invasive sills (5 to 200 m thick), dikes, and irregular bodies of massive to columnar-jointed, aphyric to rarely phyric basalt and peperite or intrusive breccia (**Tgrb**) related to Grande Ronde Basalt on basis of field relationships, petrography, chemical composition, age, and magnetic polarity (Snavely and others, 1973; Beeson and others, 1979; Murphy, 1981; Peterson, 1984; Goalen, in preparation). Unit **Tgri** intrudes upper Eocene to middle Miocene sedimentary rock units in map area and also occurs as autointrusives and younger sills and dikes in unit **Tgrp**. Probably originated as invasive flows, as hypothesized by Beeson and others (1979). Such invasive Columbia River basalt flows have also been described by Schmincke (1967) and Byerly and Swanson (1978) on the Columbia Plateau in southeastern Washington. An alternative hypothesis that the basalt originated from local vents was originally proposed by Snavely and others (1973) and further amplified by Cressy (1974), Smith (1975), Neel (1976), Tolson (1976), Penoyer (1977), Coryell (1978), Murphy (1981), and Olbinski (1983). These writers have referred to these rocks as Depoe Bay Basalt. The same chemical and magnetic polarity subtypes described for unit **Tgr**, above, are all represented in unit **Tgri** Only larger intrusives are shown on map. Whole-rock K-Ar ages for Grande Ronde (Depoe Bay) sills in Clatsop County range from 14.0 ± 2.7 million years (m.y.) to 15.9 ± 0.3 m.y. (Turner, 1970; Niem and Cressy, 1973). *GRI Source Map ID 35633* (Astoria Basin).

Tgrb - Grande Ronde Basalt, intrusive breccia

Tib - Basalt (middle Miocene)

Massive to crudely columnar and platy jointed, medium-grained, aphyric, dark-gray basalt; forms large sill on Bear River Ridge and several other large sill-like bodies; also as small irregular intrusions throughout sedimentary section, intruding strata as young as Bald Ridge unit of the Astoria Formation; petrographically, chemically, and paleomagnetically correlative with low Mg N2 polarity subdivision of the upper part of the Grande Ronde Basalt of the Columbia River Basalt Group as defined by Swanson and others (1979); rocks in report area previously correlated with the Depoe Bay Basalt (Snavely and others, 1973). *GRI Source Map ID 15326* (Cape Disappointment).

Tcf - Cape Falcon conglomerate (middle Miocene)

A local, very poorly sorted, well-indurated volcanic conglomerate containing angular to rounded cobbles and boulders of basalt, basaltic andesite, dacite, and 2-m-long blocks of fossiliferous Angora Peak sandstone (Astoria Formation). Conglomerate beds are normal to reversely graded to massive, and clasts are supported, in part, in coarse basaltic sand matrix. This channelized unit forms sea cliffs north of Cape Falcon and unconformably overlies Angora Peak member of Astoria Formation. Unit **Tcf** is intruded by the low Mg0 Grande Ronde basaltic sill that forms Cape Falcon. Cressy (1984) originally included this unit in the Astoria Formation.

Other unnamed post-Astoria conglomerates and gravels composed exclusively of Miocene Grande Ronde or Frenchman Springs basalt clasts and subordinate mudstone and thin arkosic to basaltic sandstones occur directly beneath several major Miocene basaltic breccias. These are too limited in distribution and thickness to show on map but are included in Astoria Formation or in Grande Ronde breccias. *GRI Source Map ID 35633* (Astoria Basin).

[Cape Falcon conglomerate name is informal usage]

Tsc - Smuggler Cove formation (early Miocene, Oligocene and late Eocene)

Approximately a thousand meters of predominantly thick-bedded bioturbated tuffaceous claystone and siltstone with a few graded volcanic sandstone beds, tuffs, clastic dikes, and glauconitic sandstone. Helmenthoida burrows are ubiquitous. Unit contains deep-water foraminiferal assemblages assigned to Refugian (Schenck and Kleinpell, 1936), Zemorrian, and lower Saucesian Stages of Kleinpell (1938); mollusks are referred to Galvinian, Matlockian, Juanian, and Pillarian Stages of Armentrout (1975, 1981) and Armentrout and others (1984). Locally in southwestern and northwestern corners of map, unit **Tsc** is divided into two members. Lower member (**Tsc1**) is dominantly thick-bedded tuffaceous silty claystone that is early to predominantly late Refugian in age. Upper member (**Tsc2**) consists of structureless tuffaceous siltstone and sandy siltstone that is Zemorrian to early Saucesian in age. A 10- to 15-m thick bed of glauconitic sandstone (**Tscg**) in base of unit **Tsc2** delineates contact between upper member **Tsc2** and lower member **Tsc1** (Smith, 1975; Neel, 1976; Rarey, in preparation). Elsewhere, unit **Tsc** is undifferentiated. Formation was informally called Oswald West mudstones by Cressy (1974), Niem and Van Atta (1973), Wells and others (1983), and others (see Sources of Data map). Locally, in southwest part of map, unit contains an unnamed thin sequence of well-bedded, laminated, micaceous and carbonaceous mudstone and arkosic sandstone (**Tscm**) that is possibly Zemorrian in age and probably equivalent to Northrup Creek formation (**Tn**, informal). One to three beds of unnamed, thick-bedded, mollusk-bearing, fine-grained feldspathic sandstone (**Tscs**; 10 to 35 m thick) in upper member of formation occur in northern part of study area (Nelson, 1978). Unit **Tscs** includes Pillerian-age Falls Creek member of Penoyer (1977) on northeast flank of Saddle Mountain. *GRI Source Map ID 35633* (Astoria Basin).

Tscs - Smuggler Cove formation, sandstone
Tscm - Smuggler Cove formation, mudstone
Tsc2 - Smuggler Cove formation, upper member
Tscg - Smuggler Cove formation, glauconitic sandstone
Tsc1 - Smuggler Cove formation, lower member

[Smuggler Cove formation name is informal usage]

Tn - Northrup Creek formation, turbidite (early Miocene and Oligocene?)

Informal unit consists of approximately 500 m of well-bedded, carbonaceous and micaceous, laminated, medium- to dark-gray mudstone and subordinate, thin, fine-grained to very fine-grained, feldspathic yellowish-gray sandstone. Tuffaceous mudstone is light yellowish gray when weathered and medium gray when fresh. Micro cross-laminations, slump structures, and graded grit beds occur locally in sandstone beds. Carbonized leaf imprints are ubiquitous. Thick-bedded, fine- to coarse-grained, well-sorted, micaceous, friable, arkosic sandstone (up to 15 m thick) with molluscan fossils and characteristic large laminated calcareous concretions is present near top of sequence (**Tns**). Unit **Tn** interfingers with Smuggler Cove formation to west and southwest. Age of unit is not clearly known, but unit contains diatom assemblages that could be correlated to Zemorrian Stage of Kleinpell (1938) (Barron, written communication, 1985), coccoliths in upper part of the unit that equate to early Miocene (Bukry, written communication, 1985), and Juanian to Pillarian molluscan fauna (Moore, written communication to Coryell, 1978, and to Murphy, 1981). Previously, this informal unit was mapped as lower to middle Miocene Silver Point member of Astoria Formation by Cooper (1981), Peterson (1984), and Nelson (1985). *GRI Source Map ID 35633* (Astoria Basin).

Tns - Northrup Creek formation, sandstone (early Miocene and Oligocene?)

[Northup Creek formation name is informal usage]

Tlc - Lincoln Creek Formation (early Miocene to late Eocene)

Marine, dark-gray to olive-gray, concretion-bearing, very tuffaceous siltstone and lesser feldspathic sandstone; lower two-thirds is thin-bedded, laminated, burrowed tuffaceous siltstone and thin interbeds of graded, planar-laminated, fine- to medium-grained micaceous feldspathic sandstone, in places glauconitic or tuffaceous, especially at base of unit; large-scale soft-sediment deformation is common. Abundant sandstone near base of unit mapped separately as sandstone unit at Knappton (**Tick**); upper third of unit is massive to laminated, poorly bedded, bioturbated, dark-gray siltstone and fine sandstone; white to tan tuff stringers and beds common throughout. Best exposures are in Dell Creek and along logging roads following Dell Creek and its tributaries. Formation contains foraminifers referable to Refugian and Zemorrian Stages of Schenck and Kleinpell (1936) and Kleinpell (1938); molluscan fauna from the uppermost part of the formation near Knappton are referable to the upper part of the Liracassis apta zone (Moore, 1984) and are thought to be of early Miocene age, although benthic foraminfers from the same locality are referable to the Zemorrian Stage, or Oligocene (W.W. Rau, oral commun., 1985). In part correlative with the Lincoln Creek Formation as mapped by Wolfe and McKee (1968) to the east and to the Smuggler Cove mudstone unit (Niem and Niem, 1985) and the Alsea Formation (Snavely and others, 1975) in Oregon. Locally includes unit **Tlck**. *GRI Source Map ID 15326* (Cape Disappointment).

Tlck - Lincoln Creek Formation, sandstone unit at Knappton (early Oligocene or late Eocene)

Light-gray, thick- to thin-bedded, graded and planar-laminated to trough-laminated, fine- to medium-grained micaceous feldspathic sandstone and lesser laminated siltstone, locally glauconitic or tuffaceous, with massive tuffaceous siltstone interbeds; includes thin-bedded sandstone sequences at several localities above sill on Bear River Ridge that may not be strictly correlative. Best exposures are along logging roads south of Bean Creek and along State Highway 401 at Knappton. Foraminifers from overlying siltstone generally referable to the Zemorrian Stage of Kleinpell (1938), while those beneath the sandstone are referable to the Refugian or Narizian Stages of Schenck and Kleinpell (1936) and Mallory (1959); may be deeper water facies correlative with sandstone of the Pittsburg Bluff Formation (Moore, 1976) in Oregon. *GRI Source Map ID 15326* (Cape Disappointment).

Tpb - Pittsburg Bluff Formation (Oligocene and late Eocene)

Approximately 275 m of thick, ridge-forming, bioturbated to laminated beds of tuffaceous to arkosic sandstone with glauconitic sandstone (particularly in lower part) and subordinate beds of tuffaceous siltstone-claystone. Very fine- to medium-grained silty sandstone beds are structureless and concretionary and contain thin, light-gray tuff beds. Abundant shallow-marine mollusks in unit are referrable to Galvinian Stage of Armentrout (1975, 1981) (Moore, 1976; Moore, in Olbinski, 1983, and in Nelson, 1985). Foraminifera are referred to late Refugian Stage of Schenck and Kleinpell (1936) and coccoliths to lower Oligocene (equivalent to early Zemorrian foraminiferal stage; Bukry, in Nelson, 1985). Formation becomes siltier (finer grained) and pinches out to southwest and west (Rarey, in preparation; Peterson, 1984). Locally, it passes into much thinner glauconitic sandstone and tuffaceous sandy siltstone of upper member (**Tsc2**, **Tscg**, **Tscs**) of Smuggler Cove formation (Rarey, in preparation). *GRI Source Map ID 35633* (Astoria Basin).

Ts - Sager Creek formation (late Eocene)

Thick sequence of well-laminated micaceous and carbonaceous mudstone rhythmically interbedded with thin feldspathic sandstone. Fine-grained sandstone is laminated to thin bedded and occurs locally with thin-bedded mudstones in nested channels. Some sandstone beds form concretionary ledges. The 1,160-m-thick formation thins and interfingers with tuffaceous lower Smuggler Cove formation (**Tsc1**) to west and southwest. Unit contains deep-water foraminifera assigned to upper Refugian Stage (McDougall, in Olbinski, 1983) and coccoliths of the NP19-21 calcareous nannoplankton zone (Poore and Bybell, written communication to Olbinski, 1983). Formation was informally called Vesper Church formation by Olbinski (1983) and Vesper Church member of Keasey Formation by Wells and others (1983) and Nelson (1985) in Clatsop County and lower Pittsburg Bluff Formation by Warren and Norbisrath (1946) and Kadri (1982) in Columbia County. *GRI Source Map ID 35633* (Astoria Basin).

[Sager Creek formation name is informal usage]

Tkj - Keasey Formation, Jewell member (late Eocene)

Thin-bedded to laminated, grayish-brown, tuffaceous to glauconitic mudstone with a few arkosic sandstone lenses, tuffs, and clastic dikes. Abundant bathyal foraminifera and coccoliths referrable to lower Refugian Stage of Schenck and Kleinpell (1936) (McDougall, in Nelson, 1985; McKeel, written communication, 1985; Bukry, in Mumford, in preparation). Some late Narizian foraminiferal assemblages have also been reported (Rau, in Nelson, 1985; McKeel, written communication, 1985). First described as informal unit of lower Keasey Formation by Olbinski (1983) and Nelson (1985). Jewell member is thought to overlie unconformably the Cowlitz Formation and Hamlet formation (Olbinski, 1983; Rarey, in preparation). *GRI Source Map ID 35633* (Astoria Basin).

[Jewell member name is informal usage]

Th - Hamlet formation (late Eocene)

Massive, medium-gray, carbonaceous and mica-bearing mudstone (up to 200 m thick) with a few thin interbeds of graded, rhythmic, fine-grained, arkosic, micaceous, carbonaceous sandstone and/or medium- to coarse-grained basaltic sandstone. Mudstone weathers to small chips and contains gastropods, scaphopods, and fish scales. Two members occur within formation: a basal basaltic conglomerate and basaltic sandstone unit (Roy Creek member, **Thr**) and, in eastern Clatsop County, interbedded shallow-marine micaceous lithic arkosic sandstone and basaltic sandstone (Sunset Highway member, **Ths**). Abundant foraminifera in unit are referred to late Narizian Stage of Kleinpell (1938) (Rau, in Rarey, in preparation, and in Mumford, in preparation), and coccoliths from bottom to top of section represent CP14A and CP14B nannofossil zones which equate to late Narizian foraminiferal stage (Bukry, in Rarey, in preparation, and in Mumford, in preparation). Formation was previously mapped as undifferentiated late Eocene-Oligocene sedimentary rocks by Wells and Peck (1961), Cowlitz Formation (Wells and others, 1983), and Cowlitz members Tc1-Tc4 of Olbinski (1983) and Nelson (1985). Unit correlates with Yamhill Formation of Bruer and others (1984) and, in part, with mudstone in subsurface in western Clatsop County that they equated to the Cowlitz Formation. Upper part of Hamlet formation interfingers with Cowlitz Formation in eastern Clatsop County. Unit also correlates to Nestucca Formation as mapped by Wells and others (1983). *GRI Source Map ID 35633* (Astoria Basin).

Thr - Hamlet formation, Roy Creek member

[Hamlet formation name is informal usage]

Ttv - Tillamook Volcanics (late and Middle Eocene)

Subaerial aphyric to abundantly plagioclase- and pyroxene-phyric, dark-gray to greenish-gray, high-titanium basalt and basaltic andesite flows with red oxidized to deeply weathered vesicular top and bottom flow breccias. Lavas have platy to blocky columnar-jointed interiors and display reverse magnetic polarities (Nelson, 1985; Rarey, in preparation; Mumford, in preparation). Minor andesite and dacite in Green Mountain area; upper part of unit also contains some volcanic mudflow breccias, basalt conglomerate, lapilli tuffs, basaltic sandstone, and minor medium-dark-gray to reddish oxidized siltstone interbeds. Locally, flows and breccias are hydrothermally altered. A few porphyritic to aphyric dikes (**Ttd**) occur (most included in **Ttv**). Whole-rock K-Ar age determined after acid treatment of sample from upper part of Tillamook Volcanics in Clatsop County is 40.1 ± 1.2 m.y. (Leda Beth Pickthorn, written communication to Parke Snavely, Jr., U.S. Geological Survey, 1984). Other ages reported from Clatsop County samples range from 37.1 ± 0.4 m.y. (late Eocene) to 42.4 ± 0.5 m.y. (middle Eocene) (McElwee, in Nelson, 1985). K-Ar ages of dikes in lower part of Tillamook Volcanics south of map area in Tillamook County range from 43.2 to 46.0 ± 0.9 m.y. and average 44.3±0.6 0.6 m.y. (Magill and others, 1981). *GRI Source Map ID 35633* (Astoria Basin).

Tes - Siltstone and sandstone (late and Middle Eocene)

Thin-bedded, laminated concretionary siltstone and fine micaceous sandstone in northeastern part of map; correlative with the siltstone of Cliff Point (**Tcp**), the siltstone and sandstone at Omeara Point (**Top**), and the siltstone of Shoalwater Bay (**Tsb**), undivided, and is laterally equivalent to part of Unit B of Wolfe and McKee (1968). As mapped on and near Long Island, may also include rocks correlative with the sandstone at Megler (unit **Tsm**). *GRI Source Map ID 15326* (Cape Disappointment).

Tsb - Siltstone at Shoalwater Bay (late and late middle Eocene)

Dark-gray, thin-bedded, laminated, indurated tuffaceous siltstone containing thin tuff beds, minor thin-bedded feldspathic sandstone, and calcareous concretions; unit is baked and altered over wide areas beneath the sill on Bear River Ridge; best exposures occur on U.S. Highway 101 along Shoalwater Bay. Foraminifers are referable to Narizian or Refugian Stages of Mallory (1959) and Schenck and Kleinpell (1936); unit is lateral equivalent of middle and upper part of Unit B of Wolfe and McKee (1968) and is correlative in part with siltstone of Skamokawa Creek (Wells, 1981); may be correlative in part with Nestucca, Cowlitz, and Keasey Formations of northwest Oregon (Wells and others, 1983). *GRI Source Map ID 15326* (Cape Disappointment).

Top - Siltstone and sandstone at O'Meara Point (late and late middle Eocene)

Light-gray, very well bedded, laminated, indurated siltstone and thin-bedded, planar-laminated and graded to cross-laminated, and graded, very fine grained micaceous feldspathic sandstone, locally basaltic, carbonaceous or tuffaceous with locally abundant calcareous concretionary beds; best exposed at Omeara Point on Shoalwater Bay. Contains foraminifers referable to the upper(?) Narizian Stage of Mallory (1959); may be correlative with part of the Cowlitz Formation near Longview, Washington (Livingston, 1966; Wells, 1981), and in northern Oregon (Warren and Norbisrath, 1946;

Wells and others, 1983). *GRI Source Map ID 15326* (Cape Disappointment).

Tcp - Siltstone of Cliff Point (late? and middle Eocene)

Greengray to red-gray, indurated, burrowed, thin-bedded and laminated tuffaceous siltstone and very fine volcanolithic sandstone; breaks with conchoidal fracture across bedding; best exposed at Cliff Point on the Columbia River about 4 km east of the Astoria/Bridge. Contains foraminifers referable to the Narizian Stage of Mallory (1959); partly correlative with lower part of siltstone of Unit B of Wolfe and McKee (1968) and upper part of McIntosh Formation (Pease and Hoover, 1957; Wagner, 1967a, b) in Washington; correlative with part of Yamhill Formation (Baldwin and others, 1955) in northern Oregon. *GRI Source Map ID 15326* (Cape Disappointment).

Tsm - Sandstone at Mergler (middle Eocene)

Light-gray, indurated, thin- to thick-bedded and channeled, planar-laminated and graded to locally trough-laminated or cross-laminated, very fine to medium-grained micaceous feldspathic sandstone and interbedded siltstone, locally with sole markings of flute and groove casts; lowermost sandstones are in part basaltic and interfinger with basalt lapilli breccia and flows (unit **Tbr**) and pillow basalt flows (unit **Tbf**); best exposed near Megler rest stop 1.6 km east of Astoria Bridge. Contains foraminifers referable to upper Ulatisian or lower Narizian Stages of Mallory (1959); laterally correlative with Unit A of Wolfe and McKee (1968) and lower part of McIntosh Formation of Wagner (1967a, b) in Washington; may be correlative with lower part of Yamhill Formation in northern Oregon (Baldwin and others, 1955; Snavely and others, 1976a, b, c; Wells and others, 1983). *GRI Source Map ID 15326* (Cape Disappointment).

Tbr - Basalt lapillli breccia and flows at Fort Columbia (middle Eocene)

Submarine basalt lapilli tuff, basalt breccia, and basalt sandstone and conglomerate; mostly thick-bedded to massive and locally graded, dark-green to brown-gray basalt lapilli tuff composed of vesicular basalt glass fragments cemented with calcite and zeolite, locally contains large plagioclase crystals up to 13 cm long; locally grades into medium to coarse basaltic sandstone; also includes massive basalt flow breccia and poorly sorted basalt boulder conglomerate; interbedded with the sandstone at Megler (unit **Tsm**) that contains foraminifers referable to the upper Ulatisian or lower Narizian Stages of Mallory (1959); may be correlative with Henriksen's (1956) Pe Ell Volcanics Member of the Cowlitz Formation. Locally includes: *GRI Source Map ID 15326* (Cape Disappointment).

Tbf - Basalt lapillli breccia and flows at Fort Columbia, pillow basalt flows (middle Eocene)

Amygdaloidal fine-grained pillow basalt and lesser columnar-jointed basalt and breccia, commonly showing submarine alteration of glass to green smectite clays and abundant fracture fillings of zeolite, calcite, and quartz; also interbedded with the sandstone at Megler (unit Tsm)). *GRI Source Map ID 15326* (Cape Disappointment).

Tig - Gabbro and basalt (Eocene)

Massive to crudely columnar jointed and locally banded or layered gray-green pyroxene gabbro and basalt; interstitial glass and cores of plagioclase commonly altered to clay minerals; intrudes Crescent

Formation and overlying sandstone of Megler (unit **Tsm**). *GRI Source Map ID 15326* (Cape Disappointment).

Tc - Crescent Formation (middle Eocene)

Pillowed, columnar-jointed, and massive basalt, fine to medium grained, nonvesicular to amygdaloidal, aphyric to plagioclase-pyroxene-olivine-phyric; typically shows submarine alteration of glassy pillow rims and interstitial glass to waxy green smectite clays. Clay minerals, zeolite, calcite, and quartz fill vesicles and abundant slickensided fractures; unit best exposed in sea cliffs at Cape Disappointment. Siltstone interbeds in upper part contain foraminifers referable to upper Ulatisian or lower part of the Narizian Stages of Mallory (1959). In northeast part of map area unit is laterally continuous and correlative with upper part of Crescent Formation as mapped by Wagner (1967a, b), Wolfe and McKee (1968), and Pease and Hoover (1957) in Washington. In the isolated Fort Columbia anticline, no foraminifers referable to the Ulatisian Stage have yet been found, but the stratigraphic relations there are identical to those of the upper part of the Crescent Formation in the northeast part of the map area and suggests that the two sequences are equivalent.*GRI Source Map ID 15326.* (Cape Disappointment)

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for Lewis and Clark National Historical Park, Oregon and Washington (LEWI) are presented below. Note that some cross section abbreviations (e.g., A - A') may have been changed from their source map abbreviation in the GRI data so that each GRI cross section abbreviation is unique. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (when viewing the digital format of this document).

The three geologic cross sections, A-A', B-B', and C-C', are available as a separate PDF document.
LEWI Geologic Cross Sections

GRI Source Map Citations

The GRI digital geologic-GIS map for Lewis and Clark National Historical Park, Oregon and Washington (LEWI) was compiled from the following sources:

Ma, L., Madin, I.P., Olson, K.V., Watzig, R.J., Wells, R.E., Niem, A.R., and Priest, G.R., 2009, Oregon Geologic Data Compilation (OGDC) - Release 5, Oregon Department of Geology and Mineral Industries, Portland, OR. (OGDC v5). (*GRI Source Map ID 75206*).

Martin, M.W., Kadri, M.M., Neim, A.R., and McKeel, D.R., 1985, Correlation of Exploration Wells, Astoria Basin Northwestern Oregon in Niem, A.R., Niem, W.A., Martin, M.W., Kadri, M.M., and McKeel, D.R., Correlation of Exploration Wells, Astoria Basin, Oregon, Oregon Department of Geology and Mineral Industries, Oil and Gas Investigations 14; plate 2 of 2. (Exploration Wells). (*GRI Source Map ID 75558*).

Niem, A.R. and Niem, W.A., 1985, Geologic Map of the Astoria Basin, Clatsop and Northwestern Most Tillamook Counties, Northwest Oregon in Niem, A.R., Niem, W.A., Martin, M.W., Kadri, M.M., and McKeel, D.R., Correlation of Exploration Wells, Astoria Basin, Oregon, Oregon Department of Geology and Mineral Industries, Oil and Gas Investigations 14; plate 1 of 2, 1:100,000 scale. (Astoria Basin). (*GRI Source Map ID 35633*).

Wells, R.E., 1989, Geologic map of the Cape Disappointment-Naselle River area, Pacific and Wahkiakum Counties, Washington: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1832, 1:62,500scale. (Cape Disappointment). (*GRI Source Map ID 15326*).

Additional information pertaining to each source map is also presented in the Source Map Information (LEWIMAP) table included with the GRI geology-GIS data.

Astoria Basin

Niem, A.R. and Niem, W.A., 1985, Geologic Map of the Astoria Basin, Clatsop and Northwestern Most Tillamook Counties, Northwest Oregon in Niem, A.R., Niem, W.A., Martin, M.W., Kadri, M.M., and McKeel, D.R., Correlation of Exploration Wells, Astoria Basin, Oregon, Oregon Department of Geology and Mineral Industries, Oil and Gas Investigations 14, plate 1 of 2, 1:100,000 scale. (*GRI Source Map ID 35633*).

Many Oregon Department of Geology and Mineral Industries publications including Oil and Gas Investigations 14 are available for purchase through Nature of the Northwest Information Center web site: http://www.naturenw.org

Astoria Basin Report

Oil and Gas Potential

Early oil and gas reconnaissance investigations that included the Astoria basin were conducted by Washburne (1914) and Warren and others (1945). Eleven exploration wells, many with noncommercial gas shows, have been drilled in the basin (Plates 1 and 2). Much of the drilling activity has occurred since the 1979 discovery of commercial quantities of gas in the Clark and Wilson sandstone of the upper Eocene Cowlitz Formation in the Mist gas field 4 mi to the east

(Newton, 1979; Bruer, 1980). The gas field occurs on the east flank of the northern Coast Range gravity high (Bromery and Snavely, 1964) or Nehalem arch of Armentrout and Suek (1985), which separates the Astoria basin on the west from the north Willamette basin on the east.

The more than 10,000-ft-thick Tillamook Volcanics represent economic basement in the area. These rocks are exposed in uplifted fault blocks in the southeast part of the map area and have been encountered in several wells in the basin (Plate 2). The Tertiary sedimentary section that overlies the volcanic basement generally thins over the gravity high and thickens toward the basins. The deepest part of the basin in northwest Oregon lies approximately 7 mi southeast of Astoria and contains more than 10,000 ft of upper Eocene to middle Miocene strata. The sedimentary section probably exceeds 15,000 ft in the offshore part of the basin (Snavely and others, 1977; Armentrout and Suek, 1985).

The most promising reservoir target is the thick, friable, arkosic, micaceous Clark and Wilson sandstone of the Cowlitz Formation that occurs only in the easternmost part of the basin. Incomplete drill-stem tests yielded an estimated 10,000-20,000 cfd from the Clark and Wilson sandstone in the Boise Cascade 11-14 well (daily driller's report). The Clark and Wilson sandstone rapidly thins across the northern Coast Range gravity high from 750 ft in the Mist gas field (Bruer, 1980) to less than 25 ft south of Jewell and pinches out into the bathyal Hamlet mudstone (Olbinski, 1983; Nelson, 1985). The structural high appears also to have controlled dispersal of the Cowlitz in southwest Washington, as Wells (1981) reports a similar sandstone pinchout at the same longitude. Bruer and others (1984) show that the Cowlitz Formation (Clark and Wilson sandstone) unconformably onlaps the high and is, in turn, truncated by the overlying Keasey Formation, which commonly acts as a seal at Mist. The Cowlitz in the Astoria basin does not have as good reservoir potential as it has in the north Willamette basin because the arkosic sandstone is thinner, contains more diagenetic clay, and has lower permeabilities than in the Mist area (average permeability in the Astoria basin is 79 millidarcies [rind] compared to 200 md in the Mist field [Armentrout and Suek, 1985]). Less promising but deeper reservoir targets are the shallow-marine lithic arkosic sandstones of the Sunset Highway member of the Hamlet formation. However, these sandstones are thinner and less permeable (30 md) than the Cowlitz sandstone and appear to be more restricted to the southeast part of the basin.

Other units that could act as reservoirs (i.e., porosities 16.8 to 39.7 percent; permeabilities 13.8 to 1,262 md) either are breached by erosion or not buried deeply enough (e.g., Gnat Creek formation and Angora Peak and Youngs Bay members of the Astoria Formation), are too thin and discontinuous (e.g., feldspathic sandstones, unit Tscs, in Smuggler Cove formation and Sager Creek formation), pinch out (e.g., Pittsburg Bluff Formation), or have low permeability and effective porosity due to compaction and formation of diagenetic clay rim cements and iron oxides in pore throats. Occlusion of pore space by calcite, zeolites, or smectite-chlorite clays is particularly evident in the basaltic sandstones of the Roy Creek and Sunset Highway members of the Hamlet formation.

However, two members of the Miocene Astoria Formation projected onto the inner continental shelf appear to be attractive offshore targets (Cooper, 1981). These units are the thick, permeable, deltaic to shallow-marine Angora Peak arkosic sandstone (southwest of Cannon Beach) and the highly friable, submarine channel, arkosic sandstones (Tay1 and Tay2) of the Youngs Bay member northwest of Seaside. These units may have been deposited at the mouth of the ancestral Columbia River (Niem, 1976) and Astoria canyon head-fan system (Nelson, 1978; Coryell, 1978). The overlying bathyal Cannon Beach mudstone and encasing Youngs Bay mudstone could act as seals. Structural traps in the offshore area are possible along north-south normal faults and anticlines (Snavely and others, 1977; Johnson and others, 1984), around shale diapirs, and over a seaward projection of a high of Tillamook Volcanics between the Tillamook and Astoria embayments (Wells and others, 1983). Late middle Miocene subduction of thermally mature Hoh mélange beneath this forearc sequence on the inner continental shelf could allow oil and wet gas to migrate upward into structural and stratigraphic traps (Snavely, in preparation; Snavely and Wells, 1984).

Some arkosic sandstones of the Northrup Creek formation (Tns) and the thick, shallow-marine permeable Wickiup Mountain sandstone of the Astoria Formation (270 md; Cooper, 1981) could be low-priority reservoir targets for exploration in the northernmost part of the map area if suitable updip stratigraphic pinchouts or fault traps can be defined seismically in this homoclinal sequence.

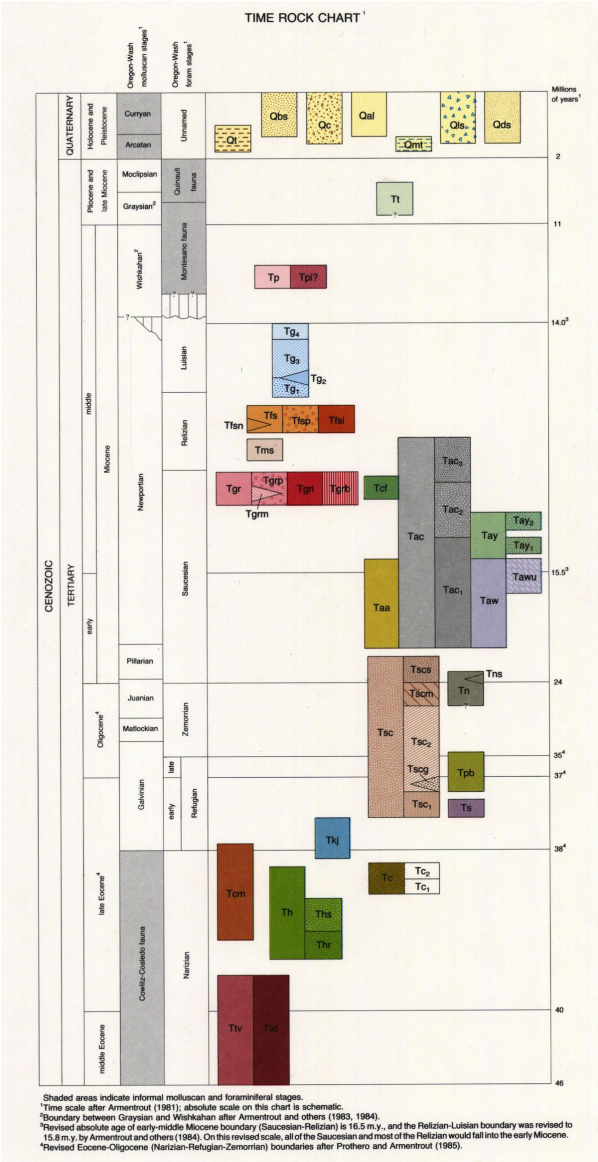
Thick, bathyal mudstones and some carbonaceous sandstones of the Cowlitz Formation; the Hamlet, Sager Creek, Northrup Creek, and Smuggler Cove formations; and Cannon Beach and Youngs Bay members of the Astoria Formation are marginal to adequate gas-prone source rocks. Although the total organic carbon (TOC) levels in these units are fair to high (ay. 1.1 percent; 84 well and surface samples), visual kerogen is primarily gas-prone terrestrial organic matter—mainly structured woody debris, vitrinite, amorphous matter, and some exinite (alginite). Hydrogen indices and genetic potentials (Si + S2; see Law and others, 1984) are low, and oxygen indices are commonly high (100), also suggesting that the organic matter is generally oxidized type-III kerogen, which is typically low yielding, gas prone, and hydrogen deficient (Tissot and Welte, 1978). The Jewell member of the Keasey Formation, the Pittsburg Bluff Formation, and the Wickiup Mountain member of the Astoria Formation are poor to fair source rocks because of marginal amounts of total organic carbon (ay. 0.62 percent; 84 samples). In addition, all these units are generally thermally immature (ay. Ro = 0.42 percent; 38 well and surface samples, generally Ro 0.55 percent). Geochemical analysis indicates that the Watson oil seep near Olney is likely a man-made dump of biodegraded, southern California asphaltic crude oil related to early 20th century logging operations (Murphy, 1981; Niem, unpublished information, 1978, 1984). In summary, these rocks are likely sources only for biogenic methane or early diagenetic gas but not oil (Tissot and Welte, 1978). However, the area is riddled with middle Miocene and upper Eocene intrusions that have thermally matured to supermatured these rocks for tens to hundreds of feet (R0 = 0.95 to 2.36 percent; ay. 1.8 percent; six samples), thereby creating possible sources for thermogenic gas. One well with a thick gabbroic sill (Crown Zellerbach 31-17 well) has significant concentrations of ethane and propane in addition to methane (i.e., approx. Ci/[C2 + C3] ratios 15 from calibrated gas chromatographs on mud log), suggesting a thermogenic effect. Thermogenic dry gas has also been reported by Armentrout and Suek (1985) in the Mist gas field.

The Astoria basin occurs in a major zone of distributed shear between the Tillamook Volcanics on the south, which show 45° of clockwise rotation (Magill and others, 1981; Nelson, 1985), and upper Eocene volcanic rocks in southwest Washington, which have undergone considerably less rotation (23°; Wells and Coe, 1985). The basin is broken by an extensive network of conjugate northwest-trending right-lateral and northeast-trending left-lateral oblique-slip faults and older major east-west oblique-slip faults that could produce fault traps. The faults, many with subhorizontal slickensides, show tens to hundreds of feet of horizontal and vertical separation, as indicated by offsets of middle Miocene dikes (piercing points; Nelson, 1985) and juxtaposition of volcanic and sedimentary units. The northwest- and northeast-trending faults and a few associated small east-west thrust faults (Nelson, 1985) reflect late middle Miocene north-south compression and wrench-fault tectonics. In the southeast corner of the map, U.S. Highway 26 traverses the length of a small pull-apart depression between a highly faulted, uplifted block of Tillamook Volcanics on the north and the main mass of Tillamook Volcanics to the south. The style and intensity of basement faulting in this area approximates the faulting in the subsurface in the Mist gas field. The major high-angle east-west faults, with shear zones as much as 100 ft wide, show greater separation of upper Eocene units and volcanic basement than of Miocene volcanics and strata, suggesting that the faults were initiated in the late Eocene (perhaps as dip-slip faults) and reactivated in the late middle Miocene as left-lateral (?) oblique-slip faults. Three major middle Miocene dikes were intruded along northeast-trending faults (?) in eastern Clatsop County. Some dikes, however, parallel the conjugate northeast-and northwest-trending joint pattern that is well developed in the middle Miocene breccias and pillow lavas. A few faults are truncated by late Eocene or Miocene unconformities. The unconformities along with sandstone pinchouts and truncations by submarine channel-fills could act as stratigraphic traps.

Folds are rare; those that are recognized are broken by extensive faulting and intrusions, creating a myriad of dip directions and juxtaposed rock units. Some northwest-trending en echelon folds are associated with the major east-west oblique-slip faults. All the mapped folds have limited closure.

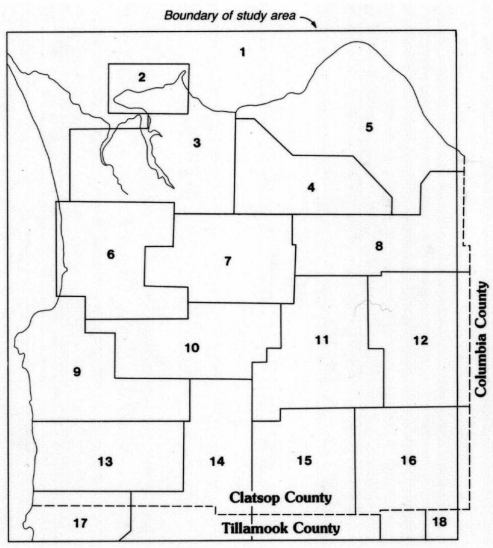
Extracted from: (Astoria Basin).

Astoria Basin Time Rock Chart



Extracted from: (Astoria Basin).

Astoria Basin Index to Geologic Mapping



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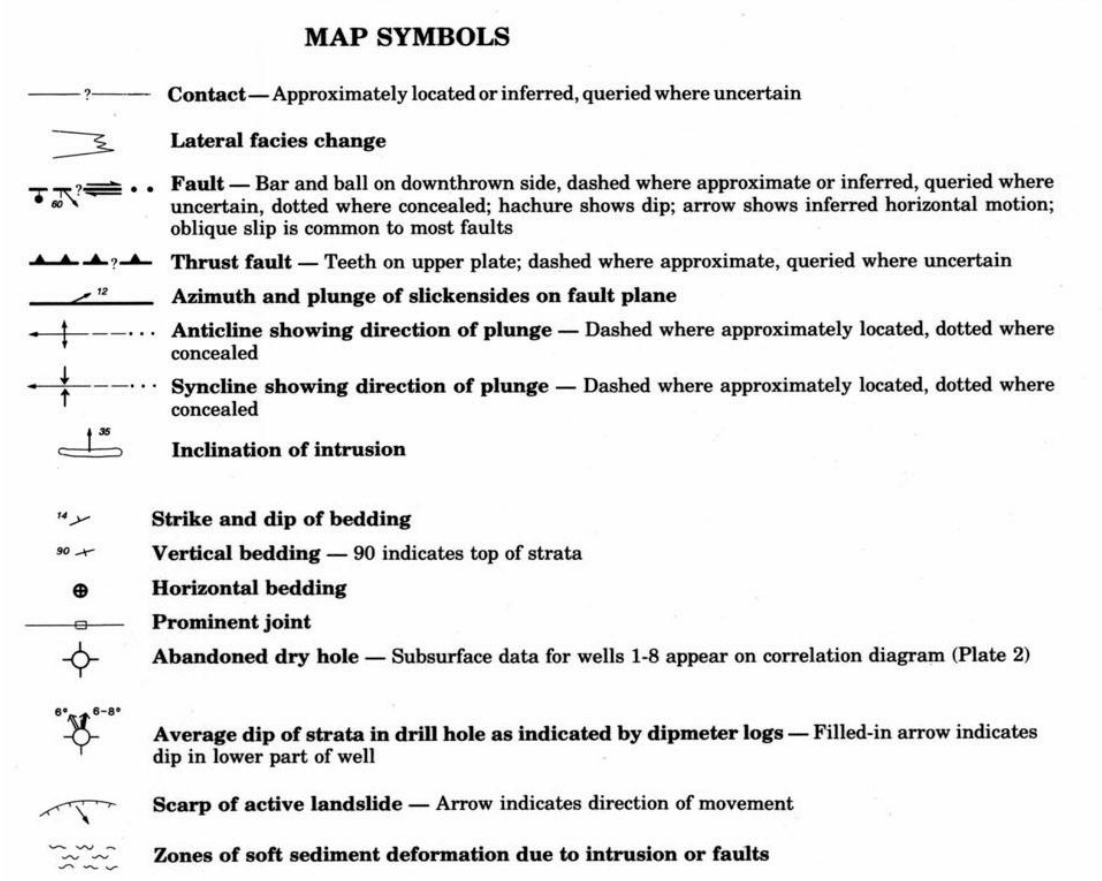
1. A.R. Niem, reconnaissance field mapping, 1983-1984; assisted by W. Niem and M. Kadri; intermittent field visits with graduate students, 1972-1983

Map compiled from following sources (with modifications):

2. Carter, J.W., 1976
3. Nelson, M.P., 1978
4. Coryell, G.F., 1978
5. Murphy, T.M., 1981
6. Tolson, P.M., 1976
7. Peterson, C.P., 1984
8. Goalen, J.S., in preparation
9. Neel, R.H., 1976
10. Penoyer, P.E., 1977
11. Nelson, D.E., 1985
12. Olbinski, J.S., 1983
13. Smith, T.N., 1975
14. Rarey, P.J., in preparation
15. Mumford, D.F., in preparation
16. Safley, L.E., in preparation
17. Cressy, F.B., Jr., 1974
18. Jackson, M., 1983
19. Other maps not shown:
    a) Schlicker, H.G., and others, 1972, and Beaulieu, J.D., 1973, for Quaternary deposits
    b) Snavely, P.D., Jr., 1960's, and Wells, R.E., current mapping, U.S. Geological Survey, unpublished reconnaissance geology, northwest Tillamook County and southernmost Clatsop County
    c) Cooper, D.M., 1981, geologic map of Astoria Formation

Extracted from: (Astoria Basin).

Astoria Basin Map Symbols



Extracted from: (Astoria Basin).

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Extracted from: (Astoria Basin).

Cape Disappointment

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Cape Disappointment Report

Introduction

The Cape Disappointment-Naselle River area is in southwestern Washington at the mouth of the Columbia River. The area encompasses several major estuaries and their adjacent highlands, which reach elevations of about 2,000 feet. Rainfall is abundant and produces heavy vegetation and deep weathering of the bedrock. Natural bedrock exposures are restricted to stream courses along larger drainages, although a network of logging roads provides excellent access to most of the area and widespread, but somewhat ephemeral, exposures of bedrock.

Published geologic mapping in the area includes a sketch map of southwest Washington geology in Weaver's 1937 monograph on the stratigraphy and paleontology of western Washington. Proprietary oil-company mapping that was published on the state geologic map (Huntting and others, 1961) also covers the area. Detailed geologic maps that cover stratigraphic sequences similar to those found in the Cape Disappointment Naselle River area are available for adjacent quadrangles (Wolfe and McKee, 1968, 1972; Wagner, 1967a, b) and nearby areas (Pease and Hoover, 1957; Snavely and others, 1958; Gower and Pease, 1965; Livingston, 1966; and Wells, 1981).

The primary purpose of this investigation is to provide a geologic tie between known geology on land and offshore seismic reflection lines that were run by the U.S. Geological Survey (Snavely and Wagner, 1982; Snavely, 1987). Major goals of this project included (1) the correlation of coastal exposures of deep-water marine Tertiary strata with well-defined stratigraphy elsewhere in the Coast Range and (2) the definition of major structures along this segment of an active convergent margin. The author spent approximately six months mapping the area during the summers of 1975 to 1977 and published a preliminary open-file report in 1979 (Wells, 1979). Weldon W. Rau of the Washington State Division of Geology and Earth Resources made the foraminiferal determinations and Warren D. Addicott and Ellen J. Moore of the U.S. Geological Survey made the megafossil identifications and correlations. Jorge Rodreguez and Chris Hathon provided able field assistance during the summers of 1976 and 1977. Insightful discussions about Coast Range stratigraphy with Parke Snavely, Jr., Allan Niem, and Weldon Rau are gratefully acknowledged.

General Geology

The Cape Disappointment-Naselle River area of southwest Washington lies along the westernmost exposed edge of the central Washington and Oregon Coast Range. The Coast Range consists of the exposed part of a Tertiary forearc basin that extends offshore and lies within an active convergent margin. Nearly 7 km of deep-water marine strata are exposed in northwest-trending, westward-vergent anticlinal uplifts in the map area. An outline of the stratigraphy of these rocks is included below and in the map description. Additional stratigraphic and petrographic information for correlative rocks is available in Wolfe and McKee (1972).

The oldest rocks in southwest Washington crop out in the cores of the anticlinal uplifts and are referred to the Crescent Formation, here considered to be of early and middle Eocene age. Pease and Hoover (1957) and Wolfe and McKee (1968, 1972) suggest the Crescent may locally extend into the upper Eocene, but four new radiometric dates from lavas in the upper part of the Crescent Formation in the Willapa Hills average about 49 Ma, and five dates from the Black Hills average about 54 Ma (Duncan, 1982). The late Eocene ages may be derived from microfossil assemblages collected from interbeds in basalt sill complexes that postdate Crescent volcanism (compare Pease and Hoover, 1957, and Wells, 1981) and may partly be a relict of earlier correlation schemes for benthic forminifers (see Rau 1981). The Crescent Formation consists primarily of sub marine-pillowed, columnar-jointed, and massive basalt flows. The basalt is chemically similar to those erupted in oceanic tectonic regimes (Snavely and others, 1968; Wolfe and McKee, 1972), and it is thought to represent either oceanic crust and seamounts accreted to the continental margin during the early and middle Eocene, or possibly the product of a continental margin-rifting episode (see Wells and others, 1984, for a summary of models). In the Cape Disappointment-Naselle River area, volcanism may have continued locally (possibly after a brief hiatus) during deposition of the overlying, continentally derived micaceous sandstone. Basalt lapilli breccia and pillow basalt flows interbedded with the sandstone are mapped separately from the Crescent Formation in this report and are called the basalt lapilli breccia (**Tbr**) and flows (**Tbf**) at Fort Columbia, after the good exposures at that locality. These breccias are probably correlative with breccias and flows near the top of the Crescent that are mapped elsewhere in southwest Washington, (Wagner, 1967a, b; Henriksen, 1956; Wells, 1981).

Deep-water marine sedimentary rocks overlying the pillow basalt basement range in age from middle Eocene to middle Miocene and consist primarily of thin-bedded, laminated tuffaceous siltstones and lesser amounts of sandstone, deposited primarily in outer shelf and slope environments. The oldest sedimentary unit is the middle Eocene sandstone at Megler (unit **Tsm**), named for exposures at the Megler rest stop, about 1.6 km east of the north end of the Astoria bridge. This unit consists of thin to thick, locally rhythmically bedded, micaceous feldspathic sandstone and lesser interbedded siltstone. Graded bedding and sole markings such as flute and groove casts suggest a turbidite on-gin for these rocks, although trough cross lamination occurs in some places. Indurated, thin-bedded, tuffaceous, deep-water marine siltstone units unconformably overlie the sandstone at Megler and are locally exposed along U.S. Highway 101 east of the Astoria bridge. They include the late (?) and middle Eocene siltstone at Cliff Point (unit **Tcp**), in part correlative to the tuffaceous upper part of the Mcintosh Formation of Wagner (1967a, b), and the siltstone and sandstone at Omeara Point (unit **Top**) and the siltstone of Shoalwater Bay (unit **Tsb**), both of late middle and late Eocene age, which are deep-water correlatives to the coal-bearing, shallow-water marine Cowlitz Formation near Longview, Washington.

A regional unconformity occurs at the base of the overlying late Eocene to early Miocene Lincoln Creek Formation, as it does elsewhere in the Washington Coast Range. A micaceous, feldspathic, and locally glauconitic sandstone, the sandstone unit at Knappton (**Tick**), occurs near the base of the unit and is probably a deep-water correlative of shallow-water sandstone described 40 km to the east of the map area near Cathlamet, Washington (Wells, 1981). The majority of the Lincoln Creek

Formation in the map area consists of very tuffaceous siltstone containing abundant tuff beds and evidence of large-scale soft-sediment deformation.

Unconformably overlying the Lincoln Creek Formation is the early and middle Miocene Naselle unit of the Astoria Formation. It consists mostly of massive to poorly bedded, abundantly micaceous, carbonaceous, tuffaceous sandy siltstone and feldspathic sandstone and is correlative in part to the Wickiup Mountain unit of the Astoria Formation in Oregon (Niem and Niem, 1985). Overlying the Naselle unit with a local unconformity is the middle Miocene Bald Ridge unit of the Astoria Formation, which crops out along the axis of the Naselle syncline. The Bald Ridge unit consists primarily of thin-bedded and laminated, abundantly micaceous and carbonaceous siltstone and sandstone. Micaceous feldspathic sandstone also forms large channel fills and abundant sandstone dikes. This unit is probably correlative to the Youngs Bay unit of the Astoria Formation in northwest Oregon (Niem and Niem, 1985).

Middle Miocene basalt forms sills and dikes intruding all of the sedimentary rock units. They are petrographically, chemically, and paleomagnetically similar to the Grande Ronde Basalt and the Pomona Member of the Saddle Mountains Basalt (both of the Columbia River Basalt Group), which are exposed as flows 40 km to the east of the map area at Cathlamet. The two largest intrusive bodies are each several hundred meters thick and are composed of basalt (unit Tib) of Grande Ronde chemistry at Bear River Ridge (Depoe Bay Basalt of Snavely and others, 1973) and olivine basalt (unit Tiob) of Pomona chemistry at Radar Ridge* (basalt of Pack Sack Lookout of Snavely and others, 1973). Both sills are intruded at or near the late Eocene angular unconformity at the base of the Lincoln Creek Formation. The downstream location of the sills and their close proximity to westward-moving flows of the Columbia River Basalt Group, which have identical characteristics, suggests that these intrusive bodies are actually the distal remnants of invasive flows that shouldered aside the less lithified marine sediments above the unconformity. Apparent invasive relations also occur in northwest Oregon (Beeson and others, 1979; Niem and Niem, 1985).

Structure

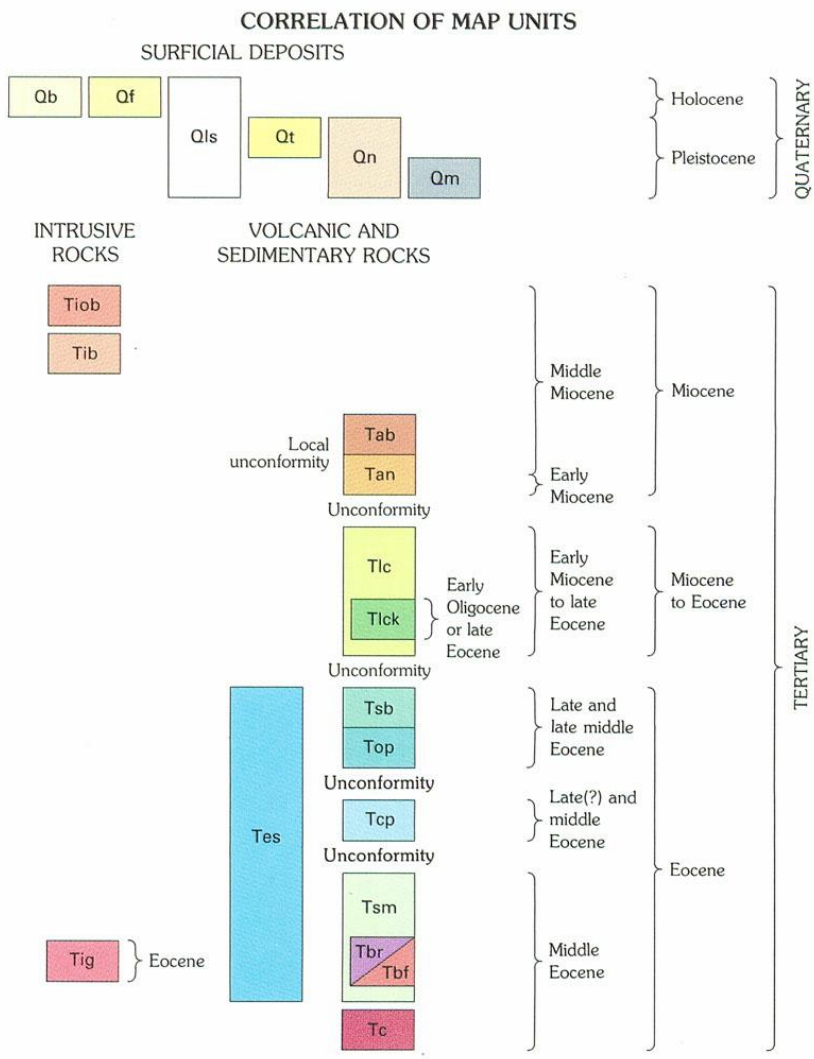
Southwest Washington lies in the middle of a Cenozoic forearc region and has under gone several deformations. The major structures consist of north- to northwest-trending basement uplifts that expose the oceanic basalt basement of the Crescent Formation in their centers. The uplifts are generally asymmetric, seaward-verging anticlinoria with over- steepened west limbs. Four of these complexly faulted and folded uplifts occur in the Cape Disappointment area. Fold axes in the Crescent Formation and in the overlying sandstone at Megler are more north-trending than those in unconformably overlying rocks and suggest that a folding episode occurred during late middle Eocene time. Sub sequent folding along more northwesterly trends has affected rocks as young as late middle Miocene (unit **Tiob**). Major reverse faults apparently bound the western margins of the uplifts, and their location is based on observation of the coincidence of sheared rock, steep dips, and major topographic linears. The Fort Columbia fault and the Naselle Nemah River fault also have dramatic aeromagnetic expression (U.S. Geological Survey, 1984). Because of poor exposures, most faults are inferred, based on lack of correlation of stratigraphy and structure across topographic lineaments.

The Cape Disappointment area has also undergone significant clockwise tectonic rotation, as summarized in Wells and Coe (1985) and Magill and others (1982). The Crescent Formation basement at Cape Disappointment and at Fort Columbia has rotated about 65° clockwise, whereas the Crescent Formation north of the Naselle-Nemah fault has rotated about 20°. These large differential rotations predate the late middle Eocene unconformity and postdate the early folding of the Crescent Formation against the continental margin (Wells and Coe, 1985). Subsequent post-middle Miocene clockwise rotations of at least 16° have affected most of the Cape Disappointment-Naselle

River area (Magill and others, 1982; R.E. Wells, unpublished data, 1982). Northeastward oblique convergence and the subduction of a sedimentary accretionary wedge beneath the frontal forearc may have facilitated the tectonic rotations (Wells and Coe, 1985). The possibility of thermally mature sedimentary rocks in the accretionary wedge thrust beneath the forearc sequence may have significant implications for renewed petroleum exploration in the area (Snavely and Wagner, 1982; Snavely, 1987). The three dry holes drilled in the area have all been located on Crescent basalt basement structures and have been relatively shallow holes. New targets may exist beneath an inferred basal thrust or in upper plate sandstones, such as the sandstone of Megler, immediately above such a thrust.

Extracted from: (Cape_Disappointment).

Cape Disappointment Correlation of Map Units



Extracted from: (Cape_Disappointment).

Cape Disappointment Map Location

Extracted from: (Cape_Disappointment).

Cape Disappointment Symbols

CONTACT—Approximately located or inferred. Dotted where concealed; queried where uncertain

U 70 D FAULT—Approximately located or inferred. Dotted where concealed; queried where uncertain. Dip shown where known. U, upthrown side; D, downthrown side; arrows show sense of strike-slip motion. Faults located on the basis of shear zones, juxtaposed blocks of strata that have dissimilar strikes and dips, and (or) topographic lineations

THRUST FAULT—Approximately located or inferred. Sawteeth on upper plate

FOLDS—Showing inferred trace of axial plane and direction of plunge. Dotted where concealed

Anticline

Syncline

STRIKE AND DIP OF BEDS—Attitudes along river beds and on coastal wave-cut platform were measured on bedrock that is intermittently exposed

13 Inclined

88 Overturned

Horizontal

Vertical

35 STRIKE AND DIP OF FOLIATION

HORIZON CONTAINING ABUNDANT GLAUCONITE

ZONE OF MAXIMUM ALTERATION AND BAKING OF SEDIMENTARY ROCKS ADJACENT TO MIOCENE BASALT SILLS

DRY HOLE

2103 TD TOTAL DEPTH—In feet

Extracted from: (Cape_Disappointment).

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Exploration Wells

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Many Oregon Department of Geology and Mineral Industries publications including Oil and Gas Investigations 14 are available for purchase through Nature of the Northwest Information Center web site: http://www.naturenw.org

Exploration Wells Report and Chart

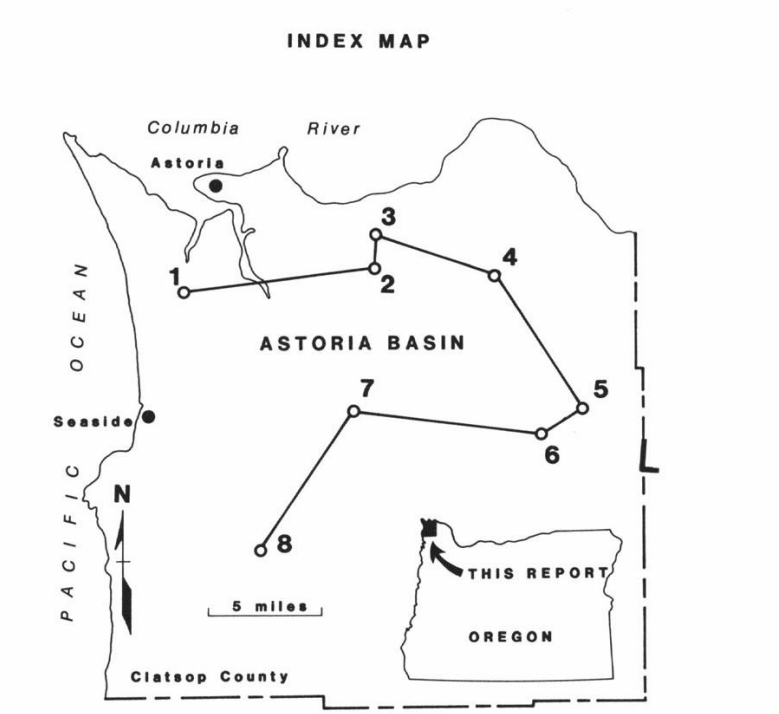
Explanatory text for Plate 2 of DOGAMI Oil and Gas Investigation 14 is available as a separate PDF document ExpWells_Report_OGI_14_02

Plate 2 is a diagram showing the correlations of Oil and Gas exploration wells found in the Astoria Basin, Oregon, and is available as a separate PDF document.ExpWell_Correlation_OGI_14_02

Extracted from: (Exploration_Wells).

Exploration Wells Location

Index map for Exploration Wells locations.



Extracted from: (Exploration_Wells).

Exploration Wells Table

Table of Oil and Gas Exploration Wells Drilled in the Astoria Basin

Well No.	Company	Well name	Total Depth (ft)
1	Standard Oil Co. of Calif.	Hoagland No. 1	7101
2	Oregon Natural Gas Development	Patton 32-9	10159
3	Oregon Natural Gas Development	Johnson 33-33	10006
4	Diamond Shamrock	Boise Cascade 11-14	7864
5	Diamond Shamrock	Clatsop County 33-11	4219
6	Quintana Petroleum	Watzek 30-1	7069
7	Diamond Shamrock	Crown Zellerbach 31-17	6096
8	Diamond Shamrock	Crown Zellerbach 11-28	5700

9	Diamond Shamrock	Watzek 22-19	5190
10	Lower Columbia Oil Co.	Brown No. 1	4806
11	Nehama Weagant Energy Corporation	Jewell 1-23	3190

(Exploration Wells).

OGDC Release 5

Ma, L., Madin, I.P., Olson, K.V., Watzig, R.J., Wells, R.E., Niem, A.R., and Priest, G.R., 2009, Oregon Geologic Data Compilation (OGDC) - Release 5, Oregon Department of Geology and Mineral Industries, Portland, OR. (*GRI Source Map ID 75206*).

The Oregon Department of Geology & Mineral Industries (DOGAMI) has compiled a statewide geologic map. This effort brings together the best available geologic mapping and data from all relevant published and unpublished geologic mapping from state and federal agencies, university thesis work, and other documents. Many DOGAMI publications including the GIS data compilation, Oregon Geologic Data Compilation Release 5 (OGDC v5), is available for purchase through Nature of the Northwest Information Center web site: http://www.naturenw.org

GRI Digital Data Credits

This document was developed and completed by Greg Mack (NPS Pacific West Office, Seattle) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Ron Karpilo (Colorado State University).

The information contained here was compiled to accompany the digital geologic-GIS map(s) and other digital data for Lewis and Clark National Historical Park, Oregon and Washington (LEWI) developed by Greg Mack (NPS Pacific West Office, Seattle) using source data (see the GRI Source Map Citations section of this document for all sources used by the GRI in the completion of this map). Quality control of GRI digital geologic-GIS data by Ron Karpilo.

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