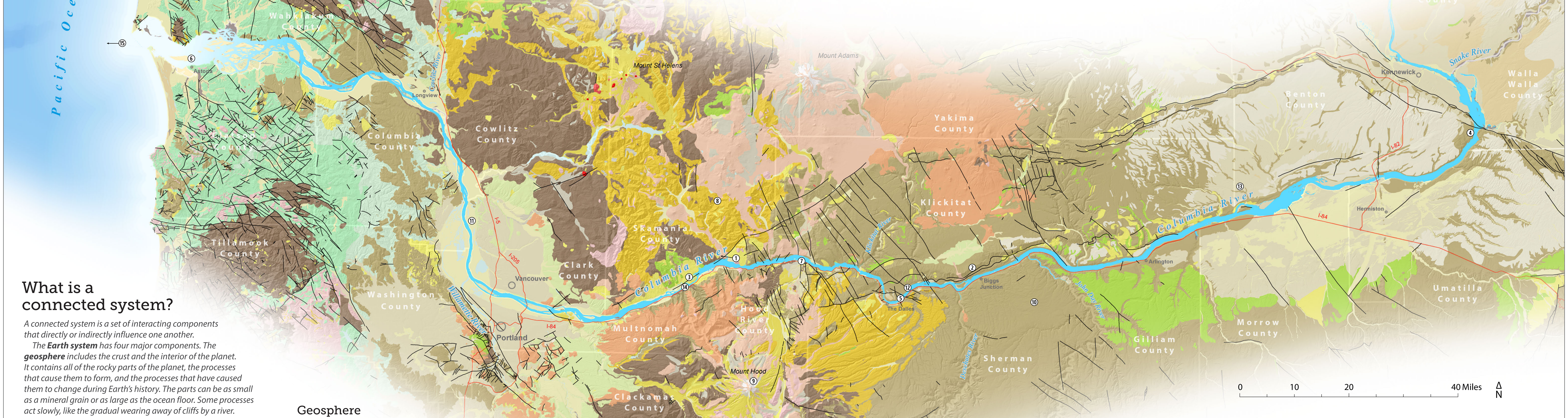
The Connected Systems of the Columbia River on the Oregon-Washington Border

The Columbia River, in its 309-mile course along the Oregon-Washington border, provides a rich and varied environment for the people, wildlife, and plants living and interacting there. The area's geology is the basis for the landscape and ecosystems we know today. By deepening our understanding of interactions of Earth systems — geosphere, hydrosphere, atmosphere, and biosphere — Earth science helps us manage our greatest challenges and make the most of vital opportunities.



What is a connected system?

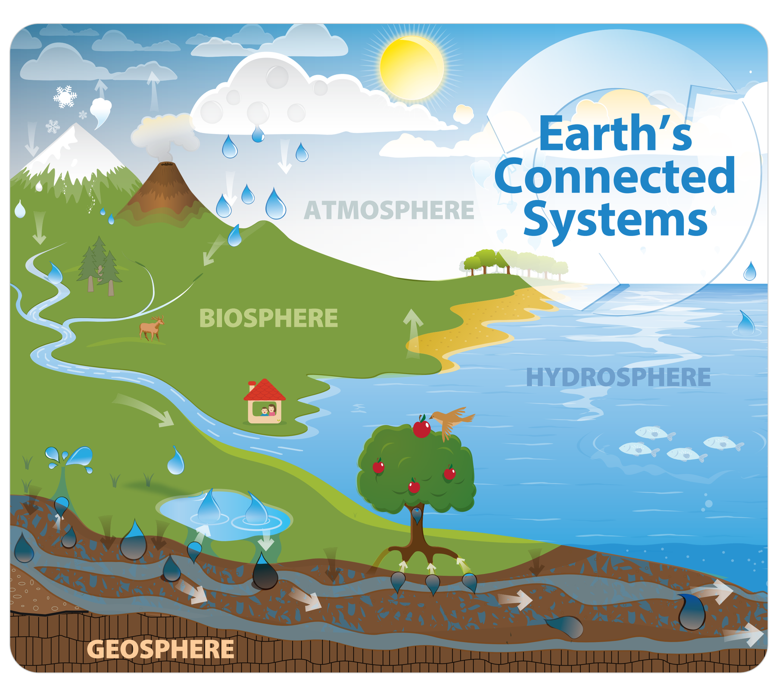
A connected system is a set of interacting components that directly or indirectly influence one another.

*The **Earth system** has four major components. The **geosphere** includes the crust and the interior of the planet. It contains all of the rocky parts of the planet, the processes that cause them to form, and the processes that have caused them to change during Earth's history. The parts can be as small as a mineral grain or as large as the ocean floor. Some processes act slowly, like the gradual wearing away of cliffs by a river. Others are more dramatic, like the violent release of gases and magma during a volcanic eruption.*

*The fluid spheres are the liquid and gas parts of the Earth system. The **atmosphere** includes the mixture of gases that surrounds the Earth. The **hydrosphere** includes the planet's water system. Its parts include oceans, lakes, rivers, and frozen water in glaciers. A special property of the fluid spheres is that their materials flow. Processes in the fluid spheres include the water cycle, the circulation of the atmosphere and oceans, and weather.*

*The **biosphere** contains the living and once-living parts of the Earth system. It is organized into complex webs of micro-organisms, animals, and plants. Processes vary from simple predator-prey relationships to changes over millions of years in the kinds of living things that make up communities.*

The interactions of these systems along the Columbia River can be dramatic and damaging: basalts spill out and build layers of rock, floods race down the river channel destroying everything in their path, volcanoes spew lava, ash and gases, earthquakes and erosion cause landslides. The interactions can also be beneficial: plants grow in weathered and deposited soils, winds and water produce electrical power, wetlands shelter birds and other life, and the river provides transportation and recreational opportunities.



Examples of the role of geology in Earth's connected systems along the Columbia River

① The town of Carson, located at the mouth of the Wind River, a tributary of the Columbia River, sits on **basaltic lava** that flowed down the valley about 340,000 years ago and blocked the ancestral Columbia River for a short period of time.

② Much of the Columbia River flows over and erodes into a thick pile of up to **300 individual 17–6 million year old basaltic lava flows** deposited over much of Washington, Oregon, Idaho, and into Nevada. Much of the erosion of the basalt occurred during the last glaciation, where numerous ice-dammed lakes repeatedly failed, sending catastrophic floods along the Columbia River's path. The rich soils that make up the Willamette River Valley were carried downstream by these floods.

③ Many of the slopes along the north bank of the Columbia River Gorge contain large landslides, including the **Bonneville landslide**, located a few miles west of Stevenson, Washington. According to native legend of the Klickitat people, the landslide (area shown in orange) initially blocked the Columbia River, creating a natural dam that filled almost 4 miles of the river. The Tribe called this dam the Bridge of the Gods. The earthen dam eventually failed, and the river continues to return to its previous course. A steel bridge was built nearby with the same name.

④ **Wallula Gap:** Wallula Gap marks the narrow opening where two ancestral rivers—the Snake and the Columbia—combined during folding and tilting of flood basalts, and subsequently widened during Missoula glacial floods. Before the peninsula was flooded behind McNary Dam, it was a stopping point for the Lewis and Clark expedition, then the site of a Hudson's Bay trading post, and later Fort Walla Walla.

Geosphere

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Hydrosphere

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⑤ The Columbia River's heavy flow makes it ideal for generating electricity. Collectively, 14 hydroelectric dams on the Columbia River in Oregon, Washington, and British Columbia are the foundation of the Pacific Northwest's power supply. Dams also provide flood control and irrigation, and aid in shipping navigation. **The Dalles Dam** is almost 9,000 feet long, and with 22 turbines, it is one of the top ten hydropower dams in the United States. Because dams block salmon migrations, fish ladders have been installed in many of the lower Columbia River dams.

⑥ Oregon and Washington are connected by 16 bridges that allow shipping and travel across the Columbia River. The **Astoria-Megler Bridge**, at 4.1 miles long, is the longest truss bridge in North America, with annual daily traffic of 23,300 vehicles. Large earthquakes can cause bridge collapse and block waterway access to industry and population centers.

⑦ Since the damming of the Columbia River, deltas (fan-shaped deposits of sediment) began reforming at the mouths of its tributaries. The **Hood River Delta** grew significantly after a debris flow—a rapidly moving destructive landslide—during a winter storm in 2007. This delta also receives large pulses of sediment due to outburst flooding from receding glaciers on Mount Hood.

⑧ About 90 dramatic and scenic waterfalls, including Oneonta Gorge and Horsetail, Multnomah, Wahkeena, and Bridal Veil Falls, can be found flowing over steep cliffs of basalt along the south side of Columbia River Gorge. The northern side of the Gorge contains fewer and smaller waterfalls because that side has been modified by numerous landslides. **Panther Creek Falls**, located a few miles north of the town of Carson, is one of several waterfalls on the northern side.

⑨ Nearly every year, the air within the Columbia River Gorge is thickened by the smoke of nearby forest fires. The eastern flank of Mount Hood was struck by lightning in the summer of 2008, causing the **Gnarl Ridge fire**.

Atmosphere

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⑩ Some of the highest wind speeds in Washington and Oregon are in and near the Columbia River Gorge. Created by differences in atmospheric pressure east and west of the Cascades, the wind is harnessed to produce electricity using **wind turbines**. Both Oregon and Washington have wind turbine farms near the Gorge, and both rate among the top ten states with wind turbine installations. The wind also provides excellent windsurfing.

Biosphere

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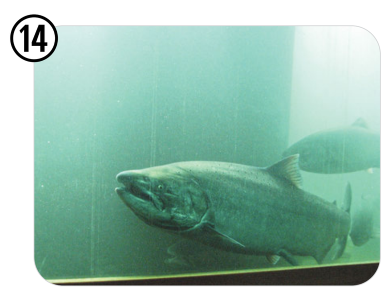
⑭ 

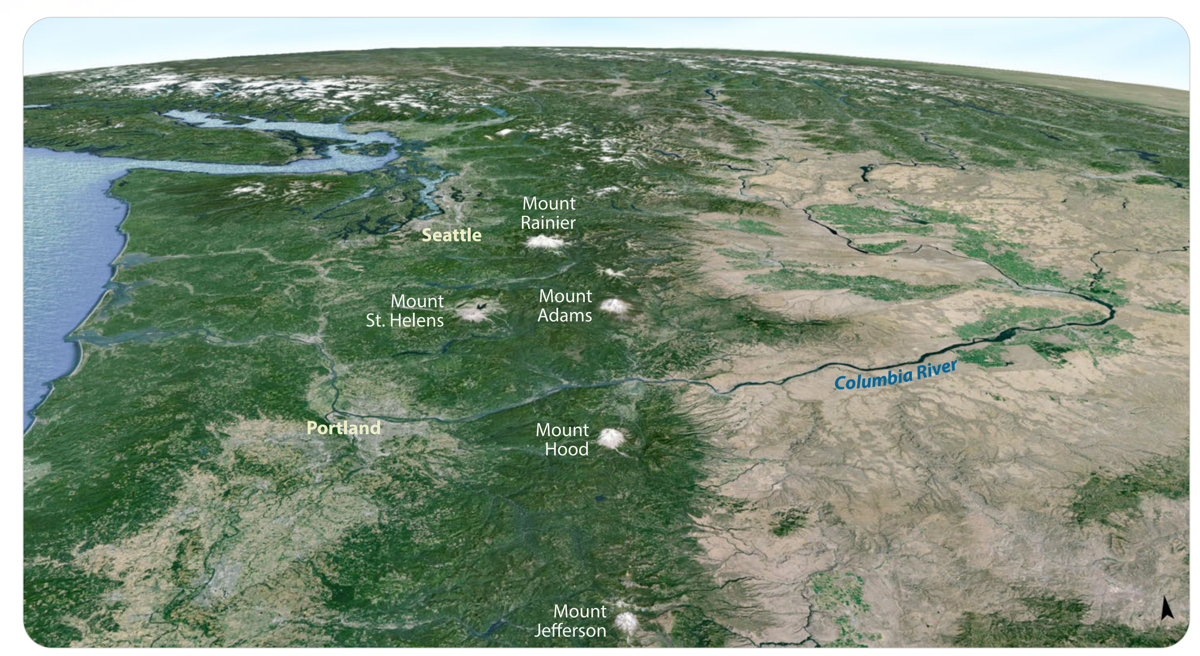
⑪ Along its length, the Columbia River ecosystem ranges between temperate rainforest and dry grassland. Diverse landforms and microclimates along the river host many kinds of plants as well as permanent and migratory fish and wildlife, although climate change, human activities, and invasive species are endangering native species. The wetlands at Ridgefield National Wildlife Refuge provide habitat for animals and waterfowl like this **great blue heron**.

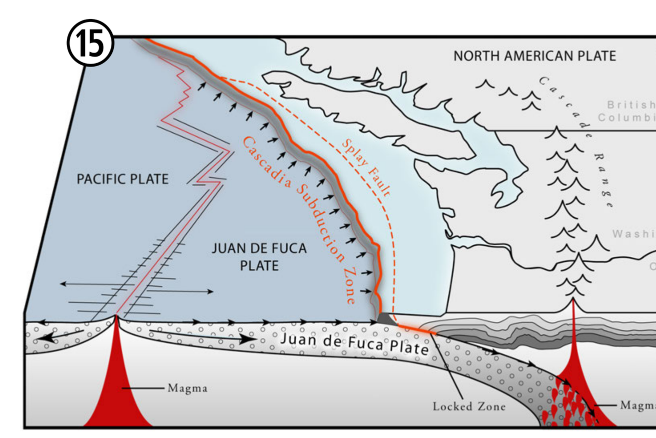
⑫ Tribal peoples, attracted by salmon and trade, historically migrated along the Columbia River. Left behind on the basalt are about 90 art sites containing paintings and carvings, called **pictographs and petroglyphs**. About half these ancient stones were rescued before damming of the river covered them with water, and they were carefully brought to the Columbia Hills State Park, north of The Dalles.

⑬ The lava flows surrounding the Columbia River Gorge produce, dark, fine, and highly fertile soil, and much of the land in this area is dedicated to farming. Because the areas east of the Cascade Mountains, like Kennewick, Washington, are dry, farmers plant **crops in circles** and use a center-pivot system for irrigation.

⑭ From March to October, Chinook, Coho, Sockeye, and Steelhead **salmon** return to the Columbia River and its tributaries to spawn where they hatched. To migrate upstream, these and many thousands of other fish must pass through manmade locks and dams.

What role does plate tectonics play?



⑮ 

⑮ **Plate tectonics** is a theory that explains many of the large-scale geologic processes we see around us. In the Pacific Northwest, as new magma wells up between the Pacific plate and the Juan de Fuca plate, the Juan de Fuca plate slides (subducts) under the North American plate. Stresses that build up from the movement are relieved by earthquakes all along the Cascadia subduction zone. As the subducting plate plunges deeper, the hot, more buoyant, and viscous magma travels up to create the line of snow-topped stratovolcanoes that make up the Cascade Range. The Columbia River Gorge cuts through this range. To the east of the Cascades, crustal extension and movement of a mantle plume beneath the Yellowstone hot spot cause more earthquakes and volcanic activity. Through all these mechanisms, plate tectonics continues to shape the landscape.

What is a geologic map?

Geologic maps show what kinds of rocks and structures make up a landscape. The geologic makeup of an area can strongly influence the kinds of soils, water resources, flora and fauna, and hazards in an area: the connected systems. That's why it's important to create and to understand geologic maps. The impact of geology on the connected systems of the Columbia River at a few specific locations is described on this poster. These examples are just a few of the many influences of geology in this area. What others can you think of?

Geologic Units

Unconsolidated Sediments
- Holocene dune sand
- Quaternary alluvium
- Quaternary mass-wasting deposits
- Quaternary loess
- Pleistocene outburst-flood deposits
- Pleistocene alpine glacial drift

Sedimentary Rocks and Deposits
- Quaternary–Tertiary continental sedimentary rocks and deposits
- Tertiary continental sedimentary rocks
- Tertiary nearshore sedimentary rocks
- Tertiary marine sedimentary rocks

Volcanic Rocks and Deposits
- Quaternary volcanic rocks
- Quaternary fragmental volcanic rocks and deposits (includes lahars)
- Quaternary–Tertiary volcanic rocks
- Tertiary volcanic rocks, Columbia River Basalt Group
- Tertiary volcanic rocks
- Tertiary fragmental volcanic rocks

Intrusive Rocks
- Quaternary intrusive rocks
- Quaternary–Tertiary intrusive rocks
- Tertiary intrusive rocks

Other Features
- Glacier and ice fields
- Water
- Fault

Geologic Time

The generalized rock units and ages shown on this map tell a simplified story of the geologic history of this area by arranging the rock units by type and age. This makes it possible to organize rocks mapped by different geologists across the two states into the major kinds of rocks that together have built the Columbia River landscape we see today. Use the time scale below to find the periods associated with the geologic units—this area developed very recently in the Earth's history!

Visit your state's geologic survey website to find more geologic maps.

GEOLOGIC TIME SCALE

EON	ERA	PERIOD			EPOCH	AGE IN MILLIONS OF YEARS BEFORE PRESENT
						Present
Phanerozoic	Cenozoic	Quaternary			Holocene	0.01
					Pleistocene	2.6
		Tertiary	Neogene		Pliocene	5.3
					Miocene	23.0
			Paleogene		Oligocene	33.9
					Eocene	56.0
					Paleocene	66.0
	Mesozoic	Cretaceous				145
		Jurassic				201
		Triassic				252
	Paleozoic	Permian				299
		Carboniferous	Pennsylvanian			323
			Mississippian			359
		Devonian				419
		Silurian				443
		Ordovician				485
		Cambrian				541
Precambrian	Proterozoic					2500
	Archean					4000
	Hadean					4567

Time scale modified from International Commission on Stratigraphy

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

How do Earth systems interact in your part of the state?
What can geologic maps tell you about your area?

For more maps and educational materials:

www.oregongeology.org

www.dnr.wa.gov/geology

WASHINGTON STATE DEPARTMENT OF **Natural Resources**

Celebrating
Earth Science Week 2014
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EARTH SCIENCE WEEK

AASG Association of American State Geologists

CREDITS

Poster
"By deepening our understanding of interactions of Earth systems—geosphere, hydrosphere, atmosphere, and biosphere—Earth science helps us manage our greatest challenges and make the most of vital opportunities" is the American Geosciences Institute Earth Science Week 2014 theme.

Geologic data in Oregon generalized by Lina Ma, Oregon Department of geology and Mineral Industries (DOGAMI), from Oregon geologic data compilation [OGDC], release 5 (statewide) by Lina Ma, Ian P. Madin, Keith V. Olson, Rudie J. Watzig, Ray E. Wells, Alan R. Niem, and George R. Priest (compilers), 2009, and DOGAMI Open-File Report O-12-03, Digital geologic map of the Hood River Valley, Hood River and Wasco Counties, Oregon, by Jason D. McClaughry, Thomas J. Wiley, Richard M. Conrey, Cullen B. Jones, and Kenneth E. Lite, Jr. Geologic data in Washington from Washington State Department of Natural Resources, 1:500,000-scale surface geology GIS data. Cartography by Daniel E. Coe, DOGAMI.
Poster team: Deb Schueller; Alyssa Pratt, Don Haines, Jason McClaughry, Ali Ryan, and Vicki McConnell, DOGAMI; Jessica Czajkowski and Dave Norman, Washington State Department of Natural Resources, Geology Division.
Connected systems text modified from "An Introduction to Earth Systems," http://www.agiweb.org/education/aapg/invest/invest12.html

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Other Imagery
Systems diagram modified from "The Water Cycle for Kids," U.S. Geological Survey General Information Product 146, by Stefanie Neno, Jim Morgan, Gabriele Zanolli, Howard Perlman, and Gerard Gonthier, http://ga.water.usgs.gov/edu/watercycle-kids.html
Cascadia Subduction Zone diagram, Dan Coe, DOGAMI. Satellite imagery of Pacific Northwest made in Google Earth; Image Landsat; Data SIO, NOAA, U.S. Navy, NGA, GEBCO