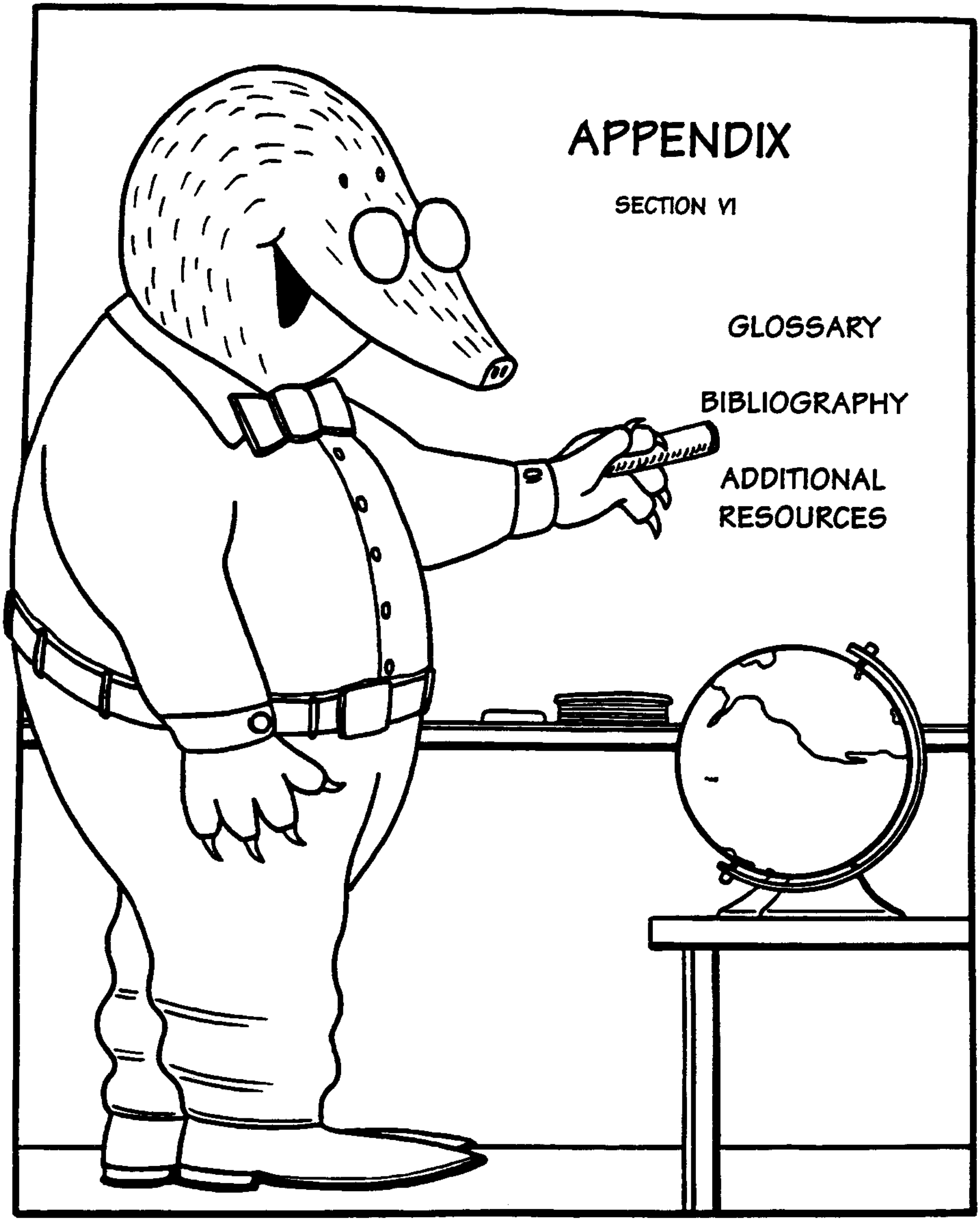
APPENDIX
SECTION VI
GLOSSARY
BIBLIOGRAPHY
ADDITIONAL RESOURCES

GLOSSARY

Section I: INTRODUCTION

customary measures: a system of measurement based on practices long held by people of the English-speaking world. Utilizes such length measures as inches, feet, yards, miles; volume measures such as ounces, pints, quarts, gallons; weight measures such as ounces and pounds as well as measures for area, capacity and dry measure.

electrical energy: a form of energy in which there is a flow of electrons.

energy: the ability to do work, such as making things move and heating them up. Energy can take many forms, including electrical energy, chemical energy, and heat (thermal) energy.

energy conversion: the changing of one form of energy into another form of energy; one of the many examples is heat energy being converted into mechanical energy.

fuel: something consumed to produce energy; examples include wood, coal, gas, oil, nuclear material, food.

geothermal resource: natural heat, hot water, and steam from within the earth; used to make electrical power and for many other applications such as space heating, agriculture, industry, aquaculture, balneology (spas).

heat (thermal) energy: a form of energy possessed by a material because of the motion of its molecules.

mechanical energy: the energy that moves objects or changes their positions.

metric system: the "international measurement language" of science; a decimal system of measurement units (using multiples of ten) based on the meter as a unit of length, the kilogram as a unit of mass, degrees celsius, as a unit of temperature, as well as measures for area, volume and capacity.

nonrenewable resource: resources that are not replaced or regenerated naturally within a period of time that is useful; this includes fossil fuels and minerals.

renewable resource: a resource that can be used continuously without being used up (because it regenerates itself within a useful amount of time).

Section II: EARTH'S NATURAL HEAT

carbon dioxide: a gas produced by the burning of such substances as fossil fuels. It is also contained in large amounts in magma, and is involved in the explosive eruption of volcanoes.

continental drift: the theory that the continents as we know them today may have drifted apart when a supercontinent, Pangaea, broke apart into tectonic plates. Continental drift is thought to be caused mostly by convection currents moving in the mantle below the earth's surface.

convection currents: the currents that are caused by hot air or fluid rising. This occurs because the hot air or fluid is lighter (due to expansion) than its cooler surroundings and so it rises; as it cools it becomes heavier and sinks back down.

core (outer and inner): the extremely hot center of the Earth. The *outer core* is probably liquid rock and is located about 3,200 miles (5,100 kilometers)down from the earth's surface; the *inner core* may be solid iron and is found at the very center of the earth-about 4,000 miles (6,400 kilometers) down.

crust: the solid outermost layer of the earth, ranging from 5 - 35 miles (8 - 56 kilometers) thick.

GLOSSARY Cont.

density: the amount of mass (weight) in a given volume of something. Two objects can be the same size, but have different densities: one of the objects has more mass "packed" into the same amount of space.

earthquake: the vibration or movement of the ground caused by a sudden shift along faults (cracks) in the earth's crust; most earthquakes occur at the places where tectonic plates are pushing against each other.

eruption: the explosive release of material such as molten rock or hot water (as from volcanoes or geysers).

fracture: a crack or fault in rock.

fumarole: a hole (vent) in the earth's surface, found near volcanic areas, from which steam or gases rise.

geothermal reservoir: a large collection of underground water in layers of permeable rock (trapped between layers of impermeable rock), heated by hot rocks and /or magma.

geyser: a natural hot spring that periodically sends up a fountain of water and steam into the air; some geysers "spout" at regular intervals and some are unpredictable.

groundwater: water that collects underground, mostly from surface water that has seeped down.

hot spring: hot mineral water which bubbles up from below to the earth's surface, and collects in pools, or flows into creeks or lakes.

lava: molten magma that has reached the earth's surface.

magma: hot, thick, molten rock found beneath the earth's surface; formed mainly in the mantle.

mantle: the layer of the earth's interior located between the crust and the core; extending down to a depth of about 1800 miles (2,900 kilometers) from the surface.

molten: made liquid by heat.

Pangaea: the huge supercontinent which scientists believe existed 250 million years ago. All of the continents may have at one time been joined together to make this huge land mass.

permeable: able to be penetrated, especially as by liquids or gasses flowing or spreading through; for example, rock with tiny passageways between holes is permeable.

plate tectonics: the forces or conditions that cause the movement of sections of the earth's crust.

porous: full of small holes (pores).

pressure: the force exerted over a certain area (such as pounds per square foot).

sea floor spreading: the process by which the sea floor is being continuously formed and spread apart, resulting in mid-ocean ridges and tectonic plate movement; caused by magma welling up through breaks in the earth's crust.

subduction: the act of one tectonic plate shoving under another tectonic plate.

tectonic plates: (continental and oceanic): large, slowly moving sections of the earth's crust.

volcano: an opening in the earth's crust from which lava, steam, and/or ashes erupt or flow, either continuously or at intervals.

Section III :

USING EARTH'S "LOW" TEMPERATURE HEAT

agriculture: the growing (farming) of plants, flowers, trees, grains, and other crops.

aquaculture: the raising of fish and other water-dwelling organisms (see aqua farmers).

aqua farmers: farmers who raise freshwater and marine organisms under controlled conditions.

balneology: use of bathing in hot spring mineral water for recreation or medical therapy.

corrode: to eat metals away gradually (such as the rusting of iron).

cultivate: to grow and tend (plants or crops).

dehydrate: in the case of fruits and vegetables, to remove moisture in order to preserve.

district heating system: a system that provides heat to a large number of buildings all from a central facility.

drying chamber: a box or drum that uses heat to dry (dehydrate) food or other materials.

geothermal water: water warmed by the natural heat inside the earth.

health spa: an establishment (often commercial) which is visited by guests seeking therapy and relaxation; many center around hot mineral springs.

heat exchanger: a device in which heat is conducted, or "flows", (usually through metal) from a hotter liquid or gas, warming a cooler liquid or gas.

injection well: a long vertical pipe through which used geothermal water is returned to an underground geothermal reservoir.

mineralized: contains minerals; for example, mineralized geothermal water contains dissolved minerals from inside the earth.

pasteurize: to use high temperatures to destroy disease-causing bacteria.

therapeutic: the treatment of disease or other disorder; something that may benefit health.

Section IV :

USING GEOTHERMAL ENERGY AT HIGH TEMPERATURES

acid rain: common name for any precipitation (rain, snow, sleet, hail, fog) having a high amount of sulfuric acid and/or nitric acid or having a pH lower than 5.6. Normal rain has a pH of 5.6 - 5.7. Living organisms generally cannot survive if the pH of their environment is too low or too high. Some noticeable effects of acid rain are found in lakes, rivers, and forests, but all parts of an ecosystem are affected by acid rain, even if it isn't readily apparent.

amperes: the measure of the amount of electric current flowing through a wire at a given time.

biomass (biofuel): in the case of electrical production, substances produced by living organisms and used as a source of fuel (bio = life). One of the best examples is wood.

combustion: a rapid chemical reaction releasing energy in the form of heat and light (fire).

condense: to change from a gas to drops of liquid.

electric current: the continuous flow of electrons; often referred to as electricity.

electron: the smallest part of an atom (atoms are the tiny particles of which all substances are made). Electrons may be freed from atoms to produce an electric current.

generator: a machine which transforms mechanical power into electricity.

global warming: the trapping of heat in the atmosphere, also referred to as the greenhouse effect. Incoming solar radiation goes through the atmosphere to the earth's surface, but outgoing radiation (heat) is absorbed by water vapor, carbon dioxide, and ozone in the atmosphere. At certain levels this is beneficial because it keeps the planet warm enough for life as we know it. However, an increase in the normal amount of particles in the atmosphere (such as carbon dioxide) may contribute to a warming trend that may have serious effects on global climate, the global ecosystem, and food supplies.

groundwater pollution: the contamination of water in natural underground reservoirs. Many populated areas depend on these reservoirs for their water supplies.

GLOSSARY Cont.

Library of Alexandria: a great center for learning; located on the Mediterranean coast in the city of Alexandria, Egypt, from about 300 B.C. to 400 A.D. The Library flourished from the period of Greek literature to the Roman and Christian eras. In addition to a huge collection of books, the library was a place for instruction and experimentation.

magnetic field: the area around a magnet throughout which its effects can be measured.

megawatt: one million watts, or 1,000 kilowatts (see *watt,* this section).

molecules: extremely tiny particles, composed of a collection of atoms, of which all materials are made .

natural gas: a gas mixture (mostly methane) trapped underground in many places near the surface of the earth; a fossil fuel.

nuclear reactor: a device which splits atoms in a controlled reaction, that results in the release of a huge amount of energy, including heat energy. In a nuclear power plant, the heat from the nuclear reaction is used to make steam to run turbine electricity generators.

photovoltaic cell: an electronic device that converts sunlight directly into electrical energy.

pollution: the presence of substances in water, soil or air in amounts that are harmful to the organisms living in or using the water, soil or air.

power plant: a central station where electricity is produced using turbines and generators.

power transmission lines: wires that transport electricity over long distances.

semiconductor: a material, such as silicon, which can be used to control the flow of electrons in electronic equipment, computers and solar cells.

solar: coming from the sun.

transformer: a device that increases or decreases the voltage of an electric current.

turbine: a machine with blades that are turned by the forceful movement of liquid or gas, (such as air, steam or water) passing quickly over the blades.

vaporize: to change any liquid or solid into the gas form; the term is most commonly used in reference to water (which vaporizes to steam).

voltage: the measure of the amount of force that "pushes" an electric current.

watt: a unit of power (energy/time), the rate energy is consumed or converted to electricity.

Section V :

A "HOT" STATE

caldera: a bowl-shaped area, usually over 1 mile (1.6 km) in diameter, created either by a huge volcanic explosion (which destroys the top of a volcano) or by the collapse of a volcano's top.

lava flow: an area which has been covered by lava. ("Lava flow" may also refer to the rate at which lava runs out onto the earth's surface.)

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RESOURCES

AIMS Education Foundation
P.O. Box 8120
Fresno, California 93747
(209) 255-4094

Sells many low-cost, comprehensive curriculum collections which integrate science and math. Two collections which relate directly to earth science and energy are *Popping with Power* and *Water Precious Water.*

Al Kettler and Associates
1429 Prince Street, Suite 202
Alexandria, Virginia 22314
(703) 548-8040

A resource for environmental education publications (designed by Al Kettler, designer and illustrator of this curriculum unit). Available for purchase are renewable energy posters, singly or as a set - geothermal, solar, wind, and water power.

Bonneville Power Administration
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Provides educational materials on energy to educators in Oregon, Washington, Idaho, and Montana.

Bureau of Land Management
P.O. Box 2965
Portland, Oregon 97201
(503) 280-7043

Provides information on geothermal resources on federal land, issues geothermal leases and regulates operations.

California Department of Conservation
Division of Oil, Gas, and Geothermal
801 K Street, 20th Floor, MS-20
Sacramento, California 95814-3530
(916) 323-2731

Provides information and free educational materials (including an illustrated "comic-style" booklet on geothermal energy).

California Energy Commission
Public Information Office
1516 Ninth Street
Sacramento, California 95814
(916) 324-3298

Provides information on energy projects in the state of California.

Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108
(801) 524-3422

Provides public information materials about geothermal and the environment, as well as geothermal in developing countries.

Energy Education Resources
(Kindergarten Through 12th Grade)
Energy Information Administration
U.S. Department of Energy
Washington D.C. 20585
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Provides an extensive catalog of organizations which offer free or low-cost energy-related educational materials.

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, Oregon 97601-8801
(503) 885-1750

Provides information and a quarterly bulletin about geothermal energy, particularly about low-temperature resources and their use worldwide.

Geothermal Division
U.S. Department of Energy
1000 Independence Ave, S.W.
Washington, D.C. 20585
(202) 586-5340

Provides technical information about current geothermal projects such as hydrothermal hot dry rock, magma and geopressurized systems.

FOR THE TEACHER

CORRELATION OF GEOTHERMAL ENERGY CURRICULUM WITH 1990 CALIFORNIA SCIENCE FRAMEWORK – *Grades 4-8*

PHYSICAL SCIENCES

Section A: **Matter**
The following Framework sections correlate with Geothermal Energy Curriculum, pages 10, 13-15, 18-19, 23, 27, 42, 44:

- A-1 Matter and its properties: Grades K - 3, 3 - 6, and 6 - 9
- A-2 Basic units of matter, origin of matter: Grades 3 -6
- A-3 Principles governing interactions of matter; chemical structure of matter: Grades 3 - 6

Section B: **Reactions and Interactions**
The following correlates with pages 9-10, 54-55:

- B-1 Changes in substances: Grades K - 3 and 3 - 6
- B-2 Controls of substances changing(e.g. environmental conditions, provision of energy, etc.): Grades K - 3 and 3 - 6

Section C: **Forces and Motion**
The following correlates with pages 8, 48-49, 51-57:

- Introduction, Newton's Laws: Grades K - 9
- C-2 Characteristics of forces and their relationship to motion: Grades 3 - 6 (forces between magnets, electrically charged objects can act without contact between the objects)

Section D: **Energy: Sources and Transformations**
The following correlates with pages 8-12, 36-44. 48-61:

- D-1 Energy and its characteristics: Grades K - 3, 3 - 6, and 6 -9
- D-2 How energy is used and changes that occur when using it: Grades K - 3, 3 - 6, and 6 - 9

Section E: **Energy: Heat**
The following correlates with pages 28, 36 -44, 53, 54-58, 70, 72- 76:

- E-1 Heat energy, its origin and properties: Grades K -3, 3 - 6, and 6 - 9
- E-2 How heat energy is used: Grades K - 3, 3 - 6, and 6 - 9

Section F: **Energy: Electricity and Magnetism**
The following correlates with pages 8, 11-12, 48-61, 72, 74, 76:

- F-1 Description of electricity and magnetism, their properties and interactions: Grades K - 3, 3 - 6, and 6 - 9
- F-2 Uses of electricity and magnetism: Grades K - 3, 3 - 6, and 6 - 9

EARTH SCIENCES

Section B: **Geology and Natural Resources**
The following correlates to pages 11, 18 - 29, 59, 71, 74, 76

- Intro Plate tectonics - the unifying theory of geology today: Grades K - 9
- B-1 Plate tectonics effect on earth's evolution: Grades K - 3, 3 - 6, and 6 - 9
- B-2 Formation, distinguishing features and classification of rocks and minerals: Grades K - 3 and 3 - 6
- B-3 History of the earth; how geomorphic processes have shaped earth's features: Grades K - 3, 3 - 6, and 6 - 9
- B-4 Responsibilities of humans toward natural resources: Grades K - 3, 3 - 6, and 6 - 9

FOR THE TEACHER

CORRELATION OF GEOTHERMAL ENERGY CURRICULUM WITH 1990 CALIFORNIA SCIENCE FRAMEWORK – *Grades 4-8*

Continued

Section C: **Oceanography**

The following correlates to pages 20, 21, 22, 23, 24:

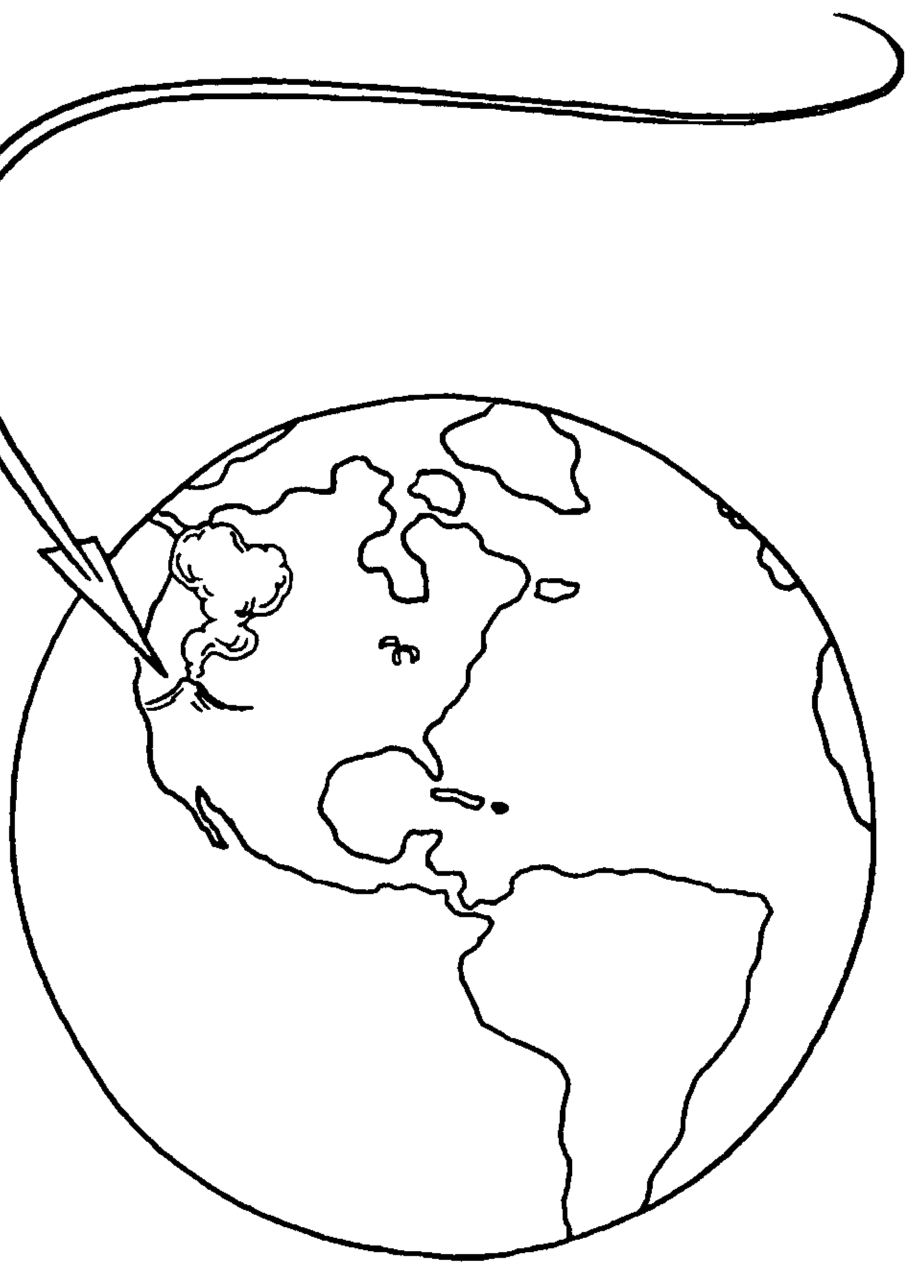
- Intro Disciplines of geology, oceanography and meteorology are all interconnected; solar energy and forces within the earth are basis for the water cycle: Grades K - 9
- C-1 The water cycle, how it affects climate, weather, life on earth, and surface features: Grades 3 - 6
- C-2 What are the environments and topography of ocean bottoms: Grades 3 - 6 and 6 - 9

Explanatory Notes:

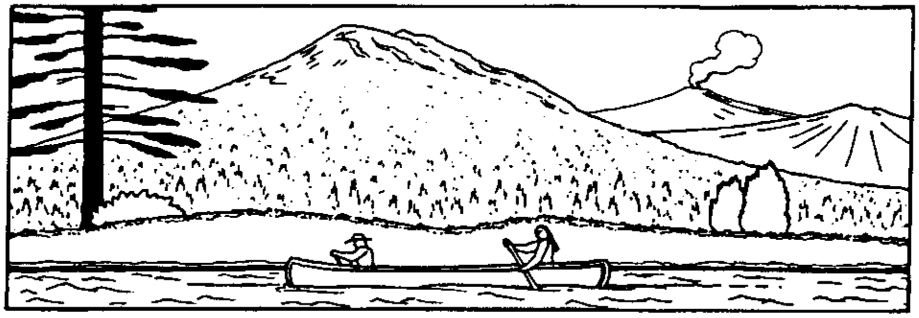
Only those sections of the 1990 Framework which directly apply to the concepts taught in the Geothermal Energy Curriculum have been identified in this correlation.

The topic of Geothermal Energy lends itself well to the thematic approach, as well as to interdisciplinary instruction. The exploration of this topic encompasses many big ideas, including deep time, plate tectonics, uniformitariaism, earth's cycles and their interactions, the electromagnetic force, forces and motion, and fundamental environmental principles.

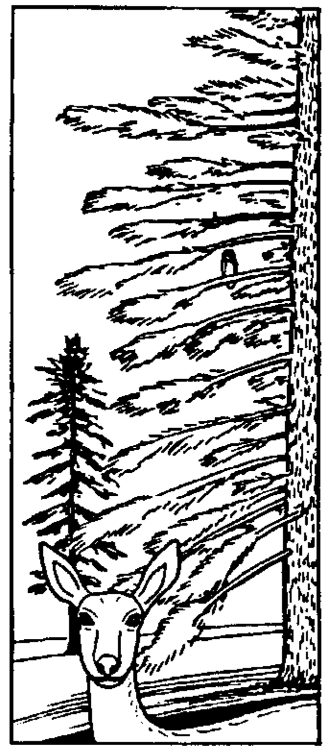
THE PACIFIC NORTHWEST —
A "HOT" REGION

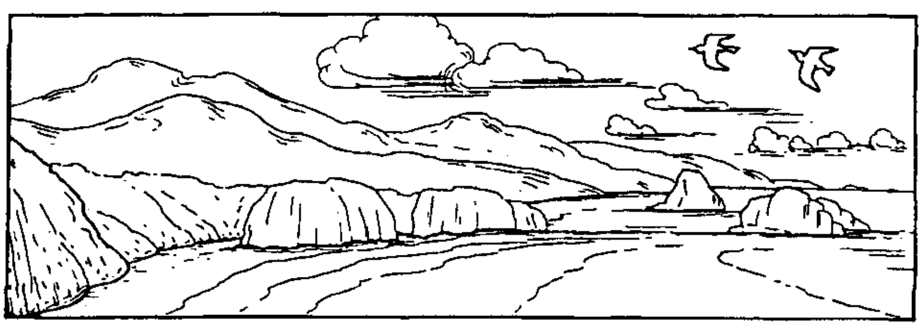


STUDENT INFORMATION

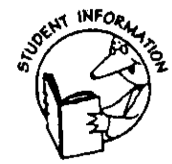


What region was home to numerous tribes of Native Americans and was the destination of explorers and determined pioneers? What land is host to thriving wildlife, towering trees, ocean cliffs, snowy mountain peaks, fertile valleys, steamy hot springs, young and old volcanoes, the deepest canyon in North America and the bluest lake in the world? Where is geothermal energy helping to grow plants and fish, and to heat hundreds of homes and buildings? Can all of this be found in one place? Yes! — in the Pacific Northwest — a wonderland rich with geothermal resources.



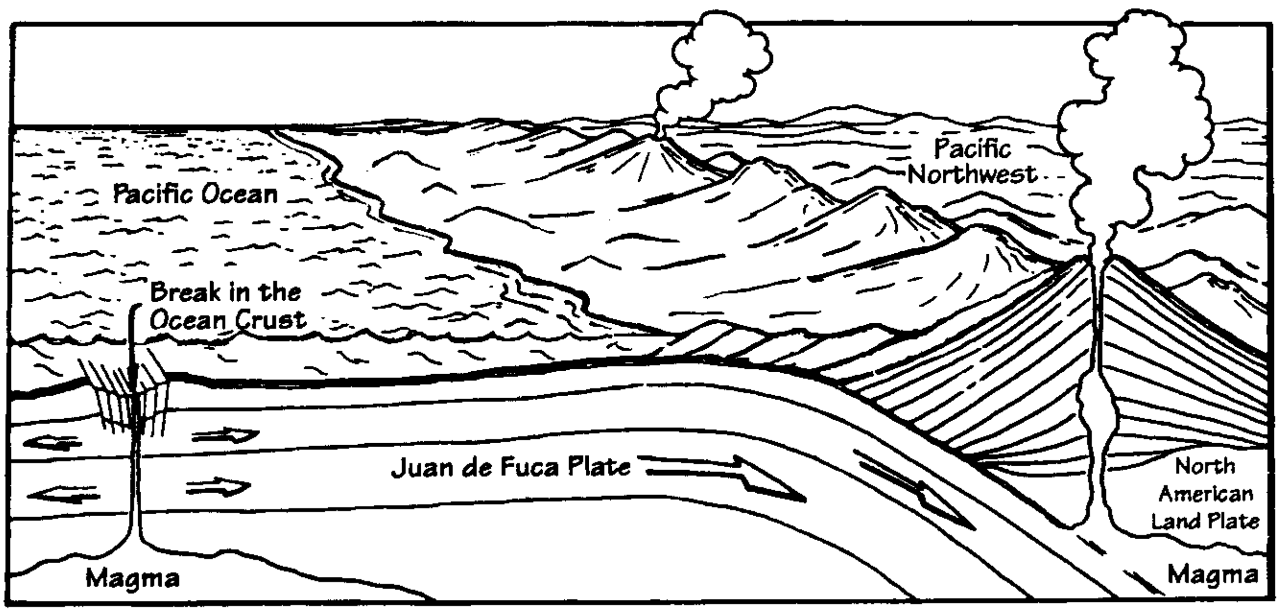


WHY DOES THE PACIFIC NORTHWEST HAVE SO MANY GEOTHERMAL RESOURCES?



Much of the Pacific Northwest sits right on the Pacific "Ring of Fire" at the western edge of the North American Land Plate. Here, dramatic, slow-motion activity is going on underground: the land plate and an oceanic plate are pushing into each other. This results in a region rich with hot magma and geothermal activity – right under the states of Washington, Oregon, Idaho and Montana. We don't feel this constant movement (or pressure) because it happens so slowly.

Let's take a closer look at what's happening: Not far off the American northwest coast there is a big crack (a fracture) in the sea floor, which has created a small oceanic plate called the Juan de Fuca Plate. Most geologists think that convection currents and the upwelling of magma out of this fracture cause the Juan de Fuca Plate to move east towards the Pacific Northwest. This ocean plate is then pushed into the North American land plate and is shoved under it. This process is called subduction.



As the Juan de Fuca plate slides under the North American land plate, it is directed downward into an area of extremely high temperature. Some of this subducting rock melts and forms magma – adding to the magma that is already there. With all this pushing and rubbing, there are great strains on the crust.

As a result:

- Over time the earth's crust has folded and risen, forming mountain ranges (like the Cascades).
- In some places, cracks (faults) have formed in the crust. When these cracks slip, earthquakes can occur.
- And where there are weak spots in the crust, magma finds its way to the surface, bursting out as volcanoes (like Mt. St. Helens), or oozing out in massive sheet lava flows (like the Columbia Basin).

With so much heat and magma below the crust, no wonder this region has so many geothermal resources. All of this moving, sliding, shoving, melting, pushing, rubbing, folding, rising, cracking, slipping, and breaking are what continually shape the dramatic landscape of the Pacific Northwest.

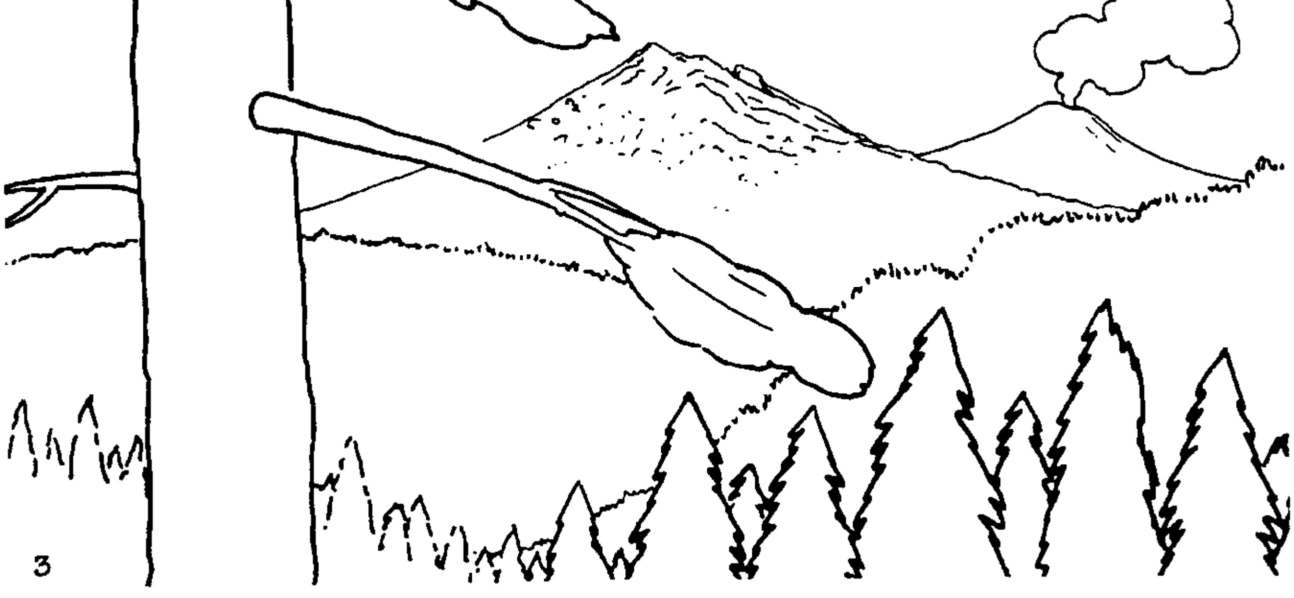
STUDENT INFORMATION

SHAPING THE LANDSCAPE OF THE PACIFIC NORTHWEST

Taking a trip across the Pacific Northwest is like taking a trip through geologic time. It is a land of startling contrasts which have resulted from a "recent" history of volcanic eruptions, gigantic lava flows, mountain building and canyon carving.

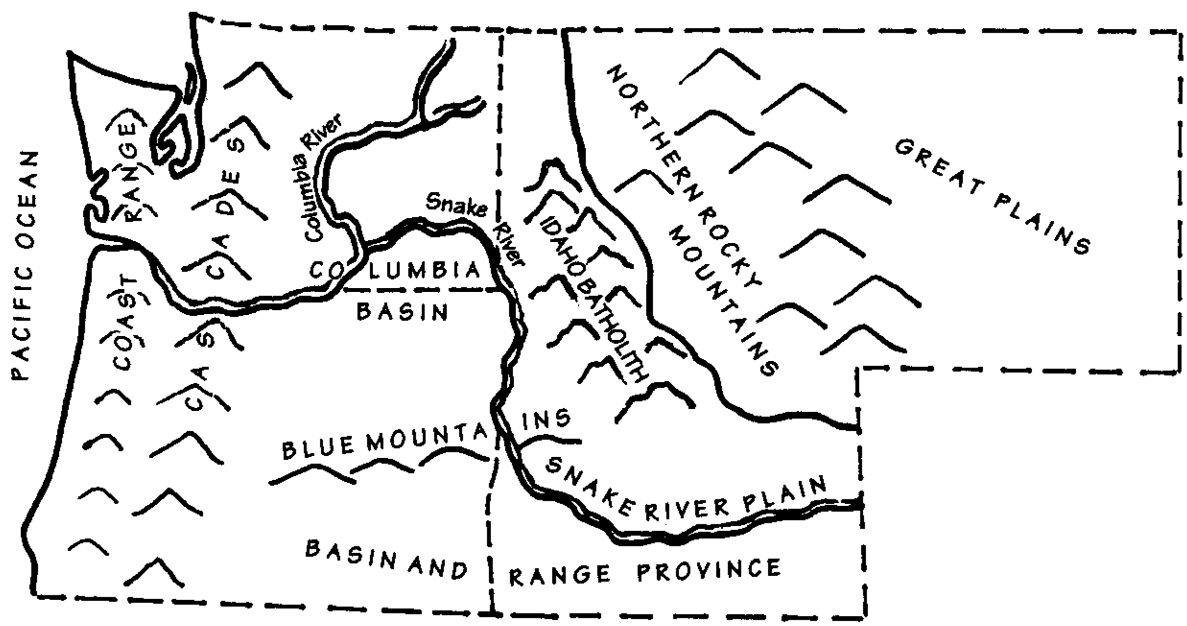
THE COAST RANGE AND THE CASCADES

The mountains of the Pacific Northwest are "young," geologically speaking — less than 45 or 50 million years old. Prior to their formation, much of Washington and Oregon lay under the waters of what is now called the Pacific Ocean. Around 50 million years ago, the Juan de Fuca plate began shoving under the western edge of North America and the continental crust began to bend and fold. Once this land began to shift, fold and rise, the sea receded. Riding raft-like on the ocean plate, sea-floor rock moved in (starting approximately 40 million years ago), crunching up against the continental plate and rising to form the Coast Range and the Olympic Mountains. About the same time, the Cascades also began developing from a series of tremendous volcanic eruptions (which continue their mountain-forming even to the present day). The Cascades extend in a nearly straight line from southern British Columbia (Mt. Meager) to northern California (Mt. Lassen). Between this range and the Coast Range lies a long string of lowlands and valleys, filled with rich soil carried down in run-off from the surrounding mountains.



EAST OF THE CASCADES

East of the Cascades there are a number of diverse geologic areas. Geographically speaking, southeastern Oregon and southern Idaho both belong to an area formed from widespread faulting (cracking) called the **Basin and Range Province**, a series of ranges and valleys, often very rugged and arid. (The Basin and Range Province also includes Nevada, and parts of Utah and California). To the north of the Basin and Range region are the **Blue Mountains** of central Oregon and the **Snake River Plain** of southern Idaho. Moving farther north, we find the Columbia Plateau, or **Columbia Basin**, which sprawls across southeastern Washington and parts of northern Oregon and western Idaho. Farther east are the many ranges of central and northern Idaho and western Montana, which are part of the **Northern Rocky Mountains**.



THE IDAHO BATHOLITH

When magma gets trapped deep beneath the surface, it can cool and solidify into a batholith, a large structure of igneous rock many miles in length and width. One of the most notable is the Idaho Batholith. Formed about 100 million years ago, it is about 250 miles long and about 100 miles at its widest part. Located in central Idaho, it is an area where huge quantities of magma forced their way into surrounding layers of rock. Because of the high temperatures and great pressures, there were dramatic reactions in the surrounding rock layers, including folding and upthrusting of rock. (Some of the thrusting was probably part of the upward movement of the Rocky Mountains in that vicinity). Erosion has exposed the batholith allowing geologists to inspect its configuration and structure.

SHAPING THE LANDSCAPE OF THE PACIFIC NORTHWEST

(continued)

The shaping of two areas East of the Cascades – the Columbia Basin and the Snake River Plain – are of particular note because their geologic history created unique geothermal resources still available today.

- **THE COLUMBIA BASIN**

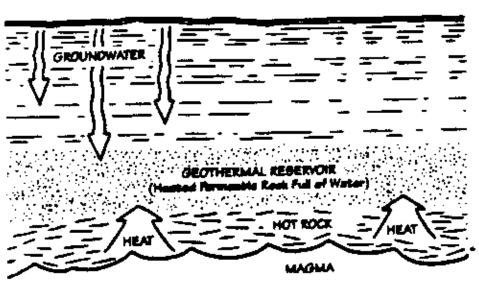
Starting about 17 million years ago, lava began flowing out of vents and fissures (long cracks) in the earth's surface. These vast sheets of runny lava spread almost like water, covering tremendous distances, in one case blanketing as much as 20,000 square miles of the Columbia Basin.

* Sometimes one flow followed another, leaving layers and layers of "naked," smooth rock;

* Other times thousands of years elapsed between flows and the lava sheets became covered with lush vegetation, lakes and streams.

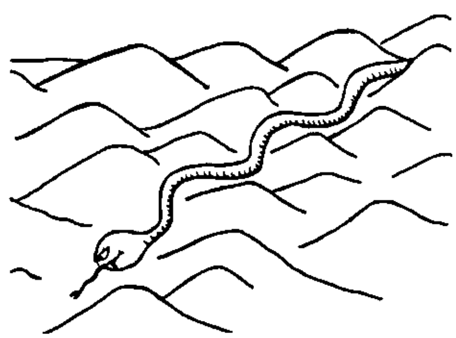
About 15.6 million years ago, most of the lava flows ceased. During the last 10 million years, surrounding mountains pushed higher while the basin sank.

Today, run-off water flows down from the Cascades and from the mountains of eastern Idaho into the Columbia Basin. It seeps into the many layers of permeable rock, forming great aquifers, many of which – heated by the surrounding hot rock – are geothermal reservoirs.



- **THE SNAKE RIVER PLAIN**

The vast Snake River Plain is one of Idaho's major geologic features. More than 65 million years ago, the Snake River began its arduous journey, starting in western Wyoming, flowing northwest where it finally joined the Columbia River in south-central Washington, after cutting the deepest canyon in North America, Hell's Canyon. This canyon is only one example of the force with which the river cut its way across the land. During the tremendous volcanism of the Cenozoic Era, lava cones kept popping up in the river's path, forming a maze and repeatedly forcing it to divert and start a new path.



All over the area surrounding the river, great lava flows spilled out, time and again, just as they had in the Columbia Basin. Eventually a very large, long land trough formed and sank (now the Snake River Basin), while surrounding mountain ranges rose. One of the world's greatest geothermal reservoirs has formed underground in the Snake River Plain.

MODERN TIMES

THE GEOLOGY OF THE PACIFIC NORTHWEST

The dramatic geologic history of the Pacific Northwest is far from over, as we know from the 1980 eruptions of Mount St. Helens. Most geologists believe that the volcanic regions in the Pacific Northwest are dormant, *not* extinct.

Today, tremendous aquifers, such as those found under the Snake River Plain and the Columbia Basin, are among the Pacific Northwest's most valuable resources.

The wild landscape of the Pacific Northwest is indeed a trip through geologic history and is to be treasured and protected.

"RECENT" GEOLOGIC HISTORY

OF THE PACIFIC NORTHWEST

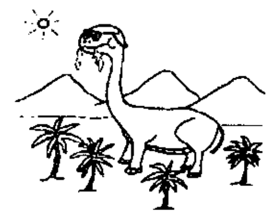
MESOZOIC ERA
225 mybp - 65 mybp

TRIASSIC PERIOD
(began 225 mybp *)

- North American plate begins breaking away from Europe & Africa.
- Atlantic Ocean widens; Pacific Ocean decreases.
- Deep ocean covers Oregon, parts of Washington & Idaho.

JURASSIC PERIOD
(began 190 mybp)

- Tropical climate.
- Blocks of crust from the west collide with the North American plate.



CRETACEOUS PERIOD
(began 136 mybp)

- Much of the Pacific Northwest is still under water.
- Around 100 mybp, the formation of the Idaho Batholith begins.
- Shoreline begins retreating westward.

CENOZOIC ERA
65 mybp - present

TERTIARY PERIOD

PALEOCENE EPOCH
(began 65 mybp)

- Snake River begins cutting path 65 mybp.
- The Pacific Northwest shoreline stops retreating around 60 mybp.

EOCENE EPOCH
(began 54 mybp)

- North American Plate continues moving westward and collides with a series of island volcanoes, forming the base of the Coast Range.
- Great lava outpourings occur between 44 and 32 mybp.
- Volcanism begins about 40 mybp forming the western Cascades.

OLIGOCENE EPOCH
(began 38 mybp)

- Coast Range begins folding up about 26 mybp.

MIOCENE EPOCH
(began 25 mybp)

- The Basin and Range begin development about 25-20 mybp.
- Lava flows spread forming basalt plains (such as the Columbia Basin and Snake River Plain) between 25 and 7 mybp.

PLIOCENE EPOCH
(began 7 mybp)

- Volcanism forms the high Cascades between 7 and 5 mybp.
- Younger lava flows again cover the Snake River Plain.

QUARTERNARY PERIOD

PLEISTOCENE EPOCH
(began 2.5 mybp)

- Ice Ages begin around 2.5 mybp. Glaciers invade, carve landscape.
- Crater Lake and Newberry Crater are formed.
- Glaciers recede about half a million years before present.
- More lava flows onto Snake River Plain forming Craters of the Moon.

RECENT EPOCH
(began 500 ybp*)

- Volcanic activity continues, including Mt. St. Helens eruptions.
- Crustal plates continue to collide.

* mybp means a "million years before present"; ybp means "years before present"

USING GEOTHERMAL RESOURCES IN THE PACIFIC NORTHWEST

The people of the Pacific Northwest have long recognized the value of geothermal resources. Native Americans were the first to use hot springs for recuperative bathing. Today, people of the Pacific Northwest still use geothermal resources for bathing and for a myriad of other creative uses like nursing young trees, growing food, and heating homes.

In the Pacific Northwest, great quantities of natural hot water lie below the ground in geothermal reservoirs. These reservoirs are proof that magma and hot rock exist deep beneath the landscape. (Remember that where groundwater reaches hot rocks we have geothermal water.) Where this hot water finds cracks in the crust, it works its way up to the surface, emerging as hot springs. Above and below the surface, hot springs and geothermal reservoirs throughout the Pacific Northwest are put to use.

QUILAYUTE VALLEY, WASHINGTON

Hot springs have been the source of many "miraculous" cures over the years. In Quilayute Valley, Sol Duc Hot Springs was established in 1912 by Michael Earles, whose potentially fatal ailment was "cured" by the mineral waters. Thousands of people from all over the United States and Europe flocked to the resort, until it was destroyed in a fire in 1915. Sol Duc was rebuilt and is now part of Olympic State Park. Other resorts were soon developed in Rainier State Park and in the Columbia River Gorge.

COLUMBIA RIVER BASIN, WASHINGTON

Over 97% of Washington's low temperature resources have been found in the Columbia River Basin in Washington. There are nearly 800 thermal wells in six counties. A few have been developed for heat pump use.

EPHRATA, WASHINGTON

An award-winning heat pump system uses warmth from a geothermal well within Ephrata's city water system to heat and cool the entire courthouse complex. Using geothermal energy cut courthouse energy consumption by 80% and has resulted in an 85% decrease in the fuel bill.

GRANDE RONDE VALLEY, OREGON

Natural hot water heats both a swimming pool and a greenhouse in Grande Ronde Valley in northeastern Oregon, where a half million pine tree seedlings are grown every year.

VALE, OREGON

Mushrooms are raised in Vale with the help of geothermal water. Not only does the geothermal heat help control growing room temperatures, but the hot water also sterilizes the soil.

LA GRANDE, OREGON

Back in the late 1800's, Hot Lake Hotel (near La Grande, Oregon) was heated by geothermal energy. A hot spring bubbled up out in front, where it came in handy as a "fishcooker."

Fish were caught in nearby cold water and, still on the rod, were popped in the hot spring water. They were then pulled out, cooked and ready to eat. Wells were drilled to heat the hotel.

KLAMATH FALLS, OREGON

The geothermal history of Klamath Falls, Oregon, began at Big Springs, which has been providing energy and healing baths to locals for many years. Native Americans came from great distances for soaking "cures". After a health resort was built in 1928, the Native Americans still came to soak in the tub baths. Today, the springs also provide a source of heat for a large high school, a large hotel, a motor company, a creamery, and a clever highway "de-icing" project which pumps geothermally heated antifreeze through a series of pipes below the pavement surface clearing snow and ice in winter. Klamath Falls is especially famous for its extensive geothermal space heating and district heating systems (see "World Famous Klamath Falls", page 76).

USING GEOTHERMAL RESOURCES IN THE PACIFIC NORTHWEST

(continued)

PUEBLO VALLEY, OREGON

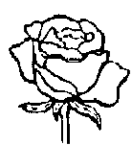
When most people think of Oregon, they picture a lush, green landscape. However, the southeast portion of the state is surprising. Geographically, it is part of an area called the "Basin and Range." The area is a "hot bed" of geothermal exploration and development because here many "cracks" in the earth allow water to flow down into the hot rock below. Wells with 300 °F geothermal water have been discovered. At least one power company is considering construction of a geothermal electrical power plant in this valley by Borax Lake in the Alvord Desert.

LAVA HOT SPRINGS, IDAHO

Lava Hot Springs has been a recreation and health center for over 200 years. Feuding Native American tribes set aside their differences to bathe together in the springs as they worshipped the "Great Spirit," healed war wounds and cleaned animal hides. In 1812, fur trappers "discovered" the hot waters. The area quickly became a restful stop for pioneers as they traveled the Oregon Trail. A railway stop was established at the turn of the century, bringing visitors from all over the United States. Lava Hot Springs is now protected as a health and recreation facility by the state of Idaho.

SNAKE RIVER PLAIN, IDAHO

The Snake River Plain region is full of geothermal resources, and locals certainly make good use of the abundant heat. Space heating, irrigation, greenhouse operations, resorts, and fish farming are all common uses in this area. An example of the flourishing greenhouse industry is found in Buhl, where thousands of potted plants are grown every year in large geothermally-heated greenhouses and Fish Breeders of Idaho raise catfish and tilapia (see "Hot Fish and Reptiles", page 77).



BOISE, IDAHO

In the 1930's, Boise became the first place in the state to use geothermal heat for greenhouses. A large geothermal greenhouse – run by the third generation of the family that started it – grows thousands of Easter lilies, geraniums, bedding plants, poinsettias and many other "hot weather" plants. An important space heating project is found in the city of Boise, where the city center is heated with 600 million gallons of geothermal water annually (see "Boise, Idaho", page 77).

FAIRMONT HOT SPRINGS, MONTANA

If vacationers want to combine wild, wide open spaces and relaxing soaks in hot mineral waters, they can visit Fairmont Hot Springs, one of many hot springs resorts in western Montana. Located in a valley between Butte and Anaconda, the resort sits near the Continental Divide.

LOLO HOT SPRINGS, MONTANA

A resort east of Missoula, has both a swimming pool and hotel which are heated geothermally.

WESTERN MONTANA

Western Montana, not known for its warm weather, is host to a number of businesses which benefit from geothermal heat:

* Flower growers operate a greenhouse in Ennis, where an acre of warmth-loving roses are grown year 'round with the help of geothermal heat.

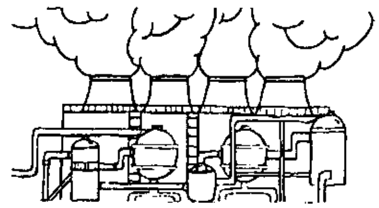
* At Hunters Hot Springs, geothermal heat is being used to help raise tomatoes which would otherwise never thrive in Montana's long cold winter season.

So far, geothermal use in the Pacific Northwest has been limited to "low temperature" resources. Energy specialists and geothermal engineers are also hard at work exploring places where high temperature geothermal resources can be used to help generate electricity for the future.

GEOTHERMAL "HOT" SHOTS

THE BONNEVILLE POWER ADMINISTRATION

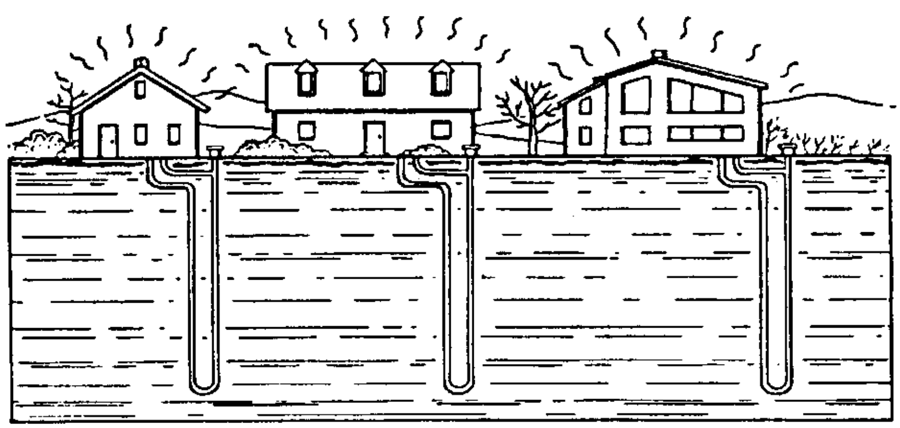
The Bonneville Power Administration (BPA) was created in 1937 to transmit and sell the power produced at Bonneville Dam on the Columbia River. Today, BPA sells power from 29 dams and one nuclear power plant, and supplies about half the electricity used in the Pacific Northwest.



Most of BPA's electricity comes from a renewable resource, hydropower. To make sure other renewable resources, like geothermal, are available to meet future energy needs, BPA is participating in the development of geothermal power projects in central Oregon and northern California. These could be the first geothermal power plants in the Pacific Northwest.

WORLD FAMOUS KLAMATH FALLS

Klamath Falls is probably the largest user of low temperature geothermal resources in the United States. Large parts of Klamath Falls sit on top of a huge underground reservoir of geothermal hot water, which comes up along faults and fractures in the bedrock, as hot springs and geothermal wells. Since the early 1900's, the city has been using geothermal hot water to heat houses, apartments, schools, commercial buildings and swimming pools. Many homes have their own personal wells that make use of this underground resource for heating. Eleven buildings are heated at the Oregon Institute of Technology using just three wells, saving about $250,000 per year in conventional fuel costs. In south Klamath Falls, a large ranch is home to ten greenhouses where cactus, succulents and other house plants are grown with the help of geothermal heat. The leftover geothermal water is then piped to a pond where tropical fish are grown, so none of the valuable warm water is wasted.



GEOTHERMAL "HOT" SHOTS

(continued)

BOISE, IDAHO:

HOME TO THE UNITED STATES' FIRST GEOTHERMAL WELLS & DISTRICT HEATING SYSTEM

When cows started disappearing in Boise, Idaho in the 1890's, town fathers decided to start drilling. Why? Here's the story.

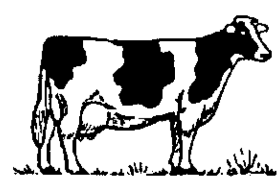
Located on the Oregon Trail, and close to recent gold discoveries, Boise was a boomtown in the late 19th century. By 1890, a city water system was desperately needed. When Hosea Eastman, a director of Boise Water Works, learned of an area which might have a geothermal reservoir close to the surface, he saw the opportunity to provide hot water to the city. What convinced him was a tip from a well driller, who insisted, "It [the ground] didn't freeze around the spot in the winter, seemed warm near the surface, and cattle stepped in the soft earth never to appear again."

When Boise Water Works finally drilled in the area, geothermal water 170 °F (77 °C) bubbled to the surface. Boise Water Works bought out a rival company, renamed itself the Artesian Hot and Cold Water Company, and began installing wooden pipes for a city water system. Mr. Eastman also built a "Natatorium," with fifty baths , a dancing and roller skating balcony, and billiard rooms.

Soon several miles of pipe served the "Nat," along with 200 homes and 40 businesses along "Warm Springs Avenue." Will Rogers loved to spoof the area, calling it "Hot Water Bottle Boulevard." By the 1930's, some 400 homes and businesses were using the hot water.

Eventually, modern automatic pumps and cement pipes were installed by the company which is now called Boise Warm Springs Water District. Geothermal waters from the Boise aquifer are now being used in other heating systems, such as those in the Boise Capital Mall and the Veterans' Regional Hospital.

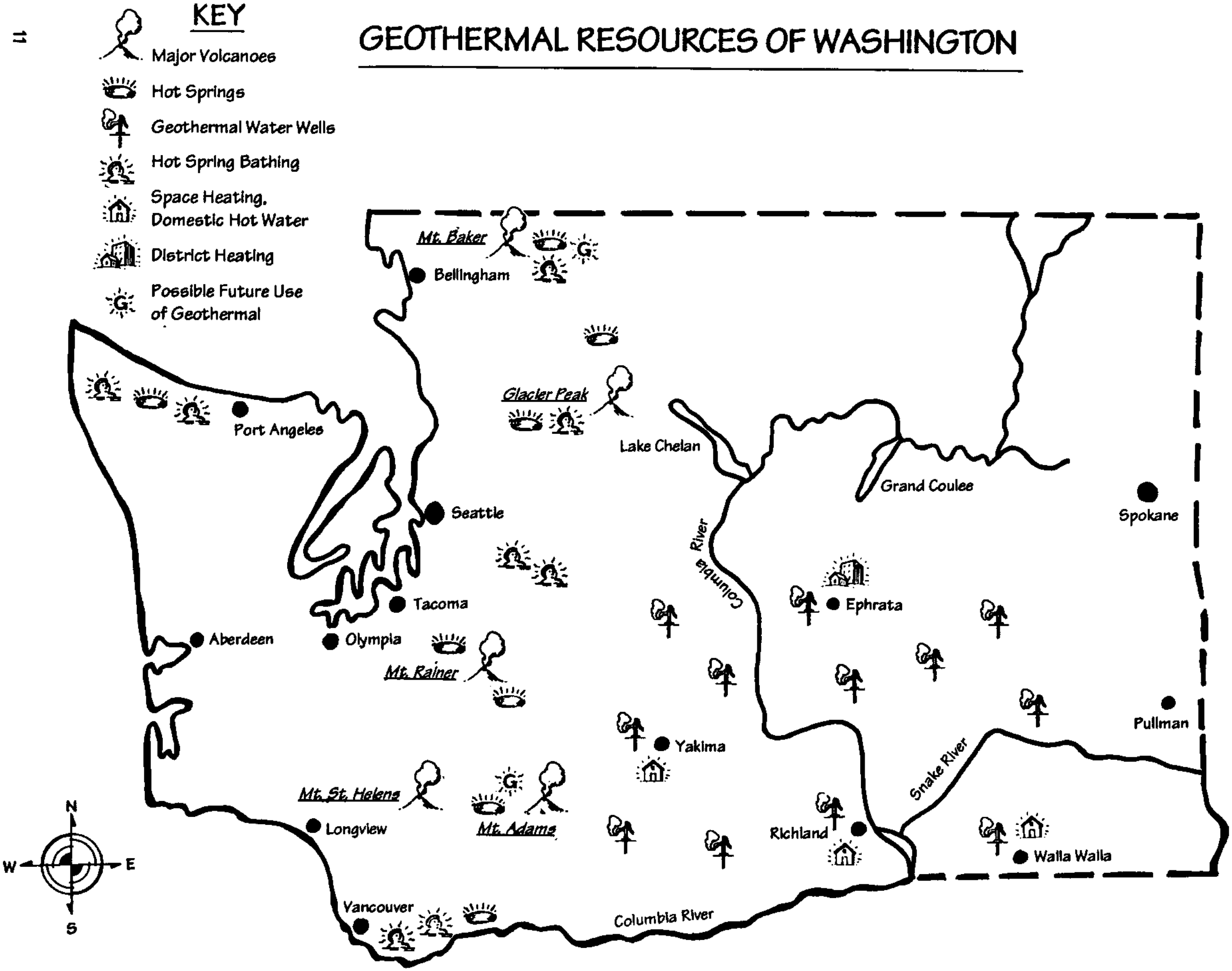
Citizens of Boise are justifiably proud of using one of nature's clean energy resources. And to think, it all started with disappearing cows!



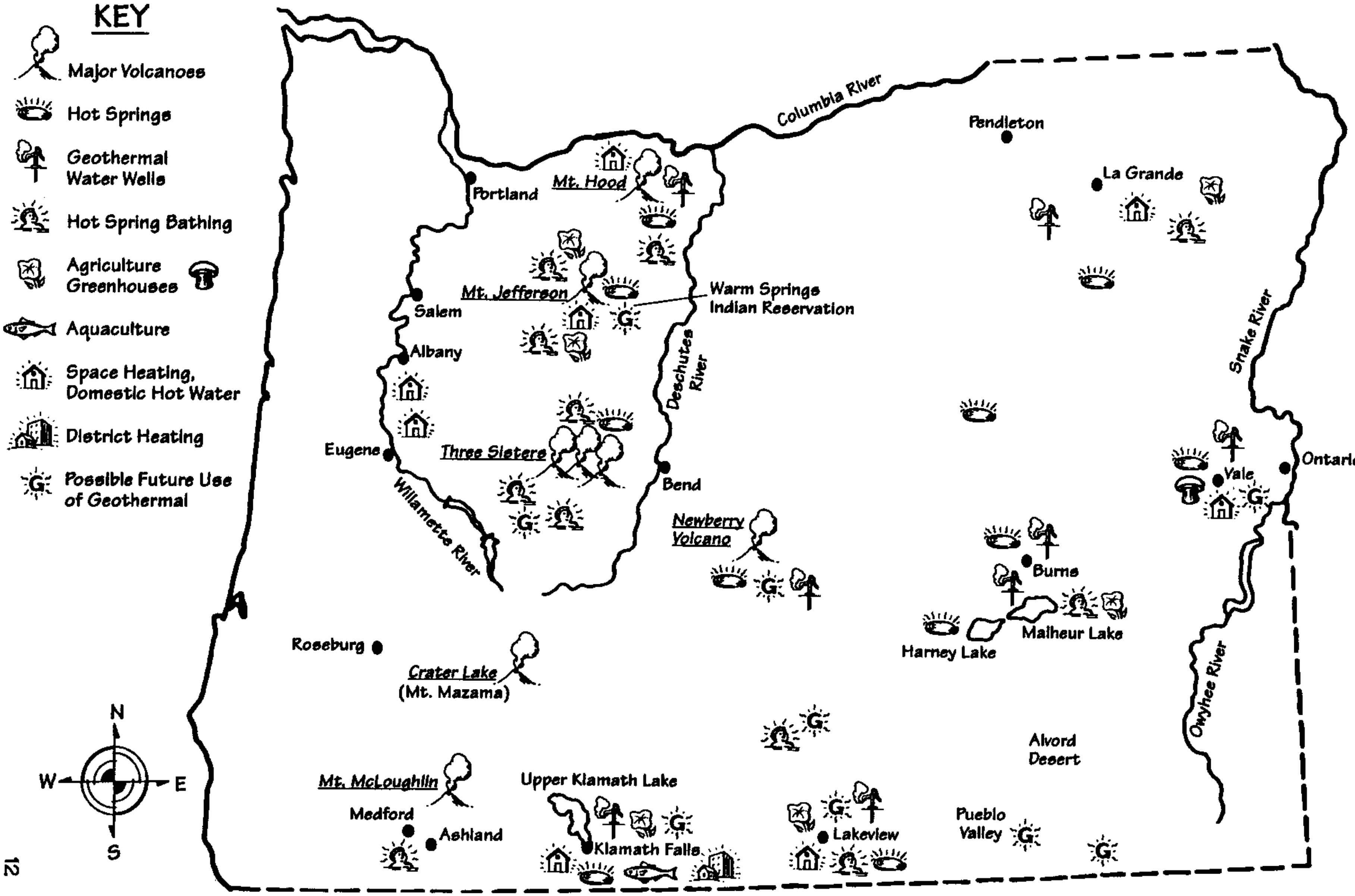
HOT FISH AND REPTILES IN THE COOL NORTHWEST

Idaho is among a number of western states where fish and other water-dwelling creatures are being grown at tremendous rates using geothermal water. The raising of fish under controlled temperatures increases growth rates by 50 - 100%. One such aquaculture operation, which started in 1973, is found in Buhl, Idaho. Here the owners mix cool spring water and hot geothermal water to the ideal temperatures for the catfish and tilapia that they raise. (Different fish grow best in different temperatures.) Not only do the fish grow faster, but they taste better. And fish aren't all that are growing at this "fish farm!" Recently, the operators added 200 baby alligators to their geothermal nursery. Newly hatched and less than two weeks old, the reptile babies are growing at much faster rates than they would "in the wild."

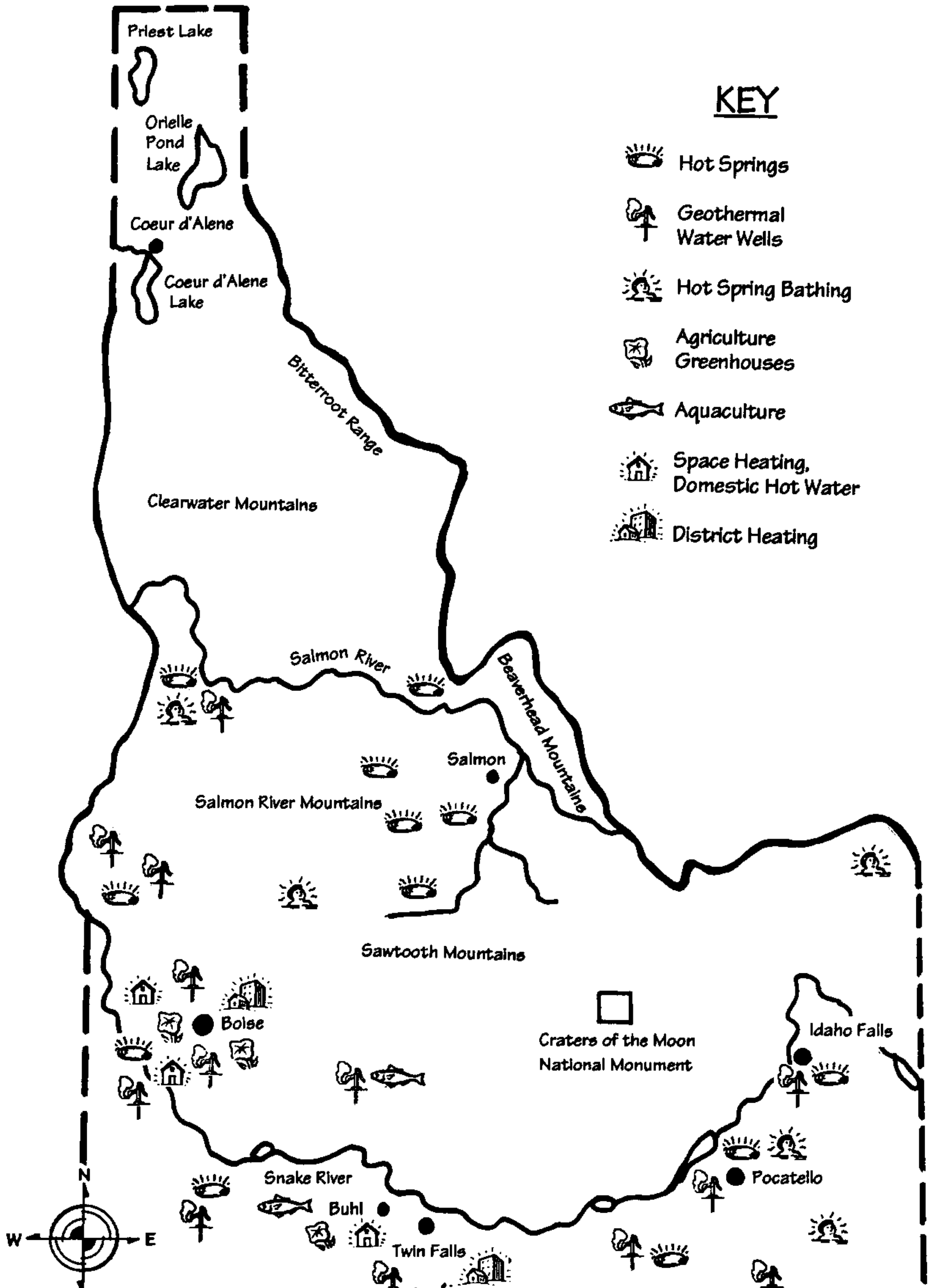
GEOTHERMAL RESOURCES OF WASHINGTON



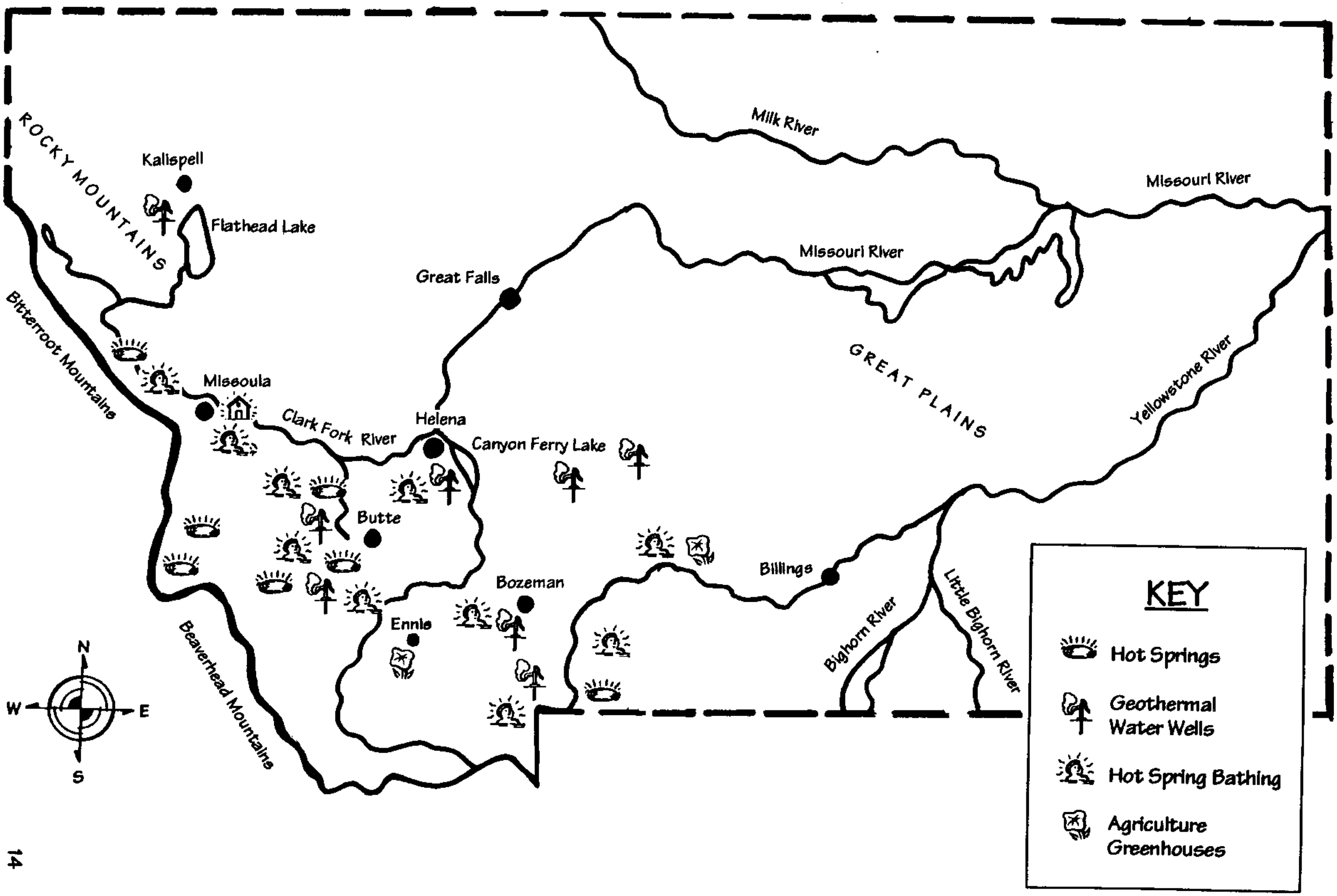
GEOTHERMAL RESOURCES OF OREGON



GEOTHERMAL RESOURCES OF IDAHO

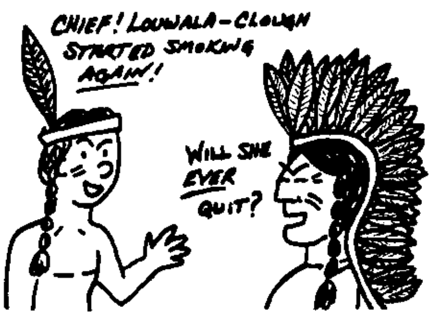


GEOTHERMAL RESOURCES OF MONTANA



SMOKING MOUNTAIN

The natives of the Pacific Northwest called it "Louwala-Clough" or "Smoking Mountain". During the mid-19th century, they witnessed the intermittent explosions of the restless volcano that we now call Mount St. Helens. The youngest volcanic mountain of the Cascade Range, Mount St. Helens gave one final burst in 1857 and then lay deceptively quiet for over a hundred years.



Beginning on March 20, 1980, a series of small earthquakes rumbled through the scenic mountain area. By mid-May, about 10,000 earthquakes had been recorded. Magma was pushing up inside the mountain causing a bulge that grew to 450 feet! Finally, on May 18, 1980, the pressures grew too great. First a 5.1 earthquake triggered the largest landscape-debris avalanche recorded in historic time. The entire north side of the mountain collapsed. Great blocks of mountain slid downward at speeds in excess of 150 miles per hour, and a deposit of volcanic debris, glacial ice and water eventually covered an area of about 24 square miles.

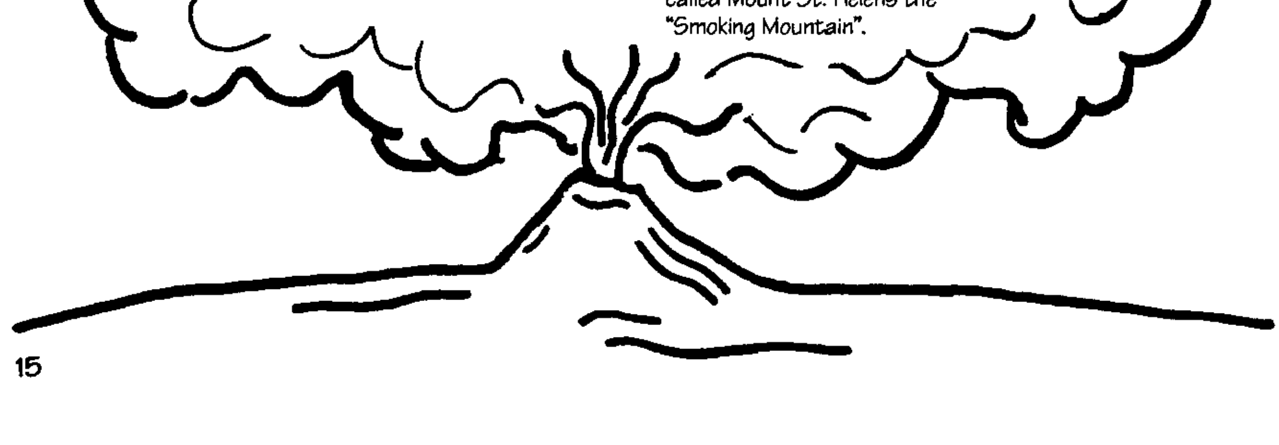
Simultaneously, the landslide caused a sudden release of pressure inside the mountain. A huge blast of rock, ash and hot gases exploded out of the north side of the mountain, shooting out material at speeds up to 670 mph and covering 230 square miles of land.

The blast could be heard over most of the Pacific Northwest–including British Columbia, Montana and Idaho. Everything close to the mountain was obliterated. Great trees lay flattened like toothpicks. A huge cloud of ash and steam shot straight up in the air, reaching up to 12 miles high and moving at about 60 mph, eventually spreading over several states. When the ash cloud reached Spokane, Washington, it was thick enough to block all sunlight, so that the streetlights stayed on all day. The ash eruption continued for about nine hours.

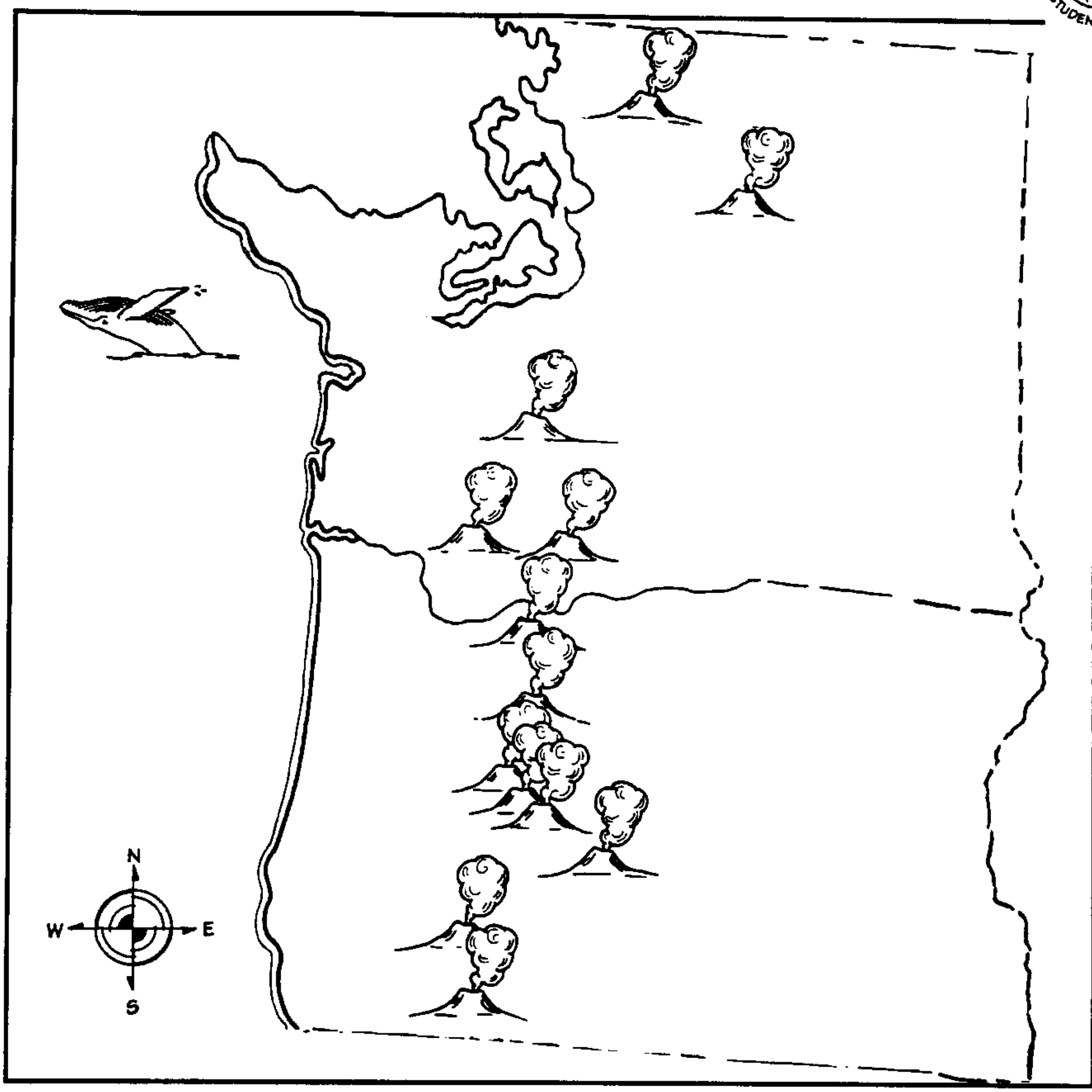
At the same time, a hot, glowing mixture of volcanic material and gases (called "pyroclastic flows") started bubbling over, flowing down the mountain sides at incredible speeds. Snow and ice melted, sending mudflows down the Touttle River and into the Columbia River, a major shipping artery, about 40 miles away.

The Mount St. Helens explosion was devastating and is considered the most destructive in the history of the United States: the eruption created a gaping bowl in the mountain about one by two miles wide, leaving the mountain 1,313 feet lower than it had been before; it caused widespread destruction of highways, prime forests, recreation sites, lakes and streams; and it led to the loss of 57 human lives.

Modern inhabitants of the Pacific Northwest were startled out of their complacency. They were reminded that their home is a hot, active, restless area and why the natives called Mount St. Helens the "Smoking Mountain".



CASCADE QUESTIONS



HINT:

Some of the answers to these questions will be found in this Pacific Northwest section and some you will have to look up in reference books.

CASCADE QUESTIONS

1. Can you name some or all of these volcanic mountains?
2. What happened to Mt. Mazama 7,600 years ago?
3. Are any of these volcanoes near your town or city?
4. The eastern parts of the Pacific Northwest appear not to have had any volcanic formations, but they have. Name some of these.
5. How many of these Cascade volcanoes erupted at least once in the last 200 years? Can you name them?
6. When did the first Cascade volcanoes begin forming?
7. What were some of the events which warned scientists and area residents that Mount St. Helens was likely to explode in 1980?

FOR THE TEACHER

After students have studied this section:

1.) Social Studies Activity: Have students do some letter writing to learn more about the low temperature uses of geothermal resources in the Pacific Northwest. Some places to write are the Geo-Heat Center (see the Resources section), the Klamath Falls Chamber of Commerce, the Oregon Department of Energy, the Oregon Department of Geology and Mineral Industries, Washington State Energy Office, Idaho Water Resources Research Institute, Idaho Department of Water Resources, Montana Department of Natural Resources and Conservation, and the Bonneville Power Administration. If the students receive enough useful information, they might report what they've learned in the form of a travel poster or brochure, perhaps including other interesting details about the area they're "advertising."

2.) Social Studies Activity: If you live in an area in the Pacific Northwest which isn't using geothermal energy (to your knowledge), have students research whether your area has the potential for using it (including what temperature the resources are, whether there might be environmental considerations, etc.). The organizations listed in SS Activity #1 (above) are good places to start. Try to find out whether there are definite plans for using the geothermal resources in the near future and what forms those uses will take. If there is potential, but nothing specific is on the drawing board, students might develop proposals for the best uses of the geothermal resources in your area. If they come up with a good idea, perhaps your class could send a copy of your proposal to your city or county planners or to the U.S. Forest Service or Bureau of Land Management (if the resources are on federal land.)

3.) Science (Geology) Activity: An interesting feature of the Snake River Plain is Craters of the Moon National Monument. Here, volcanoes have erupted very recently – the latest just several hundred years ago. The area is one of the best places in the Northwest to study "young" volcanic features. These include cinder cones, lava flows, spatter cones, "mini" shield volcanoes, tree molds and volcanic bombs. You may want to have your students research these.

4.) Science/Language Arts/Art Activity: A number of terms associated with volcanic activity are discussed in this chapter, especially in the section "Shaping the Landscape of the Pacific Northwest" and the discussion of Mount St. Helens. Have your students research and report on these terms, as well as on others such as those listed below. You may wish to have students explore the origins of some of the terms, including the origin of the word "volcano." Students might also make a class landscape display with paper mache' and other materials depicting the various volcanic features.

Some volcanic terms (add more of your own): lava, ash, cinder cones, spatter cones, volcanic plug, shield volcano, composite volcano (strato-volcano), dome volcano, magma chamber, vent, caldera, side vent, volcanic bombs, lava flows, mud flows, pillow lava, igneous rock, pumice, obsidian, "nue'e ardente," pyroclastic material, Pele's tears, batholith, dike, sill, laccolith.

5.) Answers to Cascade Questions (page 83):

1. From the top down: Mount Baker, Glacier Peak, Mount Rainer, Mount St. Helens (left), Mount Adams (right), Mount Hood, Mount Jefferson, Three Sisters, Newberry Volcano, Crater Lake, Mount McLoughlin.
2. Mt. Mazama "blew its stack," fell in on itself, and created a bowl-shaped area (a caldera.) The caldera filled with rainwater and melted snow to form what is now Crater Lake.
3. Answers will vary.
4. Some of the volcanic features of the eastern Pacific Northwest have been lava flows, lava pillows and underground batholiths.
5. Five of the Cascade volcanoes of Washington and Oregon have erupted at least once in the last 200 years. They are: Mount Baker, Glacier Peak, Mount Rainer, Mount St. Helens, and Mount Hood. (Note: Mount St. Helens has erupted three times in the last 200 years!)
6. The first Cascade volcanoes began forming around 40 million years ago.
7. Some warning events prior to the Mount St. Helens' explosion in 1980 were: a series of earthquakes, small eruptions, minor avalanches, and a swelling bulge of magma under the mountain's surface which grew up to 450 feet.

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