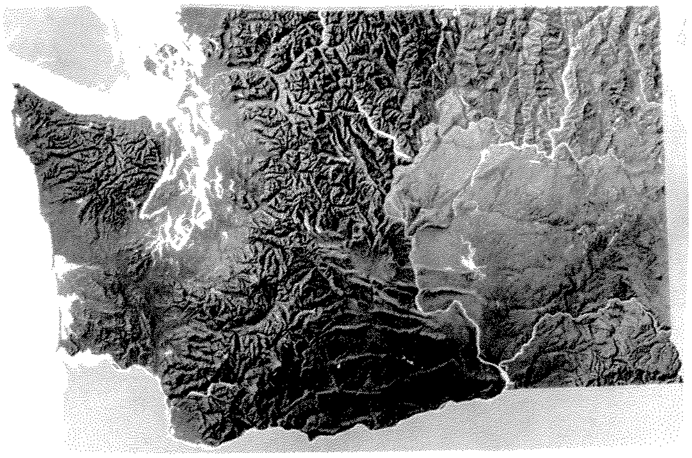
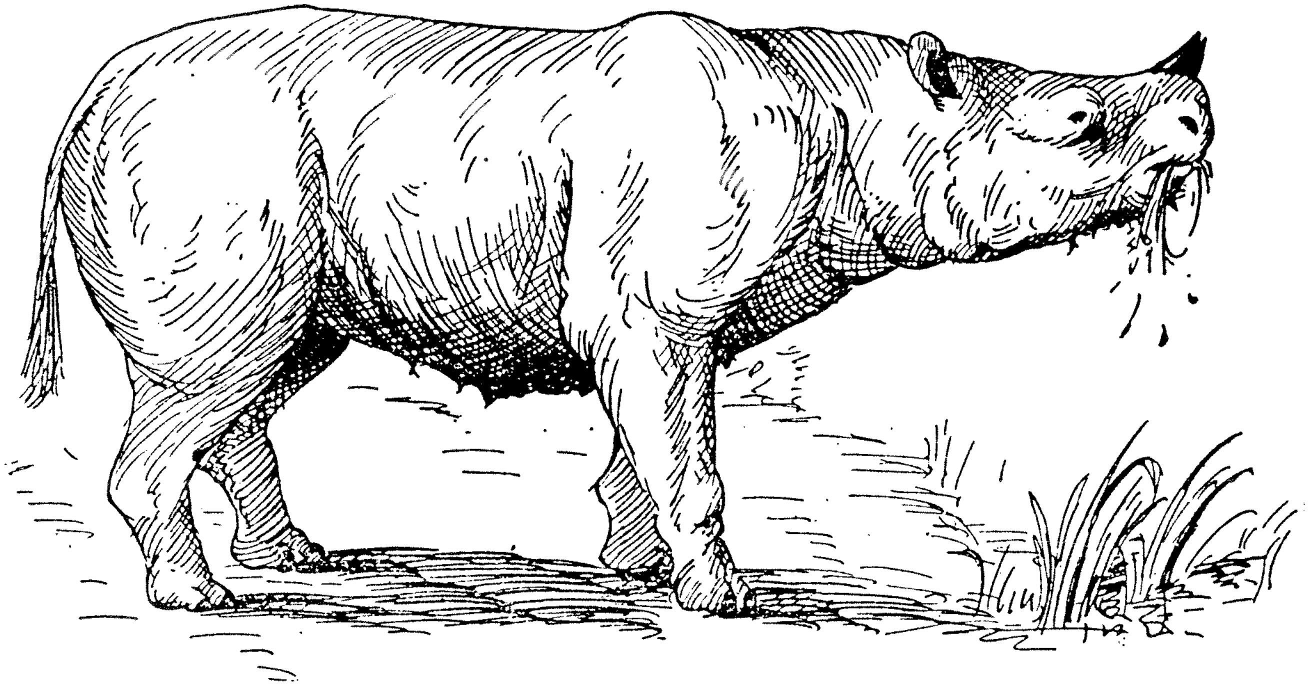


WASHINGTON GEOLOGIC NEWSLETTER

Volume 16 Number 4 October 1988

Washington State Department of Natural Resources Division of Geology and Earth Resources



The "Blue Lake rhino" as it probably appeared in life. (Sketch by Owen J. Poe, courtesy of the Geological Society of America)

IN THIS ISSUE

INDEX ISSUE

WASHINGTON
GEOLOGIC
NEWSLETTER

The Washington Geologic Newsletter is published quarterly by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request. The Division also publishes bulletins, information circulars, reports of investigations, and geologic maps. A list of these publications will be sent upon request.

DEPARTMENT OF NATURAL RESOURCES	Brian J. Boyle Commissioner of Public Lands Art Stearns Supervisor
DIVISION OF GEOLOGY AND EARTH RESOURCES	Raymond Lasmanis State Geologist J. Eric Schuster Asst. State Geologist

Geologists (Olympia)	Brent Barnett Matthew J. Brunengo Michael A. Korosec William S. Lingley, Jr. Robert L. (Josh) Logan	William M. Phillips Weldon W. Rau Katherine M. Reed Henry W. Schasse Timothy J. Walsh
Geologists (Spokane)	Nancy L. Joseph Stephanie Z. Waggoner	Keith L. Stoffel
Librarian		Connie J. Manson
Library Technician		Gwen F. Crain
Research Technician		Arnold Bowman
Editor		Katherine M. Reed
Cartographers		Nancy E. Herman Donald W. Hiller Keith G. Ikerd
Word Processor Specialist		(vacant)
Administrative Assistant		Susan P. Davis
Clerical Staff		Joy Fleenor Naomi Hall Jim Leighton Jack Sareault
Regulatory Clerical Staff		Barbara A. Preston

Surface Mining Reclamation

by Raymond Lasmanis, State Geologist

During the current state biennium, the State Geologist is responsible for 950 active surface mining permits. A majority of the permits are for sand and gravel or rock pits. The pertinent statutes are Revised Code of Washington (RCW) 78.44 and the corresponding Washington Administrative Code (WAC) 332.18. Permits for surface mining are processed according to requirements of the State's Environmental Policy Act, RCW 43.21C.120 and WAC 332.41.

During the last session of the legislature, amendments were introduced to RCW 78.44 which would encourage reclamation and at the same time reduce the number of pits that fall under the regulatory jurisdiction of the Department of Natural Resources. The most significant change is that the threshold at which a pit must have a permit is now 3 acres of disturbed ground (as defined) or slopes greater than 1:1 with a high wall exceeding 30 feet. This supersedes the old limits of 2 acres of disturbed ground or 10,000 tons of material removed in 12 months.

The significance of the change is that small borrow pits with only intermittent removal of materials need not have a permit if the disturbed area is less than 3 acres.

Most important, the changes encourage reclamation. By reclaiming the pit down to an area less than 3 acres, the permit can be closed out and the operator no longer has to pay the annual fee or carry a reclamation bond.

For additional information, contact the appropriate regional Department office in Colville, Ellensburg, Castle Rock, Chehalis, Enumclaw, Sedro Woolley, or Forks.

The Division's popular brochure, "Gems and Minerals of Washington", has been reprinted and is again available. The brochure is free, but please add $1 to mail orders, which can be sent to the Division's Olympia address, below.

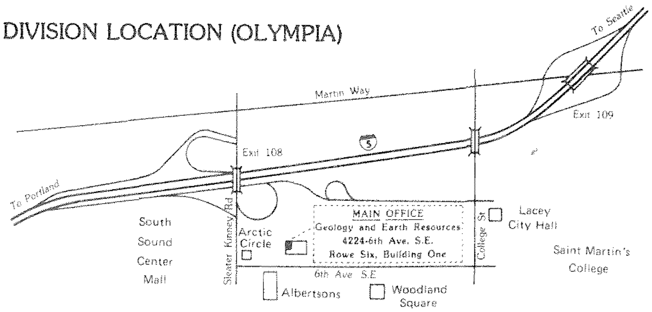
MAILING ADDRESSES

Main Office:
Department of Natural Resources
Division of Geology and Earth Resources
Mail Stop PY-12
Olympia, WA 98504
Phone: (206) 459-6372

Field Office:
Department of Natural Resources
Division of Geology and Earth Resources
Spokane County Agricultural Center
N. 222 Havana
Spokane, WA 99202
Phone: (509) 456-3255

<u>NOTE:</u> Publications available from Olympia address only.

DIVISION LOCATION (OLYMPIA)



The Blue Lake Rhinoceros

by

Keith L. Kaler

The Blue Lake rhinoceros fossil consists of a complete body mold and some associated bones of a large Miocene mammal, a member of the order Perissodactyla, which includes modern horses and tapirs. The way in which it is preserved indicates that fluid lava engulfed a probably dead, bloated animal. It is one of Washington's most famous fossils and is widely known to the world's community of vertebrate paleontologists. However, information about the fossil is sparse and scattered. Most articles about the rhino in the popular hobby magazines have been brief and general. When early technical articles were written (for example, Chappell and others, 1949, 1951), knowledge of Columbia River basalt stratigraphy was considerably less complete than it is today. As understanding of these basalts developed, mention was occasionally made of the rhino in conjunction with basalt geology (Lefebvre, 1966, 1970), but these references consisted of a few sentences and could easily be overlooked by the nonspecialist. No literature has been found that both explains the geology and describes the fossil.

This article briefly synthesizes information from published and unpublished works and interviews with some of the scientists who have studied either the geology or the fossil. For more detailed accounts, a list of sources is offered at the end of this article.

DISCOVERY AND EARLY STUDIES

The fossil site is in the west wall of Jasper Canyon at Blue Lake in Grant County, eastern Washington (Fig. 1). The lake basin was formed more than 12,000 years ago by the same process that created Dry Falls and Grand Coulee. Catastrophic outburst floods caused by releases of water from glacial Lake Missoula scoured the fractured Columbia River basalt flows and created deep and narrow canyons now occupied by the string of lakes between Soap Lake and Coulee City. Also contributing to the process of erosion was the diversion of the Columbia River through these canyons. Part of the Okanogan ice lobe blocked the river and forced it into a new channel east of the older one. The history of the Coulee

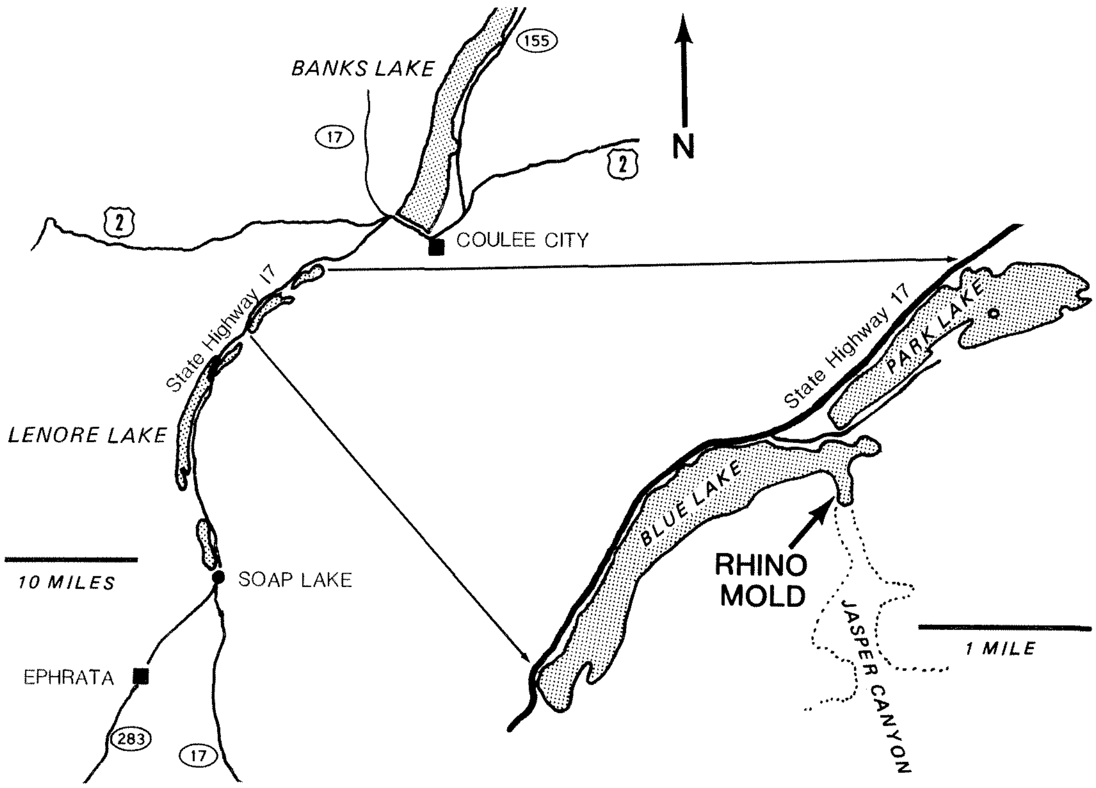


Figure 1. Location of Blue Lake rhino mold.

area is described in McKee (1973), Allen and others (1986), and numerous other reports cited in those works.

The rhinoceros mold was discovered in the summer of 1935 by Mr. and Mrs. Haakon B. Friele and Mr. and Mrs. G. B. Peabody of Seattle. They may have been looking for petrified wood, which was quite plentiful elsewhere in the vicinity in 1935, but no longer can be found at the rhino site. Mr. Friele was the first of the group to enter the cavity.

At the time of the discovery visit, several bone fragments, including part of the lower left jaw, were removed by Mr. Friele and given to Mrs. Peabody. Subsequently, she gave these to the University of Washington. Because the University lacked a vertebrate paleontologist at the time, the bones were released to George F. Beck, a paleobotanist at what is now Central Washington University at Ellensburg. Later in 1935, Beck visited the site, collected more bone fragments, and submitted the entire collection to Chester Stock, a vertebrate paleontologist at the California Institute of Technology. Stock identified them as belonging to an *Aphelops*-like rhinoceros, a middle Miocene to early Pliocene animal. At some time prior to 1948, all this material was sent to the University of California, Berkeley. In 1948, J. Wyatt Durham and Donald Savage, Berkeley geoscientists, visited the site, made measurements, and collected more bone (Chappell and others, 1951). All loose fossil bone from the rhino mold is presently at Berkeley.

GEOLOGIC SETTING

Three members of the Wanapum Basalt are exposed in Jasper Canyon. From oldest to youngest, these are the Frenchman Springs (three flows), Roza (two flows) and Priest Rapids (several flows). The Wanapum Basalt is part of the Yakima Basalt Subgroup of the Columbia River Basalt Group. Potassium-argon dates for members of the Wanapum indicate an age range from 14.5 to 15.5 million years (Reidel and others, 1987). Lefebvre (1966) states that there are four Priest Rapid flows in the Grand Coulee region and that these are the youngest basalts to occur there. The mold is in the lowermost Priest Rapids flow, which is about 50 to 60 feet thick at the site (Fig. 2). The flow encasing the rhino is probably slightly older than 14.5 million years (middle Miocene).

In the same paper Lefebvre states that pipe vesicles are present in the base of this lowermost flow and are exposed on the opposite side of Jasper Bay, 0.2 mile east of the site (Fig. 1). Pipe vesicles are cylindrical, elongate cavities formed by water vapor streaming up through lava from wet ground below. The motion of the fluid lava inclines the vesicles in the direction of flow. Vesicles that Lefebvre observed here are inclined in vertical planes that trend S30°E, S15°E (and S15°W), indicating that this part of the flow came from the northwest at the time the rhino was engulfed. This flow direction is somewhat anomalous because Priest Rapids

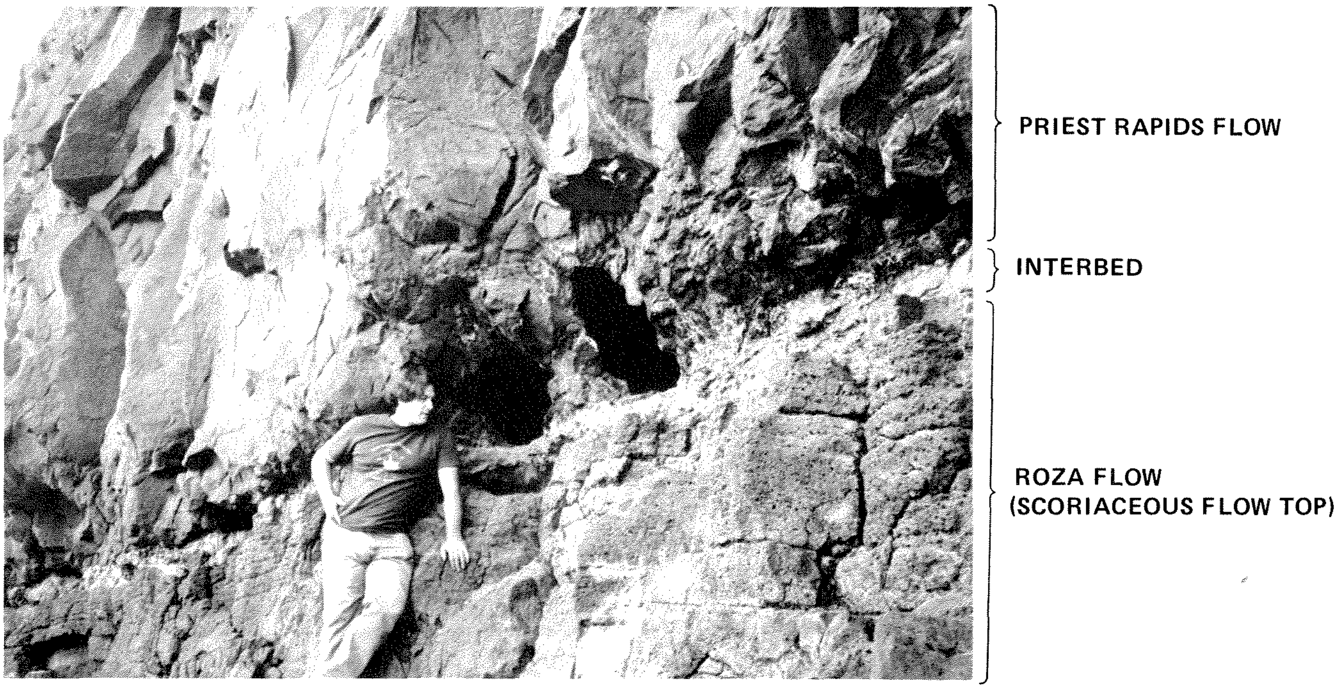


Figure 2. Rhino mold site. Rhino mold occupies the cavity on the right; to the left is a tree mold.

basalt originated from vents in Idaho, more than 120 miles to the southeast.

Between the Roza basalt and the lowest Priest Rapids flow is a sedimentary interbed, which Lefebvre (1966, p. 47) describes as "a light to dark gray pisolitic tuffaceous (?) sediment seldom over 1 foot thick". This interbed is shown in Figure 2. He suggests that all four Priest Rapids flows were laid down in rapid succession as there are no interbeds between them.

The mold is entirely encased in basal pillow lava of the lowest Priest Rapids flow; it is not in contact with the underlying interbed. Near the rhino mold, and at the same stratigraphic position, are cavities that represent trees engulfed at the same time as the rhino (Fig. 2). Pillow lava is formed when fluid lava encounters water or wet sediments. Due to rapid quenching, a tough, elastic skin forms on the lava. The lava then forms characteristic drop-like shapes that range up to several feet across. The pillows of lava, which are still plastic, are deposited on and around whatever objects may lie in their way and may incorporate the sediments they override.

From the outside, the cavity gives no clue to its origin. The opening to the cavity is an oval 2 by 1 1/2 feet (Fig. 2). It intersects what would be the posterior of the animal. The bottom of the entrance is only a few inches above the interbed. The tail region is missing due to erosion. The rhino is lying on its back with its legs sticking out and upward. The head is aligned with the main body axis, which is inclined 25° to 30° from the horizontal and rests about 1 1/2 feet above the interbed (Fig. 3). The internal shape of the cavity is clearly different from the nearby cylindrical tree molds.

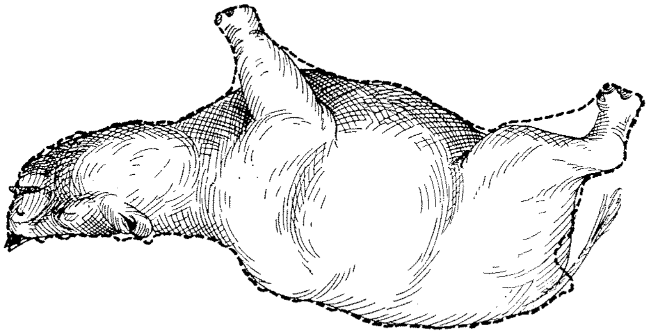


Figure 3. Sketch of the Blue Lake rhino as it might have appeared in the mold, oriented as it is found above the sedimentary interbed at the site. Sketch by Owen J. Poe, courtesy of the Geological Society of America.

THE RHINO CAST

In the late 1940s a crew from Berkeley made a cast of the inside of the mold in order to get a better idea of the original shape of the animal, which is difficult to ascertain directly from the mold. As can be seen in Figure 4, the cast has an unmistakable bloated-animal shape. The only anatomical features that can be readily identified are the legs and head. Other parts of the anatomy such as the ears or horns can be imagined, but there is no sign of them in cast or mold. Chappell and others (1951) suggest that subtle markings on the neck that were revealed by the cast may be skin folds, but these cannot be clearly seen in the cavity.

When one visits the fossil site, it seems remarkable that a cast was made at all. Obstacles abound, not the least of which is the narrow entrance to the mold itself. Materials, including water for mixing plaster used to make the cast, had to be brought up a near-vertical 200-foot cliff. The work area below the cavity is, at present, small, and photos (Lava and the River, 1959) show that it was smaller 40 years ago. Working inside the mold must have been cramped and dirty.

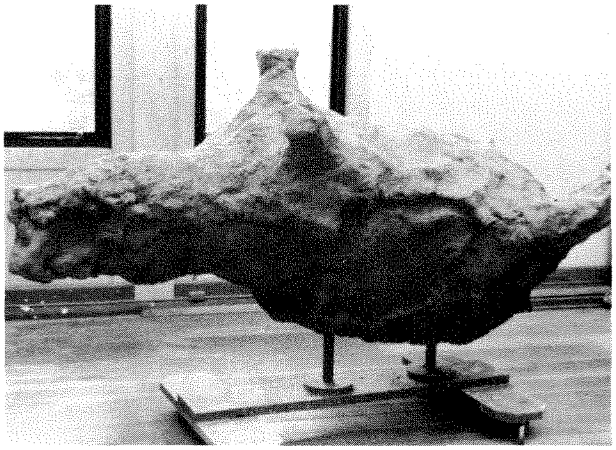


Figure 4. Rhino cast at the Burke Museum, Seattle. The cast was made by Arn Slettebak. Photo by Arn Slettebak.

FOSSIL MATERIALS

The mold and cast suggest a rhinoceros, but the bones that were found in and near the cavity firmly identified the animal as a member of the family Rhinocerotidae. According to Chappell and others (1951), all bone material is highly fractured, warped, porous, and well silicified. The best preserved bone fragment is pictured in Figure 5.

This partial jaw still has teeth attached; the teeth afford the conclusive proof that the animal was a rhino. The only complete tooth, the second molar, shows a mature state of wear, and the animal may have been old when it died.

Other identifiable bones include a portion of the right lower jaw with alveoli (sockets) for the missing teeth and a very slender pisiform, which is one of the many bones comprising the carpus or wrist

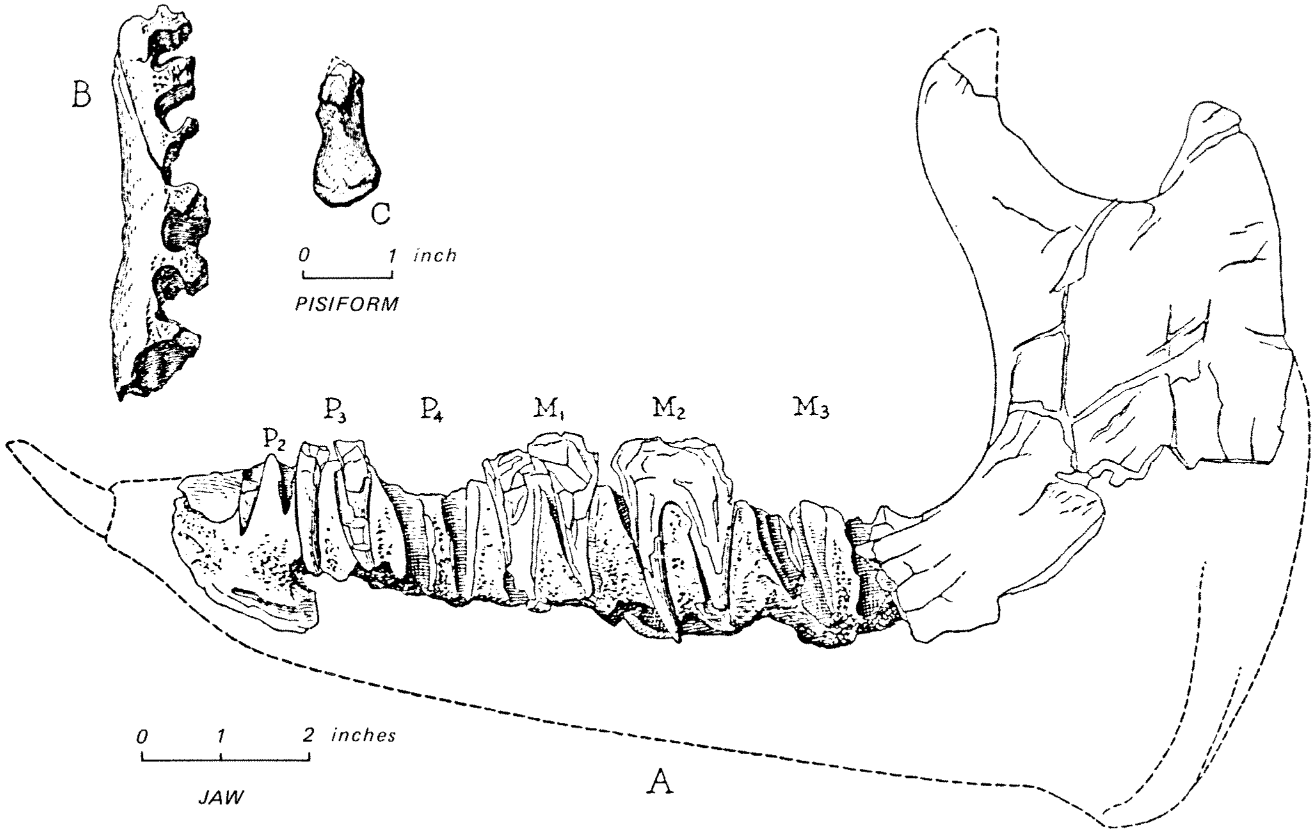


Figure 5. (A) Lower left jaw; ascending bone is the coronoid process. (B) Right lower jaw with alveoli (tooth sockets). (C) Pisiform bone. From a sketch by Owen J. Poe, courtesy of the Geological Society of America.

region. Fragments of the skull, ribs, and teeth were also found. Other bones are in unidentifiable pieces or are missing.

When the cavity was discovered in 1935, Mr. Friele and others found bone fragments outside the entrance and below the cavity. It is not known if animals were responsible for moving the bone. Beck believed that because there was no indication of animals having lived in the cavity, it might have been uncovered only weeks or months earlier. Observations in 1988 of tree and erosional cavities at other sites along the canyon wall and at the same elevation above the lake indicated no birds or mammals were living in the holes. These cavities have been exposed for at least half a century. Therefore, the bones on the talus might simply have fallen out of the mold.

RECONSTRUCTION AND IDENTIFICATION OF THE RHINO

An approximation of the animal's appearance is given on the cover of this newsletter. From measurements of the cast, the size of the live animal can be estimated. The rhino probably was at least 50 inches tall at the shoulder. Its length was close to 8 feet from snout to tail. Its weight was calculated by estimating the volume of the cast. The possibility that the animal was bloated and therefore of a reduced specific gravity was considered in the calculation. Assuming a specific gravity of 0.8 (instead of about 1.0 for a living creature), the animal probably weighed close to a ton. This compares well with weights of modern rhinos of comparable size.

Based on the lower jaw tooth formula (the numbers of incisors, canines, premolars, and molars) and the characteristics of the pisiform bone, Savage believed that the animal could have belonged to only one of two genera, *Diceratherium* or *Subhyracodon* (see Chappell and others, 1951). He stated that the size of the jaw and the angle formed by the intersection of a line drawn along the occlusal surface (where the teeth come in contact with their counterparts in the upper jaw) and a line drawn along the anterior of the coronoid process (the vertical bar of bone shown in Fig. 5) suggest that the jaw is more diceratheroid in appearance. However, Savage concluded that the two genera probably can not be distinguished by morphology alone. Because we know the age of the enclosing basalts, we can exclude the possibility that it was *Subhyracodon*. According to Carroll (1988), this genus lived in the lower to middle Oligocene of North America, at least 12 million years before any Columbia River basalt covered the site area. Savage's suggestion that the animal was most likely a *Diceratherium* is a logical choice. According to Carroll (1988) this genus ranged in North America from the upper Oligocene to the middle Miocene, well within the age range of the Priest Rapids flows.

Because of the poor condition of the bones, which are crucial to the accurate identification of the rhino, it may never be certain what genus it belonged to. The bones have not been studied for nearly 40 years. With increase in knowledge of fossil rhinos, the time may come when a review will be warranted.

THE RHINO'S ENVIRONMENT

Nothing is known of the paleoecology of the site. If any work has been done on petrified wood from this locality, it has not been reported in the literature. The only clue we have is from a study by Barnett and Fisk (1980) of an interbed in the Frenchman Springs Member near Palouse Falls, 90 miles southeast of Blue Lake. In their paper (p. 261), they cite an age (K-Ar) of 14.5 to 15 million years for the Frenchman Springs Member on the basis of personal communication with D. A. Swanson. Thus, the age of that interbed may be nearly the same as that of the rhino; flows of the Priest Rapids Member are about 14.5 million years old. Pollen extracted from the Frenchman Springs interbed reveals a diverse flora. Of the 95 types of pollen, 39 percent are angiosperms [such as *Ulnus* (elm), *Alnus* (alder), *Carya* (hickory)] and 14 percent are gymnosperms [*Thuja* (cypress), *Larix*? (larch)), to name a few]. *Equisetum* (horsetails), *Tpyha* (cat-tails) and *Salix* (willow) were also abundantly represented as pollen. The pollen represents a forest in a warm, temperate, moist climate, probably very similar to that of modern deciduous forests of the eastern United States (Barnett and Fisk, 1980).

Ordinarily, animals will avoid a threat like a fire or flood. It has been estimated that the Columbia River lavas were advancing about 5 kilometers per hour (3 mph) at this distance from the vents (Shaw and Swanson, 1970). Most animals could at least initially outrun a flow advancing at this speed, but some may have been trapped in lakes or swamps where the conditions were like those that apparently served to preserve the Blue Lake rhino. Lava flows are widespread in the Columbia Basin, so one might ask: Isn't it possible that there are more such cavities on the plateau?

VISITING THE BLUE LAKE RHINO

According to the Grant County auditor's office, the site is on land owned by the U.S. Bureau of Reclamation. Private property must be traversed to reach it. Permission to cross this land should be obtained from the landowners, most of whom live nearby.

The site is on a narrow ledge about 200 feet above the floor of Jasper Canyon. There is only a primitive trail up the talus to the site. The mold lies 12 feet above the level of the trail (Fig. 2).

At present, an estimated 150 to 200 people a year clamber up the rock slope to get a peek at the hole; most are college students from around the state. Comparisons of early photos (Lava and the River, 1959) with those taken recently show that chunks of fractured and easily eroded basalt have fallen off the cliff just below the entrance to the cavity, making access to the mold difficult.

A far easier and safer way to see the Blue Lake rhino is to visit the Burke Museum at the University of Washington. On display is the original and only cast of the mold (Fig. 4) made by the Berkeley scientists. One can also see a partial reproduction of the mold made from this cast by Arn Slettebak (Fig. 6). It was made in 1979 and took about 450 hours to produce (Slettebak, 1982). Pillows and lava vesicles have been replicated in this mold. Because the Burke museum plans an ethnographic exhibit during the state centennial in 1989, the rhino cast and mold may not be on display after the first part of the year. For current exhibit information, phone the museum [(206) 543-5590].

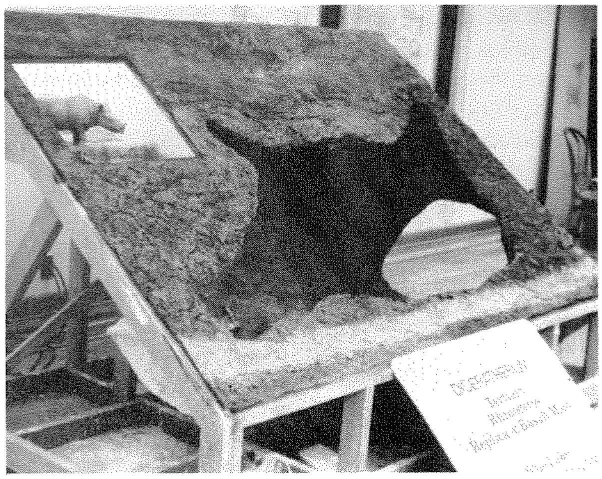


Figure 6. Partial mold made by Arn Slettebak from the cast in Figure 4. Photo by Arn Slettebak.

Fossil vertebrates are rarely preserved as whole skeletons; remnants of body outline or skin are likewise very uncommon. Three-dimensional preservation is extremely rare—examples are the frozen mammoths found in Siberia. The rhino fossil is unique in the United States and possibly the world. Therefore it is important that we treat this or any similar site with care.

ANNOTATED REFERENCES

Allen, J. E.; Burn, Marjorie; Sargent, S.C., 1986, Cataclysms on the Columbia: Timber Press, Portland, OR, 211 p.

Barnett, Jeanie; Fisk, L. H., 1980, Palynology and paleoecology of a sedimentary interbed in the Yakima basalt (Miocene), Palouse Falls, Washington: Northwest Science, v. 54, no. 4, p. 259-277.

Beck, G. F., 1935, Fossil bearing basalts (more particularly the Yakima basalts of central Washington): Northwest Science, v. 9, no. 4, p. 4-7.

(First published note of the Blue Lake rhino)

Beck, G. F., 1937, Remarkable west American fossil, the Blue Lake rhino: The Mineralogist, v. 5, no. 8, p. 7-8, 20-21.

Beck, G. F., 1965, The Blue Lake Rhino: Gems and Minerals, no. 334, p. 25, 35.

(A popular nontechnical account)

Chappell, W. M.; Durham, J. W.; Savage, D. E., 1949, Rhinoceros mold in basalt [abstract]: Geological Society of America Bulletin, v. 60, no. 12, pt 2, p. 1949.

(The first scholarly reference to the rhino)

Chappell, W. M.; Durham, J. W.; Savage, D. E., 1951, Mold of a rhinoceros in basalt, lower Grand Coulee, Washington: Geological Society of America Bulletin, v. 62, no. 8, p. 907-918.

(Still the most important and accurate description of the mold, cast and bones)

Carroll, R. L., 1988, Vertebrate Paleontology and Evolution: W. H. Freeman and Company, New York, 698 p.

(A thorough treatment of vertebrate paleontology)

Lava and the River, 1959, Martin Moyer Productions.

(A 16-mm movie that serves as a very general introduction to the geology of the Columbia Plateau; shows old photos of Vantage and the Blue Lake rhino. Can be obtained from the Washington State Film Library, Evergreen State College, Olympia)

Lefebvre, R. H., 1966, Variations of flood basalts of the Columbia River Plateau, central Washington: Northwestern University Doctor of Philosophy thesis, 212 p.

(The first mention of the rhino mold with basalt stratigraphy; see pages 47 and 150)

Lefebvre, R. H., 1970, Columbia River Basalts of the Grand Coulee area. In Gilmour, E. H.; Stradling, Dale (editors), 1970, Proceedings of the second Columbia River Basalt Symposium, Eastern Washington State College Press, p. 1-38.

(A reiteration of his 1966 thesis, mentioning the rhino on page 4)

McKee, Bates, 1972, Cascadia, the geologic evolution of the Pacific Northwest: McGraw-Hill Book Company, New York, 394 p.

(One of the best books about northwest geology. The reference on page 278 to the Blue Lake rhino is incorrect in that bones were indeed found associated with the mold.)

Reidel, S. P.; Hooper, P. R.; Price, S., 1987, Columbia River Basalt Group, Joseph and Grand Ronde Canyons, Washington: In Hill, M. L., Cordilleran Section of the Geological Society of America, Centennial Field Guide, v. 1, p. 351-356.

Shaw, H. R.; Swanson, D. A., 1970, Eruption and rates of flood basalts: In Gilmour, E. H.; Stradling, Dale (editors), 1970, Proceedings of the second Columbia River Basalt Symposium: Eastern Washington State College Press, p. 271-299.

Slettebak, Arn, 1982, Recreating the Blue Lake rhino cave: Curator, v. 24, no. 2, p. 89-95

(For those wishing to know how the replica of the rhino cave was created)

Zoretich, F. J., 1978, A day in the life of the Blue Lake rhino: Pacific Search, July/August, p. 21-22.

(A nontechnical account of the rhino)

Study of Washington's Hydrocarbon Potential

The Division of Geology and Earth Resources, in conjunction with the Washington Sea Grant Ocean Resources Assessment Program, is conducting a study titled "Reassessment of the Hydrocarbon Potential of the Washington Outer Continental Shelf". The purpose of the study is to provide technical information about the oil and gas potential of the state's outer continental shelf (OCS). The information will be used in policy decisions related to oil and gas leasing in the federal waters of Washington's OCS. The Minerals Management Service (Department of the Interior) has drawn up a preliminary schedule calling for a sale of federal OCS land adjacent to Washington and Oregon during 1992 (Lease Sale 132).

The principal investigator for this study is Stephen P. Palmer of the Washington Sea Grant Program. Steve received his Ph. D. degree in applied geophysics from the University of California, Berkeley. He has 6 years of petroleum exploration experience in onshore and offshore regions of the western United States as an employee of major oil companies. Steve's participation with the Sea Grant project will cease at the end of November 1988, when a report is to be delivered to the parent agency. Steve is being assisted in this project by William Lingley of the Division.

Overview of Earthquake-Induced Water Waves in Washington and Oregon

by

Gerald W. Thorsen

INTRODUCTION

In some settings water waves can cause greater loss of life and property damage than building collapse and all other effects of earthquake shaking combined. Such waves are generated in a variety of ways and are not necessarily confined to coastal areas. In addition to ocean-crossing tsunamis, landslide-generated waves and seiches may impact nearby shores in inlets, lakes, and reservoirs. In 1964, several Alaskan towns were devastated by landslide-induced waves within minutes of the March 27 earthquake. That same earthquake radiated tsunamis that impacted the Pacific Northwest hours later. Losses in the Pacific Northwest and along the California coast included 15 deaths and more than $100 million (1988 dollars) worth of damage. The 1964 event was the largest of the six tsunamis recorded at the Neah Bay tide gage in the past 42 years. Memories of the 1964 event were still vivid enough in some areas along the northwest coast to have spurred evacuation after the May 1986 earthquake in the central Aleutians.

Quake-induced water waves arrive at shores in many forms, but rarely as the huge curling breakers commonly portrayed by Hollywood. Tsunamis on open coastlines generally arrive as rapidly rising or falling tides; some of these have a much greater range than normal tides. The same tsunami, tide-like on an open coast, may form a "wall of water" or bore where it encounters a restricted channel in a bay or estuary. The rapid, and commonly large, rise or fall of water accompanying such waves creates strong currents. Such currents can drag ships at anchor and erode (scour) bottom sediments that support breakwaters and seawalls. Onshore, they are capable of carrying locomotives from their tracks or slamming logs, boats, and cars against structures. Damage from the impact of objects carried along by the waves is commonly greater than the damage that would occur from the waves alone.

TSUNAMIS

Tsunamis Generated at a Distance

Tsunamis capable of impacting distant shores are usually generated by abrupt vertical displacement of the sea floor during large subduction earthquakes. As subducting plate boundaries are common along the Pacific Rim and relatively rare throughout most of the rest of the world, it is not surprising that "about 80% of all tsunamis occur in the Pacific Ocean" (Steinbrugge, 1982, p. 235). Because such tsunamis have wave lengths much longer than the depth of the ocean, they act like shallow-water waves, even in depths of thousands of feet. Thus, wave fronts tend to curve towards shallows such as continental shelves or "wrap around" oceanic islands or seamounts. Such refraction is the reason that the wave fronts generated by the 1964 Alaska earthquake arrived from the west, reaching the Washington and Oregon coasts almost simultaneously (Wilson and Torum, 1972).

Coastal impacts

The report of tsunami damage along the Washington coast by Whipple (in Hogan and others, 1964), summarized in Figure 1, emphasizes the vulnerability of development along the small estuaries just north of Grays Harbor. A similar damage pattern was experienced south of the Columbia River. Spaeth and Berkman (1972, p. 58) point out that "much of the damage in Oregon occurred away from the ocean front." Homes, businesses, and bridges along estuary channels, were severely damaged or destroyed in places. The size, shape, and depth of such estuaries apparently were the main factors in determining whether the tsunamis were propagated upstream or dissipated (Schatz and others, 1964). Development along the ocean front was generally protected by dunes (Hogan and others, 1964; Figure 2).

The 1964 tsunamis were described as coming "with a terrible rush" without "any notification" in places and sending beach "logs flying around like toothpicks" (Aberdeen World, March 28, 1964, p. 11). In other places, such as La Push, the waves were described as a gradual rise in the water level (Hogan and others, 1964). These seeming contradictions may be partially accounted for by the darkness, by the location of the observers, and by whether or not they were caught by surprise. No accounts of bore development were found. However, it is obvious that strong debris-laden currents had to be responsible for some of the damage, especially to bridges. Slow flooding and buoyancy

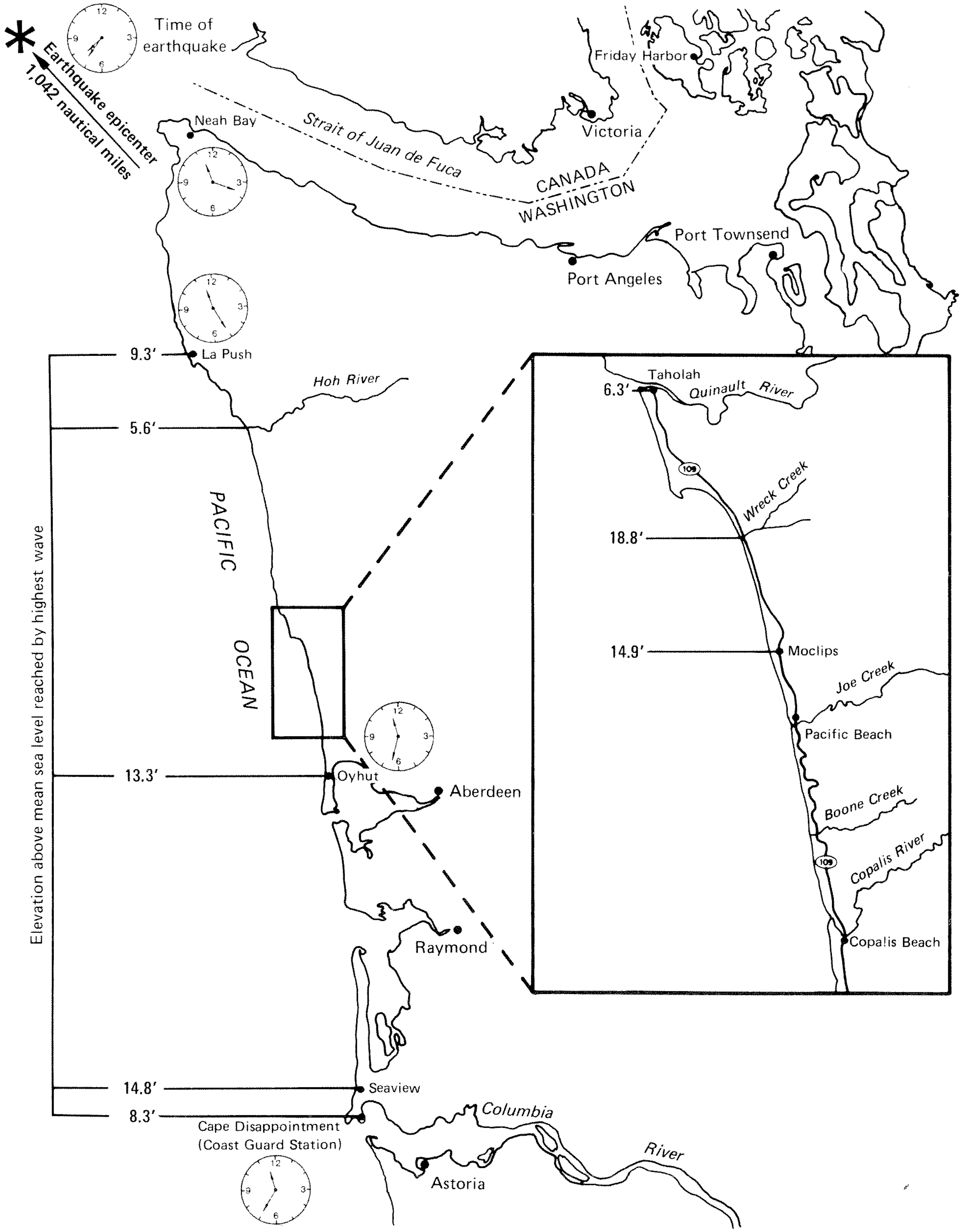


Figure 1. Clocks show time of 1964 Alaska earthquake and arrival of first tsunami along Washington coast (PST). Explanation, facing page. (From Noson and others, 1988).

La Push—Boats and floating dock broken loose, possible shoaling of channel.

Taholah—Crests below street level, no structural damage, loss of some nets and skiffs.

Wreck Creek—Debris on highway and bridge, washout of approach fills.

Moclips—Flooding one foot above ocean-front street, south end of town. Eight buildings damaged by drift logs or moved from foundations. Extensive damage to bulkheads and fills.

Pacific Beach—Dwelling* moved from foundation and destroyed, another building damaged.

Joe Creek—Logs and occupied home* slammed into bridge, three pile bents damaged or destroyed, two 20-foot spans lost.

Boone Creek—Debris on road, shoulder washout, dwelling flooded.

Copalis Beach—Damage to buildings, mobile homes.

Copalis River—Pile bents of bridge damaged, two bridge spans lost, others damaged.

Oyhut—Debris in yards and streets where dunes breached.

*(probably the same structure—Washington Highway News, v. 11, no. 5, p. 2).

Figure 1. (Continued) Description of tsunami damage at indicated sites, 1964. Damage reports from Hogan and others (1964), unless otherwise indicated.

forces alone could not have caused much of the damage described along the Oregon and Washington coastal estuaries.

Some appreciation of the possible velocity of tsunami-induced currents that night, especially near the mouths of bays and estuaries, might be gained by considering normal tidal currents at the entrance to Grays Harbor. A "spring tide" drop of 10 or 11 feet on nearby ocean beaches can result in ebb currents approaching 5 knots at the entrance. This is with a high-to-high tidal cycle of about 12 hours. Compare this to the 1964 water-level drop of about 14 feet (estimated) between tsunami crests 1 hour and 28 minutes apart at nearby Pacific Beach, or a drop of 11.9 feet between crests 1 hour and 15 minutes apart at Cape Disappointment (Hogan and others, 1964).

There are few accounts of scour (the erosion of bottom sediments by fast-flowing currents), and none of structural damage resulting from such scour along the Washington-Oregon coast. There is little doubt, however, that tsunami-generated currents were responsible for the damage reported to Grays Harbor and Willapa Bay oyster beds, even though such currents would be substantially less than at harbor entrances. Predicted oyster losses, over a period of years, from the 1964 tsunamis were as high as $900,000 (Aberdeen Daily World, April 30, 1964). Abnormal currents also broke loose three rafts at

Figure 2. The dunes that protected much of Washington's south coast in 1964 have been removed in places to improve views. Some of these dunes were being restored when this 1988 photo was taken.

Aberdeen but apparently caused no other significant damage (Aberdeen Daily World, March 28, 1964).

In regard to the prediction of tsunami frequencies and runup elevations, Houston and Garcia (1978) include in their deep-ocean and nearshore numerical models coastline interaction and tidal statistics. In their predictions of 100-year and 500-year runups on the west coast of the continental United States they considered source areas in the Aleutian and Peru-Chile trenches. They place considerable emphasis on source orientation and divide the Alaskan area into 12 segments because tsunami "elevations produced on the west coast are very sensitive to the location of a source along the Trench" (p. 25).

The results of Houston and Garcia's computations for the Washington/Oregon coasts are generalized in Figure 3 and in another form in Houston (1979). Comparing these results with storm data for two Washington coastal counties, flood insurance consultants concluded that predicted levels of flooding by the 100-year tsunami are "lower than that caused by winter storms" (Federal Emergency Management Agency 1985, p. 25; 1986, p. 11). While this may be true in regard to relatively static water levels alone, it may not accurately portray the full hazard potential from tsunamis. Flooding caused by storm surge, even though to the same elevations, is not apt to cause the kind of damage that the multiple and relatively short-term water-level fluctuations of tsunamis can cause. As previously discussed, strong currents generated by such fluctuations can cause major structural damage beyond that of flooding alone.

A study by Kowalik and Murty (1984) focuses specifically on the seismic gap in the Shumagin Island area of the Aleutians as a tsunami source. They cite research suggesting "the possibility of occurrence of a major earthquake within the 'Shumagin Gap' in the next two decades" (p. 1243). Their computations of tsunami energy from such an event "shows strong directionality" toward Hawaii. Nevertheless, they calculate that a tsunami would arrive near the coast of Washington in about three hours. Its computed amplitude as a function of time at the mouth of the Strait of Juan de Fuca shows a pattern and magnitude similar to that of the arrival of the 1964 Alaska tsunami as it was recorded at the Neah Bay tide gage. Pruess (1986) discusses the potential impact of a "Shumagin Gap"-generated tsunami on the city of Aberdeen.

Impacts along Inland Waters

The attenuation of tsunamis generated by the 1964 Alaska earthquake as they progressed into more protected waters is indicated in Figure 4. No reports of damage inside the entrance to either the Strait of Juan de Fuca or the mouth of the Columbia River were found in preparing this paper. It appears likely that few people not near the water noticed the tsunamis; however, they were detected on tide gages as far inland as Pitt Lake, near Vancouver, B.C., at Seattle, Washington (Spaeth and Berkman, 1972), and on the Columbia River as far inland as Vancouver, Washington (Wilson and Torum, 1972).

Garcia and Houston (1975) modeled 100- and 500-year tsunami runups for shorelines of the Strait of Juan de Fuca and for Puget Sound as far south as Tacoma. For this study they used tsunami sources along the Aleutian trench only and used the 1964 Alaska tide gage record at Neah Bay to calibrate the model. The computed runups, which included astronomical tides, were reported on segments of U.S. Geological Survey quadrangle maps (Fig. 5). They considered "the simultaneous occurrence of a storm surge and tsunami ... highly improbable" and also did not include wind waves in their computations. In general, they found (p. 14) that:

> "...tsunami waves in Puget Sound had small amplitudes, and runup values were governed largely by the effect of astronomical tides. Therefore, although waves had larger amplitudes at Port Townsend, Washington, than at Seattle, Washington, the greater tidal range at Seattle resulted in larger combined runup values there."

In comparing the Strait and Puget Sound with San Francisco and Monterey bays, they found that resonance was not so much a factor in Puget Sound as was wave decay "along a narrow body of water."

Locally Generated Tsunamis

Seismic sea waves generated by a nearby offshore quake are apt to have significantly greater runups than waves from a remote quake of the same magnitude. An additional element of hazard is that they may strike within as little as ten minutes or so after the earthquake. Thus, the extended duration of shaking common to such quakes may be the first, and possibly only, warning of an impending tsunami potential to individuals along nearby shores.

Evidence for such historically unprecedented earthquakes off the coast of the Pacific Northwest is summarized by Heaton and Hartzell (1987). Among the more compelling data discussed are geologic indications of repeated episodes of abrupt subsidence along the coast of Washington (Atwater, 1987).

Coastal Impacts

Simply "scaling up" the impacts of the 1964 tsunami described earlier will not describe what to expect in the event of a major subduction earthquake along the coast of the Pacific Northwest. Even Houston and Garcia's 500-year runup predictions (Fig. 3) will not be generally applicable (J. R. Hous-

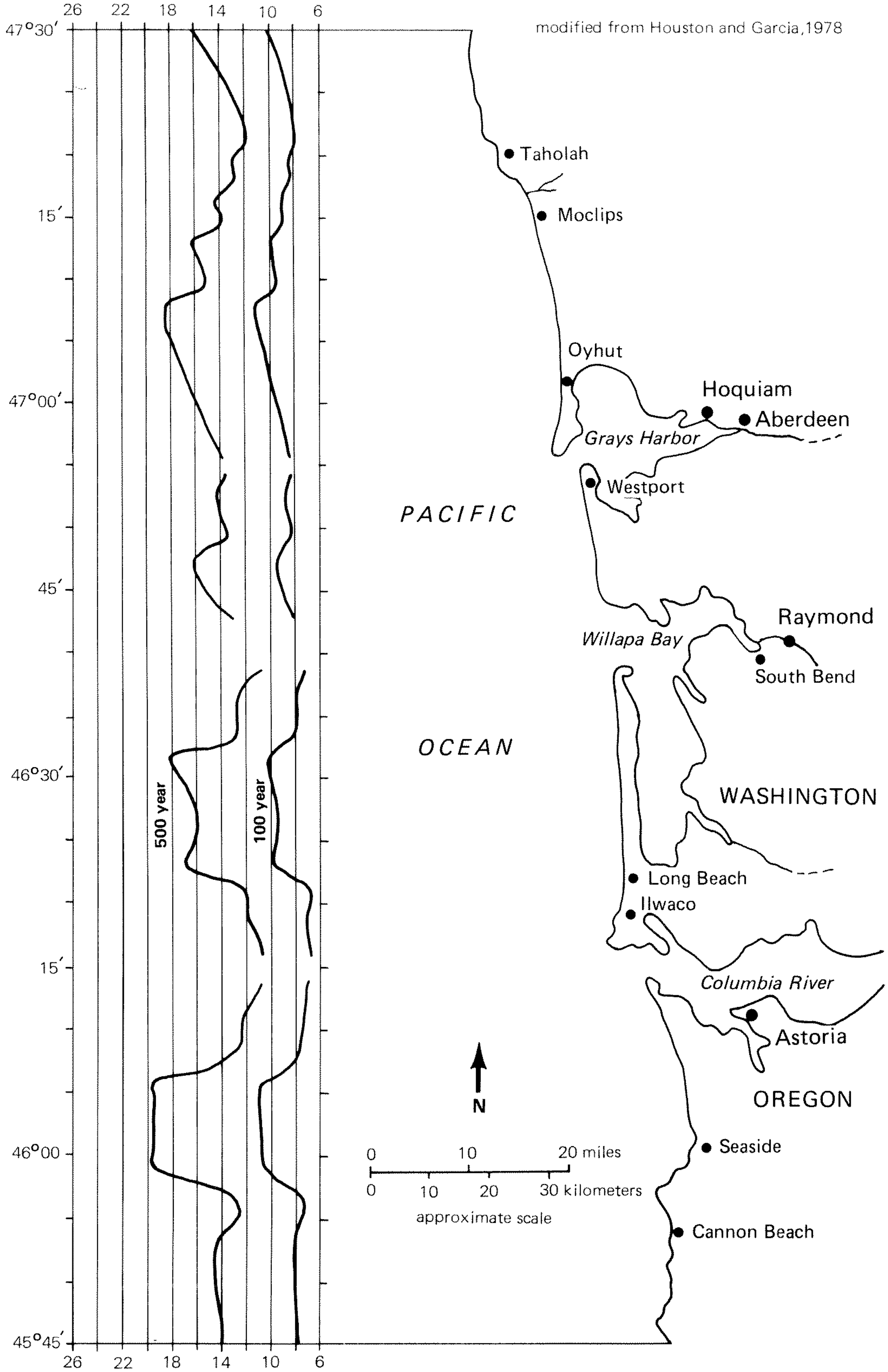


Figure 3. Computed 100- and 500- year tsunami elevations in feet above mean sea level. (Based on Garcia and Houston, 1975).

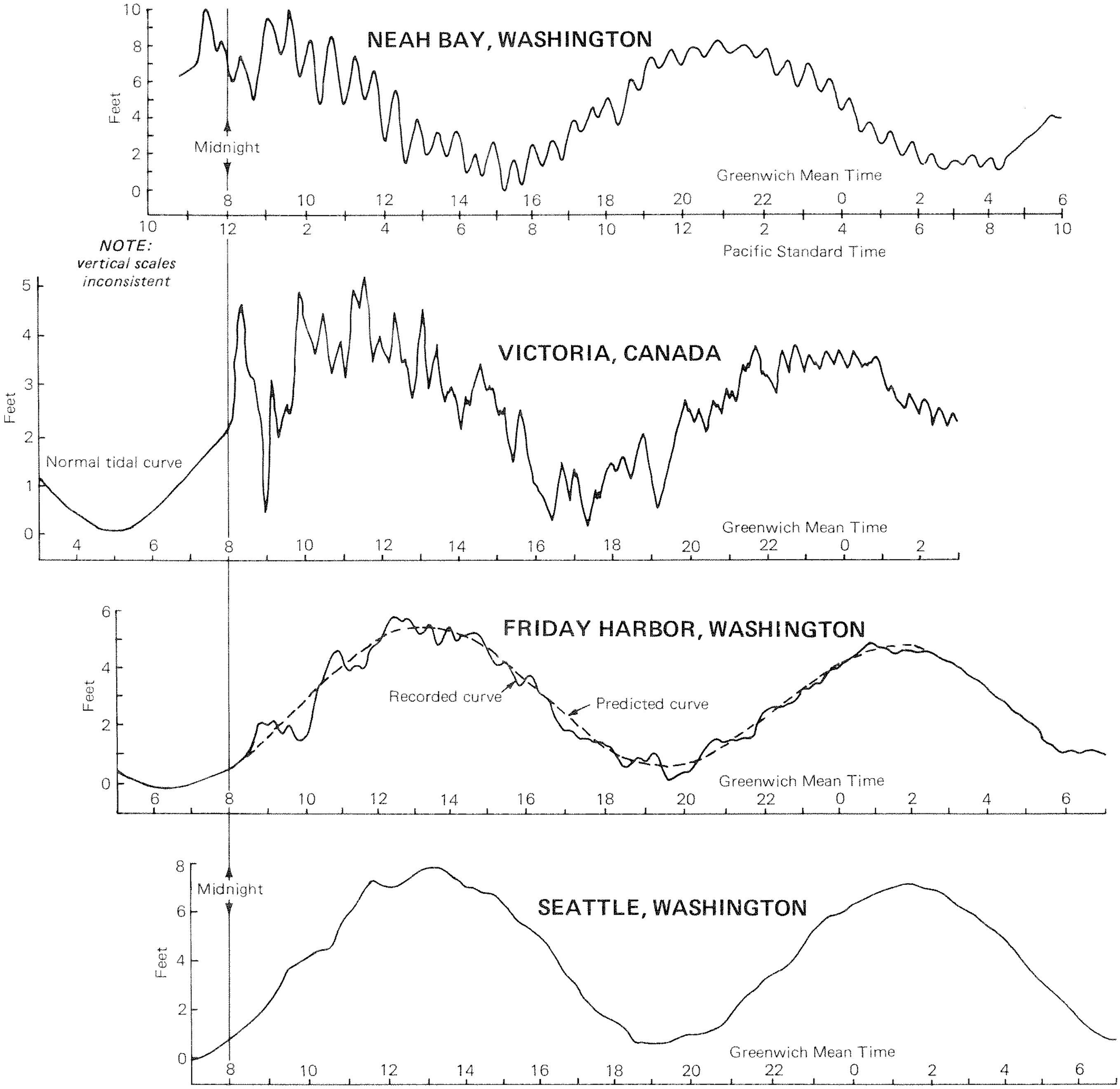


Figure 4. Tide gage records on March 27 and 28, 1964, showing tsunamis from the Alaska earthquake. Superimposed on the normal tidal fluctuations with a 12-hour period are tsunami oscillations with a period of about a half an hour. Note time lag and wave attenuation as the tsunamis progressed into more inland waters. (Modified from Spaeth and Berkman, 1972).

ton, 1987, personal commun.). Hebenstreit (1988) is currently addressing this problem with computer simulations of subduction quakes off the coast of Oregon, Washington, and Vancouver Island. In his simulations, source areas, fault rupture lengths, and fault displacement are being varied. The model used predicts areas of both uplift and subsidence. He points out (p.552) that the model is "not capable of simulating runup on shore" but that "in all cases, given the shallow dip angle" of the fault used (10 degrees), "subsidence will occur on land." Any such subsidence would, of course, compound the impact of a tsunami.

Impacts along Inland Waters

The generation of tsunamis in inland marine waters of the Pacific Northwest is currently being studied by T. S. Murty (personal commun., 1988).

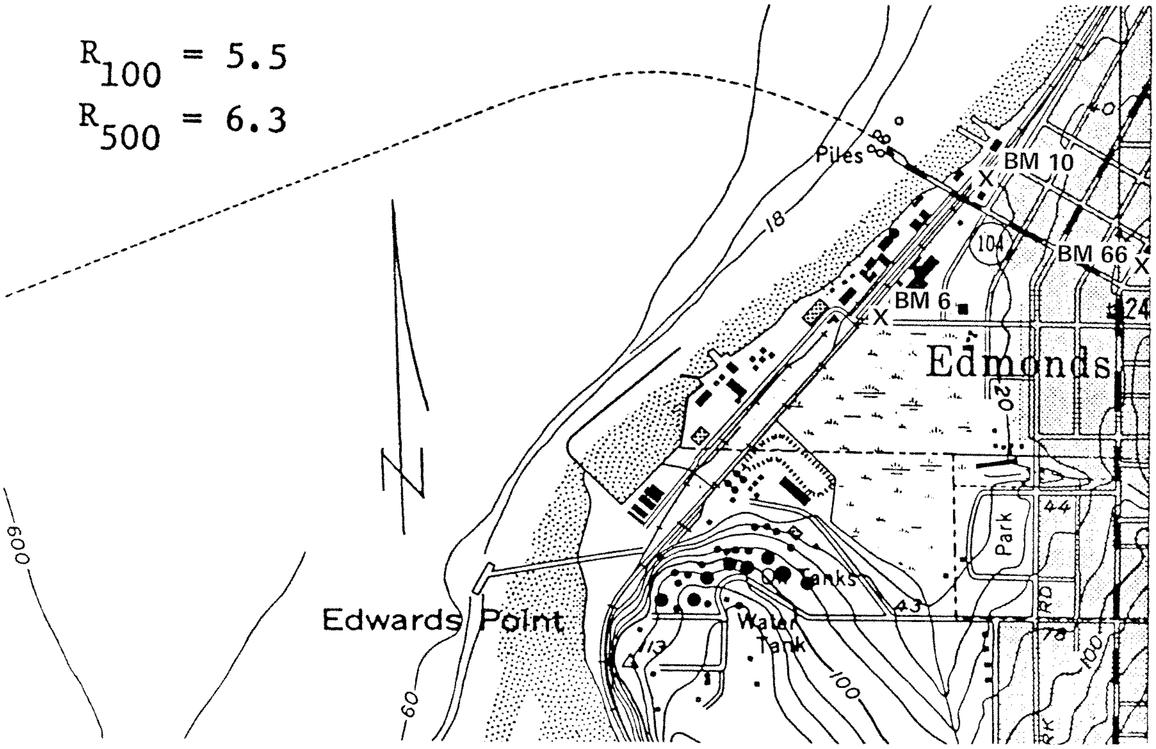


Figure 5. Map with computed tsunami runup values for a particular shoreline segment of Puget Sound. R100 and R500 are runup in feet above mean sea level "that is equalled or exceeding with a frequency of once every 100 years" and 500 years, respectively. Note the elevations of benchmarks (BM); most of the marsh and shoreline would be inundated in a R100 event. (From Fig. 121, Garcia and Houston, 1975).

He is examining the direct generation of water waves by earthquake motion rather than indirect generation such as by quake-triggered landslides. Murty's computer simulations assume three hypothetical earthquakes of magnitude 7.3, similar to the June 1946 Vancouver Island event. Epicenters were selected near Vancouver and Victoria, British Columbia, and Seattle, Washington.

LANDSLIDE-INDUCED WAVES

Landslides into, as well as within, bodies of water can cause destructive water waves. Earthquakes can trigger both types of landslide. Like seismic sea waves, the waves are generated by the sudden displacement of water. In general, the larger the volume and the more rapid the displacement, the larger the waves. This is why some of the more spectacular water waves are created in areas of high relief adjacent to deep water, such as along fjords or glacially scoured lakes. The 1946 Vancouver Island earthquake (felt widely in Washington) triggered a rockslide into a lake near the center of the island that created a wave more than 80 feet high at the lake outlet (Evans, 1988). Numerous other landslides were triggered along lakes and inlets, causing beaches to disappear, underwater cables to break, and alluvial fans to slump. One such slump triggered a wave that drowned a man in a small boat (Rogers, 1980).

Landslides into Water

The landslide into the Tacoma Narrows that was triggered by the 1949 Olympia earthquake (Noson and others, 1988) created an 8-foot wave that caused minor damage to nearby docks. Washington's inland waters are lined with hundreds of miles of unstable bluffs such as border the Narrows. Historically, Puget Sound shoreline bluffs have not been particularly sensitive to earthquake-induced failures. This is in spite of the existence of horizons of potential liquefaction such as caused devastating landslides in Anchorage, Alaska, during the 1964 earthquake (James Yount, 1983, personal commun.). A possible explanation might be that the duration of strong shaking of historic Puget Sound earthquakes has tended to be brief (less than 20 seconds) and the shaking of relatively short period (high frequency). Neither would be the case in the event of a major subduction quake such as devastated parts of Anchorage in 1964 and Mexico City in 1985.

One factor that tends to mitigate the hazard of landslide-induced water waves along Washington's inland marine waters is the almost universal existence of a wave-cut terrace fronting the bluffs. Such terraces are commonly wider than the bluff is high. Another mitigating factor is that dense beach-level residential developments are uncommon and in only a few places directly face a nearby unstable bluff.

Nevertheless, major fast-moving coastal bluff landslides, quake-triggered or not, could generate potentially hazardous waves, especially if they occurred during a high tide.

Possibly at greater hazard from waves induced by slides into water bodies are settlements along and downstream from deep lakes and reservoirs. One landslide into the area behind Grand Coulee Dam created a wave 65 feet high (Jones and others, 1961). Fortunately, residential development along this and similar water bodies in western Oregon and Washington tends to be sparse. However, downstream populations are potentially vulnerable to waves that might overtop a reservoir impoundment. Washington has three stratovolcanoes with reservoirs near their bases. The Columbia Gorge is another area of high relief, unstable slopes, and a reservoir. The U.S. Army Corps of Engineers has carefully examined slides in this area in relation to the raising of the reservoir behind Bonneville Dam.

Landslides within Water

Massive landslides, most of the volume of which was below the water's surface, created waves that caused much of the damage during the 1964 Alaska quake. These slides created "backfill waves" as water rushed to fill the void created by the downward drop of the head of the slide, as well as "far-shore waves" created by displacement of water by the slide toe (McCulloch, 1966). Only one such essentially subaqueous slide has been reported from damaging Puget Sound earthquakes. This was the collapse of a sandspit near Olympia during the 1949 earthquake (Murphy and Ulrich, 1951), and it apparently did not cause a damaging wave.

Among the more likely sites for subaqueous earthquake-triggered ground failure, deltas have apparently not failed during historic Puget Sound earthquakes. The massive collapse of the Nisqually delta (University of Washington Department of Geology, 1970) apparently occurred prehistorically and may or may not have been quake-triggered. Historic slides from the Puyallup delta, such as occurred in 1943 (University of Washington, Department of Oceanography, 1953) apparently have not been earthquake-triggered.

Other subaqueous deposits that are potentially capable of mobilization by earthquakes front many of the shoreline bluffs of the Puget Lowland. These deposits, eroded during the development of the adjacent bluffs and wave-cut terraces, are now poised on submarine slopes below tidal level. In some areas they are quite extensive and may locally be thick enough to experience massive failure during seismic shaking (M. L. Holmes and R. E. Sylwester, 1988, personal commun.). Major failures of such material could cause destructive water waves as well as disrupt submarine cables.

Landslides Impounding Water

Landslides into narrow valleys commonly dam streams. Such landslide dams may fail catastrophically when overtopped by the impounded lake, creating "waves", "walls of water", and/or flooding for great distances down stream. Concerns about the hazards of such an event necessitated quick action by the U.S. Army Corps of Engineers following both the 1959 Hebgen, Montana, earthquake and the 1980 earthquake and accompanying eruption of Mount St. Helens. Both events created major landslide dams, requiring prompt action to develop drainage structures capable of controlling or preventing overtopping of the dam.

SEICHES

Seiches, or mass oscillations of enclosed or semi-enclosed bodies of water, may be triggered directly by earthquake vibrations. They are caused by the land surface waves of the quake and may occur far from the epicenter. Seiche amplitude is dependent on the amplitude of earthquake surface waves and their similarity to the natural periods of oscillation of a particular body of water (Houston, 1979). Seiches may also occur when a body of water is abruptly tilted by the same tectonic deformation that caused the accompanying quake. Such seiches occurred with the August 1959 magnitude 7.1 Hebgen Lake earthquake near Yellowstone Park. This shallow (10-12 km) earthquake was accompanied by extensive surface faulting and ground elevation changes as great as 19 feet (Murphy and Brazee, 1964). It caused seiches on Hebgen Lake, in the epicentral area, that repeatedly overtopped the impounding earthfill dam (Stermitz, 1964).

Long-period surface waves from a large earthquake can travel great distances. The 1964 Alaska earthquake generated seiches on 15 bodies of water in Washington, 17 in Oregon, many in the U.S. Gulf States, and others as far away as Australia (McGarr and Vorhis, 1968). Most of these were too small to be detected except on sensitive recording water-level gages. The seiches on Lake Union were large enough to cause minor damage to pleasure craft, houseboats, and floats along the shore and jostled two U.S. Coast and Geodetic Survey ships (Wilson and Torum, 1972). The 1949 Queen Charlotte Islands quake generated seiches in Lake Washington and Lake Union, as well as at least two lakes in eastern Washington. Bead Lake north of Newport and Clear Lake near Cheney were reported to have had "strong wave action .... pulling boats loose from docks and leaving many fish on beaches" (Murphy and Ulrich, 1951, p. 28). Other seiches have been reported as long ago as 1891 when "Lake Washington .... was lashed into foam, and the water rolled onto the beach .... eight feet above the present state" (Bradford, 1935, p. 142). There no doubt have been others that have gone unreported.

Historic earthquakes in Washington and Oregon apparently have not developed significant long-period surface waves or been accompanied by vertical displacement at the surface. However, Atwater (1987) suggests that coastal Washington has experienced repeated abrupt subsidence, the lastest such event as recently as 300 years ago. In addition, there is a surface fault with 11 feet of movement (mostly vertical) about 3 miles northeast of Cushman Dam in the southeast Olympic Peninsula. As mentioned earlier, Hebenstreit's (1988) computer model predicts just such motion. This fault apparently experienced its major movement about 1,240 years ago (Wilson and others, 1979). Either type of faulting could cause long-period surface waves or surface tilting, both potential initiators of seiches.

SUMMARY

The Pacific Northwest includes many settings with potential for destructive water waves. Earthquakes, both distant and local, significantly increase the potential for triggering such waves. The written history of the region is too short to define what is geologically "normal", as indicated by the recent catastrophic eruption of Mount St. Helens.

The accumulating evidence for subduction earthquakes along the Pacific coast suggests that the area could be subject to seismic activity more capable of triggering the whole spectrum of water waves than historic earthquakes have been. Thus, it behooves local governments, emergency planners, and individuals to recognize water waves as an important component of earthquake hazard.

REFERENCES

Atwater, B. F., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington State: Science, v. 236, no. 4804, p. 942-944.

Bradford, D. C., 1935, Seismic history of the Puget Sound basin: Seismological Society of America Bulletin, v. 25, no. 2, p. 138-153.

Costello, J. A., 1985,Tsunamis–Hazard definition and effects on facilities: U.S. Geological Survey Open-File Report 85-533, 138 p.

Evans, S. G., 1988, Ground failure hazards in the Canadian Cordillera: Ground Failure, no. 4, p. 7, 8.

Federal Emergency Management Agency, 1985, Flood insurance study–Pacific County, Washington–Unincorporated areas: 27 p.

Garcia, A. W.; Houston, J. R., 1975, Type 16 flood insurance study–tsunami predictions for Monterey and San Francisco Bays and Puget Sound: U.S. Army Engineer Waterways Experiment Station, Technical Report H-75-17, 1 v.

Heaton, T. H.; Hartzell, S. H., 1987, Earthquake hazards on the Cascadia subduction zone: Science, v. 236, no. 4798, p. 162-168.

Hebenstreit, G. T., 1988, Tsunami threat analysis for the Pacific Northwest: U.S. Geological Survey Open-File Report 88-16, p. 550-555.

Hogan, D. W.; Whipple, W. W.; Lundy, C., 1964, Tsunami of 27 and 28 March 1964, State of Washington coastline: U.S. Army Corps of Engineers (Seattle, Wash.) unpublished file report, 29 p.

Houston, J. R., 1979, State-of-the-art for assessing earthquake hazards in the United States; Report 15, Tsunamis, seiches, and landslide-induced water waves: U.S. Army Engineers Waterways Experiment Station Miscellaneous Paper 5-73-1, 88 p.

Houston, J. R.; Garcia, A. W., 1978, Type 16 flood insurance study–Tsunami predictions for the west coast of the continental United States: U.S. Army Engineer Waterways Experiment Station, Technical Report H-78-26, 69 p.

Jones, F. O.; Embody, D. R.; Peterson, W. I., 1961 [1962], Landslides along the Columbia River valley, northeastern Washington: U.S. Geological Survey Professional Paper 367, 98 p.

Kowalik, Zygmunt; Murty, T. S., 1984, Computation of tsunami amplitudes resulting from a predicted major earthquake in the Shumagin seismic gap: Geophysical Research Letters, v. 11, no. 12, p. 1243-1246.

McCulloch, D. S., 1966, Slide-induced waves, seiching and ground fracturing caused by the earthquake of March 27, 1964 at Kenai Lake, Alaska: U.S. Geological Survey Professional Paper 543-A, 41 p.

McGaar, Arthur; Vorhis, R. C., 1968, Seismic seiches from the March 1964 Alaska earthquake: U.S. Geological Survey Professional Paper 544-E, 43 p.

Miller, D. J., 1960, Giant waves in Lituya Bay, Alaska: U.S. Geological Survey Professional Paper 354-C, p. 51-86.

Murphy, L. M.; Brazee, R. J., 1964, Seismological investigations of the Hebgen Lake earthquake. *In* The Hebgen Lake, Montana, earthquake of August 17, 1959: U.S. Geological Survey Professional Paper 435, p. 13-17.

Murphy, L. M.; Ulrich, F. P., 1951, United States earthquakes 1949: U.S. Coast and Geodetic Survey Serial 748, 64 p.

Noson, L. L.; Qamar, Anthony; Thorsen, G. W., 1988, Washington State Earthquake Hazards: Washington Division of Geology and Earth Resources Information Circular 85, 77 p.

Preuss, Jane, 1986, Tsunami and flood hazard preparedness and mitigation program for Aberdeen. *In* Hays, W. W.; Gori, P. L., editors, 1986, Proceedings of conference XXXIII; A workshop on "Earthquake hazards in the Puget Sound, Washington area": U.S. Geological Survey Open-File Report 86-253, p. 139-156.

Rogers, G. C., 1980, A documentation of soil failure during the British Columbia earthquake of 23 June 1946. Canadian Geotechnical Journal, vol. 17, no. 1, p. 122-127.

Schatz, C. E.; Curl, Herbert, Jr.; Burt, W. V., 1964, Tsunamis on the Oregon coast: The Ore Bin, vol 26, no. 12, p. 231-232.

Spaeth, M. G.; Berkman, S. C., 1972, The tsunamis as recorded at tide stations and the Seismic Sea Wave Warning System. *In* The great Alaska earthquake of 1964, Oceanography and coastal engineering: National Academy of Sciences, p. 38-110.

Steinbrugge, K. V., 1982, Earthquakes, Volcanoes, and Tsunami: New York, Skandia American Group, 392 p.

Stermitz, Frank, 1964, Effects of the Hebgen Lake earthquake on surface water. *In* The Hebgen Lake, Montana earthquake of August 17, 1959: U.S. Geological Survey Professional Paper 435, p. 139-150.

University of Washington Department of Geological Sciences, 1970, The Nisqually Delta: 88 p.

University of Washington, Department of Oceanography, 1953, Puget Sound and approaches; a literature survey, vol. II: 118 p.

Washington Highways, 1964, Tidal wave rips coast, highways: v. 11, no. 5, p. 2, 3.

Wiegel, R. L., 1970, Tsunamis, *In* Earthquake Engineering, R. L. Wiegel, Editor: Prentice-Hall, pp. 253-306.

Wilson, B. W.; Torum, Alf, 1972, Effects of the Tsunamis - An engineering study. *In* The great Alaska earthquake of 1964, Oceanography and coastal engineering: National Academy of Sciences, p. 361-523.

Wilson, J. R.; Bartholomew, M. J.; Carson, R. J., 1979, Late Quaternary faults and their relationship to tectonism in the Olympic Peninsula, Washington: Geology, v. 7, no. 5, p. 235-239.

Staff Notes

On July 18, **Matt Brunengo** began work as an environmental geologist with a joint appointment in this Division and the Division of Forest Regulation and Assistance. His primary responsibilities are associated with the Department of Natural Resources' Timber, Fish and Wildlife (TFW) Program and will be to develop a system to classify state and private forest lands by their susceptibility to landsliding, to implement this hazard zoning system in a pilot study, and to act as a consultant on slope-stability problems for the Department's divisions and regions.

A native of Portland, Matt received his Bachelor's and Master's degrees from Stanford University and comes to us from the University of Washington, where he is a doctoral candidate in the Department of Geological Sciences. His dissertation research includes field study and computer modeling of meteorologic and hydrologic characteristics of rain-on-snow storms and their effects on subsurface flow, debris slides, and long-term geomorphic development in humid mountain ranges such as the Cascades and Olympics. His involvement in these issues dates to his participation in the Forest Slope Stability Project conducted by DNR and the Department of Ecology in 1979-1981. Since then, he has been a part-time consultant in a variety of projects, including a review of the potential cumulative effects of forest practices, development of a landslide hazard zonation system for a municipal watershed, examination of potential for instability around proposed small hydroelectric sites, and analysis of the causes of landsliding that occurred during major storms in Whatcom and Skagit Counties in 1979, 1983, and 1984.

This new DGER position is funded by the Washington Legislature as a result of the TFW agreement in 1987, in which representatives of the governmental and private factions dealing with these natural resources developed a system for solving their conflicts through cooperation and learning. The TFW plan called for an increase in the number of technical personnel employed by the participant groups for work on fishery, wildlife, and forest-practice issues and a program of research and monitoring to improve and expand the base of knowledge on which resolution of controversies must be founded.

It has been recognized that forest practices on unstable slopes can cause significant problems for public and private resources downhill and down-stream, and several projects were developed to address this issue. Of these, Matt is currently responsible for the creation and implementation of a system for identification and zonation of mass-wasting hazards. He will direct a study of the effects of timber harvest on deep-seated slope failures (probably to become active in 1991). In the future, he will also be one of many scientists of various disciplines participating in review and evaluation of forest practices problem sites, another important element of the TFW program.

Mineral Industry Questionnaire is in the Mail

The annual review of Washington's mineral industry will appear in the first 1989 issue of this newsletter. In order to provide accurate information about the status of the industry, a questionnaire about exploration and mining in 1988 in Washington is being sent to more than 500 operators of mineral properties in the state. Information sought includes property name, type of work done, production, and annual expenditures. If you have received a questionnaire, we encourage you to return it, even if no work was done on the property in 1988. If you have not received a questionnaire and are working on a mineral property in the state, please contact Nancy Joseph at the Spokane field office so that a questionnaire can be sent to you. See address and telephone number on page 2.

Division Geologists Promoted

by

J. Eric Schuster

We are pleased to announce the promotions of two long-time staff geologists of the Division of Geology and Earth Resources. Effective September 1, 1988, William M. Phillips became Geologist 4 and section head for the Geology and Resources Section and Timothy J. Walsh became Geologist 4 and section head for the Environmental Geology Section.

So that our readers might become more familiar with these geologists and with their new duties, we present below a sketch of their backgrounds and new responsibilities.

William M. Phillips

An Idaho native, Bill received a Bachelor of Science degree in geology from Tufts University in February 1976 and a Master of Science degree in geology from Washington State University in February 1979. His master's thesis documents the structural geology and aspects of the Cambrian stratigraphic section in part of Stevens County, Washington. From July 1978 until May 1979, he worked for Battelle Pacific Northwest Laboratories in Richland, Washington, as a geoscientist. His duties included developing computer simulations of nuclear waste repositories in salt domes of the U.S. Gulf Coast, remote sensing of the Columbia Plateau, and field mapping of photo-lineaments in the Cascade Range. From May 1979 until October 1979, Bill worked as a park technician for Capitol Reef National Park, Torrey, Utah, where he conducted geological field trips and presented lectures illustrating the geology of the north-central Colorado Plateau.

Bill joined the Division as a Geologist 2 in April 1980. Over the years he has worked on the mapping and evaluation of King County coal resources, southwest Washington volcanic stratigraphy, Cascade geothermal resources, and compilation of a Washington gravity data base. In cooperation with Division Librarian Connie Manson, he designed and wrote the computer programs for the Division's bibliographic information system, which is used to generate bibliographies and indexes to Washington geology and mineral resources. For the last four years he has been involved in the compilation of the new state geologic map, with responsibilities for the Mount St. Helens, Vancouver, Mount Olympus, Forks, and Cape Flattery areas.

Bill has authored or co-authored 11 open-file reports and 2 geologic-map-series reports for the Division, and several articles for the Washington Geologic Newsletter (see index, this issue), professional journals, and the U.S. Geological Survey.

With his promotion, Bill is filling the position formerly held by Bonnie Bunning, who was promoted to Department of Natural Resources Management Analyst last spring. His new duties include supervision of the Geology and Resources Section, including the Spokane Field Office. He will be responsible for the geologic aspects of the state geologic map program and for research and mapping programs in geothermal, coal, oil and gas, and mineral resources. He will continue to personally conduct geologic research and mapping and serve as a key resource person regarding the use of computers in the Division.

Timothy J. Walsh

Tim received two degrees in geology from the University of California, Los Angeles: a Bachelor of Science in 1976, and a Master of Science in 1979. From October 1977 to October 1978, he worked as a research assistant analyzing intertidal sediments on the southern California coastline and islands for grain-size characteristics, carbonate minerals, and organic carbon content and preparing a final report for the U.S. Bureau of Land Management. Tim has also held summer jobs as a crew member on oil and gas production rigs.

Tim came to work for the Division of Geology and Earth Resources in March 1980 as a Geologist 2. Since then he has worked on the mapping and evaluation of coal resources, the documentation, assessment, and plugging of hazardous abandoned coal-mine openings (in cooperation with the U.S. Office of Surface Mining), gravity investigations in western Washington coal fields, and vitrinite reflectance, and he has assisted with the Division's oil and gas regulatory program. For the last several years he has been heavily involved in the compilation of the new state geologic map.

Tim has authored or co-authored 12 open-file reports for the Division and several articles for the Washington Geologic Newsletter (see index, this issue). He has also prepared papers for professional journals and other "outside" publications, and delivered many talks on aspects of the geology and resources of Washington.

Tim's new position was formerly held by Jerry Thorsen, who retired in February 1988. Tim will supervise the Environmental Geology Section. Because that section is being expanded, Tim will be instrumental over the next year or more in defining its role and in hiring at least two additional geologists to bring the section's staff from the current level of three to at least five geologists. Other responsibilities will include monitoring and advising the Division and Department of Natural Resources on geologic aspects of the Department's Timber, Fish, and Wildlife Program (TFW) and serving on the TFW subcommittee on mass wasting, overseeing the Division's geologic involvement in the National Earthquake Hazards Reduction Program (a U.S. Geological Survey program which is currently assessing earthquake hazards and formulating public education and information and hazard mitigation measures in the Seattle, Olympia, and Portland, Oregon, areas), formulating and directing the Division's own geologic hazards program, and leading the Environmental Geology Section's contribution to Quaternary geologic mapping and compilation of the new state geologic map. He will continue to conduct geologic research and mapping and assist with the Division's oil and gas regulatory program.

State Geologic Map Progress

by

J. Eric Schuster

I last reported progress on the new state geologic map in the August 1986 issue of this newsletter (Schuster, 1986). Much has happened since then.

First, the southwest quadrant of the map (Walsh and others, 1987) was released as Geologic Map GM-34 in November 1987, with its companion topographic map, TM-1. In addition, all the 1:100,000-scale geologic quadrangle maps produced in the first stage of map compilation for this quadrant have been released as open-file reports. Exceptions are the Wenatchee and Snoqualmie Pass quadrangles for which recent U.S. Geological Survey 1:100,000-scale quadrangle maps exist (Tabor and others, 1982; Frizzell and others, 1984). The Division's 1:100,000 open file maps for the southwest quadrant of the state are indicated by an asterisk in the list of references at the end of this report.

Second, significant progress has been made on preparation of the northeast quadrant of the state geologic map. The second compilation stage (1:250,000 scale) has not yet begun, but the first stage (1:100,000 scale) is far advanced. Table 1 shows the stage of completion of each quadrangle. We expect that all these maps will be available as Division open-file reports soon after January 1, 1989. The target date for release of the 1:250,000-scale full-color geologic map of the northeast quadrant is fall 1989.

Third, 1:100,000-scale quadrangles in the northwest quadrant have been assigned to staff geologists as shown in Table 2. Compilation of existing geologic maps is under way for most of these quadrangles, and preliminary compilations have been finished for a few. As before, we will not issue a

Table 1. Status of northeast quadrant 1:100,000-scale geologic quadrangle maps

		Stage of Compilation					
Quadrangle	Compiler	Base Map	Initial Compilation	Field Recon. and Fill-In Mapping	First Draft	Peer Review	Complete
Robinson Mountain	Keith Stoffel	Yes	Yes	Yes	Yes	--	--
Oroville	Keith Stoffel	Yes	Yes	Yes	--	--	--
Republic	Keith Stoffel	Yes	Yes	Yes	--	--	--
Colville	Nancy Joseph	Yes	Yes	Yes	Yes	--	--
Twisp	Bonnie Bunning	Yes	Yes	Yes	--	--	--
Omak	Chuck Gulick	Yes	Yes	Yes	Yes	--	--
Nespelem	Nancy Joseph	Yes	Yes	Yes	Yes	--	--
Chewelah	Stephanie Zurenko Waggoner	Yes	Yes	Yes	Yes	--	--
Banks Lake	Chuck Gulick	Yes	Yes	Yes	Yes	--	--
Coulee Dam	Stephanie Zurenko Waggoner	Yes	Yes	Yes	--	--	--
Spokane	Nancy Joseph	Yes	--	--	--	--	--
Moses Lake	Chuck Gulick	Yes	Yes	Yes	Yes	--	--
Ritzville	Chuck Gulick	Yes	Yes	Yes	Yes	--	--
Rosalia	Stephanie Zurenko Waggoner	Yes	Yes	Yes	--	--	--

Chelan and Wenatchee are available as U.S. Geological Survey geologic maps (Tabor and others, 1987; Tabor and others, 1982).

Table 2. Compilation assignments for the northwest quadrant of the state geologic map

1:100,000-Scale Quadrangle	Compiler(s)
Roche Harbor	Josh Logan
Bellingham	Mike Korosec
Mount Baker	Mike Korosec
Robinson Mountain	Keith Stoffel
Cape Flattery	Bill Phillips
Port Angeles	Hank Schasse
Port Townsend	Hank Schasse
Sauk River	Hank Schasse
Twisp	Bonnie Bunning
Forks	Bill Phillips
Mount Olympus	Bill Phillips
Seattle	Tim Walsh and Josh Logan
Skykomish River	Tim Walsh
Chelan	Mike Korosec
Copalis Beach	Josh Logan
Shelton	Josh Logan
Tacoma	Tim Walsh and Josh Logan
Snoqualmie Pass	Tim Walsh
Wenatchee	Tim Walsh

1:100,000-scale geologic map of quadrangles for which there is a recent geologic map already available. We hope to print this state geologic map quadrant by fall 1993.

Fourth, printing of the 1:250,000-scale geologic map of the southeast quadrant is targeted for fall, 1991. However, no compilation assignments have been made for this quadrant as yet.

Fifth, the Division has continued to support geologic mapping by graduate students and professors as part of the state geologic map program. Those supported during fiscal years 1987, 1988, and 1989 are listed in Table 3. Since the graduate student support program began in fiscal year 1985, the numbers and dollar amounts of contracts have been:

FY1985, 14 contracts for just over $26,000 (Washington Division of Geology and Earth Resources, 1984);

FY1986, 10 contracts for just over $17,500 (Washington Division of Geology and Earth Resources, 1985b);

FY1987, 6 contracts for $12,476;

FY1988, 6 contracts for $11,388; and

FY1989, 7 contracts for $11,695.

Two trends are noticeable—the number of proposals received and thus the number and dollar amounts of contracts awarded have been decreasing, and the proportion of proposals received from out-of-state universities has been increasing.

REFERENCES

Note: This list contains all publications generated to date by the Division's state geologic map program, except for a few abstracts published by other organizations. Other references, as cited above, are also included. References preceded by an asterisk are 1:100,000-scale open-file maps for the southwest quadrant of Washington.

Frizzell, V. A., Jr.; Tabor, R. W.; Booth, D. B.; Ort, K. M.; Waitt, R. B., Jr., 1984, Preliminary geologic map of the Snoqualmie Pass 1:100,000 quadrangle, Washington: U.S. Geological Survey Open-File Report 84-693, 43 p., 1 plate.

*Korosec, M. A., compiler, 1987a, Geologic map of the Mount Adams quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-5, 39 p., 1 plate, scale 1:100,000.

*Korosec, M. A., compiler, 1987b, Geologic map of the Hood River quadrangle, Washington and Oregon: Washington Division of Geology and Earth Resources Open-File Report 87-6, 40 p., 1 plate, scale 1:100,000.

*Logan, R. L., compiler, 1987a, Geologic map of the Chehalis River and Westport quadrangles, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-8, 16 p., 1 plate, scale 1:100,000.

*Logan, R. L., compiler, 1987b, Geologic map of the south half of the Shelton and south half of the Copalis Beach quadrangles, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-9, 15 p., 1 plate, scale 1:100,000.

*Phillips, W. M., compiler, 1987a, Geologic map of the Mount St. Helens quadrangle, Washington and Oregon: Washington Division of Geology and Earth Resources Open-File Report 87-4, 59 p., 1 plate, scale 1:100,000.

Phillips, W. M.; Korosec, M. A.; Schasse, H. W.; Anderson, J. L.; Hagen, R. A., 1986, K-Ar ages of volcanic rocks in southwest Washington: Isochron/West, no. 47, p. 18-24.

*Phillips, W. M.; Walsh, T. J., compilers, 1987, Geologic map of the northwest part of the Goldendale quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-13, 7 p., 1 plate, scale 1:100,000.

*Schasse, H. W., compiler, 1987a, Geologic map of the Centralia quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-11, 28 p., 1 plate, scale 1:100,000.

*Schasse, H. W., compiler, 1987b, Geologic map of the Mount Rainier quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-16, 43 p., 1 plate, scale 1:100,000.

Schuster, J. E., 1983, Division to start work on new state geologic map: Washington Geologic Newsletter, v. 11, no. 4, p. 6-7.

Schuster, J. E., 1984, State geologic map program--Graduate student mapping project: Washington Geologic Newsletter, v. 12, no. 1, p.22-23.

Schuster, J. E., 1986, Geologic map of Washington–A progress report: Washington Geologic Newsletter, v. 14, no. 3, p. 26.

Table 3. Mapping projects supported between July 1, 1986, and June 30, 1989 (fiscal years 1987, 1988, and 1989)

Name	Fiscal year	University	Title
Bittenbender, Peter E.	1989	Univ. of Texas at Austin	Geology of the eastern Prairie Mountain, Huckleberry Mountain, and western Downey Mountain 7 1/2 minute quadrangles, Skagit and Snohomish Counties, Washington
Buddington, Andrew M.	1988-1989	Western Washington Univ.	Petrography and petrology of the Similkameen batholith, Okanogan County, Washington
Campbell, Arthur	1989	Univ. of Washington	Geology of the Monument Peak and Lost Peak stocks in the Mount Lago-Rampart Ridge-Monument Peak area, North Cascades, Washington
Clark, Kenneth P.	1987	Western Washington Univ.	The structure, stratigraphy, petrography, and geochemistry of the Green Mountain and Gold Mountain area, Bremerton, Washington
Frey, Allison M.	1988	Univ. of Pittsburgh	Geology of the southeastern portion of the Methow Valley, Washington
Geary, Edward E.	1988	San Jose State Univ.	Preliminary geochronological and geochemical investigations of the Twisp Valley, Rainbow, and Cascade River Schists, North Cascades, Washington
Holder, Grace A. McCarley	1987	Washington State Univ.	Geology and structure of the Eocene plutonic rocks between the Toroda Creek and Republic grabens, Ferry County, Washington
Holder, Grace A. McCarley and Holder, Robert Wade	1988	Washington State Univ.	Geologic mapping of undifferentiated granitic rocks along the southern shore of the Columbia River (Roosevelt Lake) between Lincoln and Grand Coulee
Kiver, Eugene P. and Stradling, Dale F.	1987-1988	Eastern Washington Univ.	Quaternary geology of twelve 7 1/2 minute quadrangles in the Colville Valley and nearby areas, and a nunatak map of northeastern Washington
Knaack, Charles M.	1987	Washington State Univ.	Geology and structure of plutonic rocks between the Republic graben and the Kettle "gneiss dome", Curlew and Togo Mountain quadrangles, Ferry County, Washington
Longtine, Mark W.	1989	Univ. of Texas at Austin	Geology of the eastern Bedal, Sloan Peak, and southwestern Glacier Peak quadrangles, Snohomish County, Washington
Nicholson, Lynda S.	1989	San Jose State Univ.	Structure and petrology of portions of the Stehekin, Sun Mountain, and McAlester Mountain quadrangles northeast of the Stehekin River and Lake Chelan, Chelan County, Washington
Roback, Robert C.	1989	Univ. of Texas at Austin	Tectonic significance of upper Paleozoic rocks in the Kootenay Arc, southeastern British Columbia and northeastern Washington
Shultz, Julie M.	1987	Western Washington Univ.	Geology of the upper Rattlesnake Creek area, northwestern Yakima County, Washington
Smith, Gary A. and Shafiquallah, Muhammad	1987	Univ. of Arizona	Geochronology of the Ellensburg Formation: Constraints on Neogene volcanism and tectonism in central Washington
Smith, Moira T.	1989	Univ. of Arizona	Structural and stratigraphic study of a portion of the Covada Group near Hunters, Washington
Tepper, Jeffrey H.	1988	Univ. of Washington	Bedrock geology of the Whatcom Pass-Bear Mountain area, North Cascades, Washington

Tabor, R. W.; Frizzell, V. A., Jr.; Whetten, J. T.; Waitt, R. B.; Swanson, D. A.; Byerly, G. R.; Booth, D. B.; Hetherington, M. J.; Zartman, R. E., 1987, Geologic map of the Chelan 30-minute by 60- minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1661, 1 sheet, scale 1:100,000 with 29 p. text.

Tabor, R. W.; Waitt, R. B.; Frizzell, V. A., Jr.; Swanson, D. A.; Byerly, G. R.; Bentley, R. D., 1982, Geologic map of the Wenatchee 1:100,000 quadrangle, central Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1311, 1 sheet, scale 1:100,000, with 26 p. text.

*Walsh, T. J., compiler, 1986a, Geologic map of the west half of the Toppenish quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 86-3, 1 sheet, scale 1:100,000, with 7 p. text.

*Walsh, T. J., compiler, 1986b, Geologic map of the west half of the Yakima quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 86-4, 1 sheet, scale 1:100,000, with 9 p. text.

*Walsh, T. J., compiler, 1987a, Geologic map of the Astoria and Ilwaco quadrangles, Washington and Oregon: Washington Division of Geology and Earth Resources Open-File Report 87-2, 28 p., 1 plate, scale 1:100,000.

*Walsh, T. J., compiler, 1987b, Geologic map of the south half of the Tacoma quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 87-3, 10 p., 1 plate, scale 1:100,000.

Walsh, T. J.; Korosec, M. A.; Phillips, W. M.; Logan, R. L.; Schasse, H. W., 1987, Geologic map of Washington–Southwest quadrant: Washington Division of Geology and Earth Resources Geologic Map GM-34, 2 sheets, scale 1:250,000, with 28 p. text.

Washington Division of Geology and Earth Resources, 1984, A progress report on the graduate student mapping project, State geologic map program: Washington Geologic Newsletter, v. 12, no. 3, p. 10-11.

Washington Division of Geology and Earth Resources, 1985a, State Geologic map progress: Washington Geologic Newsletter, v. 13, nos. 3 and 4, p. 1.

Washington Division of Geology and Earth Resources, 1985b, Graduate student mapping under the state geologic map program: Washington Geologic Newsletter, v. 13, nos. 3 and 4, p. 1-2.

Washington Division of Geology and Earth Resources, 1987, State geologic map open file reports now available: Washington Geologic Newsletter, v. 15, no. 3, p. 16-17.

Washington Division of Geology and Earth Resources, 1987, State map of Washington–Southwest quadrant: Washington Division of Geology and Earth Resources, Topographic Map TM-1, 1 sheet, scale 1:250,000.

Washington Division of Geology and Earth Resources, 1988, Geologic map of Washington–Southwest quadrant released: Washington Geologic Newsletter, v. 16, no. 1, p.28.

Mineral Industry News Notes

by

Nancy L. Joseph

Metals

Chelan County

The Cannon mine produced 75,544 ounces of gold and 118,698 ounces of silver during the first half of 1988. The mine is a joint venture between Asamera Minerals Inc. and Breakwater Resources Ltd. The mine produced 262,999 tons of ore with an average grade of 0.313 ounces of gold per ton. Gold production increased 8.8 percent over the same period last year. Breakwater attributed the increase to increases in production, gold grade, and recovery.

Ferry County

Hecla Mining Company has had continued high levels of production at its Republic Unit. The second largest gold mine in the state produced 37,899 ounces of gold and 155,346 ounces of silver during the first 6 months of 1988.

An Environmental Impact Statement (EIS) for the Kettle River Project has been issued by the Washington Department of Ecology. The project is a joint venture involving Echo Bay Exploration, Inc., (a subsidiary of Echo Bay Mines Ltd.), and Crown Resources Corp., Gold Capital Corp., and Gold Texas Resources, Ltd. According to the EIS, Echo Bay plans an underground mine and related surface buildings at the Kettle River mine 1 mile west of Curlew and an underground mine and portal facilities at the Overlook mine, 8 miles northeast of Republic. Plans call for the Key mill site and tailings impoundment to be located 2 miles southeast of the Overlook mine site. Anticipated production from the Kettle mine is estimated to be between 300 and 500 tons per day, from the Overlook mine (at full production) 1,000 to 1,500 tons of ore per day. Ore from both mines would be processed at the Key mill. The project would employ 105 to 130 persons and have annual operating costs, including payroll, of $15 million to $20 million. A decision by Echo Bay on whether to proceed with plans to put the mines into production is expected by the end of 1988. Some exploration continues at the two properties.

Underground drifting and surface drilling has been completed at the Seattle-Flag Hill property, a joint venture among Crown Resources Corp., Sutton Resources Ltd., and Texas Star Resources Corp. The most recent gold production from the mine was in 1984.

Whatcom County

Steelhead Resources, Ltd. announced grade and tonnage estimates for their Excelsior mine project east of Glacier. The company listed probable reerves of 5.9 million tons at 0.033 ounces of gold per ton and 2.047 ounces of silver per ton or 4.1 million tons of 0.042 ounces of gold per ton and 2.6 ounces of silver per ton for a gold equivalent of 0.085 ounces per ton. Possible extensions of the mineralization to the west and north from the main area of exploration were indicated by the company. Further drilling is anticipated this year to test the extent of the mineralization.

Industrial Minerals

Chelan County

The M. A. Hanna Co. Rock Island silicon plant was purchased by Silicon Metaltech, Inc. on September 1. Silicon Metaltech was formed by the Palmer Group of Seattle, a private investment partnership, to purchase both the silicon plant and the silica mine in Canada that supplies the raw materials to the plant. The plant produces 17,000 tons of silicon per year and employs 117 people. The operation is the only silicon plant in Washington to sell to outside buyers. (The Northwest Alloys, Inc., silicon plant at Addy produces silicon solely for the production of magnesium metal at their Stevens County plant.)

Earthquake Preparedness Program under Development

By Carole Martens, Department of Community Development

The Department of Community Development (DCD) is beginning to develop an Earthquake Preparedness Program. The program is intended to be a long-range, comprehensive program that will deal with the numerous facets of earthquake preparedness. DCD's Division of Emergency Management (DEM) has the responsibility to develop and coordinate the program. Initially the department will establish a multi-agency planning task force and develop a 5-year program; reconvene the seismic safety advisory council; and establish goals for the next 10 years.

DCD will consider, among other things, recommendations from the 1986 Washington State Seismic Safety Council Policy Recommendations Report. Some of those recommendations included:

- State agencies taking more active roles in earthquake preparedness.
- The Legislature passing a school seismic safety act aimed at reducing the vulnerability of the school population to the life-threatening effects of future earthquakes. This would include school earthquake safety and education programs.
- The Legislature enacting a joint resolution acknowledging earthquake risks, the potential for loss of life and property, and a commitment to work cooperatively over the next decade with federal, state, and local governments on earthquake preparedness.
- Review and update the statute (Chap. 70.86 Public Health and Safety) passed in 1955 requiring design standards for the construction of new public buildings.

In addition, several short-term activities are planned:

(1) A state agency earthquake preparedness task force will be set up within the next few months. The purpose of the task force is to review each agency's role in an earthquake emergency; do an assessment of measures that can be taken (within existing authority); and determine what, if anything, needs to be changed within the statutes. DEM's role is one of providing coordination and guidance.

(2) DEM co-sponsored an Earthquake Hazard Mitigation Course for Utility Lifeline Systems with the Federal Emergency Management Agency (FEMA) on September 19-20, 1988. Co-hosts were METRO and the Seattle Water Department. A team of presenters was lead by national lifelines expert, Ron Eguchi of Dames and Moore, Los Angeles, California. Sixty participants attended, representing many utilities and governments within Puget Sound.

The two days of presentations and discussions ended with a comment by each presenter. The presenters concluded that the Puget Sound area is not prepared for a large earthquake (7.1 Richter Magnitude or greater). A call was made to move forward with the momentum generated by the meeting and to create a "Professional Brief" on the need for earthquake hazard mitigation of utility lifeline systems. Those interested in participating will reconvene in November and provide comments for the "polishing" of the document.

(3) DEM has reprinted and has available upon request, **Washington State School Earthquake Emergency Planning**, a guide developed by the School Earthquake Safety and Education Project (SESEP). The guide was written to accompany FEMA's publication 88, **A Guidebook for Developing a School Earthquake Safety Program.**

(4) The brochure, **Washington State Earthquake Safety Tips**, is being rewritten and new graphics will be developed to show citizens more clearly how to improve their earthquake safety.

(5) Initial steps are underway to develop an earthquake information catalog of resource materials and an earthquake impacts document. This work is a result of the 1988 Washington State Legislature's acknowledgment of the need for dissemination of information about earthquake risks and what can be done to reduce losses in future earthquakes.

DEM has submitted proposals at both the state and federal levels to continue the earthquake preparedness program effort as envisioned and as required by RCW 38.52.

We welcome reader comments and recommendations on these activities. Communications may be directed to:

Washington State Dept. of Community Development
Division of Emergency Management
4220 East Martin Way, MS PT-11
Olympia, WA 98504
(206) 459-9191

Washington College and University and National Science Foundation Projects: Additions and Correction

In the last issue, we published a list of current student and faculty projects. The information was derived from answers to a letter sent to academic institutions last spring. Information received since we went to press is added below.

UNIVERSITY OF WASHINGTON

Effect of local geology on intensity of earthquakes, Seattle to Portland region—*Anthony Qamar (with Tom Bodle; U.S. Geological Survey funding)*

EASTERN WASHINGTON UNIVERSITY

Faculty Projects

Mineralogy of the Golden Horn batholith, North Cascades, Washington—*Russell Boggs*

Structural states of feldspars as an indicator of sedimentary provenance—*Russell Boggs*

Mineralogy of the Sawtooth batholith, Idaho—*Russell Boggs*

Geomorphic mapping of Dhamokane Creek to evaluate the potential for enhancing fish habitat—*John Buchanan*

Hydrogeologic investigation of the basalt aquifer systems near Medical Lake, Washington—*John Buchanan*

Hydrogeology of the Spokane Valley aquifer system near Little Spokane River—*John Buchanan*

Study of the newly discovered cavern La Escondida, Bighorn Mountains, Wyoming and Montana—*John Buchanan*

Mineral inventory of Jewel Cave, Black Hills, South Dakota—*John Buchanan*

Permian bryozoans of the carbonate units of the Mission Argillite, northeastern Washington—*Ernest Gilmour*

Biostratigraphic studies of Pennsylvanian and Permian bryozoans in North America and Pakistan—*Ernest Gilmour*

Carbonate petrology and paleoecology of the Antler Peak Limestone, northeastern Nevada—*Ernest Gilmour*

Bryozoans and paleoecology of the Otter Formation, Little Belt Mountains, Montana—*Ernest Gilmour*

Rare earth element geochemistry of gold deposits—*Mohammed Ikramuddin*

Distribution of immobile trace elements of hydrothermally altered rocks associated with various types of gold deposits—*Mohammed Ikramuddin*

Thallium—a potential guide to mineral deposits—*Mohammed Ikramuddin*

Geochemistry of sediment-hosted precious metals deposits—*Mohammed Ikramuddin*

Development of new analytical methods by inductively coupled argon plasma and electrothermal atomic absorption—*Mohammed Ikramuddin*

Chemical composition of sediments from archaeological sites in central Washington—*Mohammed Ikramuddin*

Geochemistry of granitic rocks of northeastern Washington—*Mohammed Ikramuddin*

Hydrogeochemical and biogeochemical methods of exploration for gold and silver—*Mohammed Ikramuddin*

Geochemistry of platinum group elements—*Mohammed Ikramuddin*

Geochemistry of volcanic rocks and its relationship to gold-silver mineralization–*Mohammed Ikramuddi*

Geochemistry of gallium—*Mohammed Ikramuddin*

Glacial and catastrophic flood history of eastern Washington—*Eugene Kiver*

Quaternary map of northeastern Washington east of the Okanogan River—*Eugene Kiver*

Geology of national parks—*Eugene Kiver*

Structure and stratigraphy of the Middle Paleozoic Antler Orogen in northwestern Nevada—*Linda McCollum*

Stratigraphy, sedimentology, and paleontology of the Cambrian System of the Great Basin—*Linda McCollum*

Paleozoic continental margin sedimentation in western U.S.—*Linda McCollum*

Mesozoic transcurrent faulting and suspect terranes in the Great Basin—*Linda McCollum*

Alkaline igneous rocks and related precious metal deposits—*Felix Mutschler*

Compilation of computer data base of whole-rock chemical analyses of igneous rocks—*Felix Mutschler*

Laramide and younger tectonics and magmatism in the eastern Rocky Mountains—*Felix Mutschler*

Stylolites in ore deposits—*James Snook*

Thrust faulting in northeastern Washington—*James Snook*

Petrology in the Quartz Hill molybdenum deposit, Alaska—*James Snook*

Paleomagnetic investigation of glacial Lake Missoula flood deposits—*William Steele*

Use of remanent magnetization direction to correlate airfall ash deposits from Cascade volcanoes—*William Steele*

Mechanism of acquisition of remanent magnetization by airfall ash—*William Steele*

Reconnaissance lithogeochemical survey of northwest Pakistan—*Mohammed Ikramuddin*

Study of toxic elements in environmental samples—*Mohammed Ikramuddin*

Chemical analysis of ultrapure electronic materials—*Mohammed Ikramuddin*

Student Projects

Gold deposits in the alkaline rock igneous centers of Colorado—*Daniel W. Fears*

Gold deposits associated with alkaline igneous rocks: selected trace element geochemistry—*Robbin W. Finch*

Vertical geochemical variations in granodiorite associated with the molybdenum-copper porphyry deposit at Mount Tolman, Ferry County, Washington—*Danelle D. Elder*

Biogeochemical methods of exploration for Archean gold deposits—*Richard B. Lestina*

Geology of the McCullough Creek area, Douglas County, Oregon—*Allen V. Ambrose*

Bryozoan biostratigraphy of the Phosphoria Formation, southeastern Idaho—*Robert C. Walker*

Biostratigraphy and lithostratigraphy of the late Devonian-early Mississippian Pilot Shale of eastern Nevada and western Utah—*Mark E. Jones*

Sedimentation and mineralogical composition of the Latah Formation (Miocene), eastern Washington—*John D. Robinson*

FERROS—a computerized data base for Precambrian auriferous banded iron formations and related rocks—*Glen R. Carter*

Giant lode gold camps of North America—*Mark J. Mihalasky*

The use of iodine and selected trace metals in petroleum and gas exploration—*Tony L. Gordon*

Geochemistry of igneous rocks from Newport and adjacent areas, northeastern Washington—*Christine Russell*

Upper Cambrian carbonate section in the Toano Range near Wendover, Nevada—*Joseph Drumheller*

Depositional setting of quartzite beds in the middle part of the Precambrian Prichard Formation, Coeur d'Alene mining district, Idaho—*Eugene St. Goddard*

Microfacies study of the Antler Peak Limestone, northern Nevada—*Chad Johnson*

The petrology and paleoecology of the Toroweap Formation, southeastern Nevada—*Laleh Mansoury*

Hillslope recharge to the Spokane aquifer system—*Tammy Hall*

Mass wasting processes in a steep watershed: Lightning Creek drainage, Idaho—*Charles Cacek*

Saturated zone chemistry down-gradient from mine tailings ponds near Twisp, Washington—*Robert Lambeth*

Ground-water geochemistry down-gradient from a uranium mill tailings pond—*Ron Stone*

The behavior of immobile elements in volcanic hosted epithermal gold deposits—*Jianzhong Fan*

Abundance and behavior of cesium and selected trace elements in rock, soil, and water samples from the Republic area, northeast Washington—*Wilfred H. Little*

Abundance of Au, Pd, and Pt in igneous and metamorphic rocks from northeastern Pakistan-*Mohammad Zafar*

Rare earth geochemistry of granite and volcanic rocks from northeastern Pakistan—*Ghulam Mustafa Abbasi*

NATIONAL SCIENCE FOUNDATION:

Subduction underplating and uplift in a young accretionary complex—*Mark T. Brandon, Yale University, Department of Geology and Geophysics*

Erratum: In the last issue, some of the student projects on pages 21 and 22 were listed incorrectly. The six student projects listed under University of Washington, Geophysics Program (bottom left column, p. 21) should be listed under Western Washington University. The four student projects listed under Western Washington (top right column, p. 22) should be listed with Washington State University.

Selected Additions to the Division of Geology and Earth Resources Library

July, August, and September, 1988

THESES

Graham, Don, 1988, Hydrothermal alteration of serpentinite associated with the Devils Mountain fault zone, Skagit County, Washington: Western Washington University Master of Science thesis, 125 p.

Jackson, Philip Richard, 1986, Geology and lithogeochemistry of the Flagstaff Mountain barite deposit and surrounding area, Stevens County, Washington: University of Nevada, Reno, Master of Science thesis, 120 p., 6 plates.

Kriens, Bryan Jon, 1988, Tectonic evolution of the Ross Lake area, northwest Washington-southwest British Columbia: Harvard University Doctor of Philosophy thesis, 214 p., 7 plates.

Lundquist, John H., 1987, Sedimentology and stratigraphy of the Sweetwater Creek interbed, Lewiston Basin, Idaho-Washington: Washington State University Master of Science thesis, 133 p.

Raviola, Franco P., 1988, Metamorphism, plutonism and deformation in the Pateros-Alta Lake region, north-central Washington: San Jose State University Master of Science thesis, 181 p., 1 plate.

Sanford, William Edward, 1986, Detailed three-dimensional structure of the deep crust in the U.S. Cordillera in north-central Washington based on COCORP data: Cornell University Master of Science thesis, 55 p.

Squires, Garry H., 1985, An experimental investigation of the consolidation and shear strength characteristics of a Seattle clay: University of Washington Master of Science thesis, 127 p.

Summer, Neil Steven, 1987, Maturation, diagenesis and diagenetic processes in sediments underlying thick volcanic strata, Oregon: University of California, Davis, Master of Science thesis, 87 p.

Van Klaveren, Richard W., 1987, Hydraulic erosion resistance of thawing soil: Washington State University Doctor of Philosophy thesis, 218 p.

U.S. GEOLOGICAL SURVEY

Published Reports

Dethier, D. P., 1988, The soil chronosequence along the Cowlitz River, Washington: U.S. Geological Survey Bulletin 1590-F, 47 p.

Lockwood, Millington; McGregor, B. A., editors, 1988, Proceedings of the 1987 Exclusive Economic Zone symposium on mapping and research—Planning for the next 10 years: U.S. Geological Survey Circular 1018, 175 p.

Major, J. J.; Scott, K. M., 1988, Volcaniclastic sedimentation in the Lewis River Valley, Mount St. Helens, Washington—Processes, extent, and hazards: U.S. Geological Survey Bulletin 1383-D, 38 p.

Minard, J. P.; Booth, D. B., 1988, Geologic map of the Redmond quadrangle, King County, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-2016, 1 sheet, scale 1:24,000.

Whetten, J. T.; Carroll, P. I.; Gower, H. D.; Brown, E. H.; Pessl, Fred, Jr., 1988, Bedrock geologic map of the Port Townsend 30- by 60-minute quadrangle, Puget Sound region, Washington: U.S. Geological Survey Miscellaneous Investigations Series map I-1198-G, 1 sheet, scale 1:100,000.

Open-File Reports

Jacobson, M. L., compiler, 1988, National Earthquake Hazards Reduction Program, summaries of technical reports Volume XXVI: U.S. Geological Survey Open-File Report 88-434, 638 p.

Laenen, Antonius; Orzol, L. L., 1987, Flood hazards along the Toutle and Cowlitz rivers, Washington, from a hypothetical failure of Castle Lake blockage: U.S. Geological Survey Water-Resources Investigations Report 87-4055, 29 p.

Luttrell, G. W.; Hubert, M. L.; Murdock, C. R., editors, 1988, Geologic names of the United States through 1986 in the GEONAMES data base; [part M-AK, WA, OR, ID]: U.S. Geological Survey Open-File Report 88-44-M, 10 p., 1 floppy disc.

Manson, C. J.; Messick, C. H.; Sinnott, G. M., 1987, Mount St. Helens—A bibliography of geoscience literature, 1882-1986: U.S. Geological Survey Open-File Report 87-292, 205 p.

U.S. Geological Survey; U.S. Minerals Management Service, 1988, National assessment of undiscovered conventional oil and gas resources; USGS-MMS working paper: U.S. Geological Survey Open-File Report 88-373, 2 vol.

Williams, J. R.; Pearson, H. E., 1985, Streamflow statistics and drainage-basin characteristics for the southwestern and eastern regions, Washington; Volume I, Southwestern Washington: U.S. Geological Survey Open-File Report 84-145-A, 424 p., 1 plate.

Williams, J. R.; Pearson, H. E., 1985, Streamflow statistics and drainage-basin characteristics for the southwestern and eastern regions, Washington; Volume II, Eastern Washington: U.S. Geological Survey Open-File Report 84-145-B, 662 p., 1 plate.

Williams, J. R.; Pearson, H. E.; Wilson, J. D., 1985, Streamflow statistics and drainage-basin characteristics for the Puget Sound region, Washington; Volume I, Western and southern Puget Sound: U.S. Geological Survey Open-File Report 84-144-A, 330 p., 1 plate.

Williams, J. R.; Pearson, H. E.; Wilson, J. D., 1985, Streamflow statistics and drainage-basin characteristics for the Puget Sound region, Washington; Volume II, Eastern Puget Sound from Seattle to the Canadian border: U.S. Geological Survey Open-File Report 84-144-B, 420 p., 1 plate.

Wright, T. L., 1988, Chemical analyses used to compute the average chemical composition of rocks and glasses for geochemical units defined in the Yakima Basalt Subgroup, Columbia River Basalt Group, Washington, Oregon, and Idaho: U.S. Geological Survey Open-File Report 88-263, 69 p.

OTHER REPORTS OF INTEREST

Hull, D. A.; Armentrout, J. M.; Hintze, L. F.; Beaulieu, John; Rau, W. W., coordinators, 1988, Correlation of stratigraphic units of North America (COSUNA) project—Northwest region: American Association of Petroleum Geologists [Correlation chart series], 1 sheet.

King County Department of Public Works; King County Department of Parks, Planning and Resources, 1987, King County basin reconnaissance program, program summary: King County Dept. of Public Works, 3 v.

Levell, J. H.; Peterson, L. A.; Nichols, G. E., 1987, Placer mining technology and associated environmental effects: Salisbury and Associates, Inc. [Spokane, Wash., under contract to] National Park Service, 109 p.

Qamar, Anthony; Malone, S. P., 1988, Final technical report on earthquake monitoring of eastern Washington: University of Washington Geophysics Program, 19 p.

Scholl, D. W.; Grantz, Arthur; Vedder, J. G., compilers and editors, 1987, Geology and resource potential of the continental margin of western North America and adjacent ocean basins—Beaufort Sea to Baja California: Circum-Pacific Council for Energy and Mineral Resources [Houston, TX] Earth Science Series, v. 6, 799 p.

Scott, J. W.; De Lorme, R. L., 1988, Historical atlas of Washington: University of Oklahoma Press, 1 v.

Urban Regional Research, 1988, Planning for risk—Comprehensive planning for tsunami hazard areas: National Science Foundation, 246 p.

U.S. Bureau of Land Management, 1982, BLM facts—Oregon and Washington: U.S. Bureau of Land Management, 37 p.

U.S. Bureau of Mines, 1988, Minerals yearbook 1986; Vol. II, Area reports–Domestic: U.S. Bureau of Mines, 546 p.

U.S. Forest Service, 1988, Coldwater/Johnston project—Environmental assessment: U.S. Forest Service [Vancouver, WA], 151 p.

University of Washington Geophysics Program, 1988, Quarterly network report 88-B on seismicity of Washington and northern Oregon, April 1 through June 30, 1988: University of Washington Geophysics Program, 19 p.

Washington Department of Ecology, 1988, Draft environmental impact statement, Kettle River project, Ferry County, Washington: Washington Department of Ecology, 1 v.

Washington Department of Ecology, 1988, Final environmental impact statement, Kettle River project, Ferry County, Washington: Washington Department of Ecology, 1 v.

Williams, Chuck, 1988, Mount St. Helens National Volcanic Monument—A pocket guide for hikers, viewers, and skiers: The Mountaineers [Seattle, WA], 112 p.

Marine Mineral Resources Museum

The Washington State University (WSU)-National Oceanic and Atmospheric Administration (NOAA) museum of marine mineral resources consists of a display room for exhibits of interest to the public and a laboratory for scientific research. On display currently is a selection of marine manganese nodules primarily from seafloor areas east and southeast of Hawaii collected during research projects that have been under way since the mid 1960s. Also in the university's collection are thousands of nodules that have been obtained from locations mostly in the northwest Pacific Ocean, where many nodules contain appreciable percentages of nickel, copper, and cobalt as well as manganese.

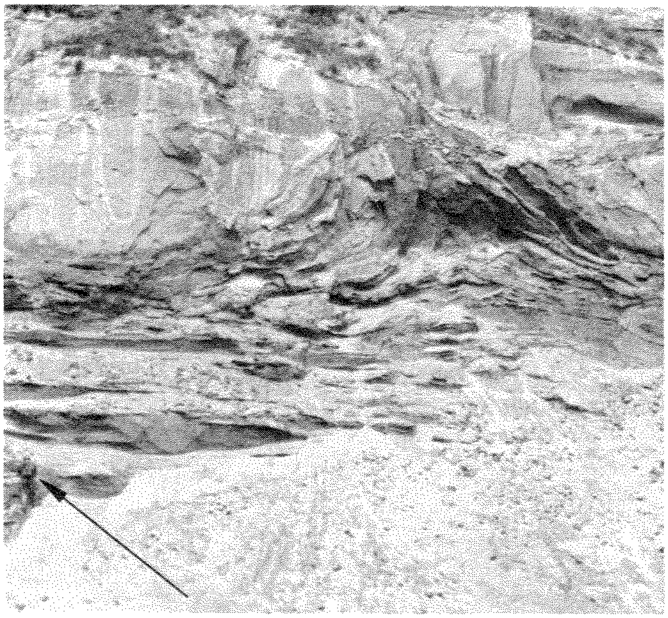
Manganese nodules are under consideration as sources of metals for which the United States is largely dependent on foreign sources. While mining and processing appear to feasible, the economics of such activities are not yet encouraging. The director of the museum, Ronald K. Sorem, has acted as technical observer on board the first prototype nodule mining vessel, the *Deepsea Miner II*, during a mining test east of Hawaii. Preliminary indications are that mining will have no significant effects on local marine life.

The museum's director participated in a Russian expedition studying manganese deposits in the Pacific in 1986. Reports of his findings have been submitted to NOAA.

Research at WSU on marine manganese deposits has been supported by the National Science Foundation, the U.S. Bureau of Mines, the U.S. Geological Survey, and NOAA. An agency of NOAA is currently funding archiving the collection. Donations to the museum are welcomed.

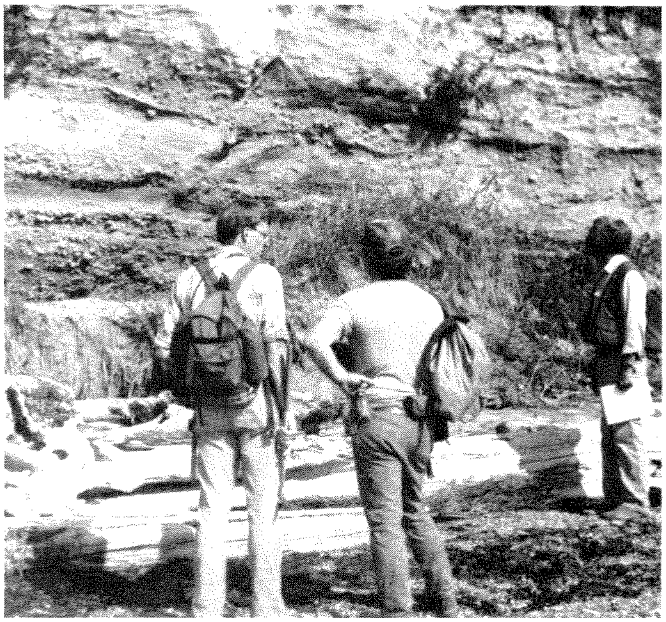
A 35-minute video tape produced by WSU about the environmental studies that were part of the mining test will be shown on request. To arrange a visit to the museum and for more information, contact:

Ronald Sorem, Director, WSU-NOAA Marine Mineral Resources Museum
WSU Research and Technology Park
NE 1345 Terre View Drive
Pullman, WA 99163 (509)353-3564



A large soft-sediment deformation structure in another Pleistocene deposit on Whidbey Island is shown in the photo above. This feature may have been caused by tectonic forces or by slumping. Note man (arrow) in lower left corner for scale.

In July, Division geologists traveled to Whidbey Island for the annual Division field trip. In the photo below, Division geologist emeritus Jerry Thorsen (far right) leads a discussion of possible tectonic disruption of glacial deposits of probable early Wisconsin age. In the foreground are (left to right) Keith Stoffel and Hank Schasse.



WASHINGTON GEOLOGIC NEWSLETTER

Author Index, 1973 - July 1988

[ANONYMOUS]

The Department of Natural Resources and Colville Tribes reach agreement for regulating mineral operations. v. 14, no. 4, p. 21. 1986.

Earthquake awareness week. v. 12, no. 2, p. 1. 1984.

Earthquakes in the news. v. 13, no. 2, p. 9. 1985.

Federal earthquake risk reduction program for the Puget Sound area. v. 15, no. 2, p. 5-11. 1987.

Geologic evidence for large earthquakes along the Pacific coast? v. 15, no. 2, p. 19-21. 1987.

Mount St. Helens ash fall distribution. v. 8, no. 3, p. 13-16. 1980.

Mount St. Helens fact sheet. v. 9, no. 2, p. 15-17. 1981.

A possible geologic explanation for the wildcat drilling by Shell in Yakima Canyon. v. 9, no. 2, p. 11-14. 1981.

River cleanup continues. v. 9, no. 2, p. 17-18. 1981.

SLAR reveals geologic structures in the Pasco Basin. v. 15, no. 2, p. 22-23. 1987.

Toutle River receives extensive damage. v. 8, no. 3, p. 17-18. 1980.

Vast amounts of ice and snow are atop Cascade volcanoes. v. 13, no. 2, p. 10-12. 1985.

Washington State Seismic Safety Commission recommendations. v. 15, no. 2, p. 4-5. 1987.

ARTIM, E. R.

Alternate methods for waste disposal. v. 2, no. 4, p. 7-8. 1974.

Application of geology to the building and real estate professions in the Puget Lowland metropolitan area, Washington. v. 3, no., 4, p. 1-9. 1975.

Fault capability. v. 4, no. 2, p. 4-5. 1976.

The importance of mineral deposits in land planning. v. 2, no. 2, p. 2-3. 1974.

Landslides–An expanding problem for the Puget Lowland. v. 1, no. 2, p. 1-3. 1973.

The Naches slide. v. 3, no. 2, p. 8-9. 1975.

The role of geology in planning and development. v. 1, no. 3, p. 6-7. 1973.

Seismic risk. v. 1, no. 3, p. 12. 1973.

BARNETT, D. BRENT

(and KOROSEC, M. A.) Geothermal exploratory drilling by the State of Washington in 1985. v. 14, no. 1-2, p. 21-28. 1986.

BLOOMQUIST, R. G.

Utilization of Washington's geothermal energy resources. v. 8, no. 1, p. 7-9. 1980.

BUNNING, BONNIE B.

High-calcium limestones tested for brightness. v. 14, no. 1-2, p. 31-33. 1986.

The Junction Reef gold prospect, Lincoln County, Washington. v. 12, no. 1, p. 17-18. 1984.

New developments in minerals and energy, Washington State, 1980. v. 9, no. 1, p. 1-7. 1981.

New developments in minerals and energy in Washington, 1982. v. 11, no. 1, p. 1-11. 1983.

New developments in mining and mineral exploration in Washington, 1984. v. 13, no. 1, p. 1-13. 1985.

New mineral inventory in progress. v. 14, no. 3, p. 26-27. 1986.

Washington's mineral industry, 1983. v. 12, no. 1, p. 1-13. 1984.

The Wenatchee gold rush. v. 11, no. 3, p. 1-5. 1983.

BUNNING, BONNIE B., see also HERDRICK, MELVIN, 1984.

CARNEY, PAUL, see GULICK, CHARLES W., III, 1985.

CARSON, R. J.

First known active fault in Washington. v. 1, no. 3, p. 1-2. 1973.

(and GRYTA, J. J.) Jorsted Creek slide, Mason County. v. 2, no. 3, p. 1-2. 1974.

Pleistocene ash on the Olympic Peninsula. v. 4, no. 3, p. 7. 1976.

(and WILSON, J. R.) Quaternary faulting on Dow Mountain, Mason County. v. 2, no. 4, p. 9-10. 1974.

FIKSDAL, ALLEN J.

Infiltration rates of undisturbed and disturbed Mount St. Helens tephra deposits. v. 9, no. 3, p. 1-3. 1981.

FORD, DONALD M.

Oil and gas activities in Washington. v. 10, no. 3, p. 12. 1982.

FORD, D. M., see also WURDEN, F. H., 1977.

FOX, KENNETH F., JR.

(and RINEHART, C. D.) Okanogan gneiss dome–A metamorphic core complex in north-central Washington. v. 16, no. 1, p. 3-12. 1988.

GRYTA, J. J., see CARSON, R. J., 1974.

GULICK, CHARLES W., III.

(and CARNEY, PAUL.) Production begins at the Wauconda Whitestone deposit. v. 13, no. 3-4, p. 5. 1985.

HERDRICK, MELVIN

(and BUNNING, B. B.) Geology of the Gold Dike mine, Ferry County, Washington. v. 12, no. 1, p. 20-22. 1984.

HUNTTING, M. T., see MOEN, W. S., 1979.

JOSEPH, NANCY L.

Eocene flora and fauna unearthed at Republic. v. 14, no. 4, p. 3-5. 1986.

High-calcium limestone. v. 14, no. 1-2, p. 29-31. 1986.

The mineral industry in Washington, 1987. v. 16, no. 2, p. 3-19. 1988.

Republic fossil locality open to public. v. 15, no. 4, p. 17. 1987.

The silica industry in Washington. v. 14, no. 4, p. 6-11. 1986.

Washington's mineral industry, 1985. v. 14, no. 1-2, p. 1-17. 1986.

Washington's mineral industry, 1986. v. 15, no. 1, p. 3-20. 1987.

KALDENBACH, GINGER

Reclaiming abandoned coal mines in Washington. v. 16, no. 1, p. 20-23. 1988.

KALER, KEITH L.

Whale hunting on the Olympic Peninsula. v. 16, no. 3, p. 16-17. 1988.

KIMMEL, R. H.

Some developments in mineral exploration in Washington in 1975–Oil and gas. v. 4, no. 1, p. 6-7. 1976.

KING, KENNETH W., see TARR, ARTHUR C., 1987.

KOROSEC, MICHAEL A.

Progress report on geothermal energy programs in Washington. v. 10, no. 3, p. 15-16. 1982.

KOROSEC, MICHAEL A., see also
BARNETT, D. BRENT, 1986.
RIGBY, J. G., 1980.
STOFFEL, KEITH L., 1984.

LASALATA, FRANK V., see WALSH, TIMOTHY J., 1984.

LASMANIS, RAYMOND

Earthquake research in Washington–Evolving program. v. 15, no. 2, p. 2, 27. 1987.

Geologic hazards program. v. 15, no. 1, p. 2, 23-24. 1987.

High-level nuclear waste repository concept–Deep geologic disposal. v. 14, no. 3, p. 3-9. 1986.

The Lyle and Lela Jacklin collection. v. 14, no. 4, p. 22. 1986.

Mineral collecting opportunities in Washington. v. 16, no. 2, p. 2, 25. 1988.

Minerals in fractured basalt–An issue. v. 14, no. 4, p. 2, 11-12. 1986.

Mount St. Helens Scientific Advisory Board. v. 15, no. 4, p. 2, 13-15. 1987.

Offshore metal deposits–Washington and Oregon. v. 11, no. 4, p. 1-2. 1983.

Oil and gas activity in Washington State–1985. v. 14, no. 1-2, p. 19-20. 1986.

Rare minerals found in Stevens County, Washington. v. 11, no. 4, p. 2-6. 1983.

Seabed mining jurisdiction question. v. 16, no. 3, p. 2. 1988.

Timber, fish and wildlife. v. 15, no. 3, p. 2, 15. 1987.

Washington offshore mineral resources. v. 16, no. 3, p. 5-10. 1988.

(and SCHASSE, H. W.) Washington's coal–Future development potential. v. 11, no. 1, p. 11-18. 1983.

LINGLEY, WILLIAM S., JR.

(and WALSH, T. J.) Issues relating to petroleum drilling near the proposed high-level nuclear waste repository at Hanford. v. 14, no. 3, p. 10-19. 1986.

Oil and gas exploration in Washington at its highest level in recent years. v. 15, no. 3, p. 12-14. 1987.

Twin River Oil and Gas, Inc. drilling near Port Angeles. v. 14, no. 3, p. 24-26. 1986.

LIVINGSTON, VAUGHN E., JR.

High-alumina-bearing mineral deposits in Washington. v. 10, no. 2, p. 4-8. 1982.

Origin of the Grand Coulee and Dry Falls. v. 6, no. 3, p. 1-3. 1978.

LOGAN, ROBERT L.

"Guidebook for developing a school earthquake safety program" to be available this summer. v. 13, no. 2, p. 3-7. 1985.

Some petrographic characteristics of pumice from the 1980 Mount St. Helens pyroclastic flows. v. 9, no. 4, p. 1-4. 1981.

LUCAS, J. M.

Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3. 1976.

Washington State exploration roundup, 1976. v. 5, no. 1, p. 1-8. 1977.

MCFARLAND, CARL R.

History of oil and gas exploration in the State of Washington. v. 7, no. 3, p. 1-6. 1979.

Metallic and nonmetallic mineral exploration wrap-up, 1979. v. 8, no. 1, p. 1-6. 1980.

Oil and gas activity in Washington, 1984. v. 13, no. 1, p. 15. 1985.

Oil and gas potential of the northwest and 1981 drilling activities. v. 10, no. 2, p. 1-4. 1982.

MCLUCAS, G. B.

Cleanup and disposal of Mount St. Helens ash in eastern Washington. v. 8, no. 4, p. 1-7. 1980.

Petrology of current Mount St. Helens tephra. v. 8, no. 3, p. 7-13. 1980.

MILNE, P. C.

Metallic mineral exploration in Washington, 1977. v. 6, no. 1, p. 1-7. 1978.

Metallic mineral exploration in Washington, 1978. v. 7, no. 1, p. 1-5. 1979.

Uranium in Washington. v. 8, no. 2, p. 1-5. 1980.

MOEN, WAYNE S.

(and HUNTTING, M. T.) Gold in Washington. v. 7, no. 4, p. 1-6. 1979.

Meteorites. v. 1, no. 2, p. 4-5. 1973.

The mineral industry of Washington–Highlights of its development 1853-1980, [Part 1]. v. 10, no. 3, p. 1-10. 1982.

The mineral industry of Washington–Highlights of its development 1853-1980, [Part 2]. v. 10, no. 4, p. 1-8. 1982.

The mines of Washington–Their overlooked worth. v. 5, no. 4, p. 1-3. 1977.

Mining activities in Washington during 1974. v. 2, no. 4, p. 1-3. 1974.

The old mining camps of Washington. v. 3, no. 2, p. 1-5. 1975.

Some developments in mineral exploration in Washington during 1975. v. 4, no. 1, p. 1-6. 1976.

A summary of mineral exploration in Washington in 1974. v. 3, no. 1, p. 1-4. 1975.

Washington metal mines. v. 1, no. 1, p. 3-5. 1973.

Washington mineral production–1975. v. 4, no. 1, p. 8. 1976.

Washington's nonmetallic minerals. v. 2, no. 1, p. 1-3. 1974.

MOEN, W. S., see also ZIMMERMAN, TOM, 1977.

NOSON, LINDA LAWRANCE

Plate tectonics and Washington earthquakes. v. 13, no. 2, p. 8-9. 1985.

Seismic summary. v. 12, no. 2, p. 2-4. 1984.

OTHBERG, KURT L.

Admiralty till (Pleistocene), or the rise and fall of a rock stratigraphic name. v. 5, no. 4, p. 5-6. 1977.

Earthquake investigations in Washington. v. 2, no. 2, p. 3-5. 1974.

"Friends of the Pleistocene" meet at Mount St. Helens. v. 1, no. 4, p. 4-5. 1973.

PALMER, PAMELA

(and SIEGFRIED, R. T.) Investigation of tectonic deformation in the Puget Lowland, Washington. v. 6, no. 3, p. 4-5. 1978.

PAPPAJOHN, STEVEN P.

Methane recovery from underground coalbeds. v. 12, no. 4, p. 11-16. 1984.

PHILLIPS, WILLIAM M.

(and WALSH, T. J.) Coal geology of King County, Washington. v. 9, no. 2, p. 1-11. 1981.

Geologic guide to the Monitor Ridge climbing route, Mount St. Helens, Washington. v. 15, no. 4, p. 3-13. 1987.

PHILLIPS, WILLIAM M., see also WALSH, TIMOTHY J., 1982.

RAU, WELDON W.

Eocene correlations–A comment. v. 9, no. 1, p. 15-16. 1981.

The Humptulips Formation–A new Eocene formation of southwest Washington. v. 12, no. 4, p. 1-5. 1984.

Oil and gas in Washington. v. 3, no. 3, p. 5-7. 1975.

The Oil City story. v. 4, no. 2, p. 1-3. 1976.

The Olympic Peninsula report. v. 1, no. 1, p. 5. 1973.

RIGBY, J. G.

(and TUCKER, G. B.) Basalt waste isolation program. v. 6, no. 2, p. 1-2. 1978.

(and KOROSEC, M. A.) Sequence of volcanic activity of Mount St. Helens, March 20-June 23, 1980. v. 8, no. 3, p. 1-6. 1980.

RINEHART, C. DEAN, see FOX, KENNETH F., JR., 1988.

SCHASSE, HENRY W.

Abandoned coal mine inventory update. v. 13, no. 3-4, p. 4-5. 1985.

Coal activity in Washington. v. 12, no. 1, p. 13-15. 1984.

Coal activity in Washington, 1984. v. 13, no. 1, p. 14-15. 1985.

Coal activity in Washington–1985. v. 14, no. 1-2, p. 18. 1986.

Coal activity in Washington–1986. v. 15, no. 1, p. 21-23. 1987.

Coal activity in Washington–1987. v. 16, no. 1, p. 20. 1988.

Coal exploration in Whatcom County. v. 16, no. 3, p. 11. 1988.

Pacific Coast Coal Company begins production. v. 14, no. 4, p. 22. 1986.

Partial seam CRIP underground coal gasification field test at Centralia Coal Mine. v. 12, no. 3, p. 4-6. 1984.

SCHASSE, HENRY W., see also LASMANIS, RAYMOND, 1983.

SCHUSTER, J. ERIC

Division to start work on new state geologic map. v. 11, no. 4, p. 6-7. 1983.

Geologic map of Washington–A progress report. v. 14, no. 3, p. 26. 1986.

Geothermal activities in Washington. v. 3, no. 4, p. 12-13. 1975.

Geothermal energy in Washington. v. 1, no. 4, p. 2-4. 1973.

Geothermal lease applications. v. 2, no. 3, p. 2-4. 1974.

Moses Coulee flash flood. v. 5, no. 4, p. 3-4. 1977.

Some developments in mineral exploration in Washington during 1975–Geothermal. v. 4, no. 1, p. 7. 1976.

State geologic map program; graduate student mapping project. v. 12, no. 1, p. 22-23. 1984.

Tower Rock–A southwestern Washington landmark. v. 1, no. 2, p. 3-4. 1973.

SIEGFRIED, R. T., see PALMER, PAMELA,1978.

SMITH, MACKEY

Coal mine subsidence investigation. v. 1, no. 2, p. 5-6. 1973.

Poulsbo slide. v. 2, no. 3, p. 7. 1974.

STOFFEL, KEITH L.

(and KOROSEC, M. A.) Low temperature geothermal resources of the Columbia Basin, eastern Washington. v. 12, no. 4, p. 5-11. 1984.

Stratigraphy of pre-Fraser Quaternary sediments applied to the evaluation of a proposed major tectonic structure in Island County, Washington. v. 7, no. 2, p. 1-4. 1979.

TARR, ARTHUR C.

(and KING, K. W.) USGS begins seismic ground response experiments in Washington. v. 15, no. 2, p. 11-18. 1987.

Subject Index, 1973 - July 1988

STOFFEL, K. L.; KOROSEC, M. A., 1984, Low temperature geothermal resources of the Columbia Basin, eastern Washington. v. 12, no. 4, p. 5-11.

Continental margin, see MARINE MINERAL RESOURCES

Copper, see MINERAL RESOURCES - COPPER

COWLITZ CO.

ANONYMOUS, 1981, River cleanup continues. v. 9, no. 2, p. 17-18.

Dams, see ENGINEERING GEOLOGY

DOUGLAS CO.

LIVINGSTON, V. E., JR., 1978, Origin of the Grand Coulee and Dry Falls. v. 6, no. 3, p. 1-3.

EARTHQUAKES AND SEISMOLOGY

ANONYMOUS, 1984, Earthquake awareness week. v. 12, no. 2, p. 1.

ANONYMOUS, 1985, Earthquakes in the news. v. 13, no. 2, p. 9.

ANONYMOUS, 1987, Federal earthquake risk reduction program for the Puget Sound area. v. 15, no. 2, p. 5-11.

ANONYMOUS, 1987, Geologic evidence for large earthquakes along the Pacific coast? v. 15, no. 2, p. 19-21.

ANONYMOUS, 1987, Washington State Seismic Safety Commission recommendations. v. 15, no. 2, p. 4-5.

ARTIM, E. R., 1973, Seismic risk. v. 1, no. 3, p. 12.

ARTIM, E. R., 1975, Application of geology to the building and real estate professions in the Puget Lowland metropolitan area, Washington. v. 3, no., 4, p. 1-9.

ARTIM, E. R., 1976, Fault capability. v. 4, no. 2, p. 4-5.

CARSON, R. J., 1973, First known active fault in Washington. v. 1, no. 3, p. 1-2.

LASMANIS, RAYMOND, 1987, Earthquake research in Washington–Evolving program. v. 15, no. 2, p. 2, 27.

LOGAN, R. L., 1985, "Guidebook for developing a school earthquake safety program" to be available this summer. v. 13, no. 2, p. 3-7.

NOSON, L. L., 1984, Seismic summary. v. 12, no. 2, p. 2-4.

NOSON, L. L., 1985, Plate tectonics and Washington earthquakes. v. 13, no. 2, p. 8-9.

OTHBERG, K. L., 1974, Earthquake investigations in Washington. v. 2, no. 2, p. 3-5.

TARR, A. C.; KING, K. W., 1987, USGS begins seismic ground response experiments in Washington. v. 15, no. 2, p. 11-18.

Economics and statistics, see MINERAL RESOURCES - ECONOMICS AND STATISTICS

Energy resources,

see

MINERAL RESOURCES - ECONOMICS AND STATISTICS

see specific energy resources, e.g.,

GEOTHERMAL RESOURCES

OIL AND GAS

ENGINEERING GEOLOGY

ANONYMOUS, 1981, River cleanup continues. v. 9, no. 2, p. 17-18.

ARTIM, E. R., 1974, Alternate methods for waste disposal. v. 2, no. 4, p. 7-8.

ARTIM, E. R., 1975, Application of geology to the building and real estate professions in the Puget Lowland metropolitan area, Washington. v. 3, no., 4, p. 1-9.

Exclusive Economic Zone, see MARINE MINERAL RESOURCES

FERRY CO.

ANONYMOUS, 1986, The Department of Natural Resources and Colville Tribes reach agreement for regulating mineral operations. v. 14, no. 4, p. 21.

HERDRICK, MELVIN; BUNNING, B. B., 1984, Geology of the Gold Dike mine, Ferry County, Washington. v. 12, no. 1, p. 20-22.

JOSEPH, N. L., 1986, Eocene flora and fauna unearthed at Republic. v. 14, no. 4, p. 3-5.

JOSEPH, N. L., 1987, Republic fossil locality open to public. v. 15, no. 4, p. 17.

LUCAS, J. M., 1976, Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3.

Floods, see GEOLOGIC HAZARDS

FORESTRY

LASMANIS, RAYMOND, 1987, Timber, fish and wildlife. v. 15, no. 3, p. 2, 15.

Fossils, see PALEONTOLOGY

FRANKLIN CO.

ANONYMOUS, 1987, SLAR reveals geologic structures in the Pasco Basin. v. 15, no. 2, p. 22-23.

GEOLOGIC HAZARDS

see also

EARTHQUAKES AND SEISMOLOGY

LANDSLIDES AND SLOPE STABILITY

ANONYMOUS, 1985, Vast amounts of ice and snow are atop Cascade volcanoes. v. 13, no. 2, p. 10-12.

ARTIM, E. R., 1973, The role of geology in planning and development. v. 1, no. 3, p. 6-7.

LASMANIS, RAYMOND, 1987, Geologic hazards program. v. 15, no. 1, p. 2, 23-24.

SCHUSTER, J. E., 1977, Moses Coulee flash flood. v. 5, no. 4, p. 3-4.

THORSEN, G. W., 1978, Flash flood caused damage in Chelan County. v. 6, no. 1, p. 10-11.

GEOLOGIC RESEARCH

ANONYMOUS, 1987, Federal earthquake risk reduction program for the Puget Sound area. v. 15, no. 2, p. 5-11.

BUNNING, B. B., 1986, New mineral inventory in progress. v. 14, no. 3, p. 26-27.

LASMANIS, RAYMOND, 1987, Earthquake research in Washington–Evolving program. v. 15, no. 2, p. 2, 27.

LASMANIS, RAYMOND, 1987, Timber, fish and wildlife. v. 15, no. 3, p. 2, 15.

SMITH, MACKEY, 1974, Poulsbo slide. v. 2, no. 3, p. 7.

THORSEN, G. W., 1986, Landslide dams–A potential geologic hazard. v. 14, no. 3, p. 22-24.

THORSEN, G. W., 1987, Soil bluffs + rain = slide hazards. v. 15, no. 3, p. 3-11.

Lead, see MINERAL RESOURCES - LEAD

LEWIS CO.

BARNETT, D. B.; KOROSEC, M. A., 1986, Geothermal exploratory drilling by the State of Washington in 1985. v. 14, no. 1-2, p. 21-28.

SCHASSE, H. W., 1984, Partial seam CRIP underground coal gasification field test at Centralia Coal Mine. v. 12, no. 3, p. 4-6.

SCHUSTER, J. E., 1973, Tower Rock–A southwestern Washington landmark. v. 1, no. 2, p. 3-4.

WURDEN, F. H.; FORD, D. M., 1977, Jackson Prairie gas storage project, Chehalis, Washington. v. 5, no, 3, p. 1-5.

Limestone, see MINERAL RESOURCES - LIMESTONE

LINCOLN CO.

BUNNING, B. B., 1984, The Junction Reef gold prospect, Lincoln County, Washington. v. 12, no. 1, p. 17-18.

LUCAS, J. M., 1976, Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3.

LOESS

THORSEN, G. W., 1983, West Beach silt–A late Pleistocene loess, central Puget Lowland, Washington. v. 11, no. 2, p. 1-4.

Maps - Geologic - Preparation, see GEOLOGIC RESEARCH

Marble, see MINERAL RESOURCES - MARBLE

MARINE MINERAL RESOURCES

LASMANIS, RAYMOND, 1983, Offshore metal deposits–Washington and Oregon. v. 11, no. 4, p. 1-2.

LASMANIS, RAYMOND, 1988, Seabed mining jurisdiction question. v. 16, no. 3, p. 2.

LASMANIS, RAYMOND, 1988, Washington offshore mineral resources. v. 16, no. 3, p. 5-10.

MASON CO.

CARSON, R. J., 1973, First known active fault in Washington. v. 1, no. 3, p. 1-2.

CARSON, R. J.; GRYTA, J. J., 1974, Jorsted Creek slide, Mason County. v. 2, no. 3, p. 1-2.

CARSON, R. J.; WILSON, J. R., 1974, Quaternary faulting on Dow Mountain, Mason County. v. 2, no. 4, p. 9-10.

Metamorphic petrology, see PETROLOGY

METEORITES

MOEN, W. S., 1973, Meteorites. v. 1, no. 2, p. 4-5.

Mineral collecting, see MINERALOGY AND MINERAL COLLECTING

MINERAL RESOURCES [GENERAL WORKS]

ARTIM, E. R., 1974, The importance of mineral deposits in land planning. v. 2, no. 2, p. 2-3.

BUNNING, B. B., 1986, New mineral inventory in progress. v. 14, no. 3, p. 26-27.

MOEN, W. S., 1973, Washington metal mines. v. 1, no. 1, p. 3-5.

MOEN, W. S., 1974, Washington's nonmetallic minerals. v. 2, no. 1, p. 1-3.

MINERAL RESOURCES - ALUMINUM

LIVINGSTON, V. E., JR., 1982, High-alumina-bearing mineral deposits in Washington. v. 10, no. 2, p. 4-8.

MINERAL RESOURCES - COAL

KALDENBACH, GINGER, 1988, Reclaiming abandoned coal mines in Washington. v. 16, no. 1, p. 20-23.

LASMANIS, RAYMOND; SCHASSE, H. W., 1983, Washington's coal–Future development potential. v. 11, no. 1, p. 11-18.

PHILLIPS, W. M.; WALSH, T. J., 1981, Coal geology of King County, Washington. v. 9, no. 2, p. 1-11.

SCHASSE, H. W., 1984, Coal activity in Washington. v. 12, no. 1, p. 13-15.

SCHASSE, H. W., 1985, Abandoned coal mine inventory update. v. 13, no. 3-4, p. 4-5.

SCHASSE, H. W., 1985, Coal activity in Washington, 1984. v. 13, no. 1, p. 14-15.

SCHASSE, H. W., 1986, Coal activity in Washington–1985. v. 14, no. 1-2, p. 18.

SCHASSE, H. W., 1986, Pacific Coast Coal Company begins production. v. 14, no. 4, p. 22.

SCHASSE, H. W., 1987, Coal activity in Washington–1986. v. 15, no. 1, p. 21-23.

SCHASSE, H. W., 1988, Coal activity in Washington–1987. v. 16, no. 1, p. 20.

SCHASSE, H. W., 1988, Coal exploration in Whatcom County. v. 16, no. 3, p. 11.

SMITH, MACKEY, 1973, Coal mine subsidence investigation. v. 1, no. 2, p. 5-6.

VONHEEDER, E. R., 1975, Washington State coal resources. v. 3, no. 4, p. 9-12.

VONHEEDER, E. R., 1977, Coal exploration on state-administered lands in Whatcom and Skagit Counties during 1976. v. 5, no. 1, p. 11-17.

WALSH, T. J., 1984, Coal found on Whidbey Island. v. 12, no. 1, p. 15-17.

WALSH, T. J., 1988, Coal mine subsidence in Washington. v. 16, no. 3, p. 3-5.

WALSH, T. J.; LASALATA, F. V., 1984, Abandoned coal mine inventory. v. 12, no. 3, p. 1-4.

WALSH, T. J.; PHILLIPS, W. M., 1982, Coal rank and thermal maturation in King County, Washington. v. 10, no. 1, p. 9-19.

MINERAL RESOURCES - COAL GASIFICATION

PAPPAJOHN, S. P., 1984, Methane recovery from underground coalbeds. v. 12, no. 4, p. 11-16.

SCHASSE, H. W., 1984, Partial seam CRIP underground coal gasification field test at Centralia Coal Mine. v. 12, no. 3, p. 4-6.

VONHEEDER, E. R., 1976, In-situ combustion of coal as an alternate energy source. v. 4, no. 3, p. 1-4.

MINERAL RESOURCES - COPPER

LASMANIS, RAYMOND, 1983, Offshore metal deposits–Washington and Oregon. v. 11, no. 4, p. 1-2.

MINERAL RESOURCES - ECONOMICS AND STATISTICS

BUNNING, B. B., 1981, New developments in minerals and energy, Washington State 1980. v. 9, no. 1, p. 1-7.

BUNNING, B. B., 1983, New developments in minerals and energy in Washington, 1982. v. 11, no. 1, p. 1-11.

BUNNING, B. B., 1984, Washington's mineral industry, 1983. v. 12, no. 1, p. 1-13.

BUNNING, B. B., 1985, New developments in mining and mineral exploration in Washington, 1984. v. 13, no. 1, p. 1-13.

JOSEPH, N. L., 1986, Washington's mineral industry, 1985. v. 14, no. 1-2, p. 1-17.

JOSEPH, N. L., 1987, Washington's mineral industry, 1986. v. 15, no. 1, p. 3-20.

JOSEPH, N. L., 1988, The mineral industry in Washington, 1987. v. 16, no. 2, p. 3-19.

LUCAS, J. M., 1977, Washington State exploration roundup, 1976. v. 5, no. 1, p. 1-8.

MCFARLAND, C. R., 1980, Metallic and nonmetallic mineral exploration wrap-up, 1979. v. 8, no. 1, p. 1-6.

MILNE, P. C., 1978, Metallic mineral exploration in Washington, 1977. v. 6, no. 1, p. 1-7.

MILNE, P. C., 1979, Metallic mineral exploration in Washington, 1978. v. 7, no. 1, p. 1-5.

MOEN, W. S., 1974, Mining activities in Washington during 1974. v. 2, no. 4, p. 1-3.

MOEN, W. S., 1975, A summary of mineral exploration in Washington in 1974. v. 3, no. 1, p. 1-4.

MOEN, W. S., 1976, Some developments in mineral exploration in Washington during 1975. v. 4, no. 1, p. 1-6.

MOEN, W. S., 1976, Washington mineral production–1975. v. 4, no. 1, p. 8.

MOEN, W. S., 1977, The mines of Washington–Their overlooked worth. v. 5, no. 4, p. 1-3.

MOEN, W. S., 1982, The mineral industry of Washington–Highlights of its development 1853-1980, [Part 1]. v. 10, no. 3, p. 1-10.

MOEN, W. S., 1982, The mineral industry of Washington–Highlights of its development 1853-1980, [Part 2]. v. 10, no. 4, p. 1-8.

U.S. BUREAU OF MINES, 1988, Washington's nonfuel mineral industry in 1987. v. 16, no. 1, p. 13.

VONHEEDER, E. R., 1979, Nonmetallic and industrial minerals and energy exploration. v. 7, no. 1, p. 5-8.

VONHEEDER, E. R., 1982, Minerals and energy activities in Washington, 1981. v. 10, no. 1, p. 1-8.

MINERAL RESOURCES - GOLD

BUNNING, B. B., 1983, The Wenatchee gold rush. v. 11, no. 3, p. 1-5.

BUNNING, B. B., 1984, The Junction Reef gold prospect, Lincoln County, Washington. v. 12, no. 1, p. 17-18.

HERDRICK, MELVIN; BUNNING, B. B., 1984, Geology of the Gold Dike mine, Ferry County, Washington. v. 12, no. 1, p. 20-22.

MOEN, W. S.; HUNTTING, M. T., 1979, Gold in Washington. v. 7, no. 4, p. 1-6.

MINERAL RESOURCES - HISTORY

MCFARLAND, C. R., 1979, History of oil and gas exploration in the State of Washington. v. 7, no. 3, p. 1-6.

MOEN, W. S., 1975, The old mining camps of Washington. v. 3, no. 2, p. 1-5.

MOEN, W. S., 1982, The mineral industry of Washington–Highlights of its development 1853-1980, [Part 1]. v. 10, no. 3, p. 1-10.

MOEN, W. S., 1982, The mineral industry of Washington–Highlights of its development 1853-1980, [Part 2]. v. 10, no. 4, p. 1-8.

RAU, W. W., 1976, The Oil City story. v. 4, no. 2, p. 1-3.

MINERAL RESOURCES - INDUSTRIAL MINERALS

JOSEPH, N. L., 1986, The silica industry in Washington. v. 14, no. 4, p. 6-11.

WALKER, C. W., 1978, Industrial minerals in Washington, 1977. v. 6, no. 1, p. 7-9.

ZIMMERMAN, TOM; MOEN, W. S., 1977, Sand and gravel in Washington. v. 5, no. 2, p. 1-7.

MINERAL RESOURCES - IRON

LASMANIS, RAYMOND, 1983, Offshore metal deposits–Washington and Oregon. v. 11, no. 4, p. 1-2.

MINERAL RESOURCES - LEAD

LASMANIS, RAYMOND, 1983, Offshore metal deposits–Washington and Oregon. v. 11, no. 4, p. 1-2.

MINERAL RESOURCES - LIMESTONE

BUNNING, B. B., 1986, High-calcium limestones tested for brightness. v. 14, no. 1-2, p. 31-33.

JOSEPH, N. L., 1986, High-calcium limestone. v. 14, no. 1-2, p. 29-31.

MINERAL RESOURCES - MARBLE

GULICK, C. W., III; CARNEY, PAUL, 1985, Production begins at the Wauconda Whitestone deposit. v. 13, no. 3-4, p. 5.

MINERAL RESOURCES - URANIUM

LUCAS, J. M., 1976, Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3.

MILNE, P. C., 1980, Uranium in Washington. v. 8, no. 2, p. 1-5.

MINERAL RESOURCES - ZINC

LASMANIS, RAYMOND, 1983, Offshore metal deposits–Washington and Oregon. v. 11, no. 4, p. 1-2.

MINERALOGY AND MINERAL COLLECTING

LASMANIS, RAYMOND, 1983, Rare minerals found in Stevens County, Washington. v. 11, no. 4, p. 2-6.

LASMANIS, RAYMOND, 1986, The Lyle and Lela Jacklin collection. v. 14, no. 4, p. 22.

LASMANIS, RAYMOND, 1986, Minerals in fractured basalt–An issue. v. 14, no. 4, p. 2, 11-12.

LASMANIS, RAYMOND, 1988, Mineral collecting opportunities in Washington. v. 16, no. 2, p. 2, 25.

MINING ENGINEERING

KALDENBACH, GINGER, 1988, Reclaiming abandoned coal mines in Washington. v. 16, no. 1, p. 20-23.

SCHASSE, H. W., 1985, Abandoned coal mine inventory update. v. 13, no. 3-4, p. 4-5.

SMITH, MACKEY, 1973, Coal mine subsidence investigation. v. 1, no. 2, p. 5-6.

WALSH, T. J., 1988, Coal mine subsidence in Washington. v. 16, no. 3, p. 3-5.

WALSH, T. J.; LASALATA, F. V., 1984, Abandoned coal mine inventory. v. 12, no. 3, p. 1-4.

MINING LAW

ANONYMOUS, 1986, The Department of Natural Resources and Colville Tribes reach agreement for regulating mineral operations. v. 14, no. 4, p. 21.

LASMANIS, RAYMOND, 1988, Seabed mining jurisdiction question. v. 16, no. 3, p. 2.

TEISSERE, RONALD F., 1988, State releases revised mining and prospecting regulations. v. 16, no. 1, p. 14-17.

MOUNT BAKER

U.S. GEOLOGICAL SURVEY, 1975, Increased volcanic activity of Mount Baker, Washington. v. 3, no. 3, p. 1-5.

MOUNT RAINIER

ANONYMOUS, 1985, Vast amounts of ice and snow are atop Cascade volcanoes. v. 13, no. 2, p. 10-12.

MOUNT SAINT HELENS

ANONYMOUS, 1980, Mount St. Helens ash fall distribution. v. 8, no. 3, p. 13-16.

ANONYMOUS, 1980, Toutle River receives extensive damage. v. 8, no. 3, p. 17-18.

ANONYMOUS, 1981, Mount St. Helens fact sheet. v. 9, no. 2, p. 15-17.

ANONYMOUS, 1981, River cleanup continues. v. 9, no. 2, p. 17-18.

FIKSDAL, A. J., 1981, Infiltration rates of undisturbed and disturbed Mount St. Helens tephra deposits. v. 9, no. 3, p. 1-3.

LASMANIS, RAYMOND, 1987, Mount St. Helens Scientific Advisory Board. v. 15, no. 4, p. 2, 13-15.

LOGAN, R. L., 1981, Some petrographic characteristics of pumice from the 1980 Mount St. Helens pyroclastic flows. v. 9, no. 4, p. 1-4.

MCLUCAS, G. B., 1980, Cleanup and disposal of Mount St. Helens ash in eastern Washington. v. 8, no. 4, p. 1-7.

MCLUCAS, G. B., 1980, Petrology of current Mount St. Helens tephra. v. 8, no. 3, p. 7-13.

OTHBERG, K. L., 1973, "Friends of the Pleistocene" meet at Mount St. Helens. v. 1, no. 4, p. 4-5.

PHILLIPS, W. M., 1987, Geologic guide to the Monitor Ridge climbing route, Mount St. Helens, Washington. v. 15, no. 4, p. 3-13.

RIGBY, J. G.; KOROSEC, M. A., 1980, Sequence of volcanic activity of Mount St. Helens, March 20-June 23, 1980. v. 8, no. 3, p. 1-6.

Natural gas, see OIL AND GAS

NUCLEAR WASTE DISPOSAL

LASMANIS, RAYMOND, COMPILER, 1986, High-level nuclear waste repository concept–Deep geologic disposal. v. 14, no. 3, p. 3-9.

LASMANIS, RAYMOND, 1986, Minerals in fractured basalt–An issue. v. 14, no. 4, p. 2, 11-12.

RIGBY, J. G.; TUCKER, G. B., 1978, Basalt waste isolation program. v. 6, no. 2, p. 1-2.

OIL AND GAS

ANONYMOUS, 1981, A possible geologic explanation for the wildcat drilling by Shell in Yakima Canyon. v. 9, no. 2, p. 11-14.

FORD, D. M., 1982, Oil and gas activities in Washington. v. 10, no. 3, p. 12.

KIMMEL, R. H., 1976, Some developments in mineral exploration in Washington in 1975–Oil and gas. v. 4, no. 1, p. 6-7.

LASMANIS, RAYMOND, 1986, Oil and gas activity in Washington State–1985. v. 14, no. 1-2, p. 19-20.

LINGLEY, W. S., JR., 1986, Twin River Oil and Gas, Inc. drilling near Port Angeles. v. 14, no. 3, p. 24-26.

LINGLEY, W. S., JR., 1987, Oil and gas exploration in Washington at its highest level in recent years. v. 15, no. 3, p. 12-14.

LINGLEY, W. S., JR.; WALSH, T. J., 1986, Issues relating to petroleum drilling near the proposed high-level nuclear waste repository at Hanford. v. 14, no. 3, p. 10-19.

MCFARLAND, C. R., 1979, History of oil and gas exploration in the State of Washington. v. 7, no. 3, p. 1-6.

MCFARLAND, C. R., 1982, Oil and gas potential of the northwest and 1981 drilling activities. v. 10, no. 2, p. 1-4.

MCFARLAND, C. R., 1985, Oil and gas activity in Washington, 1984. v. 13, no. 1, p. 15.

PAPPAJOHN, S. P., 1984, Methane recovery from underground coalbeds. v. 12, no. 4, p. 11-16.

RAU, W. W., 1975, Oil and gas in Washington. v. 3, no. 3, p. 5-7.

RAU, W. W., 1976, The Oil City story. v. 4, no. 2, p. 1-3.

WURDEN, F. H.; FORD, D. M., 1977, Jackson Prairie gas storage project, Chehalis, Washington. v. 5, no, 3, p. 1-5.

OKANOGAN CO.

ANONYMOUS, 1986, The Department of Natural Resources and Colville Tribes reach agreement for regulating mineral operations. v. 14, no. 4, p. 21.

BUNNING, B. B., 1986, High-calcium limestones tested for brightness. v. 14, no. 1-2, p. 31-33.

FOX, K. F., JR.; RINEHART, C. D., 1988, Okanogan gneiss dome–A metamorphic core complex in north-central Washington. v. 16, no. 1, p. 3-12.

GULICK, C. W., III; CARNEY, PAUL, 1985, Production begins at the Wauconda Whitestone deposit. v. 13, no. 3-4, p. 5.

OLYMPIC PENINSULA

RAU, W. W., 1973, The Olympic Peninsula report. v. 1, no. 1, p. 5.

PALEONTOLOGY

JOSEPH, N. L., 1986, Eocene flora and fauna unearthed at Republic. v. 14, no. 4, p. 3-5.

JOSEPH, N. L., 1987, Republic fossil locality open to public. v. 15, no. 4, p. 17.

KALER, K. L., 1988, Whale hunting on the Olympic Peninsula. v. 16, no. 3, p. 16-17.

PEND OREILLE CO.

BUNNING, B. B., 1986, High-calcium limestones tested for brightness. v. 14, no. 1-2, p. 31-33.

LUCAS, J. M., 1976, Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3.

PETROLOGY

FOX, K. F., JR.; RINEHART, C. D., 1988, Okanogan gneiss dome–A metamorphic core complex in north-central Washington. v. 16, no. 1, p. 3-12.

LOGAN, R. L., 1981, Some petrographic characteristics of pumice from the 1980 Mount St. Helens pyroclastic flows. v. 9, no. 4, p. 1-4.

PIERCE CO.

ANONYMOUS, 1985, Vast amounts of ice and snow are atop Cascade volcanoes. v. 13, no. 2, p. 10-12.

PUGET LOWLAND

ANONYMOUS, 1987, Federal earthquake risk reduction program for the Puget Sound area. v. 15, no. 2, p. 5-11.

ARTIM, E. R., 1973, Landslides–An expanding problem for the Puget Lowland. v. 1, no. 2, p. 1-3.

ARTIM, E. R., 1975, Application of geology to the building and real estate professions in the Puget Lowland metropolitan area, Washington. v. 3, no., 4, p. 1-9.

OTHBERG, K. L., 1977, Admiralty till (Pleistocene), or the rise and fall of a rock stratigraphic name. v. 5, no. 4, p. 5-6.

SMITH, MACKEY, 1973, Coal mine subsidence investigation. v. 1, no. 2, p. 5-6.

THORSEN, G. W., 1978, Atlas series in progress on Washington coastal zone. v. 6, no. 4, p. 1-4.

THORSEN, G. W., 1983, West Beach silt–A late Pleistocene loess, central Puget Lowland, Washington. v. 11, no. 2, p. 1-4.

THORSEN, G. W., 1987, Soil bluffs + rain = slide hazards. v. 15, no. 3, p. 3-11.

REMOTE SENSING

ANONYMOUS, 1987, SLAR reveals geologic structures in the Pasco Basin. v. 15, no. 2, p. 22-23.

Sand, see MINERAL RESOURCES - INDUSTRIAL MINERALS

Seismology, see EARTHQUAKES AND SEISMOLOGY

SHORELINES

THORSEN, G. W., 1978, Atlas series in progress on Washington coastal zone. v. 6, no. 4, p. 1-4.

SKAGIT CO.

PALMER, PAMELA; SIEGFRIED, R. T., 1978, Investigation of tectonic deformation in the Puget Lowland, Washington. v. 6, no. 3, p. 4-5.

VONHEEDER, E. R., 1977, Coal exploration on state-administered lands in Whatcom and Skagit Counties during 1976. v. 5, no. 1, p. 11-17.

WALSH, T. J., 1984, Core samples available for study. v. 12, no. 1, p. 18-20.

SKAMANIA CO.

BARNETT, D. B.; KOROSEC, M. A., 1986, Geothermal exploratory drilling by the State of Washington in 1985. v. 14, no. 1-2, p. 21-28.

Snow surveys, see GLACIERS

SPOKANE CO.

LUCAS, J. M., 1976, Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3.

STEVENS CO.

BUNNING, B. B., 1986, High-calcium limestones tested for brightness. v. 14, no. 1-2, p. 31-33.

LASMANIS, RAYMOND, 1983, Rare minerals found in Stevens County, Washington. v. 11, no. 4, p. 2-6.

LUCAS, J. M., 1976, Exploration for uranium in Washington during the bicentennial year. v. 4, no. 4, p. 1-3.

STRATIGRAPHY

CARSON, R. J., 1976, Pleistocene ash on the Olympic Peninsula. v. 4, no. 3, p. 7.

OTHBERG, K. L., 1977, Admiralty till (Pleistocene), or the rise and fall of a rock stratigraphic name. v. 5, no. 4, p. 5-6.

RAU, W. W., 1981, Eocene correlations–A comment. v. 9, no. 1, p. 15-16.

RAU, W. W., 1984, The Humptulips Formation–A new Eocene formation of southwest Washington. v. 12, no. 4, p. 1-5.

STOFFEL, K. L., 1979, Stratigraphy of pre-Fraser Quaternary sediments applied to the evaluation of a proposed major tectonic structure in Island County, Washington. v. 7, no. 2, p. 1-4.

THORSEN, G. W., 1983, West Beach silt–A late Pleistocene loess, central Puget Lowland, Washington. v. 11, no. 2, p. 1-4.

WALSH, T. J., 1984, Core samples available for study. v. 12, no. 1, p. 18-20.

STRUCTURAL GEOLOGY AND TECTONICS

ANONYMOUS, 1987, Geologic evidence for large earthquakes along the Pacific coast?. v. 15, no. 2, p. 19-21.

ANONYMOUS, 1987, SLAR reveals geologic structures in the Pasco Basin. v. 15, no. 2, p. 22-23.

ARTIM, E. R., 1976, Fault capability. v. 4, no. 2, p. 4-5.

CARSON, R. J., 1973, First known active fault in Washington. v. 1, no. 3, p. 1-2.

CARSON, R. J.; WILSON, J. R., 1974, Quaternary faulting on Dow Mountain, Mason County. v. 2, no. 4, p. 9-10.

NOSON, L. L., 1985, Plate tectonics and Washington earthquakes. v. 13, no. 2, p. 8-9.

PALMER, PAMELA; SIEGFRIED, R. T., 1978, Investigation of tectonic deformation in the Puget Lowland, Washington. v. 6, no. 3, p. 4-5.

STOFFEL, K. L., 1979, Stratigraphy of pre-Fraser Quaternary sediments applied to the evaluation of a proposed major tectonic structure in Island County, Washington. v. 7, no. 2, p. 1-4.

STUDY GUIDES

LOGAN, R. L., 1985, "Guidebook for developing a school earthquake safety program" to be available this summer. v. 13, no. 2, p. 3-7.

Subduction, see STRUCTURAL GEOLOGY AND TECTONICS

Subsidence, see MINING ENGINEERING

Tectonics, see STRUCTURAL GEOLOGY AND TECTONICS

THURSTON CO.

SCHASSE, H. W., 1984, Partial seam CRIP underground coal gasification field test at Centralia Coal Mine. v. 12, no. 3, p. 4-6.

TARR, A. C.; KING, K. W., 1987, USGS begins seismic ground response experiments in Washington. v. 15, no. 2, p. 11-18.

Uranium, see MINERAL RESOURCES - URANIUM

VOLCANIC ASH

CARSON, R. J., 1976, Pleistocene ash on the Olympic Peninsula. v. 4, no. 3, p. 7.

Waste disposal, see ENGINEERING GEOLOGY

WHATCOM CO.

PALMER, PAMELA; SIEGFRIED, R. T., 1978, Investigation of tectonic deformation in the Puget Lowland, Washington. v. 6, no. 3, p. 4-5.

SCHASSE, H. W., 1988, Coal exploration in Whatcom County. v. 16, no. 3, p. 11.

U.S. GEOLOGICAL SURVEY, 1975, Increased volcanic activity of Mount Baker, Washington. v. 3, no. 3, p. 1-5.

VONHEEDER, E. R., 1977, Coal exploration on state-administered lands in Whatcom and Skagit Counties during 1976. v. 5, no. 1, p. 11-17.

YAKIMA CO.

ANONYMOUS, 1981, A possible geologic explanation for the wildcat drilling by Shell in Yakima Canyon. v. 9, no. 2, p. 11-14.

ARTIM, E. R., 1975, The Naches slide. v. 3, no. 2, p. 8-9.

BARNETT, D. B.; KOROSEC, M. A., 1986, Geothermal exploratory drilling by the State of Washington in 1985. v. 14, no. 1-2, p. 21-28.

Zinc, see MINERAL RESOURCES - ZINC

State University of New York at Albany Summer Courses

The State University of New York at Albany, Department of Physics announces the 26th annual offering of two courses, which will be given in June and August 1989.

X-Ray Power Diffraction

June 19-23, Fundamentals
June 26-30, Advances

This course is tutorial and covers the entire field of chemical analysis by means of x-ray powder diffraction, from elementary principles to latest practices. The second week emphasizes quantitative methods employing matehmatical and computer practices. Registration many be made for one week or both weeks; each week costs $1,250.

X-Ray Spectrometry

June 5-9, Fundamentals
June 12-16, Advances
August 21-25, Math Methods

The course is tutorial and covers fundamentals through latest advances in x-ray spectrometry. The August session concentrates on mathematical and computer methods of solving the matrix problem and other problems of the advanced spectroscopist. Each week in June costs $1,250; the August session costs $1,300.

For further information and to register, contact:

Prof. Henry Chessin
State University of New York at Albany
Department of Physics
1400 Washington Ave.
Albany, NY 12222
(518) 442-4512

New Division Releases

Report of Investigations 29: Mima Mounds—An evaluation of proposed origins with special reference to the Puget Lowland, by A. L. Washburn of the University of Washington. This report is a comprehensive survey of many of the proposed origins for the enigmatic Mima and similar mounds. It focuses on the Puget Sound region but considers evidence regarding mounds elsewhere. The author concludes that runoff erosion combined with anchoring of sediment by vegetation are the most attractive factors in explaining the Puget Lowland mounds, but that no single hypothesis explains Mimalike mounds worldwide. The report's price is $1.86 + .14 (tax) = $2.00.

Information Circular 85: Washington State Earthquake Hazards, by Linda L. Noson, Anthony Qamar, and Gerald W. Thorsen. This report discusses causes and measurement of earthquakes in general and the geologic setting, distribution, recurrence interval, and historic effects of earthquakes in Washington. The authors outline simple actions to reduce injury and property loss from earthquakes. They recommend establishing policies for earthquake preparedness planning and action for homes, businesses, and communities. The 77-page report includes a list of sources of technical information about earthquakes in Washington and of booklets describing emergency planning in many settings. The publication of this report was supported by a grant from the U.S. Geological Survey's National Earthquake Hazards Reduction Program; therefore the report is available free of charge (except for the $1 per order postage and handling fee).

Open File Report 88-3: Geology of Parts of the Upper Proterozoic to Lower Cambrian Three Sisters Formation, Gypsy Quartzite, and Addy Quartzite, Stevens and Pend Oreille Counties, Northeastern Washington, by Kevin A. Lindsey. 18-p. text, 5 maps at various scales, and an explanation sheet. The price is $5.02 + .45 (tax) = $5.45.

Open File Report 88-4: Seismic Hazards of Western Washington and Selected Adjacent Areas—Bibliography and Index, 1855-June 1988, compiled by Connie J. Manson. 1,049 p. The publication of this open-file report was supported by a grant from the U.S. Geological Survey's National Earthquake Hazards Reduction Program; therefore the report is available free of charge (except for the $1 per order postage and handling fee).

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Division of Geology and Earth Resources
Mail Stop PY-12
Olympia, WA 98504

BULK RATE
U.S. POSTAGE
PAID
Washington State
Department of Printing