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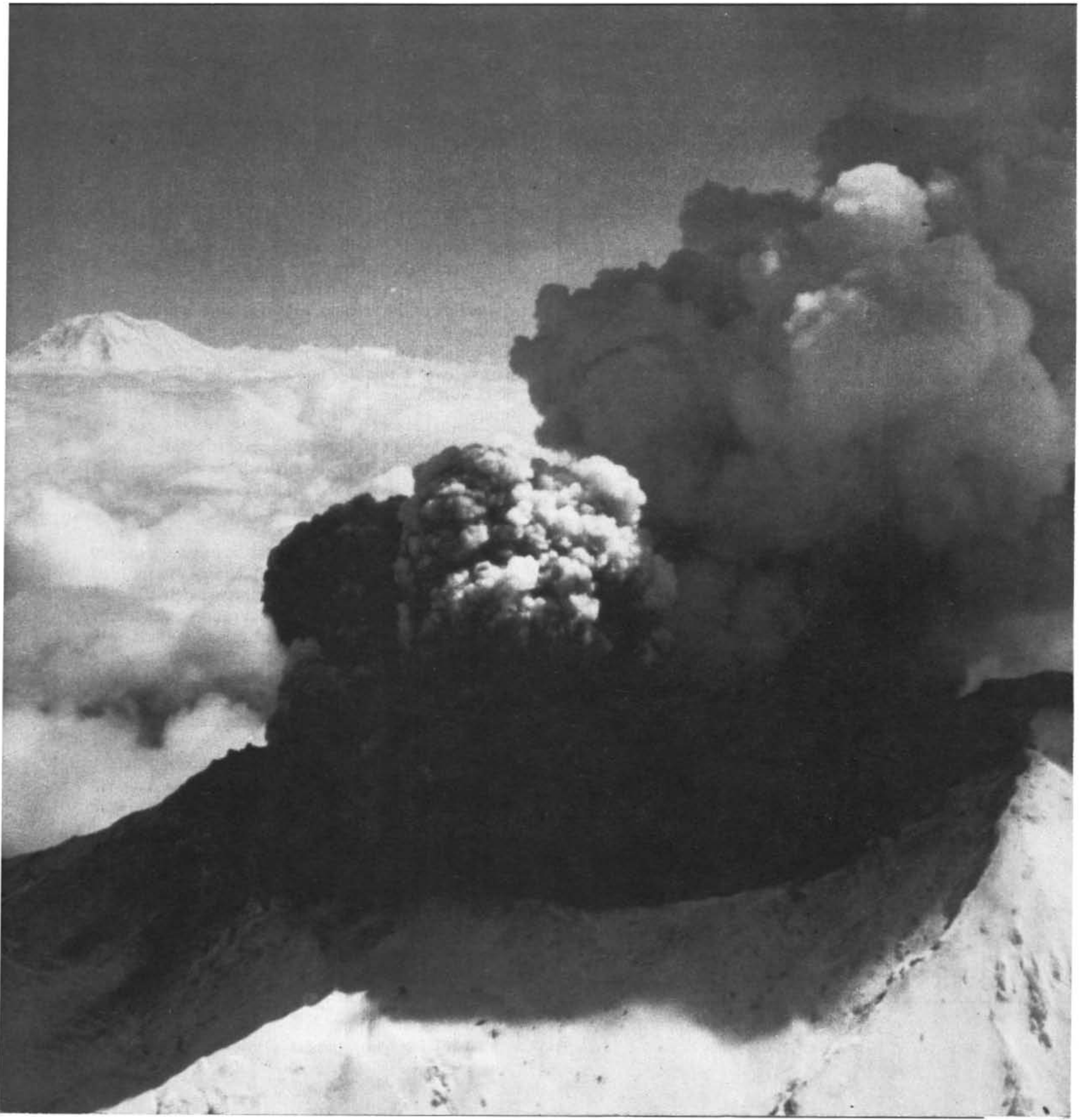

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COVER PHOTO

Phreatic eruption of Mount St. Helens volcano, Washington. Mount Adams, another Cascade volcano, is in background. White vapor cloud rises above black, ash-laden plume. Photo courtesy Len Palmer, Earth Sciences Department, Portland State University.

To our readers:

On March 27, 1980, Mount St. Helens, located approximately 35 air miles northeast of Portland in the southwest corner of Washington State, began erupting. The volcano has subsequently been monitored by staff of the U.S. Geological Survey housed in the U.S. Forest Service Headquarters in Vancouver, Washington.

The activity of the volcano is of practical and professional interest to a variety of other persons and agencies including the Emergency Services and Geology Departments of Oregon and Washington, utilities, and university geology staffs.

The Oregon Department of Geology and Mineral Industries maintains an interest in the volcano from the standpoint of public safety via coordination with the Oregon Division of Emergency Services and the U.S. Geological Survey. The Oregon National Guard, flying at the request of the Oregon Department of Geology and Mineral Industries, kindly provided the imagery and some of the photographs included in this issue.

The Department plans to pursue no scientific investigation of the volcano, as that is more appropriately handled by other groups. To address our readers' interest in this first volcanic activity in the Pacific Northwest in over a century, however, we will endeavor to make information available as seems appropriate in the future.

CONTENTS

NEXT MONTH

Geology of the Condrey Mountain Schist, Northern Klamath Mountains, California and Oregon, by Mary M. Donato and Robert G. Coleman, U.S. Geological Survey, and M. Allan Kays, Department of Geology, University of Oregon.

Mount St. Helens—an aerial view

by Charles L. Rosenfeld, Assistant Professor of Geography, Department of Geography, Oregon State University, Corvallis, Oregon

After a call from Oregon's State Geologist Donald A. Hull, the Oregon Army National Guard initiated aerial surveillance activity over Mount St. Helens volcano, Washington (Figure 1), as it began erupting during the afternoon of March 27, 1980. Employing both aerial photography and thermal mapping equipment, the OV-1 (Mohawk) aerial surveillance planes of the Guard's 1042 MICAS have provided data to the Oregon Department of Geology and Mineral Industries (DOGAMI) and U.S. Geological Survey (USGS) scientists. While more definitive accounts of this volcanic event are being prepared, it is hoped that this initial account can provide some interesting perspectives.

The first activity sighted was the formation of an explosion crater, flanked by numerous impact craters and accompanied by ash trailing off to the southeast. The initial crater, located north of the peak, was bounded by two east-west trending fracture zones (Figure 2). While no steam or vapors were visible after the initial discharge, the thermal infrared live scanner aboard the aircraft revealed more than ten gas vents or fumaroles (Figure 3).

By March 30, continued phreatic discharges (ground water explosively flashed into steam) had significantly enlarged the original crater and given birth to a new, smaller crater 100 m (300 ft) to the east. Significant ash fall littered the areas east of the activity, and continuing seismic activity along with thermal melting triggered a series of debris avalanches on the southeast flank of the volcano (Figure 4).

Harmonic earthquake tremors, possibly indicating movement of magma, were sporadically reported by the University of Washington Geophysics Program throughout the first week of activity. Phreatic eruptions, such as the one shown in Figure 5, yielded ash fall over a wide area. While estimates of ash fall over Portland's Bull Run Watershed reached 55 tons per square mile, the ash was residual pyroclastic material, leached of most solubles and composed mainly of plagioclase feldspar, and was therefore expected to have no significant acidic impact on the Portland water supply. Juvenile ash, by contrast, could have a considerable sulfur content and therefore an acidic potential.

Activity in the initial crater continued, gradually enlarging it until the wall of the smaller east crater was breached, as shown in the April 4th photograph (Figure 6). The cratered area, now extending the full 510 m (1,700 ft) width between the flanking fracture zones, has subsided significantly, indicating a "graben" structure. Figure 7 is a stereopair of vertical aerial photographs showing the fracture structure of the cratered area as of April 4, 1980. Thermal infrared imagery continues to show relatively localized "hot spots" within the crater, while indicating general, low-level heating of the entire adjacent area.

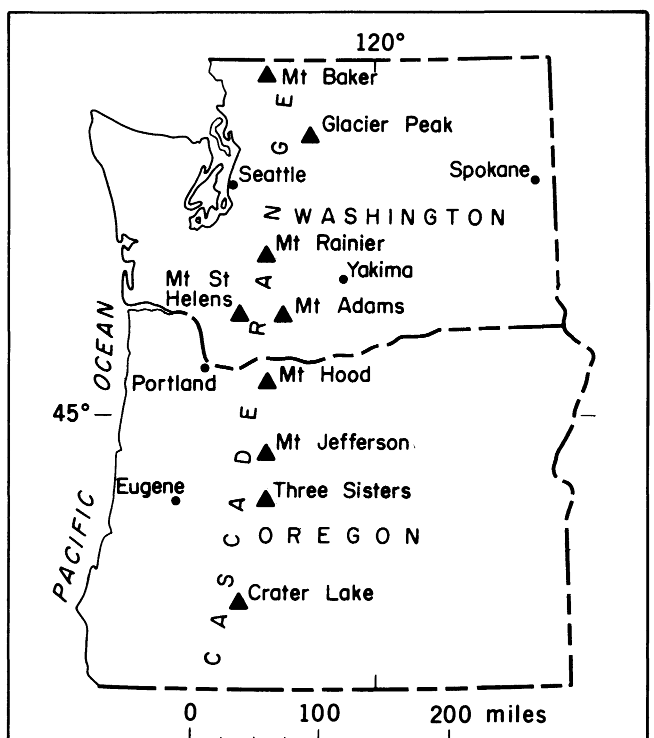
The first two weeks of eruptive activity have enabled the scientific community to learn quite a bit about the behavior of Mount St. Helens, described by Crandell and Mullineaux (1978) as "more active and more explosive during the last 4,500 years than any other volcano in the conterminous United States."

(Additional figures appear on following four pages.)

REFERENCE CITED

Crandell, D.R., and Mullineaux, D.R., 1978, Potential hazards from future eruptions of Mount St. Helens volcano, Washington: U.S. Geological Survey Bulletin 1383-C, 26 p.

Figure 1. Index map of Washington and Oregon showing locations of Mount St. Helens and other volcanoes.



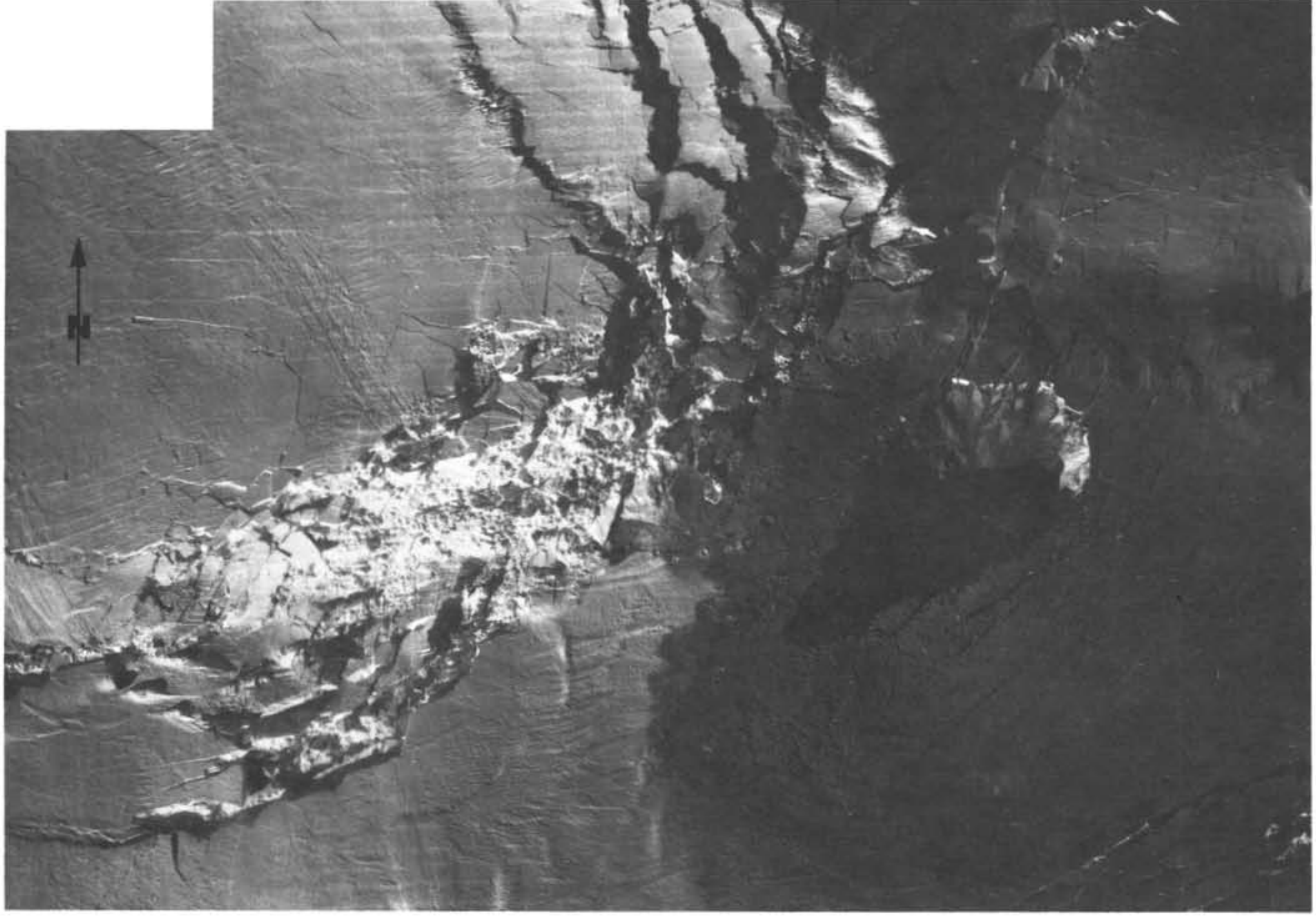


Figure 2. Vertical photo of the initial explosion crater, March 27, 1980, 2 p.m. Fracture zones indicate tensional rift.

Figure 3. Thermal infrared image of the same area, showing the initial crater, March 27, 4:15 p.m. Numerous fumaroles (gas vents) are clustered along the floor of the crater.

Figure 4. Panoramic view of the southeast flank of the mountain, March 30, 11:30 a.m. Note numerous debris avalanches.

Figure 5. Phreatic eruption, April 2, between 8:30 and 9 a.m., viewed from the northwest.

Figure 6. Crater viewed from the northwest, April 4, 1980.

Suggested reading about Mount St. Helens volcano, Washington

Some of these publications are available at local libraries or bookstores. USGS publications are sold through the USGS Public Inquiries Office, Room 678, U.S. Courthouse Building, W. 920 Riverside Ave., Spokane, WA 99201.

Crandell, D.R., and Mullineaux, D.R., 1973, Pine Creek volcanic assemblage at Mount St. Helens, Washington: U.S. Geological Survey Bulletin 1383-A, 23 p.

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Crandell, D.R., Mullineaux, D.R., and Rubin, Meyer, 1975, Mount St. Helens volcano; recent and future behavior: Science, v. 187, no. 4175, p. 438-441; reprinted by permission in Oregon Department of Geology and Mineral Industries, The Ore Bin, 1975, v. 37, no. 3, p. 41-48.

Harris, S.E., 1976, Fire and ice, the Cascade volcanoes: Seattle, Wash., The Mountaineers, and Pacific Search Books, 316 p.

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Mullineaux, D.R., and Crandell, D.R., 1962, recent lahars from Mount St. Helens, Washington: Geological Society of America Bulletin, v. 73, no. 7, p. 855-870. □

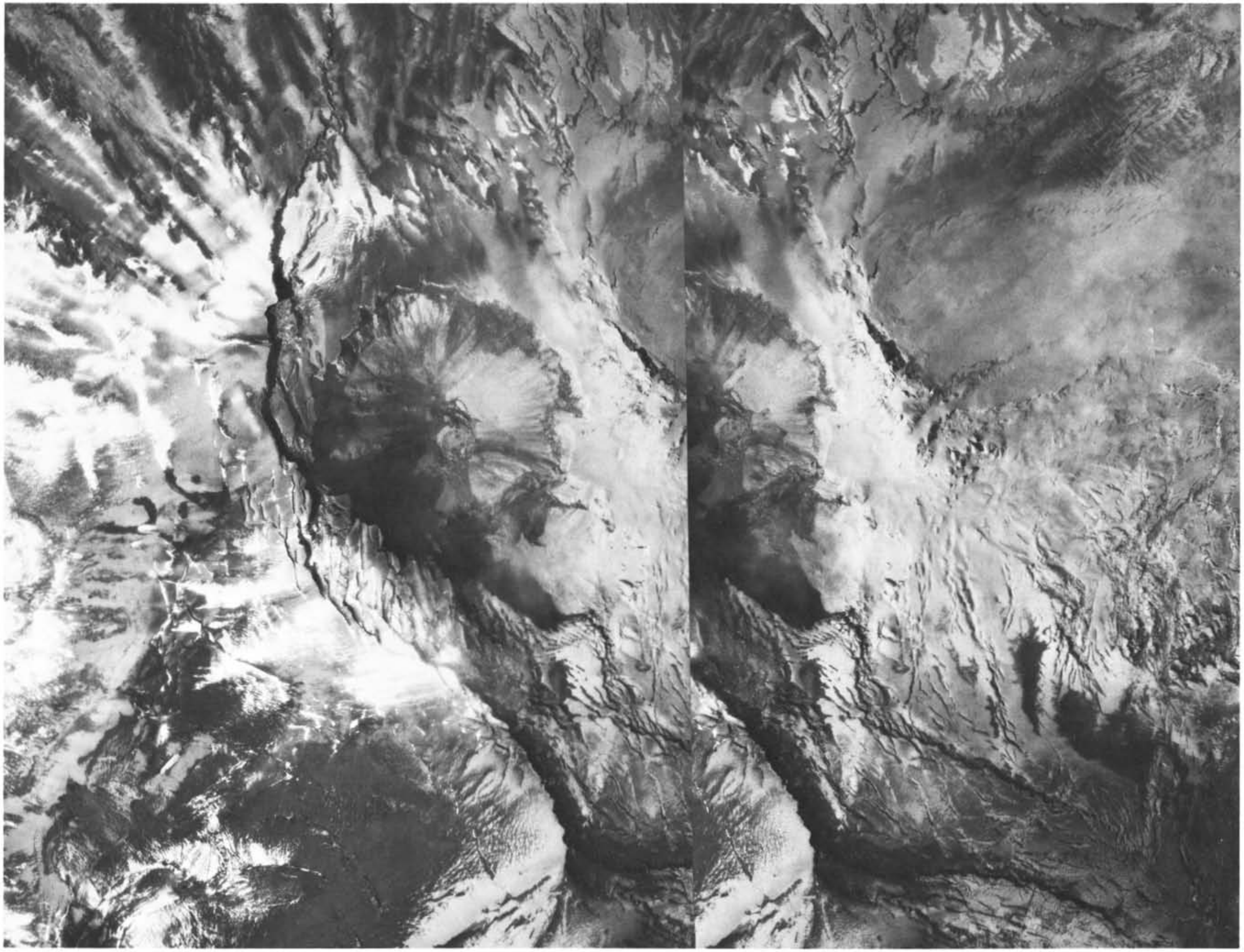


Figure 7. Stereopair of vertical photographs of the crater area, April 4, 1980.

THE DEVELOPMENT OF A CRATER, MOUNT ST. HELENS VOLCANO, 1980

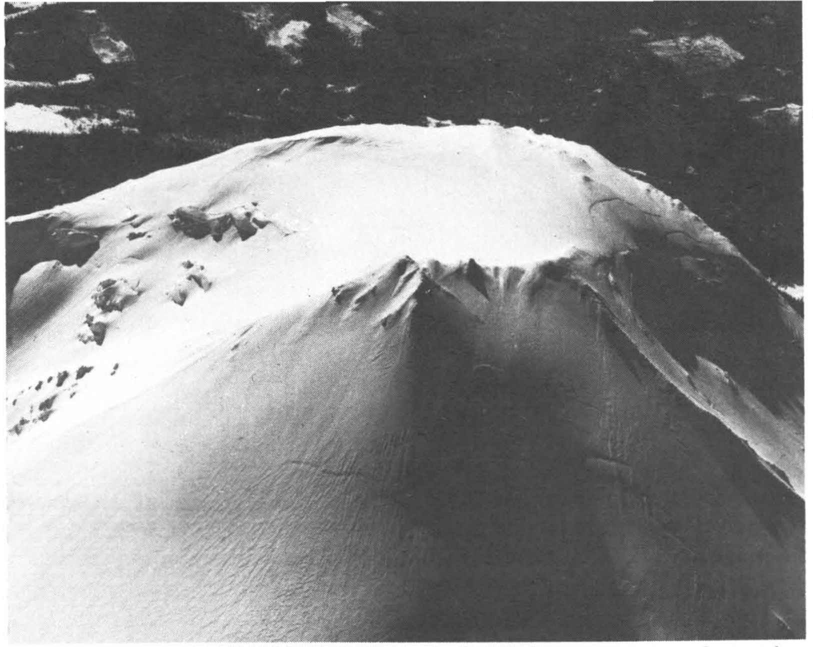


Photo courtesy Jim Vincent, *The Oregonian*

Mount St. Helens before eruptions began. ←

March 27, 1980, 2 p.m. Note ash surrounding single crater. →

Photo courtesy Michael Lloyd, *The Oregonian*

March 30, 1980, 8 a.m. Two craters have formed. →

Photo courtesy Randy Wood, *The Oregonian*

April 2, 1980, 7:45 a.m. Two craters are merging into one. →

Photo courtesy Jim Vincent, *The Oregonian*

April 4, 1980, 11:30 a.m. Crater is continuing to enlarge. ←

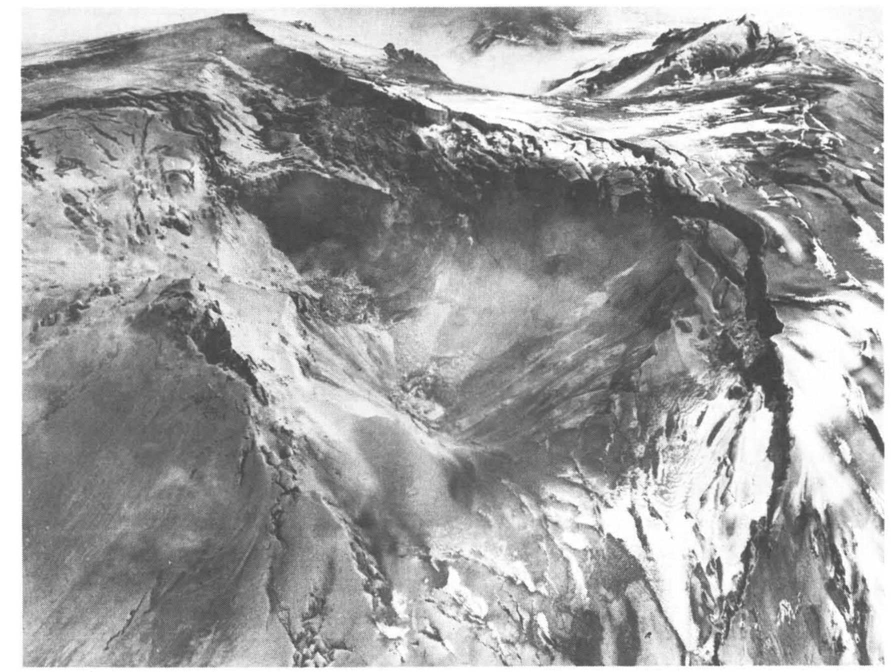


Photo courtesy Dale Swanson, *The Oregonian*

April 10, 1980, 9 a.m. ←

Photo courtesy Dale Swanson, *The Oregonian*

National Earthquake Prediction Evaluation Council established

A National Earthquake Prediction Evaluation Council was established in January 1980 to aid the director of the U.S. Geological Survey (USGS), Department of the Interior, in issuing any formal predictions of earthquakes.

The Council, to be composed of not less than eight federal and non-federal earth scientists, will review data collected by other scientists and recommend to the USGS director whether a formal earthquake prediction or advisory is warranted.

Speaking at a conference on earthquake prediction held in January in Los Angeles, Robert Wesson, Chief of the USGS Office of Earthquake Studies, Reston, Va., described the establishment of the Council as another step toward making earthquake prediction both a scientific and useful reality.

"Hard scientific predictions that spell out when, where, and how large an earthquake is expected are still several years away," Wesson said. "In the interim, however, the Council can play an important role in helping to analyze, interpret, and place in proper perspective significant geophysical data that may come to light.

"The final responsibility for whether and in what manner a prediction will be issued will rest with the USGS director," Wesson said, "but the Council will assure that the best outside expertise is always available to the USGS, and that an orderly process exists to help evaluate the data and their interpretation."

Establishment of the Council implements both the provisions of the Earthquake Hazards Reduction Act of September 1977 and a plan developed by a White House working group that called for expanded membership of an earlier prototype USGS panel. The Council was formally approved by Secretary of the Interior Cecil D. Andrus on August 9, 1979.

The Council is expected to focus its efforts on potentially destructive earthquakes which generally are those of magnitude 5.5 or greater on the Richter Scale. Data for smaller earthquakes also will be reviewed to establish a "track record" for prediction techniques.

Chairman of the Council is Clarence Allen of the California Institute of Technology. Wesson will serve as vice-chairman, and another USGS scientist, Jerry Stephens (Reston, Va.), will serve as executive secretary and a non-voting member. USGS geophysicists named to the Council are C. Barry Raleigh, Robert E. Wallace, James C. Savage, and David P. Hill, all from the USGS Western Regional Research Center, Menlo Park, Calif., and Eric R. Engdahl, USGS Denver, Colo., Federal Center. Non-federal Council members are Keiiti Aki, Massachusetts Institute of Technology; T. Neil Davis, University of Alaska; Thomas V. McEvilly, University of California, Berkeley; and Lynn R. Sykes, Columbia University.

As part of its role in advising the USGS director, the Council may also consider the crucial question of how to release earthquake predictions and warnings in such a way to allow constructive response by state and local officials.

Under terms of the charter, a prediction is defined to mean a statement on the time of occurrence, location, and magnitude of a future significant earthquake based on qualification or evaluation of the uncertainty of those factors. If the USGS director decides to issue a prediction, or an advisory or negative evaluation of a prediction, the first people to be notified are the director of the Federal Emergency Management Agency, the Secretary of the Department of the Interior, and the governors of states affected by the predicted earthquake. □

Interior Department issues temporary regs for hardrock mining on public lands

Temporary regulations that govern hardrock mining on public lands still subject to the Bureau of Land Management's (BLM) wilderness review have been issued by the Department of the Interior.

The final regulations are nearly identical to the proposed regulations except for two changes. First, the "grandfather clause" has been amended to allow mining and grazing uses as of October 21, 1976, to continue to expand in a logical fashion, even if they impair wilderness values. This means, for example, that a change from mineral exploration to production would be allowed if added impacts are not significantly different.

Second, development will be allowed on mining claims on which a valid discovery was made on or before October 21, 1976. However, such development will be subject to measures preventing unnecessary degradation of the public land.

The regulations will be in effect only temporarily, until other proposed rules become final. However, it was necessary to implement the temporary regulations to avoid impairment of wilderness suitability.

The regulations concern only such minerals as gold, silver, lead, zinc, and other minerals considered locatable under the General Mining Law of 1872, as amended. They do not affect leasable or "common variety" minerals such as sand and gravel.

The BLM regulations are similar to those effected by the Forest Service in 1974. □

Miocene stratigraphy and fossils, Cape Blanco, Oregon

by Warren O. Adicott, U.S. Geological Survey, Menlo Park, California 94025

INTRODUCTION

Seacliff exposures of marine sandstone on the southwest Oregon coast near Cape Blanco (Figure 1) contain fossil mollusks, echinoids, and barnacles of Miocene age. Fossil assemblages from the lower part of the Miocene sequence are correlated with the early and middle Miocene fauna of the Astoria Formation of the Newport embayment 200 km to the north. Assemblages that occur above an angular unconformity near the middle of this sequence are comparable to the late Miocene fauna of the Empire Formation of the Coos Bay area about 60 km to the north. Poorly preserved bivalves near the top of the sequence appear to represent a still younger faunal unit contemporaneous with the upper part of the Montesano Formation of Fowler (1965) of western Washington.

The Miocene sequence is in a relatively thin marine section that represents the most complete late Cenozoic sequence exposed on the Oregon coast. The Pliocene Epoch is not represented, but two and possibly three Miocene megafaunal stages are present—the Newportian, Wishkahan, and Graysian Stages (Addicott, 1976)—and there is a well-developed Pleistocene section (Baldwin, 1966; Allison and others, 1962).

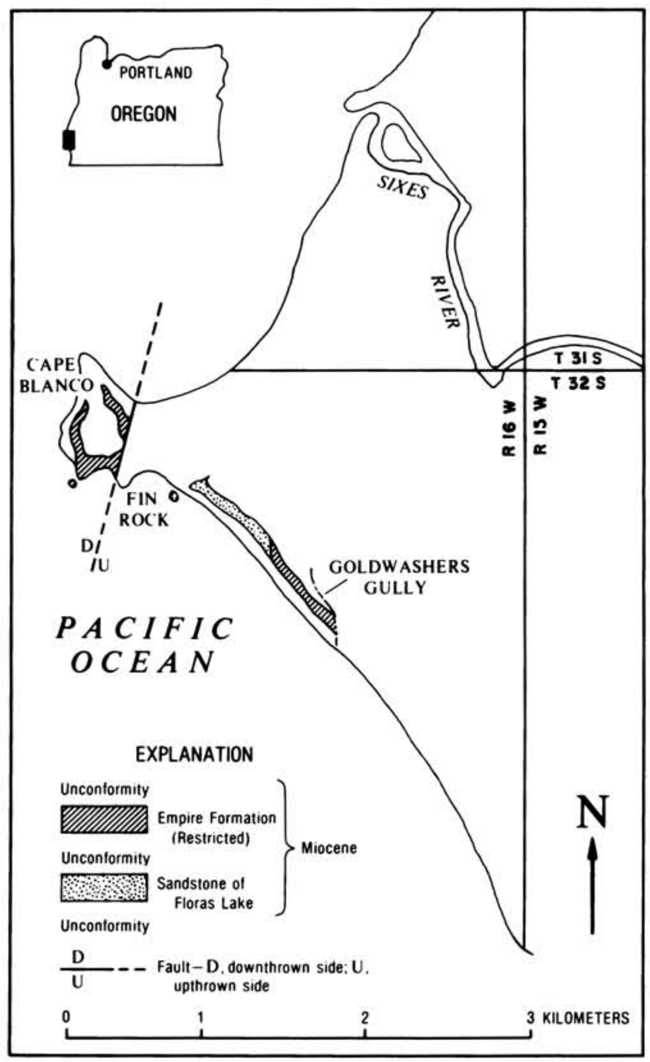
The purpose of this report is to summarize briefly the stratigraphic occurrence of the Miocene molluscan faunas and to illustrate some of the more common and biostratigraphically significant species. I am indebted to Richard Janda for assistance in the field and to Janda, E.J. Moore, and J.A. Barron for technical comments. Fossil photography is by Kenji Sakamoto.

EARLIER WORK

The age of the fossiliferous late Tertiary sandstone at Cape Blanco has been a subject of interest, and at times controversy, over the past 120 years. These strata were first noted by Newberry (1856), who compared them with marine beds exposed at Astoria, Oregon. Diller (1902, 1903) mapped and described the Neogene sequence at Cape Blanco. His fossil collections from near Blacklock Point and southeast of Cape Blanco suggested correlation with the Empire Formation of the Coos Bay area (Dall *in* Diller, 1902).

Controversy over the age of these beds arose from a stratigraphically mixed collection of invertebrates from southeast of Cape Blanco (Arnold and Hannibal, 1913, loc. NP26). This collection was considered to be of middle Miocene age but younger than the fauna of the Astoria Formation. It spanned 200 m or more of section and included molluscan assemblages from what are now known to be two provincial stages, the Newportian and Wishkahan. Subsequently, these strata were considered to be as old as Oligocene (Kew, 1920) and as young as Pliocene (Schenck, 1928; Bandy, 1950). These conflicting views were due, in part, to the composite stratigraphic collection. Clarification finally came when an unconformity was found in the Miocene section southeast of Cape Blanco (Durham, 1953). Arnold and Hannibal's collection had come from both above and below the unconformity.

Figure 1. Index map showing location of Cape Blanco and Miocene sections described in this report.



STRATIGRAPHIC SETTING

The stratigraphic sequence and structure of Cenozoic units near Cape Blanco are complex. Lower and middle Miocene sandstone rests unconformably on Eocene shale and sandstone (Bandy 1944) in the seacliffs southeast of Cape Blanco. In this seacliff section, the lower and middle Miocene unit is unconformably overlain by upper Miocene sandstone and siltstone which, in turn, are unconformably overlain by the Pleistocene Port Orford Formation of Baldwin (1945), a unit rich in molluscan fossils. There is an angular unconformity within the Port Orford Formation. Noteworthy in these Pleistocene strata are the diverse accumulations of *Psephidia* (see Clifton and Boggs, 1970), a minute bivalve that forms prominent white strata near the mouth of Elk River. At Cape Blanco proper, upper Miocene sandstone rests unconformably on Upper Jurassic sandstone and pebbly mudstone (Dott, 1971). Unconformably capping all of the older Cenozoic units at Cape Blanco are marine terrace deposits of late Pleistocene age (Figure 2). Mollusks and a few foraminifers have been identified from these gently warped strata (Bandy, 1950; Addicott, 1964; Kennedy, 1978).

The principal exposures of the Miocene section are in seacliffs about 0.5 km southeast of Cape Blanco and north of Blacklock Point, about 6 km north of Cape Blanco. Other exposures occur at Cape Blanco and several inland localities in the vicinity of Cape Blanco and nearby Port Orford (Koch, 1966). The most complete and most fossiliferous Miocene section is the 260-m-thick seacliff exposure southeast of Cape Blanco which extends from Fin Rock east-southeastward to Goldwasher's Gully. This section (Figure 3) serves as the framework for the stratigraphic and paleontologic descriptions which follow.

The Miocene sequence at Cape Blanco has been known as the Empire Formation of Diller (1903). The Empire Formation was defined for its type section, massive sandstone exposed between Sitka Dock (SW¼ sec. 40, T. 25 S., R. 13 W.) and the bridge (SE¼ sec. 2, T. 26 S., R. 14 W.) at Charleston, near the mouth of Coos Bay, Oregon (Weaver, 1945, pl. 9; Armentrout, 1967, p. 62). Unfortunately, use of this name at Cape Blanco implies correlation with the type Empire Formation. To avoid possible confusion, an informal name—sandstone of Floras Lake—is used for the lithologically distinct lower part of the Miocene sequence that occurs below the unconformity, and the name Empire Formation is used for massive sandstone of late Miocene age that unconformably overlies the sandstone of Floras Lake (Figure 3).

Sandstone of Floras Lake

This name, a term suggested by R.J. Janda (written communication, 1976), is based on the continuously exposed section of massive, conglomeratic, and concretionary sandstone exposed between Blacklock Point and Floras Lake, about 6 to 10 km north of Cape Blanco.

Figure 2. Angular unconformity between massive early and middle Miocene sandstone and flat-lying late Pleistocene terrace deposits near top of seacliff about 1 km southeast of Cape Blanco. Articulated bivalves in the terrace deposits are mostly Saxidomus giganteus *(Deshayes).*

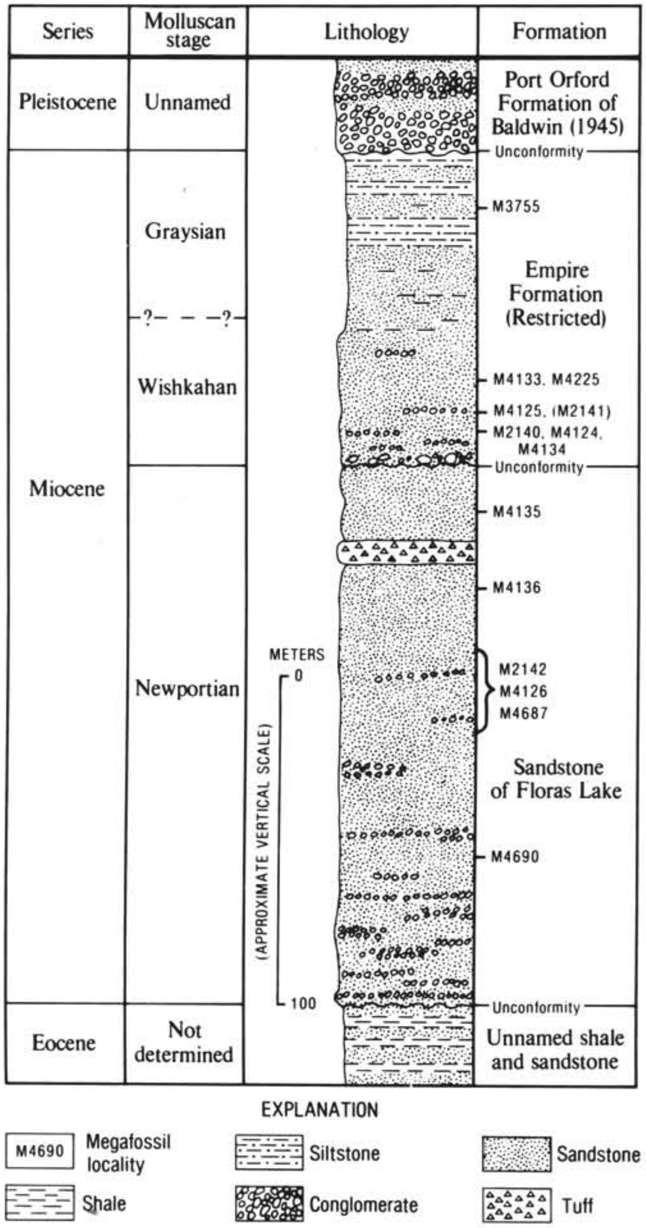


Figure 3. Diagrammatic section showing stratigraphic units exposed in seacliffs between Fin Rock and Goldwasher's Gully, southeast of Cape Blanco.

Although these strata have been referred to the Astoria Formation by Moore (1963), an alternative name is advisable because the lithology of this conglomeratic sandstone and sandstone unit differs significantly from that of the type locality of the Astoria Formation at the mouth of the Columbia River.

The basal part of the Miocene sequence is well exposed at Fin Rock, but the contact with the underlying Eocene shale and sandstone is concealed. The lowest few meters consists of pebble and cobble conglomerate with scattered barnacle plates and specimens of the gastropod *Nucella*. The principal fossiliferous localities in the sandstone of Floras Lake occur in a 50- to 60-m-thick interval below a tuff bed situated near the top of the formation. These concretionary beds are characterized by abundant specimens of the plicate mussel *Mytilus middendorffi* Grewingk. The 7- to 8-m-thick tuff contains poorly preserved fossil leaves of warm climatic aspect (Wolfe and Hopkins, 1967). Above the tuff are 30 m of massive carbonaceous and micaceous sandstone with scattered large flattened concretions. Small, articulated specimens of the bivalve *Spisula albaria* (Conrad) are extremely abundant in these concretions.

Twenty-nine larger marine invertebrates have been identified in collections made from exposures of the sandstone of Floras Lake in the seacliff section east of Cape Blanco (Table 1). The molluscan fauna of this unit is referable to the Newportian Stage (Addicott, 1976) of the Pacific Northwest. Species that are restricted to this stage include the gastropods *Molopophorus matthewi* Etherington and *Nassarius arnoldi* (Anderson) and the bivalves *Macoma flagleri* Etherington and *Mytilus middendorffi* Grewingk. The age of the Newportian is late early and middle Miocene in terms of the European standards (Addicott, 1977).

Correlative faunal assemblages occur at Coos Bay, 60 km to the north, in dredgings from the ship channel (Moore, 1963), and in an 8-m-thick section of sandstone on the east shore of Coos Bay (Baldwin, 1966; Armentrout, 1967). These *Dosinia*-rich collections contain a few specimens of the Newportian species *Mytilus middendorffi* Grewingk (USGS loc. 18284). This distinctive plicate mussel ranged from southern California to the Gulf of Alaska and possibly to Kamchatka in the western North Pacific, during the late early and middle parts of the Miocene (Allison and Addicott, 1976).

The *Mytilus-Balanus-Nucella* assemblages in the lower part of the section are indicative of deposition in an extremely shallow-water environment and proximity to a rocky shoreline. Pebble conglomerate lenses characteristic of these basal strata are similar to the pebble gravel that occurs in present-day surf zone sediments of this area. The disarticulation of these specimens (*Balanus* and *Mytilus*) and their occurrence in conglomerate and pebbly sandstone indicate transport in the surf and breaker zones; the relatively good preservation of these invertebrates, however, suggests that at least some of them were not subjected to prolonged abrasion and that deposition was probably fairly rapid.

Faunal diversity increases markedly upsection with the appearance of many gastropods and sand-dwelling bivalves. *Nucella* and *Mytilus* are joined by the bivalves *Spisula* and *Macoma* and the gastropods *Bruclarkia* and undetermined naticoids. The increase in diversity, together with the appearance of *Katherinella* and *Dentalium*, suggests deepening to about 10 to 20 m in the middle and upper parts of the section southeast of Cape Blanco.

Table 1. *Marine fossils from the Miocene sequence east of Cape Blanco, Oregon*
[x, present; cf., similar form; aff., comparable but specifically distinct; sp., species not determinable; ?, identification doubtful]

	Localities												
	Sandstone of Floras Lake						Empire Formation (restricted)						
Species	M4687	M2142	M4126	M4135	M4136	M4690	M2140	M2141	M4124	M4125	M4133	M4134	M4225
Gastropods:													
Acmaea sp.	—	x	—	—	—	—	—	—	—	—	—	—	—
Bruclarkia oregonensis (Conrad)	x	x	x	x	x	x	—	—	—	—	—	—	—
Cancellaria n. sp.? aff. *C. alaskensis* Clark	—	—	—	—	x	x	—	—	—	—	—	—	—
Cancellaria cf. *C. ocoyana* Addicott	—	—	—	—	x	—	—	—	—	—	—	—	—
Crepidula adunca Sowerby	—	—	—	—	—	—	—	cf.	—	x	—	—	—
Crepidula cf. *C. onyx* Sowerby	—	—	—	—	—	—	—	—	—	x	—	—	—
Crepidula praerupta Conrad	—	—	—	—	x	—	—	—	—	—	—	—	—
Crepidula rostralis (Conrad)	—	x	—	—	—	—	—	—	—	—	—	—	—
Cryptonatica cf. *C. clausa* (Broderip and Sowerby)	—	—	—	—	—	—	—	x	—	—	—	?	—
Cryptonatica oregonensis (Conrad)	x	—	—	sp.	—	—	—	—	—	—	—	—	—
Littorina petricola (Dall)	—	—	—	—	—	—	—	—	—	—	x	—	—
Mediargo sp.	—	—	—	—	—	—	—	x	—	—	—	—	—
Megasurcula sp.	—	—	x	—	—	—	—	—	—	—	—	—	—
Molopophorus cf. *M. anglonanus* (Anderson)	sp.	x	—	—	x	—	—	—	—	—	—	—	—
Molopophorus bogachieli (Reagan)	—	—	—	—	—	—	cf.	x	—	x	—	x	—
Molopophorus matthewi Etherington	—	x	x	—	x	x	—	—	—	—	—	—	—
Nassarius cf. *N. andersoni* (Weaver)	—	—	—	—	—	—	—	—	—	—	—	x	—
Nassarius arnoldi Anderson	—	—	—	—	—	x	—	—	—	—	—	—	—
Natica cf. *N. clarki* Etherington	—	—	x	—	—	—	—	—	—	—	—	—	—
Nucella canaliculata (Duclos)	—	—	—	—	—	—	x	—	—	x	x	—	x
Nucella etchegoinensis (Arnold)	—	—	—	—	—	—	—	x	—	cf.	—	—	—
Nucella lima (Gmelin)	—	—	—	—	—	—	cf.	cf.	—	x	x	x	—
Nucella packi (Clark)	—	x	x	—	cf.	—	—	—	—	—	—	—	—
Ocenebra sp.	—	—	—	—	—	—	—	x	—	—	—	—	—
Olivella cf. *O. ischnon* Keen	x	sp.	cf.	—	?	sp.	—	—	—	—	—	—	—
Opalia wishkahensis Durham	—	—	—	—	—	—	—	—	cf.	—	—	x	—
Ophiodermella cf. *O. olympicensis* Addicott	—	—	x	—	—	x	—	—	—	—	—	—	—
Polinices lincolnensis (Weaver)	x	—	x	—	x	—	—	—	—	—	—	—	—
Priscofusus cf. *P. medialis* (Conrad)	—	—	x	—	—	—	—	—	—	—	—	—	—
Bivalves:													
Acila blancoensis Howe	—	—	—	—	—	—	x	x	x	x	x	—	x
Anadara trilineata (Conrad)	—	—	—	—	—	—	x	—	x	x	—	cf.	?
Clinocardium meekianum (Gabb)	—	—	—	—	—	—	x	x	x	cf.	x	cf.	cf.
Cnesterium aff. *C. scissurata* (Dall)	—	—	—	—	—	—	—	x	—	—	—	—	—
Felaniella parilis (Conrad)	—	—	—	—	—	—	x	—	—	x	—	—	x
Glycymeris gabbi (Dall)	—	—	—	—	—	—	x	—	—	x	—	—	x
Glycymeris grewingki Dall	—	—	—	—	—	—	—	—	x	—	—	—	—
Katherinella cf. *K. angustifrons* (Conrad)	—	x	—	—	x	—	—	—	—	—	—	—	—
Lucinoma cf. *L. acutilineata* (Conrad)	—	—	—	—	—	—	—	—	x	—	—	—	—
Macoma cf. *M. flagleri* Etherington	—	x	x	x	—	x	—	—	—	—	—	—	—
Macoma indentata Carpenter	—	—	—	—	—	—	—	—	—	x	—	—	—
Macoma secta (Conrad)	—	cf.	—	—	—	cf.	x	—	cf.	—	—	—	—
Modiolus sp.	—	—	—	—	—	—	—	x	—	—	—	—	—
Mytilus middendorffi Grewingk	x	x	x	x	x	x	—	—	—	—	—	—	—
Pandora sp.	—	—	—	—	—	—	—	—	—	—	—	—	x

Table 1. *Marine fossils from the Miocene sequence east of Cape Blanco, Oregon (continued)*

Species	Localities												
	Sandstone of Floras Lake						Empire Formation (restricted)						
	M4687	M2142	M4126	M4135	M4136	M4690	M2140	M2141	M4124	M4125	M4133	M4134	M4225
Bivalves *(continued)*													
Securella securis (Shumard)	sp.	—	—	—	sp.	—	x	—	x	x	—	x	x
Siliqua cf. *S. lucida* (Conrad)	—	—	—	—	—	—	—	x	—	x	—	—	?
Solen conradi Dall	—	cf.	x	?	—	—	—	—	—	—	—	—	—
Spisula albaria (Conrad)	x	x	x	cf.	cf.	x	—	—	—	—	—	—	—
Spisula cf. *S. albaria coosensis* Howe	—	—	—	—	—	—	x	—	x	x	x	—	—
Spisula praecursor Dall	—	—	—	—	—	—	—	x	—	—	—	—	—
Spisula cf. *S. selbyensis* Packard	—	—	x	—	x	sp.	—	—	—	—	—	—	—
Tellina emacerata Conrad	x	?	x	—	x	—	—	—	—	—	—	—	—
Tellinella merriami (Weaver)	—	—	—	—	—	—	—	x	—	—	—	—	cf.
Tresus pajaroanus (Conrad)	—	—	—	—	—	—	—	—	x	—	—	—	—
Yoldia cf. *Y. carnerosensis* Clark	x	x	x	—	x	x	—	—	—	—	—	—	—
Yoldia cooperi Gabb	—	—	—	—	—	—	x	—	—	—	—	—	—
Echinoids:													
Kewia blancoensis (Kew)	—	—	—	—	—	—	—	x	—	—	—	—	—
Kewia cf. *K. blancoensis etheringtoni* (Weaver)	—	—	x	—	—	?	—	—	—	—	—	—	—
Barnacles:													
Balanus tintinnabulum coosensis Dall	—	—	—	—	—	—	—	x	—	—	—	—	—
Balanus sp.	—	x	x	—	—	—	—	—	—	—	—	—	—

Figure 4. Unconformity between sandstone of Floras Lake and overlying sandstone of the Empire Formation (restricted). View looking north.

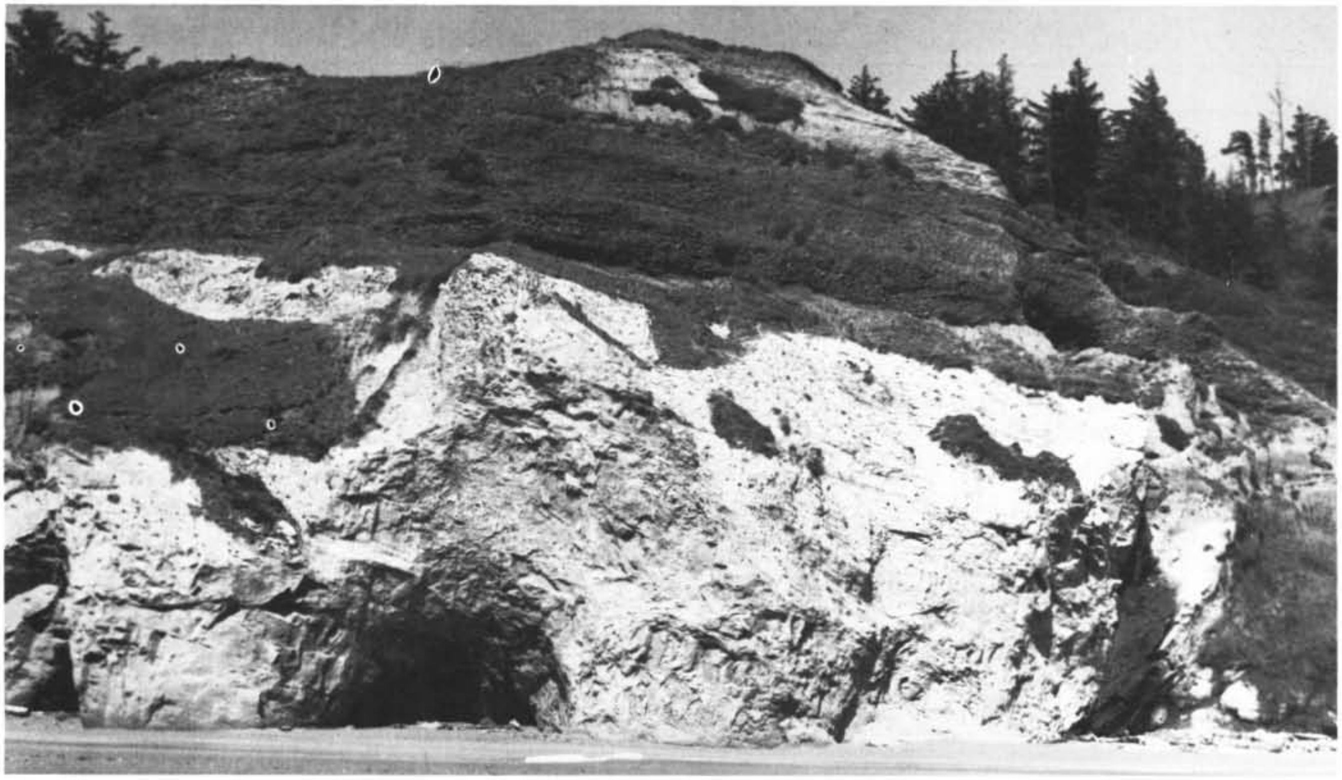


Figure 5. Massive, diatomaceous, sandy siltstone of the upper part of the Empire Formation (restricted) unconformably overlain by fluvial conglomerate of the Port Orford Formation of Baldwin (1945). Fossil locality M3755 occurs at base of seacliff about 100 m farther west. View looking north and about 100 m west of Goldwasher's Gully. Height of seacliff about 60 m.

The stratigraphically highest exposures southeast of Cape Blanco (loc. M4135) are micaceous, fine-grained, thick-bedded sandstone with small articulated specimens of *Spisula* and scattered *Dentalium*. These sediments probably were deposited in relatively deeper and quieter waters than stratigraphically lower parts of the sandstone of Floras Lake.

In summary, the succession of marine communities preserved in the 150- to 180-m early and middle Miocene section southeast of Cape Blanco is suggestive of initial deposition near the top of the inner sublittoral zone (0-100 m) with progressive deepening as deposition continued. However, the 7- to 8-m-thick tuff bed near the top of the unit that contains fossil leaves (Wolfe and Hopkins, 1967, p. 70-71) may indicate a brief reversal of the inferred deepening trend. According to Wolfe (personal communication, March 1977), the preservation of these leaf specimens implies transportation in a high-energy environment. Shoaling in the upper part of the unit is clearly indicated in the Blacklock Point section north of Cape Blanco where fluvial gravel occurs stratigraphically above the tuff bed.

Empire Formation (restricted)

The Empire Formation (restricted), equivalent to the upper part of the Empire Formation of Diller (1903), is separated from the underlying sandstone of Floras Lake by an erosional unconformity exposed at the base of the seacliff about 1.5 km southeast of Cape Blanco (Figure 4). The channeled surface is accentuated by subangular blocks of sandstone and fossiliferous concretions reworked from the underlying unit. These blocks reach a meter or more in thickness and are riddled with mollusk borings. Invertebrates in this basal stratum include *Chlamys*, *Securella*, and *Yoldia*, and the gastropod *Cryptonatica*.

The Empire Formation at Cape Blanco consists of about 100 m of massive sandstone and sandy siltstone. The lowest 35 to 40 m is a massive sandstone unit with several fossiliferous lenses. The lower 14 to 15 m includes a 1-m-thick basal conglomerate which is overlain by more or less massive, concretionary sandstone characterized by lenses of pebble conglomerate. Bedded concretions in this interval contain abundant mollusks of shallow-water aspect. The stratigraphically higher part of this massive sandstone unit is less fossiliferous and contains only scattered lenses of pebble conglomerate.

These strata in turn are overlain by 50 to 60 m of white- to tan-weathering, silty, very fine-grained sandstone and sandy siltstone (Figure 5) containing scattered molds of bivalve mollusks, especially near the top.

Commonly occurring mollusks are the bivalves *Lucinoma annulata* (Reeve), *Macoma* cf. *M. calcarea* (Gmelin), *Nuculana* sp., *Portlandia* sp., *Compsomyax* cf. *C. subdiaphana* (Carpenter), and *Cnesterium scissurata* Dall (USGS locs. M3755, M4223).

The Empire Formation (restricted) is unconformably overlain by poorly consolidated conglomerate and sandstone of the Port Orford Formation of Baldwin (1945). The angular unconformity between the two formations is well exposed near Goldwasher's Gully southeast of Cape Blanco (Figure 6). An intraformational unconformity between buff sand and gravel at the base of the Port Orford and a prominent fluvial gravel that marks the base of the so-called "Elk River Member" of the formation is well exposed in the seacliff immediately southeast of Goldwasher's Gully (Figure 6).

Mollusks referable to the Wishkahan Stage (Addicott, 1976) occur in the basal conglomeratic sandstone of the Empire Formation (restricted) at Cape Blanco and in a 30-m-thick section with three pebbly sandstone lenses in the lower unit. These late Miocene species are listed in Table 1. Species restricted to the Wishkahan Stage include the bivalves *Acila blancoensis* Howe, *Glycymeris gabbi* Dall, *Tellinella merriami* (Weaver), and the gastropod *Opalia wishkahensis* Durham. Other species that appear in the Wishkahan but range into younger strata include the gastropods *Nassarius* cf. *N. andersoni* (Weaver), *Nucella canaliculata* (Duclos), and *Molopophorus bogachieli* (Reagan), and two bivalves—*Clinocardium meekianum* (Gabb) and *Securella securis* (Shumard).

The close identity with the much larger fauna from the type section of the Empire Formation near the mouth of Coos Bay, some 50 km to the north (Dall, 1909; Weaver, 1945; Armentrout, 1967), implies that these two units are contemporaneous, but the mollusks from the lower part of the type Empire Formation at Coos Bay seem to represent a generally deeper water depositional environment. Articulated specimens of *Patinopecten coosensis* (Shumard) are especially abundant in sandstone occurring below the Coos Conglomerate Member at Coos Bay, but this bivalve does not occur in the strata exposed near Cape Blanco. The modern depth distribution of this genus in the eastern North Pacific is greater than about 20 m. Thus the fauna of the Empire Formation at Coos Bay is of somewhat deeper aspect than the intertidal to shallow subtidal fauna of the Empire Formation (restricted) at Cape Blanco.

The previously mentioned bivalve assemblage from the stratigraphically higher, finer grained unit of the Empire Formation (restricted) at Cape Blanco appears to be correlative with the Graysian Stage of western Washington on the basis of a diatom florule of late Miocene age (North Pacific Diatom Zone 14) from USGS loc. M3755 near the top of this upper unit (J.A. Barron, written communication, March 1977). Barron notes that this diatom zone also occurs in siltstone in the upper part of the Montesano Formation of Fowler (1965) in western Washington which is within the type section of the Graysian Stage.

The sequence of depositional environments repre-

Figure 6. Unconformable contact between the Empire Formation (restricted) and the Port Orford Formation of Baldwin (1945). West of Goldwasher's Gully, massive, white-weathering siltstone and silty sandstone are overlain by buff sandstone and interbedded conglomerate. East of Goldwasher's Gully, a prominent unconformity separates the so-called Goldwasher's Gully Member of the Port Orford Formation from the overlying basal conglomerate of the Elk River Member of the same formation. View looking northwest.

sented by the nearly 100 m of Empire Formation (restricted) that crops out southeast of Cape Blanco near Goldwasher's Gully is similar to that of the sandstone of Floras Lake. The high-energy, shoreline environment represented by the fossiliferous basal conglomerate of the Empire Formation (restricted) is succeeded by sandstone and pebble conglomerate containing mollusk and echinoid assemblages comparable bathymetrically to those in the middle to upper part of the sandstone of Floras Lake. The stratigraphically higher silty sandstones and sandy diatomaceous siltstones characterized by a low diversity association of the bivalves *Portlandia*, *Nuculana*, *Compsomyax*, *Lucinoma*, and *Cnesterium* record a middle to outer sublittoral environment and the greatest depths in the entire Miocene sequence at Cape Blanco.

DISCUSSION

There is a striking difference in faunal composition between the two Miocene formations at Cape Blanco (Table 1). Only one species is common to both units, and, in almost every case, genera that are common to both units are represented by entirely different species. A faunal change of this magnitude reflects either a profound change in environmental facies or a significant hiatus in the geologic record. Differences in depositional environments do not seem to account for the observed faunal change; the similar depth and sedimentary facies of each unit, as well as the similar generic compositions of the two faunas, rule out this possibility. It is more likely that the differences are due to the hiatus represented by the unconformity that separates the two units. The time gap cannot be particularly large because the faunas are referable to successive Miocene ages, the Newportian and the Wishkahan. There is, however, an appreciable time span of about 10 m.y. from the base of the Newportian to the top of the Wishkahan. Possibly the Newportian fauna of the sandstone of Floras Lake represents deposition during the earliest part of that age (range: about 18 to 12 m.y. ago), and the Wishkahan fauna of the Empire Formation (restricted) represents deposition during the later part of that age (range: about 12 to 8 m.y. ago).

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Plate 1. *Fossils from the sandstone of Floras Lake* →
[Specimens natural size unless otherwise indicated]

Figure 1. *Mytilus middendorffi* Grewingk. USNM 264110. USGS loc. M4130.
2. *Liracassis* sp. USNM 245705. USGS loc. M4132.
3. *Natica* cf. *N. clarki* Etherington, ×2. USNM 245700. USGS loc. M4126.
4. *Crepidula rostralis* (Conrad), ×1½. USNM 245708. USGS loc. M2142.
5. *Solen conradi* Dall. USNM 245713. USGS loc. M4126.
6. *Nucella packi* (Clark), ×2. USNM 245694. USGS loc. M4129.
7. *Molopophorus matthewi* Etherington, ×1½. USNM 245702. USGS loc. M2142.
8. *Molopophorus matthewi* Etherington. USNM 245711. USGS loc. M4690.
9. *Molopophorus* cf. *M. anglonanus* (Anderson), ×1½. USNM 264112. USGS loc. M2142.
10. *Tellina emacerata* Conrad. USNM 245726. USGS loc. M4126.
11. *Molopophorus matthewi* Etherington. USNM 245710. USGS loc. M4132.
12, 13. *Olivella* cf. *O. ischnon* Keen, ×4. USNM 245726. USGS loc. M4126.
14. *Molopophorus* cf. *M. anglonanus* (Anderson), ×2. USNM 245706. USGS loc. M2142.
15. *Bruclarkia oregonensis* (Conrad). USNM 245703. USGS loc. M4690.
16. *Priscofusus* cf. *P. medialis* (Conrad), ×1½. USNM 245701. USGS loc. M4126.
17. *Cancellaria* n. sp.? aff. *C. alaskensis* Clark, ×2. USNM 245724. USGS loc. M4136.
18. *Bruclarkia oregonensis* (Conrad). University of Oregon F29713. UO loc. F2011.
19. *Kewia* cf. *K. blancoensis etheringtoni* (Weaver), ×1½. USNM 245725. USGS loc. M4126.
20. *Cryptonatica oregonensis* (Conrad), ×1½. USNM 245727. USGS loc. M4126.
21. *Ophiodermella* cf. *O. olympicensis* Addicott, ×2½. USNM 245714. USGS loc. M4690.
22, 23. *Nucella packi* (Clark), ×1½. USNM 245695. USGS loc. M3637.
24. *Yoldia* cf. *Y. carnerosensis* Clark. USNM 245712. USGS loc. M4126.
25. *Spisula albaria* (Conrad). USNM 245717. USGS loc. M2142.
26. *Yoldia* cf. *Y. carnerosensis* Clark, ×1½. USNM 264113. USGS loc. M2142.
27. *Nassarius arnoldi* (Anderson), ×4. USNM 245727. USGS loc. M4690.
28. *Mytilus middendorffi* Grewingk. USNM 245720. USGS loc. M4130.

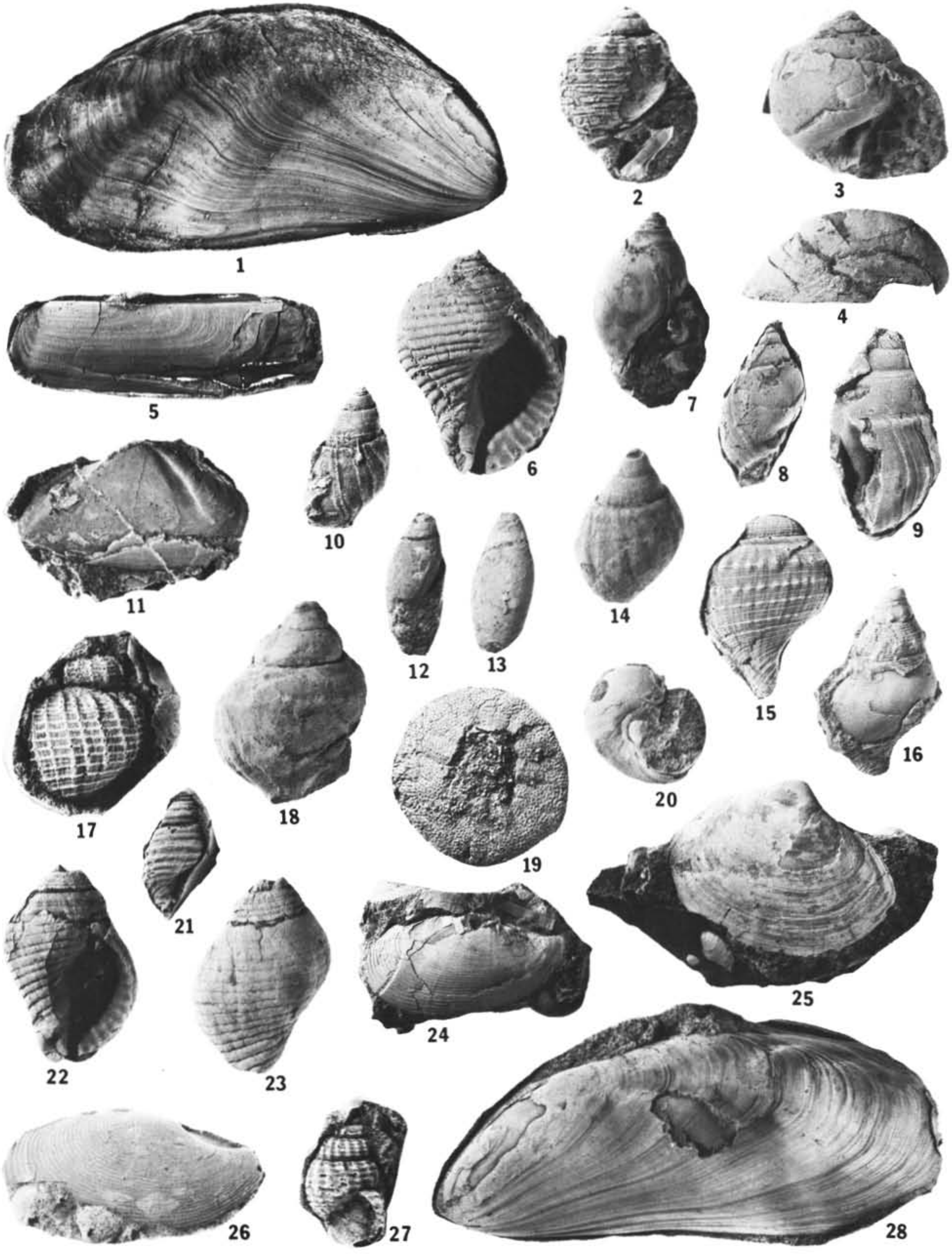

PLATE 1.

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(Continued on page 98)

Plate 2. *Fossils from the Empire Formation (restricted)* →
[Specimens natural size unless otherwise indicated]

Figure 1. *Crepidula* cf. *C. princeps* Conrad. USNM 264113. USGS loc. M3695.
2. *Siliqua* cf. *S. lucida* (Conrad), ×1½. USNM 264114. USGS loc. M4125.
3. *Macoma indentata* Carpenter. USNM 264115. USGS loc. M4125.
4. *Crepidula adunca* Sowerby, ×1½. USNM 264116. USGS loc. M3965.
5. *Nucella lima* (Gmelin), ×1½. USNM 264117. USGS loc. M4134.
6. *Glycymeris gabbi* Dall. USNM 264118. USGS loc. M2139.
7. *Nucella canaliculata* (Duclos), ×3. USNM 264119. USGS loc. M7369.
8. *Opalia wishkahensis* Durham, ×1½. USNM 264120. USGS loc. M4134.
9. *Nucella lima* (Gmelin), ×1½. USNM 264121. USGS loc. M2141.
10. *Acila blancoensis* Howe, ×1½. USNM 264122. USGS loc. M2141.
11. *Nassarius andersoni* (Weaver), ×3. USNM 264123. USGS loc. M7369.
12. *Felaniella parilis* (Conrad). USNM 264124. USGS loc. M7369.
13, 14. *Kewia blancoensis* (Kew), ×1½. USNM 264125. USGS loc. M2141.
15. *Molopophorus bogachieli* (Reagan). USNM 264126. USGS loc. M4125.
16. *Kewia blancoensis* (Kew), ×1½. USNM 264127. USGS loc. M4121.
17. *Securella securis* (Shumard). USNM 264128. USGS loc. M4125.
18. *Clinocardium meekianum* (Gabb). USNM 264129. USGS loc. M2141.
19. *Securella securis* (Shumard). USNM 264130. USGS loc. M4124.

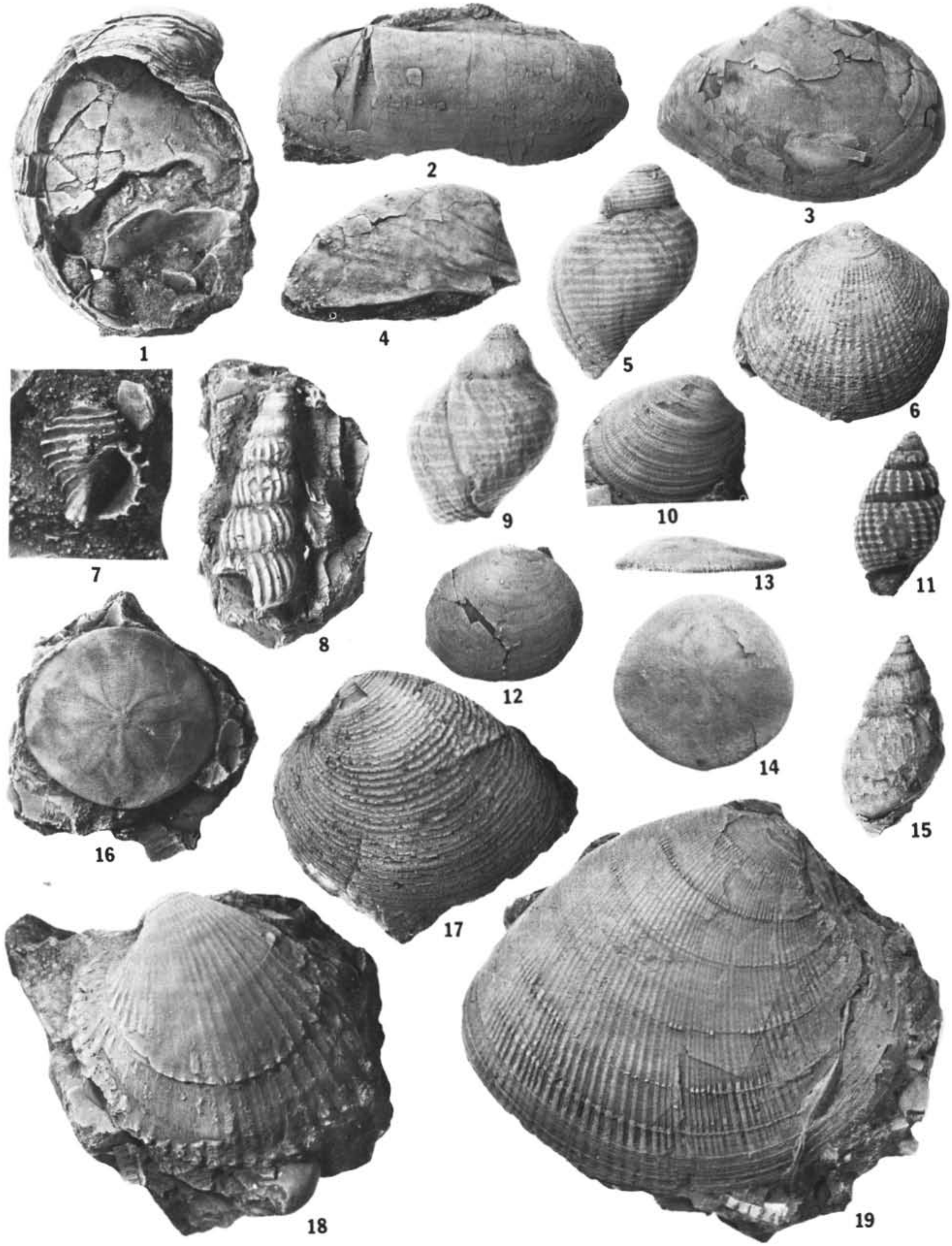

PLATE 2.

Lawson to supervise Mined Land Reclamation Program

On April 1, 1980, Paul F. Lawson became new Supervisor of the Mined Land Reclamation Program of the Oregon Department of Geology and Mineral Industries, replacing Standley L. Ausmus, now with the Office of Surface Mining, U.S. Department of the Interior. For two years prior to accepting his new assignment, Lawson was an Environmental Specialist for DOGAMI, responsible for field enforcement of Oregon's Mined Land Reclamation Act.

Paul F. Lawson

Before coming to the Department in April 1978, Lawson served for twenty years with the U.S. Army, with responsibilities in organization planning and programming, teaching, public relations, statistical research, facilities management, and development and administration of training programs. He has a bachelor's degree from the University of Illinois and a master's degree in earth science teaching from Portland State University.

Lawson's new position includes such duties as supervision of the Mined Land Reclamation Program; coordination of the Mined Land Reclamation Program with local, State, and Federal agencies; investigation of surface mining sites; and review and evaluation of permit applications. □

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The numerous eruptions of Mount St. Helens have resulted in the deposition of tephra (ash and other airborne volcanic material) over large areas of Washington and Oregon. The Oregon Museum of Science and Industry (OMSI) and the Earth Sciences Department of Portland State University have jointly begun "Operation Tephra," a project designed to study the volume of material erupted in a volcanic event, the characteristics of wind-carried material, patterns of distribution, and, possibly, even something about the geochemistry of the volcano. The project is beginning with a thorough sample-collection program over a wide area and could therefore utilize the help of many interested and dedicated volunteers willing to collect carefully, follow procedures, and stay with the program for a minimum of a month—and longer if possible.

The procedures are relatively simple, as are the equipment requirements: aluminum foil, a box, ziplock and paper bags, marking pens, and masking tape. OMSI has prepared a packet of instructions telling exactly how the sampling is to be done.

Oregon Geology readers interested in participating in this volunteer sampling program should contact Bruce Hansen, Operation Tephra, OMSI Research Center, 4015 SW Canyon Road, Portland, OR 97221, phone (503) 248-5944. □

(**Miocene fossils,** *from page 97)*

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