Preliminary observations on fossil soils in the Clarno Formation (Eocene to early Oligocene) near Clarno, Oregon

by Greg Retallack, Department of Geology, University of Oregon, Eugene, Oregon 97403

INTRODUCTION

One would expect fossil soils to be common in sedimentary rocks laid down on dry land. However, since geologists seldom have training in soil science, they often fail to recognize such soils. This is unfortunate because fossil soils can tell us much about the past. They are evidence for the nature of extinct vegetation, depth of ancient water tables and nature of the ground water, rates of subsidence and sedimentation, and ancient topography and climate.

In the summer of 1979, during a brief visit sponsored by the Oregon Museum of Science and Industry (OMSI) Paleontology Research Program, I discovered several fossil soils in the Clarno Formation near Camp Hancock in north-central Oregon (Figure 1). Fossil soils occur in the Clarno Nut Beds, which contain fossil plants and mammals of middle Eocene age; in the overlying red beds of Red Hill; and under a volcanic mudflow which overwhelmed an upright petrified tree (the "Hancock Tree") in Hancock Canyon. The red beds and mudflow are probably, in part, early Oligocene in age, like the rocks of the nearby fossil mammal quarry. The age and relationships of these localities are discussed by Hanson (1973) and Manchester (1979, 1981). All localities are protected from unauthorized collecting by OMSI and the John Day Fossil Beds National Monument.

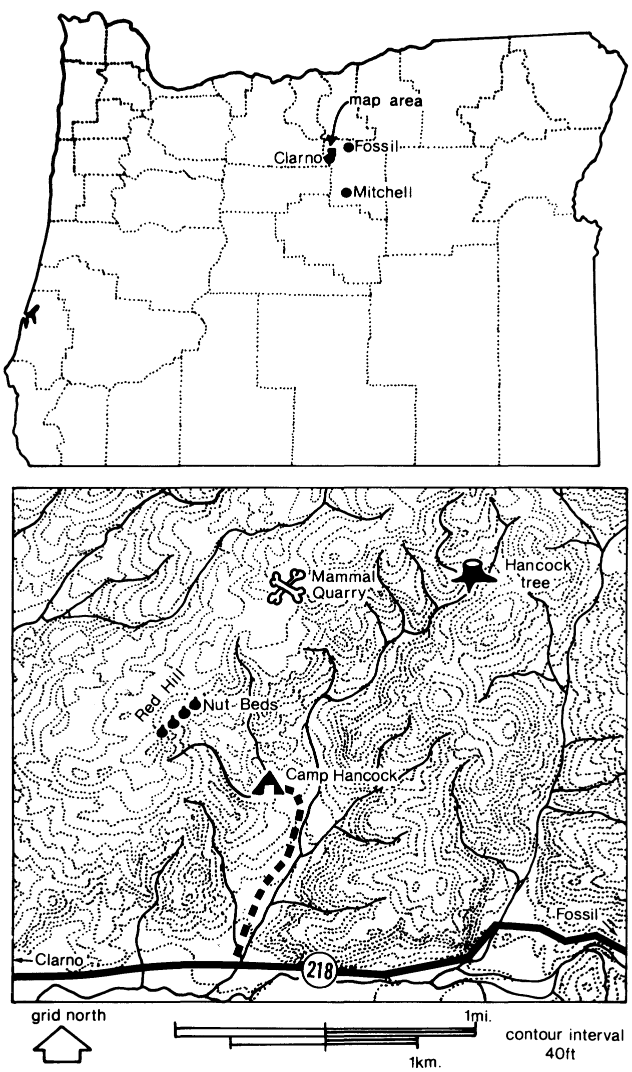


Figure 1. Locality map: Camp Hancock and Clarno fossil soil localities discussed in text.

Thick reddish fossil soils have also been reported by Oles and Enlows (1971) on erosional unconformities below and within the Clarno Formation near Mitchell (Figure 1). Such fossil soils that formed during very long periods of erosion are difficult to interpret, as they may have been initiated under different vegetation and climate than they supported just before burial, and they may also contain relict and residual features of older soils. Only the fossil soils of ancient sedimentary environments near Camp Hancock are considered further here.

AN INTRODUCTION TO MODERN AND FOSSIL SOILS

In terrestrial sedimentary environments such as river valleys, sediment may be moved around by running water, wind, or gravity slides. For most of the time, however, this sediment lies relatively undisturbed. Plants and animals colonize this material after floods. Very soon their activity modifies the sediment at the surface to such an extent that we call this material a soil. It may be penetrated by roots and churned by burrows and may contain decaying leaves and other organic matter. At an early stage of its formation, a new soil may still have some structures formed during the original flooding, such as bedding and ripple marks. Soils with a lot of sedimentary relicts and little change, apart from the addition of organic matter, are called alluvial soils or entisols. With additional time and growth of vegetation, rainfall leachates and other chemicals from plants and soil organisms may leach the upper part of the soil to form an eluvial or A horizon. Eventually, as more material is leached out, the A horizon becomes more enriched with resistant minerals, such as quartz. Not all the material is completely lost from the soil; it may accumulate to form an illuvial or B horizon.

The chemicals involved in these processes may differ in different kinds of soils. In podzolic soils, the A horizon tends to be quartz-rich, sandy, and light colored. It is leached of clay, humus, iron, and aluminum. These accumulate in the B horizon, which thus tends to be more massive, clayey, dark, and red.

Soils do not persist indefinitely. Eventually they are either covered by sediment or eroded away. In subsiding river valleys, of the sort in which many thick sequences of terrestrial sedimentary rocks accumulate, soils are periodically covered by flood sediment. If the flood is especially powerful and up to 1 m (3 ft) of alluvium is deposited over the soil, smashing down vegetation and driving off the animals, then a new soil will

Figure 2. Clarno Nut Beds, light-colored near-stream deposits, and overlying clayey fossil soils of Red Hill. OMSI Paleontology Research team (arrow, lower left) is excavating at base of large down-slumped block of Nut Beds. Colorful variegated badlands like Red Hill commonly contain numerous fossil soils.

begin to form at a higher level.

If this later soil never develops deeply enough to obscure the underlying soil, then geologists will have no trouble distinguishing the older fossil soil from the younger one. However, such simple sequences are seldom found. If only a few inches of sediment are deposited in a flooded forest, for example, trees will continue to grow and incorporate the new sediment into the existing soil. In this way, a sequence that is comprised mainly of A horizons may accumulate, a situation here called an accreting soil. Another complication is that the B horizon of a later soil may form in the A horizon of an earlier one. In this case, the younger B horizon may have a variety of older soil features (pedorelicts) inherited from the older A horizon. Such situations can be very difficult for geologists to interpret.

Another difficulty with studying older fossil soils is that they change during many years of burial and compaction. Such post-depositional changes that are not severe enough to be regarded as metamorphism are commonly called diagenesis. For example, soils may have considerable accumulations (up to 3.6 percent) of plant silica bodies (phytoliths) in the A horizon. During diagenesis, this silica can be dissolved and reprecipitated to form a hard flinty cement (Retallack, 1977). As another example, well-drained soils may have oxides of ferric iron in the form of gels or minerals such as limonite and goethite, which form a light-brown or yellow stain. During diagenesis, these iron oxides may change to the brick-red mineral hematite, giving the fossil soil a much redder color (Walker, 1974).

FOSSIL SOILS OF THE CLARNO FORMATION

There are at least three kinds of fossil soil in the Clarno Formation at Camp Hancock. As in the modern world, each of these probably formed under different vegetation and in different parts of the landscape. Although they are not necessarily all of exactly the same age, they give an idea of the mosaic of terrestrial environments during the Eocene and early Oligocene in the area which is now Camp Hancock.

Alluvial fossil soils of the Nut Beds

The Nut Beds consist of conglomerates and sandstones, both probably deposited by streams (Figure 2). The sandstone beds are usually less than 0.3 m (1 ft) thick and alternate with silty layers. Many of these sandstones are riddled with fossil horsetail plants (*Equisetum*) in life position (Figure 3). Some of the disturbed upper portions of the sandstones may be small rills or weathered hoof prints of Eocene ungulate mammals. These sediments are very similar to those found in modern streamside levees. The sandstones were probably weakly differentiated alluvial soils covered in thickets of *Equisetum*.

Figure 3. Equisetum *in position of growth in lower Nut Beds. Arrow points to branching axis. Stems are approximately a third of an inch in diameter. (Photo courtesy of S.R. Manchester)*

Horsetails are well known for their abundant phytoliths. Living mature plants average 10 percent silica by dry weight. This is why they make such excellent pot cleaners and once were called scouring rushes. Although silica-charged waters from nearby volcanic hot springs may have been important in the silicification of the Nut Beds, substantial contributions of silica from these accumulator plants are also likely.

Bottomland forested soils of Red Hill

The origin of red beds, variegated beds, and badlands has long been somewhat of a mystery. Undoubtedly they originated in several different ways, but many are turning out to be accumulations of fossil soils. My own excavations of the slumped and weathered exposures of Red Hill, just above the Nut Beds, revealed a number of fossil soils. Some of these were difficult to interpret and were evidently accreting soils. In these, each additional increment of flood sediment appeared to have been incorporated into pre-existing soil without destroying the vegetation, so that successive soil horizons were overlapping.

Some of the fossil soils in Red Hill, however, were well preserved (Figure 4). These appear to have been well-differentiated soils with gray A horizons and reddish-brown B horizons. Large drab tubules, the reduced clay around individual large roots, extend down from the A into the B horizon. These ancient soils were evidently vegetated by large trees, probably a kind of rain forest similar to that which provided much of the plant debris to the Nut Beds. Many of the plant remains in the Nut Beds have living relatives in subtropical broadleaf forests. The diversity of the plant remains and the numerous vines indicate that it was a rain forest or jungle (Manchester, 1981), at least along the streams in which the plants are preserved. Carbonaceous and gray layers, patches of purple-colored claystone, and the pattern of mottling of the well-differentiated, reddish clayey fossil soils are indications of moist, partly waterlogged conditions. The former water table was probably within 1 m (3 ft) of the surface. Thus, these fossil soils were valley bottom soils. This fact and plant remains preserved in the Nut Beds indicate that Eocene valley bottoms near Camp Hancock were vegetated by rain forest.

Each fossil soil in Red Hill represents a depositional hiatus of at least several hundred, perhaps several million, years. There are many superimposed paleosols in Red Hill. Thus, it is likely that the unconformity thought to separate older and younger parts of the Clarno Formation is split into a number of minor unconformities in Red Hill.

Upland forested soils of Hancock Canyon

One of the silicified stumps and logs in the volcanic mudflow in Hancock Canyon is still standing upright (Figure 5), rooted in a fossil soil that is not as well differentiated as the soils on Red Hill. Although better differentiated than the horsetail-bearing fossil soils of the Nut Beds, the Hancock Canyon soil is still best regarded as an alluvial soil. It has a silicified, leached, root-penetrated A horizon and also a well-preserved leaf litter. Only the flatter leaves of the lower leaf litter have been preserved in place. The curled loose leaves have been swept up into the overriding mudflow and form fossiliferous lenses as much as a foot above the base of the flow. Beyond a very indistinct clay-rich layer, the fossil soil does not have a well-differentiated B horizon. There is also much relict bedding in the fossil soil. These features are probably due to a relatively short time of formation, probably little longer than it took to grow the preserved crop of tree trunks. They could also have developed because the area was more elevated and seldom had a waterlogged layer near the surface, in which case chemicals and clay leached out of the A horizon would wash right out of the profile rather than accumulate there. The volcanic mudflow presumably slid down the flanks of a nearby volcano and is additional evidence that these soils formed in higher parts of the landscape. Interestingly, the fossil flora associated with these fossil soils is quite different from that at the Nut Beds. There are fewer species of wood and leaves, mainly forms similar to katsura (*Cercidiphyllum*) and sycamore (*Platanus*; Manchester, personal communication, 1980). Modern relatives of these plants are trees of cool temperate climates. Perhaps this less diverse, cold-adapted flora forested hills adjacent to the humid rain-forested bottomlands near Camp Hancock during the Eocene and early Oligocene.

Eocene fossil soils similar to those in Hancock Canyon are also found in northeastern Yellowstone National Park, where there are many horizons of silicified stumps in a great pile of volcanic mudflows, erupted rocks, and stream and lake deposits (Dorf, 1964; Fritz, 1980). On Specimen Ridge, some of these fossil soils have well-differentiated silicified A horizons as well as massive, clay-rich B horizons (Retallack, 1981). None have reddish B horizons of bottomland fossil soils, like those of Red Hill. The Yellowstone fossil soils were largely forested by conifers of cool, temperate climatic affinities, such as pine (*Pinus*) and redwood (*Sequoia*). As in this region today, it is likely that conifers grew at higher elevations than angiosperms.

Figure 4. Well-differentiated fossil soil in the middle of east slope of Red Hill, with light-gray A horizon over reddish B horizon. Hammer gives scale.

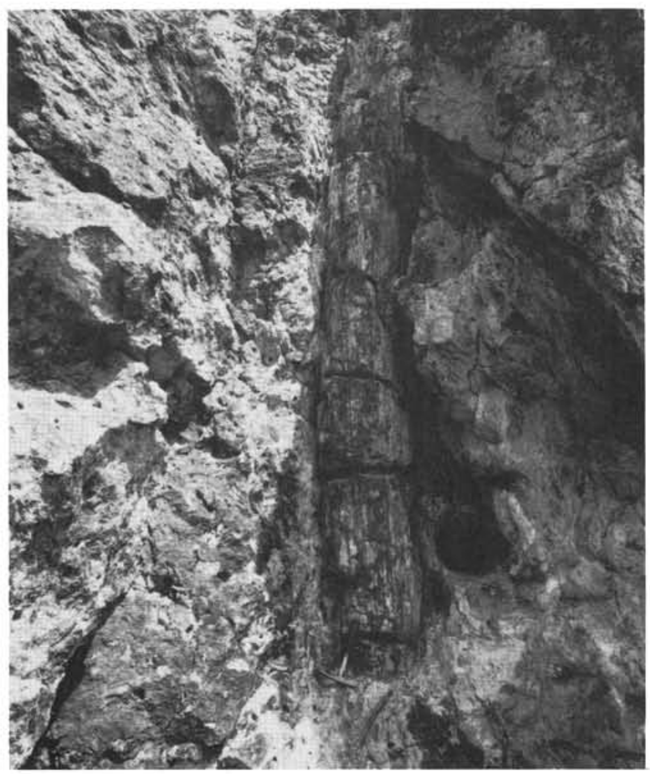


*Figure 5. "Hancock Tree," most similar to modern katsura (*Cercidiphyllum*; S.R. Manchester, personal communication, 1980), preserved in position of growth by a thick volcanic mudflow. Hammer gives scale.*

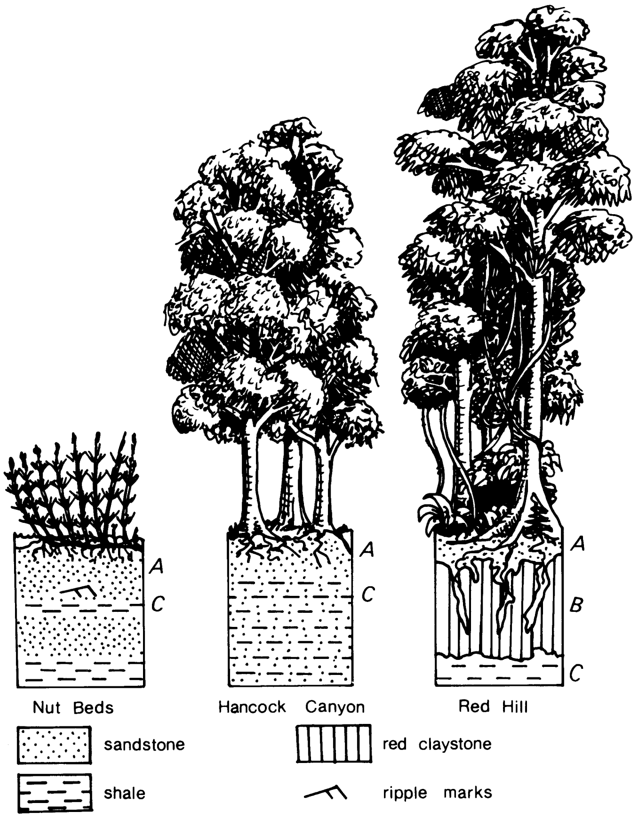


Figure 6. Soil horizons and reconstructed vegetation of some fossil soils of the Clarno Formation (schematic).

CONCLUSION

Fossil soils near Camp Hancock are important evidence of Eocene and early Oligocene vegetation and landscapes. They are reconstructed in Figure 6. Even in areas where the geology is well known, fossil studies can add much to our understanding of ancient terrestrial ecosystems. Although abundant in nonmarine rocks of all ages, pre-Quaternary fossil soils remain comparatively little studied. We need to know more about them.

REFERENCES

Dorf, E., 1964, The petrified forests of Yellowstone Park: Scientific American, v. 210, no. 4, p. 106-112.

Fritz, W.J., 1980, Reinterpretation of the depositional environment of the Yellowstone "fossil forests": Geology, v. 8, no. 7, p. 309-313.

Hanson, C.B., 1973, Geology and vertebrate faunas in the type area of the Clarno Formation, Oregon: Geological Society of America Abstracts with Programs, v. 5, no. 1, p. 50.

Manchester, S.R., 1979, *Triplochitioxylon* (Sterculiaceae): a new genus of wood from the Eocene of Oregon and its bearing on the xylem evolution of the extant genus *Triplochiton*: American Journal of Botony, v. 66, p. 699-708.

——— 1981, Fossil plants of the Eocene Clarno Nut Beds: Oregon Geology, v. 43, no. 6, p. 75-81.

Oles, K.F., and Enlows, H.E., 1971, Bedrock geology of the Mitchell quadrangle, Wheeler County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 72, 62 p.

Retallack, G.J., 1977, Triassic paleosols in the upper Narrabeen Group of New South Wales. Part I. Features of the paleosols: Journal of the Geological Society of Australia, v. 23, p. 383-399.

——— 1981, Comment on "Reinterpretation of the depositional environment of the Yellowstone 'fossil forests'" [Fritz, 1980]: Geology, v. 9, no. 2, p. 52-53.

Walker, T.R., 1974, Formation of red beds in moist tropical climates: a hypothesis: Geological Society of America Bulletin, v. 85, no. 4, p. 633-638. □

Annual award for exemplary mined land reclamation to be given

Realizing that it is as desirable to recognize outstanding performance as it is to punish offenders, the Governing Board of the Oregon Department of Geology and Mineral Industries at its April 9, 1981, meeting approved a proposal to recognize and honor an outstanding example of mined land reclamation each year. One Oregon site demonstrating either voluntary or mandatory reclamation of mined land will be selected each year. The first award will be announced in June 1982.

These awards are intended to reward outstanding achievement by operators and to further the goal of reclamation by awarding trophies and providing appropriate publicity.

Some of the criteria that will be considered include the following: The future value of the site; the imagination, innovativeness, and effectiveness involved in the completed planned reclamation; safety characteristics; aesthetics; and the appropriateness to local environment.

Nominations for consideration will be welcomed from any source. Most nominations are expected to come from personnel who frequently observe sites, such as the Mined Land Reclamation (MLR) staff of the Oregon Department of Geology and Mineral Industries; their counterparts in the Bureau of Land Management, the U.S. Forest Service, and other departments of the State; county personnel; environmental groups; and industry. Nominations will be screened by the MLR professionals, and the final selection will be by a committee which will include a member from an environmental organization, a member from industry, and the supervisor of the Mined Land Reclamation Program.

A permanent trophy listing the names of the winners will be displayed in the office of the State Geologist. An individual plaque will also be given permanently to each annual winner. An illustrated article of recognition will be published in *Oregon Geology*, and news of the award will be given to the appropriate trade journals. Whenever possible, a field day or tour of the site will be arranged with the winner's approval and will be open to the public.

The annual announcement and award are anticipated to be made on the nearest practical date to the 15th of June each year.

—Paul F. Lawson, Supervisor
Mined Land Reclamation Program

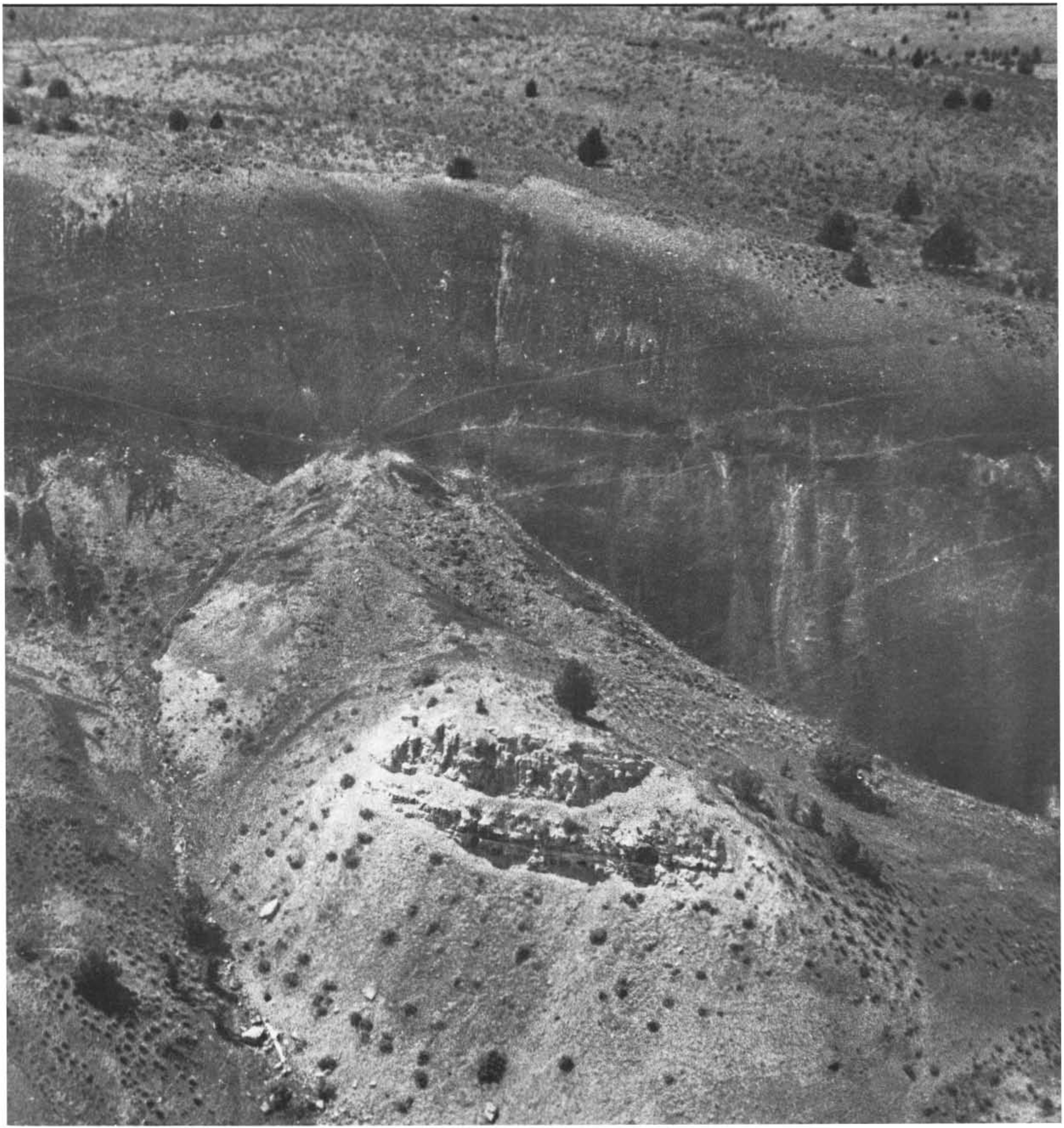
AVOID THE RUSH! RENEW NOW!

OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 43, NUMBER 11 NOVEMBER 1981



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 43, NUMBER 11 NOVEMBER 1981

Published monthly by the State of Oregon Department of Geology and Mineral Industries (Volumes 1 through 40 were entitled *The Ore Bin*).

Main Office: 1005 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.75 mailed.
Available back issues of *The Ore Bin*: $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology*, 1005 State Office Building, Portland, OR 97201.

Send news, notices, meeting announcements, articles for publication, and editorial correspondence to the editor, Portland office. The Department encourages author-initiated peer review for technical articles prior to submission. Any review should be noted in the acknowledgments.

Second class postage paid at Portland, Oregon.
Postmaster: Send address changes to *Oregon Geology*, 1005 State Office Building, Portland, OR 97201.

COVER PHOTO

Oblique aerial view of the Clarno Nut Beds (rocky, light-colored outcrops), middle Eocene stream deposits, overlain by late Eocene and early Oligocene fossil soils of Red Hill (dark slopes), near Clarno, north-central Oregon. Fossil plants and soils from here indicate that vegetation during the Eocene and Oligocene was very different from the scattered sage and juniper of today. See article beginning on next page.

Willamette Valley rock resources, volcanic hazards, and north-central/northeastern Oregon geology subjects of new reports

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the release of three new open-file reports. Open-File Report 0-81-7, *Rock Material Resources of Marion, Polk, Yamhill, and Linn Counties, Oregon*, by Jerry J. Gray and Allan H. Throop, DOGAMI, identifies 1,168 rock material sites with past or present production of sand and gravel, stone, clay, and cinder in the four-county area located in the mid-Willamette Valley. The report summarizes the results of a cooperative study by DOGAMI, the Pacific Northwest Regional Commission, and the Oregon Land Conservation and Development Commission. Included in the 47-page report are tables containing such data as location, status, and size of sites; nature of the resource; mining systems; uses of the product; and reclamation possibilities for the mined-out areas. On three accompanying maps (scale 1:125,000), the sites are located and keyed to the tables of the text. The report is intended to serve as a data base that can be used by planners, politicians, and private citizens in planning and making public decisions concerning land use and in locating resources for road and construction projects. The authors emphasize that the mineral potential of an area should be an integral part of land use considerations. Cost of 0-81-7 is $7.

Open-File Report 0-81-9, *Seismic and Volcanic Hazard Evaluation of the Mount St. Helens Area, Washington, Relative to the Trojan Nuclear Site, Oregon*, by John D. Beaulieu and Norman V. Peterson, DOGAMI, systematically evaluates the relevance of seismic activity and volcanic activity at Mount St. Helens for the nuclear power plant site at Rainier in Columbia County, Oregon. The volcanic hazards investigated include lateral blast, mudflow, ashfall, floods, and pyroclastic flows. The study was funded by the Oregon Department of Energy (ODOE), and this open-file report, which summarizes the results of the study, will be added to the body of technical material maintained by ODOE for guiding the safe operation of the Trojan plant. Purchase price of 0-81-9 is $5.

Open-File Report 0-81-10, *Post-Columbia River Basalt Group Stratigraphy and Map Compilation of the Columbia Plateau, Oregon*, by S.M. Farooqui, R.C. Bunker, R.E. Thoms, and D.C. Clayton of Shannon and Wilson, Inc., Portland, and J.L. Bela, DOGAMI, covers an area of more than 200,000 sq mi in north-central and northeastern Oregon. The report consists of a 79-page text and six blackline maps (scale 1:250,000) covering parts of The Dalles, Pendleton, Grangeville, Baker, Canyon City, and Bend 1° by 2° quadrangles. The maps were compiled from 308 7.5-minute quadrangles which had been mapped by a combination of field reconnaissance and office compilation techniques over a period of two years. Cost of 0-81-10 is $10.

All of these open-file reports are available for inspection or purchase at the Portland office of the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. Copies of these reports may also be purchased by mail. Orders under $20 require prepayment. □

CONTENTS

Preliminary observations on fossil soils in the Clarno Formation (Eocene to early Oligocene) near Clarno, Oregon 147
Annual award for exemplary mined land reclamation to be given 150
State legislation affecting mining industry summarized 151
On the marketing of earth science information: A review of USGS Circular 813 152
Oil and gas news 153
Test of Oregon's hottest geothermal well confirms substantial resource 153
Abstract 154