OREGON GEOLOGY

Oregon Department of Geology and Mineral Industries

Volume 62, Number 3, July 2000

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Late Eocene fossil plants of the John Day Formation

and

Geology and Mineralization of the Blue River mining district

DOGAMI PUBLICATIONS

Publications are available from: Nature of the Northwest, 800 NE Oregon St. #5, Portland, OR 97232, info@naturenw.org or www.naturenw.org, (503) 872-2750; or from the DOGAMI field offices in Baker City, 1831 First Street, (541) 523-3133, and Grants Pass, 5375 Monument Drive, (541) 476-2496. See also the gray pages at the center of this issue.

Released April 19, 2000:
Relative Earthquake Hazard Map of the Eugene-Springfield Metropolitan Area, by G.L. Black, Z. Wang, T.J. Wiley, Y. Wang, and D.K. Kiefer. Interpretive Map Series IMS–14, 1 map, scale 1:48,000, 16 p. text, $12.

This map incorporates the latest scientific information showing the risk that residents in the area face from earthquakes. It combines the effects of ground shaking amplification and earthquake-induced landsliding (the third common effect, liquefaction, was found to present no risk) to show the earthquake hazard relative to the local geologic conditions.

THROUGH THE EYES OF THE STATE GEOLOGIST

This column will be continued in our parallel publication, the magazine *Cascadia*. —*ed*

Pilot Project: Eugene-Springfield Earthquake Damage and Loss Estimate. Final Report, January 1999, by B. Vinson and T.H. Miller. Open-File Report O-00-02, 43 p., $10.00.

The preliminary damage and loss estimate for 200 selected buildings in the Eugene-Springfield area was prepared by members of the Department of Civil, Construction, and Environmental Engineering at Oregon State University. The project scope involves the estimation of the immediate facility damage and occupant casualties for 100 buildings in Eugene and 100 buildings in Springfield for an earthquake producing an effective peak ground acceleration of 0.3 *g*, and occurring either at 2 a.m. or at 2 p.m.

Released May 18, 2000:

Memorandum: Cape Cove Landslide, Findings from Field Visit, February 10 and March 10, 2000, by G.R. Priest. Open-File Report O–00–03, 14 p., $6.

The Cape Cove landslide occurred last winter about 13 mi south of Yachats. The 14-page report was produced by DOGAMI geologist George R. Priest for the Oregon Department of Transportation. The Cape Cove landslide affected the coastal Highway 101, when the slope above the highway failed repeatedly from December 1999 through February 2000.

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OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 62, NUMBER 3 JULY 2000

Published bimonthly in January, March, May, July, September, November by the Oregon Department of Geology and Mineral Industries. (Volumes 1 through 40 were entitled The Ore Bin.)

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Periodicals postage paid at Portland, Oregon. Subscription rates: 1 year, $10; 3 years, $22. Single issues, $3.

Address subscription orders, renewals, and changes of address to Oregon Geology, Suite 965, 800 NE Oregon Street # 28, Portland 97232.

POSTMASTER: Send address changes to Oregon Geology, Suite 965, 800 NE Oregon St. # 28, Portland, OR 97232-2162.

Cover photo

This splendid view of Broken Top, companion to the Three Sisters in the central Cascade Range, shows the east cirque which contains a small lake impounded by a moraine. Notches in the moraine are reminders of the sometimes overlooked flood hazard such moraine lakes can present. The same year this photo was taken, 1987, saw the publication of a report by the U.S. Geologic Survey describing such volcanic hazards especially in the Three Sisters region (USGS Open-File Report 87–41. See also *Ore Bin*, v.29 [1966], no. 10, p. 182–188). Photo by contributor John H. Whitmer of Issaquah, Wash.

Late Eocene fossil plants of the John Day Formation, Wheeler County, Oregon

by Steven R. Manchester, Florida Museum of Natural History, PO 117800, University of Florida, Gainesville, FL 32611-7800

ABSTRACT

Fossil leaves, fruits, and seeds are described from a late Eocene lacustrine deposit in the lower part of the John Day Formation on the southern slope of Iron Mountain east of Clarno, Wheeler County, Oregon. The Whitecap Knoll locality is closely bracketed with radiometric dates and hence provides a new datum for the evaluation of floristic and climatic change in the late Eocene. The fossil-bearing shale is above the member A ignimbrite, dated 39.17 ± 0.15 Ma, and below a tuff dated 38.4 ± 0.7 Ma and is considered to be about 38.8 Ma. The plant assemblage includes an aquatic component (*Nelumbo*, *Ceratophyllum*), and a woodland component with broad-leaved deciduous plants (Platanaceae, Fagaceae, Juglandaceae, Ulmaceae, Aceraceae), a few broad-leaved evergreen plants (*Mahonia*, *Cinnamomophyllum*), and a few unidentified ferns but apparently no conifers. The flora lacks the diversity of broad-leaved evergreen taxa present in the middle Eocene floras of the underlying Clarno Formation, but retains a few "Clarno taxa" not known in the overlying Bridge Creek flora (*Ailanthus* and *Eucommia*). The intermediate character of this flora in comparison with middle Eocene lacustrine floras of the Clarno Formation and lower Oligocene floras of the Bridge Creek flora provides some evidence for a gradational transition from the Eocene subtropical vegetation to the Oligocene temperate forests in this region.

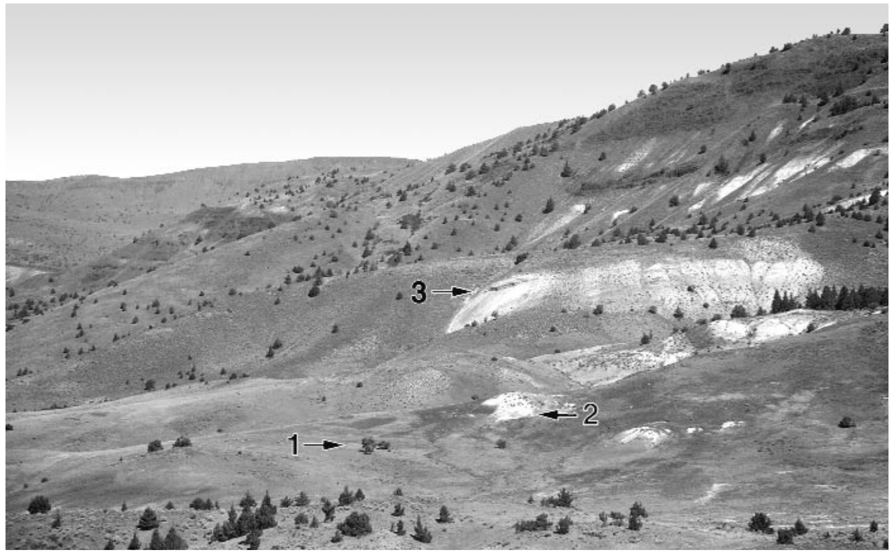

Figure 1. Oblique northwesterly aerial view of the south slope of Iron Mountain, showing (1) position of the lacustrine shale from which the Whitecap Knoll flora has been obtained, (2) the Whitecap Knoll locality from which the Ar/Ar date was obtained, and (3) the lacustrine shales of the Slanting Leaf Beds (Iron Mountain assemblage) of the Bridge Creek flora of the John Day Formation.

Figure 2. Students working at the Whitecap Knoll shale locality, with Whitecap Knoll in central part of the image and Slanting Leaf Beds to the far left.

INTRODUCTION

Paleontologically, the John Day Formation of Oregon is probably best known for its spectacular mammalian fossils of early Miocene age (e.g., Cope, 1880, 1886; Thorpe 1925; Merriam, 1930; Rensberger, 1973) and the still older plant fossil assemblages of the lower Oligocene Bridge Creek flora (Chaney, 1927; Meyer and Manchester, 1997). However, fossils from the lowermost part of the formation, which includes late Eocene strata, have received relatively little attention. Floras of late Eocene age are known from the John Day Formation in the Gray Butte area of Jefferson County, but the precise ages are difficult to determine because the associated volcanic rocks there are highly altered (Smith and others, 1998).

The Whitecap Knoll flora (Figures 1, 2; Bestland and Retallack, 1994) near the northern boundary of the Clarno Unit of John Day Fossil Beds National Monument in Wheeler County, Oregon, provides a rare opportunity to examine a late Eocene plant community that is well bracketed with radiometric dates. These dates indicate that the deposit and the species contained within it are approximately 38.8 million years old. This flora thus provides an important datum for purposes of correlation with less securely dated fossil localities in western North America. The Whitecap Knoll locality is situated near several other paleobotanically important sites (Figure 3), including sites of the underlying Clarno Formation, e.g., the Nut Beds (Manchester, 1981, 1994), the Hancock Canyon wood and leaf localities (Manchester, 1986), and Hancock Quarry (McKee, 1970; Manchester, 1994, p. 13); and of the overlying John Day Formation, such as the Slanting Leaf Beds[1] locality (Figure 1). The geology of this area has been reviewed by Bestland and others (1999) and Retallack and others (2000).

The climatic shift near the end of the Eocene from warm, equable conditions to cooler, more seasonal conditions has received much attention (e.g., Chaney, 1948; Retallack, 1992; Wolfe, 1992; Smith and others, 1998). The middle Eocene Clarno Nut Beds flora (about 44 million years old) has many tropical elements such as cycads, palms, and bananas (Manchester, 1994), indicating frost-free conditions; but the early Oligocene Slanting Leaf Beds (33.6 ± 0.19 Ma; Swisher in Bestland and Retallack, 1994, p. 137) has mostly temperate deciduous species (Meyer and Manchester, 1997). The Eocene-Oligocene boundary is currently placed at about 34 m.y. (Prothero, 1995); thus the Slanting Leaf Beds assemblage provides a glimpse of the vegetation that became established within about half a million years after the boundary. Was the climatic and floristic change abrupt, occurring over a brief interval of less than one million years, or was it rather gradual?

Detailed investigations of paleosol and alluvial sequences of the Clarno and John Day Formations in Wheeler and Grant Counties, Oregon, with ages approximated on the basis of inferred rates of sedimentation and stratigraphic position in relation to several radiometrically dated horizons, led Bestland and others (1997) to infer stepwise climatic changes across the Eocene-Oligocene transition. They recognized three major paleoclimatic shifts: from tropical to subtropical conditions at 42–43 Ma, subtropical to humid temperate conditions near the end of the Eocene at 34 Ma, and from humid temperate to subhumid temperate conditions at 30 Ma. Bestland and others (1997) note that these shifts seem to be in accord with climatic changes inferred from marine deposits and from paleobotanical studies in the Pacific Northwest. However, our understanding of vegetational and floristic change through the late Eocene remains sketchy and in danger of overgeneralization.

Wolfe (1992, p. 428) called attention to physiognomic differences between vegetation of the John Day Gulch flora of the Clarno Formation (assumed to be about 40 m.y. old but not radiometrically dated) and the Bridge Creek flora of the John Day Formation (radiometrically dated at 33.6–32.6 Ma; McIntosh and others, 1997). Whereas the former fossil assemblage is interpreted as Microphyllous Broad-Leaved Evergreen forest and contains thermophilic plants such as cycads and bananas (genus *Ensete*), the latter represents broad-leaved deciduous forest. The diverse leaf and fruit flora of John Day Gulch has not yet been described, and its age remains speculative. However, if the age estimate of the John Day Gulch assemblage is correct, there remains a gap of about seven million years between these floras; and, as Wolfe acknowledged, it is not certain whether this vegetational change, and the inferred climatic change, occurred gradually over the interval or more abruptly. Nevertheless, Wolfe concluded that there was indeed an abrupt increase of mean annual range of temperature near 33 Ma, based in part on comparison with floras in southwestern Montana. A succession of five floras through 900 m of section of the John Day Formation near Gray Butte, Jefferson County, indicates that the principal interval of climatic cooling may have been ca. 38–39 m.y. earlier, but precise radiometric control is lacking (Smith and others, 1998).

Epoch	Horizon	Unit	Radiometric age
Oligocene	John Day Formation	Slanting Leaf Beds	33.6±0.19 Ma
Eocene	John Day Formation	Whitecap Knoll tuff	38.4±0.7 Ma
Eocene	John Day Formation	Whitecap Knoll shale	
Eocene	John Day Formation	John Day member A ignimbrite	39.17±0.15 Ma
Eocene	Clarno Formation	Hancock Quarry	
Eocene	Clarno Formation	Nut Beds	43.76±0.29 Ma

Figure 3. Chart showing the relative stratigraphic positions and radiometric ages of floras and lithologic units in the vicinity of the Clarno Unit, John Day Fossil Beds National Monument.

[1] This informal name, also used by Bestland and others (1999), applies to the locality formerly referred to as Dugout Gulch by Chaney (1927) and as Iron Mountain assemblage by Meyer and Manchester (1997).

The Whitecap Knoll flora, bracketed by radiometric dates indicating an age of about 38.8 ± 0.7 million years, provides a new datum that helps to assess the transition between warm-climate vegetation of the Clarno Formation, and cooler vegetation of the overlying Bridge Creek flora. The purpose of this investigation is to evaluate the diversity, taxonomic affinities, and climatic implications of the Whitecap Knoll flora in comparison with middle Eocene and early Oligocene assemblages of the same region.

GEOLOGIC SETTING

The Whitecap Knoll assemblage takes its name from a white-topped bluff that is somewhat more resistant to erosion than surrounding strata due to an indurated white tuff (Figures 1, 2). The tuff itself has been dated at 38.4 ± 0.7 Ma based on $^{40}Ar/^{39}Ar$ analyses by C.C. Swisher III (Bestland and Retallack, 1994), providing a minimum age for the underlying fossil assemblage. The fissile, tan, lacustrine shales occur about 4 m below the white tuff, being separated by brownish to tan paleosols (referred to as an Alfisol-like paleosol; Getahun and Retallack, 1991). The shales are among sediments overlying a prominent basaltic andesite, locally mapped as member B, and are situated about 100 m above the basal ignimbrite of the John Day Formation, dated at 39.22 ± 0.03 Ma (Bestland and Retallack, 1994).

The dated white tuff of Whitecap Knoll can be traced at least 3 km east of the knoll along the southern slope of Iron Mountain. Bestland and Retallack (1994) and Bestland and others (1999) referred to this as member F tuff, because it correlates with a white tuff exposed in a cut of Highway 218 about 5 mi to the west-southwest; Robinson and Brem (1981) believed this white tuff to correspond with the member F tuff in its type area to the west near Ashwood. However, the age of the Whitecap Knoll tuff (38.4 ± 0.7 Ma), is significantly older than member F tuff in its type area (32.3 ± 0.12; Smith and others, 1998). The proper correlation of this tuff with respect to the members designated in the Ashwood area remains speculative, although it is certainly well below the distinctive member G tuff, which lies stratigraphically above the Slanting Leaf Beds (Bestland and Retallack, 1994).

METHODOLOGY

The fossil-bearing lacustrine shale of Whitecap Knoll ranges from 1 to 3 m in thickness, and is intermittently exposed over a distance of about 3 km. This treatment is based on specimens excavated from the westernmost exposure of the shale, immediately below Whitecap Knoll. It is located at 44°56.2'N., 120°25.07'W., about 3 km north-northeast of Hancock Field Station on private land adjoining the Clarno Unit of John Day Fossil Beds National Monument. The site is reached in about 30 minutes by a foot path from the field station. Scattered leaf, fruit, and seed remains and occasional fish scales were recovered by splitting the shale with hammers and chisels. We were disappointed to find that freshly removed damp shale quickly disintegrated into small fragments upon exposure as it began to dry, at the same time destroying the fossils. However, this problem was alleviated by wrapping the freshly removed fossil specimens immediately in several layers of toilet tissue, which slowed the drying process sufficiently to prevent cracking. Although the fossils are extremely rare, continued excavation over a few weeks time resulted in a collection sufficient to allow this preliminary evaluation of the flora. Fractured specimens were reassembled with Elmer's glue.

A few specimens from this locality were viewed in the collection of the John Day Fossil Beds National Monument (those cited by Bestland and Retallack, 1994). Additional samples were collected during the summers of 1995–1997 and have been deposited in the Paleobotanical Collection of the Florida Museum of Natural History. All specimens cited in the present paper that have catalog numbers prefixed by UF are housed at the Paleobotanical Collection of the Florida Museum of Natural History, University of Florida, Gainesville, Florida. Samples of the shale were also processed for palynology, but no pollen was found to be preserved.

FOSSIL PLANTS

The Whitecap Knoll flora includes three kinds of ferns, three kinds of monocots, and at least 16 species of dicots, including both extinct and extant genera. Among the genera still living today, some are still native in western North America (*Alnus*, *Quercus*, *Mahonia*, *Acer*), while others are native today in eastern North America (*Decodon*), eastern Asia (*Dipteronia*, *Craigia*, *Eucommia*), or both (*Hydrangea*, *Nelumbo*).

The three kinds of ferns (Figure 4A–C) are known only from fragments of the foliage, without fertile parts, and are thus difficult to identify relative to modern fern genera. One of the ferns, with featherlike venation (Figure 4B), appears to match a species present in the White Cliffs locality of the Clarno Formation.

Conifers are notable by their absence in this flora. Pine occurs stratigraphically below, in the Clarno Formation, and above in the Bridge Creek flora, but the distinctive needles and winged seeds are, so far, lacking from the Whitecap Knoll assemblage. The lack of *Sequoia* (common in lacustrine shales of the Clarno Formation) and the absence of *Metasequoia*, which is so common in the overlying Slanting Leaf Beds (and all other Bridge Creek flora localities), is particularly noteworthy. Getahun and Retallack (1991) and Bestland and Retallack (1994) reported *Metasequoia* from Whitecap Knoll, but I reexamined the cited specimen (JODA 3857) and could not agree with the previous identification. The specimen was

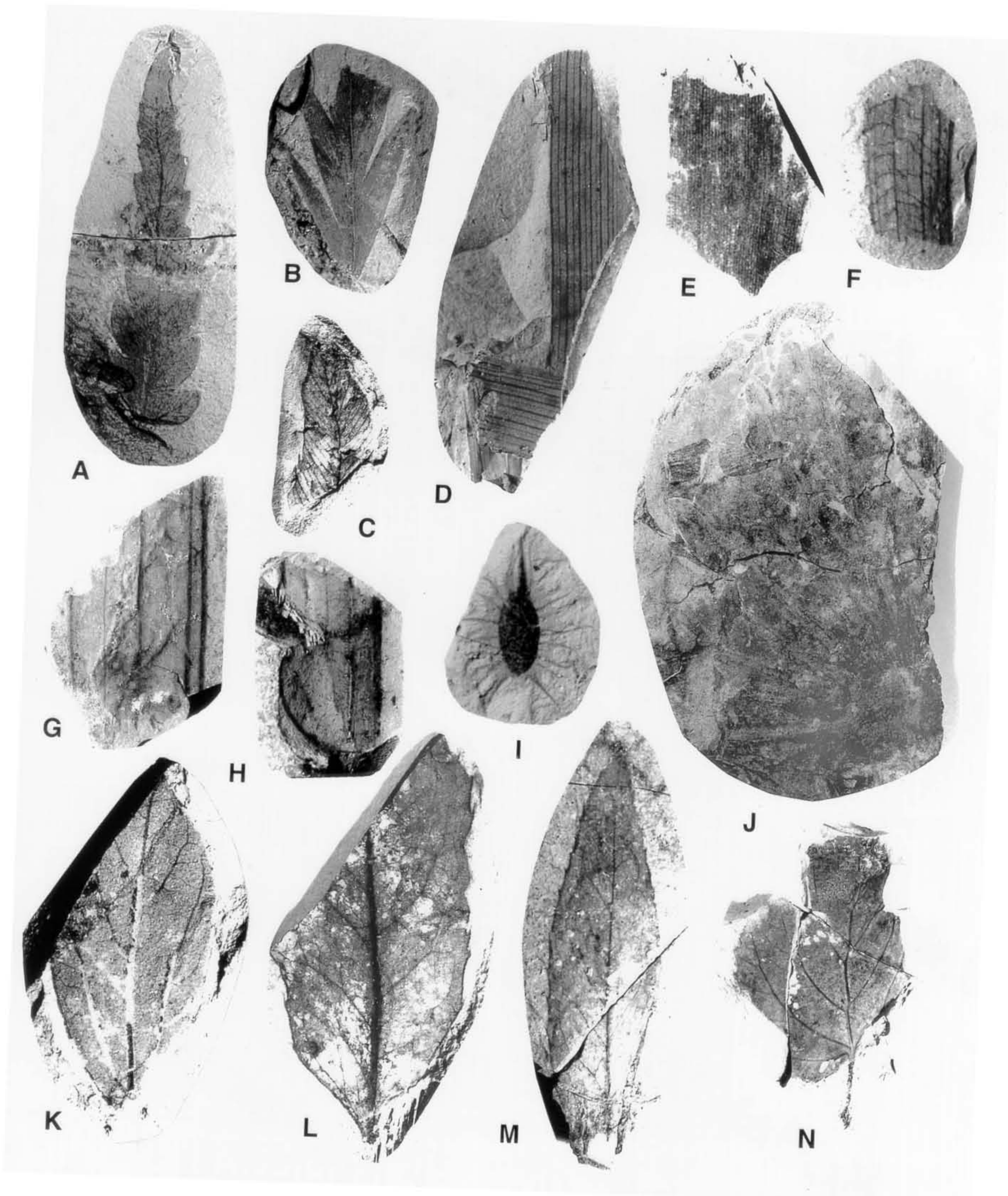

Figure 4. A. Fern 1, UF26285, x1.5. B. Fern 2, UF26289, x1.5. C. Fern 3, UF26287, x2. D. Monocot 1, UF26293, x2.5. E. Monocot 2, UF26294, x2.5. F. Monocot 3, UF26298, x2.5. G. Monocot 3, UF26304, x1.5. H. Monocot 3, UF26303, x1.5. I. Pondweed, *Ceratophyllum*, spiny fruit, UF26262, x2.5. J. Lotus leaf, *Nelumbo*, UF26344., x1. K. Lauraceae: *Cinnamomophyllum*, UF26281, x2.5. L. *Mahonia*, UF26307, x2. M. *Mahonia*, UF26310, x1.5. N. Sycamore, *Platanus*, UF26331, x1.

presumed to be a seed cone but does not show any cone scales. In our excavations, we looked especially for conifer foliage but did not observe even a single needle that could represent *Metasequoia*. *Metasequoia* was present already in the middle Eocene of Washington and British Columbia (Basinger, 1981; Wehr and Schorn, 1992). Its arrival in central Oregon evidently was sometime after 38 Ma but prior to 33 Ma.

Monocots are locally common in the assemblage, represented mostly by fragmentary remains. There are three kinds, distinguishable by their venation patterns. The first (Figure 4D) has three main orders of parallel veins organized in such a way that veins of intermediate thickness alternate with the thickest veins, with much finer parallel veins lying between them. Short, thin, wavy cross veins connect between the thickest veins and the adjacent medium-thick veins. The second kind (Figure 4E) has parallel veins that are all about equal in strength and closely spaced cross veins. The third kind (Figure 4F–H) has widely spaced thick veins interspersed with one to three veins of intermediate thickness, and with five to ten very fine veins occurring between the adjacent thick and medium-thick veins. In this species, the cross veins are more widely spaced than in the second kind. They are wavy and traverse between adjacent medium or thick veins, uninterrupted by the finer veins. Although the precise affinities of these plants are uncertain, their venation does not correspond to *Sabalites*, the palm leaves found in older floras of the region (Hancock Canyon and Nut Beds).

Ceratophyllaceae. The pondweed, *Ceratophyllum*, a rootless plant that grows submerged below the water surface, is represented in the fossil flora by its distinctive elliptical spiny fruit (Figure 4I). Although not previously known from the Tertiary of Oregon, the fruits of this genus are recorded from the middle Eocene of Washington (Wehr, 1995) as well as the Paleocene of Montana, Eocene of Wyoming, and Miocene of Nevada (Herendeen and others, 1990).

Nelumbonaceae. *Nelumbo*, the lotus, is confirmed by fragments of the large peltate floating leaves, with primary veins radiating in all directions from the center of the lamina (Figure 4J). A fine honeycomb pattern of thin veins visible under the dissecting microscope verifies that this is *Nelumbo* rather than one of the other genera of waterlilies. This represents the first report of lotus fossils from Oregon. Although widespread in the fossil record (e.g., Hickey, 1977), *Nelumbo* is more restricted in its modern distribution, with one species in eastern North America, extending south to Colombia, and a second species extending from warm parts of Asia to Australia.

Lauraceae. The Avocado family is represented by some entire-margined leaves corresponding to *Cinnamomophyllum* (a fossil genus for leaves similar to those of Cinnamon) in having a strong pair of basal secondary veins that depart from the midvein well above the base of the lamina and ascend more than $^2/_3$ the length of the lamina before looping at the margin (Figure 4K). There is also a vein that runs directly along the margin. Such leaves occur in more than one living genus of the Lauraceae, so the precise identity with modern genera remains uncertain. Another leaf that might represent the Lauraceae is slender, with entire margins and more standard pinnate secondary venation (Figure 7A) and is provisionally placed in *Litseaphyllum*.

Berberidaceae (*Mahonia*). The Oregon grape genus is represented by a few leaflets in the assemblage (Figures 4L,M). Each leaflet has a serrate margin with a thick marginal vein and spiny teeth. The secondary veins are pinnate and camptodromous, giving rise near the margin to tertiary veins that either loop or enter the teeth. The same genus is present in the Slanting Leaf Beds and other assemblages of the Bridge Creek flora, but that species, *M. simplex*, is distinguished by fewer secondary veins and fewer but more prominent teeth.

Platanaceae. The sycamore family is represented by many fragmentary leaf specimens with regularly spaced blunt teeth (e.g., Figures 4N, 5E,H,I) and by a few isolated fruitlets (Figure 5C). As is the case with most extant species of *Platanus*, the base of the petiole is much enlarged (Figure 5D). There is no trace of *Macginitiea*, the common extinct sycamore (plane tree) of the Clarno Formation (also known from the Sumner Spring flora of the John Day Formation near Gray Butte; Manchester, 1986; McFadden, 1986).

Ulmaceae. Elm was also a component of the flora, as indicated by a few fragmentary specimens of *Ulmus* leaves (e.g., Figure 6F) showing the characteristic thick petiole, basally asymmetrical lamina, and serrate margin. In addition, two of the distinctive winged fruits have been recovered (e.g., Figure 6K). *Ulmus* is present both in the Clarno and Bridge Creek floras, but is more diverse in the later.

Fagaceae (*Quercus*, 2 species). The oaks are represented by two kinds of leaves in the assemblage. Both have narrow elliptical laminae with many (15–20) pairs of secondary veins. One kind (Figure 5A) has mostly entire-margined leaves but with a few inconspicuous teeth where secondary veins enter the margin, particularly in the upper half of the leaf. The other type (Figures 5B,G) has regularly spaced prominent, often spiny teeth corresponding to each of the secondary veins. This second kind is similar in general form to *Castanea* as well as *Quercus*, but the former is ruled out by the presence of a marginal vein in the fossil laminae—a feature of oaks but not chestnuts.

Betulaceae. The genus *Alnus* (alder) is represented by a few fragmentary leaves (Figures 5F, 6A). They are similar in form and venation to *Alnus heterodonta* of the Bridge Creek and West Branch Creek floras but tend to have more subtle teeth. As yet, the distinctive fruits and fruiting cones have not been recovered, although they are common in the Clarno and Bridge Creek floras.

Juglandaceae. The walnut family is represented by at least one kind of leaflet (Figures 6B,C) and two genera of wind-dispersed winged nuts in the Whitecap Knoll assemblage. *Palaeocarya* is the name given to fossil winged nuts that resemble the fruits of two modern genera in the Juglandaceae: *Engelhardia* (of modern Asian distribution), and *Oreomunnea* (of modern tropical American distribution). The fruits of *Palaeocarya* from Whitecap Knoll (Figures 6L,M) are similar—in form

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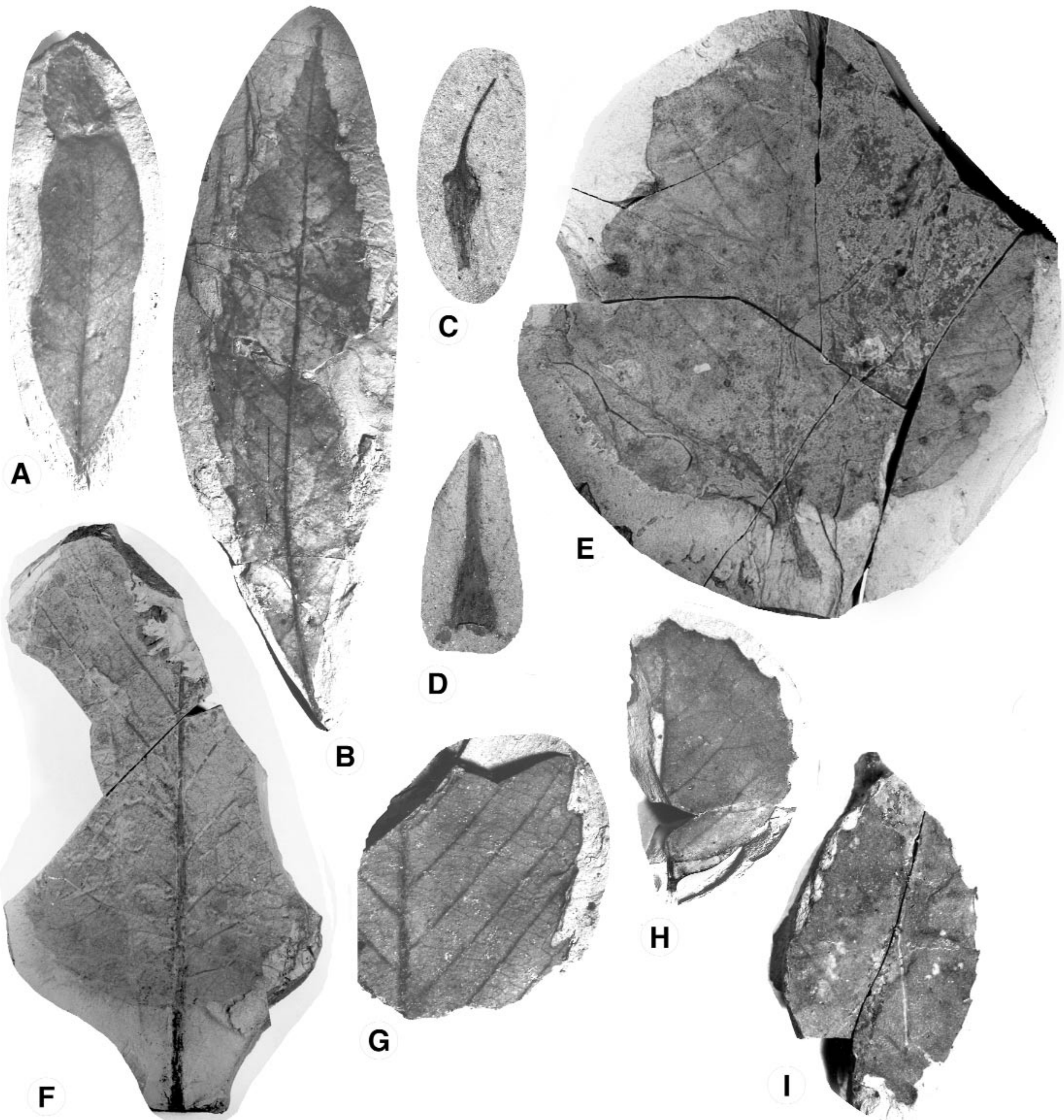

Figure 5. A. Oak leaf, *Quercus*, with a few small teeth on the margin, UF26354, x1.5. B. *Quercus* with more prominent teeth, UF26072, x1. C. Sycamore fruitlet, *Platanus*, UF26386, x3. D. Characteristic expanded petiole base of *Platanus*, UF30544 x1. E. *Platanus* leaf, UF30896, x1. F. Alder, *Alnus*, UF26339, X1. G. *Quercus* with detail of venation, UF26371, x2. H. *Platanus*, UF26077, x1. I. *Platanus*, UF26329, x1.5.

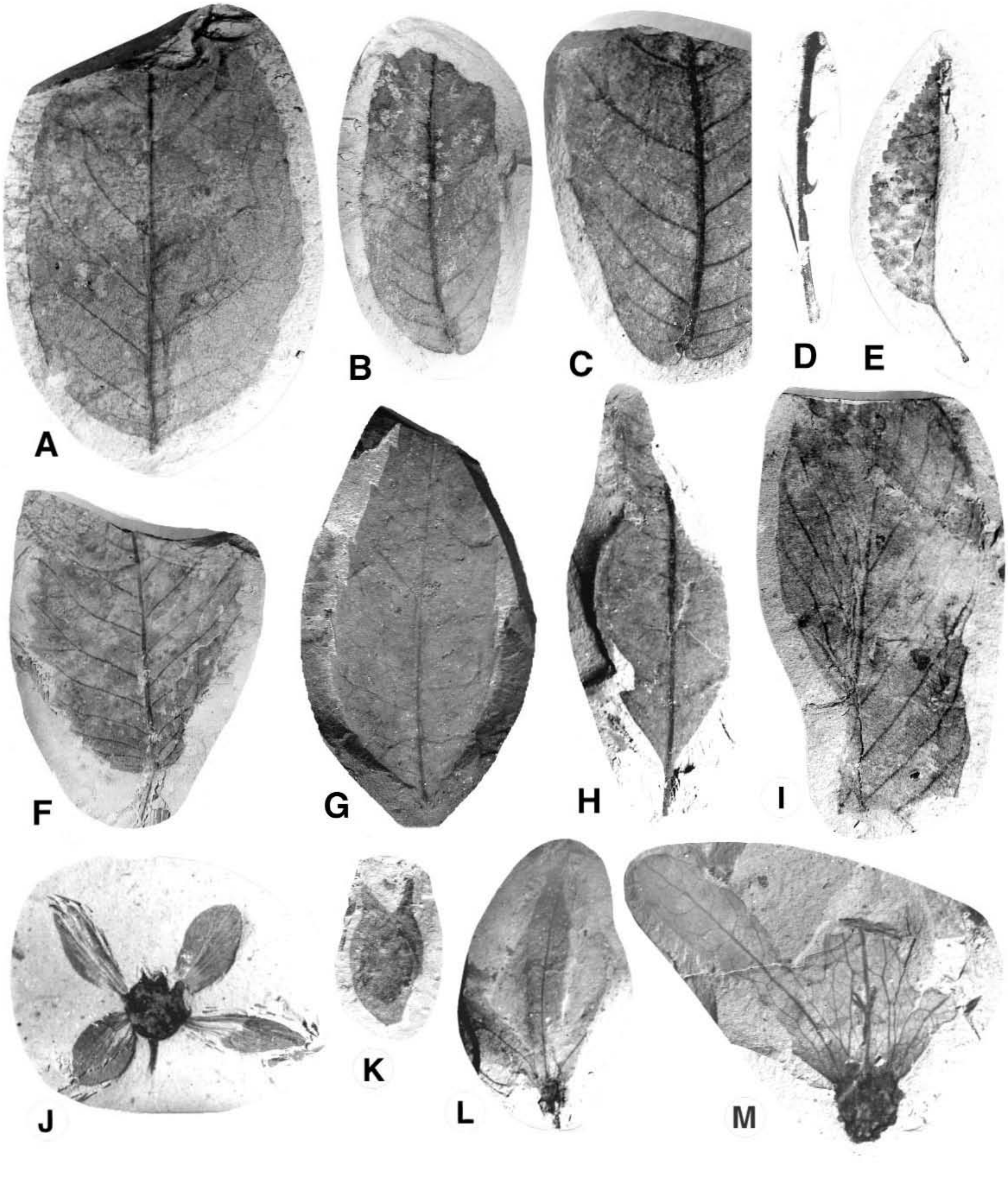

Figure 6. A. *Alnus*, UF26347, x2. B. Juglandaceae, UF26073, x1 C. Counterpart of the leaflet in B, UF26073', x2. D. Rose family prickly twig, UF26277, x1. E. Rose leaflet, *Rosa* sp., UF26273, x2. F. Elm leaf, *Ulmus* sp., UF26264., x1. G. Unidentified leaflet, UF30895, x1.25. H. *Decodon*, UF26284, x2. I. Rhamnaceae, showing very closely spaced tertiary veins, UF26369, x3. J. 4-winged fruit of *Cruciptera*, UF26231, x2.5. K. Winged fruit of Elm, *Ulmus*, UF 26313, x4. L. *Palaeocarya*, UF26074, x1.1. M. *Palaeocarya*, UF26248, x2.

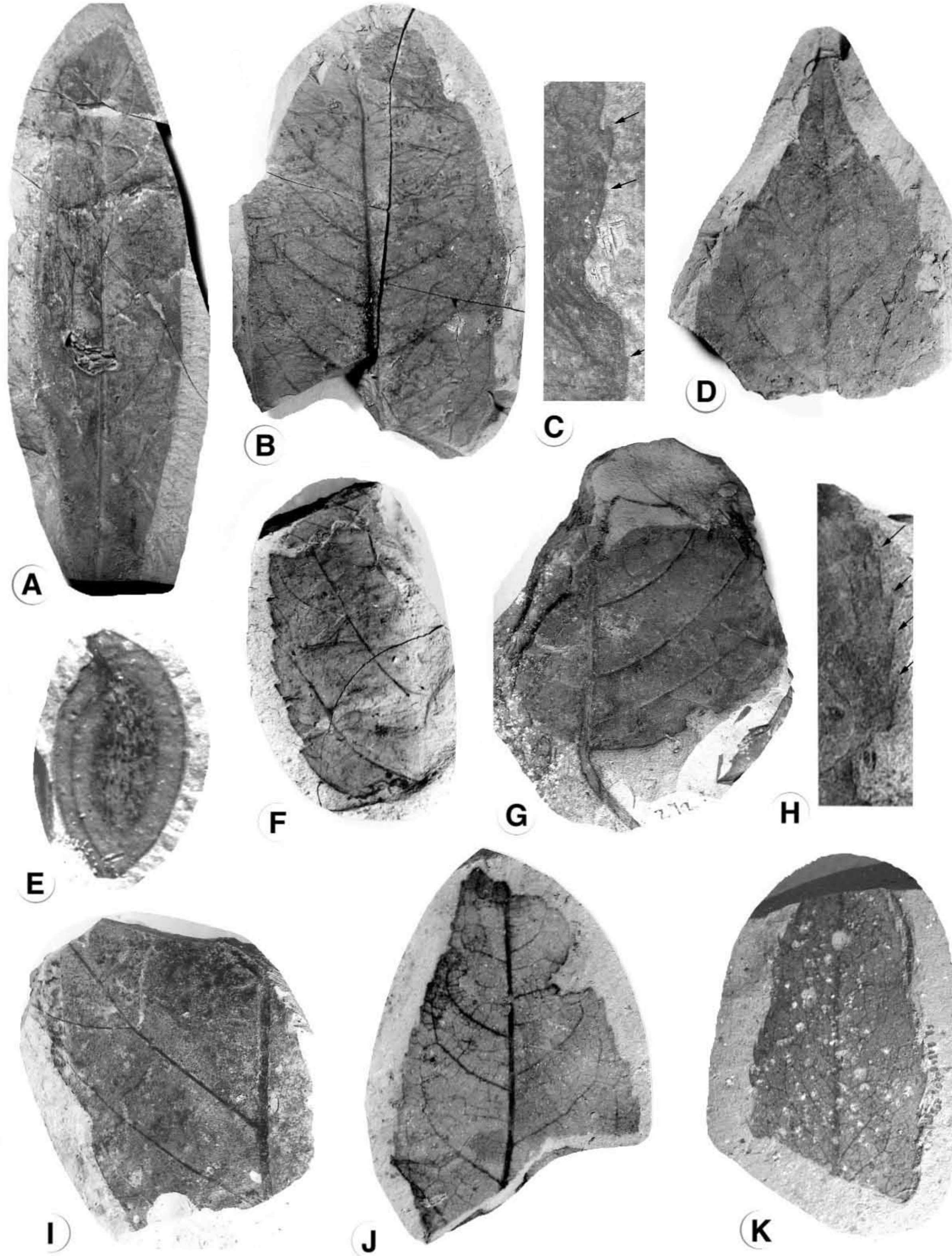

Figure 7. A. *Litseaphyllum*, UF 30540, x1. B. Unidentified leaf with prominent intersecondary veins and fine marginal serration, UF26346, x1. C. Detail of margin from B, showing teeth (arrows), x3. D. Apical portion of an unidentified serrate leaf, possibly *Acer*, UF 26352, x1.5. E. Elliptical winged fruit of *Eucommia montana*, UF , UF26321 x4. F. Unidentified serrate leaf, UF26345, x2. G. Basal portion of a leaf with prominent petiole, UF 26327, x1. H. Detail of margin from G, showing teeth (arrows), x. 2.5. I. Unidentified leaf with crenulate margin, UF26340, x1.25. J. Unidentified serrate leaves, UF26342, x 2.5. K. Small serrate leaf, UF26306, x 3.

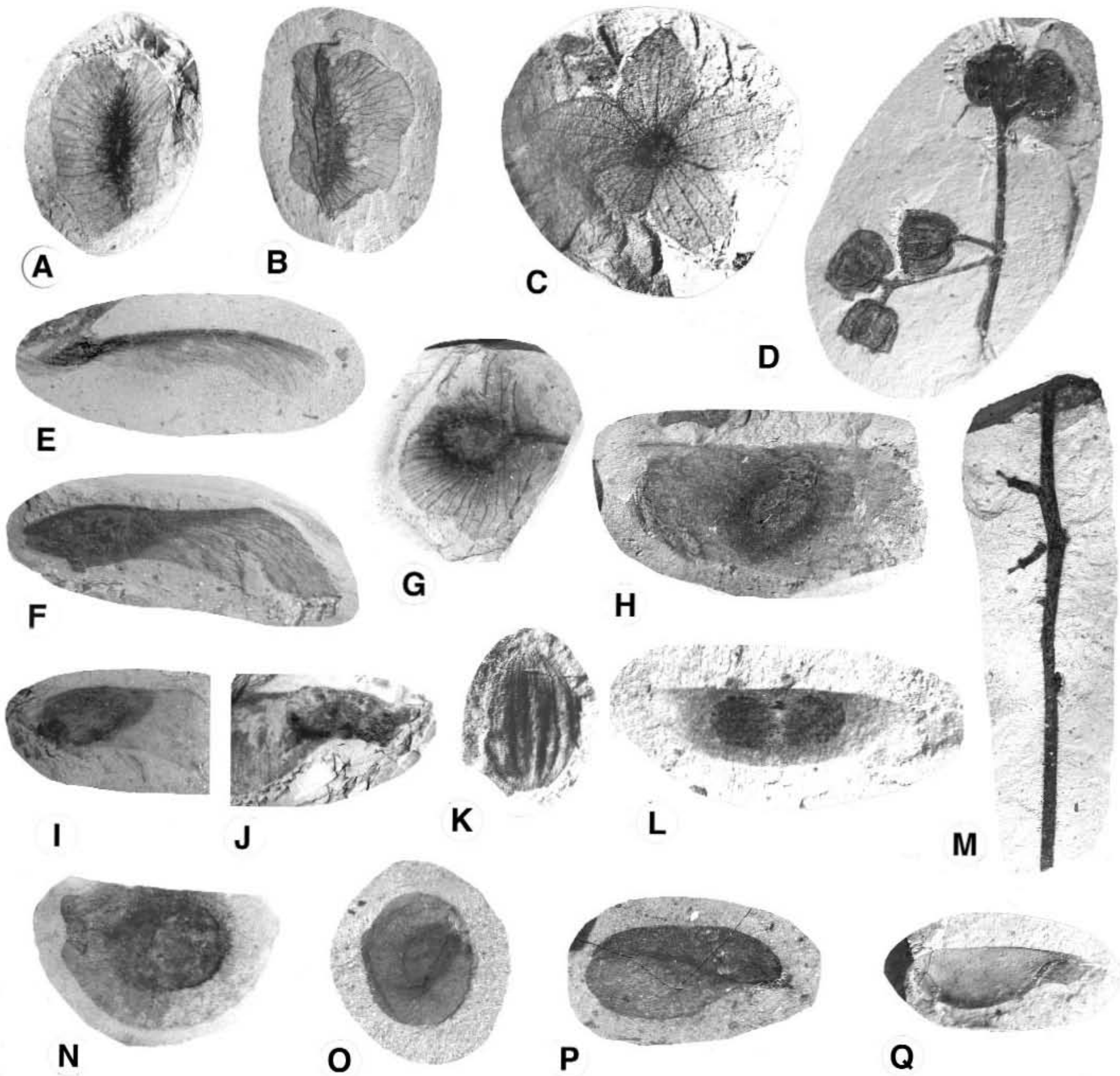

Figure 8. A. Winged fruit valve of *Craigia*, UF26261, x2. B. *Craigia*, UF26259, x2. C. *Florissantia ashwilli*, UF26271, x1.5. D. *Hydrangea infructescence*, UF26376, x2.5. E. *Acer* 1, UF26242, x2.5. F. *Acer* 2, 30533, X2.5. G. *Dipteronia* winged fruit, UF26428, x2. H. *Ailanthus*, UF26255, x2. I. *Acer*, UF26241, x2. J. *Acer*, UF26240, x2. K. *Nyssa*, UF26383, x1.5. L. *Catalpa*, UF26394, x6. M. Unidentified fruiting axis with fruits previously shed, 26392, x 1.5. N. Unidentified winged seed with prominent attachment scar, UF26244, x2. O. *Beckerospermum ovalicarpa* seed, UF26391, x3.5. P. Unidenfied winged seed, UF30546, x4. Q. Unidentified winged seed, UF26377, x2.

(Continued from page 56)
and venation of the trilobed wing and in presence of a long style—to those known from the West Branch Creek and Cherry Creek lacustrine shale localities of the Clarno Formation.

Cruciptera is an extinct genus of the walnut family with a nut surrounded by four orthogonally arranged, straplike wings (Figure 6J). Getahun and Retallack (1991) referred to these winged fruits as *Tetrapteris*, a modern genus of the Malphigiaceae, but subsequent study showed that they belong to the fossil genus *Cruciptera* of the Juglandaceae. *Cruciptera simsonii* is a characteristic species of the Clarno Formation, occurring at the Nut Beds and in lacustrine deposits of West Branch Creek and Cherry Creek (Manchester, 1991). Whereas the *C. simsonii* specimens have a wing span of 21–41.5 mm, the *Cruciptera* fruits at Whitecap Knoll range only from 12 to17 mm, placing it in the size range of *Cruciptera schaarschmidtii*, a species first described from the middle Eocene of Germany (Manchester and others, 1994). Similarly small fruits with wingspans of 12–19.5 mm (n=16) also occur in the Sumner Spring assemblage.

Eucommiaceae. Distinctive elliptical winged fruits of *Eucommia*, a genus native only to China today, are especially abundant in the deposit (Figure 7E). In their review of the North American fossil record of this genus, Call and Dilcher (1997, Figures 29,30) illustrated two Whitecap Knoll specimens which they assigned to the *Eucommia montana*—a species known also from lacustrine shales of the Clarno Formation and from localities in Montana, Utah, and Colorado. Although present in the middle Eocene shales of the Clarno Formation, this genus has never been observed in the Bridge Creek flora.

Malvaceae. *Craigia* is a genus of the Malvaceae (as broadly circumscribed including Tiliaceae) that grows today in southern China and Vietnam. The genus has an excellent fossil record, based on its distinctive winged fruit valves (Figures 8A,B), from the Tertiary of Europe and Asia as well as western North America. In North America, *Craigia* is common in the Bridge Creek flora (Meyer and Manchester, 1997; called *Pteleaecarpum* by Manchester and Meyer, 1987). The genus is not known from middle Eocene deposits of the Clarno Formation, (not found in the Nut Beds, West Branch Creek, or Cherry Creek) but does occur in the presumed late Eocene John Day Gulch flora.

Flowers of the extinct genus ***Florissantia*** are known from Eocene and Oligocene localities in western North America (Manchester, 1992) and the Miocene of Sikhote Alin (Manchester, 1999). The small size of the Whitecap Knoll calyces and prominence of sepal lobes (Figure 8C) identifies the species as *Florissantia ashwilli*, which also occurs in the Sumner Spring flora at Gray Butte. Although formerly placed in the Sterculiaceae, that family has recently been merged with Tiliaceae and Bombacaceae in the more broadly circumscribed Malvaceae.

Hydrangeaceae. *Hydrangea* is represented by a single fruiting branch (Figure 8D). The woody fruit capsules show a flat apical disk and remnants of at least two styles and have prominent longitudinal ribs, conforming to the fruits of other modern and fossil species. The attractive four-parted calyces, known both in the Clarno Formation (Manchester, 1994, pl. 58, fig. 6) and in the Bridge Creek flora (Meyer and Manchester, 1997, pl. 45, figs. 7,8), have not yet been recovered from the Whitecap Knoll assemblage.

Rosaceae. The rose genus, *Rosa*, can be recognized on the basis of its small leaflets with closely spaced, rounded teeth (Figure 6E). Stems with rosaceous prickles have also been recovered (Figure 6D). *Rosa* is not known from the Clarno Formation but occurs in the Slanting Leaf Beds and other localities of the Bridge Creek flora (Meyer and Manchester, 1997).

Nyssaceae. The impression of an ellipsoidal woody fruit with longitudinal ribs (Figure 8K) is similar to that which might be made by the stone of *Nyssa*, the tupelo tree. However, this identification remains uncertain because the impression of germination valves could not be seen. *Nyssa* is represented in the Nut Beds flora of the Clarno Formation but has not been confirmed in the Bridge Creek flora. Some of the modern species grow along lakes and streams and in swampy areas.

Sapindaceae. The maple family, traditionally called the Aceraceae but now merged with the Sapindaceae (Judd and others, 1999), is represented in the Whitecap Knoll flora by two extant genera: *Acer* and *Dipteronia*. Four fragmentary *Acer* fruits have been recovered from the Whitecap Knoll assemblage (Figures 8E,F,I,J). No complete leaves have been recovered, but one fragmentary specimen (Figure 7D) appears to represent one of the lobes of a maple leaf. *Acer* is not found in the middle Eocene lacustrine assemblages of the Clarno Formation but occurs in the late Eocene John Day Gulch and at the Sumner Spring assemblages.

Native to China today, *Dipteronia* has distinctive fruits that are readily recognized as fossils (Figure 8G; Manchester, 1999). The fruits are also known as rare components of Clarno lacustrine localities. A single specimen has been identified in the Bridge Creek flora (Meyer and Manchester, 1997, pl. 60, fig. 18). They are sometimes encountered in the Sumner Spring flora near Gray Butte (McFadden, 1986).

Rhamnaceae. A small leaf with entire to slightly undulating margins, pinnate secondary veins, and thin, very closely spaced, parallel tertiary veins (Figure 6I) compares favorably with leaves of extant *Berchemia* and *Rhamnidium* of the Rhamnaceae.

Simaroubaceae. The Chinese tree of heaven, *Ailanthus*, is known from a single specimen of its characteristic biwinged fruit (Figure 8H). *Ailanthus* occurs in lacustrine floras of the Clarno Formation and in the Sumner Spring flora at Gray Butte but has never been observed in the Bridge Creek flora.

Lythraceae. A small slender leaf with an intramarginal vein and irregular tertiary venation (Figure 6H) corresponds to those identified as *Decodon* from the the Bridge Creek flora (Meyer and Manchester, 1997). The leaves correspond in venation to the single living species, *D. verticillata* of eastern North America, but the lamina is relatively small, as are those from the Sumner Spring and Bridge Creek floras. The genus is known from silicified fruits in the Clarno Nut Beds flora (Manchester, 1994).

Bignoniaceae. *Catalpa* is recognized by a single seed (Figure 8L), which is bilaterally symmetrical with a straight, straplike wing on either side of the central body and with a tuft of hairs at the distal margin of each wing. *Catalpa* seeds are also present at two assemblages of the Bridge Creek flora (Meyer and Manchester, 1997).

Beckerospermum. This is a winged seed of uncertain affinity (Figure 8O) that is relatively common at the Slanting Leaf Beds and most other localities of the Bridge Creek flora (Meyer and Manchester, 1997) and is also known from the Mormon Creek flora of Montana (Becker, 1960, pl. 30, figs. 16-20) and Haynes Creek flora of Idaho (Axelrod, 1998, pl. 9, fig. 6).

Unidentified reproductive structures. A few of the fruits and seeds from Whitecap Knoll remain mysterious. Included are a fruiting axis from which the fruits had shed prior to fossilization (Figure 8M), an oval winged seed (Figure 8N), and some laterally winged seeds (Figures 8P,Q). Although superficially similar to seeds of *Cedrela* and pinaceous conifers, the cellular patterns of the wings do not correspond (Howard Schorn, written communication, March 2000).

Unidentified leaves. Current collections include several leaf types whose identity remains uncertain. I illustrated them here in the hope that future work will be able to link them to fossils from other sites and/or to extant genera. They include a serrate leaflet with the secondary veins terminating in prominent acute teeth (Figure 6G), a leaf with common intersecondary veins and very finely serrate margin (Figures 7B,C), one with a crenulate margin (Figure 7I), and three additional serrate leaf types (Figures 7F,J,K).

VEGETATION TYPE

The Whitecap Knoll plant assemblage includes elements representing both the aquatic plant community of the lake and the surrounding forest community. The aquatic indicators are *Ceratophyllum*, which grows suspended in the water without roots, and *Nelumbo*, which has floating leaves with long petioles that attach a rhizome located at the bottom of the pond or lake. Together, these plants indicate quiet water conditions and relatively shallow water depth. *Decodon* is also at home in shallow water areas. It is likely that some of the unidentified monocot foliage represents marshy plants like *Typha* (cattail).

Aside from the aquatic plants and the three kinds of ferns, the remaining plants represent woody trees and shrubs. Some were broad-leaved evergreens, including Oregon grape (*Mahonia*) and perhaps *Cinnamomophyllum*, but most appear to have been deciduous (e.g., *Platanus*, *Quercus*, *Ulmus*, *Acer*, *Dipteronia*, *Rosa*, *Catalpa*). These plants are typical of temperate forest today.

COMPARISON WITH OLDER AND YOUNGER FLORAS IN THE REGION

The Whitecap Knoll flora has a moderate diversity of about 35 species, but this is lower than the Nut Beds (173 species), West Branch Creek (55 species), and the Slanting Leaf Beds (44 species). It lacks remains of palms, cycads, bananas, Menispermaceae and other thermophilic indicators common in the Clarno Formation Nut Beds, West Branch Creek, Gosner Road, and John Day Gulch localities. Table 1 compares the taxonomic composition of the Whitecap Knoll flora with specified Clarno and John Day Formation floras. Elements shared with the Clarno flora but not known from the Bridge Creek flora include *Ailanthus*, and *Eucommia*. Two genera are shared with the Bridge Creek flora that are not known from the Clarno: *Rosa* and *Catalpa*.

At the species level, the Whitecap Knoll flora shows greater similarity to the Sumner Spring flora near Gray Butte than to the Clarno or Bridge Creek floras. In the cases of *Florissantia*, and *Cruciptera*, the Whitecap Knoll species is distinct both from those in the middle Eocene localities of the Clarno Formation (West Branch Creek, White Cliffs, Gosner Road), and from those in the Oligocene Bridge Creek flora but corresponds to those known from the late Eocene Sumner Spring flora. The Sumner Spring flora is situated stratigraphically below John Day Formation member B basalts, in lacustrine sediments interpreted to represent John Day member A (Smith and others, 1998). In contrast, the Whitecap Knoll flora occurs above basalts that were mapped as member B (Bestland and others, 1999). Whether the member B basalts are actually coeval in these different areas, is uncertain. Whole-rock radiometric dates of this basalt show a lack of precision due to alteration (Smith and others, 1998). If the B basalts are assumed to be coeval, then the Sumner Spring flora predates the Whitecap Knoll flora. However, the maximum age of the Sumner Spring flora is constrained by the radiometric dates of 39.22 ± 0.03 Ma on the basal ignimbrite of the Formation. If the Whitecap Knoll flora is correctly placed at about 38.8 Ma, then the Sumner Spring flora would be less than a million years older.

The Whitecap Knoll flora is about five million years older than the overlying Slanting Leaf Beds assemblage and differs in various respects, due to the disappearance of some taxa and the appearance of new ones, perhaps partially in response to changing climate. The apparent absence of conifers is striking, compared to the Clarno localities which have *Pinus*, *Sequoia*, and Taxaceae. *Metasequoia*, which was to become a dominant in the Slanting Leaf Beds and other assemblages of the Bridge Creek flora, is not seen in the Whitecap Knoll flora, although it was already present in the middle Eocene of Washington. Its arrival in the John Day basin evidently occurred sometime between 38 and 33.8 Ma.

CLIMATE

The floristic composition suggests temperate climate. Exclusively tropical to subtropical plants such as cycads, palms, bananas, and various families of lianas, seem to be absent, suggesting winters with frost. With the exception of Oregon grape, which is known to tolerate freezing temperatures, broad-leaved ever-

Table 1. List of the plant genera in the Whitecap Knoll assemblage, showing shared (×) occurrences in other selected Eocene and Oligocene assemblages of north-central Oregon: NB = Nut Beds, WBC= West Branch Creek, JDG = John Day Gulch, WCK = Whitecap Knoll, SS= Sumner Spring, SLB= Slanting Leaf Beds, FO = Fossil-Wheeler High School

	Clarno Formation			John Day Formation			
Taxa	NB	WBC	JDG	WCK	SS	SLB	FO
Fern 1 (Figure 4A)				×			
Fern 2 (Figure 4B)		×		×			
Fern 3 (Figure 4C)				×			
Monocot 1 (Figure 4D)				×			
Monocot 2 (Figure 4E)				×			
Monocot 3 (Figure 4F-H)				×			
Ceratophyllum (Figure 4I)				×			
Nelumbo (Figure 4J)				×			
Cinnamomophyllum (Figure 4K)	×	×	×	×	×	×	
Mahonia (Figure 4L,M)		×	×	×	×	×	×
Platanus (Figure 4N, 5E,H,I)	×	×	×	×	×	×	×
Quercus sp. 1 (Figure 5A)				×	×		
Quercus sp. 2 (Figure 5B,G)				×		×	×
Alnus (Figure 5F, 6A)		×	×	×	×	×	×
Palaeocarya (Figure 6L,M)	×	×	×	×	×	×	×
Cruciptera (Figure 6J)	×	×	×	×	×	×	×
Eucommia (Figure 7E)		×	×	×	×		
Ulmus (Figure 6F,K)		×	×	×	×	×	×
Hydrangea (Figure 8D)	×	×		×		×	×
Rosa (Figure 6D,E)				×	×	×	×
Rhamnaceae (Figure 6I)	×	×	×	×			
Acer (Figure 8E,F,I,J)			×	×	×	×	×
Dipteronia (Figure 8G)		×		×	×		
Ailanthus (Figure 8H)		×	×	×	×		
Florissantia (Figure 8C)		×	×	×	×	×	×
Craigia (Figure 8A,B)			×	×		×	×
Decodon (Figure 6H)	×	×	×	×	×	×	×
Beckerospermum (Figure 8O)				×	×	×	×
Catalpa (Figure 8L)				×			×

green plants are also rare: the flora is dominated by deciduous elements. The absence of large-leaved broad-leaved evergreens is another indication that the climate was not as warm as during deposition of the Clarno Formation. This suggests that the transition to temperate climate had already occurred by about 38.8 Ma.

Using the simple linear correlation reported by Wolfe (1979; also Wing and Greenwood, 1993) between the percentage of dicotyledonous species with entire-margined (not serrated or lobed) leaves and mean annual temperature derived from modern vegetation, it is possible to infer the approximate mean annual temperature (MAT) of fossil leaf assemblages. For this exercise, I used the equation derived from Wolfe's work on modern vegetation of China (Wolfe, 1979): MAT (°C) = 1.14 + 0.306 × E, where E is the percentage of entire-margined leaves. The dicotyledonous leaves from Whitecap Knoll include five species that are entire margined and 14 that are not (toothed or spiny along the margin). Hence, about 26 percent are entire margined, in comparison with 23 percent in Iron Mountain (Slanting Leaf Beds). Table 2 compares the results of this univariate evaluation of MAT for selected floras of the Clarno and John Day Formations.

The Whitecap Knoll flora indicates a MAT only about 1° higher than that of the Slanting Leaf Beds (considering the margin for error, they can be considered as overlapping) but perhaps 8° lower than that of the Nut Beds, and 5° lower than White Cliffs. The Oligocene assemblage of Fossil, Oregon (ca. 32.6 Ma, McIntosh and others, 1997; Meyer and Manchester, 1997), actually appears a few degrees warmer than the Whitecap Knoll flora (Table 2). Based on the relatively low values of MAT computed for both the Sumner Spring and the Whitecap Knoll flora, we may infer that the regional cooling had already occurred or was in progress by 38.8 Ma, well before the Eocene-Oligocene boundary (34 m.y.).

Our current understanding of the Whitecap Knoll flora remains limited by the relatively small number of samples, filling only three drawers in our museum cabinets (vs. 30 drawers from West Branch Creek, 25 from the Iron Mountain assemblage). It may be that continued collecting will bring forth significant additional taxa helpful to a more reliable reconstruction of the flora and climate.

ACKNOWLEDGMENTS

I thank Mary and Donald Maurer for permission to collect and study the fossils from their property. Shu Chan prepared many of the photographs and participated in the preliminary sorting and curation of specimens. I thank the following individuals for their help in securing specimens in the field: Nick Young, Rick and Thomas Dillhoff, Shu Chan, Patricia Dodge, Adam Kipp, Wendy Lindquist, Amber Marshall, Jeff Myers, Daniel Stewart, Yumei Wang, Michael Weinstein, and Jon Bradie; also Ted Fremd for access to study specimens in the collection of John Day Fossil Beds National Monument. Melvin Ashwill, Richard Dillhoff, and Gregory Retallack provided helpful corrections to the initial manuscript. This research was supported in part by NSF grant EAR 9506727.

Table 2. Comparison of conifer abundance, diversity of dicotyledons, proportion of entire-margined leaves and inferred Mean Annual Temperature (MAT) for selected floras of the Clarno and John Day Formations, north-central Oregon

	Clarno Formation				John Day Formation			
	West Branch Creek	Nut Beds	White Cliffs	John Day Gulch	Sumner Spring	Whitecap Knoll	Slanting Leaf Beds	Fossil
Age (to nearest 0.5 Ma)	45	44	44.5	40	38	39	33	32.5
No. conifers	3	3	3	5	1	0	2	2
No. dicot species	41	69	61	40	19	19	31	53
No. entire margined	17	33	26	12	4	5	7	19
Percent entire margined	42	52	43	30	21	26	23	35
Inferred MAT (°C)	14	17	14	10.3	7.6	9	8–9	11–12

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Letter to the authors

of "The other face of Oregon: Geologic processes that shape our state," in the November/December 1999 issue of *Oregon Geology* (v. 61, no. 6, p. 131–150), Reprinted here in part, with permission.

I'd like to commend you on tackling a summary article on this important theme. I have studied hazardous geologic processes for nearly 20 years and have been involved in extensive outreach and educational efforts about those same hazards; so I realize how important this topic is—I sincerely hope my comments will be helpful in future revisions of this article—which I hope to see.

Re. lateral blasts:

On p. 131 you note (and I agree) that the "media will often pump up any event to catastrophic levels" The closeup focus of some media coverage (often with minimal background information) pumps events up simply by virtue of its lack of context.

I think one way to encourage a better resolution or visualization of the hazards by the media is to repeatedly emphasize to them that natural events such as lahars, pyroclastic flows, etc., follow natural laws and tend to behave, within certain ranges of probability anyway, in reasonably expectable ways. For example, lahars have a certain physical scale and range of behaviors (flow depth, runout distance, velocity, etc.) when flowing along a valley bottom. To this end, I strongly believe that we earth scientists should very carefully consider what we say and how we say it when explaining these processes. One of the reasons for my concern about this is my experience that the general public does not adequately understand the nature and scale of many hazardous natural processes. On one recent TLC "documentary" about Mount Rainier hazards, for example, a geologist made the claim that lahars from Mount Rainier would inundate Seattle—not one effort was made to discuss the flow limitations of lahars and how they might be topographically channeled! The result of such statements could more properly be called "tabloid journalism" than documentary journalism.

I think that your statement that "lateral blasts are not uncommon in Cascade volcanoes" exaggerates the hazard of this kind of eruption and is one example of where discussion of natural processes should have included better definition of the nature, scale, and frequency of the hazardous process. The public visualizes "lateral blast" as having the same scale and power as the 1980 event. In truth, most of the recognized Holocene sedimentologic evidence for lateral explosions in the Cascades is that of events that probably were considerably less energetic and less extensive than the Mount St. Helens blast. Examples are found at Mount Rainier (F and S tephra layers) and the Sugar Bowl and March 1982, February 1983, and May 1984 small explosive events at Mount St. Helens). I certainly agree that a Mount St. Helens 1980-scale event is possible; we have analogs at Bezymianny, Kamtchatka, and probably elsewhere. But I don't think there is any evidence that would justify us to say it's "not uncommon".

Were the truly catastrophic events humongous?—heck yes, but we need to show that lesser events (though potentially very serious and relatively huge in their own right) are much more common, that those processes obey the laws of physics, and that they commonly have a scale and flow behavior that constrains their extent topographically. Encouraging this realistic understanding reduces the sensationalism and allows interpretation of hazard maps as positive information for planning and preparedness options, not as frightening scenarios of "doom and gloom."

Re. increased volcanism:

[Article, p. 146: ". . . and there is speculation that the Northwest may be entering another period of volcanic activity."—*ed.*]

While W.E. Scott (1980; Geoscience Canada, v. 17, no. 3) notes a statistical clustering of eruptive activity that seems to show a period of increased volcanism over the past 4,000 years, I don't know of any evidence to suggest that we are now "entering another period of volcanic activity."

Re. the Bonneville landslide:

[Article, p. 135: ". . . massive slides that took place around 300 years ago—the same time as the last great subduction earthquake."—*ed.*]

New radiocarbon ages on the Bonneville landslide have created a fair amount of interest; however, there is no compelling evidence so far to say it occurred "at the same time as the last great subduction zone earthquake." In fact, [a new study] shows that the rockslide-debris avalanche (not "earth flow") is most likely to have occurred in the century and a half before A.D. 1700, with the highest probability roughly between about 1550 and 1670 (estimating). In fact, although there are no high-quality master chronologies of tree ring data for the area near the Bonneville slide, I did measure the ring width and latewood width of the sample we dated and have attempted to cross-date these series with those of old-growth trees near Carson and west of Mount Hood. So far, a matrix of best possible matches does not include A.D. 1699 as the date of the last ring—what it would be if the Bonneville landslide were triggered by the great Cascadia earthquake of 1/26/1700. While our data still permit the slide to be generated by the great Cascadia quake, we should include other hypotheses on its cause until we get better resolution of the age—and because of the nature of the slide, those hypotheses could certainly include triggering by a regional shallow-crustal fault or even a slab earthquake.

Patrick Pringle, Geologist,
Washington Division of Geology and Earth Resources, Olympia, Wash.
e-mail<Pat.Pringle@wadnr.gov>

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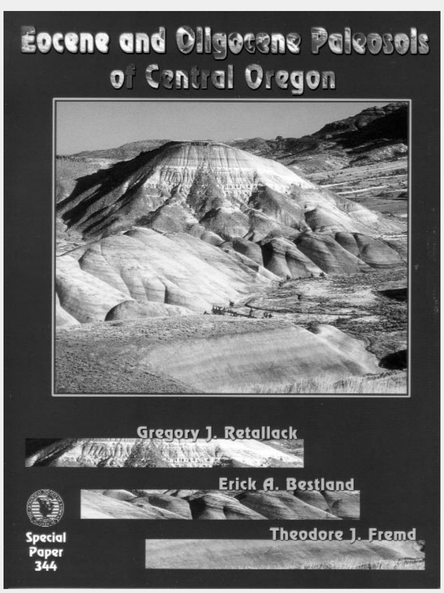

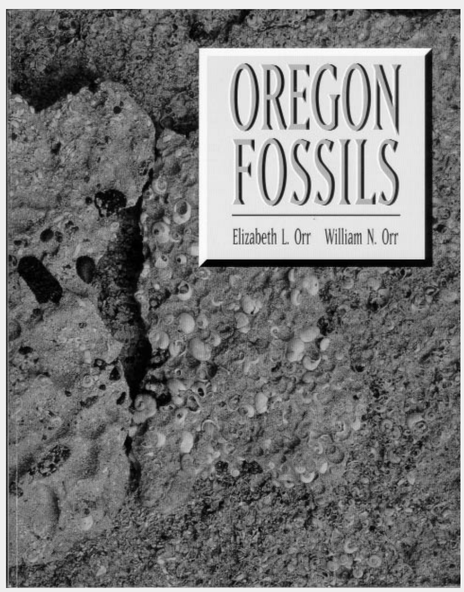

Oregon Fossils, by Elizabeth L. and William N. Orr, published 1999 by Kendall/Hunt; 381 pages, $40.95.

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Fossil Shells from Western Oregon, by Ellen J. Moore (formerly of the U.S. Geological Survey), published 2000 by Chintimini Press, Corvallis, Oregon; 131 pages, $12.

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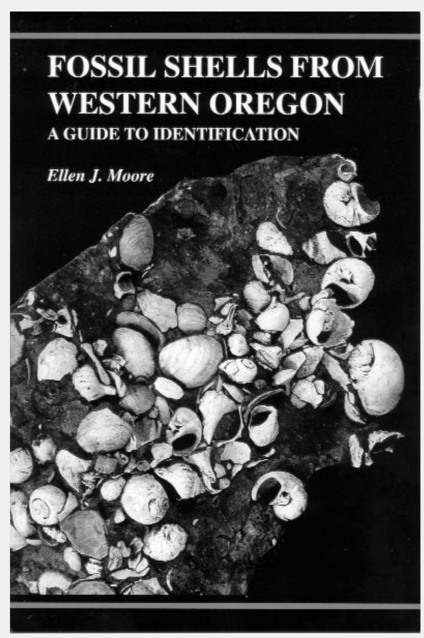

The geology and mineralization of the northern portion of the Blue River mining district, Lane and Linn Counties, Oregon

by Robert E. Streiff, Geologist, Newmont Mining Corporation, P.O. Box 669, Carlin, Nevada 89822-0669

ABSTRACT

The geology and mineralization of the Blue River mining district of Oregon has not been described in any detail, nor is it well understood. Base metal sulfides are noticeably lacking in the district compared to some of the other Oregon Cascade districts. The morphology of the veins is generally more complex, with stockworks and sheeted vein sets common, compared to other Cascade districts such as Bohemia and North Santiam. Mineralization at Blue River consists mainly of quartz-adularia-pyrite veins with significant base metals reported at depth in only two veins: the Lucky Boy and Rowena (Callaghan and Buddington, 1938). The northern arc of mineralization is characterized by a general lack of base metal sulfides and an increase in carbonates compared to the central part of the district. Gold values are associated with pyrite in quartz-adularia veins and are erratic but locally high grade. All of these characteristics suggest that the Blue River district represents a higher level volcanogenic epithermal system than other Cascade districts such as Bohemia or North Santiam. The increase in base metal sulfides toward the Nimrod stock and the increase in carbonates away from the stock indicate a crude zoning which suggests that the Nimrod stock may be related to the mineralization. Only the northern portion of the district has been studied in any great detail and is described in this paper.

Two major phases of faulting, three stages of mineralization and three vein-types have been identified in the northern portion of the Blue River district. Early stages of mineralization, which occupy small fault sets, contain quartz with pyrite plus traces of galena and sphalerite. They do not contain significant gold mineralization in the northern part of the district. Geochemical evidence in addition to crosscutting relationships strongly suggest that economic gold mineralization is intimately associated with pyrite in a later episodic quartz-adularia-pyrite event. These quartz-adularia-pyrite veins contain very erratic bonanza-type gold mineralization. This gold mineralization tends to be controlled by either proximity to northwest vein intersections or to dioritic dikes. Vein sediments are also associated with the later quartz-adularia mineralization, suggesting boiling as a depositional mechanism. Vuggy quartz-pyrite without adularia marks the end of this phase. Carbonate minerals, consisting mainly of calcite but also including some dolomite and ankerite, are found as a late-stage mineralization event that may or may not contain significant precious metals. Gold in the carbonate portions of the veins may be associated with a late-stage quartz-pyrite event which occurs as colloform bands within the carbonates, similar to the President Mine in the Bohemia mining district (Streiff, 1994). These carbonate minerals comprise the bulk of the gangue minerals in a few of the veins, such as the Great Northern and Higgins. Carbonate mineralization cuts earlier quartz-adularia and quartz-pyrite veining in some deposits, such as the Poorman. Post-mineralization right-lateral faulting cuts all mineralization in many of the veins. Alteration and mineralization indicate that the Blue River veins fit a quartz-adularia epithermal model. The presence of illite and montmorillonite indicate that depositional conditions were relatively basic and low in temperature.

INTRODUCTION

The Blue River mining district is located in the Western Cascade physiographic province of Oregon, on a ridge dividing the Calapooya and McKenzie Rivers approximately 45 mi east of Eugene. The ridge averages 1,372 m (4,500 ft) in altitude and has been heavily glaciated on north-facing slopes. The district has

Table 1. Summary of Cascade mining district production 1880–1930
(after Callahan and Buddington, 1938, page 24)

District	Production ranking	Gold (ounces)	Silver (dollar value)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total dollar value
Salmon Creek	7	48.38	0	0	0	0	$1,000
North Santiam	5	277.63	$1,146	14,206	3,336	12,528	$10,544
Quartzville	2	8,402.29	$2,894	0	0	0	$176,585
Blue River	3	7,727.89	$8,601	257	0	0	$168,300
Bohemia	1	28,285.55	$6,473	14,831	120,816	0	$599,442
Buzzard	4	1,080.51	0	0	0	0	$24,000
Barron	6	63.79	0	0	0	0	$1,500

had a very modest gold production (7,727 oz) and consequently has not been thoroughly examined, especially in comparison with some of the other Cascade mining districts such as Bohemia or Quartzville. The lack of interest in the Blue River district is unwarranted, since a comparison of the recorded productions of the various districts shows that Blue River has produced almost the same amount of gold as Quartzville, the second largest producer in the Oregon Cascades (Table 1). Blue River gold production might even exceed

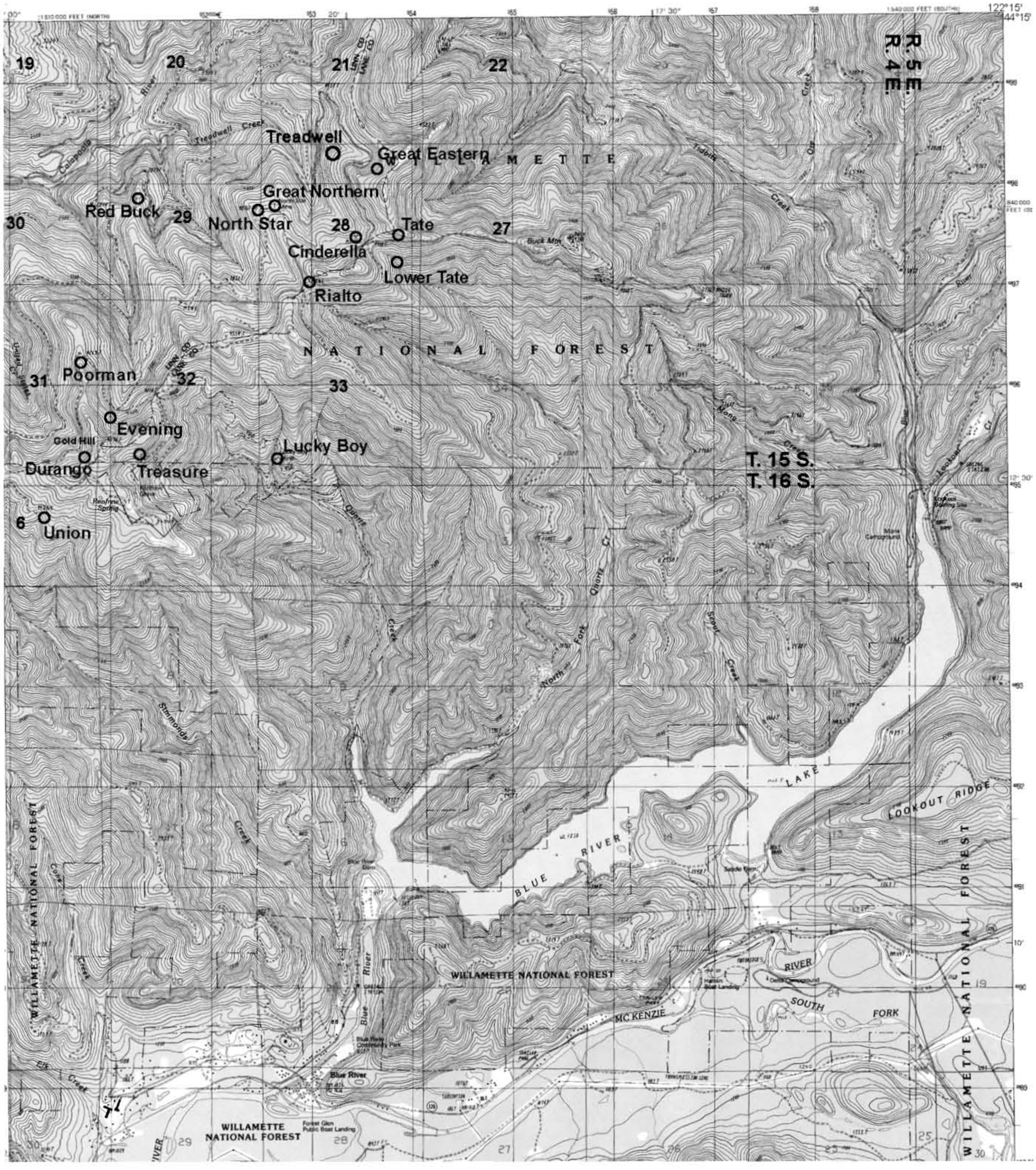

Figure 1. Map of most (north 5/6) of Blue River 7½-minute quadrangle, showing approximate locations (circles with names) of mines and prospects mentioned in this paper. Digital Raster Graphic (DRG) 044122b3.

Quartzville if additional unreported production were included. The literature on the district is confined mainly to Tuck (1927) and Callaghan and Buddington (1938). Some additional information can be found in Diller (1900), Stafford (1904), and Parks and Swartley (1918). Later publications, including Oregon Department of Geology and Mineral Industries Bulletins 14-D (DOGAMI, 1951) and 61 (DOGAMI, 1968) put the Blue River district in context with the Cascade stratigraphy but tend to restate earlier reports on the individual prospects.

The northern portion of the district which is described in this paper consists mainly of secs. 21, 27, 28, 29, 30 and 31, T. 15 S., R. 4 E., (Figure 1). This area includes the following mines or prospects: Cinderella, Evening, Great Eastern, Great Northern, Higgins, North Star, Nimrod, Poorman, Red Buck, Sochwich, Tate, and Treadwell. Also included in this discussion are the Union and Uncle Sam prospects in sec. 6, T. 16 S., R. 4 E. A mineralized belt appears to arc westward from the Tate Mine (sec. 28) to the Red Buck (sec. 29). A second, similar belt extends southwest from the Poorman (sec. 31) through the Durango to the Uncle Sam and Union (sec. 2). Exposures of the veins are generally poor and consist mainly of surface trenches and outcrops with limited underground access.

HISTORY

The recorded history of the Blue River district is largely that of the Lucky Boy Mine, which was discovered in 1887 and was in production from about 1898 to 1915 (Tuck, 1927). Most of the other mines and prospects were discovered and worked during this period (Tuck, 1927). The Great Northern, the second largest producer (about 1,200 oz) in the district, is located in the northern part of the district. Minor production from this northern area is implied from the Cinderella, Higgins, Poorman, Red Buck, Tate, Uncle Sam and Union (Callaghan and Buddington, 1938).

Kenneth O. Watkins was active in the northern part of the district in the early 1960s. In 1960, Watkins shipped, from a surface trench on the Cinderella Mine, about five tons of ore averaging 63.0 g/ton (1.84 oz/ton) gold and 33.1 g/ton (1.19 oz/ton) silver to the Tacoma, Wash., smelter. The price of gold, however, prevented serious development (H.E.L. Barton, a geologist retained by the claim owner in the 1950s, oral communication, 1977).

Coarse gold was discovered in a surface trench on the Tate ground by the author in 1986. A mapping and sampling program followed that resulted in the discovery of coarse gold in a new vein (the Nimrod) by William Barton in 1992. Mapping and sampling is ongoing at present.

REGIONAL GEOLOGY

The Cascade Range is the product of arc volcanism that has been active since Eocene times (McBirney and others, 1974; Power, 1984). In Oregon, the Cascade Range has been subdivided into two belts of volcanic rocks, the Western Cascades of Eocene to Pliocene age and the High Cascades of Pliocene to recent age (Peck and others, 1964; Priest and Vogt, 1983). The Blue River mining district lies within the Tertiary Western Cascades physiographic province of Oregon.

The Western Cascades consist of flows and pyroclastic and volcaniclastic sediments that were deposited from numerous volcanic centers (Peck and others, 1964). Minor folding of the Western Cascades, along a northeast-trending fold axis, occurred during several periods in the late Eocene and late Miocene (Peck and others, 1964). The High Cascades, consisting mainly of basaltic to andesitic flows and of stratovolcano complexes, fill a north-south-trending graben that developed in older volcanic rocks (Priest and Vogt, 1983).

DISTRICT GEOLOGY

An active volcanic center existed in the Blue River area during the Oligocene to early Miocene (Peck, 1960). Interstratified flows, tuffs, lahars, and volcanic breccias of basaltic to andesitic composition of the Sardine Formation have been mapped and divided into two informal units by Streiff (after Tuck, 1928):

Andesitic and pyroclastic flows that fill erosional paleotopographic features characterize the lower unit (at least 200 m or 650 ft thick). The lower unit is cut by numerous basaltic andesite dikes, which are presumed to be feeders for the upper unit. The upper unit (at least 50 m or 160 ft thick) consists predominantly of basaltic andesite flows. Numerous dioritic dikes crosscut all volcanic units. Crosscutting relationships show that the epithermal veins of the district postdate the various dikes and are therefore younger than the associated volcanic and intrusive rocks. Pervasive propylitic alteration can be found in all volcanic and intrusive rocks in the district.

The district is thought to be related to the Nimrod stock, a large granodiorite stock roughly 4.1 km (2½ mi) long and 2.4 km (1½ mi) wide, which is exposed by the McKenzie River south of the district (Callaghan and Buddington, 1938). Slight zoning of mineralization in the district strongly suggests this relationship. Pyritization and argillic alteration of the Nimrod stock is similar to the outer pyritic halo of many porphyry systems.

LOCAL SURFACE GEOLOGY

Currently ongoing mapping by the author has shown that erosion has removed most of the upper basaltic-andesite unit, so that only isolated outcrops remain on the ridge above about 1,448 m (4,750 ft). This unit consists of numerous massive flows of basaltic andesite. The lower unit consists of a complex sequence of onlapping andesite flows, pyroclastic flows, volcanic breccias composed of andesite fragments in a matrix of tuff, and isolated lacustrine tuffs. Numerous andesitic and basaltic-andesite dikes invade these volcanics. The andesitic dikes are presumed to be the hypabyssal equivalent of the lower unit, while the less altered basaltic-andesite dikes are presumed to be feeders to the upper unit. A large sequence of thin volcanic flow breccias fills a north-south-striking paleovalley in the andesites at the Tate and Great Eastern Mines, forming the ridge between these two deposits. In this paper, this flow breccia is informally referred to as the "Tate breccia sequence." Individual flow thickness in the breccia sequence varies from 0.6 m to more than 6 m (2–20 ft). The volcanic breccias consist of angular andesite boulders, from 10.2 cm to more than 75 cm (4–30 in.) across, suspended in a silty tuff matrix. Propylitic alteration has affected the tuff matrix more than the clasts, giving the flows a distinct color contrast from clasts to matrix. Postdepositional silica has filled voids between clasts in some individual flows. The paleovalley appears to dip to the south. Several small, isolated lacustrine tuffs are intercalated with the breccia sequence on the margins of the paleovalley.

Several previously unmapped dioritic dikes occur in the northern area of the district. One of them, ~100 m (330 ft) east of the Tate vein, strikes about N. 30° E. and dips steeply to the south. It is approximately 46 m (150 ft) wide. Contact metamorphism, consisting of knots and veinlets of chlorite and magnetite, occurs in a halo approximately 30 m (100 ft) around this dike. Two smaller dioritic dikes occur west of the Great Northern Mine. The North Star vein follows a 12.2-m (40-ft)-wide, fresh-looking, fine-grained diorite dike that strikes N. 10° W. and dips steeply to the south. The Nimrod vein follows a 3- to 4.5-m (10- to 15-ft)-wide argillic to sericitically-altered, fine-grained dioritic dike trending N. 40° W. and dipping steeply to the west. All three of these veins contain high-grade gold mineralization, suggesting a relationship to the dioritic dikes. The developed portion of the Poorman vein occupies a fault contact between the small dioritic plug at Gold Hill and Sardine Formation volcanic rocks. The Gold Hill diorite plug appears larger than previously mapped by Callaghan and Buddington (1938). Additional unmapped dikes are thought to exist in the Blue River district.

STRUCTURE

The veins occupy minor faults of unknown total displacement. Two main northwest conjugate fault sets are recognized. One set strikes from N. 40° to N. 60° W. and dips steeply to the southwest. A second set strikes from nearly due north to N. 20° W. and dips steeply to the west. Mineralized zones occupy relatively small strike lengths along much more continuous fault zones. These mineralized areas are often near the intersections of the northwest-striking faults with the more northerly striking faults. Mineralization tends to occur on either fault set approximately 45–150 m (150–500 ft) away from these intersections. A third fault set, striking N. 50°–70° E. and dipping steeply to the southeast, has also been observed. This northeast-striking set is much weaker than the two northwest sets and does not appear to control significant mineralization.

A postmineralization faulting event displaced the quartz and carbonate mineralization in several of the veins, including the Cinderella, Nimrod, and Tate. Moderate brecciation, some gouge formation and heavy postmineralization oxidation characterize this late faulting. Free gold has been found smeared along the slickensides in the Nimrod and Tate veins. Slickensides tend to be oriented nearly horizontal, with kinematic indicators suggesting a possible right-lateral displacement similar to the Bohemia mining district to the south of Blue River (McChesney, 1987; Streiff, 1994). The slickensides tend to have a slight rake (10° or less) toward the south.

Vein morphology tends to be more complex than in other Cascade districts such as Bohemia or North Santiam and consists of either numerous anastomosing branches, such as at the Tate and Nimrod, or as parallel, sheeted veins like the Great Northern, Poorman, Red Buck, and Union. Wallrock lithology tends to determine the vein morphology. Tuffs and volcanic breccia units tend to host anastomosing, bifurcating vein systems, while flow rocks such as andesite tend to host more simple sheeted vein sets. Mineralized zones are shorter in strike length than those in other Cascade districts such as Bohemia. These mineralized zones typically consist of anastomosing quartz-adularia veins from 15 cm to 91 cm (6–36 in.) wide that have a strike length of about 150 m (500 ft). Barren, argillically altered fault zones typically extend several hundred meters beyond the mineralized segments. Small topographic lows or streambeds tend to follow the outcrops of a number of the veins, including the Great Eastern, Nimrod, and Tate.

ALTERATION

Alteration types found in the northern portion of the Blue River mining district include propylitic, argillic, and sericitic alteration plus silicification. Earlier pervasive propylitic alteration is overprinted by later argillic and sericitic alteration or silicification. Alteration in the northern part of the Blue River district tends to be lower in intensity than in the Bohemia district, with propylitic assemblages dominating.

The volcanic rocks show pervasive propylitic alteration throughout the Blue River district. Locally, this alteration consists of chlorite + calcite + magnetite ± epidote. Chlorite is pervasive and is found both replacing mafic minerals and within the groundmass. Epidote appears to be slightly later and is often structurally controlled. Calcite is often found replacing plagioclase and is also in the matrix. Magnetite is a minor, local constituent replacing mafics in the various volcanic rocks. Magnetite and chlorite tend to increase in abundance in the contact-metamorphic aureoles surrounding intrusive dikes. These minerals occur as knots and veinlets adjacent to the Tate dike.

Argillic alteration occurs as an outer alteration envelope around sericitic zones. Argillic alteration consists mainly of illite grading outward to montmorillonite, which replaces both plagioclase and groundmass with <1 percent disseminated pyrite. Groundmass can look slightly bleached in some locations but is sometimes fresh looking in other locations. Argillic alteration is often found in the fault systems where mineralization is not significant, such as at the Treadwell Mine or in extensions of the mineralized faults well outside of the mineralized segments, such as the northern extension of the Great Eastern fault. The footwall diorite at the Poorman adit is argillically altered, with white clay (illite?) replacing plagioclase. Argillic alteration can also occur as broad envelopes surrounding some of the larger sheeted vein systems, such as in the Great Northern, Red Buck, and Union systems.

Sericitic alteration forms 0.3- to 3-m (1- to 10-ft) envelopes in the dioritic dike hosting the Nimrod vein. This alteration consists of sericite or illite, pyrite, and chlorite with local silicification. Sericite replaces both mafics and groundmass. Chlorite replaces mafics and appears to be a retrograde alteration product. Pyrite occurs as 1-mm cubes disseminated in the dike around the vein.

Silicification often occurs as 5- to 20-mm (0.2- to 0.8-in.) envelopes around quartz veining and is most intense within the vein, where it completely replaces breccia clasts and vein sediments locally. Silicification in the Nimrod vein appears to occur both simultaneously with and postdating gold mineralization. Silicified vein sediments suggest a post-boiling remobilization of some of the silica or a very late stage silicification event.

Elsewhere, sericitic alteration forms very restricted alteration envelopes around the quartz veins or occurs as local envelopes within a more pervasive argillic envelope. It is often most recognizable in volcanic clasts within the quartz veins. Sericite is generally found replacing mafics and feldspars. Usually, a noticeable increase in disseminated pyrite accompanies sericitic alteration. Silicification is restricted to volcanic clasts within the quartz veins or as very narrow (<1 m) envelopes in the volcanics at the quartz-vein contacts. No pervasive or extensive silicification has been noted.

VEIN MINERALOGY

At least three stages of mineralization have been identified in the northern Blue River veins. These three stages have been classified based on crosscutting relationships, brecciation, and colloform banding. Oxidation followed these mineralization events. All three stages exhibit crustification, colloform banding, and other features of open-space filling.

Stage 1

Quartz, pyrite, and traces of sphalerite and galena characterize the earliest mineralization in the northern Blue River veins. Base metal sulfides tend to decrease in abundance, as distance from the Nimrod stock increases. The gangue often consists of cherty, light-gray quartz. Silicification is common. Gold values tend to be low, at least in the northern part of the district. Base metal sulfides are generally lacking in the Blue River district compared to other Cascade districts such as Bohemia, Quartzville, and North Santiam. Diller (1900) notes that galena and sphalerite were observed only in the Lucky Boy Mine. The Rowena Mine is the only other mine in the district known to contain significant base metal sulfides. Many of the references to sulfides in the literature probably refer to pyrite. In some prospects such as the Poorman and Union, a milky white bull quartz containing 2–5 percent coarsely crystalline pyrite but no base metal sulfides may represent this early phase of mineralization.

Stage 2

A brecciation event and subsequent mineralization mark the beginning of stage 2 quartz-adularia-pyrite mineralization. The quartz contains various amounts of pyrite (1–5 percent) with only traces of other sulfides present. The quartz and adularia form alternating crustiform bands, with adularia tending to be slightly later than the quartz. Several brecciation events and associated vein sediments followed by renewed quartz-adularia-pyrite mineralization have been seen in the Nimrod vein, with later quartz-adularia-pyrite cementing earlier breccia clasts of quartz-adularia-pyrite. Silicification overprints all phases. Silicified vein sediments and subrounded breccia clasts indicate that boiling probably occurred. Coarse free gold can often be found associated with pyrite in all the quartz-adularia events. The gold can be found just within breccia clasts or just in later interclast fillings associated with pyrite or goethite pseudomorphs after pyrite. A later vuggy quartz and pyrite event has been noted in the Nimrod and Tate veins. Coarse gold has also been found in vugs of this late stage quartz. In general however, gold mineralization is intimately associated with pyrite in this phase. Diller (1900) reported some of the pyrite to be very rich in gold values.

Stage 3

The quartz-adularia-pyrite phase is followed by minor refracturing and stage 3 carbonate mineralization. Manganiferous calcite is the most common carbonate mineral in the veins, with lesser ankerite and probably some dolomite present. The calcite occurs as massive white calcite or as small scalenohedral crystals that line vugs and open fractures within the veins. Locally, the calcite is sometimes brown or black in color. Some ankerite has been found with calcite lining vugs in the adularia. Carbonates appear to be distal to the center of the Blue River district and are not limited to the northern arc of mineralization. Extensive manganese wad, containing trace amounts of gold, has been reported from the Great Western claims south of the main district (W. Barton, oral communication, 1997). Only few exposures of unoxidized carbonates are found in the district. Unoxidized carbonates are locally present on some of the adit dumps. Callaghan and Buddington (1938) report carbonates underground at the Higgins and Great Northern Mines, which are currently inaccessible. Many veins are inferred to carry carbonates due to the presence of significant quantities of manganese-limonite wad. Veins with significant manganese wad include the Cinderella, Great Northern, Higgins, Poorman, and the northeast-striking vein on the lower Tate. At the Poorman, mapping has shown that the manganese wad veining crosscuts earlier quartz-pyrite veining. Vuggy, crystalline quartz fragments are present in the heavy manganese wad portions of the Cinderella, Great Northern, and Poorman veins, suggesting that some quartz was deposited during the time of carbonate mineralization. This quartz mineralization may be responsible for gold values locally found in these veins.

This late carbonate stage contains no sulfides and is thought to be low in gold and silver, although manganese-limonite wad can locally carry appreciable values. The gold values associated with the manganese wad may be due to quartz-pyrite mineralization deposited during the same time period as the carbonates as a result of periodic boiling, similar to the mineralization at the President Mine in the Bohemia mining district (Streiff, 1994). No unoxidized carbonate ore shoots containing significant gold are currently exposed in the district.

Oxidation

Oxidation and weathering occurred following the carbonate stage. The carbonates were particularly susceptible to weathering, and are responsible for much of the residual limonite and manganese minerals. Sulfides were mainly leached away, so that the net result is probably a slight concentration of gold in the oxidized zone and a liberation of fine gold from encapsulation. However, cellular, boxwork quartz common to the oxidized portions of base metal veins such as in the Bohemia district is conspicuously absent in Blue River, which suggests a lack of significant sulfide mineralization.

Fine gold liberated during oxidation may have moved chemically, probably by manganese, to the lower oxidized zone and recrystallized on the surface of goethite pseudomorphs in coarser leaves and wires. The importance of this chemical enrichment in the veins is probably minor.

Erosion has been rapid in the district which has very steep slopes. Therefore, the level of oxidation is relatively shallow (≤ 60 m), since the outcrop is stripped off by erosion shortly after oxidation. The depth of oxidation tends to be deeper on ridge tops than near the bottoms of the stream valleys. Glaciation in the upper north-facing slopes has also rapidly removed the vein material. Shallow topographic depressions or small streambeds mark many of the vein outcrops.

Small amounts of anglesite are not uncommon in the oxidized zone, occurring as small greenish-yellow crystals. Some perfectly translucent, coarsely crystalline quartz is present and has been found lining limonite-stained vugs and boxwork at the Cinderella Mine. This quartz is probably a late supergene remobilization of earlier quartz existing in the vein. In some cases, this quartz can clearly be seen postdating initial oxidation of the host vein rock.

VEIN GEOCHEMISTRY

Geochemical analyses on 40 vein and fault samples indicate elevated levels of antimony, arsenic, copper, lead, mercury, and zinc (Table 2). The three toxic metals, antimony, arsenic, and mercury, tend to correlate well with each other and to a lesser extent with gold (Figures 2 and 3). Arsenic is elevated compared to antimony and mercury. Lead and zinc both are significantly elevated compared to copper. The base metals tend to correlate well with one another (Figure 4) but do not correlate well with the toxic metals such as arsenic (Figure 5) or with gold (Figure 6), which suggests that the gold mineralization is related to the mineralization of the epithermal toxic metals rather than the base metals. However, the limited size of the geochemical database makes definitive interpretations difficult.

INDIVIDUAL PROSPECTS

A detailed description of the characteristics of some of the individual mines and prospects illustrates both the similarities and differences found in the northern part of the Blue River mining district. Only the better studied deposits are described.

Cinderella Mine

The Cinderella Mine is located in a glacial cirque on the north side of the ridge near the center of sec. 28. The main vein extends south from the old workings across Cinderella saddle into the McKenzie River drainage, striking N. 40°–45° W. and dipping steeply to the south. Production has come from two segments of the vein on the north side

(Continued on page 77)

Table 2. Geochemical analyses of samples from the Blue River mining district, Oregon
(n.d. = not determined)

General sample location	AU (oz/ton)	AG (oz/ton)	SB (ppm)	AS (ppm)	HG (ppb)	MO (ppm)	TL (ppm)	CU (ppm)	PB (ppm)	ZN (ppm)
#1515 RDCUT	<0.002	n.d.	<2.0	20.0	<1.0	<1.0	<10.0	58.0	68.0	114.0
#1515 RDCUT	0.036	n.d.	2.0	40.0	<1.0	<1.0	<10.0	166.0	174.0	162.0
#1515 RDCUT	0.096	n.d.	<2.0	68.0	<1.0	4.0	<10.0	541.0	456.0	180.0
#1515 RDCUT	<0.002	n.d.	<2.0	<2.0	<1.0	<1.0	<10.0	20.0	<2.0	70.0
CINDERELLA	0.150	0.20	15.0	60.0	155.0	n.d.	n.d.	171.0	n.d.	n.d.
CINDERELLA	0.012	0.18	32.0	190.0	50.0	n.d.	n.d.	n.d.	n.d.	n.d.
CINDERELLA	0.002	0.04	7.0	12.0	40.0	n.d.	n.d.	n.d.	n.d.	n.d.
CINDERELLA	0.015	0.05	5.0	36.0	40.0	n.d.	n.d.	n.d.	n.d.	n.d.
CINDERELLA	0.180	0.20	9.0	22.0	140.0	n.d.	n.d.	n.d.	n.d.	n.d.
CINDERELLA	0.002	0.04	10.0	20.0	15.0	n.d.	n.d.	n.d.	n.d.	n.d.
CINDERELLA	0.149	0.20	203.0	123.0	398.0	n.d.	n.d.	90.0	121.0	164.0
CINDERELLA	0.062	0.03	2.0	18.0	1.0	1.0	n.d.	88.0	44.0	92.0
GREAT NORTHERN	0.074	0.13	2.0	40.0	1.0	1.0	n.d.	357.0	454.0	668.0
LOWER TATE	0.073	0.05	24.0	33.0	43.0	n.d.	n.d.	51.0	35.0	64.0
LOWER TATE	0.000	0.00	14.0	36.0	50.0	n.d.	n.d.	17.0	12.0	60.0
LOWER TATE	0.054	0.25	6.0	50.0	1.0	9.0	n.d.	1,505.0	5,780.0	2,990.0
LOWER TATE	0.057	0.22	2.0	28.0	1.0	3.0	n.d.	446.0	1,215.0	1,500.0
NIMROD	0.055	0.00	55.0	68.0	77.0	n.d.	n.d.	157.0	289.0	272.0
NIMROD	0.310	0.65	47.0	39.0	97.0	n.d.	n.d.	173.0	324.0	186.0
NIMROD	0.302	0.80	51.0	58.0	18.0	n.d.	n.d.	192.0	339.0	403.0
NIMROD	1.300	2.20	64.0	56.0	10.0	n.d.	n.d.	147.0	147.0	145.0
NIMROD	0.522	0.40	31.0	47.0	61.0	n.d.	n.d.	218.0	189.0	430.0
NIMROD	0.003	0.00	26.0	43.0	61.0	n.d.	n.d.	137.0	138.0	133.0
NIMROD	0.042	n.d.	2.0	50.0	<1.0	<1.0	<10.0	132.0	156.0	326.0
NIMROD	0.010	n.d.	4.0	162.0	<1.0	7.0	<10.0	158.0	678.0	186.0
NIMROD	0.097	0.10	95.0	79.0	82.0	n.d.	n.d.	137.0	114.0	172.0
NORTH STAR	0.241	0.40	15.0	45.0	235.0	n.d.	n.d.	140.0	n.d.	n.d.
NORTH STAR	0.477	0.30	52.0	52.0	20.0	n.d.	n.d.	93.0	312.0	231.0
NORTH STAR	0.344	0.35	56.0	42.0	64.0	n.d.	n.d.	138.0	290.0	254.0
NORTH STAR	0.057	0.00	49.0	37.0	60.0	n.d.	n.d.	49.0	150.0	149.0
NORTH STAR	0.128	0.19	4.0	52.0	1.0	1.0	n.d.	156.0	1240.0	706.0
POORMAN	0.005	1.40	16.0	516.0	1.0	3.0	n.d.	119.0	270.0	226.0
POORMAN	0.063	0.51	4.0	272.0	1.0	1.0	n.d.	43.0	48.0	148.0
RD#2820 ADIT	0.018	n.d.	2.0	74.0	<1.0	2.0	<10.0	49.0	142.0	202.0
RED BUCK	0.011	0.00	39.0	129.0	94.0	n.d.	n.d.	32.0	112.0	86.0
RED BUCK	0.010	0.00	40.0	132.0	201.0	n.d.	n.d.	48.0	98.0	169.0
RED BUCK	0.005	0.00	34.0	122.0	36.0	n.d.	n.d.	32.0	19.0	48.0
RED BUCK	0.002	0.02	2.0	162.0	1.0	1.0	n.d.	7.0	10.0	62.0
TATE	0.001	0.03	13.0	14.0	10.0	n.d.	n.d.	n.d.	n.d.	n.d.
TATE	0.010	0.00	73.0	165.0	173.0	n.d.	n.d.	137.0	129.0	47.0

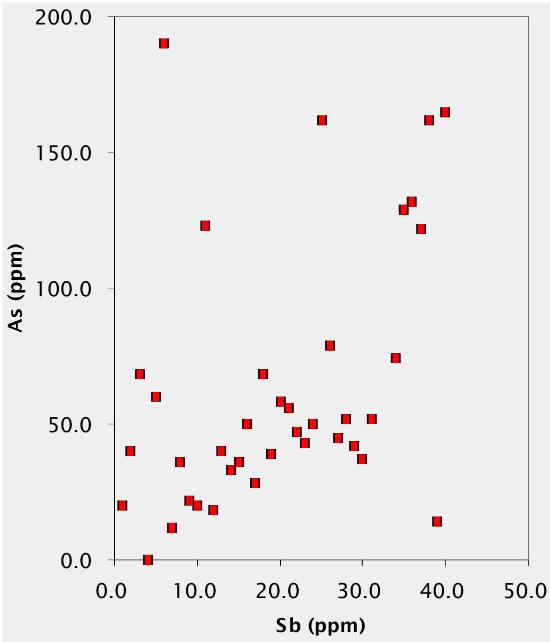

Figure 2. Scattergram of arsenic vs. antimony in the Blue River district. Data from Table 2.

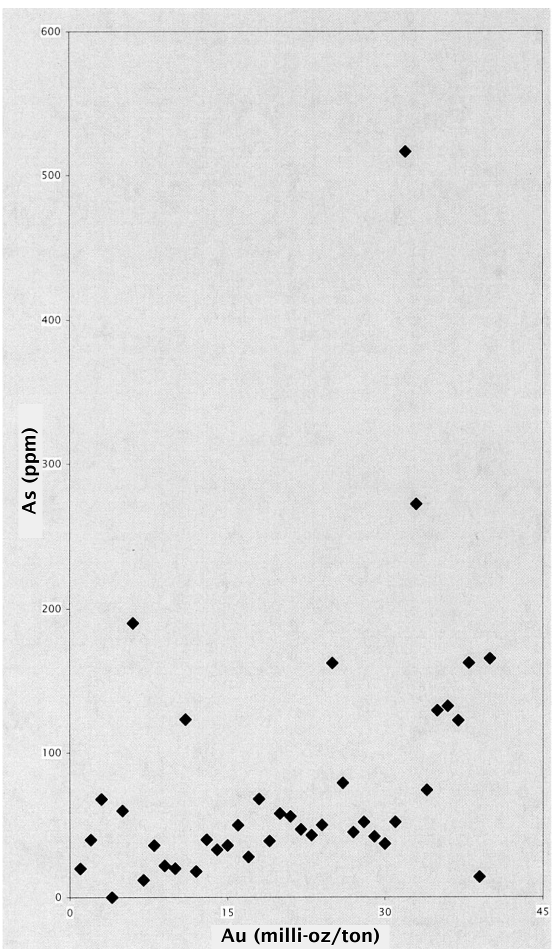

Figure 3. Scattergram of arsenic vs. gold in the Blue River district. Data from Table 2.

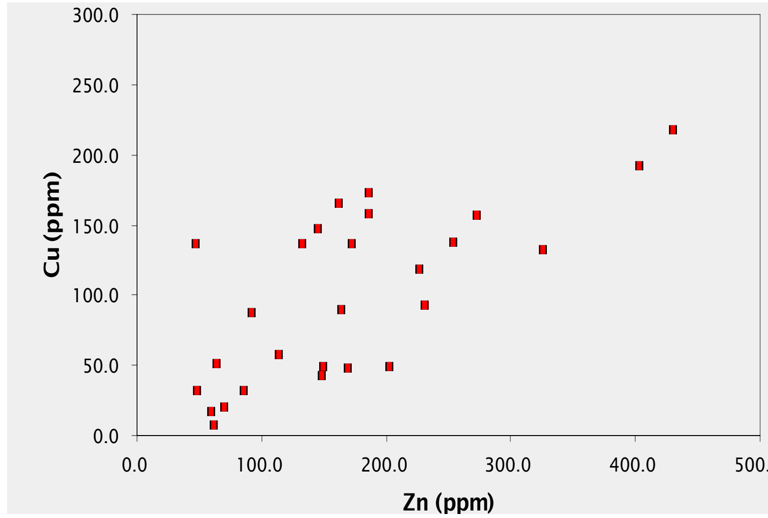

Figure 4. Scattergram of copper vs. zinc in the Blue River district. Data from Table 2.

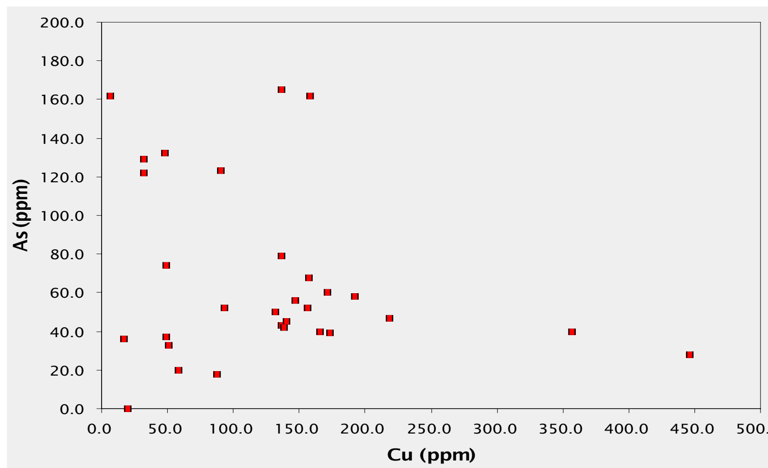

Figure 5. Scattergram of arsenic vs. copper in the Blue River district. Data from Table 2.

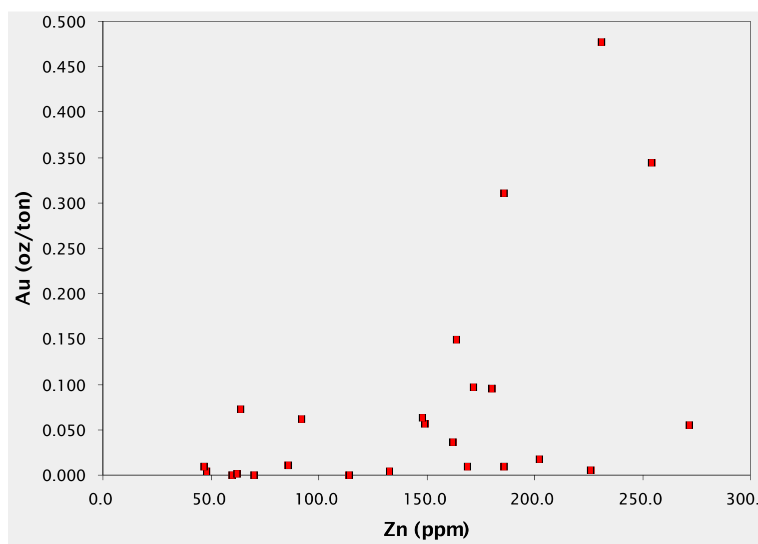

Figure 6. Scattergram of gold vs. zinc in the Blue River district. Data from Table 2.

(Continued from page 74)
of the ridge. Several small stopes were mined in the original workings which are now caved. Five tons averaging 63.0 g/ton gold (1.84 oz/ton) and 33.1 g/ton silver (1.19 oz/ton) were shipped from a surface cut on the Cinderella vein above the main workings (H.E.L. Barton, oral communication, 1977).

The 20- to 61-cm (8- to 24-in.)-wide vein consists of a rubble of wallrock and quartz suspended in a matrix of limonite, manganese wad, and various clays. Argillic alteration occurs in a broad envelope up to 10 m (33 ft) around the vein but may be due to oxidation of a higher grade alteration type. A postmineralization shear follows the hanging wall in the vicinity of the original adits. The vein is completely oxidized. It consists of a single structure at the old workings but splays into three or four anastomosing veins on the ridgetop south of the workings, where it enters the Tate breccia sequence. The south ore zone is located on the main vein near this splay. Gold mineralization occurs both as free gold suspended in the clay-wad matrix and in individual quartz fragments associated with goethite pseudomorphs after pyrite. Carbonates probably made up the bulk of the gangue mineralogy before oxidation. The vein rubble containing abundant manganese and limonite suggests that the carbonate may have originally been ankerite. The outcrop is very similar to the President Mine in the Bohemia mining district, where gold is associated with a quartz phase within a complex dolomite gangue assemblage (Streiff, 1994). Limited geochemistry from the vein indicates that mercury values tend to be higher than normal and arsenic and antimony values higher than the base metals.

Great Eastern

The Great Eastern vein crops out on the north side of the main ridge just below the summit in the northeast quarter of sec. 28. There is no evidence of historical production. The mineralized portion of the vein is hosted by the Tate breccia sequence. The original adit is caved. Several dozer trenches follow the vein south, from the adit to near the top of the ridge. The vein strikes N. 45° W. and dips 70°–85° degrees to the south. The quartz vein averages 0.9 m (36 in.) near the adit, but mineralization pinches out both north and south of the adit. The overall strike length of the quartz-mineralized zone is approximately 122–152 m (400–500 ft). A shear zone extends north and south beyond the mineralized section.

The vein consists of 25–102 cm (10–40 in.) of white quartz containing 1–5 percent very fine grained disseminated pyrite. No adularia or other sulfides have been observed. Oxidation extends only a few meters below the surface. The vein appears to occupy a single fault plane, but exposures are poor. Although some areas of the vein locally assay as high as 10 g/ton (0.34 oz/ton) of gold, no mineable ore shoots have yet been identified. The Great Eastern fault zone can be found in the cutbank of USDA Forest Service (USFS) Road 2820, approximately 152 m (500 ft) northwest of the old adit portal, where the road crosses a small drainage. The 9-m (30-ft)-wide fault zone consists of four to five parallel shears that are 15–102 cm (6–40 in.) wide. Argillic alteration is most intense within the shears and forms a low-grade envelope around the zone. The fault zone is not mineralized at this location. The drainage has formed along the outcrop of the fault zone.

Great Northern

The Great Northern Mine workings are located in NW¼ sec. 28. A USFS road passes between the upper and lower adits. Both adits are completely caved. However, the first 46 m (150 ft) of the lower adit was open for mapping in 1986, including a 12-m (40-ft) crosscut that exposed the western vein. Most of the production, estimated to be approximately 1,200 oz of gold, has been from the western vein (H.E.L. Barton, oral communication, 1977). Various trenches expose the vein south of the main adits.

The Great Northern consists of two parallel veins approximately 30 ft apart striking N. 25° W. and dipping 70°–85° to the east. The vein system is hosted mainly by andesite. The eastern vein is poorly exposed.

The western vein has been heavily stoped underground. It ranges from 30 to 122 cm (12–48 in.) in width and consists of a rubble of andesite wallrock fragments and quartz supported by a limonite-manganese wad clay gouge, similar to the Cinderella vein. A postmineralization shear is located on the hanging wall of the vein in the lower adit. The accessible portions of the veins are completely oxidized. Gold is found within the limonite-manganese wad gouge and as small flakes associated with goethite pseudomorphs after pyrite in the quartz fragments. The gold is probably related to the quartz phase of mineralization. Callaghan and Buddington (1938) report lenses of white calcite without pyrite and minor associated quartz up to 3 m (10 ft) long and 0.31 m (1 ft) wide within a 1-m (3.05-ft) sheared zone in the currently inaccessible lower drift. Abundant calcite and quartz cementing an angular andesite breccia can be found on the lower adit dump. Calcite was also reported in the Cummins adit northwest of the main workings. The calcite is probably the source of the manganese wad in oxidized sections of the veins as suggested by Callaghan and Buddington (1938). Carbonates such as ankerite may also be present.

Nimrod Vein

The Nimrod vein, discovered in 1992 by William Barton during a mapping and sampling program, is located west of the Great Northern. No old workings are present on the Nimrod vein. The Nimrod affords the opportunity to examine an undisturbed, high-grade gold occurrence.

The Nimrod vein strikes N. 42° W. and dips 70°–80° south. In the discovery cut, the vein is hosted by a 9.1-m (30-ft)-wide, fine-grained, porphyritic, sericitically altered dioritic dike. This dike is much more highly altered than the dike hosting the North Star No. 5 vein. The Nimrod vein averages 30.5 cm (12 in.) in width, is completely oxidized at the outcrop, and contains appreciable but erratically distributed free gold. A stockwork of 2.5- to 10.2-cm (1- to 4-in.) veins occur up to 7.6 m (25 ft) into the hanging wall of the main vein. These stockwork veins also strike about N. 40° W. but dip more steeply south, so that they appear to intersect the main Nimrod vein below the outcrop. These small stockwork veins also contain appreciable free gold, including one vuggy quartz vein that produces near-perfect gold octahedra up to 2 mm across. Local pockets or enrichments of gold can be found where several of these small stockwork veins intersect. Post-mineralization faulting has occurred along the Nimrod vein itself. The fault plane locally cuts quartz mineralization and exhibits near-horizontal slickensides.

The main Nimrod vein consists of multiple quartz and quartz-adularia phases containing 1–5 percent goethite pseudomorphs after pyrite. Traces of sulfides have been found, consisting mainly of pyrite, with minor galena and sphalerite in early breccia fragments cemented by later quartz-adularia. Locally, associated anglesite may indicate galena in the unoxidized portion of the vein. However, no cellular boxwork quartz has been found. Early quartz-adularia mineralization cements silicified, sulfide-bearing breccia and hosts free gold associated with goethite pseudomorphs after pyrite. At least two of such quartz-adularia events can be seen . Some silicified vein sediments can be found filling voids in the early phases. A later vuggy quartz event cuts earlier quartz-adularia phases and silicified breccia clasts. Free gold is also present in this vuggy quartz and can be found either in vugs with white clay (kaolin or illite?) or associated with goethite pseudomorphs after pyrite. This gold mineralization can assay as high as 336 g/ton (9.80 oz/ton) of gold and averages about 51 g/ton (1.50 oz/ton) gold. Geochemistry from a limited number of mineralized vein samples indicates that base metal sulfides are roughly twice as abundant as the toxic metals.

The exposure of the Nimrod vein in a lower cut shows a weaker vein with less alteration and more carbonate in the vein. Float between the two main cuts shows some free gold from additional, currently unexposed ore shoots. The quartz-mineralized portion of the Nimrod vein is currently known to be at least 152 m (500 ft). The full lateral extent of the mineralized zone has not yet been determined.

A vein thought to be the Pooler (Parks and Swartley, 1916) is just south of the Nimrod and is probably intersected by the Nimrod under a dump from an old adit. This vein strikes N. 20° W. and dips steeply south. The partly caved adit follows a strong argillically altered shear zone up to 1.5 m (5 ft) wide, hosting narrow, anastomosing quartz veining. Trenches above the adit indicate that the veining widens from 0.3 to 0.6 m (1–2 ft) and consists of vuggy, coarsely crystalline quartz cementing angular tuff breccia fragments. Some goethite pseudomorphs after pyrite are present which locally host free gold. The Nimrod vein either merges with or is offset by this shear zone. The northern extension of this Pooler vein consists of two argillically altered 0.6-m (2-ft) shear zones without quartz mineralization that are exposed in a cut about 180 m (300 ft) north of the partly caved adit.

North Star

The North Star vein crops out approximately 152 m (500 ft) west of the main Great Northern adits, close to the west sideline of sec. 28, near the crest of a small ridge. The vein is exposed in the cutbank of the same USFS road that cuts the Great Northern vein. It has been prospected by several trenches and two short adits which are now caved. The vein assays 8.6 g/ton (0.25 oz/ton) gold across 102 cm (40 in.) in the road cut. Assay values in the mineralized portion of the vein are as high as 25.7 g/ton (0.75 oz/ton) gold. The North Star vein strikes about N. 20° W. and dips steeply southwest. The vein follows a 15.2-m (50-ft)-wide, fine-grained, porphyritic diorite dike which is sericitically altered along the vein margins but otherwise appears fresh. Fine-grained intrusive rock crops out west of the vein in the road cut also. The vein consists of quartz-adularia containing pyrite which cements an angular andesite or diorite breccia fragments plus quartz clasts containing some minor sphalerite. Oxidation is relatively shallow, and sulfides can be found within a few feet of the surface. The mineralized section is approximately 122 m (400 ft) along the strike of a small fault that extends northwest and southeast of the quartz-adularia mineralization. Limited geochemistry from mineralized vein samples indicates that the base metals are twice as abundant as the toxic metals, similar to the Nimrod vein.

Poorman

The Poorman group of patented claims occupies a ridge mainly in the eastern half of sec. 31. The Poorman is included in this discussion of the northern arc of mineralization at Blue River because of the similarity of the mineralization, especially later carbonate mineralization. The main adit is on the east side of the ridge near the boundary between secs. 31 and 32. The first 300 ft of the adit are partly accessible (Figure 7). Numerous outcrops and subcrops of a coarse-grained dioritic plug are present on the southern portion of the

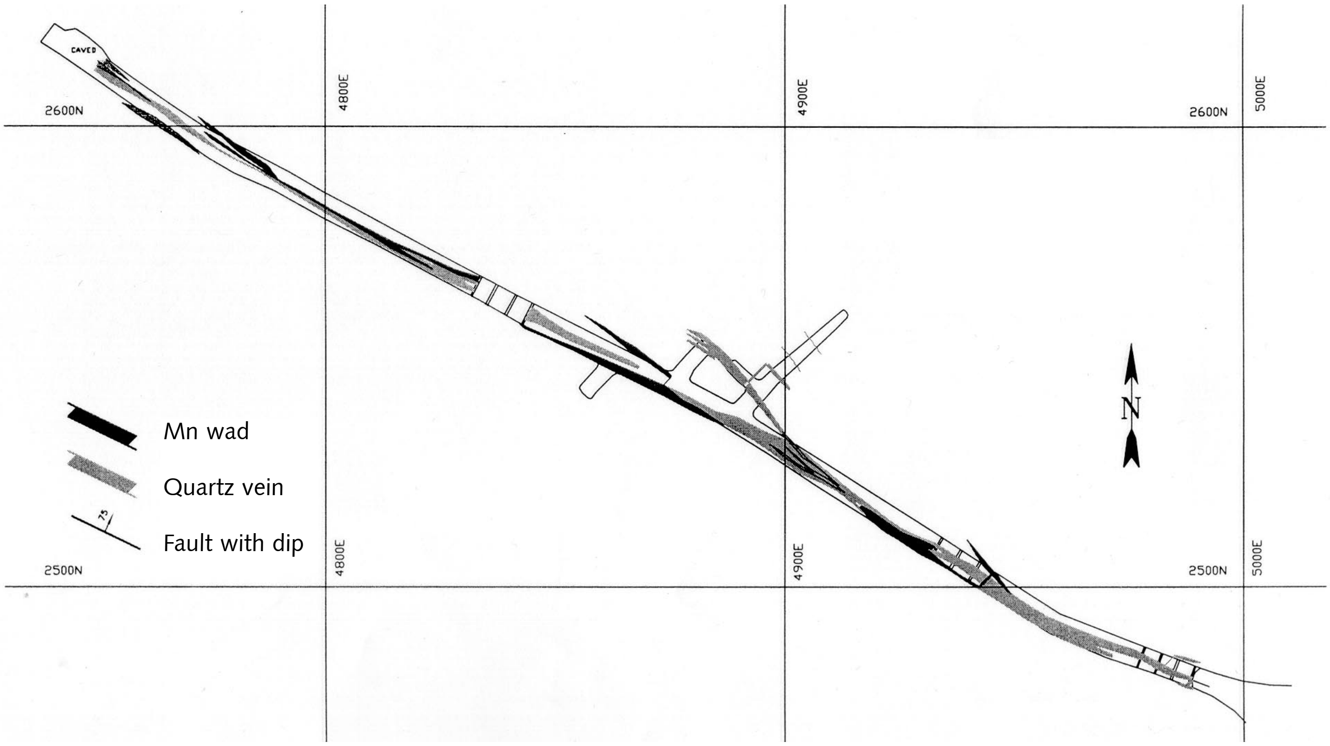

Figure 7. Poorman adit, Blue River mining district, interpretive geology.

claims, while typical andesitic flows and pyroclastics occur on the northern half of the claims.

The main adit drifts on a vein striking about N. 50° W. and dipping steeply south. Several crosscuts in the drift show that the vein occurs on a fault contact between the hanging wall of diorite and a footwall of andesites intercalated with some tuff. The vein consists of an early stage of massive, vuggy quartz containing a few percent of oxidized to partly oxidized fine-grained goethite pseudomorphs after pyrite, cut and offset by a later oxidized carbonate mineralization. Both types of mineralization pinch and swell from <10 cm up to 1.5 m (4–60 in.) wide. The later carbonate mineralization consists of the typical manganese-limonite wad and clay-supported rubble of volcanic rock and earlier quartz. Only a trace of original calcite remains in the vein locally. The carbonate nature of this later mineralization is inferred from the abundance of manganese wad. Grab and channel samples of the earlier vuggy quartz and pyrite mineralization indicate low gold grades, up to 1.7 g/ton (0.050 oz/ton). Channel samples of the later carbonate mineralization indicate gold grades as high as 51 g/ton (1.50 oz/ton). Although Parks and Swartley (1916) report sulfides, the only sulfide found at the Poorman is pyrite. Base metal sulfides have not been seen, nor is much boxwork quartz present in the oxidized portions of the vein. Geochemical analyses of two samples show relatively low base metals.

Red Buck

The Red Buck workings are near the center of the eastern half of sec. 29. The caved adit is just above the USFS Road 2820. Several caved trenches and shallow shafts are on the hillside above the adit to the top of the small ridge, where some old dozer trenches cut the zone. The best exposure of the Red Buck vein system is found in the road cut of two USFS spur roads. One road is on the west side of the ridge near the summit. The second road (682) is west of the first in a draw. A broad zone of alteration hosted by lapilli tuff is exposed and contains two main quartz veins and numerous small quartz stringers. This zone is at least 30.5 m (100 ft) wide.

Most of the old workings are centered on the more northern of the two quartz veins. This vein strikes about N. 60° W. and dips steeply northeast in the road cut. However, this may be a local roll in the vein. The quartz vein is from 0.3 to 1.0 m wide (1–3 ft) and consists of quartz cementing angular breccia clasts of lapilli tuff. The quartz is vuggy and shows some colloform banding. The vein is completely oxidized with moderate limonite stain and traces of goethite locally. Numerous quartz stringers 0.5–1.5 cm (0.2–0.6 in.) across are present in the hanging wall of the vein. The southern vein is parallel to the main vein and about 22 m (75 ft) south. This southern vein is similar in composition to the main vein but is narrower (0.2–0.5 m or 10–18 in. wide) and dips steeply to the south. The lapilli tuff wallrock hosting both veins is bleached, argillically altered and limonite-stained for up to 15 m (50 ft) around the veins. This broad zone of alteration does not host significant gold mineralization. Geochemically, values of base metals are significantly lower at the Red Buck than in most other veins in the northern arc of mineralization. It is unclear why such a broad zone of alteration should contain such insignificant geochemical values.

Tate Mine

The main Tate workings are almost in the center of E½ sec. 28, near the top of the ridge. USFS Road 1510 cuts the Tate vein system just below the main adits and offers good exposures of both the Tate veins and the volcanic breccia host rock. The adits are all caved. Old workings, in elevation approximately 91 m (300 ft) below the main workings, explore a complex system of intersecting northwest and northeast veins, which appear unrelated to the main Tate vein system. One adit in this lower group of workings is still accessible (Figure 8). Stafford (1904) listed this property as the Noonday.

The main Tate workings explore an anastomosing vein system striking due north and dipping nearly vertical. Several parallel to subparallel veins, 30.5–122 cm (12–48 in.) wide and consisting of quartz-adularia with minor pyrite, are exposed by trenching. These veins are hosted by the Tate breccia sequence. The host rock has probably influenced the anastomosing form of the Tate vein. The breccias are argillically altered near the veins and contain a pyritization halo up to 6.1 m (20 ft). Sericitic alteration, if present, has been masked by weathering. Several of the individual volcanic breccia units are mineralized with chalcedonic quartz, pyrite, and some hematite. This mineralization is probably deuteric in nature. These mineralized flows do not contain significant gold values.

The central Tate vein consists of colloform quartz and quartz-adularia with 1–10 percent goethite pseudomorphs after pyrite that cements angular breccia clasts of tuff or andesite from the breccia unit. Some weathered sphalerite was noted by Callaghan and Buddington (1938). The colloform banding consists of outer paired sequences of quartz-adularia and an inner late-stage vuggy quartz that tends to wrap around individual breccia clasts. Postmineralization faulting has left near-horizontal slickensides on the hanging wall contact of this vein. The movement appears to be right-lateral. Free gold has been found either associated with goethite pseudomorphs after pyrite in the quartz-adularia or as vug fillings in the late quartz event. One sample was found with free gold attached to goethite pseudomorphs along a wallrock contact. A sample across the vein assayed 15.4 g/ton (0.45 oz/ton) of gold.

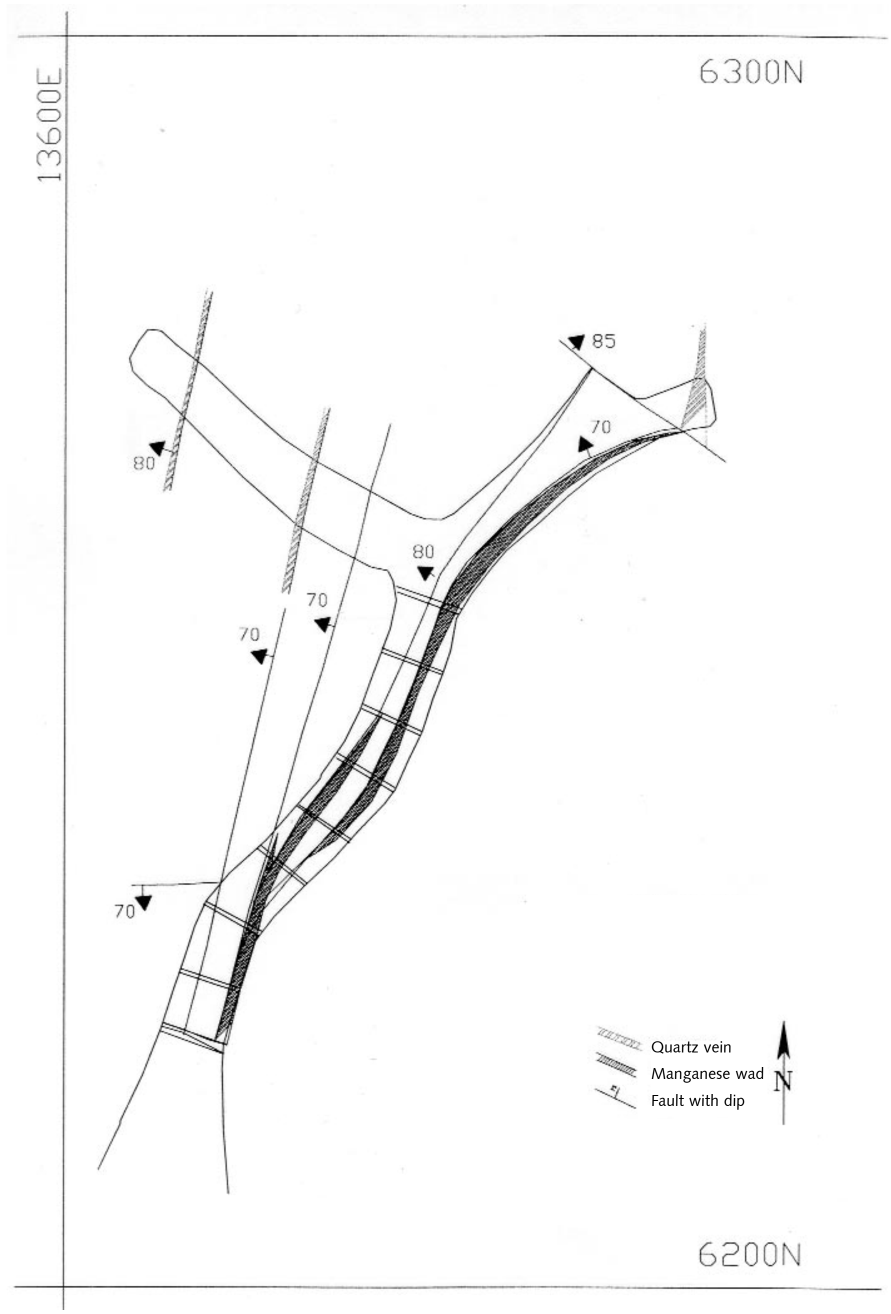

Figure 8. Lower Tate adit, Blue River mining district, interpretive geology.

The quartz-adularia mineralization in the main Tate fault system has a strike length of at least 122 m (400 ft). The mineralization pinches out to the south. The extent of the mineralization to the north is unknown. A similar-looking quartz-adularia vein with angular breccia clasts crops out on the ridgetop about 100 m (300 ft) east of the Tate workings, where a coarse-grained dioritic dike, striking about N. 20° E., crosses the ridge and is cut by the vein. This vein strikes roughly N. 30°–40° W., parallel to the Cinderella vein. A wide zone of alteration in the road cut of USFS Road 1510, hosted by a coarse-grained diorite, contains little or no quartz. The lower workings, which are about 91 m (300 ft) in elevation below and to the south of the main Tate adits, explore a complex area of narrow, intersecting northwest and northeast veins. The upper adit, as described in Callaghan and Buddington (1938), is still accessible (Figure 8). It drifts approximately 24 m (80 ft) on a N. 40° E. shear zone that consists of brecciated andesite with abundant gouge and manganese wad containing some quartz fragments. Several parallel quartz veins averaging 10.2 cm (4 in.) in width are exposed by a north-trending crosscut. The first 9.1 m (30 ft) of the drift has caved and has been retimbered. A sample at the portal assayed 5.1 g/ton (0.15 oz/ton) of gold. The bulk of the adit, which was sampled on 5-ft centers, shows very low gold values, however. The northeast shear is cut off at the face of the drift by a 10.2-cm (4-in.) quartz vein trending N. 7° E. and dipping nearly vertically. Drag folding of the shear indicates a near-horizontal right-lateral movement of the north-trending quartz vein.

Treadwell Mine

The Treadwell Mine is located in the lower part of sec. 21, near the sec. 28 line. The old adit is caved and is located about 15 m (50 ft) above USFS Road 2820. This road cuts the Treadwell vein and exposes it in the road cut.

The Treadwell consists of a 1.8- to 3.1-m (6- to 10-ft)-wide shear zone trending N. 40° W. and dipping 75°–80° southwest. The shear contains heavy gouge and consists of argillically altered volcanic rocks with moderate (3–5 percent) pyrite. No other sulfides are present. Oxidation is shallow, with sulfides exposed in the road cut along with minor quartz stringers. Some calcite and very minor quartz can be found on the dump of the adit. No significant gold values were found. It is possible that the Treadwell shear may be the same fault that hosts the Cinderella mineralization to the southeast.

Union Mine

The Union Mine is located in sec. 2, T. 16 S., R. 4 W., in the headwaters of Simmonds Creek on the extreme western side of the district. The vein system is prospected by two main levels and numerous short adits and prospect pits. The upper adit, approximately 100 ft above the lower or crosscut adit, drifts along the main Union vein for about 400 ft. Several crosscuts expose parallel veins. The lower crosscut adit is sketched and described in Callaghan and Buddington (1938). The 1,200 ft of development reported by Callaghan and Buddington (1938) is on two levels, not one. The lower level map in their report scales out to be only approximately 800 ft on that level. Both adits are open but in poor condition. The Republican Mine reported by Diller (1900) is the same as the main workings on the Union claims. The Happy Jack property described by Stafford (1904) is now part of the Union group of claims.

The Union vein system consists of a broad zone of alteration hosting a set of subparallel sheeted quartz veins ranging from a few millimeters up to ~1 m across. The Union zone is similar to the Red Buck zone, except the host rock at the Union is a fine-grained andesite instead of a lapilli tuff. Argillic alteration is more restricted at the Union and forms overlapping halos around the principal veins and fault zones.

The main Union vein strikes N. 40°–45° W. and dips 70°–80° to the south. A postmineralization fault zone, consisting of about 6–12 in. of clay and granular andesite fragments plus some quartz clasts, forms the footwall of the quartz vein. The fault has formed very distinct slickenside walls on each side of the gouge. The quartz vein consists of quartz (and some adularia?) containing 1–2 percent pyrite which has oxidized to goethite pseudomorphs in many areas. The vein consists of a single quartz vein that locally breaks into anastomosing sets of stringers that join back into a single vein. Angular, equant andesite breccia clasts are commonly hosted within the vein. Crustification and vuggy, coarsely crystalline quartz around breccia clasts is common. Gold values appear erratically associated with the pyrite. The sulfides reported by Callaghan and Buddington (1938) must refer to pyrite, the only sulfide found at the Union Mine.

A subparallel vein, narrower than the main vein, is exposed for several hundred feet in the upper adit. This vein is located ~30–40 ft in the hanging wall of the main vein and is similar to the main vein. It also has associated postmineralization faulting along the footwall. The lower adit map from Callaghan and Buddington (1938) indicates several subparallel veins in both the hanging wall and the footwall of the main structure. Although mapping is mostly incomplete, there is a suggestion that the smaller veins located in the hanging wall and footwall may not be parallel but instead cross each other at low angles (<15°). There is also some evidence that suggests that the Union may consist of an en-echelon set of quartz veins.

DISCUSSION

Crustification, colloform banding, anomalous antimony, arsenic and mercury geochemistry, silicification, vein sediments, and complex anastomosing vein morphology in the northern part of the district are characteristic of epithermal deposits. Epithermal characteristics in other Cascade districts, particularly the Bohemia district, have been previously reported (Lutton, 1962; McChesney, 1987; Katsura, 1988; Streiff, 1994). The complex vein morphologies, more extensive silicification, carbonates, general lack of significant base metals, and auriferous pyrite suggest that the northern Blue River veins are an upper level epithermal system, higher in relative elevation than the Bohemia or North Santiam epithermal systems. The relatively short strike lengths of the mineralization indicate a smaller system than in some of the other Cascade districts such as Bohemia. The Cascade district most similar to the northern Blue River district is the Quartzville district, which also contains fewer base metal sulfides and relatively coarse, pocket-type gold.

Zoning appears to be an important ore-controlling feature in the Blue River district. A central copper-rich base metal zone, represented by the Rowena Mine, is surrounded to the west by an arc of zinc-lead-copper base metal veins. Base metal sulfides decrease in abundance toward the north, while occurrences of auriferous pyrite in quartz and pockets of coarse gold increase. A northern, outer carbonate zone interfingers with an auriferous pyrite-quartz zone. This carbonate mineralization often appears to cut earlier quartz-adularia veining. Gold mineralization appears to be most significant in the outer base metal sulfide and auriferous pyrite zones. This may be due in part to an arc of later quartz-adularia-pyrite mineralization that overlaps and overprints earlier mineralization. The Blue River veins tend to dip south toward the Nimrod stock, and zoning appears to arc northward away from the stock, strongly implying that the Nimrod stock does control mineralization in the district. Zoning of the Blue River district plus extensive pyritization and argillic alteration of the stock itself suggests that the Blue River area may host a porphyry copper system at depth (Power and others, 1981; Power, 1984). Mineral zonation probably consisted of "shells" or "domes" over the Nimrod stock prior to erosion of the volcanic pile.

Electrum-bearing pyrite is the major gold occurrence in the northern part of the Blue River district and is contained within stage 2 veining only. This suggests that perhaps stage 2 is an upper level quartz-pyrite epithermal event, while stage 1 represents deeper base metal epithermal mineralization below the elevation of precious metals mineralization. Deeper stage 1 mineralization being overprinted by shallower stage 2 mineralization is suggestive of an evolving hydrothermal system that collapsed in upon itself over time as the heat source for hydrothermal activity cooled. This is similar to the Bohemia mining district, where vein paragenesis, mineral associations, and geochemistry all imply a collapsing system over time.

The quartz-adularia veins of the Blue River district fit into a quartz-adularia epithermal model. Argillic alteration consists of illite grading outward into montmorillonite clays. Thermodynamics of these clay minerals suggest that the Blue River veins were deposited by relatively low temperature (<250°C) and moderate ph solutions (4–6). Episodic boiling suggests shallow depths.

The gold mineralization tends to be "pockety" or very erratic and occurs in very small ore shoots with limited strike length. Most of the significant gold mineralization is found near the center of zones of relatively short strike-length (<152 m or 500 ft) containing quartz-pyrite mineralization which occupies small right-lateral faults with strike lengths up to several hundred meters. Callaghan and Buddington (1938) describe the vein in the lower drift of the Evening Mine (p. 118) as pinching out or narrowing toward the face of the drift into a shear zone of altered rock without quartz mineralization. This is typical of the lenticular nature of the quartz mineralization over several hundred meters in the Blue River fault systems. These zones of quartz mineralization are often near fault intersections, especially between north- and northwest-striking faults as in the Lucky Boy Mine. The mineralization tends to be on a limb of one of the faults, often 100 m or so from the actual fault intersection. This "diamond pattern" of conjugate vein systems is very noticeable in the Cinderella-Tate and Great Northern areas. Another favorable location for gold mineralization is proximal to dioritic dikes, such as at the North Star, Nimrod, and Tate Mines. Some veins follow and are hosted by dikes, such as the North Star No.5 and Nimrod veins. Careful geologic mapping will probably reveal additional gold mineralization.

ACKNOWLEDGMENTS

The manuscript was reviewed by Helen Robinson. I wish to thank my colleague Bill Barton for his companionship on long treks through the district; thoughtful geologic observations and discussions, and his hospitality during my visits to the Blue River district. Many thanks also to his wife Barbara, who put up with both of us.

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BOOK REVIEW

Fossil Shells from Western Oregon. A Guide to Identification, by Ellen J. Moore, published 2000 by Chintimini Press, Corvallis, Oregon; 131 pages, $12. [See also page 68.]

Ellen Moore has done an outstanding job on her new book, *Fossil Shells from Western Oregon*. It is a book necessary for anyone who beachcombs or has any curiosity about shells.

A nice, easy-to-understand style, along with lucid descriptions, make Moore's book especially good for nonprofessional paleontologists.

The book is roughly divided into four parts. Introductory chapters on geologic time, fossils, geologic processes, and history conclude with glances at fossils occurring elsewhere in Oregon, those older than Tertiary in the western part of the state, and fossils other than shells from western Oregon. The second portion of the book has sections arranged by location, northwest, west-central, and southwest. These areas are in turn subdivided by geologic formations arranged from oldest to youngest. The third portion of the book is organized by age, beginning with Eocene and ending with Pleistocene, while the final part is "Geologic Excursions" (field trips) to specific regions of the coast such as Cape Kiwanda or Depoe Bay.

At the core of this book are excellent descriptions and illustrations of diagnostic as well as common invertebrate marine species from the Coast Range and Willamette Valley. For this, the author draws on her own considerable knowledge, having authored many of the significant publications on Oregon Tertiary invertebrates. Abundant photographs and diagrams throughout contribute to the ease of understanding.

Expanded from her earlier work, *Fossil Mollusks of Coastal Oregon*, the glove-compartment-size book is an indispensable tool for professional and nonprofessional paleontologists in Oregon. At the price, it is a definite bargain. Fossil Shells from Western Oregon can be ordered from Moore at Chintimini Press, 3324 SW Chintimini Avenue, Corvallis, Oregon, 97333, for $12, which includes postage.

—Elizabeth L. and William N. Orr
University of Oregon

[Editor's note: Copies available from the Nature of the Northwest Information Center in Portland—see page 65— or any DOGAMI field office—see page 50—are signed by the author.]

(Continued from page 50)

Released July 14, 2000:

Geologic Map of the Summerville Quadrangle, Union County, Oregon, by M.L. Ferns and I.P. Madin, 1999. Geological Map Series GMS-111, map scale 1:24,000, 23 p. text, $10.

The new geologic map encompasses one of the most spectacular and youthful rangefront fault systems in northeastern Oregon and the dramatic escarpment that culminates in Mount Emily with its commanding view of the valley. The fault zone may have been active in the past 10,000 years and may be capable of producing earthquakes up to magnitude 7.

Mapped landslide deposits around the flanks of Mount Emily point toward another geologic hazard in the quadrangle. The map also includes information from water wells to help identify the important groundwater resources in the area.

Crushed rock is the only mineral resource mined from the Summerville quadrangle, but the new map shows that sand and gravel resources exist as well as low-temperature geothermal resources.

Two adjoining maps were completed and published earlier: of the Tucker Flat quadrangle (GMS–110, 1997) and the Fly Valley quadrangle (GMS–113, 1998). □

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Places to see—Recommended by the Oregon Department of Geology and Mineral Industries:

Sheep Rock, one of the landmarks in the John Day Fossil Beds National Monument, Grant County (National Park Service photo, negative no. 370).

Below a cap of erosion-resistant basalt, eroded channels lead down throught 1,000 ft of ancient volcanic ash to the John Day River. This ash, now turned to claystone, contains the fossils of plants and animals from 25 million years ago. Sheep Rock is located 2 mi north of the junction of U.S. Highway 26 and Oregon Highway 19, west of Dayville, close to the John Day Fossil Beds National Monument headquarters at the Cant Ranch on Highway 19.