A field guide to mid-Tertiary paleosols and paleoclimatic changes in the high desert of central Oregon—Part 2

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This field trip guide was prepared for the Theme Meeting of SEPM (Society for Sedimentary Geology) to be held August 15-18, 1991, in Portland, Oregon. The theme of this meeting is "Continental margins—sedimentation, tectonics, eustasy, and climate." Part 1 of the guide for the two-day field trip appeared in the last (May 1991) issue of *Oregon Geology* and ended with the return to John Day to spend the night. This second part presents the guide for the second day and the conclusion of the paper. *—Editor*

EXCURSION ITINERARY FOR SECOND DAY

Leave John Day heading west on U.S. Highway 26. The valley of the John Day River is flanked to the south by Triassic and Jurassic schists and to the north by a Miocene and Pliocene sequence of white to gray silty claystones and volcanic ashes, within which the Rattlesnake ash-flow tuff forms a prominent scarp. Picture Gorge Basalt in a gorge south of the highway at a point 16 mi west of John Day has yielded a K-Ar age of 15.8 m.y. (Evernden and others, 1964, corrected by method of Dalrymple, 1979). The overlying gray to brown, clayey Mascall Formation is also middle Miocene in age. The prominent rhyodacitic ash-flow tuff of the Rattlesnake Formation in this area has a corrected radiometric age of 6.6 m.y., so that the tuffaceous sediments enclosing it are late Miocene and Pliocene in age. This ash-flow tuff represents a catastrophic volcanic event and is here over 100 mi distant from its source in the Harney Basin south of Burns (Oles and others, 1973).

In the river bank near the roadside rest stop that is immediately west of the bridge across the John Day River about 11 mi west of Mount Vernon is a locality for fossil leaves in the middle Miocene Mascall Formation (Chaney, 1948; Chaney and Axelrod, 1959). The ten most common species at this locality, comprising 78 percent of the flora, are (in order of decreasing abundance): Swamp cypress (*Taxodium distichum*), black oak (*Quercus pseudolyrata*), hickory (*Carya bendirei*), sycamore (*Platanus dissecta*), black oak (*Quercus merriami*), maple (*Acer bolanderi*), redwood (*Sequoia heerii*), maidenhair tree (*Ginkgo adiantoides*), box elder (*Acer negundoides*), and elm (*Ulmus speciosa*). This mixed broadleaf and conifer assemblage is an indication of cool-temperate, seasonal conditions. Paleoclimate was still very different from the high-desert climate of the present day and was more like the present-day climate of southern Indiana or Ohio. By using foliar physiognomic data from the Mascall flora, Wolfe (1981b) estimated a mean annual temperature of 9° to 10 °C and a mean annual range of temperature of 12° to 23 °C. Winters may have been consistently snowy by this time.

About 4 mi west of Dayville on Highway 26, look for and turn onto an unsealed road leading southwest onto the high terrace.

STOP 9. Picture Gorge overlook

One-half mile south of U.S. Highway 26 on Day Creek Road, 4 mi west of Dayville (NE¼NE¼ sec. 29, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle), we find a spectacular view of Picture Gorge and overlying sedimentary rocks (Figure 6). The Gorge itself is formed of tholeiitic flood basalts of the middle Miocene Picture Gorge Basalt of the Columbia River Basalt Group. Here the flows dip to the southeast and have been deeply incised by the John Day River, which was an antecedent stream to this tectonic deformation. Although the scene makes a fine photograph, this is not the origin of the name Picture Gorge: that name is based on the early discovery of Indian pictographs within the gorge.

Overlying the basalt with a slight angular discordance is a thick sequence of gray and brown tuffaceous alluvial sediments of the Miocene Mascall Formation. In places, diffuse dark layers of paleosols and light-colored, prominently outcropping sandstones of paleochannels can be seen. The formation onlaps tilted basalts, so that some deformation had been initiated during Miocene time. The blocky, mesa-forming unit overlying the Mascall Formation is welded tuff of the Pliocene Rattlesnake Formation. It onlaps the Mascall Formation with an angular discordance that resulted from continued Pliocene tilting.

Just over the bank here, in the Mascall Formation, Downs (1956, highway locality) reported fossil mammal remains including three-toed horse (*Merychippus seversus*) and pronghorn antelope (*Blastomeryx, Dromomeryx*) typical of middle Miocene faunas (Barstovian North American land mammal "age"). These are considered grassland-adapted mammals because of their high-crowned teeth and elongate limbs with hard hooves. Such open vegetation is also indicated by the thin, gray, calcareous paleosols visible in badlands of the

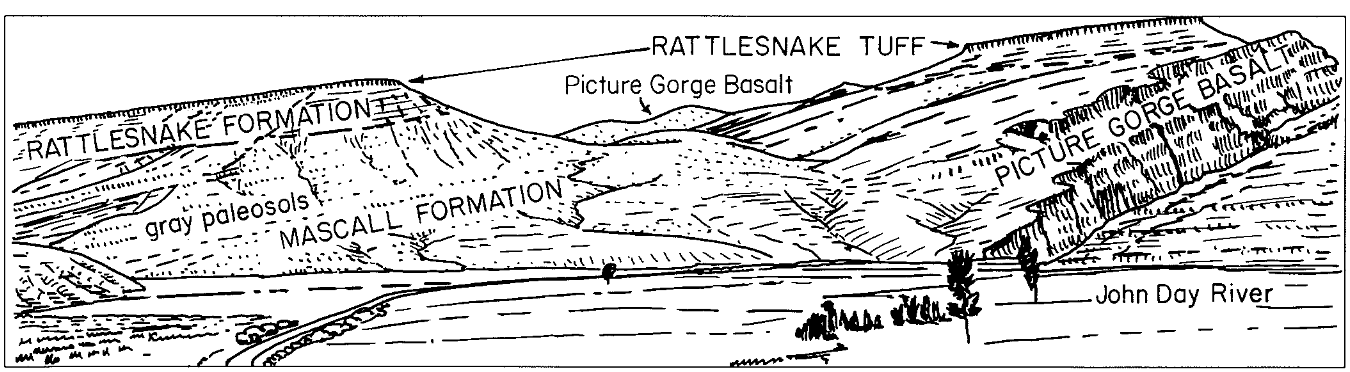

Figure 6. Geological sketch of Picture Gorge, viewed from the east.

Mascall Formation to the west, although it would not have been suspected from the Mascall flora already discussed from east of Dayville (Chaney, 1948). That broadleaf forest and swamp vegetation was probably widespread around lowland lakes and streams, and its fossil leaves accumulated and were preserved in them. On dry, grassy parts of the landscape, however, plant material decayed in the oxidized, calcareous soil where bones of animals accumulated.

The Rattlesnake Formation in Cottonwood Creek to the west also has yielded fossil mammals (Merriam and others, 1925), principally one-toed grazing horses (*Pliohippus spectans*) and three-toed horses (*Cormohipparion occidentale*) of late Miocene age (Hemphillian land mammal "age").

En route

Return to Highway 26 and continue west into Picture Gorge.

STOP 10. Picture Gorge Basalt and paleosols

Road cuts 0.5 mi northwest of the entrance to Picture Gorge (NW¼SW¼ sec. 17, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle) show prominent red paleosols dividing flows of the Picture Gorge Basalt of the middle Miocene Columbia River Basalt Group. Red paleosols are widespread between flows in this area and allow flows to be distinguished readily. The paleosol profile just above road level is almost 2 m thick and appears to have been developed on a scoriaceous upper portion of the flow. The top of the profile is clayey and contains sparse root traces and strongly weathered fragments of basaltic scoria. This kind of clayey soil is formed over a considerable period of time (several tens of thousands of years) under woodland or forest in humid to subhumid climates (Retallack, 1990). Current radiometric estimates on the geological time represented by the Columbia River basalt allow periods on the order of 20,000 years between eruptions (Hooper and Swanson, 1990). These reddish interflow zones have been attributed entirely to baking of flow tops by the succeeding flow. While baking may have hardened and reddened the paleosols and added zeolites and other highly alkaline minerals to them, it is unlikely to have generated their clayey texture, soil structure, primary oxidation, root traces, and other weathering features.

En route

Continue on Highway 26 until it turns off to the west; then follow Highway 19 to the north.

STOP 11. Sheep Rock Overlook

Sheep Rock is a prominent conical hill, and an overlook is well signposted along Oregon Highway 19, north of its intersection with U.S. Highway 26 in Picture Gorge (NW¼NW¼ sec. 8, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle). This hill is capped by middle Miocene Picture Gorge Basalt of the Columbia River Basalt Group (Figure 7). Also exposed is Oligocene to early Miocene John Day Formation, which is here divided into characteristically colored members (Fisher and Rensberger, 1972). These colors reflect paleosols of different paleoenvironments that have suffered different kinds of alteration after burial. The division of the John Day Formation into distinctly colored members as seen here is not possible in all locations where the formation crops out.

At the base of the exposed sequence along the river to the north are red claystones of the Big Basin Member of the John Day Formation. This is presumably early Oligocene in age, but only a fragment of entelodon jaw (*Archaeotherium*) has been reported at this stratigraphic level (Evernden and others, 1964). These red noncalcareous paleosols were not generally suitable for the preservation of bone. White bands interbedded with the red claystones are fresh beds of volcanic ash. These ashes represent the parent material of most of the paleosols of the John Day Formation, here oxidized to brown or red clay under former humid forest and probably reddened further by dehydration of ferric hydroxides (as commonly documented for paleosols; G.S. Smith, 1988; Retallack, 1990). As climate dried during the Oligocene and Miocene, this ash was less and less altered within soils under drier and sparser vegetation.

Above the red beds are the green calcareous claystones and siltstone of the Turtle Cove Member. As already discussed (Stop 8), fossil soils, mammals, snails, and hackberries at this stratigraphic level are evidence of a lowland mosaic of woodland and wooded grassland.

The prominent dark-brown unit halfway down the slope of Sheep Rock is a thick and extensive rhyolitic welded tuff. This represents a catastrophic eruption of a large ash-flow tuff from a vent in the Ochoco Mountains to the west (Robinson and others, 1984).

Buff-colored siltstones near the top of the sequence are the Kimberly Member of the John Day Formation. These alluvial deposits contain numerous brown calcareous paleosols, probably formed under a mosaic of woodland and wooded grassland.

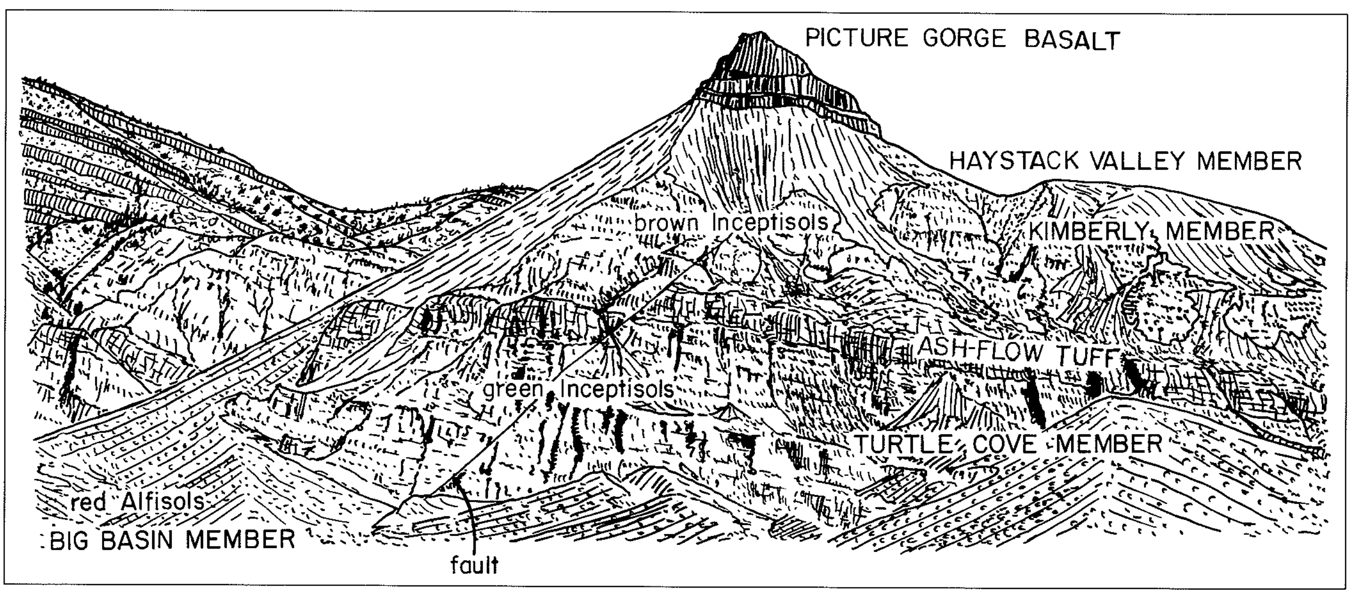

Figure 7. Geological sketch of Sheep Rock, viewed from the west.

The mammalian fauna of the Kimberly Member is diverse and includes hoglike oreodons (*Promerycochoerus superbus*), camels (*Paratylopus cameloides*), and tapirs (*Protapirus robustus*). This new fauna represents a significant advance in adaptations for open country, as in similar faunas in other areas of North America (Hunt, 1985) of early Miocene age (late Arikareean and Hemingfordian land mammal "ages"; Rensberger, 1983; Prothero and Rensberger, 1985).

STOP 12. Cant Ranch Visitor Center

North of Sheep Rock Overlook is the Visitor Center for John Day Fossil Beds National Monument at the old Cant Ranch (NE¼SW¼ sec. 6, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle). Displays on the geology and paleontology of the mid-Tertiary sequence exposed in the John Day Valley and a fossil preparation laboratory are worth a visit. Maps and publications on the natural history of this region can be purchased here.

En route

Continue back south on Highway 19 into Picture Gorge, then west on U.S. Highway 26.

STOP 13. Mascall paleosols

A long, low road cut south of U.S. Highway 26, 2 mi west of its junction with Oregon Highway 19 (SE¼NE¼ sec. 24, T. 12 S., R. 25 E., Picture Gorge 15-minute quadrangle) reveals alluvial sediments and volcanic ash of the Miocene Mascall Formation. Remains of three-toed horse (*Merychippus seversus*) have been found in this formation 0.3 mi southwest of here (Rock Creek locality of Downs, 1956). White volcanic ash forms prominent, white bedded units, 3 m above the base of the cut. This ash was derived from Miocene volcanoes in the present area of the Western Cascades. Underlying the ash are three moderately developed paleosols (Inceptisols). They have thin (10 to 20 cm), yellowish-brown upper (A) horizons, with fine soil structure (granular peds of U.S. Department of Agriculture, 1975), over light-yellowish, weakly calcareous subsurface (Bk) horizons.

Calcareousness of the profiles is compatible with a subhumid climate. Their simple profile form and pattern of root traces are most like those found now under wooded grassland, a conclusion supported by dental and cursorial adaptation of mammal fossils found in the Mascall Formation. Topographic relief of these paleosols was probably low, but they show no mottles or restriction of rooting depth that might indicate waterlogging. Their parent material was air-fall ash from the Western Cascades mixed with rock fragments of local Mesozoic schists and sandstones. The time for formation of these paleosols was on the order of several thousands of years, considering the destruction of bedding in them and the fact that none show well-developed calcareous nodules.

En route

Some additional exposures of both the Mascall and Rattlesnake Formations can be observed in the hills to the west along U.S. Highway 26. Here, bluff and creek exposures of the Rattlesnake Formation have yielded the following fossil mammals (Merriam and others, 1925; MacFadden, 1984): Squirrel (*Spermophilus gidleyi*), single-toed horse (*Pliohippus spectans*), three-toed horses (*Cormohipparion occidentale* and *Hippotherium sinclairi*), rhinoceros (*Teleoceras* sp. cf. *T. fossiger*), peccaries (*Platygonus rex* and *Prosthennops* sp.), camel (Camelidae), bear (*Indarctos oregonensis*), and cat (Felidae).

Picture Gorge Basalt crops out 3.7 mi west of the junction of Highways 19 and 26 and includes a photogenic outcrop of columnar jointing. At a point 10 mi west of the junction, the road enters a narrow valley with exposures of lahars and flows of the Clarno Formation. As the road climbs up toward Keyes Summit, it passes upsection through Picture Gorge Basalt to Rattlesnake ash-flow tuff. Descending from Keyes Summit, the road passes down again through John Day Formation and then, in a number of large road cuts excavated in 1989, through magnificent series of volcanic breccias, plugs, and flows of the Clarno Formation.

Just west of Mitchell and north of the highway is Bailey Butte, a steeply-dipping andesite sill of the Clarno Formation. The sill intrudes the Hudspeth Formation, a middle Cretaceous (Albian to Cenomanian) marine shale. Ammonites (*Brewericeras hulensis* and *Leconteites lecontei*) can be found in calcareous nodules of the Hudspeth Formation a few miles north of here (Jones and others, 1965). The Hudspeth Formation interfingers with submarine fan conglomerates of the Gable Creek Formation in this area (Kleinhans and others, 1984).

Along U.S. Highway 26 and 3 mi west of Mitchell, look for a well-marked turnoff and take it north to the Painted Hills Unit of John Day Fossil Beds National Monument. At 2.4 mi north of Highway 26, the paved road to Painted Hills passes from Clarno Formation to the disconformably overlying John Day Formation, which includes an alkali olivine basalt 3.3 mi north of the highway.

The entrance to the Painted Hills Unit is southwest across Bridge Creek where the sealed road surface ends. Continue past the turnoff to the Visitors Center and into the colorful badlands, then turn south along a ridge to Lookout Point.

STOP 14. Painted Hills Overlook

From Lookout Point (SE¼NE¼ sec. 1, T. 11 S., R. 20 E., Painted Hills 7½-minute quadrangle) and several places on the way to it, spectacular outcrops of the color-banded, lower Oligocene Big Basin Member of the John Day Formation (Figure 8) are visible. The red bands are mainly subsurface (Bt) horizons of fossil soils of the kind formed under woodland (Alfisols). These interfinger with less developed, yellow fossil soils formed under open woodland and wooded grassland (Inceptisols) and also with fossil soils whose black subsurface horizons (iron manganese or placic horizons) formed in poorly drained parts of the landscape (gleyed Inceptisols).

Low on the hill 2 mi west of the lookout, numerous fossil plant remains have been collected at the type locality for assemblages called the "Bridge Creek Flora." This locality was discovered by Thomas Condon in 1865 (Clark, 1989) and subsequently studied in great detail by Ralph Chaney (Chaney, 1948) and Roland Brown (Brown, 1959). The fossil flora is generally similar to that examined in the John Day Formation behind the high school in Fossil (Stop 7). Wolfe (1981b) has estimated from foliar physiognomy of this flora that mean annual temperature was 11° to 12 °C, with a mean annual range of 22° to 24 °C.

The bluffs of John Day Formation to the north of the lookout are capped by the same extensive ash-flow tuff as seen at Sheep Rock (Stop 11). This tuff has been K-Ar dated near here at 25.9 m.y. (from Evernden and others, 1964, corrected by method of Dalrymple, 1979). Tuffs low in this bluff at a stratigraphic horizon 55 m above the base of the John Day Formation were dated at 31.9 m.y. (corrected from the same authors). Compared with outcrops of the stratigraphically equivalent Turtle Cove Member near Picture Gorge, few fossil mammals of the same kinds have been reported from here (T. Fremd, personal communication, 1991).

The brown badlands of the Kimberly Member and the white bluffs of the Haystack Member of the John Day Formation in the distance, under the long rampart of Columbia River basalt, have also yielded fossil mammals (of the late Arikareean and Hemingfordian land mammal "ages"). The lighter color, more calcareous composition, and less clayey texture of this part of the formation reflect less severe weathering in an increasingly dry climate. The middle Tertiary climatic deterioration of north-central Oregon is written prominently in paleosols of these scenic, color-banded badlands.

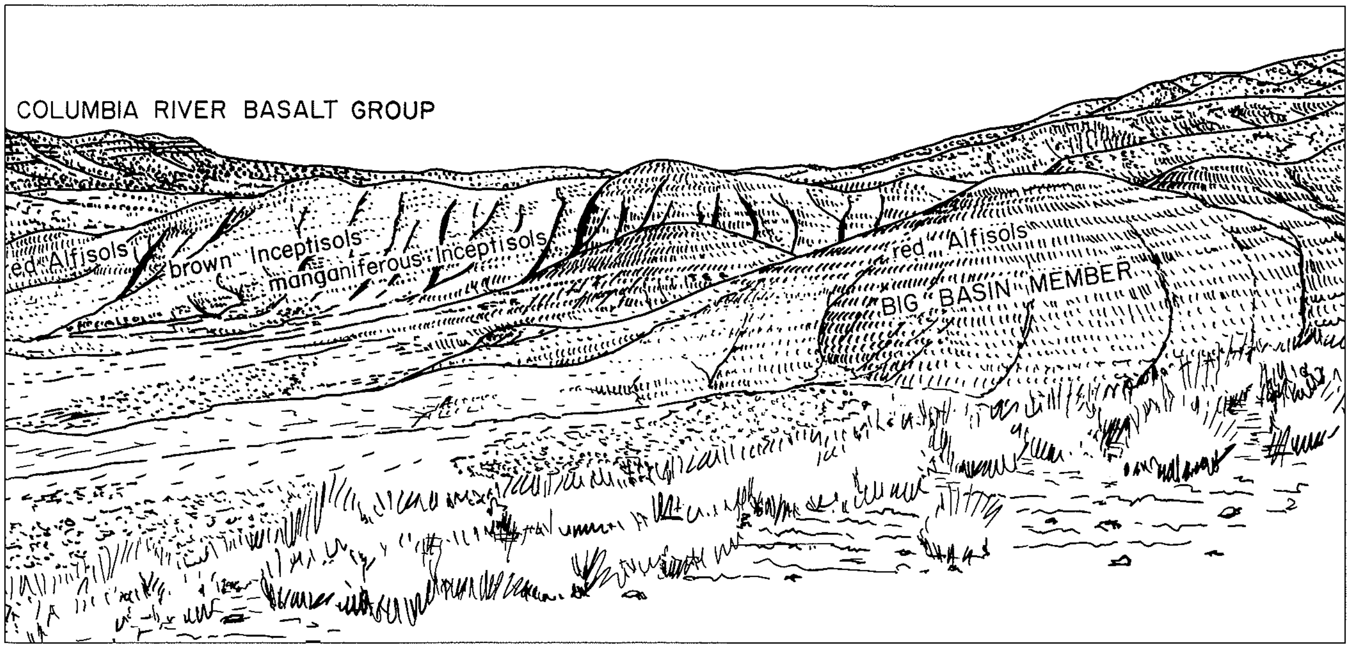

Figure 8. Geological sketch of the Painted Hills Unit of the John Day Fossil Beds National Monument, viewed from the west.

En route

Return south to U.S. Highway 26 and continue west toward Prineville. Ammonite-bearing Lower Cretaceous shales and sandstones of the Hudspeth Formation are exposed in road cuts low in the valley of Cherry Creek. These deposits of submarine fans are unconformably overlain by lacustrine and volcanic rocks of the Eocene Clarno Formation, which form the hills on either side of the road. The road cuts reveal more Clarno Formation as Highway 26 climbs toward Ochoco Summit.

STOP 15. Clarno lake beds, Ochoco Summit

Near the Ochoco National Forest boundary on the northeast side of Ochoco Summit, in a deep road cut on both sides of U.S. Highway 26 and 10 mi west of the Painted Hills turnoff (NW¼NW¼ sec. 17, T. 12 S., R. 20 E., Lawson Mountain 7½-minute quadrangle), occur black shales and gray, bedded sandstones of the Clarno Formation, intruded by a large sill of diabase containing veins of calcite, zeolites, and gabbro. The sill has uparched sediments in the central portion of the road cut, and there is a narrow chilled margin and zone of altered sediments. The sill is faulted against fluvial sandstones in the eastern portion of these road cuts.

The black shale is a deposit of a eutrophic lake. In an especially carbonaceous layer near road level are numerous scales and disarticulated skeletal debris of fish (Cavender, 1968), including remains of bowfins (cf. *Amia*), mooneyes (cf. *Hiodon*), catfish (aff. *Ictalurus*), and suckers (cf. *Amyzon*). These were large subtropical fish.

Overlying the lake deposits are alluvial sandstones and siltstones, in places with well-preserved fossil leaves, including viburnum (*Viburnum eocenicum*), cordia (*Cordia oregona*), and wingnut (*Pterocarya mixta*; all identified by the author). This fossil plant assemblage is similar to the late Eocene Goshen floras of the Willamette Valley (Chaney and Sanborn, 1933), from a time predating the Oligocene climatic deterioration and subsequent divergence in vegetation of western and eastern Oregon (Wolfe, 1981a). Paleosols in these alluvial deposits are limited to weakly developed profiles (Psamments) with fossil root traces and abundant relict bedding: an indication that these plants formed early successional vegetation of streamsides, again like the Goshen flora.

En route

Continue west over Ochoco Summit on U.S. Highway 26. Exposures of the Clarno Formation are poor in the drainage of Marks Creek. Past Ochoco Reservoir near Prineville, exposures of the basal ash-flow tuff of the John Day Formation occur. Closer to Prineville, the Rattlesnake ash-flow tuff forms a conspicuous ledge high on the hillsides. The rimrock on the skyline to the east and north of Prineville is the Madras flow of the Deschutes Formation. Prineville itself is built on Pleistocene lacustrine shales that were deposited when the Crooked River was dammed by intracanyon flows. These flows are well exposed in the gorge of the Deschutes River north of Redmond.

From Prineville, the road north toward Madras climbs between uplifted rocks of the John Day and Clarno Formations in Grizzly Butte to the east and Gray Butte to the west. The plateau over which the road approaches Madras provides excellent views on the skyline of Pliocene-Pleistocene volcanoes of the Cascade Crest: from the south, the Three Sisters, Mount Washington, Three Fingered Jack, and Mount Jefferson.

Return to Madras to conclude the second day of the field trip.

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