OREGON GEOLOGY

published by the
Oregon Department of Geology and Mineral Industries

VOLUME 53, NUMBER 3 MAY 1991

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OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 53, NUMBER 3 **MAY 1991**

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

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Second class postage paid at Portland, Oregon. Subscription rates: 1 year, $8; 3 years, $19. Single issues, $2. Available back issues of *Ore Bin/Oregon Geology* through v. 50, no. 4, $1. Address subscription orders, renewals, and changes of address to *Oregon Geology*, 910 State Office Building, 1400 SW 5th Ave., Portland, OR 97201. Permission is granted to reprint information contained herein. Credit given to the Oregon Department of Geology and Mineral Industries for compiling this information will be appreciated. POSTMASTER: Send address changes to *Oregon Geology*, 910 State Office Building, 1400 SW 5th Ave., Portland, OR 97201.

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The style to be followed is generally that of U.S. Geological Survey publications. (See the USGS manual *Suggestions to Authors*, 6th ed., 1978 or recent issues of *Oregon Geology*.) The bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the acknowledgments.

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of the Oregon Department of Geology and Mineral Industries.

Cover photo

This view of an area at Hancock Field Station shows red paleosols on a clayey slope above a ridge of conglomerates and sandstone of the middle Eocene "nut beds" of the Clarno Formation.

Hancock Field Station, operated as a natural-history camp by the Oregon Museum of Science and Industry, Portland, is within the Clarno Unit of the John Day Fossil Beds National Monument in Wasco County, Oregon. It is a major point of interest in the field trip guide beginning on the next page.

Twilight fireball reported

by Richard N. Pugh and Nathan Stratton, Cleveland High School, Portland

A large fireball occurred over northern Oregon and southern Washington on January 21, 1991, at 5:26 p.m. (1726 PST; January 22, 1991, 0126 Greenwich Mean Time). It entered the atmosphere over Gresham, Multnomah County, Oregon (about 45.5° N., 122.7° W.), and moved roughly northeast at a 30° angle of descent to its end point near Narrowneck Gap, Yakima County, Washington (45.5° N., 121.1° W.). The event lasted at least five seconds.

The limits of reported observations (all in Oregon) were as follows: North, The Dalles, Wasco County (44.5° N., 122.3° W.); South, Madras, Jefferson County (44.5° N., 122.3° W.); and West, Tigard, Washington County (45.5° N., 122.6° W.). Eleven persons reported this fireball, the second author being one of them.

Most observers reported that the object was as bright as a full moon, brightening as it fell, and was approximately the moon's apparent size. Its shape was reported as oval to round with a long, yellow-green-white tail that was emitting "sparks." Almost all colors were reported seen in the head of the fireball, most commonly green and white. The fireball flared brightly near the end of its path and divided into four smaller fireballs that followed each other in a train and then faded out. No sounds or shadows were reported. However, the fireball was bright enough to backlight the few clouds present in the sky.

Even though the sun had set at the time, it was still daylight. Therefore, the object should be considered a daylight fireball.

At present, there is no evidence that any meteorites were produced in the event. Usually, several fireballs are reported over Oregon each month and one or two daylight fireballs each year. Of this number, 5-10 percent will produce sonic booms, indicating that meteorites made it to the ground.

The sightings of this fireball were reported to the Global Volcanism Network, Smithsonian Institution, and published in the *Bulletin of the Global Volcanism Network*, v. 16, no. 1 (January 31, 1991), p. 13-14. Anyone with any additional information about this event or other fireball sightings should contact Dick Pugh, Cleveland High School, 3400 SE 26th Avenue, Portland, OR 97202, phone (503) 280-5120. ☐

Financial assistance for geologic studies in Washington available

Awards to help defray expenses will be available in the 1992 fiscal year for original geologic mapping and other geologic studies useful to the Washington Division of Geology and Earth Resources (DGER) in compiling the new geologic map of Washington.

Available funds will be approximately $15,000 for fiscal year 1992, and awards will be made on the basis of proposals submitted. The individual awards are expected to range approximately from $500 to $2,500. First priority will be given to proposals for work in areas lying within the northwest and southeast quadrants of the new state geologic map, specifically areas that are currently unmapped, poorly mapped, or poorly understood geologically.

Deadline for the submission of proposals is June 3, 1991. Copies of the request for proposals are available through geoscience department chairpersons. The editors of *Oregon Geology* also have a copy of the request for proposals on file.

These quadrants of the state geologic map are scheduled for completion by 1995 and 1993, respectively.

For more information and suggestions, contact J. Eric Schuster, Department of Natural Resources, Division of Geology and Earth Resources, Mail Stop PY-12, Olympia, WA 98504, phone (206) 459-6372 or SCAN 585-6372. *—DGER news release*

A field guide to mid-Tertiary paleosols and paleoclimatic changes in the high desert of central Oregon—Part 1

by Gregory J. Retallack, Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403

> 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 this paper presents the introduction and the guide for the first day of the two-day field trip. Part 2, the guide for the second day and the conclusion of the paper, including the list of references, will be published in the following (July 1991) issue of *Oregon Geology*. *—Editor*

ABSTRACT

Colorful badlands of the high desert of north-central Oregon have long been known for their plant and animal fossils of Tertiary geological age. Fossil soils (paleosols) in these sequences account in part for the scenic interbedding of red, green, and orange claystone, and also are allowing reassessment of Tertiary paleoenvironments. The transition from steamy jungles of the Eocene to the sagebrush desert of today is recorded in the change from deeply weathered, red, kaolinitic clayey paleosols of the Eocene, to the red, brown, and green smectitic paleosols of the Oligocene, to the thin, brown calcareous paleosols of the Miocene, and to the gray, silty calcareous paleosols of the Quaternary. Episodic paleoclimatic deterioration evident from this sequence of paleosols can be related to stepwise global cooling and marine regression. These global effects were exacerbated locally by accretion of the Oregon Coast Range and by volcanic construction of the Western Cascades. Both barriers to westerly storms cast a rain shadow over central Oregon, so that it has become drier as well as cooler and more continental in climate during Neogene time.

INTRODUCTION

The high desert of Wheeler and Jefferson Counties in north-central Oregon is now widely associated with the name of John Day, after whom the main river of the region was named. He passed through this area in 1812 with the Overland Expedition of the Pacific Fur Company. This bleak scenic landscape is one of climatic extremes, often covered with snow in winter but hot and dry in summer. Mean annual temperature for Antelope is 8 °C, with January mean of -1 °C and August mean of 19 °C (Ruffner, 1978). Due to low rainfall (mean of 320 mm annually in Antelope), it supports desert scrub of sage and juniper, and a colorful volcanic and alluvial sequence of Tertiary geological age crops out well (Figure 1). In contrast to the present vegetation, fossil plants of Eocene age, now well known from several localities near Clarno, indicate a climate much wetter, warmer and more equable than at present, more like that of modern lowland Panama (Manchester, 1981). The transition from steamy jungles of the past to the open ranges of today is recorded in a copious fossil record of plants, nonmarine snails, freshwater fish, reptiles, and mammals in this

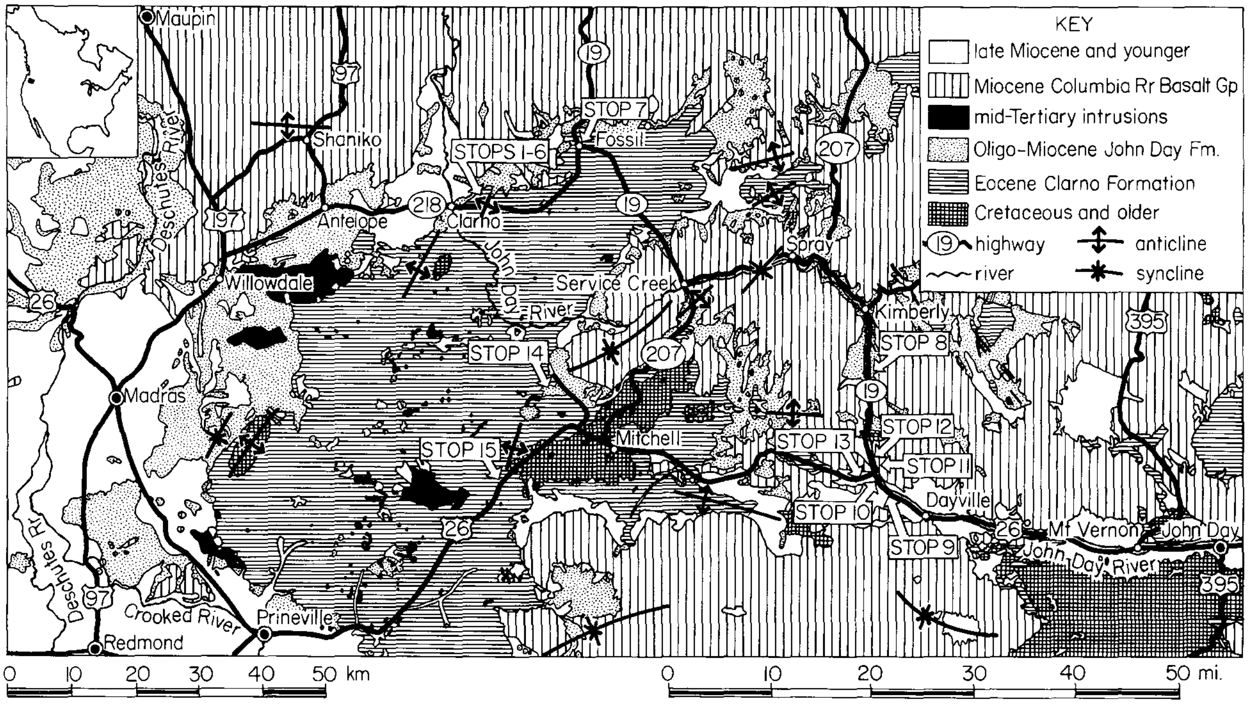


Figure 1. Simplified geology and excursion stops in the John Day country of north-central Oregon (adapted from Walker, 1977).

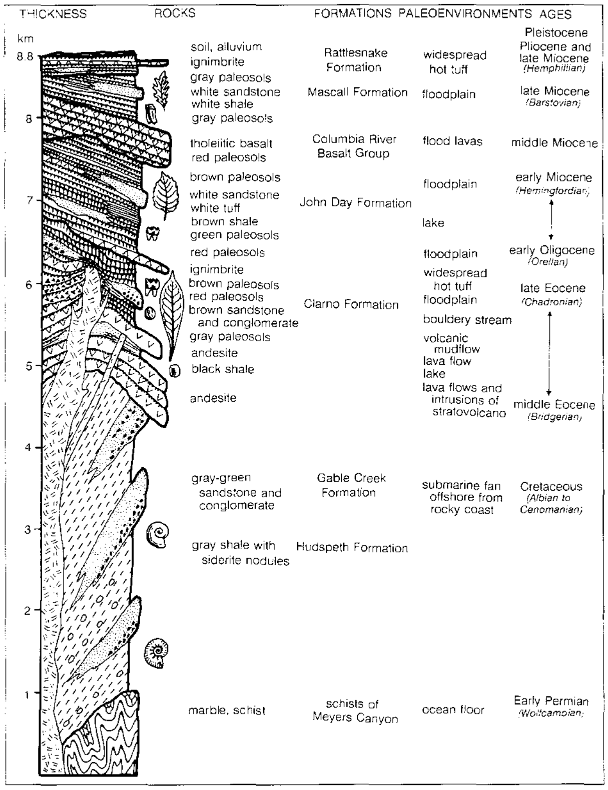


Figure 2. A composite stratigraphic column for central Oregon (from Oles and others, 1973; Swisher and Prothero, 1990).

region (Merriam and Sinclair, 1907; Merriam and others, 1925; Chaney, 1948; Downs, 1956; Manchester, 1981; Wolfe, 1981b; Ashwill, 1983; Rensberger, 1983; Manchester and Meyer, 1987). These profound paleoenvironmental changes also are reflected in a sequence of paleosols ranging in age from middle Eocene to the present. In contrast to more than a century of investigation of the region's fossil riches, scientific study of its paleosols is just beginning (Fisher, 1964; Retallack, 1981, 1985; Pratt, 1988; G.S. Smith, 1988). This excursion explores the potential for paleopedological studies and their implications for understanding paleoenvironmental changes in north-central Oregon over the past 45 million years (m.y.).

The oldest rock units in the region are highly deformed schists of Permian age (Figure 2). These are overlain by a thick sequence of Cretaceous marine rocks, formerly considered deltaic (Oles and others, 1973). Later study of these sediments and their foraminifera concluded that the sediments formed in a submarine fan complex (Kleinhans and others, 1984). An isolated exposure of Early Cretaceous conglomerates that occurs at Goose Rock north of Picture Gorge (Aguirre and Fisk, 1987), probably was deposited in braided streams or a fan delta.

These basement rocks are intruded and overlain by andesitic volcanic and alluvial rocks of the Clarno Formation, which ranges in age from middle to late Eocene, some 54 to 37 m.y. old (McKee, 1970; Rogers and Novitsky-Evans, 1977; Manchester, 1981; Vance, 1988; Walker and Robinson, 1990). Volcanic plugs, lava flows, and lahars of the formation are indications of accumulation in and around a chain of andesitic volcanic cones. During Eocene time, before development of the modern Cascades or the Oregon Coast Range, this part of Oregon was much closer to the coast than it is today (Figure 3). The lower part of the Clarno Formation includes lacustrine deposits with fossil fish (Cavender, 1968; Lundberg, 1975) and leaves (Hergert, 1961). Some of these plant-bearing beds in northeastern Oregon near Heppner and Pilot Rock (outside the area of this excursion) are more likely of Paleocene age and may be better placed in a separate unit underlying the Clarno Formation (Elmendorf and Fisk, 1978; Gordon, 1985; Walker and Robinson, 1990). Near the middle of the Clarno Formation are the well-known "nut beds," which have yielded fossil fruits, seeds, leaves, wood, and rare vertebrate fossils compatible with a middle Eocene age (or Bridgerian land mammal "age") and a warm, wet, tropical paleoclimate (Manchester, 1981; Pratt, 1988). Also compatible with such a paleoenvironment are red, highly weathered fossil soils (Retallack, 1981; G.S. Smith, 1988) associated with the "nut beds." In the upper part of the formation are some fossil plants of tropical affinities (McKee, 1970) but also a number of decidedly more temperate forms (Manchester, 1986). Fossil vertebrates at this level are very different from the archaic forest faunas of the North American middle Eocene, and more like later Eocene (Chadronian land mammal "age" as redated by Swisher and Prothero, 1990) faunas of more open country (McKenna *in* Evernden and others, 1964; Hanson, 1989). Moreover, fossil soils associated with these vertebrates provide evidence of disturbed streamside grassland and woodland less dense than earlier during Eocene time (Retallack, 1985; Pratt, 1988). Thick, red paleosols of kinds formed under forest are common along the unconformity between the Clarno and John Day Formations (Fisher, 1964).

Rhyolitic ash-flow tuff and dacitic to rhyodacitic air-fall tuffs are conspicuous in latest Eocene, Oligocene, and early Miocene (22- to 37-million-year-old) John Day Formation (Woodburne and Robinson, 1977; Robinson and others, 1990). These alluvial and lacustrine deposits were well supplied with volcanic ash from the present area of the Western Cascades to the west (Robinson and others, 1984). This volcanic arc active during Oligocene time was far to the west of the Eocene Clarno volcanic arc (Figure 3). The John Day Formation has been divided into nine units (A to I) in the basin to the northwest of the ridge formed by the old Clarno arc (Robinson and others, 1984), but to the southeast there are four distinctly colored members (Fisher and Rensberger, 1972). The basal red part of the John Day Formation consists of a succession of noncalcareous and oxidized woodland paleosols, in which neither fossil plants nor vertebrates were preserved. Local lake deposits in this part of the formation contain abundant fossil leaves, and sometimes also fossil fish (Cavender, 1969) and insects (Cockerell, 1927; Peterson, 1964). The fossil leaves are mainly deciduous temperate angiosperms together with the dawn redwood (*Metasequoia occidentalis*). Fragmentary and rare vertebrate fossils from this stratigraphic level are compatible with, but not compelling evidence for, an early Oligocene age (Orellan or Whitneyan land mammal "age"). The middle green and buff member of the John Day Formation is well known for its abundant and diverse vertebrate faunas (of the early Arikareean land mammal "age"; Merriam and Sinclair, 1907; Fremd, 1988). In tooth and limb design, these faunas were better adapted to open country than their Eocene antecedents (Webb, 1977); but they were not nearly so well adapted to former open vegetation, indicated by associated fossil soils, as are modern faunas of wooded grassland. The uppermost yellow and white member of the John Day Formation also contains abundant fossil mammals (of the late Arikareean and Hemingfordian land mammal "ages"), and its fossil soils are evidence of drier climate and wooded grassland vegetation (Retallack, 1985). Few fossil lake deposits or fossil leaves have been found in these early Miocene rocks. An especially well developed fossil soil occurs at the very top of the formation capping a landscape of moderate relief.

Covering this ancient landscape are extensive flows of the Columbia River Basalt Group. Most of these were erupted during middle Miocene time (13 to 17 m.y. ago; Tolan and others, 1984; Hooper and Swanson, 1990). Individual flows of these flood basalts had volumes of 10 to 30 km^3, but some flows are known to have exceeded 600 km^3 in volume. Eruption of such a large flow is thought to have lasted from several days to weeks. Many of them were erupted from fissures in northeastern Oregon, eastern Washington, and western Idaho and flowed all the way out to the Pacific Ocean near Portland. In the John Day region of north-central Oregon, however, the Columbia River basalts were more local in origin. Some flows of the Picture Gorge Basalt at the base of the Columbia River Basalt Group along the John Day River between Dayville and Spray can be traced back to a swarm of dikes near Monument and Kimberly (Figure 1). To the west around Madras, the lowest Columbia River Basalt Group flows are of the Prineville chemical type and geologically younger than the Picture Gorge Basalt. They were probably erupted from vents now buried near Powell Buttes to the south (G.A. Smith, 1986).

Sediments overlying the Picture Gorge Basalt and interbedded with later flows of the Columbia River Basalt Group are referred to as the Mascall Formation. These volcaniclastic sediments contain a mammalian fauna of middle Miocene age (Barstovian land mammal "age"; Downs, 1956). The Mascall Formation represents a major stream system draining the older Mesozoic and Paleozoic rocks of the Blue Mountains to the south. Much of its sediment load consisted of volcanic ash from the ancestral Cascade volcanoes to the west. Fossil leaves of cool-temperate deciduous angiosperms and conifers dominate lacustrine deposits of the Mascall Formation (Chaney, 1948), whereas its vertebrate fauna of camel, horse, and pronghorn antelope indicates grassy woodland or wooded grassland (Downs, 1956). Fossil soils in the formation are additional evidence for dry, open vegetation apparent from the structure of fossil mammalian teeth and limbs. If there were closed-canopy woodlands at that time, they were restricted to stream margins and lake shores.

Overlying and interbedded with Columbia River Basalt Group rocks in a small area of the valley of the Deschutes River near Gateway, north of Madras, are alluvial clays and sandstones of the Simtustus Formation (G.A. Smith, 1986). What little is known about its fossil plants (Pelton flora of Ashwill, 1983) and paleosols conveys an impression of paleoenvironments similar to that for the Mascall Formation, with which it was at one time identified.

Disconformably overlying the Mascall Formation in most of north-central Oregon is the Rattlesnake Formation, which includes local fanglomerates and alluvial sandstones and claystones as well as a thick rhyodacitic ash-flow tuff (Oles and others, 1973). This widespread ash-flow tuff is thought to have erupted from a vent in the Harney Basin south of Burns. Other parts of the formation represent ancestral drainages of the John Day and Crooked Rivers, which continued to receive ash from the ancestral Cascades to the west. Fossil mammals of the Rattlesnake Formation are of late Miocene age (Hemphillian land mammal "age") and include a markedly more modern fauna of grazing horses and pronghorn antelope (Merriam and others, 1925). Its fossil flora also is more modern and includes elm, sycamore, and willow (Chaney, 1948). This vegetation of deciduous angiosperm trees may be contrasted with open grassy vegetation apparent from fossil soils and vertebrates in the Rattlesnake Formation.

Coeval with deposition of the Rattlesnake Formation to the east, the region around Madras received enormous amounts of basalt, tuff, and gravel of the Deschutes Formation during a period of late Miocene and early Pliocene active volcanism (G.A. Smith, 1987). The source volcanoes are no longer exposed, because they subsided in a large graben along the current Cascade crest. This graben has been filled by the Pliocene-Pleistocene basaltic shield volcanoes as well as the prominent stratovolcanoes of Mount Jefferson, Three Fingered Jack, Mount Washington, and the Three Sisters. Fossil plants (Ashwill, 1983), fish (Cavender and Miller, 1972), mammals (Downs, 1956, Gateway locality), and paleosols (G.A. Smith, 1987) of the Deschutes Formation are similar to those of the Rattlesnake Formation and indicate a semiarid, cool climate approaching the one found in this high-desert region today.

Much remains to be done to learn more about the details of climatic change recorded in this fossiliferous Tertiary sequence, but the causes of climatic change must be sought beyond this region. Climatic drying may have been caused by reorientation of continental subduction with accretion of the Oregon Coast Range (Engebretson and others, 1985). During Eocene time, this region was dotted with andesitic volcanoes closer to the coast than now. By Oligocene time, this volcanic arc had reformed in the present area of the Western Cascades, and it began to cast a rain shadow over the John Day region (Figure 3). This climatic drying would have been exacerbated by the increased continentality and by profound marine regression at the Eocene-Oligocene boundary (Haq and others, 1987). These changes could also have been responsible for the climatic cooling observed. Other possible causes for cooling at about this time are the thermal

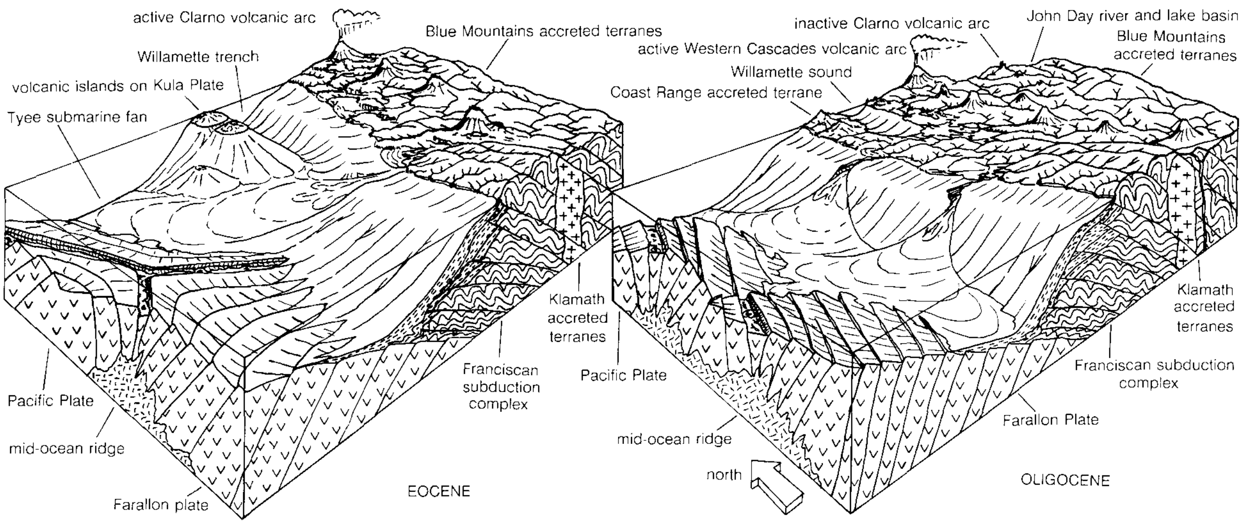


Figure 3. Paleogeographic cartoons of the Pacific Northwest during Eocene (left) contrasted with Oligocene time (right), illustrating a rearrangement of oceanic plates and volcanic arcs with accretion of the Oregon Coast Range. These events predated Miocene spreading of the Basin and Range and volcanic activity of the High Cascades (adapted from Engebretson and others, 1985).

isolation of Antarctica by a surrounding ocean current following the rifting away of Australia (Kennett, 1982); impact of extraterrestrial bodies, which left a strewn field of tektites in rocks of about this age in the United States Gulf Coast (Glass and others, 1979); and reduced atmospheric carbon dioxide and its diminished greenhouse effect because of reduced Neogene rates of subduction and volcanism (Creber and Chaloner, 1985). The Eocene-to-Oligocene transition was prominent among a number of Neogene climatic deteriorations, as the world slipped from a regime of middle Eocene maximal expansion of tropical climate toward the ice ages of the past few million years.

EXCURSION ITINERARY FOR FIRST DAY

This two-day excursion originates and ends in Madras, Jefferson County, Oregon. Madras is built on the Pliocene Deschutes Formation, which forms an extensive plateau to the north and west. U.S. Highway 97, heading north from Madras, provides excellent views of surrounding peaks. Hills to the east of the plains are faulted ash-flow tuffs and sedimentary rocks of the Oligocene-Miocene John Day Formation. Grizzly Mountain to the southeast is a rhyolitic dome of the John Day Formation. Gray Butte, west of Grizzly Mountain, is mainly John Day Formation, but exposes also some underlying rocks of the Eocene Clarno Formation. Round Butte farther west is a late Pliocene basaltic shield volcano. Pleistocene composite volcanoes of the High Cascades are visible on the skyline to the west. From south to north these include multiple peaks of the Three Sisters, the rock spire of Mount Washington, eroded towers of Three Fingered Jack, and the cone of Mount Jefferson.

A road cut 10 mi north of Madras on U.S. Highway 97 toward The Dalles exposes the contact between the Deschutes Formation and the underlying Columbia River Basalt Group. A mile farther north on the ridge top to the east of the road is a Pleistocene intracanyon flow. This flow erupted from a small shield volcano east of Madras and flowed down ancestral Hay Creek toward the Deschutes River. Hay Creek has since cut a new valley parallel to the flow (Oles and others, 1973). Another mile farther north, we see tuffaceous claystones of the upper John Day Formation (Unit I of Robinson and others, 1984), and a red paleosol separating it from the overlying Yakima Basalt of the Columbia River Basalt Group.

Turn east from U.S. Highway 97, 17 mi north of Madras, onto Oregon Highway 218 toward Antelope. Yakima Basalt shows excellent columnar jointing 3 mi east of this junction. Some 5 mi east is a prominent ledge of ash-flow tuff within the upper John Day Formation (Unit H of Robinson and others, 1984). At 6 mi east of the junction is another ash-flow tuff (Unit G) and at 7 mi east an alkali olivine basalt flow (Unit F) of the John Day Formation. These Oligocene basalts are associated with dikes of local vents and are compositionally distinct from tholeiitic flood lavas of the Columbia River Basalt Group. At 9 mi east of the junction of Highways 97 and 218 in the cut south of the road is another ash-flow tuff of the John Day Formation (Unit E). The abundance of thick ash-flow tuffs and basalts is characteristic of the western facies of the John Day Formation, which filled a topographic basin between the Western Cascades and the moribund Eocene Clarno volcanic arc (Robinson and others, 1984).

At the small town of Antelope, turn southeast, continuing on Oregon Highway 218 toward Clarno. Trachyandesite of the lower John Day Formation (Unit B) is exposed in a road cut 1.5 mi southeast of Antelope. Continue east along Highway 218, past the unsealed road to the south that leads to Ashwood and via Muddy Road to the abandoned commune of Rajneeshpuram. From that turnoff, Highway 218 climbs to a pass that affords excellent views of the valley of the John Day River to the east. The cliffs north of the pass consist of tuffs (Unit F) and a welded tuff (Unit G) of the upper John Day Formation. These are capped by the Columbia River Basalt Group on the skyline. These middle Miocene flood basalts also cap Iron Mountain in the distance to the east across the river. The white, tan, green, and red John Day Formation crops out in scattered badlands along the river, but its contact with overlying flood basalts is obscured in places by slumping. Dark red, orange, and gray sediments and lava flows of the Clarno Formation crop out extensively to the southeast past the bridge across the John Day River. The higher peaks farther south are capped by Columbia River basalt overlying the John Day Formation.

Clarno was the site of a ferry, later replaced by a bridge, across the John Day River. It now consists of a few farmhouses and a grange hall. In the hills north of Highway 218, 1 mi east of the bridge, the basal ash-flow tuff of the John Day Formation can be seen overlying red claystones of the upper Clarno Formation. These tuffaceous claystones immediately under the ash-flow tuff yielded a radiometric (K-Ar) age of 32.8 m.y. (Evernden and James, 1964, corrected by method of Dalrymple, 1979). This date is anomalously young and is regarded as suspect (Woodburne and Robinson, 1977). Massive volcanic rocks farther southeast are andesitic lava flows of the lower Clarno Formation.

Access to Hancock Field Station is by a gravel road that turns off north at a point 2.5 mi east of the bridge across the John Day River. This facility is within the Clarno Unit of John Day Fossil Beds National Monument, and is run as a natural-history camp by the Oregon Museum of Science and Industry in Portland. Inquiries and permission to visit should be obtained from the caretaker living there: Joseph Jones, telephone (503) 763-4691.

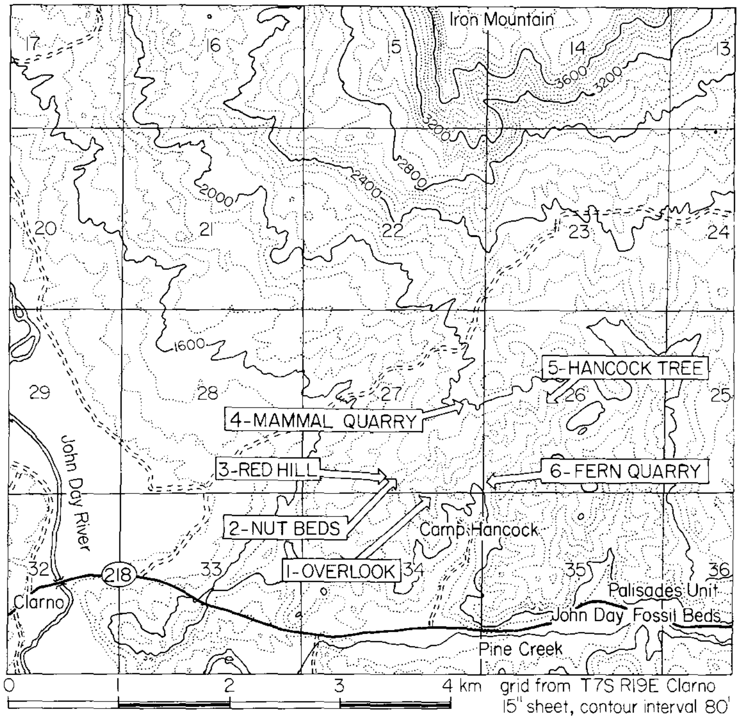


Figure 4. Excursion stops on a walking tour of the principal fossil localities around Hancock Field Station near Clarno, Oregon.

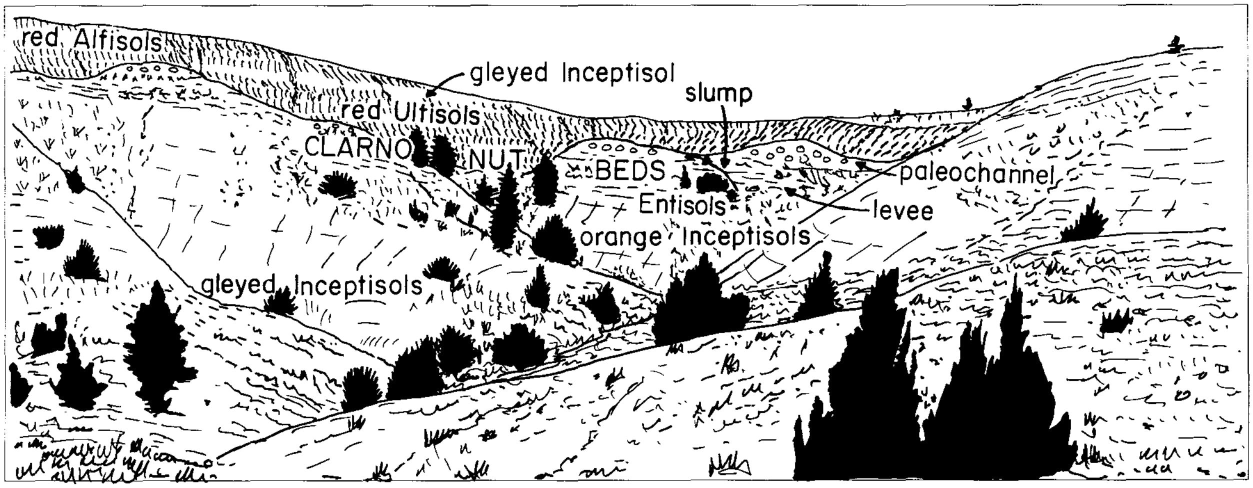


Figure 5. Geological sketch of facies associated with the Clarno "nut beds," viewed from the east.

Park the vehicles at the lower parking lot and prepare for a walking tour of at least three hours (Figure 4). Walk west up into the camp and then northwest past the A-frame huts and away from "Berrie Hall," a large enclosed dining area. A footpath leads uphill from the northeastern huts out of the camp.

STOP 1. "Nut beds" overlook, Hancock Field Station

Some 300 m west of Camp Hancock, on the crest of a low ridge, is an excellent view (Figure 5) of middle Eocene alluvial rocks of the Clarno Formation (NW¼NE¼ sec. 34, T. 7 S., R. 19 E., Clarno 15-minute Quadrangle). The prominent bluffs of sandstone and conglomerate are the Clarno "nut beds", a well-known fossil locality for leaves, fruits, seeds, wood, and mammals. From here, the "nut beds" can be seen to be lenticular in outline and sandwiched between red claystones of the hill on the skyline and variegated red, green, and orange claystones of the gullies below. The lenticular shape of the "nut beds" is obscured somewhat by slumping, especially of the central bluff. These coarse-grained sedimentary rocks represent sandy levees and conglomeratic channels of a meandering stream that flowed through clayey soils now preserved in the varicolored badlands. Some of the paleosols were waterlogged, for example, the gray-green ones below the "nut beds" and the two gray bands in the red hillside above. Most of the paleosols, however, were freely drained and have been highly oxidized to orange and red colors. Blocky outcrops at the top of the red badlands are the basal welded tuff of the John Day Formation.

En route

Continue west downhill toward the "nut beds" and through the gate in the barbed-wire fence. The white powder prominent during summer months in the dry clayey washes here is mirabilite ($Na_2SO_4 \cdot 10H_2O$; J. Pecor, personal communication, 1982). It forms by evaporation of ground water flowing off the plant-bearing andesitic conglomerates and smectitic claystones of the badlands immediately to the west. Mirabilite rather than anhydrous sodium sulfate (threnardite) is favored at temperatures of <32 °C in the laboratory, and <16 °C in nature (Wells, 1923). Probably, mirabilite forms here following evaporation of winter rain and persists for much of the nearly rainless summers of this region.

Also seen near the gate is a dike of porphyritic andesite about 1 m wide dipping at 66° to the west and striking northeast (azimuth 068°) to intersect a large andesitic intrusion forming the ridge 200 m in that direction.

The nature of surface soils on these badland slopes can be seen along the trail. As in many badland regions in dry parts of the western United States, these soils are weakly developed (Torriorthents of U.S. Department of Agriculture, 1975). Their surface horizon (some 10 to 20 cm thick) is cracked, with irregular blocky ("popcorn") ped structure. Below that (extending to some 40 cm) is a zone of carbonate powder and flattened, zoned crystals of gypsum and calcite within cracks in the rock. Most of the weathering observed in these claystones dates back to Eocene time, when these paleosols formed soils of floodplains. In order to properly understand Eocene soil formation, it is necessary to dig a meter or so into fresh bedrock, beyond the overprint of the thin surface soil.

STOP 2 Clarno "nut beds," Hancock Field Station

The "nut beds" of the Eocene Clarno Formation are interbedded sandstones and siltstones with a cap of massive conglomerate, 0.5 mi northeast of Camp Hancock (SW¼SE¼ sec. 27, T. 7 S., R. 19 E., Clarno 15-minute Quadrangle). The conglomerate forming the top of the bluffs contains principally boulders and pebbles of porphyritic andesite, which have conspicuous phenocrysts of zoned plagioclase. Sorting, roundness, and imbrication of the clasts are poor. The matrix to the conglomerates includes clay, silt, sand, and plant debris—all cemented by multiple generations of chalcedony with local calcite and zeolites. Large voids and copiously branched veins within the conglomerate are filled with chalcedony. These sediments and their uniquely preserved fossils, may have been altered by hot spring activity, perhaps associated with intrusion of the nearby andesitic dikes and plug. The interbedded sandstones and siltstones underlying the conglomerates also are silicified in places, and show a variety of small-scale sedimentary structures, including ripples and scour-and-fill. Some of these small erosional features are steep sided and may be footprints of large mammals. The conglomeratic facies is typical for paleochannels of streams in mountainous regions, and the interbedded sandstones and siltstones may represent point bar and levee deposits of a stream on the seaward slope of a large coastal andesitic volcanic arc (Figure 3).

Fossil fruits and seeds, the "nuts" after which these beds are informally named, are found throughout the sequence. Most of the large fruit and seed collection made by the late Thomas Bones (Bones, 1979) came from the basal unit of the upper conglomerate. Over the past several years, Steven Manchester has systematically excavated a layer low in the underlying sequence of sandstones and siltstones. A cherty siltstone bed there contains fossil fruits, seeds, leaves, and wood—an uncommon occurrence for a plant fossil locality, offering the promise of allowing reconstruction of complete fossil plants from their different organs. About 100 genera of fruits and seeds, 80 of leaves and 40 permineralized woods had been recognized in the "nut beds" (Bones, 1979; Manchester, 1981, 1986). Common among these are fruits of walnuts(*Juglans clarnensis*), moonseed (*Chandlera lacunosa*), icanica vine (*Palaeophytocrene foveolata*), dogwood (*Langtonia*), palm (*Palmocarpon*), and leaves of aguacatilla (*Meliosma*). Modern relatives of most of these plants are restricted to vegetation of moist, equable tropical regions, such as lowland Panama and Taiwan. In addition, modern relatives of many of the fossils are vines and epiphytes, from which it can be inferred that the fossil flora was a rain forest community with several distinct tiers. It is possible that the climatic preferences of these plants have changed through time, but paleoclimate also can be reconstructed from adaptive features of plants that presumably reflect fundamental aspects of plant physiology. A warm paleoclimate is indicated for the Clarno "nut beds" because many of the leaves are large and most (60 percent) are entire margined. Some seasonality is suggested by growth rings in fossil wood. Presumably this was due to a dry rather than cool season, because Wolfe (1978) envisages climate with a mean annual temperature of 21° to 25 °C and a mean annual range of temperature of only 3° to 7 °C for Eocene floras of the nearby Puget Group in southwestern Washington.

Fossil mammals have been recovered from the base of the conglomerate in the southernmost outcrop of the "nut beds." The fauna is still under study by C.B. Hanson (personal communication, 1990), but includes crocodile, turtle (*Hadrianus), small browsing horse (Orohippus major*), small cursorial rhinoceros (*Hyrachyus eximius*), brontothere (*Telmatherium*), and creodont carnivore (*Patriofelis ferox*). These creatures are typical of middle Eocene faunas (Bridgerian land mammal "age") and of forest communities elsewhere in western North America. This assessment of geological age is confirmed by K-Ar estimates of 43.7 and 43.6 m.y. for pumice layers in the "nut beds" (Vance, 1988).

Paleosols in the "nut beds" are weakly developed (Psamments and Fluvents). They are recognized principally by the presence of fossil root traces, because they contain few other indications of soil formation and much relict bedding. Especially conspicuous are thickets of scouring rushes (*Equisetum clarnoi*) fossilized erect and in place of growth in several of these streamside paleosols (Retallack, 1981). These paleosols indicate frequent disturbance by flooding along stream banks.

En route

Continue uphill west from the "nut beds" to the area of past excavations into the central gray band high on the red badlands slopes.

STOP 3. "Red hill", Hancock Field Station

Red claystones overlying the "nut beds" on the hill to the west contain numerous strongly developed paleosols of the Eocene Clarno Formation (SE¼SW¼ sec. 27, T. 7 S., R. 19 E., Clarno 15-minute Quadrangle). The thick (2.4 m), gray (Munsell hue 5Y) band in the center of the slope includes a weakly developed, seasonally waterlogged paleosol (gleyed Inceptisol). Relict bedding is conspicuous in most of the profile, but is less apparent in a surficial dark-gray (A) horizon. A diffuse subsurface horizon (Bg) contains blocky peds defined by purple-black mangans. Underlying this is brick-red (hue 10R) paleosol of a kind more typical of those excavated in the rest of the trench on this hill (G.S. Smith, 1988). These are thick (1.8 m), moderately developed profiles (Ultisols below this red paleosol and Alfisols above and including it). A drab silty surface horizon (A) and scattered drab-haloed root traces pass down into a clayey subsurface horizon (Bt) with blocky structure and scattered small (3-4 mm diameter) ferruginous concretions.

The green discoloration of the surface horizon and root traces within the paleosols may be due to burial gleization around remnant organic matter, and their brick-red color may in part be due to burial dehydration of ferric hydroxides that were originally reddish brown in color. Slickensides along the faces of former soil clods and reduction in thickness due to burial compaction also are likely. These kinds of alteration are common among paleosols (Retallack, 1990, 1991). Although they compromise some interpretations of these paleosols, much evidence of former soil formation remains.

Paleoclimatic indications from these paleosols are well in accord with evidence from fossil plants and animals in the "nut beds" below. These paleosols are noncalcareous throughout and have deep and copious root traces and burrows, as is typical of tropical forested soils in humid climates. The red paleosol below the drab profile and other red profiles to the top of the hill have up to 94 volume percent of mainly smectitic clays and a ratio of alkalies and alkaline earths to alumina of 0.26 to 0.29. By comparison, other red paleosols between these and the "nut beds" below have up to 98 volume percent of mainly kaolinitic clay, with less abundant smectite, and base-to-alumina ratios of 0.18 to 0.17 (G.S. Smith, 1988). There was thus a pronounced paleoclimatic change during accumulation of the paleosol sequence in this hill, from wetter to somewhat drier but still generally humid climate. There may also have been a shift to greater climatic seasonality, because complex ferric concretions become more abundant in paleosols higher up in the hill.

The paleosols also offer evidence of past landscapes and their history. The drab and manganiferous paleosols may have escaped oxidation in areas of periodically high water table. The brick-red ones have shown patterns of redistribution of iron around root traces in recent microprobe studies (G.S. Smith, 1988), unlike near-constant amounts of total iron found around drab root haloes presumed to have formed entirely after burial (Retallack, 1983, 1990, 1991). There may have been, during soil formation, some chemical reduction and mobilization of iron (gleization) in clay around roots in these formerly well-drained paleosols as well. Thus both red and gray paleosols formed in low-lying floodplains. The parent materials for all these soils were gravelly andesitic debris, as for the soils of the "nut beds." The more thorough weathering to red claystone in some of these paleosols indicates periods of landscape stability and soil formation on the order of tens of thousands of years.

En route

Walk along the red badlands slope to the north toward a saddle between the Clarno "nut beds" and the cliffed hill to the west. The cliffs and large blocks littering the slope are the basal ash-flow tuff of the John Day Formation. This is probably the material K-Ar dated at 35.7 m.y. (from Evernden and James, 1964, corrected by method of Dalrymple, 1979) and mistakenly thought to be from the Clarno "nut beds." More recent fission track ages on this welded tuff are 36.8 and 37.4 m.y. (Vance, 1988), which is late Eocene (Swisher and Prothero, 1990).

Continue on foot trails toward a broad marshy area traversed by a rough jeep track. From the saddle overlooking this low area can be seen a flat spur held up by an andesite flow within the upper Clarno Formation. This flow is separated by additional sediments from the eroded top of a large intrusion of andesite forming a ridge closer to Hancock Field Station. The location also offers good views to the north of the basal ash-flow tuff of the John Day Formation on a low ridge. Above that are red, then brown and green, then white badlands of the John Day Formation below a thick sequence of Columbia River Basalt Group flows that cap Iron Mountain on the skyline.

Continue along the jeep trail over a low rise and to a quarry into brown claystones and conglomerates.

STOP 4. Clarno "mammal quarry," Hancock Field Station

The "mammal quarry" in the upper Clarno Formation is about 1 mi north from the "nut beds" (SE¼NE¼ sec. 27, T. 7 S., R. 19 E., Clarno 15-minute Quadrangle). These clayey rocks underlie the basal ash-flow tuff of the John Day Formation, but their orange and brown color contrasts with brick-red badlands above the "nut beds." This sequence is a different alluvial facies that accumulated in an erosional landscape developed on top of the "nut beds" and overlying red beds. The floor of the quarry represents a conglomeratic channel deposit with clasts that consist mainly of porphyritic andesite. The walls of the quarry have been re-excavated recently, and reveal levee deposits of silt and clay with numerous paleosols (Pratt, 1988).

A few fossil fruits and seeds have been found in paleochannel deposits here (McKee, 1970). These were identified with better known forms from the nearby Clarno "nut beds" and include walnut (*Juglans clarnensis*), moonseed (*Odontocaryoidea nodulosa* and *Diploclisia*), icanica vine (*Palaeophytocrene* cf. *P. foveolata*) and grape (*Vitis* and *Tetrastigma*). These remains are anomalous compared to fossil mammals and paleosols here, which indicates paleoenvironmental change during the late Eocene as compared with middle Eocene.

Mammal fossils were first discovered here in 1956 by Lon Hancock, an amateur paleontologist from Portland. Between 1956 and 1959, Hancock, Arnold Shotwell, and Malcolm McKenna developed a large collection of vertebrates, most of it now in the Condon Collection at the University of Oregon. The bones are preserved disarticulated and cracked, within clumps that each include few kinds of animals. They appear to have accumulated on the point bar of a stream, as carcasses that rotted and disarticulated in place (Pratt, 1988). Taxonomic work continues on these remains (Mellett, 1969; Hanson, 1973, 1989, personal communication, 1990; Pratt, 1988; Schoch, 1989), which include fish, crocodile (*Pristichampsus*), rodent, anthracothere (*Heptacodon*), rhinoceros (*Teletaceras radinskyi* and *Procadurcodon*), brontothere (*Protitanops*), tapir (*Plesiocolopirus hancocki* and *Protapirus*), agriochoere (*Diplobunops*), horse (*Epihippus gracilis* and *Haplohippus texanus*), creodont carnivore (*Hemipsalodon grandis*), and saber-tooth cat (Nimravinae). These mammals show closest affinities with late Eocene faunas (Chadronian land mammal "age" as redated by Swisher and Prothero, 1990) elsewhere in North America. At more than 38 m.y. old, this is the oldest known fossil fauna of Chadronian type. These faunas show a slight modernization in tooth height and in limb proportions for more open country than found in archaic Eocene forest faunas. For many years it has been thought that Chadronian faunas evolved in open-country refugia in Asia and migrated across the Bering land bridge during late Eocene time to displace older forest faunas of North America (Webb, 1977). The rhinos, tapir, and brontothere are similar to Japanese, Korean, and Siberian Eocene mammals, but the other mammals are North American endemic forms (Hanson, personal communication, 1990). Isolated intermontane basins in the western United States, such as the one represented by this "mammal quarry," could have been important to the evolution of these distinctive faunas that later became widespread in the rest of North America (Retallack, 1985).

Several kinds of paleosols have been recognized in the "mammal quarry" above the conglomeratic layer bearing fossil mammals, fruits, and seeds (Pratt, 1988). They are thin (20-30 cm), olive-colored, weakly calcareous, and with large root traces and much relict bedding (Fluvents). They contain prominent black horizons and septarian nodules rich in manganese. Above these is a thick (1 m), weakly developed, orange-yellow paleosol (Inceptisol) with abundant surficial, very fine root traces preserved by chalcedony (A horizon) and with a subsurface zone of clay enrichment (Bt or incipient argillic horizon).

Such weakly developed paleosols cannot be considered compelling evidence for paleoclimate, but their weakly calcareous composition compared to comparably developed noncalcareous paleosols lower in the Clarno Formation may indicate a somewhat drier climate than earlier in the Eocene. These paleosols contain large root traces of a size formed under trees, as well as abundant very fine root traces, and they probably supported early successional, riparian, grassy woodland. These paleosols are associated with stream deposits, but there is no sign of coal, gray-green clay, pyrite, or other indications of permanent waterlogging. The manganiferous zones may have been placic horizons of soils in locally wet zones of streamsides, but the generally orange hue of the paleosols and deep penetration of root traces are indications of good drainage. These paleosols probably flanked a steep, upland, gravelly stream. Parent materials of the paleosols were andesitic gravelly alluvium. Relict bedding is conspicuous in these paleosols, which each represent only a few hundreds to thousands of years of soil formation.

Paleosols and fossil mammals of the "mammal quarry" are evidence of drier and less dense forest vegetation during late compared with middle Eocene, but there is little evidence of this from the fossil plant remains here. The plant fossils are not silicified like those of the "nut beds" and were in a separate drainage—and so probably were not redeposited after erosion from the "nut beds." Instead, these fossils may represent relict stands of wet forests and are perhaps comparable to those relict species from Miocene rain forests that persist today in well-watered gullies of eastern Australia (Beadle, 1981).

En route

Walk northeast around the hill at about the same elevation below cliffs of the basal ash-flow tuff of the John Day Formation. Continue 400 m into the headwaters of a deep gully with extensive exposures of lahars of the upper Clarno Formation and into a narrow canyon draining south.

Hills to the north and east consist of a poorly exposed sequence of olive claystones and white ash similar to that exposed in the "mammal quarry." These are overlain by an andesite flow of the upper Clarno Formation also seen along the way between "Red hill" and the "mammal quarry." A thick red paleosol developed on sediments overlying this flow is the same ancient land surface described elsewhere by Fisher (1964).

STOP 5. Clarno "Hancock tree," Hancock Field Station

The "Hancock tree" is a conspicuous permineralized trunk near the entrance of a small gully extending north from Hancock Canyon, about 2.5 mi northeast of Camp Hancock (SE¼NW¼ sec. 26, T. 7 S., R. 19 E., Clarno 15-minute Quadrangle). Additional fossil trunks and stumps have been excavated from the base of a volcanic mudflow or lahar (a widely used Indonesian term for such deposits) higher in the gully. This locality lies within the Clarno Formation, at a stratigraphic level below the "mammal quarry," and is probably of middle Eocene age.

The thick (11 m) lahar contains jumbled angular clasts of porphyritic andesite that were extensively zeolitized and weathered during late Eocene time. Phenocrysts in the andesite clasts include hornblende and plagioclase. The silty matrix of the lahar also includes scattered granules of zoned plagioclase. The lahar was preceded by a thin (20 cm) traction deposit, similar to those attributed to hyperconcentrated flow preceding lahars (G.A.Smith, 1987). Neither this flood of water nor the lahar itself succeeded in dislodging all the trees. Although very close to their volcanic source, these mudflows were slowing down out on the flanks of a volcano.

The "Hancock tree" (Do not deface or sample!) has been identified as similar to the katsura (*Cercidiphyllum japonicum*) of China and Japan. The soil on which it grew is preserved under the lahar, along with its leaf litter (Retallack, 1981). The paleosol is moderately thick (30 cm) and weakly developed (Inceptisol), with a light-colored, sandy near-surface horizon (E) and an orange, weakly ferruginized, and slightly clayey subsurface horizon (Bw), over weakly calcareous sandstone (C). Its leaf litter includes both leaves and fruits of extinct plants allied to sycamore (*Macginitea angustiloba*) and katsura (*Joffrea speirsii*), plants of cool-temperate climatic and early successional affinities (Crane and Stockey, 1985; Manchester, 1986). The fossil leaf litter also contains a variety of other leaves, including those of fan palms, that today are intolerant of frost. This leaf litter probably represents vegetation early in ecological succession to colonize areas disturbed by lahars and associated hyperconcentrated flow close to the volcano.

These inferences from the fossil flora can be compared with those from the paleosol. The profile is weakly calcareous at depth and probably formed in a subhumid-to-humid climate, more like that revealed by paleosols in the "mammal quarry" than those associated with the "nut beds." Differentiation of a weakly ferruginized subsurface zone (Bw) is compatible with woodland vegetation, evident from its fossil leaf litter and trunks. This paleosol formed on flood deposits in the lower regions of hummocky topography and alluvial outwash flanking andesitic volcanoes of a kind comparable with those of the present Cascade Range. Parent materials of the soil were sandy and gravelly alluvium and lahars of andesitic composition. Time for formation of this paleosol was not long, considering its weak development, lacking a subsurface horizon that would qualify as spodic or argillic. Nevertheless, there was some leaching of carbonate and remobilization of iron and clay. The paleosol represents a hiatus of several hundred to a few thousand years, enough for plant succession and growth of the observed crop of tree trunks.

Along the path north of the "Hancock tree" is the midden of a packrat (*Neotoma* spp.) with well-preserved plant fragments of middle Holocene age (W.G. Spaulding, personal communication, 1985). These rodents collect vegetation for their nests and for food, and the plant fragments are preserved by their pungent urine. With radiometric dating to establish their age, packrat middens can provide a detailed picture of Pleistocene changes in vegetation of arid regions (Spaulding and others, 1983).

En route

Continue down the gully past the "Hancock tree" and into the main valley of Hancock Canyon. A footpath follows the dry creek bed south toward Hancock Field Station and past a small stock pond. At a point between this stock pond and a second one farther down the valley, the long scar of a quarry into white rocks can be seen on the hillside, 200 m above and to the west of the canyon floor. Scramble up to this outcrop.

STOP 6. Clarno "fern quarry," Hancock Field Station

The "fern quarry" is a prominent excavation on a hill 0.3 mi northeast of Camp Hancock (SW¼SW¼ sec. 26, T. 7 S., R. 19 E., Clarno 15-minute Quadrangle). It is a long excavation into plant-bearing white volcanic ash of the upper Clarno Formation, at a stratigraphic level above lahars and the "Hancock tree," but below the "mammal quarry." Radiometric dating to 43 m.y. old (Vance, 1988) indicates that these leaf beds are middle Eocene in age like the "nut beds."

One-half meter above the base of the excavation is a layer rich in fossil plant remains, principally roots and rhizomes but occasionally with recognizable plant remains (here identified by the author): mostly horsetails (*Equisetum clarnoi*), bird's nest fern (*Salpichlaena anceps*), and tree fern (*Hemitelia pinnata*), as well as rare angiosperm leaves (of kinds traditionally identified as "*Ficus plinerva*" and "*Cryptocarya eocenica*"; Hergert, 1961). These remains represent the leaf litter of early successional vegetation on a thin (10 cm), weakly developed paleosol (Fluvent). This vegetation was more advanced in ecological succession than that of the thickets of *Equisetum* seen in the "nut beds" (Stop 2) but is not as advanced as woodlands preserved around the "Hancock tree" (Stop 6). Comparable colonization of volcanic ash by ferns has been observed around El Chichon, an active volcano in Mexico (Burnham and Spicer, 1986).

En route

Descend into Hancock Canyon and continue south along the foot trail past the southern stock pond to Hancock Field Station and the vehicles. This is the conclusion of the walking tour.

After reboarding the vehicles, head back out to Oregon Highway 218 and proceed east toward Fossil. Lahars of the upper Clarno Formation are well exposed in the Palisades, a line of cliffs north of the highway 1 mi east of Hancock Field Station, near the rest area and marked trails of the Clarno Unit of John Day Fossil Beds National Monument. These are the same lahars of presumed middle Eocene age seen in Hancock Canyon (Stop 5). Here they have weathered into hoodoos: narrow pillars protected from erosion by more weather-resistant clasts of the lahar. High on the hills to the north of this point is an andesite flow of the uppermost Clarno Formation and above that, on the skyline, is the basal ash-flow tuff of the John Day Formation.

Additional lahars and andesitic flows of the Clarno Formation are exposed along the highway as it climbs into the headwaters of Pine Creek. From Pine Creek summit and on the long descent toward Fossil, the Columbia River Basalt Group can be seen overlying the John Day Formation.

Continue across Highway 19 into downtown Fossil, turning east and then north to Wheeler County High School at the foot of the hill on the north side of town.

STOP 7. John Day leaf beds, Fossil

In the bank north of the playing fields behind Wheeler County High School in Fossil (SW¼NW¼ sec. 33, T. 6 S., R. 21 E., Fossil North 7½-minute Quadrangle) light brown shales of the lower John Day Formation yield numerous fossil leaves and rare insects, fish, and salamanders. These fossil remains are similar to the "Bridge Creek flora" and similar fossil floras at numerous localities in central Oregon (Wolfe, 1981a). The most common fossils are foliar spurs of dawn redwood (*Metasequoia occidentalis*), a genus of deciduous conifer that has survived in the wild only in remote regions of China (Chaney, 1948). This is a diverse fossil flora (Manchester and Meyer, 1987; Wolfe and Tanai, 1987), but the following species are especially common: Alder (*Alnus hollandiana*), a hornbeamlike dicot (*Paracarpinus chaneyi*), maple (*Acer osmonti*), and an exinct dicot (*Pteleaecarpum oregonensis*). Also found are fossil beetles, flies, cases of caddis flies (Trichoptera: ichnogenus *Folindusia*), mudminnow fish (*Novumbra oregonensis* Cavender, 1969), salamanders (*Taricha lindoei* Naylor, 1979), and a tooth of an unidentified bat (Brown, 1959).

The fossil plants are evidence of a substantially cooler climate than existed during deposition of the Clarno Formation (Chaney, 1948). *Metasequoia* in today's China (Bartholomew and others, 1983), grows in regions of moderately high summer rainfall (averaging 1,280 mm annually) that are cool and seasonal (January mean of 1.7 °C and August mean of 22 °C). Other elements of the flora also show cool-temperate affinities and were part of an extinct kind of mixed mesophytic forest that was widespread in the Pacific Northwest. Modern comparisons and foliar physiognomy of this fossil flora can be considered evidence that mean annual temperature was 3° to 11 °C, with a mean cold-month temperature of -2° to 1 °C, and mean warm-month temperature of 20° to 27 °C (Manchester and Meyer, 1987).

These deposits are varved in places and, with their fossil fish, were clearly deposited in lakes. Such lacustrine deposits can be contrasted with massive claystones that yield terrestrial mammal fossils elsewhere in the John Day Formation and are sequences of paleosols in alluvial floodplain sequences. Revisions of an original lacustrine interpretation have occurred at one time or another for many of the fossiliferous sequences of Tertiary age in the western United States (Gregory, 1969). While there are some clearly lacustrine deposits, such as parts of the Eocene Green River Formation of Wyoming, many mammal-bearing Tertiary deposits are now recognized to be floodplain deposits, including numerous paleosols.

En route

Return south through Fossil to Oregon Highway 19 and turn east toward Spray and Kimberly. Up the hill east of Fossil we see numerous exposures of andesite flows of the Clarno Formation. This is the main axis of the Clarno volcanic arc, which was a topographic ridge trending northeast and separating the western from eastern depositional basins of the John Day Formation (Robinson and others, 1984). The eastern facies consists of air-fall volcanic ash variably modified by streams, lakes, and soils and has fewer thick ash-flow tuffs and basalt flows than the western facies.

Over the summit past Shelton State Park, the road descends into the valley of the John Day River and runs upsection through the eastern limb of the broad, northeast-trending Fossil anticline. Red beds and tuffs of the John Day Formation crop out 14 mi southeast of Fossil. Near Service Creek, the gorge of the John Day River is flanked by cliffs of the Picture Gorge Basalt flows of the Columbia River Basalt Group.

Continue following Highway 19 through Service Creek and toward Spray (rather than turning south on 207 toward Mitchell). The John Day Formation crops out by the road again in the core of the broad Spray anticline centered on the small town of Spray. There is a thick, red paleosol at the contact between John Day Formation and Picture Gorge Basalt in road cuts here.

Near Kimberly, continue south on Highway 19 (rather than turning east on 207). About 3 mi south of Kimberly, a conspicuous wall of Columbia River basalt is visible to the west across the John Day River. This dike is about 8 m wide and can be traced northwest (azimuth 325) for 5 mi. This dike and a swarm of similar dikes farther east near the town of Monument are thought to have been feeders of the Picture Gorge Basalt flows.

Turn into the Foree unit of the John Day Fossil Beds National Monument, signposted at a turnoff leading east, 8.5 mi south of Kimberly. Leave the vehicles in the parking area and walk east 200 m along the nature trail into the badlands.

STOP 8. John Day mammal beds, Foree

The most accessible outcrops by the nature trail in the Foree area of the John Day Fossil Beds National Monument (Sec. 32, T. 10 S., R. 26 E., Picture Gorge 15-minute Quadrangle) are green tuffs and tuffaceous claystones deposited by streams and locally altered by ancient soil formation. This is in the middle part of the John Day Formation, at a higher stratigraphic level than the lake beds behind Fossil School (Stop 7). The prominent weather-resistant stratigraphic marker bed high in the cliffs is an ash-flow tuff in the middle John Day Formation.

The Foree area exposes the same fossiliferous deposits found to the south in Turtle Cove, where Thomas Condon discovered fossil vertebrates as early as 1869. Many fossils collected between 1870 and 1877 were sent to O.C. Marsh at Yale University and provided valuable evidence for, among other things, the Tertiary evolution of horses (Clark, 1989). Around the turn of the century, collections also were made by field parties from the University of California at Berkeley (Merriam and Sinclair, 1907). Collecting continues from the University of Washington (Rensberger, 1983) and the John Day Fossil Beds National Monument (Fremd, 1988). This is a very diverse fauna of more than 100 species (Merriam and Sinclair, 1907; T. Fremd, personal communication, 1991), including turtle (*Stylemys capax*), deerlike chevrotain (*Hypertragulus hesperius*), oreodon (*Eporeodon occidentalis*), rhinoceros (*Diceratherium armatum*), three-toed horse (*Miohippus anceps*), dog (*Mesocyon josephi*) and saber-tooth cat (*Nimravus debilis*). Also found here are land snails (*Polygyra dalli*) and pits of hackberry (*Celtis willistoni*). The faunas of the green, middle John Day Formation are late Oligocene in age (early Arikareean land mammal "age"). Their great diversity and range of adaptations for locomotion and feeding but lack of high-crowned teeth or elongate cursorial limbs can be interpreted as indications of former woodland vegetation (Van Valkenburgh, 1985; Prothero, 1985).

A variety of paleosols have been found in the John Day Formation. Those of the Foree area are a peculiar lime-green color from the clay mineral celadonite (Hay, 1963). This illitelike clay includes magnesium and more ferric than ferrous iron, and is thought to have formed by burial illitization of smectite in paleosols, lake beds, and basalts (Porrenga, 1968; Norrish and Pickering, 1983; Weaver, 1989). These paleosols are moderately developed (Inceptisols and Aridisols), thin (50 cm or less), clayey to silty profiles. They have abundant fine root traces and scattered large root traces near the surface (A horizon) over a white, nodular or massive, calcareous horizon (Bk). Their paleoclimate was presumably subhumid to semiarid, allowing accumulation of carbonate. The abundant fine root traces and lack of clayey subsurface (Bt) horizons are compatible with wooded grassland or open woodland vegetation, rather more open than would be expected from adaptive features of the mammalian fauna. The preservation of bones along with land snails and calcareous hackberry pits was favored by the calcareous composition of the paleosols, but the soils were too oxidized for the preservation of organic remains of plants (Retallack, 1983, 1984). The paleosols contain significant amounts of ferric iron, but have not been as thoroughly oxidized to red and brown colors as paleosols in the lower John Day Formation. These distinctive green paleosols may have been seasonally dry marsh soils, like alkaline flats around Lake Rukwa, Tanzania (Vesey-Fitzgerald, 1963). Parent material for the paleosols of the John Day Formation was mainly white air-fall ash derived from the ancestral Cascades with some admixture of clay and rock fragments from surrounding older sediments. The time for formation of these soils was on the order of thousands of years, because some of them have well-developed calcic horizons (Stage III in the developmental scheme of Gile and others, 1966).

En route

Return to the vehicles and continue south on Highway 19. It passes a spectacular exposure of John Day Formation, called "Cathedral Rock." This consists of the Turtle Cove Member and a thick ash-flow tuff of the John Day Formation, slumped down to create the large meander in the John Day River.

About 2 mi south of the bridge over the John Day River at Humphrey Ranch there is a roadside outcrop of sandstone and conglomerate on which the Tertiary sequence rests unconformably. These conglomerates are even better exposed in a bend of the John Day River to the south. The conglomerate is Early Cretaceous (Aptian to early Albian) in age (Aguirre and Fisk, 1987) and may have been deposited in braided streams or fan deltas (Kleinhans and others, 1984). Fossil plant fragments have been recovered from shale partings in the conglomerates and include cycadophytes (*Taeniopteris*) and conifers (*Elatocladus*: identifications by author from Condon collection, University of Oregon).

Farther south on Highway 19 is a sign indicating the Visitor Center of John Day Fossil Beds National Monument and then the junction with U.S. Highway 26. By this time it will be quite late in the day, and it is best to return to these outcrops on the next day, after staying overnight at John Day, 38 mi to the east along U.S. Highway 26.

**CONTINUED NEXT MONTH: PART 2
WITH ITINERARY FOR SECOND DAY**

Oil and gas exploration and development in Oregon, 1990

by Dan E. Wermiel, Petroleum Geologist, Oregon Department of Geology and Mineral Industries

ABSTRACT

Oil and gas lease activity in Oregon declined slightly in 1990. Four Bureau of Land Management (BLM) lease sales were held, with one lease purchased. Applications were filed for 67,881 federal acres. The total of federal acres under lease was 471,379 acres at year's end. No state or county lease sales were held during the year.

Five wells were drilled in the Mist Gas Field, of which three were exploratory wells drilled by Nehama and Weagant Energy Company, and two were service wells at the Mist Natural Gas Storage Project drilled by Northwest Natural Gas Company. One Nehama and Weagant Energy Company well was completed as a gas producer, one was an apparent gas producer but had not been flow-tested by year's end, and one was abandoned. The field had 19 gas producers and four completed wells awaiting pipeline connection at year's end. A total of 2.8 billion cubic feet (Bcf) of gas was produced during 1990, with a value of $3.9 million. ARCO abandoned 11 depleted wells during 1990.

Northwest Natural Gas Company injected and withdrew about 6 Bcf of gas at the Mist Natural Gas Storage Project. The gas is delivered to the Portland metropolitan area via the recently completed South Mist Feeder Pipeline.

The Department of Geology and Mineral Industries (DOGAMI) revised its rules for oil and gas drilling in Oregon and adopted new rules relating to drilling and reclamation requirements for shallow holes drilled in oil and gas exploration activities, such as seismic shot holes.

DOGAMI continues a study of the Tyee Basin, located in Douglas and Coos Counties, and has published reports and maps on the geology and oil, gas, and coal resources of the area.

During the legislative session, DOGAMI introduced two bills that affect the oil and gas industry. One will provide for civil penalty authority and the other will increase permit fees.

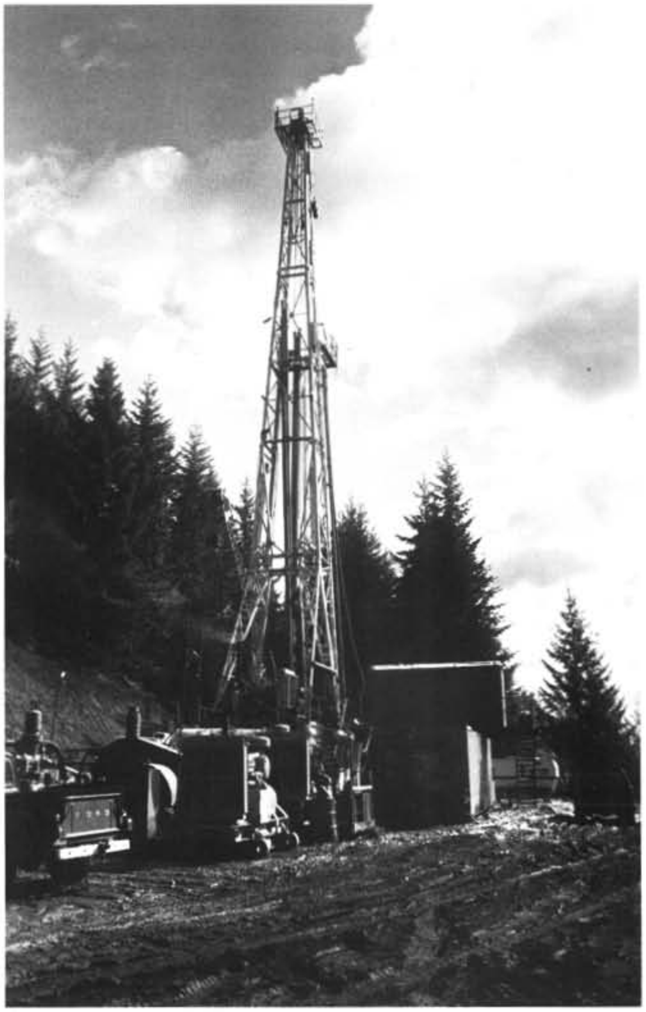


Figure 1. Nehama and Weagant Energy Company drilled the well CER 11-16-64 and completed it as a successful gas producer at the Mist Gas Field. Drilling was performed by Rig 5 of Taylor Drilling Company.

LEASING ACTIVITY

Leasing activity experienced a small decline during 1990, which is a continuation of the pattern in leasing that began during 1988. Activity included four public land sales by BLM as well as over-the-counter filings of BLM property. One lease was acquired during the BLM lease sale held in June 1990, when Oregon Natural Gas Development acquired a parcel in Washington County. This was the first bid on any parcel offered in Oregon at a BLM lease sale since the competitive bidding system was imposed. Applications were filed for 16 parcels totaling 67,881 acres located in Wheeler, Jefferson, and Washington Counties. These were filed by Norwestco, Inc., of Bend, Oregon, and by D.M. Yates of Portland, Oregon. Leases were issued on 23 parcels containing 80,018 acres located in Wheeler, Jefferson, Columbia, and Crook Counties. A total of 24 parcels comprising 72,167 acres was relinquished during the year, so that, at year's end, a total of 182 parcels comprising 471,379 acres were under lease. The total rental income during 1990 was about $520,000.

During the year, no State of Oregon leases were acquired. A total of 19 State of Oregon leases were relinquished consisting of 24,451 acres. At the end of 1990, active State of Oregon leases numbered 39, totaling 48,977 acres. Total rental income was $48,977 for the year.

No state or county lease sales were held during the year.

DRILLING

Three exploratory oil and gas wells and two injection-withdrawal service wells were drilled during 1990. This is a decline from the 14 exploratory oil and gas wells drilled during 1989. All of the wells were drilled at the Mist Gas Field, where most of the oil and gas drilling activity in Oregon has occurred since the field was discovered in 1979.

Of the two operators active during the year, Nehama and Weagant Energy Company was the most active, drilling the three exploratory oil and gas wells at Mist Gas Field. These wells were (1) CER 11-16-64, located in sec. 16, T. 6 N., R. 4 W., drilled to a total depth of 2,328 ft, and completed as a gas producer (Figure 1); (2) CER 41-21-64, located in sec. 21, T. 6 N., R. 4 W., drilled to a total depth of 2,121 ft, and suspended after the setting of production casing; and (3) LF 13-35-65, located in sec. 35, T. 6 N., R. 5 W., drilled to a total depth of 2,150 ft, and plugged and abandoned.

The two injection-withdrawal service wells drilled at the Mist Natural Gas Storage Project were drilled by Northwest Natural Gas Company which operates the project. The IW 32c-10, located in sec. 10, T. 6 N., R. 5 W., was drilled in the Flora Pool to

Table 1. *Oil and gas permits and drilling activity in Oregon, 1990*

Permit no.	Operator, well, API number	Location	Status, depth(ft) TD=total depth PTD=proposed TD
440	Norwestco 1-29 Donnelly Dome 36-069-00009	SW¼ sec. 29 T. 9 S., R. 23 E. Wheeler County	Application; PTD: 5,000.
441	NW Natural Gas IW 13b-11 36-009-00267	SW¼ sec. 11 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,600
442	NW Natural Gas IW 33ac-3 36-009-00268	SE¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 2,897.
443	NW Natural Gas IW 23d-3 36-009-00269	SW¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 3,000.
444	NW Natural Gas IW 32c-10 36-009-00270	NE¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Completed, service well; TD: 2,749.
445	Nehama & Weagant CER 12-12-55 36-009-00271	NW¼ sec. 12 T. 5 N., R. 5 W. Columbia County	Application; PTD: 2,000.
446	Nehama & Weagant LF 13-35-65 36-009-00272	SW¼ sec. 35 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 2,150.
447	Nehama & Weagant CER 41-21-64 36-009-00273	NE¼ sec. 21 T. 6 N., R. 5 W. Columbia County	Suspended; TD: 2,121.
448	Nehama & Weagant CER 22-16-64 36-009-00274	NW¼ sec. 22 T. 6 N., R. 4 W. Columbia County	Application; PTD: 2,500.
449	Nehama & Weagant CER 11-16-64 36-009-00275	NW¼ sec. 16 T. 6 N., R. 4 W. Columbia County	Completed, gas; TD: 2,328.
451	Nehama & Weagant CER 14-16-64 36-009-00277	SW¼ sec. 16 T. 6 N., R. 4 W. Columbia County	Application; PTD: 2,500.

a total depth of 2,897 ft; and the IW 33ac-3, located in sec. 10, T. 6 N., R. 5 W., was drilled in the Bruer Pool to a total depth of 2,749 ft.

Total drilling footage for the year was 12,245 ft, a decrease from the 33,823 ft drilled during 1989. The average depth per well was 2,449 ft, a small increase from the 2,416 ft per well drilled during 1989.

During 1990, DOGAMI issued 8 permits to drill (Table 1) while 5 permits were canceled during the year (Table 2).

ARCO Oil and Gas Company performed, at Mist Gas Field, a multi-well program in which 11 wells were plugged and abandoned and three wells were reperforated for return to production. The plugged and abandoned wells were depleted producers no longer capable of commercial production. These include the CFI 12-1-55 (Figure 2), CC#4 RD#1, CC 43-27-65, LF 12-33-75, Busch 14-15-65, Foster 42-30-65, LF 11-31-64, CC 34-4-65, LF 23-36-65, LF 41-35-65, and CC 11-34-65. The reperforated wells were the CFI 34-1-55, CC 21-35-65, and LF 23-25-65.

DY Oil Company reperforated the Neverstill 33-30 well and returned it to production during the year (Figure 3).

DISCOVERIES AND GAS PRODUCTION

Mist Gas Field saw one new producer, and one suspended well that is an apparent producer but had not yet been flow-tested by year's end. This is a decrease from the four new producers in 1989. Nehama and Weagant Energy Company is the operator of the new producer, the CER 11-16-64, and the suspended indicated producer, the CER 41-21-64.

Figure 2. ARCO well CFI 12-1-55 was plugged along with 10 other depleted producers at Mist Gas Field.

At the end of 1990, three companies were operating 19 gas producers at Mist Gas Field: ARCO Oil and Gas Company, DY Oil Company, and Nehama and Weagant Energy Company. In addition, four wells were suspended, awaiting pipeline connection.

Gas production for the year totaled 2.8 Bcf. This is an increase from the 2.5 Bcf of gas produced during 1989. The cumulative field production as of the end of 1990 was about 41.2 Bcf of gas. The total value of the gas produced for the year was $3.9 million, an increase from the $3.5 million during 1989. Gas prices ranged from 14 cents to 15 cents per therm, which is about the same as during 1989.

GAS STORAGE

During the year, Northwest Natural Gas Company drilled two new service wells at the Mist Natural Gas Storage Project. The IW 32c-10 is an injection-withdrawal well drilled in the Flora Pool, and the IW 33ac-3 is an injection-withdrawal well drilled in the Bruer Pool. The storage project now has a total of seven injection-withdrawal wells; three in the Flora Pool and four in the Bruer Pool. These pools have a combined storage capacity of 10 Bcf of gas. This allows for cycling the reservoirs between approximately 400 psi to 1,000 psi and will provide for an annual delivery of one million therms per day for about 100 days. During the year, about 6.0 Bcf of gas was injected and withdrawn from the gas storage projects. This gas is delivered to the Portland metropolitan area via the recently competed South Mist Feeder Pipeline.

Table 2. *Canceled permits, 1990*

Permit no.	Operator, well, API number	Location	Issue date	Cancellation date	Reason
421	ARCO Col. Co. 42-32-74 36-009-00250	NE¼ sec. 32 T. 7 N., R. 4 W. Columbia Co.	4-17-89	4-17-90	Permit canceled; expired.
426	LEADCO CC-Jackson 23-17 36-009-00255	SW¼ sec. 17 T. 5 N., R. 4 W. Columbia Co.	7-19-89	7-19-90	Permit canceled; expired.
434	ARCO Col. Co. 13-3-55 36-009-00263	SW¼ sec. 3 T. 5 N., R. 5 W. Columbia County	8-28-89	8-29-90	Permit canceled; expired.
435	ARCO Col. Co. 13-4-54 36-009-00264	SW¼ sec. 4 T. 5 N., R. 4 W. Columbia County	8-28-89	8-29-90	Permit canceled; expired.
450	Nehama & Weagant CC 23-35-75 36-009-00276	SW¼ sec. 35 T. 7 N., R 5 W. Columbia County	9-17-90	11-29-90	Permit canceled; by permittee's request.

OTHER ACTIVITIES

The administrative rules relating to oil and gas exploration and development in Oregon were revised during 1990. This revision was done as a triannual rule review, and led to several changes. In addition, new administrative rules relating to shallow oil and gas exploration holes drilled in Oregon were adopted during the year. These new rules were developed to provide for ground-water protection and reclamation whenever shallow holes are drilled in oil and gas exploration activities, such as seismic shot holes and stratigraphic core holes. Copies of these rules (OAR 632, Division 15) are available free from DOGAMI.

DOGAMI continues the study of the oil and gas potential of the Tyee Basin, located primarily in Douglas and Coos Counties in southwestern Oregon. The study, which is funded by landowners in the study area and by county, state, and federal agencies, is intended to investigate those characteristics needed to generate and trap gas and oil: source rock, stratigraphy, and structural framework. The first phase of the study resulted in the publication of DOGAMI Open-File Report O-89-3, *Geology and Oil, Gas, and Coal Resources, Southern Tyee Basin, Southern Coast Range, Oregon.* This report includes the stratigraphic and structural framework and source rock data of the Tyee Basin and is available from DOGAMI ($10). During 1990, a detailed geologic map of the Reston 7½-minute Quadrangle was published and is available from DOGAMI as map GMS-68 ($6). This geologic map has led to a revision of the understanding of the geologic framework of the Tyee Basin. During 1991, a fence diagram will be published that will tie surface and subsurface data and geophysical data together. In addition, a detailed geologic map of the Camas 7½-minute Quadrangle will be published during the year.

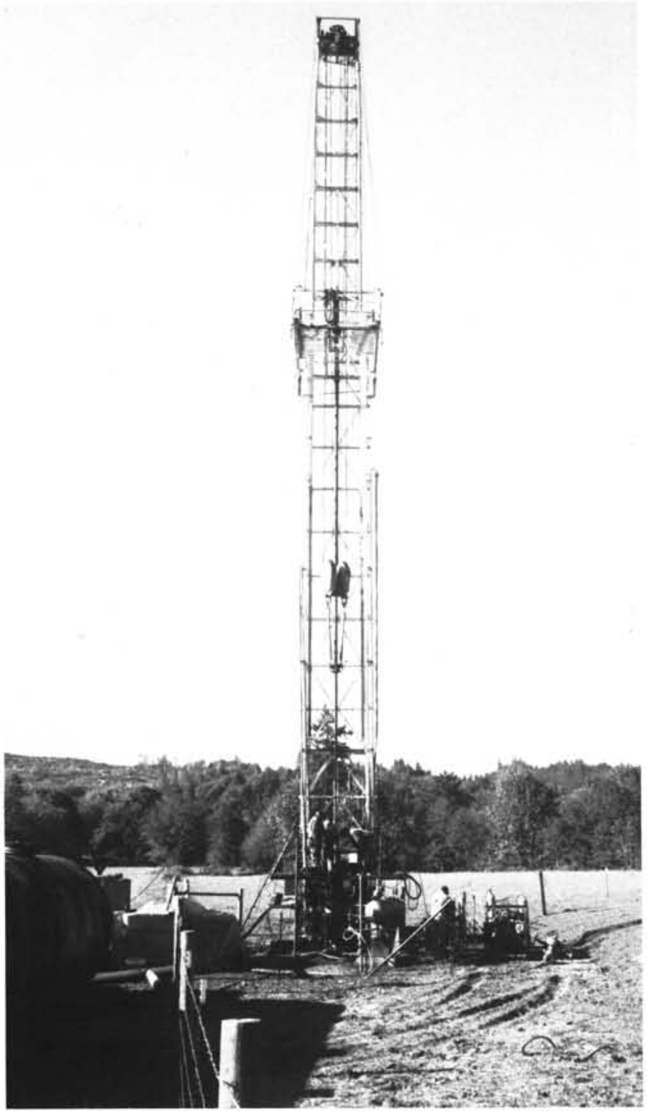


Figure 3. DY Oil Company reperforated the well Neverstill 33-30 during 1990 and returned it to production.

During 1990, a transect was published by DOGAMI which presents a geological and geophysical cross section extending from the Mist Gas Field to the northwest Oregon continental shelf and slope. This publication, OGI-17, is available from DOGAMI ($10).

The Northwest Petroleum Association remained active during 1990 and had about 130 members at year's end. At monthly meetings, papers related to the oil and gas industry are presented. For 1991, plans are to hold the annual symposium in the Bellingham Basin in the northern Puget Sound, Washington.

During the year, the U.S. Minerals Management Service placed a moratorium on a planned oil and gas lease sale for the outer continental shelf off Oregon and Washington for a 10-year period through the year 2000. The sale was originally scheduled for 1992. During the 10-year moratorium on leasing, a study of the environmental effects of oil and gas activity is to be conducted.

Columbia County will hold a lease auction during 1991. Some 120 parcels comprising about 46,000 acres will be offered for oral bid. Details can be obtained from the Columbia County Commissioners Office, St. Helens, Oregon.

DOGAMI has introduced two bills during the current legislative session which may affect the oil and gas industry. One bill will give the agency civil penalty authority as part of its oil and gas regulatory program. Another bill will increase permit fees for oil and gas drilling in Oregon. Copies of these bills are available free from DOGAMI. □

Mining and exploration in Oregon during 1990

by Thomas J. Wiley, Regional Geologist, Grants Pass Field Office, Oregon Department of Geology and Mineral Industries

ABSTRACT

Mineral production of about $225 million is anticipated in 1990, primarily from sand, gravel, cement, crushed stone, and nickel operations. Glenbrook Nickel produced 8.3 million pounds of nickel, a ten-fold increase in production over 1989. Formosa Resources Silver Peak Mine in Douglas County is producing copper, zinc, silver, and gold. Atlas Precious Metals Company continues permitting, environmental monitoring, and definition drilling for its Grassy Mountain gold prospect in Malheur County. Exploration in the Lake Owyhee region has reached the prospect evaluation phase, while broad reconnaissance has shifted northward to early Tertiary intrusions and vein systems in pre-Tertiary rocks. The Oregon Department of Geology and Mineral Industries (DOGAMI) is beginning a new geologic mapping and sampling program in southern Oregon to assess mineral resources of the Western Cascades.

NEW DEVELOPMENTS IN OREGON DURING 1990

The U.S. Bureau of Mines (USBM) estimate of mineral production value for 1990 is $225 million, primarily from sand, gravel, cement, crushed stone, and nickel operations (Table 1). The USBM estimate of 1989 production included $55 million worth of metals and industrial minerals; this figure rose to $89 million during 1990, largely as a result of increased production at Glenbrook Nickel. The Oregon Department of Geology and Mineral Industries (DOGAMI) values natural gas produced from Columbia County's Mist Gas Field at about 4 million dollars for 1990. Active mines and exploration sites are shown on Figure 1.

Table 1. *Summary of mineral production value (in millions of dollars) in Oregon for the last 19 years. Data for 1990 derived from U.S. Bureau of Mines annual preliminary mineral-industry survey and Oregon Department of Geology and Mineral Industries natural-gas statistics.*

	Rock materials[1]	Metals and industrial minerals[2]	Natural gas	Total
1972	54	22	0	76
1973	55	26	0	81
1974	75	29	0	104
1975	73	33	0	106
1976	77	35	0	112
1977	74	35	0	109
1978	84	44	0	128
1979	111	54	+	165
1980	95	65	12	172
1981	85	65	13	163
1982	73	37	10	120
1983	82	41	10	133
1984	75	46	8	129
1985	91	39	10	140
1986	96	30	9	135
1987	102	52	6	160
1988	130	48	6	184
1989	131	55	4	190
1990	132	89	4	225

[1] Includes sand, gravel, and stone.

[2] For 1990, this includes cement; clays, including bentonite; copper-zinc; diatomite; gemstones, including Oregon sunstone; gold-silver; nickel; perlite; pumice; quartz; silica sand; talc, including soapstone; and zeolites.

The construction minerals segment of the industry will be affected by changing growth patterns in the state. Preliminary 1990 population figures released by the U.S. Census Bureau show a state-wide increase of about 200,000 residents since 1980; this brings the state's population to 2.8 million. Five counties experienced ten-year growth rates of 15 percent or more; four of these are in the Portland area. Deschutes County grew 20 percent. Three counties in north-central Oregon showed population declines greater than 10 percent. Overall, the population increased in 23 of 36 counties.

PRODUCTION HIGHLIGHTS

Eastern Oregon

The Bonnanza placer mine (Mine site 2, Table 2) on Pine Creek in Baker County remains the state's largest gold producer. Work is limited to April through November. At full production, the mine runs two shifts and employs 25 to 30 people. Reclamation and habitat improvement on mined areas has been concurrent with production; the northern part of the site has already been reclaimed. Mining at the current rate, the deposit will be mined out during the year 1991.

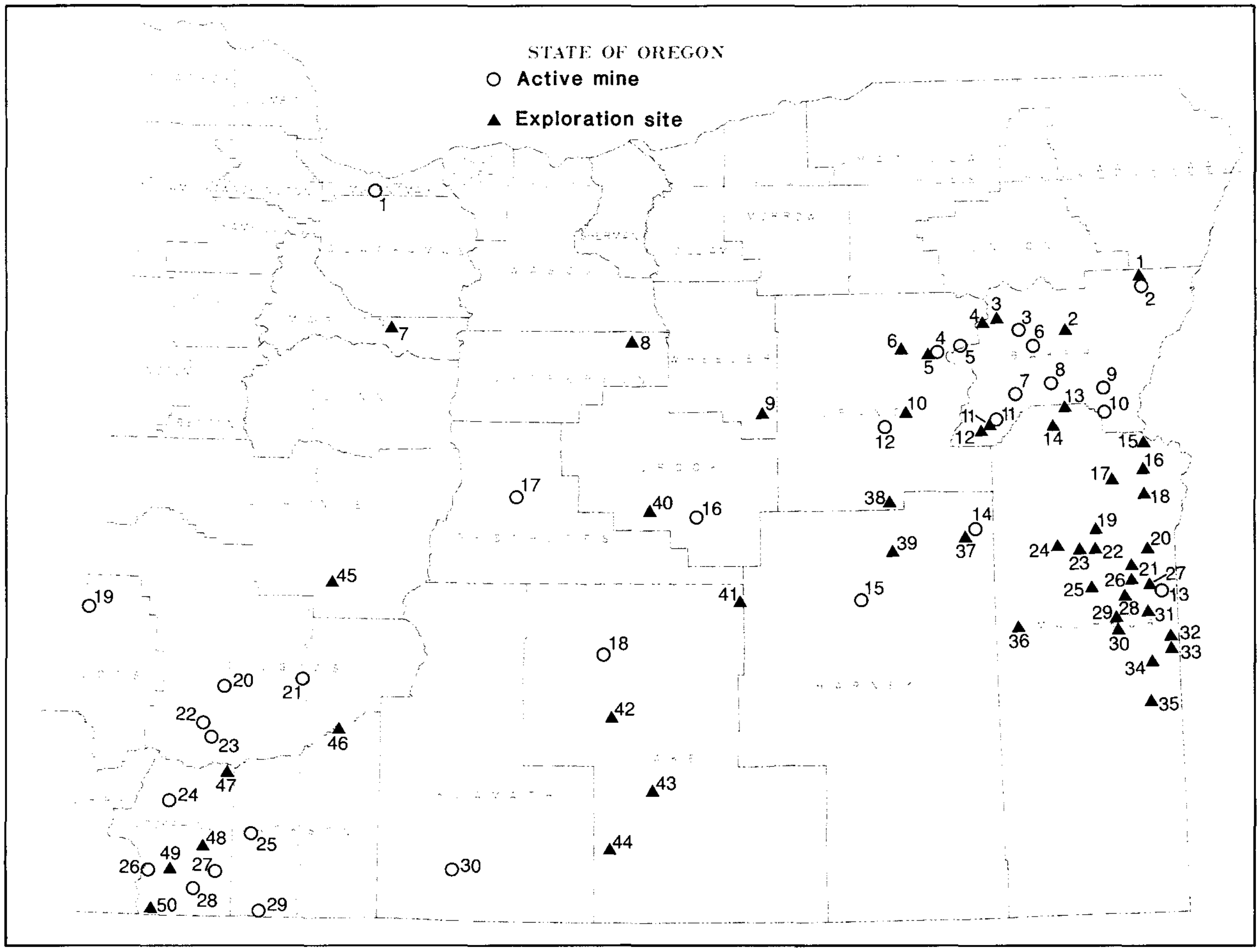
Ash Grove Cement West, Inc., near Baker (Mine site 9, Table 2) achieved capacity production of 500,000 tons of cement and 220,000 tons of crushed limestone (sold as "sugar rock") during 1990. This represents a small increase in production over 1989. The company employs 105 workers.

The Ponderosa Mine (Mine site 15, Table 2) in Harney County near Hines is processing altered basalt to produce sunstone, a variety of feldspar that is Oregon's state gem. One Track Mines and Western Consolidated cooperated to produce 200 kg (440 lbs) of sunstone valued at $250,000 in 1990. This represents a 100-percent increase over 1989 levels, and production is expected to double again in 1991. Average grade is about 0.1 kg per ton (0.22 lbs/ton). Some stones are valued at more than $1,000 per carat.

Western Oregon

Glenbrook Nickel (Mine site 22, Table 2; Figure 2) estimates that 1990 production has increased an order of magnitude above 1989 levels. In 1989, 150,000 dry tons of stockpiled ore reached the furnaces, and 750,000 lbs of nickel was produced as ferronickel. In 1990, Glenbrook estimates, 600,000 tons of ore reached the smelter, and 8.35 million pounds of nickel was produced with a value near $33 million (based on a nickel price of $4/lb). Glenbrook has begun mining fine-grained ore from waste dumps and abandoned settling ponds to improve the size mix of furnace feed. The company is developing a plan to mine high-grade pods of ore from Nickel Mountain.

Formosa Resource's Silver Peak Mine (Mine site 23, Table 2; Figure 3) has begun producing copper, zinc, silver, gold, and possibly sulfur from a Kuroko-type massive-sulfide deposit near Riddle in Douglas County. Formosa geologist Will Beach reports a resource of about 425,000 tons grading two percent zinc, three percent copper, 0.045 oz/ton gold, and 1 oz/ton silver. The deposit is characterized by a combination of early soft-sediment deformation of massive sulfide lenses and subsequent structural dismemberment, the latter possibly related to the Coast Range fault that crops out a few hundred meters to the west. The company is installing a 200 ton per day mill and plans to increase output to 400 tons per day. Concentrates will be hauled to Vancouver, Washington, and then shipped to Japan for smelting. Waste rock will be backfilled in the underground workings.



EXPLANATION

Active Mines and Areas

1. Columbia Brick Works
2. Bonanza Mine (placer gold)
3. Deer Creek (placer gold)
4. Big Creek (placer gold)
5. Greenhorn area (placer gold)
6. Elk Creek (placer gold)
7. Pine Creek (placer gold)
8. Dooley Mountain (perlite)
9. Ash Grove Cement West (cement and crushed limestone)
10. Rye Valley/Mormon Basin (placer gold)
11. Lower Grandview Mine (placer gold)
12. Canyon City Placers (placer gold)
13. Teague Mineral Products (bentonite and clinoptilolite)
14. Eagle-Picher Industries (diatomite)
15. Ponderosa Mine (Oregon sunstone)
16. Central Oregon Bentonite/Oregon Sun Ranch (bentonite clay)
17. Cascade Pumice/Central Oregon Pumice
18. Oil-Dri Production (diatomite)
19. CooSand (silica sand)
20. Oregon Portland Cement (limestone)
21. Quartz Mountain (silica)
22. Nickel Mountain (nickel)
23. Silver Peak (copper, zinc, gold, silver)
24. Galice area (placer gold)
25. Bristol Silica and Limestone (silica)
26. Josephine Creek area (placer gold)
27. Jones Marble quarry (agricult. limestone)
28. Sucker Creek area (placer gold)
29. Steatite of Southern Oregon (soapstone)
30. Klamath Falls Brick and Tile

Exploration Sites and Areas

1. Cornucopia Mine (lode gold)
2. White Swan—U.P. (lode gold)
3. Bourne (gold, silver)
4. Herculean Mine (gold and base metals)
5. Mammoth (gold, silver, copper)
6. Susanville (lode gold)
7. Bornite (copper, gold, silver)
8. Red Jacket (lode gold)
9. Spanish Gulch (lode gold)
10. Prairie Diggings (lode gold)
11. Record and Grouse Creek (gold, copper)
12. Grouse Creek (copper, silver)
13. Racey property (lode gold)
14. Cow Valley Butte (lode gold)
15. Kerby/East Ridge (lode gold)
16. Tub Mountain area (lode gold)
17. Hope Butte (lode gold)
18. Vale Butte (lode gold)
19. H claims (lode gold)
20. Calavera (lode gold)
21. Grassy Mountain (lode gold)
22. Harper Basin (lode gold)
23. BCMX (lode gold)
24. Gold Creek area (lode gold)
25. Freeze (lode gold)
26. Burnt Mountain area (lode gold)
27. Camp Kettle (lode gold)
28. Dry Creek Buttes area (lode gold)
29. Jessie Page (lode gold)
30. Red Butte (lode gold)
31. South Owyhee Ridge area (lode gold)
32. Bannock (lode gold)
33. Mahogany (lode gold)
34. Mahogany Gap and Storm (lode gold)
35. Jordan Valley area (lode gold)
36. Stockade area (lode gold)
37. Drewsey area (lode gold)
38. Baboon Creek (limestone)
39. Idol City area (lode gold)
40. Bear Creek Butte (lode gold)
41. Glass Butte (lode gold)
42. Summer Lake area (lode gold)
43. Paisley area (lode gold)
44. Quartz Mountain (lode gold)
45. Bohemia District (lode gold)
46. Prospect Silica (silica)
47. Martha Mine (lode gold)
48. Marble Mountain (limestone)
49. Eight Dollar Mountain (nickel laterite)
50. Turner-Albright (copper, zinc, gold)

Figure 1. Mining and mineral exploration sites in Oregon in 1990, excluding sand, gravel, and stone. Active mines are keyed to Table 2; exploration sites are keyed to Table 3.

Table 2. *Active mines in Oregon, 1990*

No.	Mine name	Company	Commodity	Location	Remarks
1	—	Columbia Brick Works	Brick	Sec. 14, T. 1 S., R. 3 E., Multnomah County	—
2	Bonnanza	Bonnanza Mining Company	Placer gold	Sec. 3, T. 7 S., R. 45 E., Baker County	Oregon's largest producing gold mine; reclamation and mining are concurrent. Company plans to close mine during 1991.
3	Deer Creek	Cammtex International, Inc.	Placer gold	Sec. 30, T. 9 S., R. 38 E., Baker County	Reopened after a two-year lapse in operation.
4	Big Creek	—	Placer gold	T. 10 S., R. 34 E., Grant County	—
5	Greenhorn area	—	Placer gold	Tps. 9, 10 S., R. 35 E., Baker and Grant Counties	—
6	Elk Creek	—	Placer gold	Tps. 9, 10 S., R. 39 E., Baker County	—
7	Pine Creek	—	Placer gold	T. 12 S., R. 38 E., Baker County	—
8	Dooley Mountain	Supreme Perlite Company	Perlite	Tps. 11, 12 S., R. 40 E., Baker County	Produced 1,000 tons during 1990.
9	—	Ash Grove Cement West, Inc.	Cement, crushed limestone	Sec. 11, T. 12 S., R. 43 E., Baker County	Reached capacity production of 500,000 tons of cement plus 200,000 tons of limestone; employs 105.
10	Rye Valley/ Mormon Basin area	—	Placer gold	T. 13 S., Rs. 42, 43 E., Baker County	—
11	Lower Grandview	—	Lode gold	Sec. 6, T. 14 S., R. 37 E., Baker County	Mill tailings hauled to cyanide-leach facility in Nevada. New drift of 400 ft. Mine closed.
12	Canyon City Placers	Cammtex International, Inc.	Placer gold	Sec. 6, T. 14 S., R. 32 E., Grant County	Reclaimed and closed during 1990.
13	—	Teague Mineral Products	Bentonite and clinoptilolite	Secs. 28, 29, T. 23 S., R. 46 E., Malheur County (and nearby Idaho)	Plant located Sec. 8, T. 23 S., R. 46 E. Company reports increasing sales, including Europe and Latin America.
14	Eagle-Picher	Eagle-Picher Industries, Inc.	Diatomite	Tps. 19, 20 S., R. 35, 36 E., Malheur and Harney Counties	Plant located Sec. 6, T. 19 S., R. 44 E.
15	Ponderosa Mine	One Track Mines/ W. Consolidated	Oregon sunstone	T. 23 S., R. 30 E., Harney County	Produced 200 kg gemstones in 1990. Company plans to double production in 1991.
16	—	Central Oregon Bentonite Co./ Oregon Sun Ranch, Inc.	Bentonite	Sec. 4, T. 19 S., R. 21 E., Crook County	Produced about 10,000 tons in 1990 for cat litter, road construction material, and pond linings.
17	—	Cascade Pumice Co./Central Oregon Pumice Company	Pumice	Tps. 17, 18 S., R. 11 E., Deschutes County	—
18	—	Oil-Dri Production Company	Diatomite	Secs. 14, 21, 23, T. 26 S., R. 16 E., Lake County	—
19	—	CooSand Corporation	Silica sand	Sec. 34, T. 24 S., R. 13 W., Coos County	Product used for glass, foundry work, and traction. Company patented several sand claims near Oregon Dunes; employs five in Oregon.
20	Oregon Portland Cement quarry	Mountain Valley Resources	Limestone	Sec. 20, T. 28 S., R. 5 W., Douglas County	Formerly D and D Ag Lime and Rock Company.
21	Quartz Mountain	—	Silica	Sec. 2, T. 28 S., R. 1 W., Douglas County	—
22	Nickel Mountain	Glenbrook Nickel Company	Nickel	Secs. 28, 29, T. 30 S., R. 6 W., Douglas County	Tenfold increase in production; very limited mining.
23	Silver Peak Mine	Formosa Resources, Inc.	Copper, zinc, gold, silver	Sec. 23, T. 31 S., R. 6 W., Douglas County	Began producing at end of 1990.
24	Galice area	—	Placer gold	Tps. 34, 35 S., R. 8 W., Josephine County	—
25	—	Bristol Silica and Limestone Company	Silica	Sec. 30, T. 36 S., R. 3 W., Jackson County	—
26	Josephine Creek area	—	Placer gold	Tps. 38, 39 S., R. 9 W., Josephine County	—
27	Jones Marble quarry	Campman Calcite Company	Agricultural limestone	Sec 31, T. 38 S., R. 5 W., Josephine County	Closed.
28	Sucker Creek area	—	Placer gold	Tps 39, 40 S., Rs. 6, 7 W., Josephine County	—
29	—	Steatite of Southern Oregon	Soapstone	Secs. 10, 11, T. 41 S., R. 3 W., Jackson County	Acquired adjacent land.
30	—	Klamath Falls Brick and Tile Co.	Brick	Sec. 19, T. 38 S., R. 9 E., Klamath County	New markets in Washington and California; employs 26.

Figure 2. Glenbrook Nickel plant near Riddle (Mine site 22, Table 2) increased its production 1,000 percent from 1989 to 1990. Eight million pounds of nickel (as ferronickel) was produced from 600,000 tons of ore smelted during 1990.

Figure 3. Formosa Resources' Silver Peak Mine (Mine site 23, Table 2) is producing copper, zinc, silver, and gold. Mill and settling pond are located on the ridge crest, and ore is trucked to the mill from the portal at left.

Inspiration Resources Corporation purchased LTM, Inc., and Rogue Aggregate, Inc., the largest producers of sand, gravel, and crushed rock in Jackson County. A DOGAMI review of Jackson County aggregate was stimulated by a 1970 estimate that the resource would be exhausted sometime between 1985 and 2005. Additional resources have been discovered since 1970, and there is currently a reserve base that should last well into the 21st century.

Campman Calcite has rebuilt the road to the Marble Mountain limestone quarry (Exploration site 48, Table 3) outside Grants Pass and terminated operations in the Jones Marble quarry (Mine site 27, Table 2) near Williams.

Placer gold

In addition to the Bonnanza placer described above, several small placer mines opened and operated intermittently on Sucker Creek (Mine site 28, Table 2), Josephine Creek (Mine site 26, Table 2), and in the Galice area (Mine site 24, Table 2) in Josephine County; on Deer Creek (Mine site 3, Table 2), Elk Creek (Mine site 6, Table 2), and in Rye Valley (Mine site 10, Table 2) in Baker County; in the Mormon Basin (Mine site 10, Table 2) near the Baker County-Malheur County line; and on Big Creek (Mine site 4, Table 2) in Grant County.

EXPLORATION HIGHLIGHTS

Eastern Oregon

Malheur Mining's Kerby/East Ridge prospect (Exploration site 15, Table 3) saw an additional 90 drill holes completed, including 6 core holes, to bring the total to 340 holes. Airborne EM resistivity studies, bulk sampling, and pilot metallurgical studies were undertaken during 1990. Environmental monitoring is in its second year.

Developments in the private sector have involved a large number of negotiations to create partnerships and joint ventures. Horizon Gold Shares, Inc., entered a joint venture with Chevron Resources Company at Hope Butte (Exploration site 17, Table 3) in northern Malheur County. This year, Horizon added 26 drill holes to the 77 holes drilled by Chevron. More than 30 holes have already been reclaimed. Cultural and small-mammal surveys are complete, an air-quality monitor is going up, and a ground-water monitoring well has been drilled.

Atlas Precious Metals Company has begun the permit process for the 1.2-million-ounce Grassy Mountain gold prospect (Exploration site 21, Table 3) in Malheur County. The U.S. Bureau of Land Management reports that the Final Scoping Document and Final Study Plan are completed and the draft environmental impact statement should be finished by next summer. A feasibility study indicates the potential for 100,000 troy oz of gold per year and a similar amount of silver for at least eight years. A six million dollar annual payroll supporting 190 jobs is projected.

Chevron Resources granted MK Gold of Boise a 40-percent interest in the Jessie Page (Quartz Mountain) property (Exploration site 29, Table 3) near Vale, Malheur County. Operating from its camp at the site, Chevron completed about 140 new drill holes this year.

Pegasus Gold Corporation is presently in the second year of a two-year option with Wavecrest Resources at the Quartz Mountain prospect (Exploration site 44, Table 3) in Lake County, where the current emphasis is on feasibility studies and problematic metallurgy of sulfide ores. An additional 28 development holes and 19 large-diameter core holes were drilled in 1990. Baseline environmental studies are ongoing.

Exploration in the Lake Owyhee "gold rush" region has generally shifted to the prospect evaluation phase, while broad reconnaissance exploration has moved elsewhere in eastern Oregon. New plays receiving attention in eastern Oregon include the following:

(1) Disseminated ore associated with vein systems in pre-Tertiary rocks, such as the Mammoth Property (Exploration site 5, Table 3) in Grant County, where Formation Capital Corporation has combined the Stalter, Pioneer, Golden West, and Wray Mine properties into a single prospect with gold-copper (Stalter) and gold-silver (Pioneer) targets. Gold and copper were produced from wide zones of quartz veins and stockworks in granodiorite and greenstone that typify this part of the Greenhorn District.

(2) Disseminated deposits associated with late Eocene to early Oligocene intrusives in argillite and flysch such as Manville's Record/Grouse Creek prospect (Exploration site 11, Table 3) in southwest Baker County.

Baker County is seeing some new underground activity, as J.R. Simplot Resources' Bourne project opens a new drift along the E and E portion of the North Pole-Columbia Lode (Exploration site 3, Table 3) in the Cracker Creek District near Sumpter. The Cracker Creek "vein" is a compound quartz-argillite breccia/vein system that cuts the Elkhorn Argillite. The company plans to drill during 1991.

Bond Gold Exploration Company's Red Jacket prospect (Exploration site 8, Table 3) extends the area of recent gold exploration activity into Jefferson County. Company geologists completed 12 drill holes during 1990 and conducted geophysical investigations and geologic mapping.

Table 3. *Exploration sites in Oregon, 1990*

No.	Mine name	Company	Commodity	Location	Remarks
1	Cornucopia Mine	UNC Corporation	Lode gold	Sec. 27, T. 6 S., R. 45 E., Baker County	—
2	White Swan-U.P.	Gold River Exploration	Lode gold	T. 9 S., R. 41 E., Baker County	Trenching and underground mapping.
3	Bourne (N. Pole-Columbia Lode)	J.R. Simplot Resources	Gold, silver	T. 8 S., R. 37 E., Baker County	More than 20 core holes; retimbered workings.
4	Herculean Mine	Cable Cove Mining Company	Gold, base metals	Sec. 22, T. 8 S., R. 36 E., Baker County	Underground exploration.
5	Mammoth	Formation Capital Corporation	Gold, silver, copper	Secs. 8, 17, T. 10 S., R. 34 E., Grant County	190 claims, combined Stalter, Pioneer, Golden West, and Wray mines; opened workings, trenching, soil sampling, geologic mapping.
6	Susanville	Cradle Mountain Resources, Am. Copper and Nickel jt. venture	Lode gold	Tps. 9, 10 S., Rs. 32, 33 E., Grant County	ACNC drilled 3 core holes before joint venture.
7	Bornite	Plexus Resources Corporation	Copper, gold, silver	Sec. 36, T. 8 S., R. 4 E., Marion County	Drilled 16 holes. Increased reserves beyond 2.8 million tons reported in 1989.
8	Red Jacket	Bond Gold Exploration, Inc.	Lode gold	T. 9 S., R. 17 E., Jefferson County	Drilled 12 holes; geologic mapping, geophysics.
9	Spanish Gulch	ASARCO, Inc.	Lode gold	T. 13 S., Rs. 24, 25 E., Wheeler County	Drilled 2 holes.
10	Prairie Diggings prospect	Western Gold Exploration and Mining Company	Lode gold	Sec. 33, T. 13 S., R. 32 E., Grant County	Drilled.
11	Record/ Grouse Creek prospects	Manville Corporation	Gold, copper	T. 14 S., Rs. 36, 37 E., Baker County	Drilled 12 holes; bulk sampling for geochemistry.
12	Grouse Creek prospect	Golconda Resources, Ltd.	Copper, silver	Secs. 24, 25, T. 14 S., R. 36 E., Baker County	—
13	Racey property	Billiton Minerals USA and ICAN Minerals, Ltd., joint venture	Lode gold	Tps. 12, 13 S., Rs. 40, 41 E., Malheur County	Billiton enlarged the project area through a joint venture with Earth Search Sciences, Inc., Goldsearch, and Beaver Resources on adjacent Shasta Butte properties, drilled 65 holes, and sampled in 28 trenches.
14	Cow Valley Butte	Cambiex USA, Inc.	Lode gold	T. 14 S., R. 40 E., Malheur County	Soil sampling and surface sampling along 2 mi of new road.
15	Kerby/ East Ridge	Malheur Mining Company	Lode gold	Secs. 22, 27, T. 15 S., R. 45 E., Baker County	Six core holes and 84 r-c holes drilled during 1990 for a total of 340 holes at the prospect; geophysics, pilot metallurgy, and continued environmental monitoring.
16	Tub Mountain area	Atlas Precious Metals, Inc., Euro-Nevada Mining Corporation, Echo Bay Exploration, Inc.	Lode gold	Tps. 16, 17 S., R. 45 E., Malheur County	Geologic mapping by Atlas, drilling and geophysics at Echo Bay's Hot Tub prospect.
17	Hope Butte	Horizon Gold Shares, Inc., and Chevron Resources Company	Lode gold	Sec. 21, T. 17 S., R. 43 E., Malheur County	Joint venture, 123 claims; drilled 26 holes, reclaimed drill holes; environmental monitoring continues, permitting underway.
18	Vale Butte	Atlas Precious Metals, Inc.	Lode gold	Secs. 28, 29, T. 18. S., R. 45 E., Malheur County	Geologic mapping and surface sampling.
19	H claims	U.S. Gold	Lode gold	Secs. 2, 10, 11, T. 20 S., R. 42 E., Malheur County	44 claims, geologic mapping and sampling.
20	Calavera	Nerco Exploration Company	Lode gold	T. 21 S., R. 45 E., Malheur County	Drilling, surface sampling, and geologic mapping.
21	Grassy Mountain	Atlas Precious Metals, Inc.	Lode gold	Sec. 8, T. 22 S., R. 44 E., Malheur County	981 claims; drilling, water wells. BLM released Final Scoping Document and Final Study Plan; Atlas completed a feasibility study.
22	Harper Basin	American Copper and Nickel Company, Inc., and Atlas Precious Metals, Inc.	Lode gold	T. 21 S., R. 42 E., Malheur County	90 claims; Atlas drilled one hole.
23	BCMX	American Copper and Nickel Company, Inc.	Lode gold	Secs. 10, 11, 14, 15, T. 21 S., R. 41 E., Malheur County	Geologic mapping and geophysics.
24	Gold Creek area	Manville Corporation	Lode gold	Secs. 3, 4, 10, T. 21 S., R. 40 E., Malheur County	33 claims; geologic mapping and geophysics.
25	Freeze	Western Mining Corporation and Larry Smith	Lode gold	T. 23 S., R. 42 E., Malheur County	169 claims; 32 holes drilled; geophysics, geologic mapping, and geochemistry.
26	Burnt Mountain area	Noranda Exploration, Inc., Echo Bay Exploration, Inc.	Lode gold	Tps. 22, 23 S., R. 44 E., Malheur County	Sampling and geophysics by Noranda, mapping by Echo Bay.

Table 3. *Exploration sites in Oregon, 1990 (continued)*

No.	Mine name	Company	Commodity	Location	Remarks
27	Camp Kettle	ASARCO, Inc.	Lode gold	T. 23 S., R. 45 E., Malheur County	Geologic mapping and geochemical sampling.
28	Dry Creek Buttes area	Manville Corporation and ASARCO, Inc., Noranda Expl., Inc.	Lode gold	Tps. 23, 24 S., Rs. 43, 44 E., Malheur County	Drilling, surface sampling, and geophysics by Noranda; geologic mapping and geochemistry by ASARCO.
29	Jessie Page (Quartz Mtn.)	Chevron Resources Co. and M.K. Gold	Lode gold	Sec. 6, T. 25 S., R. 43 E., Malheur County	About 140 drill holes.
30	Red Butte	Chevron Resources Company	Lode gold	Secs. 26, 27, 34, 35, T. 25 S., R. 43 E., Malheur County	Hand sampling and trenching.
31	South Owyhee Ridge area	Manville Corporation and ASARCO, Inc.; Noranda Exploration, Inc., and Euro-Nevada Minerals joint venture	Lode gold	Tps. 24, 25 S., R. 45 E., Malheur County	ASARCO ran geophysics and drilled 9 holes at Katey; Noranda Exploration did surface sampling, geophysics, geochemistry, and drilling at Goldfinger.
32	Bannock	Manville Corporation	Lode gold	Sec 11, T. 26 S., R. 46 E., Malheur County	Drilled one hole, geochemical sampling.
33	Mahogany	Chevron Resources Company, leased from Manville Corp.	Lode gold	Secs. 25, 26, T. 26 S., R. 46 E., Malheur County	Drilled two holes.
34	Mahogany Gap and Storm	Phelps Dodge	Lode gold	Secs. 18, 19, 30, T. 27 S., R. 45 E., Malheur County	39 claims; drilling and hand sampling.
35	Jordan Valley area	Manville Corporation, Battle Mountain Expl. Co., Nerco Expl. Co.	Lode gold	T. 29 S., R. 45 E., Malheur County	Geologic mapping and geophysics at Manville's Hillside prospect; drilling and geophysics at Battle Mountain's Lava Project.
36	Stockade area	BHP-Utah International, Carlin Gold jt. venture; Phelps Dodge	Lode gold	Tps. 25, 26 S., R. 38 E., Malheur County	44 claims; drilling and hand sampling by Phelps Dodge. BHP-Utah International drilled 18 holes at Stockade Mountain.
37	Drewsey area (Red Butte/Pine Creek)	Battle Mountain Expl. Company and others	Lode gold	T. 20 S., R. 35 E., Harney County	Battle Mountain permitted to drill at Pine Creek.
38	Baboon Creek	Chemstar Lime, Inc.	Limestone	T. 19 S., R. 32 E., Grant County	Drilled 2 holes.
39	Idol City area	Newmont Exploration, Ltd.	Lode gold	Tps. 20, 21 S., R. 32 E., Harney County	Drilled during 1989.
40	Bear Creek Butte	Coeur d'Alene Mining	Lode gold	Tps. 18, 19 S., R. 18 E., Crook County	Geologic mapping and surface sampling, aero-mag.
41	Glass Butte	Galactic Resources	Lode gold	Tps. 23, 24 S., R. 23 E., Lake County	Drilled during 1989.
42	Summer Lake area	N.A. Degerstrom, Inc.	Lode gold	Sec. 14, T. 30 S., R. 16 E., Lake County	Drilling and surface geochemistry.
43	Paisley area	N.A. Degerstrom, Inc.; Atlas Pr. Metals, Inc.	Lode gold, perlite	T. 34 S., Rs. 18, 19 E., Lake County	Degerstrom drilled 4 holes, did soil sampling, VLF resistivity, and magnetics; Atlas drilled perlite prospect at Tucker Hill.
44	Quartz Mountain	Pegasus Gold, Inc.; Quartz Mountain Gold Corporation; Wavecrest Resources	Lode gold	Secs. 26, 27, 34, 35, T. 37 S., R. 16 E., Lake County	Drilled 28 development holes and 19 large-diameter core holes; pilot metallurgy; 9.8 million tons grading 0.045 oz/ton gold and 64 million tons grading 0.025 oz/ton gold.
45	Bohemia District (Grouse Mtn./ Noonday Ridge prospects)	Bond Gold Exploration, Inc.	Lode gold	T. 22 S., Rs. 1, 2 E., Lane County	Geologic mapping, trenching, geophysics, dropped property.
46	Prospect Silica (Quartz Mountain / Abbott Butte)	Mountain Valley Resources	Silica	T. 30 S., R. 2 E., Jackson and Douglas Counties	Hand sampling and feasibility studies.
47	Martha Mine	Cambiex and Dragon's Gold, joint venture	Lode gold	Sec. 28, T. 33 S., R. 5 W., Josephine County	Cored 3,000 ft in 4 holes; soil sampling.
48	Marble Mountain	Campman Calcite	Limestone	Sec. 19, T. 37 S., R. 6 W., Josephine County	Road work, feasibility study.
49	Eight Dollar Mountain	Geoff Garcia	Nickel laterite	T. 38 S., R. 8 W., Josephine County	Sampling.
50	Turner-Albright	Cominco	Copper, zinc, gold	Secs. 15, 16, T. 41 S., R. 9 W., Josephine County	—

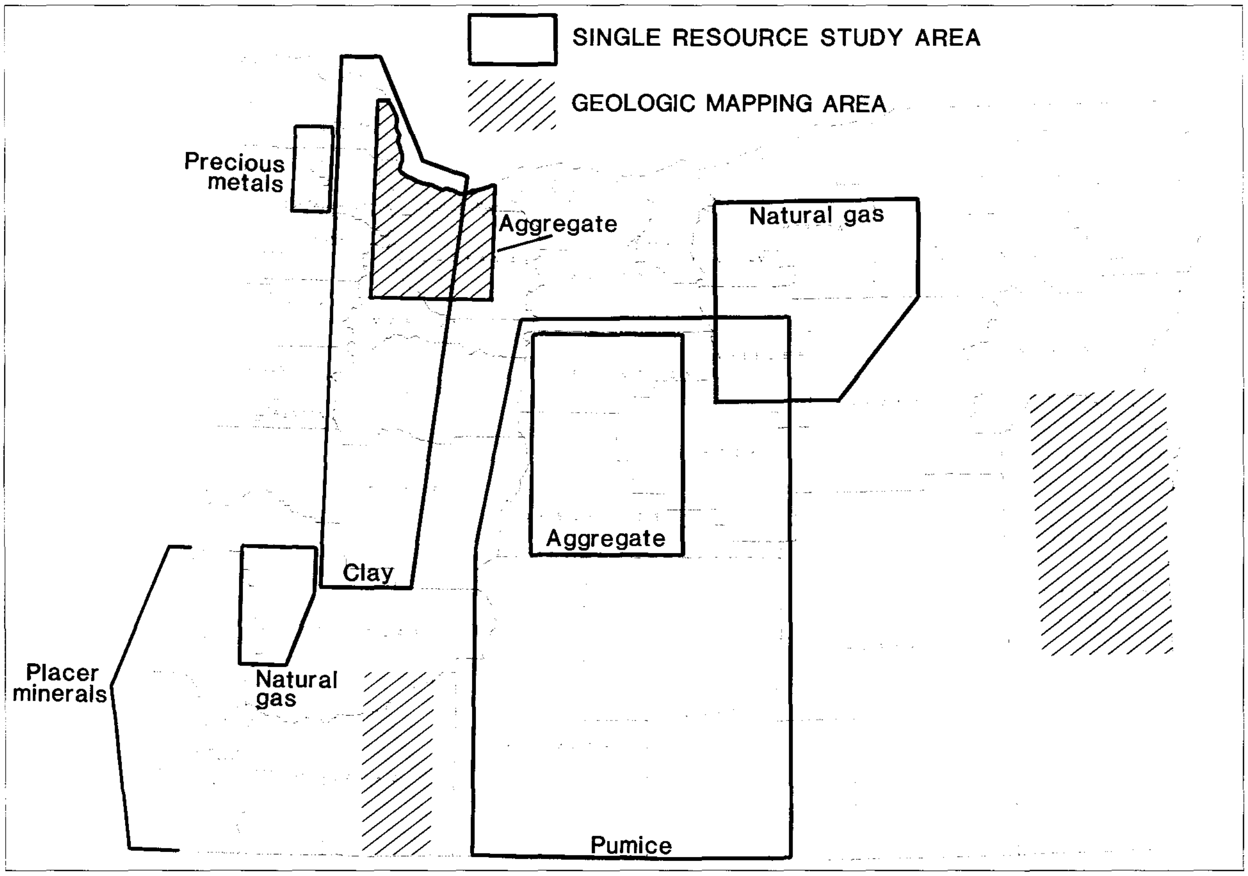


Figure 4. Areas of ongoing or planned mapping and commodity studies by the Oregon Department of Geology and Mineral Industries.

Western Oregon

Plexus Resources Corporation drilled 16 new core holes at the Bornite copper-gold-silver prospect (Exploration site 7, Table 3) in Marion County. This brings the number of holes to 29 for a total drilled thickness of 21,403 ft. The ore body is a breccia pipe 400 ft in diameter and 850 ft deep. Based on the work completed this year, reserves should increase from earlier estimates of 2.8 million tons copper grading 2.44 percent, 0.02 oz/ton gold, and 0.58 oz/ton silver at a 1-percent copper cutoff. Highest grades occur at the perimeter of the deposit.

Bond Gold evaluated the Grouse Mountain and Noonday Ridge prospects (Exploration site 45, Table 3) near the Helena Mine in Lane County's Bohemia Mining District and dropped the properties.

Cambiex and Dragon's Gold began a 10,000-ft core-drilling project at the Martha Mine in Josephine County's Greenback District (Exploration site 47, Table 3). Four holes were completed for a total of 3,000 ft, each intercepted the primary vein. More than 900 ft of tunnel was completed on two levels and 100,000 tons of 0.3 oz/ton ore have been blocked out along a 6-ft-wide vein.

Cominco is beginning a project at the Turner-Albright copper, zinc, and gold prospect (Exploration site 50, Table 3) in southern Josephine County. The company has plans for a geophysics program. Metallurgical problems have stymied development in the past, and Cominco brings considerable expertise to bear on the problem.

DOGAMI research

The Department is currently conducting geologic mapping projects in Malheur, Jackson, and Douglas Counties and in the Portland area. These projects should provide new insights into the distribution and occurrence of mineral resources. Regional studies emphasizing single commodities including talc, limestone, bentonite, and silica have been published during the last three years. Studies of pumice, strategic minerals, natural gas, aggregate, clay, and precious metals are planned for the next six years (Figure 4).

ACKNOWLEDGMENT

I would like to thank the many geologists and corporations that provided the information contained in this report. ☐

Mist Gas Field Report revised

The Mist Gas Field Report published by the Oregon Department of Geology and Mineral Industries (DOGAMI) has been revised and is now available with all 1990 activity and changes included.

This report includes the Mist Gas Field Map, which was revised to show the three wells drilled by Nehama and Weagant Energy Company and the two service wells drilled by Northwest Natural Gas Company during the year. The location, status, and depth of all wells are indicated on the map.

The report also includes production figures for the wells at Mist from the initial production in 1979 through the end of 1990. Included are well names, revenue generated, pressures, annual and cumulative production, and other data.

The Mist Gas Field Report, Open-File Report 0-91-1, is now available at the DOGAMI office, 910 State Office Building, 1400 SW Fifth Avenue, Portland, Oregon 97201-5528. The price is $8. See further ordering instructions on the last page of this issue.☐

MINERAL EXPLORATION ACTIVITY

MAJOR MINERAL-EXPLORATION ACTIVITY

County, date	Project name, company	Project location	Metal	Status
Baker 1990	Baboon Creek Chemstar Lime, Inc.	T. 19 S. R. 38 E.	Limestone	App
Baker 1990	Cracker Creek Mine Bourne Mining Co.	T. 8 S. R. 37 E.	Gold	Expl
Baker 1991*	Gold Ridge Mine Golconda Resources	T. 12 S. R. 43 E.	Gold	App
Crook 1988	Bear Creek Freeport McMoRan	Tps. 18, 19 S. R. 18 E.	Gold	Expl
Grant 1990	Prairie Diggings Western Gold Explor.	T. 13 S. R. 32 E.	Gold	Expl
Grant 1991*	Bear Creek Project Coeur Explorations.	T. 18 S. R. 18 E.	Gold	App
Harney 1990	Pine Creek Battle Mtn. Explor.	T. 20 S. R. 34 E.	Gold	Expl
Jefferson 1991*	Red Jacket Bond Gold	Tps. 9, 10 S. R. 17 E.	Gold	App
Josephine 1990	Martha Property Cambiex USA, Inc.	T. 33 S. R. 5 W.	Gold	App
Lake 1988	Quartz Mountain Wavecrest Resources.	T. 37 S. R. 16 E.	Gold	Expl
Lake 1990	Glass Butte Galactic Serives, Inc.	Tps. 23, 24 S. R. 23 E.	Gold	Expl
Lane 1990	Grouse Mtn. Project Bond Gold Exploration	T. 23 S. Rs. 1, 2 E.	Gold	Expl
Malheur 1988	Grassy Mountain Atlas Precious Metals	T. 22 S. R. 44 E.	Gold	Expl, com
Malheur 1988	Harper Basin Project Amer. Copper & Nickel	T. 21 S. R. 42 E.	Gold	Expl
Malheur 1988	Jessie Page Chevron Resources Co.	T. 25 S. R. 43 E.	Gold	Expl
Malheur 1988	Kerby Malheur Mining	T. 15 S. R. 45 E.	Gold	Expl, com
Malheur 1989	Hope Butte Chevron Resources Co.	T. 17 S. R. 43 E.	Gold	Expl, com
Malheur 1990	Ali/Alk Atlas Precious Metals	T. 17 S. R. 45 E.	Gold	App
Malheur 1990	Buck Gulch Teague Mineral Prod.	T. 23 S. R. 46 E.	Bentonite	Expl
Malheur 1990	Calavera NERCO Exploration	T. 21 S. R. 45 E.	Gold	Expl
Malheur 1990	Cow Valley Butte Cambiex USA, Inc.	T. 14 S. R. 40 E.	Gold	Expl
Malheur 1990	Freezeout Western Mining Corp.	T. 23 S. R. 42 E.	Gold	Expl
Malheur 1990	Goldfinger Site Noranda Exploration	T. 25 S. R. 45 E.	Gold	Expl
Malheur 1990	Grassy Mtn. Regional Atlas Precious Metals	T. 22 S. R. 44 E.	Gold	App
Malheur 1990	Katey Claims Asarco, Inc.	Tps. 24, 25 S. Rs. 44, 46 E.	Gold	Expl
Malheur 1990	KRB Placer Dome U.S.	T. 25 S. R. 43 E.	Gold	App
Malheur 1990	Lava Project Battle Mtn. Explor.	T. 29 S. R. 45 E.	Gold	Expl
Malheur 1990	Mahogany Project Chevron Resources Company	T. 26 S. R. 46 E.	Gold	App
Malheur 1990	Racey Project Billiton Minerals USA	T. 13 S. R. 41 E.	Gold	Expl
Malheur 1990	Sand Hollow Noranda Exploration	T. 24 S. R. 43 E.	Gold	Expl
Malheur 1990	Stockade Mountain BHP-Utah International	T. 26 S. Rs. 38, 39 E.	Gold	Expl
Malheur 1990	Stockade Project Phelps Dodge Mining Company	Tps. 25, 26 S. R. 38 E.	Gold	App
Malheur 1991*	Rhinehardt Site Atlas Precious Metals	Tps. 18, 19 S. R. 45 E.	Gold	Expl
Malheur 1991*	White Mountain D.E. White Mtn. Mining and Manufacturing	T. 18 S. R. 41 E.	Diatoms	App
Marion 1990	Bornite Project Plexus Resources Corporation	T. 8 S. R. 3 E.	Copper	App

Explanations: App=application being processed. Expl=Exploration permit issued. Com=Interagency coordinating committee formed, baseline data collection started. Date=Date application was received or permit issued. *=New site

Status changes

During January and February, three exploration permits were closed and five new ones were opened. The new sites are denoted by an asterisk (*) adjacent to the year. Three sites were inadvertently omitted from the list in March, they are returned to the list.

The files that were closed include the following: (1) The Kappes Cassiday Susanville project, where reclamation has been completed; (2) the Malheur Mining East Ridge application, which was incorporated into the permit area for the Kerby project; and the Carlin Gold Company South Star application, which was withdrawn before any work was done on the site.

The permit area of the Atlas Snake Flat permit was increased, and the name was changed to Grassy Mountain Regional to reflect this change.

An application for a bulk sample to conduct metallurgical testing by Atlas Precious Metals at its Grassy Mountain Project is being reviewed. The agency will provide public input opportunity prior to any permit decision.

Doug Smith has submitted an application for a small nickel surface mine on Eight Dollar Mountain in Josephine County.

Regulatory issues

Numerous bills relating to the regulation of mining have been introduced in the state legislature. Most bills target large-scale, open-pit gold mining in southeastern Oregon where cyanide is to be used in the recovery process. Governor Roberts has convened a Governor's Mine Work Group consisting of members from industry, the environmental community, and state regulatory agencies to try to identify areas of consensus for a comprehensive mine regulatory program for the State of Oregon.

Questions or comments about exploration activities in Oregon should be directed to Gary Lynch or Allen Throop in the Mined Land Reclamation Office, 1534 SE Queen Avenue, Albany OR 97321, telephone (503) 967-2039. □

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

		Price	√
GMS-4	Oregon gravity maps, onshore and offshore. 1967	4.00	
GMS-5	Geologic map, Powers 15-minute Quadrangle, Coos/Curry Counties. 1971	4.00	
GMS-6	Preliminary report on geology of part of Snake River canyon. 1974	8.00	
GMS-8	Complete Bouguer gravity anomaly map, central Cascade Mountain Range. 1978	4.00	
GMS-9	Total-field aeromagnetic anomaly map, central Cascade Mountain Range. 1978	4.00	
GMS-10	Low- to intermediate-temperature thermal springs and wells in Oregon. 1978	4.00	
GMS-12	Geologic map of the Oregon part of the Mineral 15-minute Quadrangle, Baker County. 1978	4.00	
GMS-13	Geologic map, Huntington and parts of Olds Ferry 15-minute Quadrangles, Baker and Malheur Counties. 1979	4.00	
GMS-14	Index to published geologic mapping in Oregon, 1898-1979. 1981	8.00	
GMS-15	Free-air gravity anomaly map and complete Bouguer gravity anomaly map, north Cascades, Oregon. 1981	4.00	
GMS-16	Free-air gravity and complete Bouguer gravity anomaly maps, south Cascades, Oregon. 1981	4.00	
GMS-17	Total-field aeromagnetic anomaly map, southern Cascades, Oregon. 1981	4.00	
GMS-18	Geology of Rickreall/SalemWest/Monmouth/Sidney 7½-minute Quadrangles, Marion/Polk Counties. 1981	6.00	
GMS-19	Geology and gold deposits map, Bourne 7½-minute Quadrangle, Baker County. 1982	6.00	
GMS-20	Geology and geothermal resources, S½ Burns 15-minute Quadrangle, Harney County. 1982	6.00	
GMS-21	Geology and geothermal resources map, Vale East 7½-minute Quadrangle, Malheur County. 1982	6.00	
GMS-22	Geology and mineral resources map, Mount Ireland 7½-minute Quadrangle, Baker/Grant Counties. 1982	6.00	
GMS-23	Geologic map, Sheridan 7½-minute Quadrangle, Polk and Yamhill Counties. 1982	6.00	
GMS-24	Geologic map, Grand Ronde 7½-minute Quadrangle, Polk and Yamhill Counties. 1982	6.00	
GMS-25	Geology and gold deposits map, Granite 7½-minute Quadrangle, Grant County. 1982	6.00	
GMS-26	Residual gravity maps, northern, central, and southern Oregon Cascades. 1982	6.00	
GMS-27	Geologic and neotectonic evaluation of north-central Oregon. The Dalles 1° x 2° Quadrangle. 1982	7.00	
GMS-28	Geology and gold deposits map, Greenhorn 7½-minute Quadrangle, Baker and Grant Counties. 1983	6.00	
GMS-29	Geology and gold deposits map, NE¼ Bates 15-minute Quadrangle, Baker and Grant Counties. 1983	6.00	
GMS-30	Geologic map, SE¼ Pearsoll Peak 15-minute Quadrangle, Curry and Josephine Counties. 1984	7.00	
GMS-31	Geology and gold deposits map, NW¼ Bates 15-minute Quadrangle, Grant County. 1984	6.00	
GMS-32	Geologic map, Wilhoit 7½-minute Quadrangle, Clackamas and Marion Counties. 1984	5.00	
GMS-33	Geologic map, Scotts Mills 7½-minute Quadrangle, Clackamas and Marion Counties. 1984	5.00	
GMS-34	Geologic map, Stayton NE 7½-minute Quadrangle, Marion County. 1984	5.00	
GMS-35	Geology and gold deposits map, SW¼ Bates 15-minute Quadrangle, Grant County. 1984	6.00	
GMS-36	Mineral resources map of Oregon. 1984	9.00	
GMS-37	Mineral resources map, offshore Oregon. 1985	7.00	
GMS-38	Geologic map, NW¼ Cave Junction 15-minute Quadrangle, Josephine County. 1986	7.00	
GMS-39	Geologic bibliography and index maps, ocean floor and continental margin off Oregon. 1986	6.00	
GMS-40	Total-field aeromagnetic anomaly maps, Cascade Mountain Range, northern Oregon. 1985	5.00	
GMS-41	Geology and mineral resources map, Elkhorn Peak 7½-minute Quadrangle, Baker County. 1987	7.00	
GMS-42	Geologic map, ocean floor off Oregon and adjacent continental margin. 1986	9.00	
GMS-43	Geologic map, Eagle Butte and Gateway 7½-minute Quadrangles, Jefferson and Wasco Counties. 1987	5.00	
	as set with GMS-44/45	11.00	
GMS-44	Geologic map, Seekseequa Junction and Metolius Bench 7½-minute Quadrangles, Jefferson County. 1987	5.00	
	as set with GMS-43/45	11.00	
GMS-45	Geologic map, Madras West and Madras East 7½-minute Quadrangles, Jefferson County. 1987	5.00	
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