OREGON GEOLOGY

Oregon Department of Geology and Mineral Industries
Volume 68, Number 1, Fall 2007

IN THIS ISSUE:

TO OUR READERS

From the State Geologist:

Oregon's spectacular geology sometimes overshadows the paleontological wonders that can also be found in our state. This issue highlights some recent finds and reminds us that biology and geology are inseparable.

— Vicki S. McConnell

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Cover photo

Ammonite (species unknown) found by DOGAMI geologist Jason McClaughry about 10 miles WNW of Izee and the south fork of the John Day River along the Izee Highway (CR-63) on July 1, 2005. This locality is one of the few easily accessible areas in Oregon where ammonites have been collected. The ammonite specimen is about 10 cm across.

The specimen is from the Middle Jurassic (Bajocian) Snowshoe Formation (Basey member, unit Jsby of Dickinson and Vigrass, 1965). This series of rocks is strongly folded and faulted (see above photo) and is composed mostly of marine volcaniclastic strata. The geology of the Suplee-Izee area is covered by Dickinson and Vargas in DOGAMI Bulletin 58, 1965.

Reference: Dickinson, W. R., and Vigrass, L. W., 1965, Geology of the Suplee-Izee area, Crook, Grant, and Harney counties, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 58, 109 p.

Photo credits: Jason McClaughry, DOGAMI

Early Pliocene (Blancan) Always Welcome Inn local fauna, Baker City, Oregon

by Jay Van Tassell[1], Eric Bergey[1], Calvin Davis[1], Misty Davis[1], Bryan Grimshaw[1], Jayson Kisselburg[1], Robert Ledgerwood[1], Story Miller[1], Carli Morris[1], Jesse Steele[1], Corby Wehymiller[1], Mark L. Ferns[2], Gerald R. Smith[3], H. Gregory McDonald[4], Jim I. Mead[5], and Robert A. Martin[6]

ABSTRACT

Early Pliocene lake and stream sediments behind the Always Welcome Inn in Baker City, Oregon, contain fossil diatoms, sponges (*Ephydatia fluviatilis*), gastropods (*Gyraulus*, lymnaeids), bivalves (*Sphaerium* and *Pisidium*), ostracods (*Cypricercus*), charophytes, root casts, leaf fragments, salamanders (*Ambystoma,* most of which were neotenic), frogs, snakes (*Nerodius* or *Thamnophis*?), turtles (*Trachemys* or *Clemmys*?), sunfish (a new species of *Archoplites)*, minnows (a new genus, plus *Achrocheilus*), ducks (Anatidae), rails (Rallidae), and a raptor (owl?), shrews (*Paracryptotis* rex), a gopher (geomyid), voles (*Ophiomys*), beaver (*Castor californicus* and *Dipoides* sp. cf. *vallicula* and *wilsoni;*), rabbits (*Hypolagus*?), a mustelid (*Trigonictis*), and a small carnivore. A lower left jaw of the beaver *Castor californicus* was found near the base of the sequence. The morphology and the lack of diversity of the fish fossils indicate long-term isolation and argue against any long-term aquatic connection with the Pliocene Snake and Columbia rivers. The archaic vole found at the Always Welcome Inn site may be the oldest species of *Ophiomys* found in the Columbia River Basin and appears to be an ancestor of *Cosomys primus,* the most common microtine rodent found in the ~3.7–3.1 Ma localities in the area of Hagerman, Idaho. A metapodial of a camelid, possibly a llama, was found in the late Pliocene to early Pleistocene gravels overlying the tilted sequence that contains the other fossils.

INTRODUCTION

Late Miocene and Pliocene sediments of the Powder Valley in eastern Oregon have produced a number of important fossils, including 1) the lower jaw and other parts of the Miocene mastodon *Gomphotherium* (Downs, 1952), 2) over 100 kg of bone fragments identified as bones of the rhinoceros *Aphelops*, a mastodont, and the camel *Megatylopus* by J. A. Shotwell (1969, written communication cited by Brooks and others, 1976), 3) plant fossils known as the Keating and Sparta floras (Gilluly, 1937; Chaney, 1959; Hoxie,1965), and 4) the Keating diatomite deposits (Moore, 1937; VanLandingham, 1985). This paper describes a new fossil locality discovered in May 2002 behind the Always Welcome Inn in Baker City, Oregon, by Terry Frest, a malacologist from Seattle, who collected fossil sunfish and minnow bones,

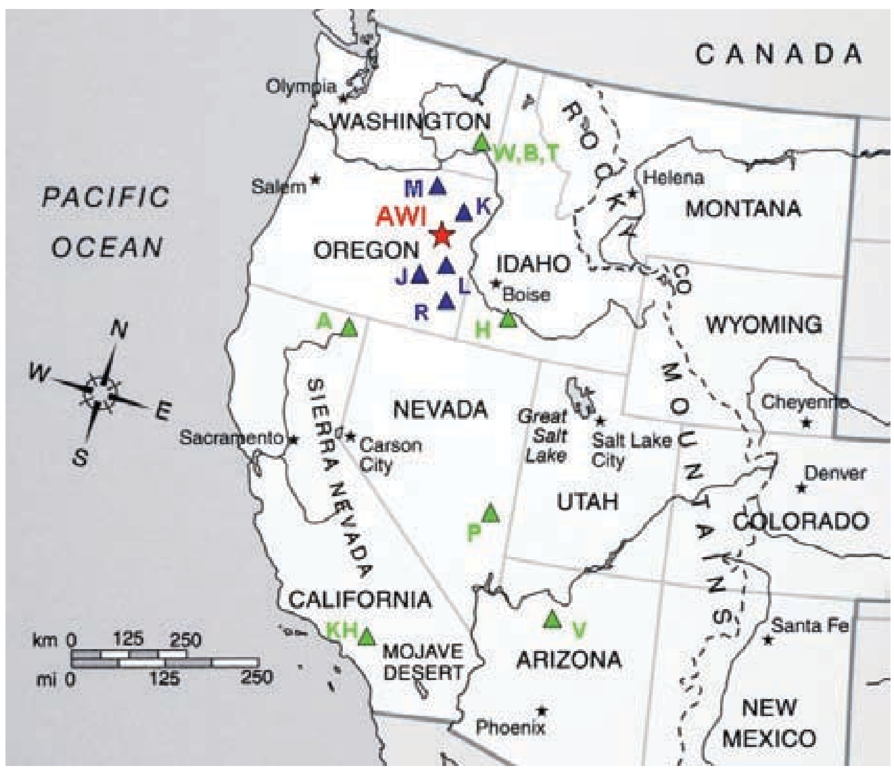

Figure 1. Location of the Always Welcome Inn fossil site and other fossil localities mentioned in the text. Blancan localities (green and red): A, Alturas, California; AWI, Always Welcome Inn, Oregon (this study); H, Hagerman, Idaho (plus Grandview and other nearby localities); KH, Kettleman Hills, California; P, Panaca, Nevada; V, Verde, Arizona; and W, B, T., White Bluffs, Bluff Top, and Taunton, Washington. Hemphillian localities (blue): J, Juntura; K, Keating; L, Little Valley; M, McKay Reservoir; and R, Rome, all in Oregon.

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(AWI fauna, continued from page 3)

gastropods (*Gyraulus* and lymnaeids), bivalves (*Sphaerium* and *Pisidium*), ostracods, charophytes, and diatoms from the outcrop. The site is located at 44°47.106′N latitude, 117°48.300′W longitude at an elevation of ~1,050 m (3,440 ft) on the southeast end of the Powder Valley in the northwest corner of section 15, T. 9 S., R. 40 E. of the Baker City 1:24,000 quadrangle (Figure 1).

During the past five years, faculty and students of Eastern Oregon University, the University of Michigan, Northern Arizona University, and the University of Montana and geologists from the Oregon Department of Geology and Mineral Industries and the National Park Service have searched the Always Welcome Inn outcrop for fossils. These studies have opened an important new window on the Pliocene geologic history of the Baker City area.

STRATIGRAPHY

The geology of the Powder Valley area has been mapped by Lindgren (1901), Gilluly (1937), Prostka (1962), Brooks and others (1976), Whitson (1988), and Bailey (1990). Brooks and others (1976) included the sedimentary sequence in the Always Welcome Inn area as part of their tuffaceous sedimentary rock unit (Tst). According to their report (p. 19), this unit includes a lower lacustrine facies, an upper fluvial facies, and overlying imbricated gravels. The "lake beds" consist mainly of 1) thinly bedded, light-gray to yellowish tuffaceous clay, siltstone, and sandstone, 2) diatomite, and 3) glass-shard tuff. Isolated outcrops of the unit preserved in fault blocks well above the present valleys suggest that the lacustrine sediments were deposited in basins that were larger than the present valleys in which these sediments are mainly confined. This unit was dated as early Pliocene on the basis of the presence of widely scattered mammal fossils near the top of the sequence.

Bailey (1990) used geochemical analyses to subdivide the volcanic sequence in the Powder Valley area into the Columbia River Basalt Group and the Powder River Volcanic Field. He confirmed that pyroclastic materials as well as fluvial and lacustrine sediments rich in volcaniclastic material that were lumped into the unit of Tertiary sediments and tuffs (Tst) by Brooks and others (1976) occur as 1) thin interbeds throughout the volcanic sequence, 2) a unit between the Grande Ronde Basalt unit of the Columbia River Basalts and the overlying olivine basalt that marks the lower boundary of the Powder River Volcanics, and 3) a unit above the Powder River volcanic sequence. The Always Welcome Inn fossil site is located in the younger Tst unit above the Powder River volcanic sequence (Figure 2).

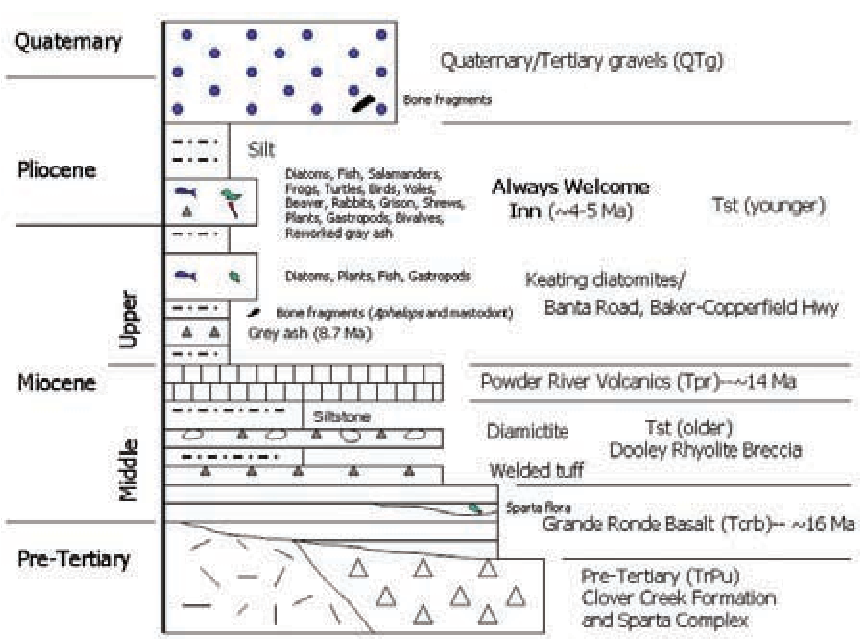


Figure 2. Generalized stratigraphy of the Tertiary sediments and volcanics of the study area. Modified from Ledgerwood and Van Tassell (2005).

METHODS

The Always Welcome Inn section was measured in October 2004 using the Jacob staff technique, and samples were collected from each of the major sedimentary units. The samples were examined in the laboratory using a binocular microscope. Smear slides were made by mixing small fractions of each sample with distilled water, dropping the water-sediment mixture on a petrographic slide, drying the slide on a hot plate, and then mounting a cover slip on top of the slide using type A mounting medium. These slides were then examined on a petrographic microscope at 400× power, and the percentages of different types of diatoms, minerals, and other constituents were determined by point-counting.

At the beginning of this study, fossils exposed on the surface of the outcrop were collected and their positions in the stratigraphic sequence noted and plotted on sketches and photographs of the outcrop whenever possible. Next, we collected bulk samples in layers where fossils were abundant and took the samples back to the laboratory, where the fossils were picked out of the sediment, examined under a binocular microscope, identified, and catalogued. In the past year we have begun collecting samples at 0.25-m intervals in the sequence and dry-sieving the sediment at the outcrop through screen with a square mesh measuring 1.5 mm on each side. The fossils obtained by sieving were taken back to the laboratory, where they were washed, examined, and

(AWI fauna, continued from page 4)

sorted using a binocular microscope, and the numbers and types of fossils in each interval were recorded and catalogued. We have also collected bulk samples and wet-sieved them in the laboratory. One sample of volcanic ash from the site was dated using ^{40}Ar/^{39}Ar techniques by the University of Alaska at Fairbanks Geochronology Laboratory.

Sample number prefixes used in this paper are EO, Eastern Oregon University; IMNH, Idaho Museum of Natural History; UO, University of Oregon; and USNM, U.S. National Museum.

THE ALWAYS WELCOME INN SEQUENCE

Excavation of the hillside to the south of the Always Welcome Inn exposed a 10-m-thick sequence of diatomites, massive and laminated silts, volcanic ash, and fine sands that is capped unconformably by gravels that contain imbricated clasts of argillite and chert (Figure 3). The beds strike at an angle of ~97° ESE and dip at an angle of ~9° in a SSW direction. The outcrop is cut by a dozen NE-trending normal faults that have dip angles ranging from 44° to 88° in a NW direction. The faults have a total offset of ~7.3 m; one fault has an offset of over 1 m (Davis and others, 2005).

The Always Welcome Inn sequence includes the three facies described by Brooks and others (1976). The lower half of the Always Welcome Inn section consists of an ~5-m-thick coarsening-upward sequence of pale yellow, light gray, and light brown diatomites and silts that contain high percentages of diatoms, sponge spicules, fish bones, bivalves, and gastropods. Two organic-rich (lignite) layers are found in this part of the sequence. Charophytes, leaf fragments, and small pieces of wood are also common. Turtle shell fragments were discovered in a layer 0.3 m above the base of the section. Fossil sunfish bones are abundant in the dark gray silt layers close to the diatomites, especially in a laminated silt layer ~2.5 m above the base of the sequence. The jaw of a beaver, including a lower left incisor, premolar, and molar, was found near the base of the sequence.

The upper half of the Always Welcome Inn section begins with a 1.5-m-thick layer of light yellow, light gray, and light brown massive and

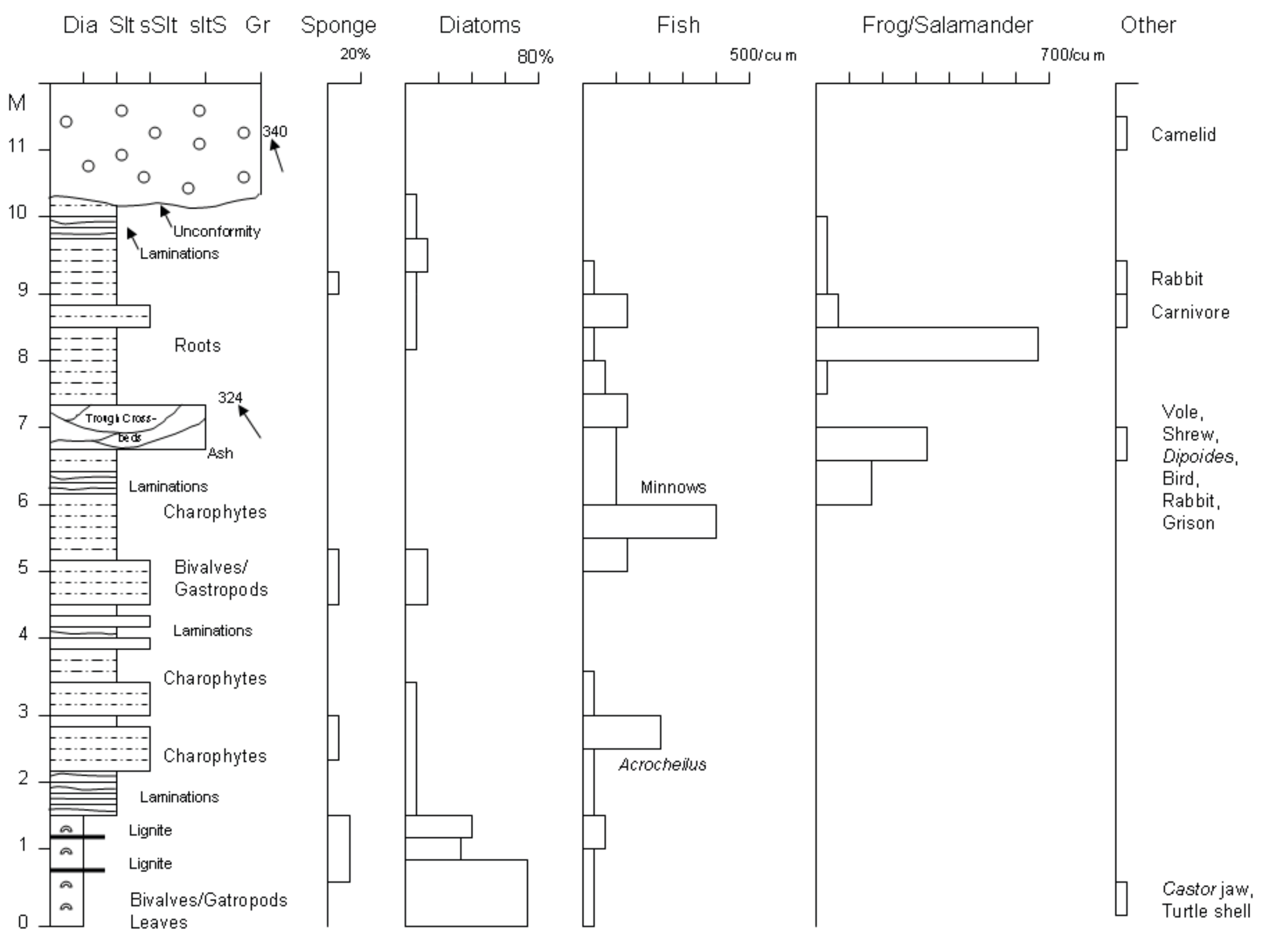


Figure 3. The Always Welcome Inn sedimentary sequence, showing the distribution of diatomite (Dia), silt (Slt), sandy silt (sSlt), silty sand (sltS), gravel (Gr); and fossils in the sequence. Percentages of sponges and diatoms in the sediments are based on point counts. The abundances of fish, frogs, and salamanders were determined by sieving a known volume of sediment from each interval.

(AWI fauna, continued from page 5)

Table 1. Fossils from the Always Welcome Inn locality.

Kingdom PROTOCTISTA
Phylum BACILLARIOPHYTA (**diatoms**)
Anomoeneis *Cyclotella* *Navicula*
Aulacoseira *Epithemia* *Nitzchia*
Cocconeis *Fragilaria* *Rhopaloidia*
Phylum CHLOROPHYTA
Class CHAROPHYCEAE (**Charophytes**)

Kingdom PLANTAE
Root casts; leaf and wood fragments

Kingdom ANIMALIA
Phylum PORIFERA (**sponges**)
Ephydatia fluviatilis (**sponge spicules**)
Phylum MOLLUSCA (**clams. snails, octopus, and their relations**)
Class GASTROPODA
Family Lymnaeidae (**snail**)
Family Planorbidae
Gyraulus (**snail**)
Class BIVALVIA (**bivalves**)
Family Sphaeriidae
Genus *Sphaerium* Scopoli 1777 (**clam**)
Genus *Pisidium* Pfeiffer 1821 (**clam**)
Phylum ARTHROPODA
Class CRUSTACEA
Subclass OSTRACODA
Order Podocopida
Family Cyprididae
Genus *Cypricercus* Sars,1895 (**ostracod)**
Phylum CHORDATA
Subphylum VERTEBRATA
Class OSTEICHTHYES
Family Centrarchidae
Genus *Archoplites* Gill 1862
Archoplites, sp. nov. (**sunfish**)
Family Cyprinidae
Genus *Achrocheilus* Agassiz (**minnow**)
Genus nov. (**minnow**)
Class AMPHIBIA
Order Anura
Family Ranidae
Rana? (**frog)**
Order Caudata
Family Ambystomatidae
Ambystoma (**salamander**)
Class REPTILIA
Order Squamata
Family Colubridae
Thamnophis or *Nerodius?* (**snake**)
Subclass Anapsida
Order Testudine
Family Emydinae
Trachemys or *Clemmys*? (**pond turtle**)
Class AVES (**birds)**
Subclass Neognathae
Infraclass Galloanserae
Order Anseriformes (**water fowl**)
Family Anatidae (**ducks**)
Infraclass Neoaves
Order Gruiformes (**coots, cranes and rails**)
Family Rallidae (**rails**)
Order Strigiformes Wagler 1830 (**owls**)
Class MAMMALIA
Order LIPOTYPHYLA Haeckel 1866 (INSECTIVORA)
Family Soricidae
Genus Paracryptotis Hibbard 1950
Paracryptotis rex Hibbard 1950 (**shrew**)
Order LAGOMORPHA (**rabbits, hares, and pikas**)
Family Leporidae
Hypolagus? **(extinct hare**)
Order RODENTIA Bowditch 1821
Family Geomyidae Bonaparte 1845 (**gopher**)
Family Castoridae (**beavers**)
Genus *Castor* Linnaeus 1758
Castor californicus Kellogg 1911 (**beaver**)
Genus *Dipoides* Jäger 1835
Dipoides cf. vallicula Shotwell 1970 and *wilsoni* Hibbard 1949 (**extinct beaver**)
Family Cricetidae Rochebrune 1883 (**primarily New World mice and rats**)
Subfamily Arvicolinae Gray 1821 **(voles, lemmings, and muskrats)**
Genus *Ophiomys* Hibbard and Zakrzewski 1967
Ophiomys sp. (**extinct vole**)
Order ARTIODACTYLA
Family Camelidae (**extinct llama?)**
Order CARNIVORA
Family Mustilidae
Genus *Trigonictis* (**grison**)
Small carnivore

(AWI fauna, continued from page 6)

laminated silts that contain abundant root casts. This layer is overlain by a 3.5-m-thick fining-upward sequence of trough cross-bedded silty fine sand and light yellow, light brown, and light gray massive and laminated silts that contain fossil fish bones, salamander and frog bones, plant fossils, a beaver tooth, vole teeth and jaws, snake vertebrae, bird bones (a rail and ducks), the bones and tooth of a rabbit, and turtle shell fragments. Detailed sampling suggests that these fossils are concentrated in pockets rather than distributed uniformly throughout the sequence. Where salamander fossils are numerous, fish fossils are less common and intervals with abundant fish fossils tend to have fewer frog and salamander bones (Kisselburg, 2006). The trough cross-bedding indicates paleocurrents that flowed from the southeast toward the northwest (324°). Pockets of light gray coarse-grained volcanic ash are found in the base of the cross-bedded sand unit 6.6 m above the base of the sequence. Preliminary 40Ar/39Ar age dating suggests that the glass shards in this ash range from ~13 to 15 m.y. old, with an average plateau age of ~13.6 ± 0.4 Ma (Jeff Drake, University of Alaska at Fairbanks Geochronology Laboratory, written communication, 2007). This suggests that the ash has been reworked from one of the late Miocene tuffs in the area. The silts overlying the cross-bedded sequence have yielded the tooth of a small carnivore. One layer 9.5 m above the base of the section is rich in planktic diatoms.

An angular unconformity separates these layers from the overlying gravels. The imbrication in the gravels suggests that paleocurrents flowed from the southeast toward the northwest (340°). The gravel has yielded the bone of a camelid, possibly a llama.

ALWAYS WELCOME INN FOSSILS

Fossils found at the Always Welcome Inn site (Table 1) now include diatoms, charophytes, plant remains, sponges, bivalves, gastropods, ostracods, fish, rabbits, shrews, a gopher, primitive voles, beaver, a small carnivore, a camelid, birds, a mustelid, and a small carnivore.

Diatoms, Plants, and Sponges

Planktic (floating), epiphytic, and benthic (littoral, epipelic, and epilithic) diatoms (Figure 4) are common in the thick diatomite layers in the lower part of the Always Welcome Inn sequence but are also found in the upper part. The genera include *Anomoeneis*, *Aulacoseira*, *Cocconeis*, *Cyclotella*, *Epithemia*, *Fragilaria*, *Navicula*, *Nitzchia*, and *Rhopaloidia*. *Epithemia* is commonly found in littoral zones and is an indicator of alkaline water somewhat enriched in nutrients. The diatoms are dominantly shallow water forms, suggesting that the Always Welcome Inn site was located near the lake margin. Overall, the diatoms indicate a eutrophic environment rich in organic matter and nutrients with oxygen depletion during the summer (Round and others, 1990).

Charophytes (also known as stoneworts) are large algae that range in size from a few millimeters to over a meter in length. They are found primarily in freshwater but also grow in brackish and semi-terrestrial environments. They have gained even more attention recently because they are now known to be the most closely related group of organisms to land plants. Unlike other green algae, charophytes have phragmoplast cells, formed by a method of cell division called cytokinesis, which are also found in land plants. Fragments of charophytes are very common in the Always Welcome Inn sequence (Figure 5). Rushes or reed fossils are also present in the sequence. The base of the sequence also contains organic-rich layers (lignites) that contain abundant broken and fragmented leaves that are difficult to identify. Root casts are abundant in the upper part of the sequence. More research is needed to determine whether the plants and pollen in the Always Welcome Inn se-

Figure 5. Charophyte fossils from the Always Welcome Inn sequence (EO-767).

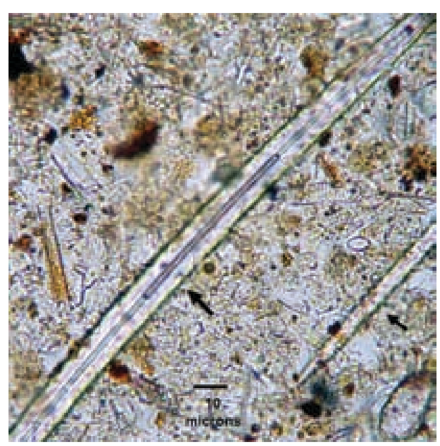


Figure 6. Spicule of the freshwater sponge *Ephydatia lacustris* (arrows) in a matrix of diatoms and organic matter.

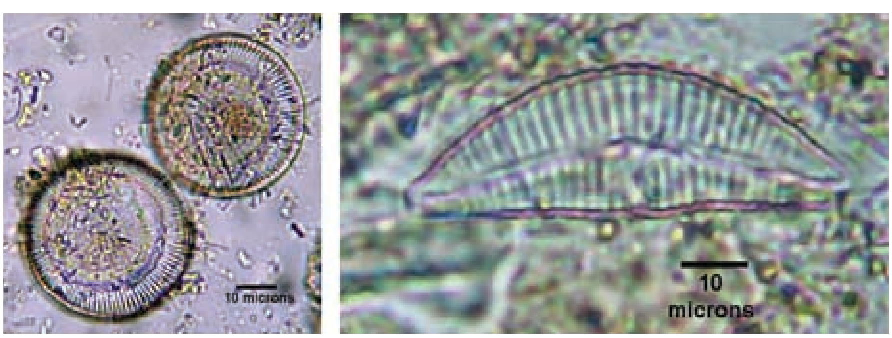


Figure 4. (left) Planktic and (right) benthic diatoms from near the base of the Always Welcome Inn sequence. The planktic diatom is *Aulacoseira* and the benthic diatom is *Cymbella*.

(AWI fauna, continued from page 7)

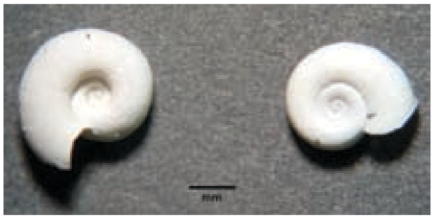


Figure 7. Gastropods (*Gyraulus*) from the Always Welcome Inn sequence (EO-803).

Figure 8. Bivalves (*Pisidium*) from the Always Welcome Inn sequence (EO-794).

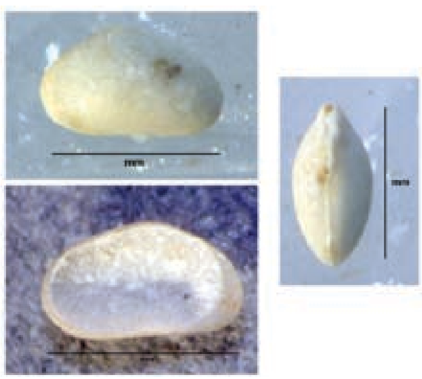


Figure 9. Ostracods (*Cypricercus*) from the Always Welcome Inn sequence (EO-944). (top left) Lateral view of exterior of female left valve; (right) Dorsal view of female carapace; (bottom left) Lateral view of interior of female left valve.

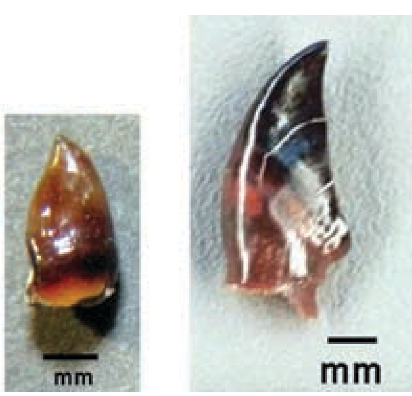


Figure 10. Minnow teeth from the Always Welcome Inn. (left) a new genus of minnow (EO-900); (right) *Achrocheilus* (EO-766).

quence match the fossil plants found in the Keating area.

Freshwater sponge spicules are abundant in the lower part of the Always Welcome Inn outcrop (Figure 6). The most common sponge is *Ephydatia lacustris.* This species prefers water depths less than 1.5 m with a pH of 6–8 and temperatures of 12–34°C. *Ephydatia lacustris* is common in lakes and ponds (Harrison, 1974).

Gastropods, Bivalves, and Ostracods

Gastropods are very abundant in the lower part of the Always Welcome Inn sequence (Figure 7). Terry Frest identified the shallow, warm-water gastropod *Gyraulus*, along with a group of gastropods called lymnaeids.

The bivalves *Sphaerium* and *Pisidium* were first identified in the Always Welcome Inn sequence by Terry Frest. Like the gastropods, these small clams (Figure 8) are usually found in shallow, warm water. They are very abundant in some layers in the Always Welcome Inn sequence.

Ostracods, tiny crustaceans whose body parts are enclosed in a hinged carapace, are common in some Always Welcome Inn sediment layers. Our preliminary studies suggest that ostracods in the Always Welcome Inn sediment (Figure 9) belong to the genus *Cypricercus*. The color is white, and valve surfaces are smooth. The carapace has an oval outline when viewed laterally, and the anterior is broader than the posterior. The dorsal margin is arched anteriorly. The maximum height of the carapace is toward the anterior and is more than half the length. In dorsal view, the ostracod is oval, with both ends coming to similar rounded points, and the breadth is slightly less than one half the length. Modern *Cypricercus* species inhabit the borders of larger lakes and are found in small weedy or grass-bottomed ponds (Sars, 1925; Henderson, 1990).

Fish

Always Welcome Inn fish fossils include the bones of an undescribed genus of the minnow family **Cyprinidae** (Figure 10). Approximately 170 fragments of minnow bones were collected by Terry Frest and E. Johannes on April 21, 2002. Included among the bones are fragments of maxillae, dentaries, opercles, preopercles, palatine, urohyal, ceratohyal, pterotic, and pharyngeal teeth. The maxillae have anterodorsal condyles conjoined, with the premaxillary arm extending downward and forward below and behind the posterior condyle; the body of the maxilla is slender. The dentaries have an outwardly flared (non vertical) outer edge of the front and sides of the jaw, with the mental foramen half way along its length. The opercles and pterotic are much thicker than other North American minnows and are highly textured externally. The pharyngeal teeth are short, round in cross-section, and pointed or hooked. These traits separate the Always Welcome Inn cyprinid from all other western North American cyprinid genera, but the dentary traits are shared by members of the clade (Smith and others, 2002) containing *Pogonichthys*, *Mylocheilus*, and *Richardsonius*, and the maxilla traits are shared with *Pogonichthys*.

A tooth of *Achrocheilus*, another minnow in the Family **Cyprinidae**, has also been found at the Always Welcome Inn (Figure 10). It resembles the teeth of the Snake River chiselmouth chub *Achrocheilus latus* (Cope), which has been found in the Pliocene deposits of the western Snake River Plain. Fragments of *Achrocheilus* pharyngeal arches with one tooth each and four detached teeth that are not differentiable from arches and teeth of *Achrocheilus latus* of the Snake River Plain or *Achrocheilus alutaceus* of the Columbia River basin have been found in the Taunton local fauna of Washington (Smith and others, 2000).

(AWI fauna, continued from page 8)

Bones of a new species of the genus *Archoplites* of the sunfish family **Centrarchidae** are widespread at the Always Welcome Inn locality (Figure 11). Sunfish are represented by fragments of premaxillaries, maxillaries, lacrymals, frontals, articular-angulars, urohyal, ceratohyal, preopercles, vertebrae, and fin spines. The species is diagnosed as an *Archoplites*, differing from all other known species by the well-developed serrations on the lower and posterior edges of the preopercle and the lacrymal. Other *Archoplites* have serrations only at the lower edges of the preopercle. The frontals have a long anterior sensory canal, usually not interrupted in the middle by a pore; other species have a pore half way along the length of the anterior sensory canal. The articular-angulars have a broad, half moon-shaped posterior sensory canal opening that extends from below the articular condyle and is well-separated from the retroarticular. The sunfish is apparently not closely related to the sunfishes from the Chalk Hills, Glenns Ferry, or Ringold formations.

Two growth forms of sunfish occur in the Always Welcome Inn fauna. Bones of a form characteristically found in lake and pond sediments are very common in the lower part of the sequence. These bones are delicate and fragile, from fish about 130 mm in standard length (body length excluding the caudal fin) that live 7 or 8 years without growing much larger. A form characteristically found in stream sediments is common in other layers, especially in the upper part of the sequence. This form has robust bones, about twice the growth rate of the lake and pond form, and reaches larger sizes.

The limited sizes and lack of fish diversity at the Always Welcome Inn site contrast with the Snake River and Columbia River faunas in the Pliocene. The sharp morphological differences between the minnow and sunfish of the Always Welcome Inn site from the Miocene and Pliocene forms from localities in California, Oregon, Washington, Idaho, and Nevada indicate

Figure 11. Sunfish (*Archoplites*) fossils from the Always Welcome Inn. (A) Sunfish spine (EO-762.1), (B) Sunfish vertebra (EO-819), (C) Sunfish scale (EO-779.24), (D) Sunfish lacrymal (EO-762.2), (E) Sunfish maxilla (EO-762.3), and (F) Sunfish preopercle (EO-776.11). Scale bars are in millimeters.

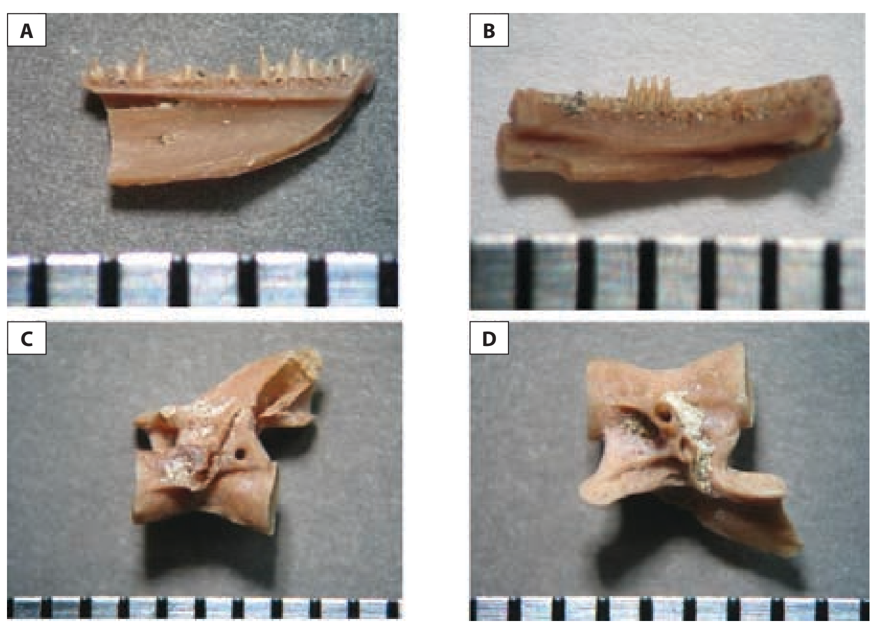


Figure 12. Salamander (*Ambystoma*) fossils from the Always Welcome Inn (EO-866). (A and B) dentary fragments and (C and D) vertebrae. These salamanders were neotenic. Scale bars are in millimeters.

(AWI fauna, continued from page 9)

long-term isolation. Furthermore, the absence of diverse suckers, minnows, salmonids, catfish, and sculpins argues against any long-term aquatic connection with the Pliocene Snake and Columbia rivers, which had diverse fish faunas (Smith, 1975; Smith and others, 1982, 2000).

The fish affinities (*Acrocheilus*, *Archoplites*) indicate that the past drainage connections, however sporadic, were to the Snake River before it joined the Columbia River drainage. *Acrocheilus* did not appear in the Columbia drainage until after the Columbia captured the Snake River at the head of Hells Canyon (Smith and others, 2000). The Always Welcome Inn sunfish, *Archoplites* sp., shares more traits with *Archoplites taylori*, the Snake River form, than with *Archoplites molaris* of the Columbia drainage.

Frogs and Salamanders

Our preliminary analysis of samples from the Always Welcome Inn fossil locality suggests that the herpetofauna are worthy of more detailed research. Currently, the Always Welcome Inn amphibian fauna consist of small anurans (frogs and toads, yet to be described) and a single taxon of salamander (Figure 12).

There are many species of salamanders in five families (**Ambystomatidae**, **Dicamptodontidae**, **Plethodontidae**, **Rhyacotritonidae**, and **Salamandridae**) living today in the greater northwest of North America. Of these, only two forms, *Ambystoma* (**Ambystomatidae**) and *Dicamptodon* (**Dicamptodontidae**), attain a size that would be considered a large salamander. All recovered salamander vertebrae from the Always Welcome Inn fossil site are from large individuals and are too large to belong to the families **Plethodontidae**, **Rhyacotritonidae**, or **Salamandridae**.

In addition to size, details of the spinal nerve foramina of salamanders are taxonomically diagnostic (Edwards, 1976). The spinal nerve exits the spinal column intervertebrally (i.e., between the vertebrae) on all trunk and pre-saccral vertebrae in *Dicamptodon* (as well as other smaller taxa). The spinal nerve exits a foramen distal to the paradiapophysis on vertebrae of *Ambystoma* species (posterior to the two trunk vertebra). All of the vertebrae of the Always Welcome Inn salamanders show spinal nerve foramina that indicate that they do not belong to the large *Dicamptodon* and can tentatively be assigned to a species of *Ambystoma*.

One very interesting feature of the Always Welcome Inn salamander vertebrae is that most of the centra of the very large vertebrae show a continuous passageway for the notochord; the septum has not developed. This persistence of the notochord illustrates that most, if not all, of the salamander vertebrae are from relatively young (albeit large) larval (neotenic) forms.

Only a few species of late Miocene to Pliocene salamanders show neoteny (Holman, 2006). These include 1) *Ambystoma kansense* (assigned to the *A. mexicanum* group by Tihen, 1958), which is found in the late Hemphillian Edson (~5.5 Ma) and Sawrock Canyon (~4.8 Ma) local faunas of Kansas, 2) *Ambystoma hibbardi*, whose type locality is in the ~4.3-m.y.-old Fox Canyon sequence in Kansas, and 3) *Ambystoma tigrinum*, which has a geologic age range from Clarendonian (~10 Ma) to the present. Fossil populations of *A. hibbardi* and *A. tigrinum* show clear evidence of both neoteny and metamorphosis, while *A. kansense* is exclusively neotenic. More research is needed to determine to which of the three late Miocene to Pliocene neotenic salamander species the Always Welcome Inn salamander species is most closely related.

Snakes and Turtles

Two fossil snake vertebrae have been found in the cross-bedded sands in the upper part of the Always Welcome Inn sequence (Figure 13). The genus has not yet been identified. Preliminary study suggests that it may be the garter snake *Thamnophis* or the water snake *Nerodius*.

Figure 13. Snake vertebra, possibly from a garter snake (*Thamnophis*) or water snake (*Nerodius*), from the Always Welcome Inn sequence (EO-945).

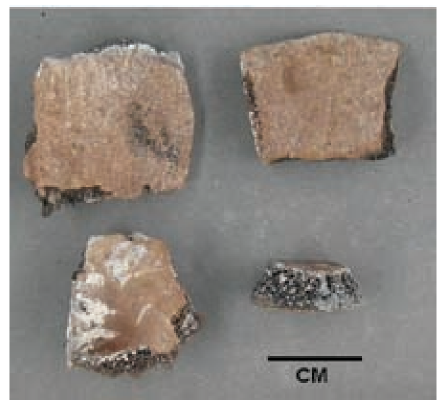


Figure 14. Fragments of turtle shell (*Trachemys* or *Clemmys*?) found in the lower part of the Always Welcome Inn sequence (EO-728).

Fossil turtle shell (Figure 14) is most abundant near the base of the Always Welcome Inn sequence. It has also been found in cross-bedded sands in the upper part of the sequence. The genus has not been identified. It may be *Trachemys*, the slider turtle, or *Clemmys*, the pond turtle, which are both found in the Hagerman fossil beds of Idaho. The living species of both *Trachemys* and *Clemmys* are aquatic turtles that stay mainly in the water. Along with the beaver,

(AWI fauna, continued from page 10)

frogs, salamanders, and waterfowl, the turtles support the interpretation that the Always Welcome Inn was an extensive wetlands area during the time the sequence was deposited.

Birds

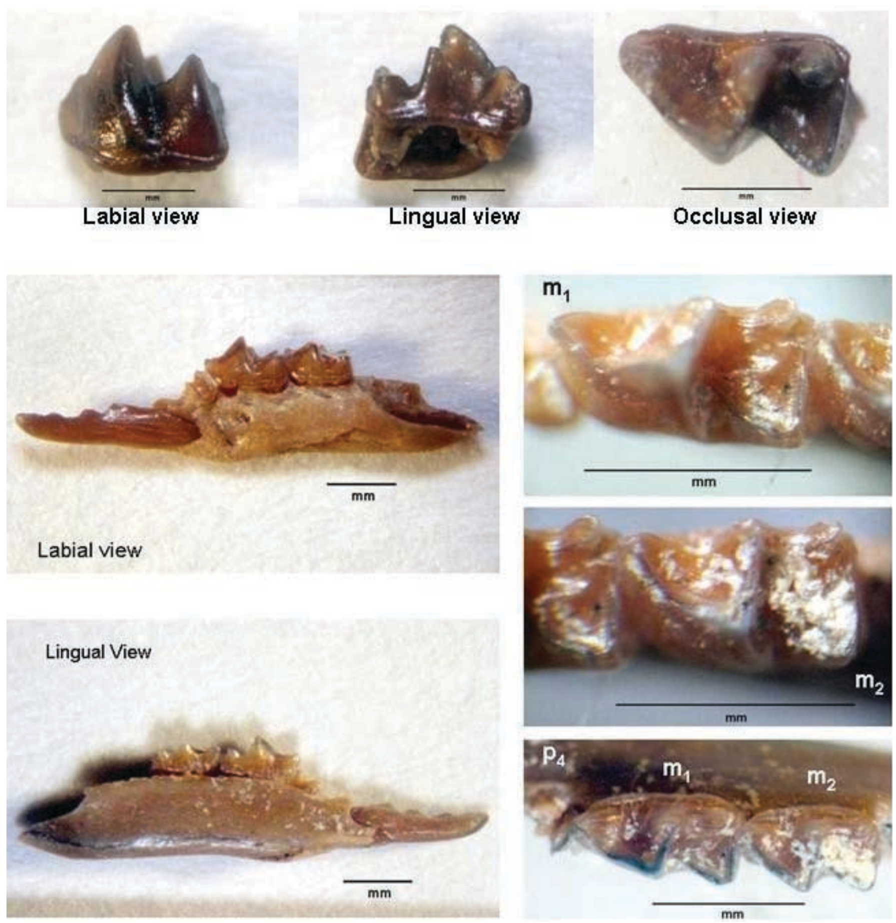
Cross-bedded sands in the upper part of the Always Welcome Inn sequence have yielded a number of bird bones and a bird claw (Figure 15). Dr. David Steadman of the Florida Museum of Natural History identified one of the bones as the carpometacarpus of a rail (Rallidae) and another bone as a tarsometarsus of a duck (Anatidae). According to Dr. Steadman, the claw is from a raptor, probably an owl. The claw is the same size as the claws of modern short-eared owls (*Asio flammeus*). Pliocene *Asio* fossils have also been found in the ~4.3-m.y.-old Fox Canyon locality in Kansas (Ford, 1966) and the ~ 3.7- to 3.1-m.y.-old Hagerman Fossil Beds (Ford and Murray, 1967). We have also discovered numerous fragments of egg shells in the Always Welcome Inn sediments, but we do not yet know from what types of birds these shells came.

Shrews

The cross-bedded sand layer in the upper part of the Always Welcome Inn sequence has yielded a lower left second molar of an adult shrew and a lower left jaw of a juvenile shrew (Figure 16). The adult shrew tooth measures 1.83 mm in an anteroposterior direction and has a maximum width of 1.12 mm (Table 2). The juvenile left lower jaw includes the incisor and the first (m_1) and second (m_2) molars. A fragment of the fourth premolar (P_4) is present. The canine and third molar are missing. The lower left second molar in the jaw resembles that of the adult tooth but is smaller (1.00 mm length, 0.61 mm width). The lower left first molar in the jaw is slightly larger (1.16 mm length, 0.65 mm width) than the lower left second molar. Both the lower first and second molars are characterized by a metalophid that joins the protolophid well lingual to the protoconid, a well-developed entoconid separated from the hypolophid by a small valley, and a tall talonid. These features are characteristic of the genus *Paracryptotis* (Hibbard, 1950). The size of the lower second molar suggests that the species found at the Always Welcome Inn is *Paracryptotis rex* Hibbard 1950 (Table 2).

Paracryptotis rex was first collected and described by Hibbard (1950) from the ~4.3-m.y.-old Fox Canyon and ~3.3- to 3-m.y.-old Wendell Fox Pasture localities of the Rexroad Formation of Kansas. Dalquest (1978) described *P. rex* in the ~3.4-m.y.-old Beck Ranch local fauna of Texas. *P. rex*

Figure 15. Bird fossils from the Always Welcome Inn sequence. From top to bottom: Raptor (owl?) claw (EO-884); Coracoid (EO-933); rail carpometacarpal (EO-918); duck? (EO-768); duck tarsometatarsal (EO-917); and duck? (EO-897).



▸Figure 16. Shrew fossils (*Paracryptotis rex*) found in the Always Welcome Inn sequence:. (top) lower left second molar of an adult shrew (EO-935). (bottom) lower left jaw of a juvenile shrew jaw with incisor, P_4 (broken) and intact first and second molars (EO-971).

(AWI fauna, continued from page 11)

Table 2. Shrew tooth measurements and ages of shrews from different localities.

	Always Welcome Inn	***Sorex meltoni*** **Hagerman, Idaho (3.7–3.1 Ma)** Hibbard and Bjork (1971)	***Sorex hagermanensis*** **Hagerman, Idaho (3.7–3.1 Ma)** Hibbard and Bjork (1971)	***Sorex powersi*** **Hagerman, Idaho (3.7–3.1 Ma)** Hibbard and Bjork (1971)	***Paracryptotis gidleyi*** **Hagerman, Idaho (3.7–3.1 Ma)** Gazin (1933), Hibbard and Bjork (1971)	***Paracryptotis rex*** **Fox Canyon, Kansas (4.3 Ma)** **Blufftop, Washington (3.9 Ma)** Hibbard (1950), Hibbard and Bjork (1971), Gustafson (1985)
LENGTH (mm)						
m_1	1.16 (j)	1.16	1.38	1.47	1.93–2.30	2.14–2.65 (Kansas)
	1.83 (a)	1.02	1.30	1.31	1.56–1.77	2.34 (Washington)
m_2	1.00 (j)					1.67–2.10
m_1	0.65 (j)	0.64	0.85	0.83	1.12–1.37	1.26–1.59 (Kansas)
						1.50 (Washington)
WIDTH (mm)						
m_1	0.65 (j)	0.64	0.85	0.83	1.12–1.37	1.26–1.59 (Kansas)
	1.12 (a)	0.67	0.76	0.81	0.96–1.21	1.50 (Washington)
m_2	0.61 (j)					1.03–1.40

Notes: m_1, lower first molar; m_2, lower second molar; j, juvenile; a, adult. Length is anteroposterior length. Width is greatest width.

has also been found in the ~9-6-m.y.-old Rome fauna of northeast Oregon (Repenning, 1967), the ~4.8-m.y.-old Saw Rock Canyon fauna of Kansas (Hibbard and Bjork, 1971), and the ~3.9-m.y.-old Blufftop fauna of Washington (Gustafson, 1985).

Rabbits (Hares)

Three hare fossils have been found at the Always Welcome Inn site. The first is a metatarsal or metacarpal found in the upper part of the sequence (Figure 17); the second is a tooth found in a bulk sample from just below the cross-bedded sand sequence (Figure 18); and the third is a broken incisor. The tooth from the cross-bedded sand sequence is similar to the upper first molar of the leporid *Hypolagus gidleyi*, one of the fossil hares found in the Hagerman beds of Idaho, but the tooth also resembles *Hypolagus vetus* fossils found in the Rattlesnake Formation of Oregon. It seems likely that the Always Welcome Inn hare belongs to the genus *Hypolagus* but, as fossil hare classifications are not based on upper first molars, a more diagnostic tooth will need to be found before the Always Welcome Inn hare species can be identified.

Figure 17. Metatarsal or metacarpal of a hare from the Always Welcome Inn sequence (EO-872).

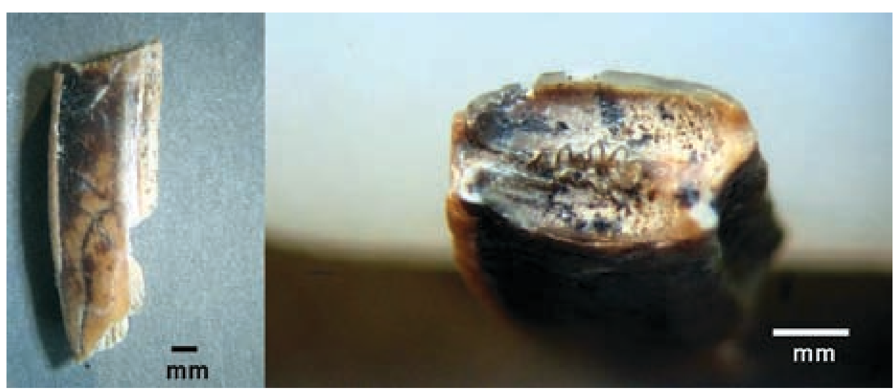


Figure 18. An upper molar from a hare from the Always Welcome Inn sequence (EO-932). The overall shape and the crenulations in the reentrant on the occlusal (biting) surface of the tooth suggest that the Always Welcome Inn hare is *Hypolagus*.

(AWI fauna, continued from page 12)

Gophers

An upper third molar or lower first or second molar of a juvenile pocket gopher (**Geomyid**) was found in stream sediments in the upper part of the Always Welcome Inn sequence in October 2007 (Figure 19). The occlusal (biting) surface of the tooth measures 0.78 mm in an anteroposterior direction and 1.38 mm in a transverse direction. The overall height of the tooth is 3.42 mm.

More teeth are needed to tell from which genus of pocket gopher the tooth came. The tooth that most resembles the Always Welcome Inn geomyid tooth is a cheek tooth of *Thomomys* sp. from the Grandview local fauna (IMNH 30039) illustrated by Conrad (1980, Figure 9P). It is possible that the Always Welcome Inn gopher is related to *Thomomys gidleyi*, a species of pocket gopher that was first described in the Hagerman Fossil Beds of Idaho (Wilson, 1933; Zakrzewski, 1969). *Thomomys* sp. has also been described in the Wildhorse Butte locality in Idaho by Shotwell (1967), and a species very similar to *Thomomys gidleyi* was noted in the White Bluffs Formation of Washington by Gustafson (1978). Another possibility is that the Always Welcome Inn pocket gopher is related to *Pliogeomys parvus*, a species found in the Hagerman Fossil Beds (Zakrzewski, 1969).

Fossil Beaver

***Dipoides*.** A left upper first molar of the beaver *Dipoides* was found ~7 m above the base of the Always Welcome Inn sequence (Figure 20). It was described in detail by Burton and Van Tassell (2005). The tooth has the almost square occlusal outline typical of *Dipoides* (Shotwell, 1955). The Always Welcome Inn beaver tooth is closest in length to the sizes of upper first molars of *D. stirtoni* from the area of Rome and the Juntura Basin, Oregon, described by Wilson (1934) and Shotwell (1955). The tooth is slightly smaller than the upper first molars of *D. smithi*, a species described by Shotwell (1955, 1956) in the late Hemphillian McKay Reservoir fauna near Pendleton, Oregon, and *D. vallicula* described by Shotwell (1970) from its type locality near Little Valley, 20 km west-southwest of Vale, Oregon. It is much smaller than *D. rexroadensis*, the species found in the ~4.3-m.y.-old White Bluffs Formation local fauna of Washington (Gustafson, 1978), and *D. intermedius*, the species found in the ~ 3.7- to 3.1-m.y.-old Hagerman Fossil Beds of Idaho (Zakrzewski, 1969).

It is difficult to assign an isolated tooth to a species of *Dipoides* because male/female dimorphism, regional variations, and age all play a role (William Akersten, written communication, 2007). The overall loph pattern on the occlusal surface of the Always Welcome Inn *Dipoides* tooth is similar to the occlusal pattern illustrated by Shotwell (1970, p. 31, Figure 13-D) on an upper left first molar in a palate of

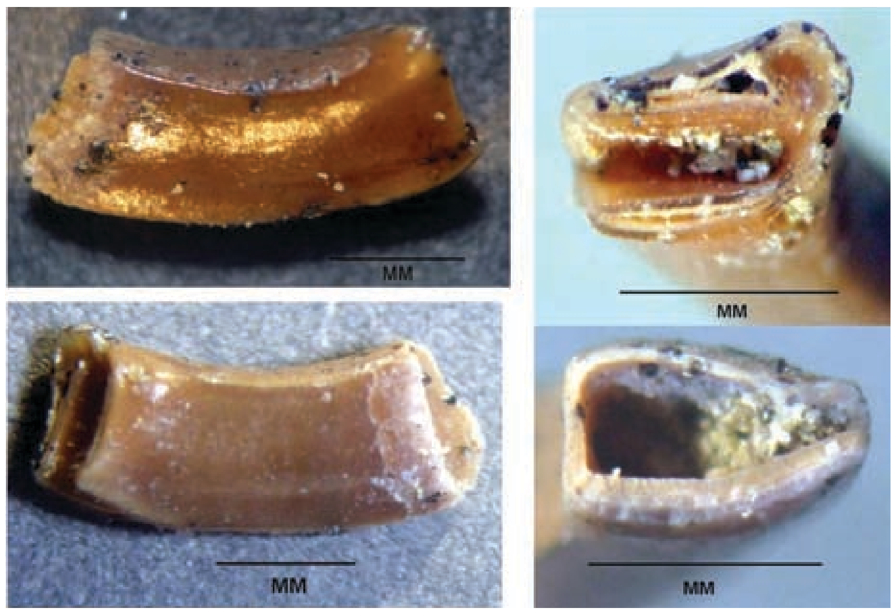


Figure 19. Juvenile geomyid (pocket gopher) upper third molar or lower first or second molar from the Always Welcome Inn sequence (EO-977). This geomyid tooth is similar to those of *Thomomys* but is not diagnostic.

Figure 20. *Dipoides* tooth found at the Always Welcome Inn (EO-765). The tooth resembles upper first molars of *D. vallicula* and *D. wilsoni.* Scale bar is in millimeters.

(AWI fauna, continued from page 13)

D. vallicula Shotwell, 1970 (sample UO 26698) from the type section of the species in Little Valley, Oregon. The type locality of *Dipoides vallicula* is in a sequence of lacustrine sediments in the Chalk Butte Formation that was mapped as late Hemphillian to early Blancan age by Ferns and others (1993). The Chalk Butte Formation is the western extension of the Chalk Hills Formation of Idaho into northeastern Oregon (Kimmel, 1982).

Dipoides vallicula is usually associated with later Hemphillian faunas (Shotwell, 1970), and its sister species, *D. wilsoni*, is found in the early Blancan (~4.8 Ma) Sawrock Canyon local fauna of Kansas (Martin, 2003). In addition to its similarity to *D. vallicula*, the shape of the first loph of the Always Welcome Inn *Dipoides* tooth is very similar to that of *D. wilsoni*. For these reasons, we have decided to refer the specimen to *Dipoides* sp. cf. *vallicula* and *wilsoni* until additional material to confirm the identification is found.

Modern beaver belong to the genus *Castor*, which apparently migrated to North America over six million years ago and has undergone little evolutionary change since that time. *Dipoides*, on the other hand, evolved into the giant Pleistocene beavers *Procastoroides* and *Castoroides*, which reached the size of a small bear. According to Martin (1989), two lineages led to giant beavers. One stemmed from *Dipoides stirtoni*, a species found in the late Miocene beds near Rome, Oregon. The other lineage started with the smaller species *Dipoides wilsoni*. It is likely that the species found at the Always Welcome Inn is an important link in this second line of descent, which led to the much larger beaver *Dipoides rexroadensis*, found in the ~4.3-m.y.-old White Bluffs fauna in the Columbia River drainage basin, and then to the giant Pleistocene beaver *Castoroides ohioensis*, which was the same size as *"Castoroides" kansasensis*, which resulted from the *Dipoides stirtoni* lineage.

***Castor*.** A lower left jaw of the fossil beaver *Castor californicus* (Figure 21) was found in April 2007 at the base of the Always Welcome Inn sequence by Adora Brockman, a student at Pine-Eagle High School in Halfway, Oregon. The jaw includes a lower incisor, fourth premolar, and first, second, and third molars. *Castor californicus* is common in Blancan deposits but rare in late Hemphillian faunas. It has been reported from several Hemphillian localities in eastern Oregon, including the McKay Reservoir site near Pendleton, Oregon (Shotwell, 1970). The diatom-rich sediments that yielded the Always Welcome Inn beaver jaw also contain turtle shell, gastropods, bivalves, and thin organic-rich layers that suggest shallow water deposition near the shore of a lake.

A comparison of the sizes of the teeth of the Always Welcome Inn *Castor* with others described in the literature suggests that the Always Welcome Inn *Castor* jaw ranks with larger fossil *Castor* fossils found at Hagerman, Idaho, and other localities in the western United States (Table 3). The anteroposterior dimensions of the premolar and molars, the transverse dimensions of the second and third molars, and the overall length from the fourth premolar to the third molar of the Always Welcome Inn *Castor* jaw are large compared to *Castor* fossils from the other areas. Only the transverse dimensions of the Always

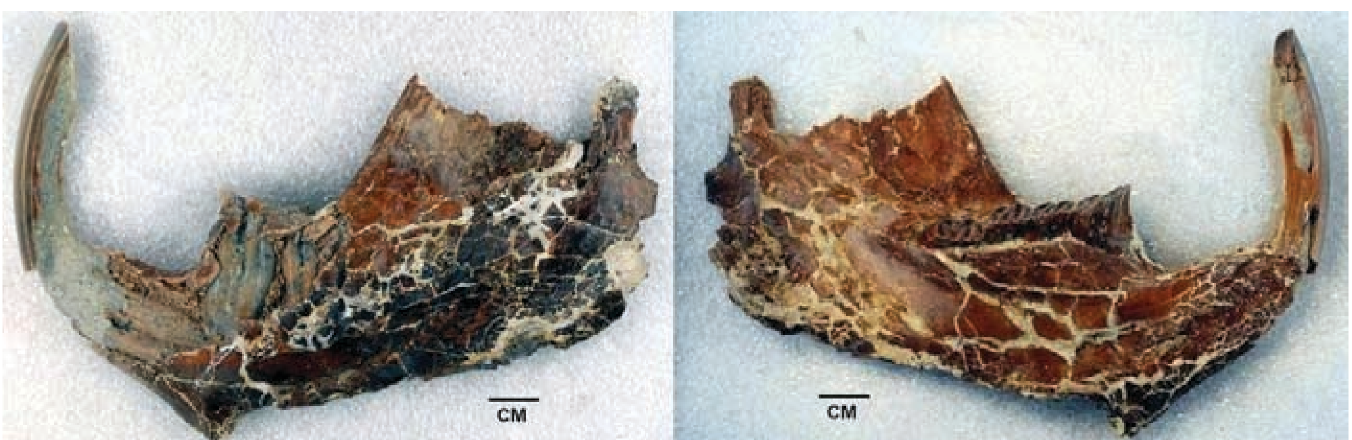


Figure 21. The lower left jaw of the beaver *Castor californicus* found at the base of the Always Welcome Inn sequence (EO-919). (left) Lateral view; (top right) medial view; (bottom right) occlusal view.

(AWI fauna, continued from page 14)

Table 3. Sizes of *Castor* Teeth.

	Always Welcome Inn	**White Bluffs, Washington (4.3 Ma)** Gustafson (1975)	**Kettleman Hills, California (4.1 Ma)** Kellogg (1911), Stirton (1935)	**Hagerman, Idaho (3.7-3.1 Ma)** Wilson (1933), Shotwell (1970)
LENGTH (mm)				
p_4 AP	11.5 mm	—	—	8.3–11.0
m_1 AP	8.8	8.1?	—	7.0–7.8
m_2 AP	8.6	8.1?	—	6.0–7.9
m_3 AP	9.7	8.9	—	6.7–7.6
p_4-m_3	38.7	—	—	30.2–36.4
WIDTH (mm)				
I_1 TR	9.1	—	8.8	8.2–9.1
p_4 TR	7.8	—	—	7.1–8.2
m_1 TR	7.5	—	—	7.3–8.7
m_2 TR	8.8	—	—	6.7–7.9
m_3 TR	7.3	—	—	5.6–6.8

Notes: I_1, lower incisor; p_4, lower fourth premolar; m_1, lower first molar; m_2, lower second molar; m_3, lower third molar. Length is measured in an anteroposterior direction. Width is maximum width transverse to length.

Welcome Inn *Castor* lower incisor and first molar fall within the range of *Castor* tooth dimensions found in the Hagerman area.

The occlusal patterns of the teeth in the Always Welcome Inn jaw (Figure 22) are less convoluted than those of the teeth of a lower left *Castor* jaw from Jackass Butte assigned to *Castor accessor* by Shotwell (1970). The Always Welcome Inn *Castor* occlusal patterns are slightly more complex than the occlusal patterns of the *Castor californicus* teeth from Grandview, Idaho, illustrated by Conrad (1980). The overall shape of the occlusal pattern of the lower left second molar from the Always Welcome Inn is very similar to a lower second molar (or possibly a lower first molar, according to Stirton [1935]) from the 4.1-m.y.-old Etchegoin Formation. This tooth is the paratype of *Castor californicus*.

How did two types of beaver live together at the Always Welcome Inn site? Rybyczynski (2004) modeled the incisors of both genera in steel and experimented with different wood types to see how well each incisor worked. She discovered that *Dipoides* teeth were specialized for chewing trees similar to red cedar, while *Castor* incisors were better suited for exploiting a number of woody vegetation types compared *Dipoides* teeth. This shows that the two types of beaver were able to live together in the same areas because they ate different types of vegetation. The *Castor* jaw at the Always Welcome Inn was found in lake deposits, while the *Dipoides* tooth was found in stream sediments. It is possible that the two types of beavers occupied different habitats along the margin of the Powder Valley lake system during the early Pliocene.

Jackass Butte, Idaho
2.3–2.0 Ma
(Shotwell, 1970; UO 16388)

Grandview, Idaho
2.3–2.0 Ma
(Conrad, 1980, IMNH 29563, reversed)

Always Welcome Inn, Baker City, Oregon
(this study, EO-919)

Etchegoin Formation, California
4.1 Ma
(Stirton, 1935; USNM 12941, reversed)

Figure 22. Comparison of the occlusal patterns of the Always Welcome Inn *Castor californicus* jaw with *Castor* teeth from Idaho and California (not to scale); m_1, lower first molar; m_2, lower second molar; m_3, lower third molar; p_4, lower fourth premolar.

(AWI fauna, continued from page 15)

Arvicolid Rodent (Vole) Fossils

Sixteen molars and one lower jaw with a right first molar from a primitive vole plus three incisors that may be from the same species have been recovered from the Always Welcome Inn fauna (Figure 23). The identity of the Always Welcome Inn vole remains a puzzle. The sizes of the Always Welcome Inn vole teeth (Table 4) are closest to the sizes of the teeth of "*Mimomys" panacaensis* described by Mou (1997; described as *Ophiomys mcknighti* by Reynolds and Lindsay, 1999) found near Panaca, Nevada, and *Ophiomys mcknighti* molars found in the White Bluffs local fauna of Washington (Gustafson, 1978). They are smaller than the *Cosomys primus* molars described in the Hagerman local fauna of Idaho by Hibbard (1959) and Zakrzewski (1969) and the molars of *Ogmodontomys poaphagus* described in the Verde local fauna of Arizona by Czaplewski (1990).

The Always Welcome Inn first molars do not resemble first molars of the primitive vole *Ogmodontomys* (= *Mimomys sawrockensis* of Repenning, 2003) in the ~4.8-m.y.-old Upper Alturas fauna of California. The shapes of the occlusal surfaces of some of the Always Welcome Inn lower first molars are very similar to *O. mcknighti*. This suggests that the two are closely related. The narrowness of the anteroconid (the broad area with the enamel atoll) of the juvenile lower left first molar from the Always Welcome Inn, in part due to deep penetration by lingual reentrant 4, is almost never seen in *Ophiomys* and *Ogmodontomys* specimens that have atolls (for example, those illustrated by Hibbard and Zakrzewski, 1967), especially early forms such as *"Mimomys" panacaensis* described by Mou (1997) or *Ophiomys mcknighti* described by Gustafson (1978). Instead, this is a feature, along with the bulbous form of the anterior part of the anteroconid above lingual reentrant 4, that is seen in *Cosomys* from the Hagerman local fauna. This evidence suggests that the Always Welcome Inn primitive vole may be an ancestor of *Cosomys*.

The primitive vole teeth found at the Always Welcome Inn support an early Blancan age for the sequence. The information available at present suggests an age range of ~4.8–3.7 Ma, older than the 3.7–3.1 Ma age of *Cosomys* at the Hagerman site and younger than the time when, according to Repenning (1987, 2003), arvicolid rodents of the genus present at the Always Welcome Inn site first arrived in North America from Siberia. If the Always Welcome Inn vole proves to be related to *Ophiomys mcknighti*, this would help to narrow the age range to ~4.8–4.3 Ma.

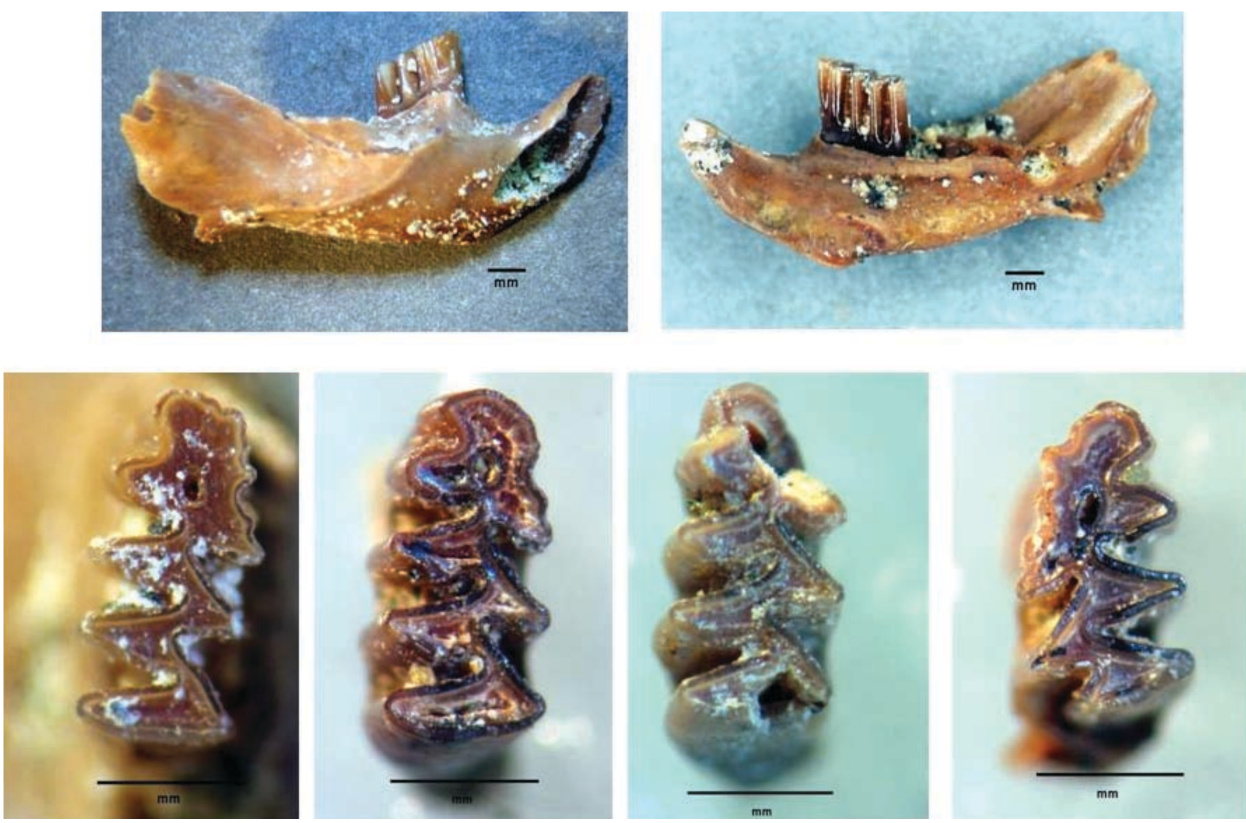


Figure 23. Vole (*Ophiomys* sp.) lower jaw with first molar (top and lower left; EO-935) and other lower first molars found at the Always Welcome Inn (from left to right, EO-936, EO-881, and EO-878A).

(AWI fauna, continued from page 16)

Table 4. Comparison of Always Welcome Inn microtine teeth with microtine teeth from nearby areas.

	Always Welcome Inn	*"Mimomys" panacaensis* (4.8 Ma) Mou (1997)	*Ophiomys mcknighti* (4.3 Ma) Gustafson (1978)	*Ogmodontomys poaphagus* (4.2 Ma) Czaplewski (1990)	*Cosomys primus* (3.7–3.1 Ma) Hibbard and Zakrzewki (1967), Lich (1990)
LENGTH (mm)					
M^1	1.90–2.10	2.16–2.74	2.1–2.3	2.21–2.92	2.76–3.33
M^2	1.62–1.85	1.92–2.32	2.0	2.13–2.16	2.0–2.2
M^3	1.38–1.52	1.52–2.24	1.8–1.9	2.10–2.33	1.90
m_1	2.22–2.36	2.54–3.00	2.7	3.11	2.47–3.34
m_2	1.60–1.85	1.74–2.12	1.8	2.13–2.16	2.1
m_3	1.45	1.48–1.92	1.5	2.10–2.33	2.1–2.2
WIDTH (mm)					
M^1	1.08–1.31	1.24–1.76	1.2–1.4	1.21–1.90	1.7–1.9
M^2	1.08–1.36	1.26–1.62	1.3–1.5	1.51–1.64	1.6–1.7
M^3	0.89	0.84–1.40	1.0–1.2	1.21–1.44	1.3–1.4
m_1	1.07–1.19	1.04–1.48	1.2–1.4	1.41–1.51	1.16–1.69
m_2	0.98–1.00	1.00–1.48	1.4	1.34–1.51	1.5
m_3	0.87	0.86–1.24	1.0	1.28–1.33	1.1–1.4

Notes: Length of tooth was measured along the bisector of the tooth in a mesial-distal direction. The measured width is the maximum dimension perpendicular to the length. M1, upper first molar; M2, upper second molar; M3, upper third molar; m_1, lower first molar; m_2, lower second molar; m_3, lower third molar.

Grison and Small Carnivores

The mustelid family includes skunks, weasels, badgers, and wolverines, a group of animals that all have well-developed scent glands. Our first mustelid bone at the Always Welcome Inn site was collected in April 2007 (Figure 24). It has been identified as a juvenile *Trigonictis*, a member of the mustelid family known as a grison. Grison fossils were described in the Hagerman fossil beds of Idaho by Gazin (1934) and have also been found in the White Bluffs local fauna of Washington (Gustafson, 1978). The modern grison (*Galictis*), a carnivore that lives in South America, was derived from North American ancestors. It is about the size of a pine marten, and its body is elongated like those of minks and weasels. This is the largest predator found so far at the Always Welcome Inn.

One of the most puzzling finds at the Always Welcome Inn is the tooth of a small carnivore found near the top of the sequence (Figure 25). We are not sure to which species it belongs.

Camelid: Llama?

The largest bone found so far at the Always Welcome Inn was discovered by a guest at the motel. The bone is from a camelid, possibly a llama (Figure 26). It was apparently collected from the late Pliocene to early Pleistocene gravels that cap the sequence. If the location is correct, the camelid fossil is younger than the other fossils from lower in the section.

Figure 24. Humerus of the grison *Trigonictis* (EO-919).

Figure 25. Tooth of a small carnivore found at the top of the Always Welcome Inn sequence (EO-863).

Figure 26. Camelid bone, possibly a llama distal metapodial (EO-785), found in gravels above the unconformity at the top of the Always Welcome Inn section. (left) medial view, (right) ventral view. Scale is in millimeters.

(AWI fauna, continued from page 17)

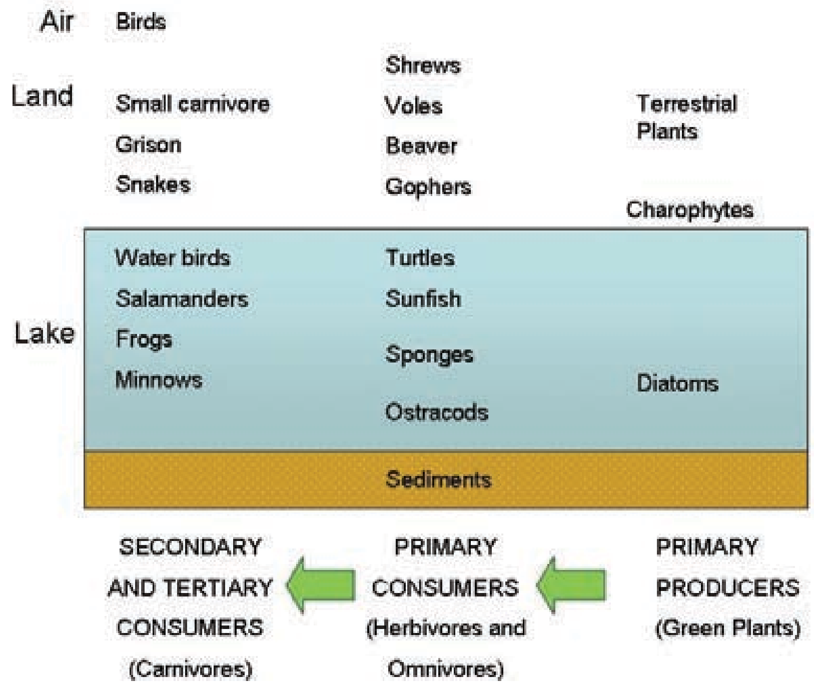


Figure 27. Schematic trophic structure of the Always Welcome Inn local fauna.

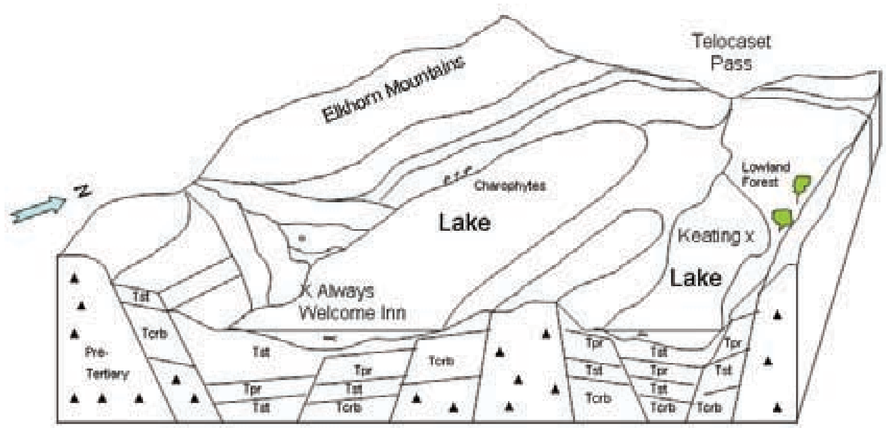


Figure 28. Schematic block diagram illustrating the paleogeography and geology of the Always Welcome Inn area during the early Pliocene. The block diagram shows the area during a period of lower lake levels. At higher lake levels the two lakes may have merged into one. Rock unit symbols are Tcrb (Columbia River Basalts), Tst (Tertiary sediments and tuffs), and Tpr (Powder River Volcanics).

DEPOSITIONAL ENVIRONMENTS

The Always Welcome Inn sequence was deposited on the geographic barrier that separated the Snake River Plain and the Columbia River basin during the early Pliocene. Cooling climate brought subarctic fishes south into Idaho while cool-water fishes were absent in the area of southwestern Washington, where environments were warmer, lower in elevation, and experienced much warmer winters compared to the Snake River (Smith and others, 2000). Many new mammals appeared in the area as they migrated from other continents and other regions in North America. The woodlands and forests of the Miocene were depleted until in the mid-Pliocene they were present only along stream drainages and at higher elevations, with savannah and open grassland occupying much of the area that was once forested. This trend continued, except for a temporary reversal in the late Pliocene (Shotwell, 1963).

The fish, diatoms, gastropods, bivalves, sponge spicules, and thin lignite layers present in the lower 6 m of the Always Welcome Inn outcrop indicate a shallow freshwater environment such as a shallow lake and lake margin, with charophytes and other vegetation growing in and around the margins of the water (Figures 27 and 28). Terry Frest (written communication, 2002) suggested that the environment was rather warm and the water depth was not extremely deep because cold-water gastropods are not present. The percentages of diatoms and sponge spicules decrease upward, suggesting that the water depth may have become shallower with time. The trough cross-bedded sand and overlying silt unit in the upper 4 m of the sequence are interpreted to be the channel and floodplain deposits of a stream flowing into the lake. Bird, frog, salamander, shrew, vole, beaver, and other fossils suggest the presence of numerous bodies of fresh water, both ponds and streams. *Ophiomys* suggests the presence of permanent water courses (Gustafson, 1978) and *Castor* and *Dipoides* are strong indicators of trees along the stream and lake banks. Shrews and many of the other rodents would be expected in marshy areas (Dalquest, 1978). The raptors fed mainly on voles and pocket gophers but also ate birds. Many of the small rodent fossils may be accounted for as an accumulation of remains from pellets of owls or hawks that nested nearby (Hibbard, 1950; Dalquest, 1967). Young beaver and rabbits, along with other small mammals, were probably the prey of the wide-ranging grison (Bjork, 1970). The occurrence of minnow fossils in the upper part of the sequence indicates cooler water. The recurrence of diatoms and sponge spicules in the layers from ~8 to 10 m in the sequence suggests a return to shallow lake conditions, probably oxbow lakes and ponds in floodplain environments.

(AWI fauna, continued from page 18)

Overall, the sediments and fossils at the Always Welcome Inn fossil site record the change from shallow lake to stream deposition documented in other sequences in the Powder Valley by Brooks and others (1976). The fish species present at the Always Welcome Inn site suggest that the lakes in the area did not drain into either the Columbia River drainage basin or Lake Idaho. Voles and beaver were able to migrate across the drainage divides into the area. The type of sunfish present in the Always Welcome Inn outcrop suggests that the elevation was probably below 1,000 m (3,281 ft), which is slightly lower than the present elevation of the outcrop (~1,050 m or ~3,440 ft). Precipitation in the area was probably much higher than it is today. The area around the lake and the surrounding hills may have been forested with trees similar to those that grew during the late Miocene to early Pliocene on the northeast side of the Powder Valley and on the flanks of the Wallowa Mountains near Keating, Oregon. These included maple, hornbeam, hickory, sweetgum, magnolia, tupelo gum, oak, redwood, swamp cypress, and water chestnut (Gilluly, 1937; Chaney, 1959; and Hoxie, 1965).

All of the basic types of small animals present in the Always Welcome Inn area during the early Pliocene are also found in the ~4.8-m.y.-old Saw Rock Canyon fauna of Kansas and in the ~ 3.7–3.1 Ma Hagerman fauna of Idaho. The paleoenvironments and paleoecological relationships of the smaller animals in the Always Welcome Inn area during the early Pliocene closely resemble those at the ~3.7–3.1 Ma Hagerman fossil locality of Idaho. The paleoclimate was more humid and slightly wetter in both areas than at present, and both sites were located near large lakes. The Hagerman fossil assemblage was preserved in sediments deposited by a fluvial system that connected with nearby Lake Idaho, the great lake that occupied much of the Snake River Plain during parts of the Pliocene, and includes beavers (both *Castor* and *Dipoides)*, muskrats (*Pliopotamys minor*), voles (including *Cosomys primus* and *Ophiomys taylori*), ground squirrels, gophers, pocket mice, kangaroo rats, rabbits, gazin, and other mammals, along with turtles, fish, frogs, salamanders, water snakes, and water and shore birds. The salamander *Ambystoma* found at the Always Welcome Inn is also found in the Hagerman local fauna and younger faunas of the Glenns Ferry Formation in Idaho (Mead and others, 1998), but we do not know if the species were the same in both areas. The Always Welcome Inn gastropods and bivalves are similar to those in the upper third of the Hagerman sequence (Terry Frest, written communication, 2002). Many of the microsites in the Hagerman fossil beds preserve autochthonous assemblages of fossils of small animals without any fossils of larger animals like the one at the Always Welcome Inn. Numerous bodies of fresh water, both ponds and streams, were present, with two types of beaver living in a marsh and meadow habitat in close proximity to trees and competing for similar resources (Zakrzewski, 1969).

The suite of fossils at the Always Welcome Inn is also similar to those present at the ~4.3-m.y.-old White Bluffs, the ~3.9-m.y.-old Blufftop, and the ~ 3.0- to 2.8-m.y.-old Taunton localities of Washington, but the Washington faunas also include the fossils of animals that lived in savannah, woodland, and grassland environments. The beavers *Castor* and *Dipoides* are present in the White Bluffs and Taunton faunas, and the vole *Ophiomys* is present in all three areas. The shrew found at the Always Welcome Inn (*Paracryptotis rex)* is present in the Blufftop fauna but not in the White Bluffs or Taunton faunas (Gustafson, 1985; Repenning and others, 1995; Smith and others, 2000).

The most important difference between the fossil assemblage present at the Always Welcome Inn site and those found in neighboring late Miocene and early Pliocene fossil localities in Oregon, Washington, and Idaho is the scarcity of the bones of large mammals such as horses, camels, and rhinoceros at the Always Welcome Inn site, with the exception of the bone of a camelid (llama?) that was found in the gravels above the angular unconformity in the Always Welcome Inn sequence. The taphonomy of the site is largely biased toward preserving a small autochthonous assemblage with very little transport of large animals into the depositional environment.

POST-DEPOSITIONAL HISTORY OF THE ALWAYS WELCOME INN SEQUENCE

After the Always Welcome Inn sediments below the angular unconformity were deposited, they were tilted, faulted, and uplifted by mountain-building activity. Then the tilted and faulted lake and stream beds were eroded and covered with gravels by streams that flowed from the southeast toward the northwest. Brooks and others (1976) noted that the gravel beds are composed mainly of clasts of pre-Cenozoic igneous and metamorphic rocks (argillite and chert), plus minor amounts of basalt and rhyolite. They concluded that the influx of clasts of pre-Cenozoic rocks indicates accelerated uplift of nearby areas. They also noted that the reddish-brown color of the tuffaceous interbeds in the gravels indicates deposition in an oxygenated environment. Together, the color and coarse texture suggest that the topographic gradient had increased and that streams had drained the lake that had earlier occupied the Powder Valley.

It seems likely that the deposition of the gravels above the angular unconformity at the Always Welcome Inn is related to the diversion of the Snake River through Hells Canyon. This occurred during the late Pliocene, when the distribution of the snail, *Fisherola nutti*, which first occurs as a fossil in the Bruneau Formation of the western Snake River Plain, and

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which, because of its streamlined, limpet-like shell, could have migrated up the swift current of Hells Canyon to the western Snake River Plain (Taylor, 1985). By ~2.75–2.5 Ma (Hearst, 1999; Wood and Clemens, 2002), the Imnaha-Salmon-Clearwater river system had eroded headward and captured a tributary of the Snake River in the Hells Canyon area. This caused the Snake River to flow west through Hells Canyon into the Columbia River drainage system, carving Hells Canyon in a few million years (Lindgren, 1901; Livingston, 1928; Wheeler and Cook, 1954; Cook and Larrison, 1954; Taylor, 1985; Othberg, 1988, 1994). The connection between the Powder and Grande Ronde valleys closed around the same time (Van Tassell and others, 2001), cutting off the route through which Lake Idaho flowed into the Columbia River basin between ~3.8 and 3 Ma. The increase in topographic gradient noted by Brooks and others (1976) may have been the result of the changes in the courses of the rivers in the region as they flowed around the uplifting Elkhorn and Wallowa Mountain blocks and began to entrench and to erode headward in response to the draining of Lake Idaho and rerouting of the Snake River through Hells Canyon that began at ~2.7–2.5 Ma. This steepened the gradients of the streams draining into Hells Canyon, including the Powder River. By 1.7–1.6 Ma, the Glenns Ferry lake had drained and its sediments had been covered by gravels (Taylor, 1985; Othberg, 1988, 1994; Malde, 1991; Sadler and Link, 1996; Sankey, 2002; Wood and Clemens, 2002). As the climate cooled and Hells Canyon deepened, the Pliocene lake that had occupied the Powder Valley disappeared and the Powder River assumed its present course (Zublin, 2005).

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The Always Welcome Inn locality is a significant new fossil site that provides an important window into what the Powder Valley area was like during the early Pliocene. The sediments and fossils at the site record a change from shallow lake to stream deposition. The lower 6 m of this 10-m-thick section consists of shallow lake and lake-margin diatomites and silts that contain abundant diatoms, sponge spicules (*Ephydatia fluviatilis*), gastropods (*Gyraulus*, lymnaeids), bivalves (*Sphaerium* and *Pisidium*), charophytes, turtle shell fragments (*Tracheymys* or *Clemmys*?), a new species of the sunfish *Archoplites*, the lower left jaw of a beaver (*Castor californicus*), and leaf and wood fragments. The silts and silty sands in the upper 4 m of the section were deposited in channels and floodplains by streams that flowed toward the northwest. The upper part of the sequence has yielded ostracods (*Cypricercus*), gastropods (*Gyraulus*, lymnaeids), fossil sunfish *(Archoplites)*, minnows (a new genus, plus *Achrocheilus*), salamanders (*Ambystoma*), rails (Rallidae), ducks (Anatidae),and a raptor (owl?), frogs (*Rana*?), snakes (*Thamnophis* or *Nerodius*?), rabbits (*Hypolagus*?), a shrew (*Paracryptotis rex*), a gopher (geomyid), voles (*Ophiomys*), beaver (*Dipoides* sp. cf. *vallicula* and *wilsoni)*, grison (*Trigonictis*), and a small carnivore. Most of the salamanders were neotenic. The Always Welcome Inn archaic vole may be the oldest *Ophiomys* species documented in the present-day Columbia River basin and is a possible ancestor of *Cosomys primus*, a vole that is very common in the ~ 3.7- to 3.1-m.y.-old localities in the area of Hagerman, Idaho. The Always Welcome Inn *Dipoides* could be an important link in one of the lineages leading to the giant beavers of the Pleistocene. There is little evidence, with the possible exception of the minnow *Acrocheilus*, to document a water connection with Lake Idaho or the Columbia River drainage basin. The sequence was tilted, faulted, and eroded before the deposition of the overlying gravels, which have yielded the bone of a camelid, possibly a llama.

Further study of the Always Welcome Inn sequence and other Pliocene sequences in the Powder Valley promises to provide new insights into what the area was like during the Pliocene and how climate changes, lake level variations, and drainage changes in the area influenced the migration patterns of fish and mammals between the Pliocene Columbia River and Snake River drainage basins.

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Student finds rodent skull

Adora Brockman, a student at Pine-Eagle School District in Richland, Oregon, found the lower left jaw of the beaver *Castor* described in the accompanying article at the Always Welcome Inn April 6, 2007, in the layer 0–0.5 m above the base of the sequence. The class trip of 7th and 8th graders from Pine-Eagle school to the outcrop was organized by Story Miller, an Eastern Oregon University student, as part of her senior thesis.

North America Research Group

Jurassic crocodile discovered in Crook County, Oregon

by Andrew Bland[1], Robert Rosé[2], and Aaron D. Currier[3]

In October 2005, while searching for ammonites (extinct marine cephalopods) near Suplee, Oregon (Figure 1) members of North America Research Group (NARG) discovered the remains of a sea crocodile tentatively identified as *Metriorhynchus* (Figure 2) that lived over 160 million years ago. The crocodile was not a resident of Oregon but was transported thousands of miles from the South Pacific via continental drift on a journey that took millions of years.

With the landowner's permission and assistance the specimen was carefully excavated within two days. Several large sandy limestone blocks encasing the crocodile were recovered (Figure 3). Rescued from environmental degradation and further erosion, the material was stabilized and prepared over a period of six months (Figures 4 and 5). With nearly 50 percent of the crocodile's skeletal remains preserved, it is the most complete single specimen of *Metriorhynchus* found in Oregon to date and the third from the Jurassic Snowshoe Formation.

The first crocodile specimen from Oregon was found in the late 1930s by Earl Packard, then Dean of the School of Science at Oregon State College. He collected a skull, jaw, several vertebra, and long bones of crocodiles from several localities and sent them to the Smithsonian (Orr and Orr, 1999). Nearly 40 years later these bones were described by Buffetaut (1979) and determined to be in the *Teleosaurid* family — the first in North America. It was also stated that some of the vertebrae could be from the *Metriorhynchid* family. In the late 1980s Stricker and Taylor (1989) reported finding a second crocodile specimen. They stated in an abstract that the crocodile belongs to the *Metriorhynchidae* family of *Mesosuchia*. This specimen is not professionally described.

NARG donated the 2005 crocodile specimen to the Thomas Condon State Museum of Fossils at the University of Oregon. Following accession and cursory examination the specimen will be shipped to the University of Iowa, where Dr. Chris Brochu, associate professor of vertebrate paleontology at the university and well-known crocodile expert, will study the specimen and formally report it in the scientific literature. This work is expected to take about two years. After this step the crocodile will return to Oregon and become a permanent part of the Condon Museum at the University of Oregon.

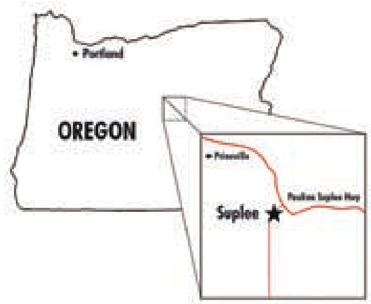

Figure 1. Location map.

CROOK COUNTY GEOLOGY

The Snowshoe Formation crops out extensively between Suplee and Izee (Crook and Grant counties) and is geologically part of what geologists map as the Izee terrane (Orr and others, 1992). It consists of marine sandstone, sandy limestone, and siltstone overlain by claystone beds and marine volcaniclastic rocks. All sedimentary rock units change laterally, and in distances of only 16 to 24 km these units can vary significantly in lithology. The Weberg member of the Snowshoe Formation is recognized only around Suplee where limestone and calcareous sandstone are common and marine invertebrate fossils are prevalent. It is in this latter unit that crocodilian fossil remains were exhumed. These rocks represent a tropical warm-water, high-energy (turbulent), relatively shallow marine environment.

The western part of the Snowshoe Formation has been dated with some precision using ammonite biostratigraphy (Imly, 1973). The Weberg Member represents most of the Bajocian Stage of middle Jurassaic age; Taylor (1982; 1988) has detailed

Figure 2. Artist's rendering of the crocodile *Metriorhynchus*. Credit: Jon Hughes.

1 13116 NW 6th Avenue, Vancouver, WA 98685
2 P. O. Box 844, Cascadia, OR 97329
3 P. O. Box 1026, Salem, OR 97308

(Crocodile, continued from page 24)

Figure 3. In situ numbered blocks of crocodile specimen. Photo: Peg Johnson.

a biochronology of the Snowshoe Formation.

The Izee terrane consists of Triassic, Jurassic, and older rocks that were deposited in the proto-Pacific Ocean more than 1,900 km south of its present latitude, and perhaps from the far western side of the Pacific basin. The Jurassic rocks here "represent the environment of a shallow marine forearc basin between a volcanic island archipelago and the oceanic subduction trench" (Orr and others, 1992, p. 254). This terrane was accreted to the North American plate during late Jurassic.

MARINE CROCODILES

The subject crocodile belongs to suborder *Thalattosuchia*, a name applied to a clade of Early Jurassic to Early Cretaceous marine crocodylomorphs. Buffetaut in 1982 assigned two families of marine crocodiles; *Teleosauridae* and *Metriorhynchidae* to the suborder *Thalattosuchia*.

Members of the *Teleosauridae* family are, characteristically, slim-bodied, marine crocodilians similar to the modern day gharial. They bear rostrate snouts, reflective of a piscivory (fish eating) niche. Especially characteristic are forelimbs, which are only one half the length of the hind limbs (Carroll, 1988). Shortened forelimbs are common in aquatic reptiles. Some early members of *Teleosauridae* have been found in terrestrial formations suggesting thalattosuchians were in transition from being semi-aquatic freshwater forms to fully marine forms. The teleosaurs retained their armor covering.

Metriorhynchids were a group of Jurassic/Cretaceous marine crocodilians with refined paddlelike forelegs. Unlike the teleosaurs they lacked dermal armor covering. Their streamlined body minimized drag though water, as did a tail with a fishlike dorsal appendage. Metriorhynchids were the only group of archosaurs to become fully adapted to life at sea. The *Metriorhynchidae* family has a wide geographic distribution, with material re-

Figure 4. One of many needle-like teeth of the crocodile. 6.3 cm long.

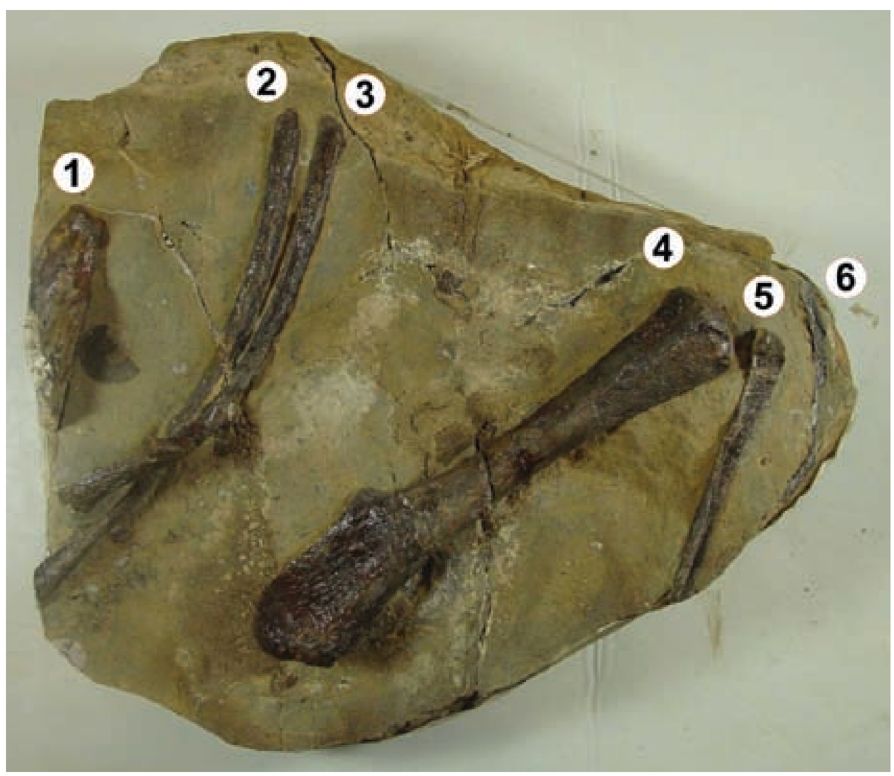

Figure 5. Prepared limestone block showing humerus and ribs of crocodile. 1, Unidentified bone, 8.25 cm; 2, rib, 21.5cm; 3, rib, 17.75 cm; 4, ulna, 21.5cm; 5, rib, 10.75 cm; 6, rib, 8.25 cm.

(Crocodile, continued from page 25)

ported from Britain, England, France, Switzerland, Germany, Russia, Cuba, Mexico, Argentina and Chile.

The type genus *Metriorhynchus* was a carnivore that spent much, if not all, of its life at sea. No *Metriorhynchus* eggs or nests have been discovered, so little is known of the reptile's reproductive life cycle. Other large marine reptiles of the Mesozoic, such as plesiosaurs and ichthyosaurs, are known to have given birth to live young at sea. Averaging around three meters in length, *Metriorhynchus* is considered to be medium sized compared to extant crocodilians.

Metriorhynchus was a versatile and opportunistic predator that fed on belemnites, ammonites, fast-moving fish, and the larger *Leedsichthys*. Occasionally *Metriorhynchus* was also capable of capturing flying animals such as pterosaurs and scavenging plesiosaur carcasses on the sea floor.

Acknowledgements: Dr. William Orr, University of Oregon; Dr. James Martin, South Dakota School of Mines and Technology; and Dr. Christopher Brochu, University of Iowa.

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FOSSIL COLLECTING

Ammonite collected by NARG. Longest dimension is ~ 14 cm.

Fossil collectors must adhere to rules and regulations established by owners or managing agencies of the lands on which they wish to collect. Federal laws prohibit the collection of higher vertebrate fossil material without a permit. Collecting of common invertebrate and plant fossils is permitted on public lands except within the boundaries of U.S. national parks, Oregon state parks, Oregon Forestry lands, or Oregon Fish and Wildlife lands. Before collecting, first check federal, state, and county laws for additional rules that may govern the area you wish to visit. Fossils collected from public lands are to be for personal, educational, and scientific purposes and may not be exploited commercially. To access or collect on privately owned lands, collectors must contact and obtain permission from the owners prior to entering the property. Please respect the wishes of private land owners, observe the rules, and be courteous — otherwise, future access may be denied to everyone.

Untrained but observant people can and do frequently discover fossils of great significance, so keep your eyes open. It's important that new and significant finds are reported to the scientific community to provide an opportunity for them to be studied.

NORTH AMERICAN RESEARCH GROUP (NARG)

The Pacific Northwest region extends from Northern California through Oregon, Washington, and British Columbia to inland Idaho. To fully comprehend the complex geology of this area more research is necessary. Paleontologic contributions are a key component of this research. NARG's mission is to promote and educate the public on the paleontology of the region and to contribute to paleontologic research. Our organization consists of members of all ages and experience with interests and professions in the fields of paleontology, paleobotany, and geology.

By forming associations with professionals, NARG has a base of advisors who provide instructional guidance and consultation. Advisors also give direction to areas where NARG can make contributions to the fossil record. NARG is committed to doing whatever is necessary to ensure that fossils are available to be studied and enjoyed by future generations.

NARG schedules numerous field trips throughout the year; finds are frequently donated to the public domain for scientific study and display. NARG holds monthly meetings at the Rice Museum in Hillsboro, Oregon. NARG also coordinates the annual Northwest Fossil Fest. For more information about NARG visit our web site at www.narg-online.com.

Watershed assessment, river restoration, and the geoscience profession in Oregon

by Stephen B. Taylor[1]

INTRODUCTION

Geologists have long been fascinated by the power, form, and function of river systems. Classical works in the U.S. include those by Powell (1882), exploration of the Colorado River; Davis (1889), drainage patterns and landscape evolution; Gilbert (1914), sediment transport by rivers; and Horton (1945), quantitative analysis of drainage networks. The historic importance of river environments in the geosciences is further emphasized by a key-word search in GeoRef, the bibliographic database sponsored by the American Geological Institute (American Geological Institute, 2007). The Boolean search string "river or fluvial" returns over 198,000 entries with publication dates ranging from 1801 to present. This paper discusses the role of professional geologists in the context of modern river restoration science, particularly as it pertains to watershed assessment and restoration in the state of Oregon.

Watersheds are composed of channel networks of varying spatial scales and represent one of the most fundamental landscape systems on the Earth's surface (Figure 1). Fluvial systems transport water, sediment, organic material, and chemical nutrients from the continents to the ocean basins. These systems have formed important habitat for freshwater aquatic and terrestrial life over a significant portion of geologic time. From an ecological perspective, watersheds provide services along riparian corridors that form critical habitat for flora and fauna. Humans in turn leverage these ecological goods and services to yield water resources, food, raw materials, and value-added economic infrastructure (e.g., transportation networks, industrial infrastructure, recreational facilities, agricultural land). Hence, watersheds serve as one of the fundamental regulatory units for allocating water, with the total estimated value of ecosystem services and natural capital approaching $12.3 billion (McCaffrey, 2001; Conca, 2005). The historic interplay between human occupation, intensive land management, and fluvial systems has resulted in significant impairment or pollution of waterways over the past century (U.S. Environmental Protection Agency, 2000; Gleick, 2003).

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THE OREGON WATERSHED MOVEMENT

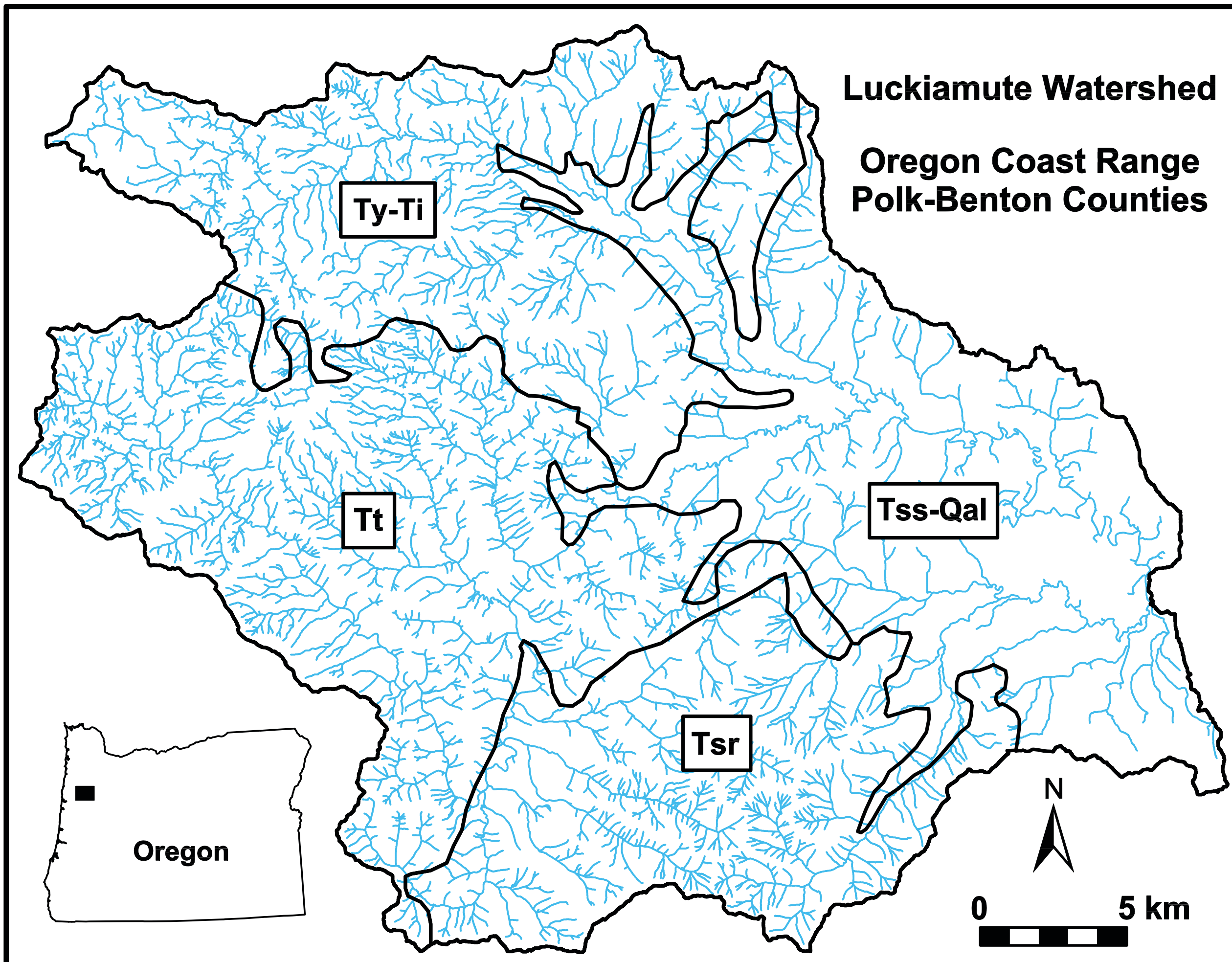
Over the past 30 years, the state of Oregon has recognized the importance of watershed services to the economic vitality and environmental quality of the state. Oregon was a pioneer in the national environmental movement of the late 1970s, particularly with respect to land-use planning and water quality (Walth, 1994). The most recent manifestation of this priority recognition is exemplified by the Oregon Plan for Salmon and Watersheds (State of Oregon, 1997), a statewide initiative that was developed in response to proposed listings of native salmonids under the federal Endangered Species Act. The purpose of the Oregon Plan is to ensure watershed health and restore native salmonid fisheries to a sustainable level. To this end, the Oregon Watershed Enhancement Board (OWEB) was established by State Legislature in 1999 to monitor watershed conditions, coordinate programs, and administer lottery-derived restoration funds. With a current budget of $80 million, one of the primary functions of OWEB is to support protection, recovery, and restoration projects by community-based watershed councils across the state. The fundamental council philosophy is to engage citizens in understanding their local watershed conditions and to garner support for investment in the improved health therein.

The initial step in this process is completion of a basin-wide watershed assessment. As described by OWEB (1999, p. 3), "watershed assessment is a process for evaluating how well a watershed is working." The purpose is to determine locations that would most benefit by restoration of natural processes to improve fish habitat and water quality. Primary goals include:

1. Identifying features and processes important to fish habitat and water quality,
2. Determining how natural processes influence those resources,
3. Understanding the types of human activities that affect fish habitat and water quality, and
4. Evaluating cumulative effects of land management practices over time.

Thus, the philosophical premise of a watershed assessment "is that streams and their channels are the result not only of surrounding landform, geology, and climate, but of all upslope and in-stream influences as well. The assessment is directed at broad-scale patterns. It uses aspects of water quality and fish habitat as indicators of watershed health. To identify potential problems, the assessment relies on existing data, local knowledge of land managers, and field surveys." (OWEB, 1999, p. 4). Clearly, geological

(Watersheds, continued from page 27)



Bedrock Geology	No. Sixth-Field Subbasins	Avg. Drainage Density (km^{-1})	Avg. Basin Ruggedness	Avg. Shreve Magnitude	Avg. Basin Relief (m)	Avg. 1st Order Channel Gradient	Avg. Stream Power Index	Avg. No. Tributary Junctions Per Unit Area (km^{-2})
Tsr	6	2.2	1.2	49	530	0.23	0.20	2.9
Tt	5	2.4	1.6	55	660	0.22	0.19	2.9
Ty-Ti	5	2.0	1.1	32	540	0.21	0.41	1.9
Tss-Qal	6	1.4	0.2	14	150	0.06	0.03	0.7

Average Sixth-Field Subbasin Drainage Area = 10-20 km^2

Tsr Siletz River Volcanics (Paleocene to Eocene; basalt)
Tt Tyee Formation (middle Eocene; sandstone)
Ty-Ti Yamhill Formation-Tertiary Intrusives (Eocene-Oligocene; siltstone intruded by gabbro)
Tss-Qal Spencer Formation-Quaternary Alluvium (patchwork of Eocene siltstone-sandstone and alluvium)

Figure 1. Generalized geologic map and drainage network of the Luckiamute River basin, Polk and Benton counties, Oregon. The watershed is subdivided into four lithospatial domains: Siletz River Volcanics, Tyee Sandstone, Yamhill-Intrusive, and Spencer-Valley Fill (terminology after Taylor and others [2002]; map units from Walker and MacLeod [1991]). Tabulated morphometric data illustrate the controlling influence of site geology on fundamental watershed characteristics such as basin topography, drainage pattern, and channel configuration (from Taylor [2002, 2005]).

(Watersheds, continued from page 28)

observation, data analysis, and interpretation are critical activities that lead to the understanding of landforms, processes, and ecological services in a given watershed (Figure 1). Once an initial assessment is completed, this baseline information is used to guide development, design, and implementation of river restoration projects to improve ecological function. River restoration is here defined as the act of improving "hydrologic, geomorphic, and ecological processes in a degraded watershed system and replacing lost, damaged, or compromised elements of the natural system" (Wohl and others, 2005, p. 2).

The river restoration industry has experienced an exponential sixfold growth in the United States during the last decade (Figure 2). Over $1 billion is spent annually on small- to medium-scale restoration projects across the nation, with median costs of $45,000 per implementation (Bernhardt and others, 2005). Most restoration actions are performed on channel reaches less than 1 km in length. Through the work of community volunteers, government agencies, non-governmental organizations, and professional consultants, Oregon watershed councils have completed over 90 assessments, and OWEB has invested approximately $180,000,000 in restoration initiatives since 1999 (K. Bierly, OWEB, personal communication, 2007). Of the 37,099 restoration projects tallied in the National River Restoration Science Synthesis (NRRSS) database (survey years: 1990–2004; http://nrrss.nbii.gov), Oregon ranks second nationally behind Maryland in numbers of projects completed per 1000 km of river length (65.31/1000 km in Oregon) (Bernhardt and others, 2005). The most commonly cited restoration goals are (1) in-stream habitat improvement (pool development, woody debris augmentation), (2) riparian management (livestock containment, invasive removal), (3) fish passage (ladder installation, culvert modification), and (4) water quality management (riparian buffers, runoff control).

THE OREGON GEOSCIENCE PROFESSION

The laws governing the practice of geology in Oregon were established by the State Legislature in 1977 (Oregon Revised Statutes 672.505 to 672.991[2]; Oregon Administrative Rules 809[3]). Action was deemed necessary "to safeguard the health and welfare and property of the people of Oregon. These safeguards are in the fields of geology as related to engineering, ground water, land use planning, mineral exploration and development, geologic hazards, the further development of the science of geology, and other geologic matters of concern to the people of the state" (ORS 672.505). By statutory definition, "geology" refers to the science that involves the study of the Earth and its related processes and materials. Geologists utilize this knowledge for the benefit of the state and society at large. Engineering geology is a specialty area that refers to the application of geologic data, principles, and interpretations to naturally occurring materials so that geologic factors affecting planning, design, construction, and maintenance of civil engineering works are properly recognized and utilized.

As part of the 1977 legislation, the State Board of Geologist Examiners (OSBGE) was instituted as a five-member panel serving under the governor. Four members are appointed from the professional community and one as a public representative, each serving three-year terms. Board objectives include:

- Licensing professionals engaged in the public practice of geology
- Responding to complaints from the public and profession
- Educating the public and communicating with regulatory agencies
- Cooperating with related boards and commissions
- Promoting professional ethics and standards
- Providing systematic outreach to government agencies, non-governmental organizations, citizens, and registrants.

OSBGE currently administers licensing for over 1200 registered geologists (RG), certified engineering geologists (CEG), and geologists-in-training (GIT). The board is a member of the National Association of State Boards of Geology (ASBOG, 29 member states). Qualifications for professional registration include a college degree in geoscience or successful completion of 45 quarter hours (30

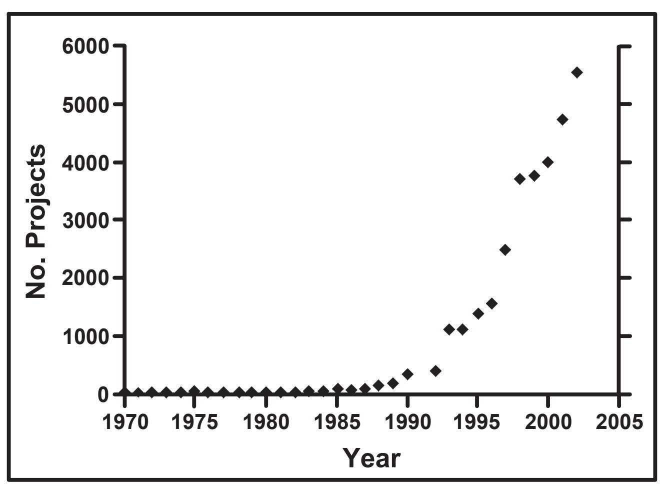


Figure 2. Time trend of number of river restoration projects recorded in the National River Restoration Science Synthesis (NRRSS) database (http://nrrss.nbii.gov) and years in which they were conducted (from Bernhardt and others [2005]).

2 Oregon Revised Statutes, Chapter 672 — Professional Engineers; Land Surveyors; Photogrammetrists; Geologists: Legislative Counsel Committee, Oregon Legislative Assembly, Salem, Oreg., Online document http://www.leg.state.or.us/ors/672.html.

3 Oregon Administrative Rules, OAR 809 Board of Geologist Examiners: Oregon State Archives, Salem, Oreg., Online document http://arcweb.sos.state.or.us/rules/OARS_800/OAR_809/809_tofc.html.

(Watersheds, continued from page 29)

semester hours) of related course work, five years of post-baccalaureate work experience under the supervision of a registered geologist, and passing nationally standardized competency exams (ASBOG). The CEG requires licensing as an RG with additional experience and testing in that specialty area.

One of the primary duties of the board involves compliance actions related to the geologic profession. OSBGE reviews an average of 10 compliance cases per year with the most commonly cited complaints consisting of poor-quality workmanship and public practice without a license. From a regulatory standpoint, OSBGE defines the *public practice of geology* as the "performance for another of geological service or work, such as consultation, investigation, surveys, evaluation, planning, mapping and inspection of geological work, that is related to public welfare or safeguarding of life, health, property and the environment" (ORS 672.505). The geoscience profession contributes significantly to sustainability and development of the natural resource base in the state. OSBGE and the state licensing laws provide a framework in which this work can be conducted safely, knowledgeably, and ethically for the greater good of Oregonians.

WATERSHED PROJECTS AND GEOLOGY LICENSURE

Given the long history of scientific contributions by geoscientists to the understanding of fluvial dynamics, and the stated importance of geomorphic and geologic analyses to watershed assessment, licensed professional geologists are well positioned to play a significant role in guiding river restoration practice in Oregon. Additionally, existing state licensing laws require that geologic components of watershed assessments and river restoration projects be performed under the supervision of a registered geologist (RG) or a certified engineering geologist (CEG). While only portions of watershed projects are geological in nature, it is recognized that properly designed river management plans require an interdisciplinary team with integrated contributions from geologists/geomorphologists[4], engineers, ecologists, fisheries biologists, botanists, foresters, hydrologists, landscape architects, social scientists, construction contractors, and community members. Because of the inherent overlap between Earth-resource professions (e.g., geology, engineering, hydrology), there is commonly confusion among regulators, project managers, and practitioners as to which state licensing board has legal primacy with respect to professional practice. The integrative nature of watershed assessment and restoration work renders these types of projects particularly vulnerable to practice outside of specialty disciplines and under-trained practitioners (Geological Society of America, 2004).

The OSBGE guiding policies for delineation of the public practice of geology are as follows. If the activity involves the simple review and reporting of previously published historical records, maps, and documents that explain the geology of a watershed (i.e., "the book report" approach), professional geology licensure is not required to write the summary report. However, if the professional activity involves re-analyzing published historical records, maps, and documents to conduct new analyses and to derive new or updated interpretations, the work must be conducted or stamped by a licensed geologist. Any work that involves direct observation, analysis, and interpretation of previously unpublished geologic data must be supervised or conducted by a registered professional geologist. Federal employees working on employment-related projects are exempt from Oregon geology licensing laws. However, federal employees working as independent consultants on geology-related projects at federal, state, or private locations, outside of their prescribed work duties, are required to hold professional licensure. State employees and private citizens, including retired federal workers, are required to abide by the state geology licensing laws and must have their work supervised and stamped by a registered professional. Exemptions include university professors conducting geologic analyses as part of their employment-related research and teaching duties. If watershed professionals are acting as private citizens to provide personal testimony at public hearings (e.g., planning commissions, city council meetings, etc.), free-speech laws allow those individuals to present geologic data, interpretations, and opinions without licensure. However, if such individuals are acting as third-party expert witnesses representing clients or other individuals, this constitutes the public practice of geology and professional registration is required.

The following is a summary of watershed assessment and restoration activities[5] that involve the practice of geology, require formalized training in the geosciences, and fall under the existing state licensing laws if professionally executed:

- ***Map and air photo interpretation of geologic features:*** any map and photo analyses used to delineate landforms, identify Earth materials (rock and/or sediment), and interpret Earth surface processes (including sediment sources); geologic analysis and interpretation of digital elevation models and LIDAR surveys.
- ***Geologic mapping:*** mapping and interpretation of bedrock type and lithostratigraphic units.

4 On the basis of alignment with the National Association of State Boards of Geology (ASBOG, www.asbog.org), OSBGE views geomorphology as a subdiscipline of geology that requires academic training in mathematics and physical sciences (geology, physics, chemistry). Geomorphology is documented as a qualifying geology subject area under OAR 809-030-0025.

5 This list was derived from extensive review of the Oregon Watershed Assessment Manual (OWEB, 1999). The numerous watershed activities that fall outside of geologic practice are not included in this discussion.

(Watersheds, continued from page 30)

- ***Geomorphic mapping:*** mapping and interpretation of landforms including active channels, in-channel features (e.g., bars, cut banks, thalwegs), floodplains, terraces, alluvial fans, landslide terrain, and mine-land features.
- ***Fluvial geomorphology and geomorphic analysis:*** quantitative measures of channel dynamics including derivation of channel geometry; identification of sediment storage and transport sites; flood history and paleoflood analyses.
- ***Geologic interpretation:*** using landforms, Earth materials, and surface processes to render interpretations about the history of a watershed or stream reach on geologic or historic time scales.
- ***Hydrogeology:*** hyporheic conditions, groundwater-surface water interaction, and aquifer characterization; vadose zone (unsaturated soil) hydrology, porosity and permeability analyses; recharge studies, groundwater flow, spring hydrology, water quality and groundwater resource evaluation; contaminant migration; wetlands hydrology.
- ***Engineering geology:*** erosion and slope stability studies; channel-bank stability analysis; landslide hazard evaluation; erosion and sedimentation analyses; road drainage analyses; abandoned mine land assessment; seismic hazard analysis including floodplain liquefaction potential.
- ***Channel modification and enhancement:*** any restoration activity involving channel modification that may result in erosion, flooding, slope instability, or alteration of groundwater conditions as defined by the practice of Engineering Geology.

While portions of the above watershed assessment and restoration activities overlap in scope and content with allied professions, they are considered part of the geologic practice and, accordingly, may be regulated by the licensing laws administered by the Oregon State Board of Geologist Examiners.

SUMMARY AND CONCLUSION

The study of physical properties of river systems is historically rooted in the geoscience discipline. This paper examines the role of professional geologists in the burgeoning field of river restoration. The state of Oregon has long recognized the importance of fluvial systems to society, most recently exemplified by enactment of the Oregon Plan for Salmon and Watersheds. The plan utilizes an integrative process of watershed assessment and restoration to improve ecological function in degraded river systems. Oregon is a national leader in watershed restoration efforts with the majority of projects focusing on in-stream modification, riparian management, fish passage, and water quality improvement.

Given the long history of scientific contributions by geoscientists to the understanding of fluvial dynamics, and the importance of geomorphic and geologic analyses to watershed assessment, Oregon professional geologists are well positioned to play a lead role in guiding river restoration. The interdisciplinary nature of watershed management plans requires a team approach involving geologists and a suite of other natural resource professionals. Related geologic practice is in turn governed by well-established state licensing laws that have been in effect since 1977 to ensure public welfare and safeguard life, health, property, and the environment. These laws require that geologic components of watershed assessments and river restoration projects be performed under the supervision of a registered geologist (RG) or a certified engineering geologist (CEG). Project activities that involve the public practice of geology include map and air photo analysis of geologic features, geologic mapping, geomorphic mapping, geomorphic analysis, geologic interpretation, groundwater investigations, slope stability studies, and channel modification.

Water resources and ecological services are critical to the economic vitality and environmental quality of the state. To this end, the Board of Geologist Examiners stands ready to work with allied professional organizations to promote cost-effective and successful watershed enhancement projects in Oregon. For more information on the professional practice of geology in the state of Oregon, contact the OSBGE office administrator at (503) 566-2837 (email: osbge.info@state.or.us), or visit the web site at www.oregon.gov/OSBGE/index.shtml.

ACKNOWLEDGMENTS

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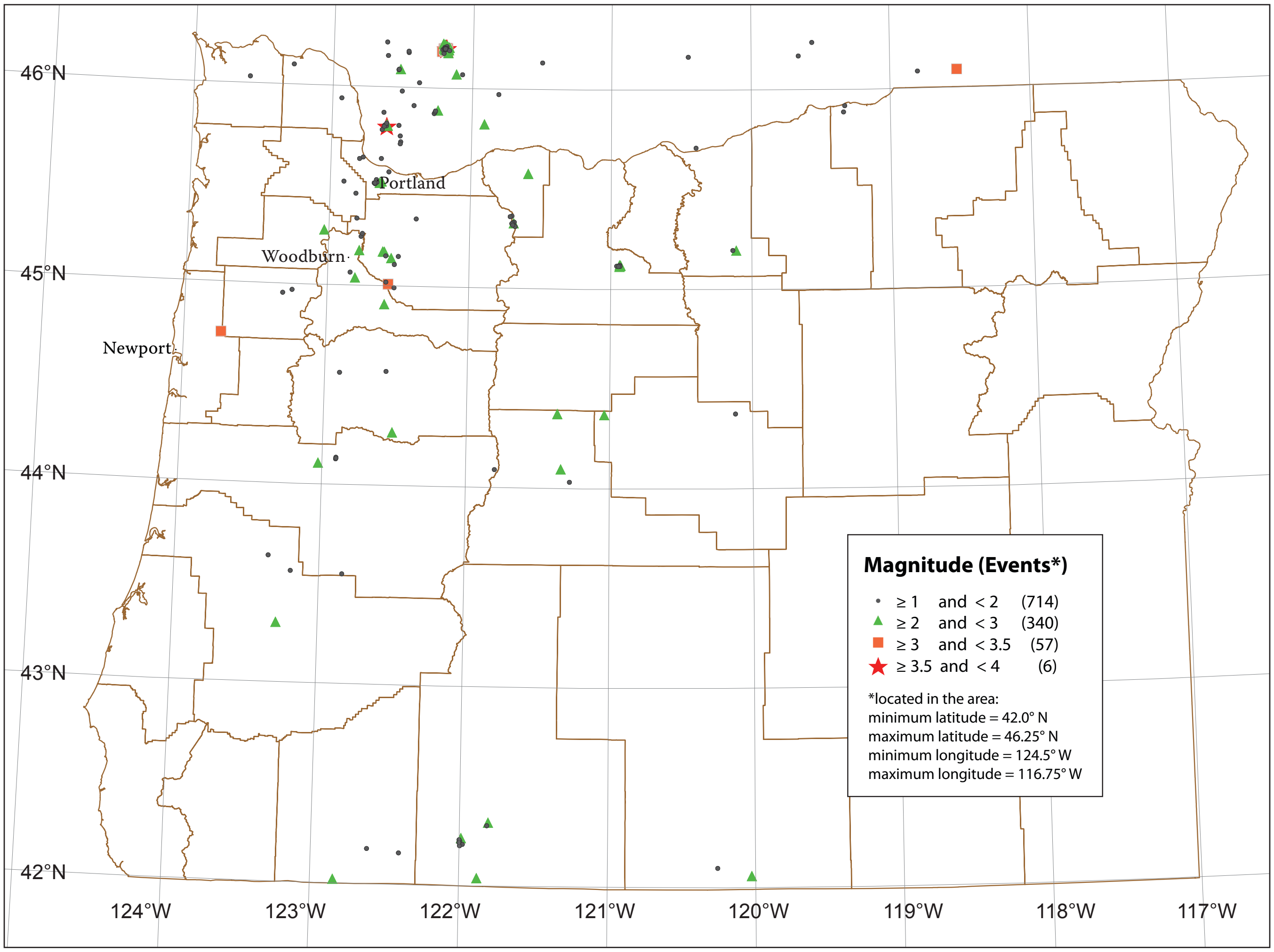
OREGON SEISMICITY IN 2006

Map data were generated from the Advanced National Seismic System (ANSS) Worldwide Earthquake Catalog (http://www.ncedc.org/anss/catalog-search.html).



In 2006 the most significant earthquakes in Oregon were:

- Saturday, March 4, 2006 at 09:38:47.12 AM (PST) — Magnitude 3.2, ENE of Newport
- Wednesday, April 26, 2006 at 07:24:6.80 AM (PDT) — Magnitude 3.0, ESE of Woodburn
- Thursday, August 3, 2006 at 01:39:18.70 AM (PDT) — Magnitude 3.8, N of Portland
- Sunday, November 5, 2006 at 09:34:35.69 PM (PST) — Magnitude 2.6, SW of Portland

Significant earthquakes source: http://www.pnsn.org/SEIS/EQ_Special/pnwtectonics.html

Preliminary assessment of the extent of the leaf fossil beds at Wheeler High School, Fossil, Wheeler County, Oregon

by Mark L. Ferns[1], Jason D. McClaughry[1], and Ian P. Madin[2]

EXECUTIVE SUMMARY

At the request of the Oregon Paleo Lands Institute Board, geologists from the Oregon Department of Geology and Mineral Industries (DOGAMI) undertook a preliminary investigation of the extent of the fossil beds at Wheeler High School in the town of Fossil, Wheeler County, Oregon. The investigation included several days of fieldwork, a magnetometer survey, chemical analysis of lava flows, and water well drilling log analysis. Our findings include:

- The fossil beds exposed north of the football field slope southwest at 20° to 30°, which means that they are at depths of almost 60 m (200 ft) below the surface beneath the existing high school building.
- The beds are probably cut off by a fault that runs east to west beneath the football field and have probably been displaced to even greater depths on the south side of the fault.
- There is probably little additional fossil resource available on school property adjacent to the currently exposed deposits.
- Thick soil and colluvium appear to cover bedrock on most slopes in the area; shallow excavations may be required for new fossil discoveries.
- The fossil beds at the high school likely extend east and west onto private property but would require excavation to reveal.
- Fossil beds occur adjacent to the Wheeler County Waste Transfer Facility.
- Water well data and some field evidence suggest that fossil beds may be present south and east of the County Fairgrounds in Fossil.

Our conclusion is that it is unlikely to be possible to develop additional fossil resources on the high school property beyond the existing beds. These findings are preliminary; extensive additional fieldwork and drilling are needed. A more cost effective strategy may be to prospect for additional fossil beds on nearby public property at the fairgrounds or at the waste transfer facility. A detailed map of the distribution of fossil-bearing layers in the existing deposit, along with a program to manage excavation spoils, would give an improved understanding of the volume and geometry of the fossil deposits and help conserve the resource to extend the life of the public fossil collecting program.

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INTRODUCTION

Staff from the Oregon Department of Geology and Mineral Industries (DOGAMI) conducted short field visits to the Wheeler High School leaf fossil locality in Fossil, Oregon, in November 2004 and January 2005. The visits were at the request of Richard Ross, the Director of the Oregon Paleo Project, in response to questions raised by potential funding organizations. The curator for the Wheeler High School locality, Karen Masshoff, accompanied DOGAMI staff in the field. The purpose of the visit was threefold: 1) to determine, if possible, whether a sufficiently large fossil resource remains on school property to support further development; 2) to provide guidance for the Oregon Paleo Lands Institute Board regarding the steps needed to fully determine the size, physical location, geologic character, and significance of the fossil resource; and 3) to identify other areas in and around the town of Fossil where similar paleontological resources may occur.

Present site development plans assume that the same fossil leaf beds excavated on the ridge north of the high school football field are present beneath the football field. The initial DOGAMI visit noted indirect geologic evidence for a fault that probably truncates the southward extension of the fossil beds beneath the football field. A ground magnetometer survey to determine if there is geophysical evidence for the suspected fault, coupled with cursory examination of water well logs in the area, indicates a strong probability that a large fault is present. The overall geologic structure of the area, together with a few field observations, suggests that the fossiliferous layers may be present on the hill to the southeast of the fairgrounds. Additional exposures of fossiliferous layers were observed at the Wheeler County Waste Transfer Facility.

BACKGROUND

One of Oregon's most accessible fossil collecting sites is located on the Wheeler High School grounds. School groups and hobbyists have collected a large variety of plant fossils from this central Oregon site since its discovery in 1949. The locality contains plant macrofossils (including leaves, stems, and fruits) that make up the well-known Bridge Creek flora (Chaney, 1925). Most Bridge Creek flora sites are located in the John Day Fossil Beds National Monument and as such are not open to public collecting. The Wheeler High School site is one of the few fossil collecting sites in central Oregon that is currently open to the general public. If sufficient fossil-rich material remains after more than 50 years of use, then the high school site would

(Leaf beds, continued from page 34)

be an ideal place to develop educational, collecting, and curatorial facilities.

SITE GEOLOGY

The fossil beds at Wheeler High School, herein referred to as the "Fossil High" leaf beds, are shown as a small inlier of John Day Formation rocks surrounded by older Clarno Formation rocks on Robinson's (1975) large-scale reconnaissance map of the John Day Formation. Younger, tilted Miocene Columbia River Basalt flows overlie more steeply dipping strata of Clarno and John Day formations just west of Fossil, forming the northwest limb of a broad, east- to northeast-trending fold. The Fossil High leaf beds dip to the south. Where exposed, the local base of the John Day Formation north of Fossil is marked by thick-bedded, pumice-lapilli tuff as much as 200 m (600 ft) thick that is correlative with member "g" of the John Day Formation (Robinson, 1975). A rhyodacite flow overlies the lapilli tuff north of Fossil (Robinson, 1975).

The Fossil High leaf beds are exposed on the south side of a 15 m (50 ft) high northeast-trending ridge located at the north end of the high school football field. The ridge is here referred to as the "gun club ridge" (Figures 1 and 2). The gun club ridge is separated from the main mass of the John Day Formation to the north by landslide- and colluvium-mantled low hills and by ridges of tilted and deeply eroded lava flows. A speculative north-northeast trending fault separates the ridge from lava flows of the Clarno Formation on the west.

Exposures of leaf beds on the gun club ridge extend over an area of about 0.012 km^2 (3 acres) on Wheeler County School District property (Figure 2). Excavation sites are scattered along the steep, south side of the gun club ridge and extend upslope to a fence line that runs east-west beneath the crest of the ridge. Spoil from past digs mantles the slope and obscures the extent of excavated ground. An alkali basalt flow crops out along the south face at the east end of the gun club ridge and can be traced westward along the ridge crest, north of the fence line. The lava flow underlies the fine-grained, fossil-bearing sedimentary rocks. Rounded basalt and rhyolite clasts scattered along the contact suggest that a thin gravel layer separates the fossil-bearing rocks from the lava.

Manchester and Meyer (1987) showed that the fossil leaf beds are layered strata with apparent dips to the southwest. Beds in pits (Figure 3) open in 2004 have strikes ranging from N 84° W to N 86° E with dips of 20°–30° S.

Along the south side of the gun club ridge, most of the current dig sites are in thin-bedded, tuffaceous siltstone or fine-grained sandstone. Plant fossils occur along bedding planes in gray or grayish-white siltstone. Although not enough material is exposed to be certain, it appears that leaf-bearing layers are relatively thin and form fossil-rich zones less than 0.3 m (1 ft) thick. Exposures are insufficient to determine if excavations exploit fossil-rich horizons or a single fossil-rich horizon offset by small faults. Manchester and Meyer (1987) noted that the beds are cut by many vertical fracture planes, which may indicate that the Fossil High leaf beds are disrupted by small faults.

Figure 1. View northwest from the Wheeler High School football field to "gun club ridge" in Fossil, Oregon. The discovery site for the "Fossil High" leaf beds was located near the upper right hand corner of the white building.

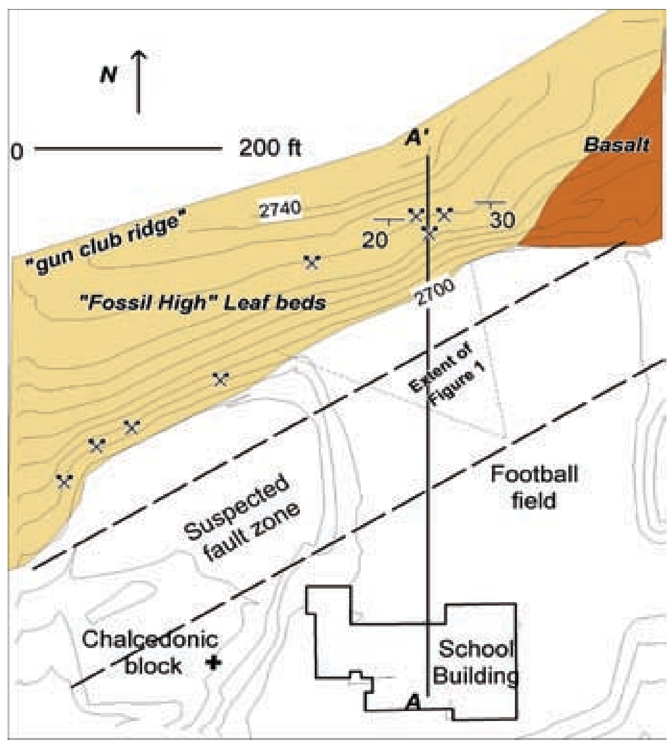

Figure 2. Geologic sketch map of the south flank of the "gun club ridge" near Wheeler High School, Fossil, Oregon, showing "Fossil High" leaf beds in tan and underlying lava flow in brown. Strike and dip symbols indicate slope of beds; prospect symbols indicate recent excavations. Location of suspected fault zone shown by heavy dashed lines, field of view of photo in Figure 1 shown by fine dashed lines. Contours at 1.6 m (5 ft) intervals were provided by Rowall Brokaw Architects, Eugene, Oregon.

(Leaf beds, continued from page 35)

At the east end of gun club ridge the Fossil High leaf beds overlie a weathered alkali basalt flow (Figures 2 and 4), which is approximately 20 m (60 ft) thick in a nearby water well (Figure 8, well WHEE-50122). Similar appearing tuffaceous siltstone beds with leaf fossils were found on strike overlying a lava flow 600 m (1800 ft) to the east, at the Wheeler County Waste Transfer Facility. Although the base of the lava flow is not exposed on the school property, the flow at the Wheeler County Waste Transfer Facility overlies massive claystone. It is unclear as to whether the claystone is part of the John Day Formation or, as mapped by Robinson (1975), is part of the underlying Clarno Formation. Retallack and others (1996) showed a thick sequence of claystone, with interbedded mafic lava flows, beneath the "Slanted Leaf Beds" elsewhere in the John Day Formation.

Because the rocks that overlie the Fossil High leaf beds have been removed by erosion or faulting along the gun club ridge, the true thickness of the beds cannot be determined. The leaf fossils may have been overlain at some time by a pumice lapilli tuff that marks the base of the John Day Formation north of Fossil (Robinson, 1975). The sandstone-siltstone dominated unit with the leaf fossils apparently becomes coarser grained up-section. Overlying, coarser-grained, tuffaceous sandstone beds exposed on the west end of the gun club ridge contain desiccated woody material (note that the log of well WHEE-50122, Figure 8, shows 12 m [35 ft] of "coal-like rock" overlying the alkali basalt, perhaps correlative with the woody strata). If the Fossil High leaf beds were formed by the same processes that formed the "Slanted Leaf Beds" in the John Day Fossil Beds National Monument, the leaf beds are probably about 15 m (50 ft) thick.

Figure 3. Plant fossils are found in white to gray, fine-grained tuffaceous siltstone and fine-grained sandstone of the "gun club ridge" behind Wheeler High School, Fossil, Oregon, that here dip to the south. Discarded siltstone fragments are fossiliferous. Rock hammer for scale.

CORRELATION

The Fossil High leaf beds are one of several sites from which the distinctive Bridge Creek flora have been collected (Manchester and Meyer, 1987). The Bridge Creek flora sites are included within the middle Big Basin Member of the John Day Formation as defined by Bestland and others (2002). In addition to flora similarities, correlation is based on radiometric ages of associated ashes. McIntosh and others (1997) reported a $^{40}Ar/^{39}Ar$ date of 32.58 ± 0.13 Ma from sanidine crystals in the fossil-bearing tuffaceous shale in the Fossil High leaf beds. This age date is consistent with other age dates from the Bridge Creek flora site in Painted Hills Unit of the John Day Formation, including 31.8 Ma and 32.3 Ma K-Ar ages (Evernden and others, 1964; Manchester and Meyer, 1987) and 32.99 ± 0.11 Ma and 32.66 ± 0.03 Ma $^{40}Ar/^{39}Ar$ ages (Retallack and others, 1996). Bestland and others (2002) reported a slightly older 33.6 ± 0.19 Ma $^{40}Ar/^{39}Ar$ date from the "Slanting Leaf Beds" in the John Day Fossil Beds National Monument Clarno Unit.

STRUCTURE

Preliminary site development plans assume that the Fossil High leaf beds continue to the south, beneath the north end of the existing football field. Whether there are any deposits accessible at reasonable depths depends on the structure of the leaf beds and the shape of the prefill slope beneath the football field.

The foot of the gun club ridge west of the football field is fairly steep, and therefore the fill is probably close to 3 m (10 ft) thick against the foot of the slope. The log of well WHEE-50122 indicates that soil cover is at least 3 m (10 ft) thick in the eastern extension of the swale occupied by the football field, so it is likely that any Fossil High leaf beds beneath the football field are at least 6 m (20 ft) deep.

The situation is complicated by the likely structure of the beds. There are two possible models. In one model the beds are simply tilted; in the other model the beds are tilted and faulted. The measured dip (tilt) of the Fossil High beds along the gun club ridge ranges from 20° to 30° S (Figure 2). As shown in the cross section in Figure 4, this means that the beds beneath the high school will be approximately 60 m (200 ft) deep. Given the steepness of the slope, it is unlikely that any of the fossil beds underlie the football field at accessible depths, except perhaps at the very northern edge.

The structural model shown in Figure 4 assumes a constant tilt of the beds and no other change or interruptions. Although not seen in outcrop, fragments of silicified siltstone and fault breccia along the road at the west edge of the school property suggest that a northeast-trending fault (Figure 5) may extend between the gun club ridge and the high school building, following the course of the small swale. A large block of chalcedonic quartz exposed in the flat to the west and below the high school is evi-

(Leaf beds, continued from page 36)

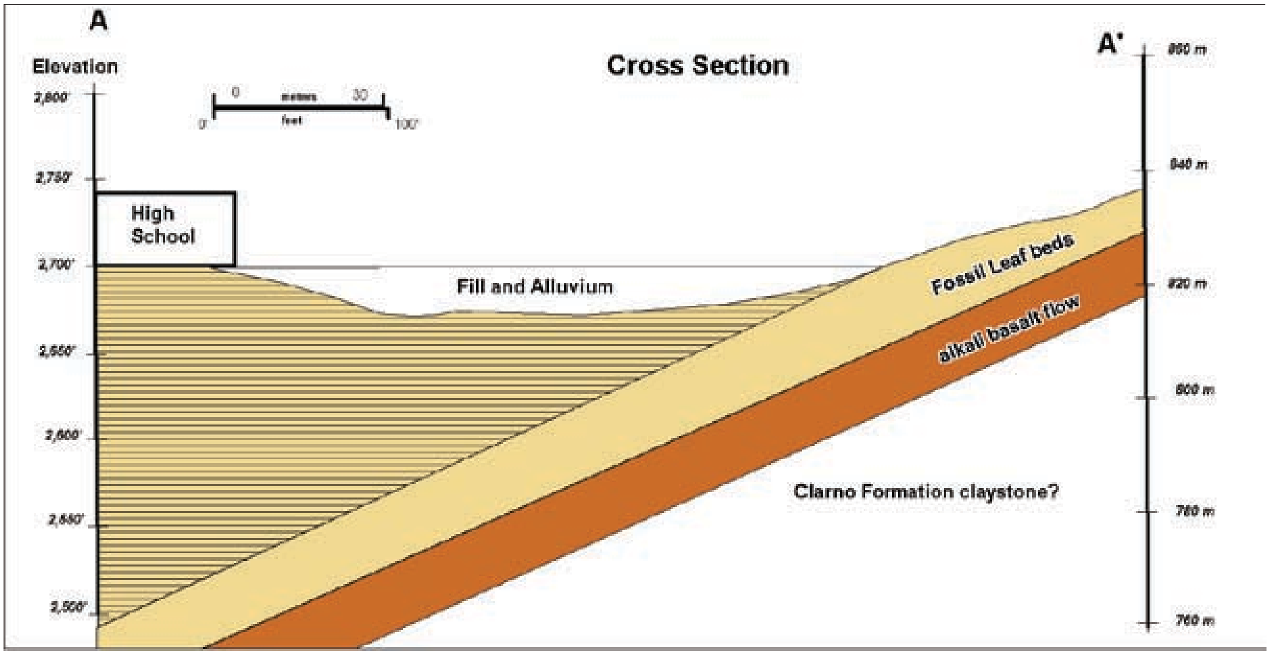

Figure 4. Cross section across the central part of the "gun club ridge" behind Wheeler High School, Fossil, Oregon, showing relationships between the "Fossil High" leaf beds (tan, no pattern) and underlying alkali basalt flow (brown) and overlying nonfossiliferous beds (tan with horizontal lines). Claystones beneath the alkali basalt are tentatively correlated with the Clarno Formation. The section is drawn such that the leaf beds are not faulted and are about 12 m (40 ft) thick. The number and thickness of individual fossil-bearing horizons within the leaf beds is not known. See Figure 2 for location of the A-A' section line.

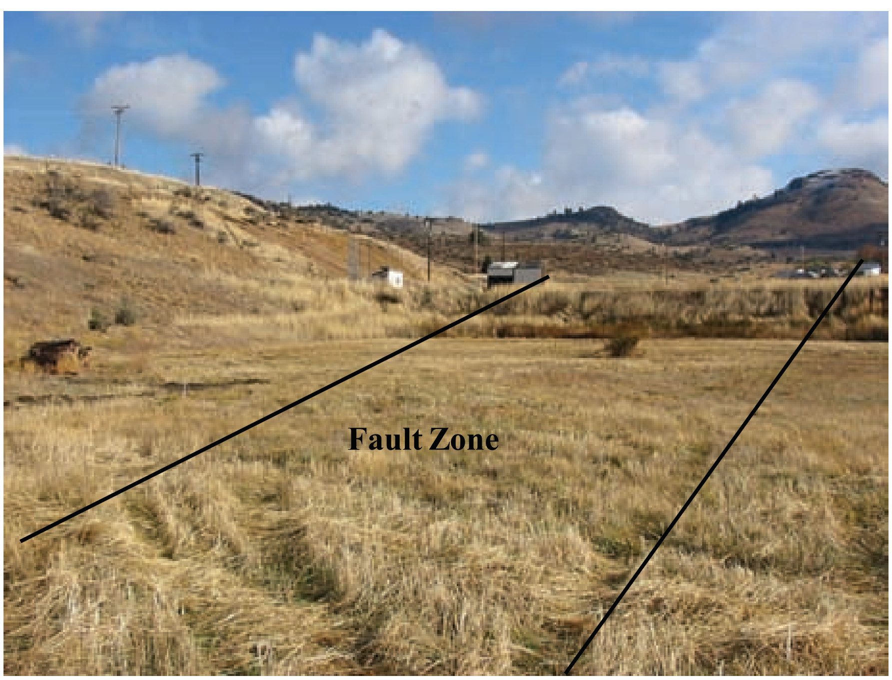

Figure 5. Looking northeast from the low area west of the Wheeler High School, Fossil, Oregon, football field and across the suspected fault to the face of the "gun club ridge."

dence of the type of hydrothermal alteration that is expected along a fault zone.

Figure 6 is a cross section showing the fault model. In this case, a fault zone cuts off the Fossil High leaf beds beneath the football field, and offsets the beds down on the south side to even greater depths than the tilted beds would have reached. In addition to making the beds deeper, the fault zone would likely disrupt the beds beneath the football field, again reducing the likelihood of finding a significant new fossil resource.

In order to test the fault hypothesis, we conducted a ground magnetometer survey in January 2005. Results of the survey (Figure 7) show a strong linear break between relatively highly magnetized rocks (red and orange) and less magnetized rocks (greens and blues) that coincides with the suspected fault trace. Basalt flows are typically strongly magnetic, while siltstone and sandstone are not, so this pattern suggests an abrupt edge to the basalt flow exposed in the gun club ridge. The magnetic pattern indi-

(Leaf beds, continued from page 37)

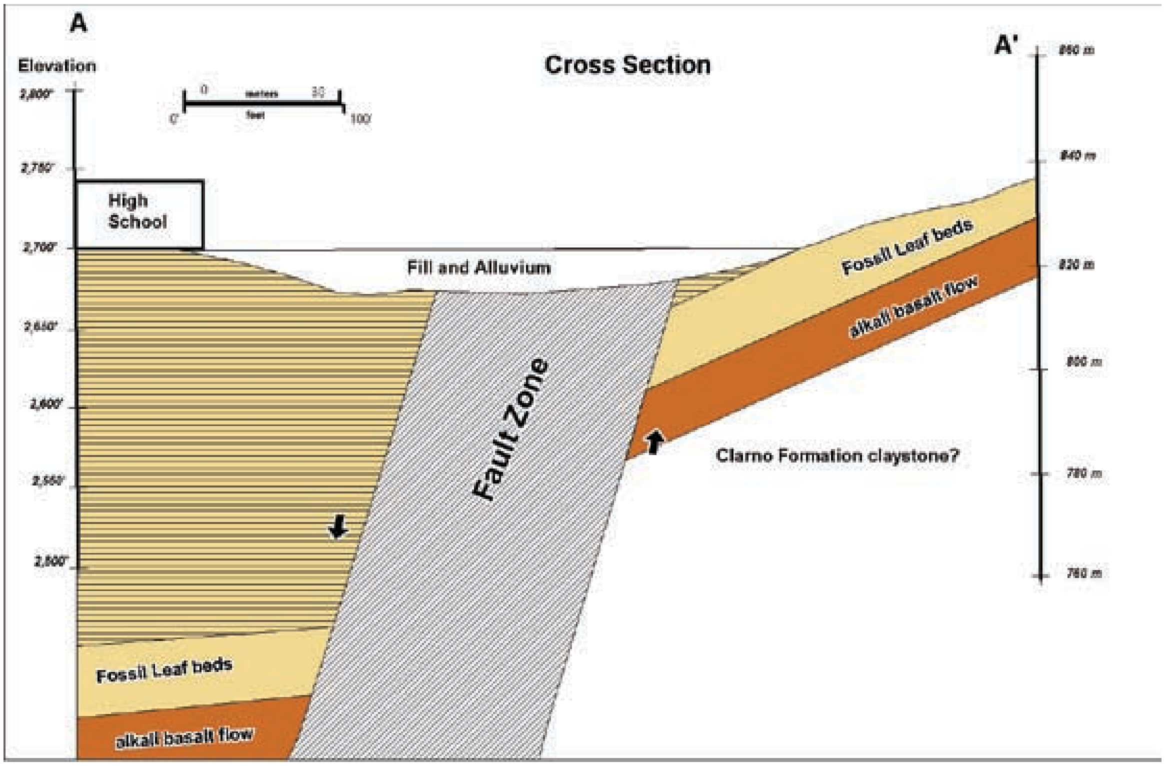

Figure 6. Cross section A-A' as in Figure 4, with a fault zone cutting off the "Fossil High" beds beneath the Wheeler High School football field. Line of section shown on Figure 2.

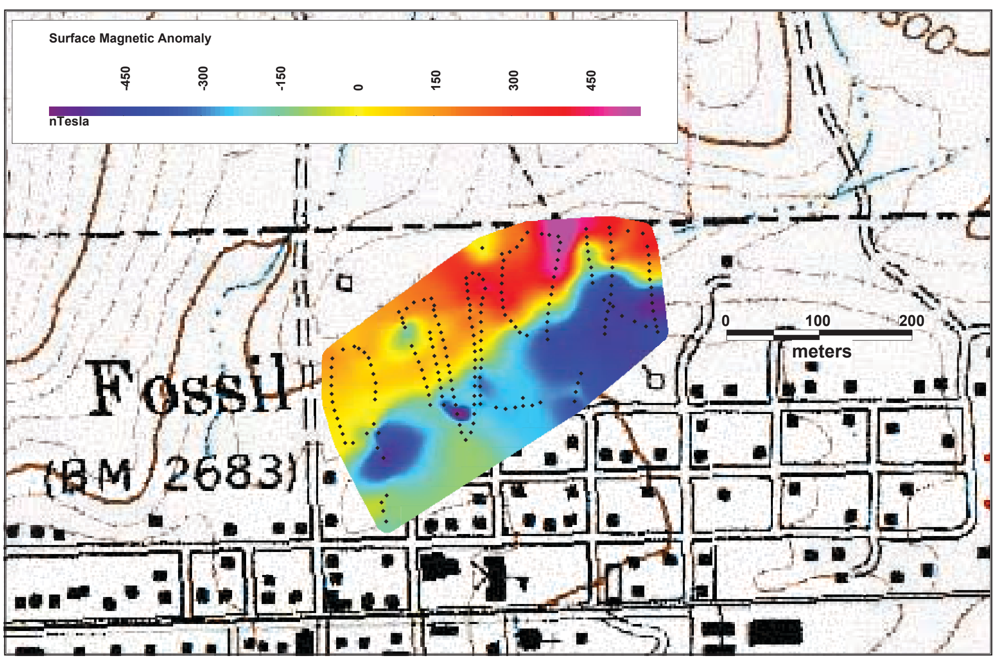

Figure 7. Ground magnetic anomaly map of the Wheeler High School area, Fossil, Oregon. Ground stations shown as black diamonds. More highly magnetized areas are shades of red and orange. Less highly magnetized areas shown in green and blue. Sharp break in color represents areas with strong magnetic gradients. Linear gradients such as this one are often associated with faults.

(Leaf beds, continued from page 38)

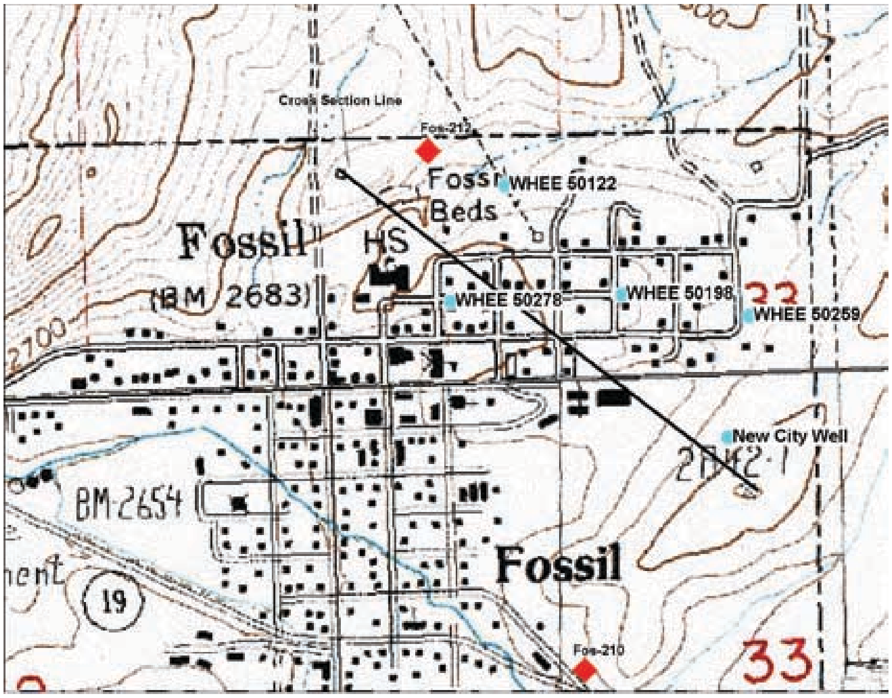

Figure 8. Map of the town of Fossil, Oregon. Water wells used to create the cross section in Figure 9 are blue dots, labeled with Oregon Water Resources Department log identification numbers, except new city well, which has no formal log yet. Red diamonds are locations of geochemically analyzed basalt samples (see Table 1). Base map is U.S. Geological Survey digital raster graphic (DRG) of the Fossil North 7.5' quadrangle.

cates that a northeast-trending fault with substantial offset extends between the Fossil High beds and the high school building.

To further test the hypothesis that a fault cuts off the Fossil High beds, we located and interpreted the drillers logs of several water wells to try to build a geologic cross section through the town of Fossil. Figure 8 shows approximate locations of the wells used and the line of section that was chosen. The new Fossil city well was located by global positioning system coordinates as was well WHEE-50122. The remaining wells were located to the nearest city block by address. Figure 9 shows the interpreted cross section. In this model, the sequence of the Fossil High beds and the underlying alkali basalt and clay stone layers is broken into a northern block that is tilted to the south and a southern block that is tilted to the north. Geochemical analysis of the basalt (Table 1, Figure 8) from directly beneath the fossil beds, and from exposures just south of the fairgrounds indicates a high likelihood that the basalt flows are the same in both blocks. This model strongly supports the hypothesis that the Fossil High beds are cut off by a fault just north of the high school and raises the possibility that similar fossil beds may be present near the surface in the slopes south and east of the fairgrounds. Field reconnaissance around the fairgrounds indicated that tuffaceous sandstone and siltstone including some carbonized wood fossils are present.

The combination of field evidence at the high school and the strong linear magnetic gradient argue for the existence of a fault. The cross section derived from the water wells is consistent with the presence of a fault. In order to be absolutely certain that the Fossil High beds are cut off by a fault, further exploration in the form of deep excavations or drilling is needed.

Table 1. Geochemistry of basalt samples in Fossil localities; data not normalized.

Whole-Rock Major Element Oxides, wt. %											**LOI*, wt. %**
Sample†	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	
Fos-210	45.98	3.97	14.67	3.44	9.96	0.20	4.94	8.39	3.41	1.17	0.93	2.51
Fos-212	46.37	4.04	14.49	7.68	5.02	0.17	3.24	8.92	3.50	1.29	0.98	4.11

Trace Elements, parts per million																		
Sample†	Rb	Sr	Y	Zr	V	Ni	Cr	Nb	Ga	Cu	Zn	Co	Ba	La	Ce	U	Th	Sc	Pb
Fos-210	17	577	34	283	262	31	49	25	27	39	123	50	355	24	52	2	3	21	4
Fos-212	20	605	35	292	250	34	44	25	25	32	128	46	375	26	55	1	1	19	4

*LOI is loss on ignition.
†See Figure 8 for sample locations.

(Leaf beds, continued from page 39)

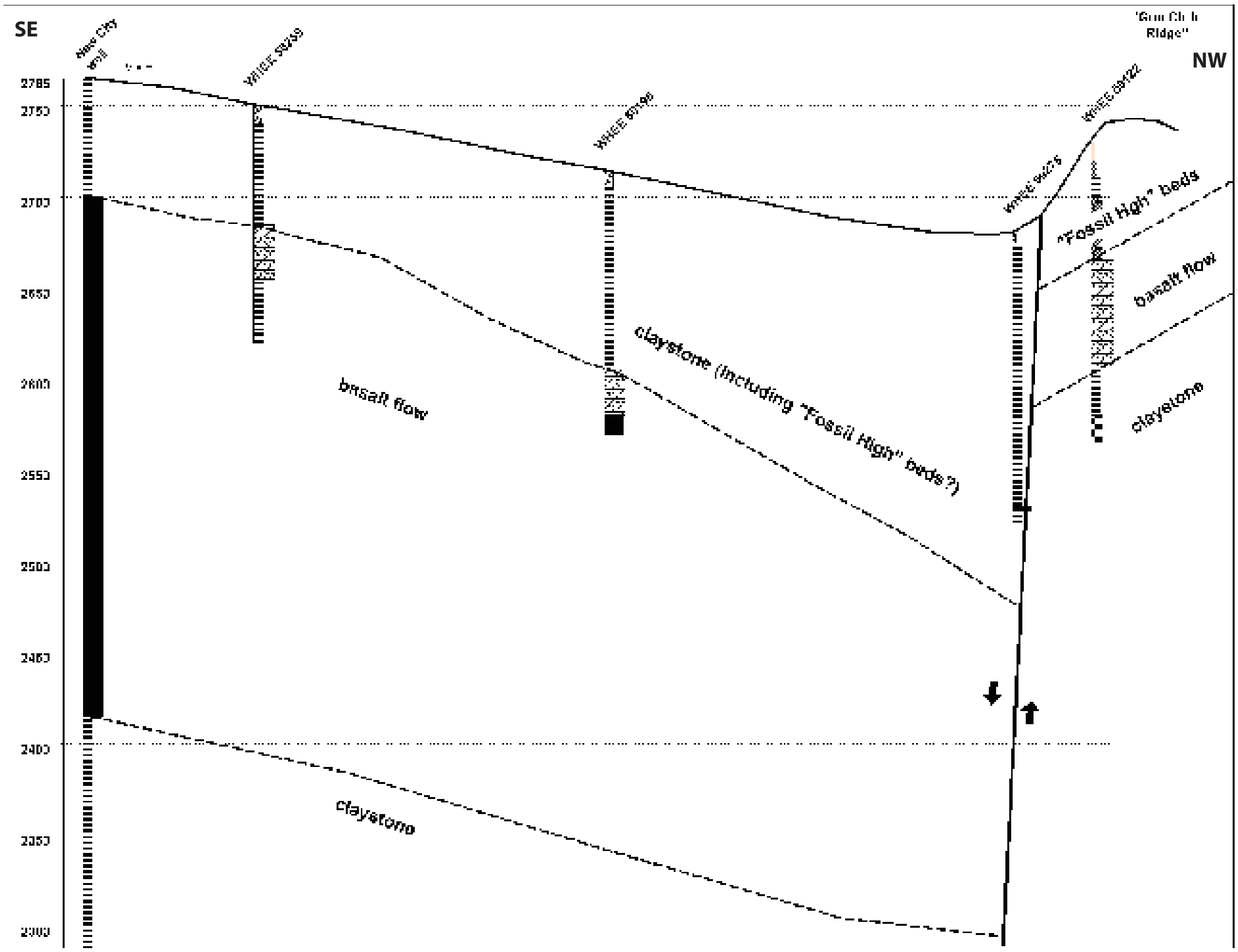

Figure 9. Geologic cross section from the new Fossil city well to "gun club ridge" behind Wheeler HIgh School. See Figure 8 for location of line. SE is southeast; NW is northwest.

DISCUSSION AND RECOMMENDATIONS

Our preliminary study suggests that the fossil resource in the Fossil High beds on the high school grounds is probably largely limited to the existing exposures along the gun club ridge. Discovery of a fault that very likely runs between the high school building and the gun club ridge means that the Fossil High beds cannot be expected to extend beneath the north end of the football field for any distance. Even if there is no fault, the relatively steep tilt of the beds means that they are likely to be inaccessibly deep on most of the school property.

Beyond the simple survey that we performed, a definitive answer to the extent of the Fossil High beds beneath the football field would require drilling a series of shallow (< 30 m [100 ft]) core holes in the northwest corner of the field. Although drill core would be more useful in determining the character of the fossil beds, information can obtained more cheaply by using a reverse-circulation drill rig that provides clean cuttings. Costs for core drilling can easily run several thousand dollars per hole, with substantial additional cost involved in analyzing and interpreting the core or cuttings.

The swale west of the football field could also be tested by drilling. Based on the way the Fossil High leaf beds dip to the south, the wood-bearing tuffaceous sandstone exposed on the west end of the ridge probably overlies the siltstone and fine-grained sandstone that contained the productive leaf-bearing horizons above the football field. However, as noted in the discussion of the fill and alluvium in the swale now occupied by the football field, there may be as much as 3 m (10 ft) of overburden covering fossil bearing beds in the swale.

Another issue to be addressed is whether more than one fossil-rich horizon occurs in the Fossil High leaf beds. This requires development of detailed stratigraphic sections and could be accompanied by 1) detailed mapping and trenching on the slope north of the football field or 2) detailed logging of drill core or cuttings. The cheapest approach would be to excavate a shallow backhoe trench

(Leaf beds, continued from page 40)

down the face of the gun club ridge and then systematically map and log it. Trench excavation costs would be minimal, but logging would require several weeks of a geologist's time.

A detailed and systematic geologic survey of the City of Fossil and adjoining area might result in discovery of additional Birch Creek flora localities near town. In the limited time DOGAMI staff spent in the area, one additional leaf locality was found near the Wheeler County Solid Waste Transfer Facility. Indications of siltstone and some carbonized wood around the fairgrounds also suggest that further deposits might be located there.

A detailed geologic study would include field mapping and correlation of well cuttings, well logs, and surface outcrops. Preliminary steps to acquire and preserve data are being taken. At the time of the initial visit, a water well drilling rig was in the process of being set up at the county fairgrounds. Karen Masshoff was able to contact the driller and ensure that cuttings were saved for future examination. It is also important to note that most of the slopes in the area are mantled with colluvium (loose rock fragments mixed with clay and sand) and soil deposits many feet thick. This means that shallow excavations will be needed in most instances to uncover new deposits.

Costs for exploration for further deposits could range from relatively minor (a few days of surface mapping work, or backhoe trenches at the fairgrounds) to substantial (several diamond core holes at the high school). Given the strong evidence for a substantial fault at the high school, pursuing other local deposits may be a more cost-effective approach.

Despite the geologic limitations of the site, it is important to note that there remains a substantial amount of material in the currently known Fossil High beds. On the basis of our mapping of the site there are at least 437,000 cubic m^3 (680,000 yd^3) of material available if one were to excavate off the top 3 m (10 ft) of the deposit. This is equivalent to 68,000 standard dump trucks worth of material, and should last for decades with proper management. The slope will become dangerously steep long before the deposit is exhausted, so the real challenge for the future may be to manage the excavations and spoils. Spoils from past digging cover much of the slope, and removing and stockpiling the material may improve digging conditions. As the stockpiled spoils weather, they are likely to continue to yield fossils. An important part of managing the excavation would be to know whether the entire deposit was fossiliferous or just a few thin layers. In this case, a detailed stratigraphic study by trenching or drilling would be needed.

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DOGAMI Agency News for 2007

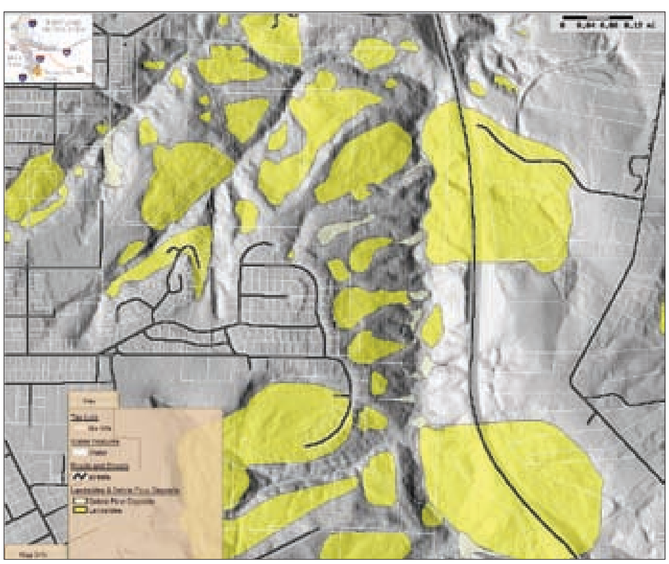
— contributed by James Roddey, DOGAMI Earth Sciences Information Officer

STATEWIDE SEISMIC NEEDS ASSESSMENT

The big news at DOGAMI for 2007 is the completion and publication of the Statewide Seismic Needs Assessment (DOGAMI Open-File Report O-07-02). Presented to the Joint Subcommittee on Emergency Preparedness and Ocean Policy in May, the Statewide Seismic Needs Assessment, commissioned by the 2005 Oregon Legislature, catalogued and ranked the seismic safety of emergency and educational facilities across the state and included K–12 schools with more than 250 students, community colleges, acute care hospitals, county sheriff offices, city police, fire departments, and rural fire districts.

Assistant Director Don Lewis and Project Coordinator Natalie Richards (on loan from the U.S. Army Corps of Engineers) led a team that surveyed over 3,350 buildings, which were scored and ranked for probability of collapse in a maximum considered earthquake. Of the surveyed buildings, 1,280 schools (totalling 2,369 buildings), 143 city police and fire departments, and 191 rural fire protection districts were included in the report. The public schools assessed represent 97% of the total statewide enrollment for the 2005-2006 academic year. Survey team leaders included Bill Burns of DOGAMI, Carol Hasenberg of Portland State University, Tom Miller of Oregon State University, and Christine Theodoropoulos of the University of Oregon.

An interactive web site containing the complete report, building scores and background information is also online at http://www.oregongeology.com/sub/projects/rvs/.



Portion of the Pilot LIDAR Mapping Project - Portland, Oregon, Metro Area interactive web map (http://www.oregongeology.com/sub/lidar/) showing mapped landslides in Oregon City overlaid on LIDAR-derived shaded relief.

DOGAMI geologist Margi Jenks leads a field trip near Klamath Falls.

DOGAMI GOVERNING BOARD

Our Governing Board continues to be a strong guiding hand for the Department. The five-member Board consists of Chairman Don Haagensen of Portland, Co-chair Steve Macnab of Bend, Barbara Seymour of Oceanside, Vera Simonton of Pendleton, and R. Charles Vars of Corvallis, who was appointed in October. The Governing Board meets quarterly. This year, in addition to meetings in Portland, the Board met in Boardman, where water issues in northeast Oregon were discussed. Another Board meeting in Klamath Falls included an evening presentation by geologist Margi Jenks on the volcanic landscapes of the area that was attended by over 150 people. Two associated field trips also attracted large crowds.

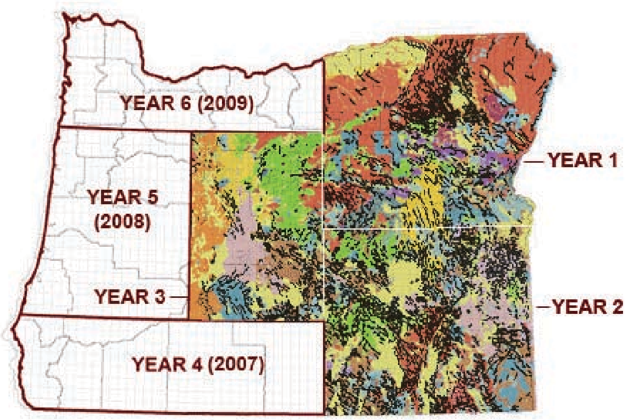
MAPPING WITH LIDAR

DOGAMI's Light Detection and Ranging (LIDAR) program has grown substantially with the award of $1.5 million from the 2007 Oregon legislature via Oregon Watershed Enhancement Board (OWEB) research funds. DOGAMI uses LIDAR data to identify existing natural hazards like earthquake faults and landslides that normally are very difficult to detect in forested terrain, as well as to construct accurate, precise, and high-resolution hazard maps and risk assessments.

DOGAMI has formed the Oregon LIDAR Consortium (OLC; http://www.oregongeology.com/sub/projects/olc/), with the ultimate goal of providing high-quality LIDAR coverage for the entire state. Led by DOGAMI Chief Scientist Ian Madin, acquisition of new LIDAR data has begun. The first areas of interest are the inhabited portions of western Oregon with special emphasis on the Oregon coast.

From LIDAR data collected in the Portland metro area, DOGAMI has created an interactive web site using "bare earth" data that is searchable by street address. One can then compare and contrast these LIDAR images against aerial photographs, topographic maps, and older style 10-m digital elevation models (DEMs) derived from the topographic maps. Where earthquake and landslide haz-

(Agency news, continued from page 42)



The Oregon Geologic Data Compilation, version 3, comprises the northeastern, southeastern, and central portions of the state. A subset of the data can be accessed at http://www.oregongeology.com/sub/ogdc/.

On the basis of findings from a Federal Emergency Management Agency funded seismic rehabilitation study coordinated by DOGAMI, cross-bracing was installed in Ondine Residence Hall, Portland State University.

ard data are included, these hazard layers are also available for viewing. Learn more at http://www.oregongeology.com/sub/lidar/.

STATEWIDE DIGITAL GEOLOGIC MAP COMPILATION PROGRAM

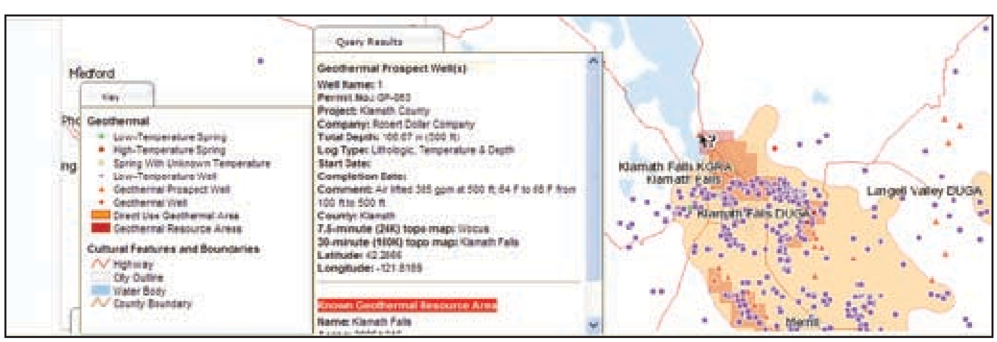
The statewide digital compilation map program, now in its fourth year, remains a high priority. The third iteration of the Oregon Geologic Data Compilation has been released (DOGAMI Digital Data Series, OGDC-3; map sheet only: DOGAMI Open-File Report O-07-08. OGDC-3 incorporates a digital and spatial database for northeast, southeast, and central Oregon. The southwestern portion of the state has been published as a separate map (DOGAMI Open-File Report O-07-16) and will be added to the compilation next with the publication of OGDC-4 in 2008. We anticipate this project and the final digital model to be our primary mapping product, with completion by 2010. A visual web interface to the northeast, southeast, and central Oregon OGDC data is available online at http://www.oregongeology.com/sub/ogdc/.

Geologic and fault mapping of the Portland urban corridor is continuing with the completion of the Linnton and Dixie Mountain 7.5′ quadrangles (publication in preparation). Ian Madin and Bill Burns continued mapping landslides in the Portland area using LIDAR-derived DEMs. Part of this project includes working with the City of Oregon City and the City of Portland.

GEOTHERMAL ENERGY

DOGAMI has created a new digital data base of statewide geothermal resources. Developed by Mineral Resources Geologist Clark Niewendorp, Publications Coordinator Deb Schueller, and Portland State University student Tim Welch, the Geothermal Information Layer for Oregon (GTILO) establishes a database of the state's geothermal resources that is an effective means to communicate Oregon's geothermal potential and helps promote future investment in geothermal energy. GTILO is available online (http://www.oregongeology.com/sub/gtilo/). DOGAMI has also published a 12-page issue of Cascadia on geothermal energy that can be downloaded as a PDF at http://www.oregongeology.com/sub/quarpub/CascadiaSpring2007.pdf.

Portion of interface of the Geothermal Information Layer for Oregon (GTILO; http://www.oregongeology.com/sub/gtilo/). Hot and warm springs, known geothermal areas, direct use geothermal areas, and geothermal wells are given, and users can click on individual springs and wells to display data.



(Agency news, continued from page 43)

GEOHAZARDS

In addition to the completion of the Statewide Seismic Needs Assessment (Open-File Report O-07-02), the enhanced rapid visual screening (E-RVS) method developed for the assessment program (DOGAMI Special Paper 39) is in the process of being adopted by the Applied Technology Council and the Federal Emergency Management Agency (FEMA). Demonstration tours of two university seismic mitigation projects (OSU's Nash Hall and WOU 's Humanities and Social Sciences Building) received high visibility among state leaders and the press, and three university seismic mitigation projects (PSU's Ondine Residence Hall [DOGAMI Special Paper 38] and Montgomery Court [DOGAMI Open-File Report O-07-04] and OIT's Snell Hall) were completed. All were funded in part by FEMA Pre-Disaster Mitigation grants.

The DOGAMI Landslide Program plays an increasing role at DOGAMI as we continue to work with the USGS Landslide Program on the "collaborative landslide hazard study initiative" in Oregon. This program consists of roughly five years of concentrated research on landslides in Oregon by the USGS landslide program and DOGAMI landslide experts and mappers. DOGAMI has begun working with the City of Astoria and with Washington County to help them understand current and future landslide risks. Ongoing work with the City of Oregon City is utilizing LIDAR data and modeling technology to identify previously unmapped landslides and to create the first of its kind landslide susceptibility map for that community.

It was a Department team effort as we organized and hosted a DOGAMI/USGS/ASCE/AEG Landslide symposium and field trips in Portland that saw over 120 engineers and geologists from across the world participate. Symposium presentations and posters were complied and released as DOGAMI Open-File Report O-07-06. The Geohazards team also co-hosted the USGS National Earthquake Prediction Evaluation Council meeting in Portland, which concentrated on understanding "slow earthquake" or episodic tremors along the Cascadia Subduction Zone.

GRANTS PASS FIELD OFFICE AND SOUTHWEST OREGON

A recently published map (DOGAMI Open-File Report O-06-26) by Southwest Oregon Regional Geologist Tom Wiley identifies the geology of the Albany quadrangle and improves our understanding of Willamette Valley geology and groundwater. A data compilation (DOGAMI Open-File Report O-07-05) by Margaret D. Jenks brings together detailed and reconnaissance geologic mapping in the Klamath River basin in Oregon.

THE BAKER CITY FIELD OFFICE AND EASTERN OREGON

Eastern Oregon Regional Geologist Mark Ferns and Field Geologist Jason McClaughry are currently working jointly with Tom Wiley, conducting geologic mapping in the Lebanon and Corvallis area of Willamette Valley. Ferns and McClaughry are also in the process of completing a comprehensive report on the geology of the Lower Crooked River basin of central Oregon. A public workshop is planned for the Fall of 2008 with publication of a final report thereafter. Ferns and McClaughry have completed preliminary geologic mapping of the Eagle Rock, Hensley Butte, and Stearns Butte 7.5' quadrangles (DOGAMI Open-File Reports O-07-10, O-07-11, and O-07-12).

DOGAMI Baker City Field Office geologist Jason McClaughry takes a statistical point count of the composition of the cobbles in a conglomerate unit near Lebanon, Oregon, as part of the Middle Willamette geologic mapping project for the U.S. Geological Survey STATEMAP program. Field observations provide information about the source area and possible relative age of the unit.

DOGAMI Coastal Office-U.S. Army Corps of Engineers partner Lindsey Gay takes measurements at Rockaway Beach. Regular monitoring at a network of sites along the Oregon coast helps us understand the effects (erosion or accretion) of storms and improves our understanding of long-term coastal change due to sea level rise and climate change.

(Agency news, continued from page 44)

THE COASTAL FIELD OFFICE IN NEWPORT

In conjunction with the Department of Land Conservation and Development (DLCD), Oregon Parks and Recreation Department (OPRD), and the Northwest Association of Networked Ocean Observing Systems (NANOOS), DOGAMI maintains and expands its beach and bluff observation network on the central and northern Oregon coast. The network now includes sites along Rockaway, Clatsop, and Neskowin (15 sites) beach areas and the Newport area from Yachats to Otter Rock. Results and information concerning changes at each of these sites can be accessed at http://www.oregongeology.com/sub/nanoos1/. Coastal erosion has also been the focus of additional work in Clatsop County, Cape Lookout State Park in Tillamook County, and at Gleneden Beach near Lincoln City.

Other partnerships include a project with OPRD involving evaluating potential causes and mitigation options related to historical observations of rising water levels in Cleawox Lake. DOGAMI is also working with the U.S. Fish and Wildlife Service to carry out a beach monitoring study of the effects of dune lowering on the Elk River Spit to improve breeding habitat for the Western Snowy Plover near Port Orford. Another monitoring project partners DOGAMI with the Oregon Department of Transportation to document the effects of the Gregory Point landslide near Port Orford. As part of the National Tsunami Hazard Mitigation Program, a tsunami hazard assessment at Cannon Beach is underway and should be completed in spring 2008.

MINERAL LANDS REGULATION AND RECLAMATION

Our Mineral Land Regulation and Reclamation Program (MLRR) is the lead program for mine regulation in Oregon. MLRR administers a fee-based statewide program with authority to regulate all upland and underground mining. The program also issues federal Clean Water Act General Stormwater Permits and state Water Pollution Control Facility Permits at aggregate mine sites in cooperation with the Oregon Department of Environmental Quality.

MLRR oversees mining 830 permits. To date, over 5,400 acres of mined land have been reclaimed and put to secondary, beneficial use. As part of our strategy to encourage best practices in mining, MLRR hosts an annual Awards Program for operators that recognizes operation and reclamation above and beyond the requirements of regulation (see page 46 for 2006 award winners).

PUBLICATIONS AND OUTREACH

Outreach efforts have included dozens of presentations by our staff to both private and public organizations around the state, on topics ranging from tsunami preparedness to the Statewide Seismic Needs Assessment and LIDAR. DOGAMI staffers are also becoming familiar faces to television news viewers across Oregon as the Department geologists have become the recognized experts to call when earthquakes, landslides, tsunamis, volcanic eruptions and other earth science related events make the news.

DOGAMI Chief Scientist Ian Madin was DOGAMI's 2007 Performance Award winner. Among the reasons for his award was Ian's enthusiastic public outreach at events like the Klamath Falls area field trip.

The Nature of the Northwest Information Center, DOGAMI's cooperative venture with the U.S. Forest Service, continues to attract many people looking for information on Oregon and Washington outdoors. We distribute all DOGAMI and USGS maps and publications as well as guidebooks, photo books, Northwest Forest Passes and more, both through a "bricks and mortar store" in Portland and online (http://www.naturenw.org).

2007 PERFORMANCE AWARD

Chief Scientist Ian Madin was this year's recipient of DOGAMI's annual Performance Award. Ian was lauded for his work on advocating the use of LIDAR by our agency, and for the ongoing benefits to other agencies. "Ian's leadership, tenacity, enthusiasm, and above all unrelenting hard work have placed the agency in a new positive light for both our federal partners and our bosses both in Salem and back at home throughout urban and rural Oregon," said Don Lewis.

PERSONNEL ON THE MOVE

With the formation of the Oregon LIDAR Consortium, much of the Department's focus will shift to working with this new technology. To this end, Mark Sanchez has moved from GIS Specialist to LIDAR Project Database Coordinator. GIS Specialist Rudy Watzig has moved into the Geospatial Data Specialist position. Lina Ma has joined the Department full time as a geologist and is now coordinating the statewide geologic data compilation project. Vaughn Balzer became a full time Reclamation Specialist with the MLRR program. Paul Staub and Mark Neuhaus, both long time veterans of the Department, retired in 2007, as did Geologist Margi Jenks. State Geologist Vicki McConnell was appointed Secretary of the American Association of State Geologists (AASG) and is chair of the planning committee for the 2009 GSA Conference to be held in Portland.

MLRR Program 2006 Mined Land Reclamation Awards

An Oregon Plan Award for restoring floodplain habitat in an urban environment highlights this year's Mined Land Reclamation Awards presented by the Mineral Land Regulation and Reclamation Program (MLRR) of the Oregon Department of Geology and Mineral Industries (DOGAMI).

Each year the MLRR office, with an independent panel of experts, selects specific mine sites and operators to receive awards for outstanding reclamation, mine operation and salmon protection (The Oregon Plan Award). This year's awards, based on an operator's performance during the 2006 calendar year, were presented at the Oregon Concrete and Aggregate Producers Association (OCAPA) annual conference in June 2007.

"We consider these awards important recognition to those owners and operators that go beyond the basic requirements of rules and regulations," said Vicki S. McConnell, State Geologist and Director of DOGAMI. "By using innovative ideas and responsible techniques of reclamation they are working to improve the environment and be good neighbors."

This year's Oregon Plan Award recognizes the City of Eugene for the restoration of Delta Ponds, a 150-acre natural area in the heart of Eugene that borders the Willamette River.

In the late 1800s, the Delta Ponds area was part of a river floodplain network of side channels, sloughs, and tributaries that provided a rich habitat well-suited for many fish and wildlife species. Over time, flood control management, urbanization, and gravel mining changed the area so that only a few remaining ponds and sloughs offered refuge to fish and wildlife. The highly disturbed ground and steep banks were quickly colonized by invasive plants, such as Armenian blackberry, Scotch broom, and English ivy.

In the past five years, that has all changed. Invasive plants have been removed and native trees and shrubs have been planted. The ponds are being re-linked to the Willamette River and to each other. The City of Eugene built the final section of the Ruth Bascom Riverbank Trail through the Delta Ponds area, including a unique raised causeway that takes users out over a portion of the ponds to view wildlife up close.

"Like the work the City of Eugene has put into restoring Delta Ponds, the companies and government organizations we recognize with these annual awards really show a deep commitment to the environment and to the communities where they are based," notes Gary Lynch, Assistant Director of Regulation for DOGAMI's MLRR office. "It's also an encouragement to others in the mining industry to follow suit."

For more information on the MLRR Program, contact Ben Mundie, telephone (541) 967-2149; email: ben.a.mundie@mlrr.oregongeology.com

2006 Award Winners

Oregon Plan Award

City of Eugene - Lane County. Contacts: Scott Milovich, City of Eugene - (541) 682-6086; Doug Putman, U.S. Army Corps of Engineers -(503) 808-4733

Over the past seven years the City of Eugene, working with Oregon Solutions (http://www.orsolutions.org/willamette/deltaponds.htm) has planned and executed a large-scale floodplain restoration project at Delta Ponds in partnership with the U.S. Army Corps of Engineers and other natural resource agencies and volunteer groups. The goal of the project has been to reestablish the floodplain of the river and to improve habitat conditions and diversity for a wide variety of fish and wildlife species with an emphasis on Chinook salmon, western pond turtles, and neo-tropical migratory birds.

Outstanding Operator

Westside Rock, Hayden Quarry, LLC - Washington County. Contact John Malnerich - (503) 351-2917

The Hayden Quarry is located approximately four miles southwest of Cornelius. Westside Rock has demonstrated an ability to move onto an existing quarry site and to dramatically improve the entire operation, with particular attention to the stormwater control system.

Outstanding Reclamation

Hap Taylor & Sons Inc. - Deschutes County. Contact: Hap Taylor - (541) 388-0445

The Klipple Pit, operated by Hap Taylor and Sons, Inc. (HTS) is located 2.5 miles west of Tumalo and is bordered by Tumalo Creek. The Deschutes River is located nearby. HTS is recognized for an outstanding job of reclamation and stormwater control in a sensitive area near two important waterways.

Outstanding Reclamation, Exploration

Newmont North America Exploration Ltd. - Malheur County. Contact: Brian Johnson - (775) 778-3929

The Ruiz exploration project site is located 10 miles west of McDermitt in the area of the Bretz Mine, an old mercury mine that operated between the 1920s and 1940s. This exploration project was conducted on Bureau of Land Management (BLM) lands. Newmont is recognized for efforts to minimize disturbance of land during this operation, for not impacting the old mercury mine waste rock piles, and for final reclamation of the drill pads in this harsh environment.

(MLR awards, continued from page 46)

Oregon Plan Award

The 2006 MLR Oregon Plan Award recognized the City of Eugene for the restoration of Delta Ponds, a 150 acre natural area in the heart of Eugene that borders the Willamette River. Revegetation efforts at Delta Ponds included removing invasive species and planting native tree and shrubs. Photo by Vern Rogers.

Outstanding Operator Award

The 2006 MLR Outstanding Operator Award recognized Westside Rock for its ability to move onto the existing Hayden Quarry site, located approximately four miles southwest of Cornelius, Oregon, and dramatically improve the entire operation. The operator has done an excellent job in designing and installing the storm water retention structures to allow sufficient holding time for fines to settle out of the water column.

Outstanding Reclamation Award

The 2006 MLR Outstanding Reclamation Award recognized Hap Taylor & Sons Inc. for reclaimed land at the Klipple Pit, located 2.5 miles west of Tumalo, Oregon. This area is located within a recognized winter deer range and is considered important deer habitat. Maintaining internal drainage of the excavations protected the creek from stormwater discharges. Stormwater was contained on-site and allowed to infiltrate the subsurface. The shallower slopes allowed quicker establishment of required revegetation of a native grass mixture.

Outstanding Reclamation, Explorarion Award

The 2006 MLR Outstanding Reclamation, Exploration Award recognized Newmont North America Exploration Ltd. for minimizing disturbance and reclaiming the area after exploration drilling at the Ruiz Project site, 10 miles west of McDermitt, Oregon, in the area of the former Bretz mercury mine. The company used existing access roads, and drill pads and sumps for drilling fluids were kept to a minimum surface disturbance. Caution was exercised during all exploration activity not to disturb the abandoned mine workings. After drilling, seeding of the disturbed areas was completed with a grass mixture native to the high-desert sagebrush country.

RECENT DOGAMI PUBLICATIONS

Publications are available from Nature of the Northwest, 800 NE Oregon St., #5, Portland, OR 97232, info@naturenw.org, (503) 872-2750; or from the DOGAMI field offices in Baker City, 1510 Campbell Street, (541) 523-3133, and Grants Pass, 5375 Monument Drive, (541) 476-2496. For online purchasing, go to http://www.naturenw.org, select "Store" and "Maps and Reports" and use the short identification of the publication (e.g., RMS-1) for a search.

- **Assessing the temporal and spatial variability of coastal change in the Neskowin littoral cell: Developing a comprehensive monitoring program for Oregon beaches**, by Jonathan C. Allan and Roger Hart. Open-File Report O-07-01. CD, $10.
- **Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings -- Report to the Seventy-Fourth Oregon Legislative Assembly**, by Don Lewis. Open-File Report O-07-02. CD, $10.
- **Coastal Erosion Hazard Zones along Dune and Bluff-Backed Shorelines, Southern Lincoln County, Oregon: Seal Rock to Cape Perpetua**, by Robert C. Witter, Jonathan C. Allan, and George R. Priest. Open-File Report O-07-03. CD, $10.
- **Portland State University Montgomery Court Seismic Rehabilitation Project, Portland, Oregon**, by Yumei Wang and Christopher J. Heathman. Open-File Report O-07-04. CD, $10.
- **Geologic compilation map of part of the Upper Klamath Basin, Klamath County, Oregon**, compiled by Margaret D. Jenks. Open-File Report O-07-05, *in press*, CD, $10.
- **2007 Landslide Symposium proceedings and field trip guide: New tools and techniques for developing regional hazard maps and future risk management practices**, compiled by William J. Burns and Yumei Wang. Open-File Report O-07-06. CD, $10.
- Open-File Report O-07-07. Final Report: Johnson Creek Landslide Project, Lincoln Couny, Oregon, *withdrawn* — will be issued as a DOGAMI Special Paper in 2008.
- **Preliminary geologic compilation map of the central portion of Oregon** (map sheet only), by Clark A. Niewendorp, Margaret D. Jenks, Mark L. Ferns, Paul E. Staub, Edward M. Taylor, Lina Ma, and Ian P. Madin. Open-File Report O-07-08. CD, $10.
- **Preliminary geologic map of the Brown Mountain 7.5' quadrangle, Jackson and Klamath counties, Oregon**, by Stanley A. Mertzman and others. Open-File Report O-07-09. CD, $10.
- **Preliminary geologic map of the Eagle Rock 7.5' quadrangle, Crook County, Oregon**, by Jason D. McClaughry and Mark L. Ferns. Open-File Report O-07-10. CD, $10.
- **Preliminary geologic map of the Hensley Butte and Salt Butte 7.5' quadrangles, Crook County, Oregon**, by Mark L. Ferns and Jason D. McClaughry. Open-File Report O-07-11. CD, $10.
- **Preliminary geologic map of the Stearns Butte 7.5' quadrangle, Crook County, Oregon**, by Jason D. McClaughry and Mark L. Ferns. Open-File Report O-07-12. CD, $10.
- **Preliminary geologic map of the Lake of the Woods South 7.5' quadrangle, Klamath County, Oregon**, by Stanley A. Mertzman and others. Open-File Report O-07-13. CD, $10.
- **Preliminary geologic map of the Hamaker Mountain, Worden, and Lost River 7.5' quadrangles, Klamath County, Oregon**, by Frank R. Hladky and Margaret D. Jenks. Open-File Report O-07-14, *in press,* CD, $10.
- **Preliminary geologic map of the Umatilla Basin, Morrow and Umatilla counties, Oregon**, by Ian P. Madin and Ronald P. Geitgey. Open-File Report O-07-15, *in press*, CD, $10.
- **Preliminary geologic compilation map of the southwest portion of Oregon** (map sheet only), by Margaret D. Jenks, Stanley A. Mertzman, Thomas J. Wiley, Paul E. Staub, Marina Drazba, Lina Ma, Clark A. Niewendorp, and Ian P. Madin. Open-File Report O-07-16. CD, $10.
- **Preliminary geologic map of the Aspen Lake 7.5' quadrangle, Klamath County, Oregon**, by Stanley A. Mertzman and others. Open-File Report O-07-17. CD, $10.
- **Portland State University Ondine Residence Hall seismic rehabilitation demonstration project**, by Yumei Wang and Christopher J. Heathman. Special Paper 38. CD, $10.
- **Enhanced rapid visual screening (E-RVS) method for prioritization of seismic retrofits in Oregon**, by Yumei Wang and Kenneth A. Goettel. Special Paper 39. CD, $10.
- **Oregon geologic data compilation — version 3, southeast, northeast, and central Oregon**, compiled by Clark A. Niewendorp, Margaret D. Jenks, Mark L. Ferns, Ian P. Madin, Paul E. Staub, and Lina Ma, 2007, OGDC-3. 1 CD, $25.

Look online (http://www.oregongeology.com) for:

- **Oregon Geologic Data Compilation (OGDC-3) interactive map–** http://www.oregongeology.com/sub/ogdc/index.htm
- **GTILO - Geothermal Information Layer for Oregon–** http://www.oregongeology.com/sub/gtilo/
- **Pilot LIDAR Project - Portland Metro Area–** http://www.oregongeology.com/sub/lidar/
- **Statewide Seismic Needs Assessment Using Rapid Visual Screening (RVS)–** http://www.oregongeology.com/sub/projects/rvs/

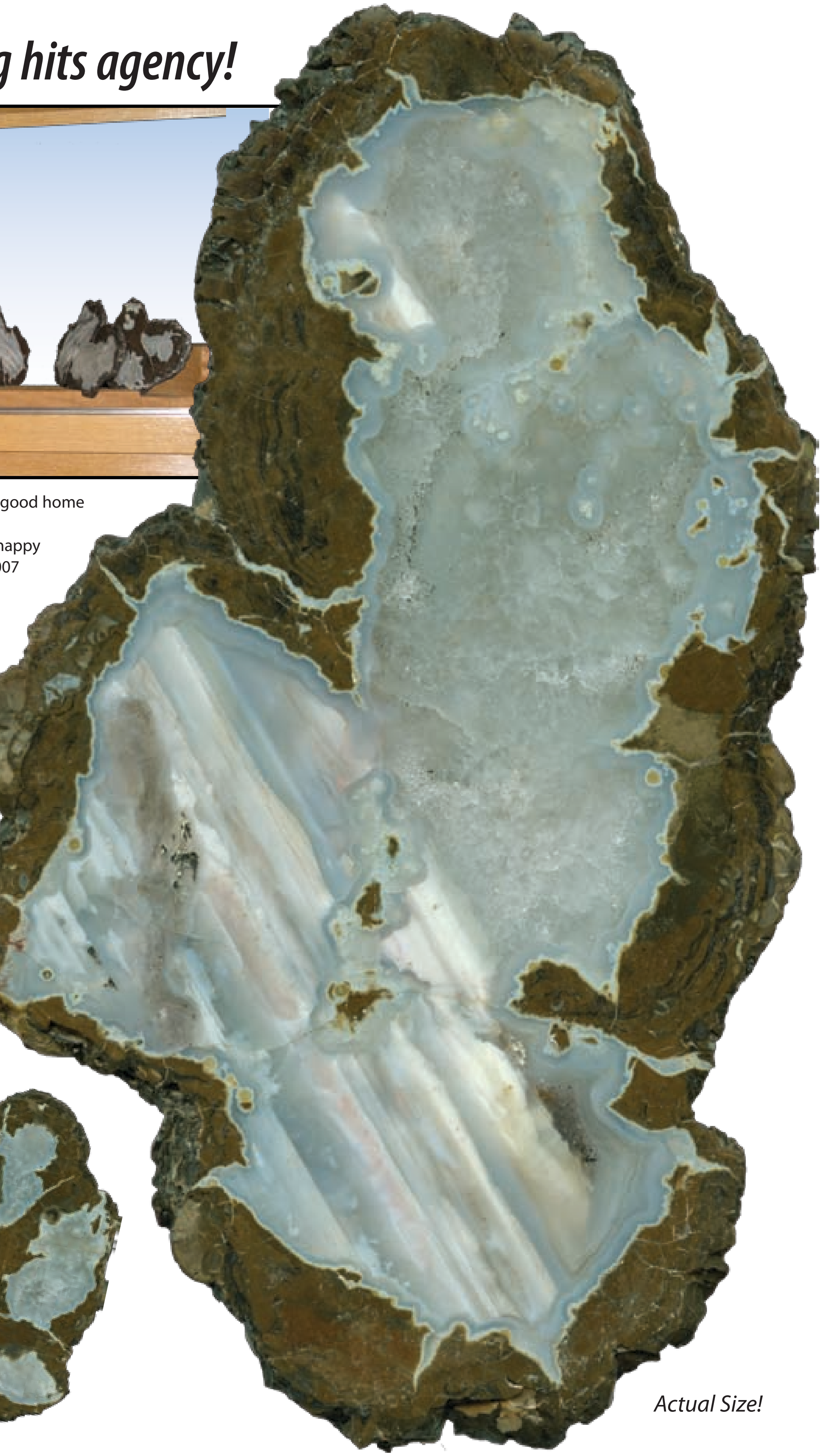
  Individual seismic needs assessment site reports: http://www.oregongeology.com/sub/projects/rvs/county/county-sites.htm
- **DOGAMI liquefied natural gas (LNG) fact sheet–** http://www.oregongeology.com/sub/publications/LNG-factsheet.pdf.
- **All *Ore Bin* and *Oregon Geology* past issues–** http://www.oregongeology.com/sub/quarpub/OrGeo.htm
- **All Geologic Map Series (GMS) maps–** http://www.oregongeology.com/sub/publications/GMS/gms.htm

Huge thunderegg hits agency!

Ron Clark, of Austin, Texas, wanted to find a good home for this treasure—4 slabs cut from one large thunderegg specimen—and DOGAMI was happy to receive it. Included with Ron's summer 2007 donation is a custom display stand he made from Oregon myrtlewood.

Ron commented, "My parents, Luther and Betty Clark, were rock-hounds, and they found this thunderegg near Bend around 1980. They had it around their home until they passed their rock saw and their many "treasures" down to me. I consulted with a lapidary shop here in Austin, and they told me how to cut it. I cut and polished it and have enjoyed it for years."

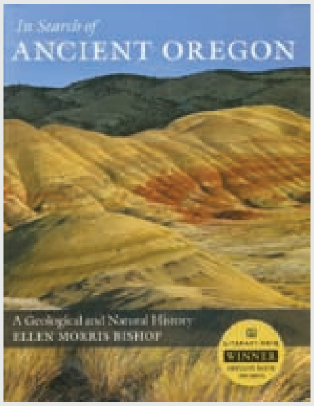
The four slabs are shown here.



Actual Size!

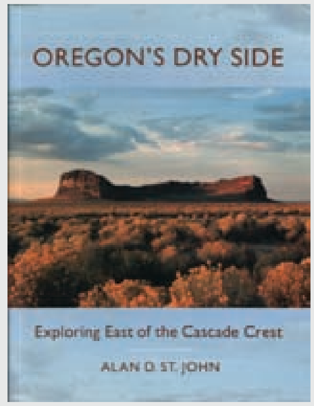
Highlighting Publications

Available from The Nature of the Northwest Information Center



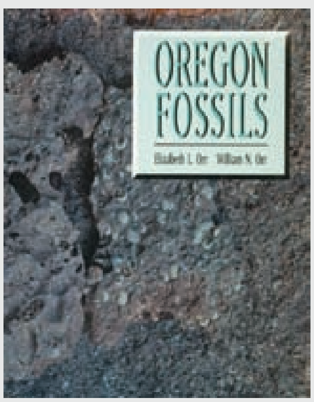
In Search of Ancient Oregon: A Geological and Natural History, revised edition, by Ellen Morris Bishop. Timber Press, Portland, Oregon, 288 p., 2003. Paperback, $29.95.

More than 220 photographs by the author exemplify Oregon's evolving landscapes.



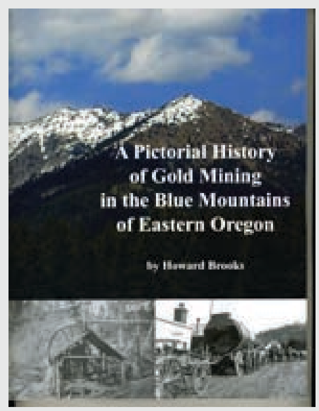
Oregon's Dry Side: Exploring East of the Cascade Crest, by Alan D. St. John. Timber Press, Portland, Oregon, 323 p., 2007. Paperback, $29.95.

Explore Oregon's central, southeastern, and northeastern regions on three driving and hiking tours that highlight the state's geology, mountains, desert, cultural history, fossils, wildlife, wild flowers, and more. Hundreds of the author's photographs illustrate the journeys.



Oregon Fossils, by Elizabeth L. Orr and William N. Orr. Kendall/ Hunt Publishing Company, Dubuque, Iowa, 1999. 381 p., paperback, $30.00.

Locality maps, photos, pen and ink drawings, and stratigraphy and correlation charts illustrate "major events and people who have made significant contributions to the story of Oregon's geologic past."



A Pictorial History of Gold Mining in the Blue Mountains of Eastern Oregon, by Howard Brooks. Baker County Historical Society, P. O. Box 83, Baker City, Oregon 97814, 200 p., 2007. Paperback, $20.00.

Historic and contemporary photographs highlight a sampling of gold mines and prospects in northeastern Oregon.

Nature of the Northwest Information Center
800 NE Oregon St., Suite 177, Portland, OR 97232
Hours: Monday-Friday 9:00 AM to 5:00 PM
phone (503) 872-2750   TDD (503) 872-2752   fax (971) 673-1562
Order online: http://www.naturenw.org/

Publication of *Oregon Geology*

Budget cutbacks and changing technology require that we make changes to the magazine. We will now try to publish two issues a year as a journal on our web site.

We will also predominantly compile rather than extensively edit the material submitted. Consequently, we are now asking that material be submitted to us in production-ready quality. For details and the new publication schedule, see "Information for Contributors" below.

We believe *Oregon Geology* is an important publication, offering a unique and suitable place to share information about Oregon that is useful for the geoscience community and ultimately for all Oregonians. Please help us by continuing to read the journal *Oregon Geology* and submit articles.

Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers in the geoscience community who are interested in all aspects of the geology of Oregon and its applications. Informative papers and notes, particularly research results, are welcome, as are letters or notes in response to materials published in the journal.

Two copies of the manuscript should be submitted, one paper copy and one digital copy. While the paper copy should document the author's intent as to unified layout and appearance, all digital elements of the manuscript, such as text, figures, and tables should be submitted as separate files. Hard-copy graphics should be camera ready; photographs should be glossies. Figure captions should be placed together at the end of the text.

Style is generally that of U.S. Geological Survey publications. (See USGS *Suggestions to Authors*, 7th ed., 1991, or recent issues of *Oregon Geology*.) References are limited to those cited. We accept only those articles that have at least one acknowledged outside review. We maintain the authority to request a copy of the reviewer's comments. Pre-submission reviewers should be included in the acknowledgments. In view of increasing restrictions on editing time, adherence to such style will be required more strictly than in the past.

For the foreseeable future *Oregon Geology* will be published twice annually on the Department web site http://www.oregongeology.org, a spring issue on or shortly after March 15 and a fall issue on or shortly after October 1. Deadline for submission of scientific or technical articles will be January 31 and August 15, respectively. Such papers will be subjected to outside reviews as the Department will see appropriate.

Conclusions and opinions presented in articles are those of the authors and are not necessarily endorsed by the Oregon Department of Geology and Mineral Industries.

Authors will receive a complimentary CD with a PDF version of the issue containing their contribution.

Manuscripts, letters, notices, and photographs should be sent to Deb Schueller, Editor, *Oregon Geology*, 800 NE Oregon Street #28, Portland, OR 97232-2162, e-mail contact deb.schueller@dogami.state.or.us.

Please send us your photos

Since we have started printing color pictures in *Oregon Geology*, we are finding ourselves woefully short of good color photographs showing geologic motifs in Oregon. That is why we invite your contributions.

Good glossy prints or transparencies will be the best "hard copy," while digital versions are best in TIFF or EPS format.

If you have any photos you would like to share with other readers, please send them to us (Editor, *Oregon Geology*, 800 NE Oregon Street #28, Portland, OR 97232-2162, # 28; e-mail deb.schueller@dogami.state.or.us.) with information for a caption. If they are used, publication and credit to you is all the compensation we can offer. If you wish to have us return your materials, please include a self-addressed envelope.

OREGON GEOLOGY
800 NE Oregon Street #28, Suite 965
Portland, OR 97232-2162

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

Oregon Paleo Lands Institute (OPLI), Fossil, Oregon: OPLI will help you discover Oregon's past and explore its present landscapes. With the John Day basin as its "home base," OPLI provides trips, classes, and adventures throughout Oregon. You can fine-tune your skills in photography and art, collect fossils, learn about bats, butterflies, bunchgrass, and bears, earn college credit, float a wild and scenic river, or take a cycle trip. OPLI can guide you on a day hike through Painted Hills onto an ancient beach where pterosaurs flew and plesiosaurs swam. OPLI also offers customized day hikes to collect fossils and coordinates volunteers to assist paleontologists in their research. The Thomas Condon Paleontology Center at the Sheep Rock Unit of the John Day Fossil Beds is nearby. You can also take Highway 218 south to the Clarno Unit, John Day Fossil Beds, and the Pine Creek Ranch.

The Big Basin Member of the John Day Formation, composed of ash, tuffs, and soils. The Big Basin Formation is generally red or yellow, reflecting its heritage of tropical-type soils and climate. It is exposed in the Painted Hills and along the John Day River between Kimberly and the John Day Fossil Beds Thomas Condon Visitors Center. Photo copyright Ellen Morris Bishop.

OPLI ACCESS: **FROM PORTLAND**: Follow Interstate 84 east to Biggs Junction (exit 104), turn right (south) on US 97 to Wasco, then take Oregon Hwy 206 40 miles to Condon. From Condon, head south for 20 miles to Fossil on Hwy 19.
FROM BEND: Follow US 97 north to Madras, and then continue on US 97 20 miles past Madras. At Willowdale (now a road junction, not a town!) turn right on Oregon 218. Then, continue on Hwy 218.

For a catalog describing children's and family programs, classes and adventures, day trips, and field studies, contact:

Oregon Paleo Lands Institute
P. O. Box 104
Fossil, Oregon 97830

office hours: 8 AM-5 PM, Monday-Friday
phone: (541) 763-4480
web: http://www.paleolands.org