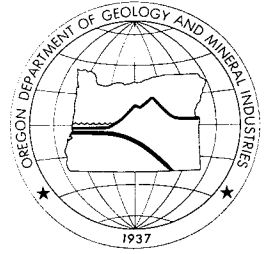


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NOVEMBER 1991



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A Paleosol from the John Day Formation
and
A Survey Questionnaire for our Readers

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

Cover photo

Area near Camp Hancock in Wheeler County, central Oregon. The person visible near the center of the photo is standing in front of an outcrop of red John Day Formation claystone capped with white ash. This prominent knoll is the location of the Luca clay paleosol described in the article beginning on page 131.

OIL AND GAS NEWS

Drilling activity at Mist Gas Field

Drilling activity continues at the Mist Gas Field, Columbia County. Nahama and Weagant Energy continued the multi-well drilling program that began during July. The Columbia County 34-31-65, located in the SE $\frac{1}{4}$ sec. 31, T. 6 N., R. 5 W., reached a total depth of 2,064 ft, was plugged and redrilled to a depth of 1,902 ft, and is now a successful gas completion. The next well drilled, Longview Fibre 22-31-65, located in the NW $\frac{1}{4}$ sec. 31, T. 6 N., R. 5 W., reached a total depth of 1,991 ft and was plugged and abandoned. The CER 14-26-64, located in the SW $\frac{1}{4}$ sec 26, T. 6 N., R. 4 W., reached a total depth of 2,702 ft and is a successful gas completion. So far for the year, Nahama and Weagant Energy has drilled five wells and one redrill, and three of these attempts have led to successful gas completions.

Northwest Natural Gas Co. began drilling at the Natural Gas Storage Project at the Mist Gas Field during September. The IW 13b-11 is a gas injection-withdrawal service well being drilled in the Bruer Pool. Upon completion of this well, drilling of an injection-withdrawal service well, IW 23d-3, is planned for the Flora Pool.

Seismic surveys conducted in Oregon

Two seismic surveys were completed in Oregon during September and October. The first was by Cimmaron Land Services, which conducted a wide-range refraction/reflection seismic survey in Wasco, Jefferson, and Wheeler Counties. The survey is located in the western Columbia River Basin and intended to define areas with stratigraphic and structural conditions necessary for potential oil and gas accumulations. The U.S. Geological Survey conducted a seismic refraction survey in western Oregon with the intent of helping scientists assess earthquake hazards in the Pacific Northwest more accurately. This seismic survey is a portion of a total project that extends north from western Oregon through Washington into southern British Columbia, Canada.

NWPA Kyle Huber luncheon scheduled

The annual Kyle Huber luncheon will be held by the Northwest Petroleum Association (NWPA) on November 8. At this luncheon, the Kyle Huber Award will be presented to the individual or company that has been selected to have made the most significant contribution to energy resource development in the Pacific Northwest during the year. Paul Dudley, independent geologist from Bend, will be the speaker. Details on the luncheon can be obtained from Shelley at (503) 220-2573.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
468	Nahama and Weagant CER 24-22-64 36-009-00293	SW $\frac{1}{4}$ sec. 22 T. 6 N., R. 4 W. Columbia County	Permit; 2,600. <input type="checkbox"/>

REMEMBER TO RENEW

Many of you will find that the code number on your address label ends in "1291," which means your subscription expires with the December issue of 1991. If so, or if your expiration date is anywhere near this, please use the renewal form on the last page to make sure you will continue receiving *Oregon Geology*. And while you are at it—why not consider a gift subscription for a friend?

Early Oligocene paleoenvironment of a paleosol from the lower part of the John Day Formation near Clarno, Oregon

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

ABSTRACT

The red basal part of the lower Oligocene John Day Formation consists of numerous, superimposed fossil soils. One of these, reported here and named Luca clay paleosol¹, is a well-developed red clayey profile similar to modern Udalfs². It represents a well-drained land surface that was stable for at least a few tens of thousands of years. It probably formed under forest vegetation, as can be judged from abundance of root traces and a well-developed subsurface clayey horizon. Its smectitic-kaolinitic clays and base-poor chemical composition are compatible with a sub-humid to humid paleoclimate.

INTRODUCTION

The colorful badlands of mid-Tertiary nonmarine rocks in the high desert of the John Day country of central Oregon are a delight to the eye, well known from scenic landmarks such as the Painted Hills and Sheep Rock now protected within the John Day Fossil Beds National Monument. Only recently has it been realized that these striking color bands are ancient soils within tuffaceous deposits (Retallack, 1981, 1985).

This study of a fossil soil in the Oligocene part of the John Day Formation in north-central Oregon aims to provide a brief description of the paleosol and to interpret its significance for paleoenvironment and paleoecology of the area. The lower member of the John Day Formation, which rests unconformably on older rocks of the Clarno Formation, is composed mainly of brilliant red claystones and siltstones. The red color of the lower John Day Formation has been ascribed to mixing of volcanic ash with lateritic soil derived from the Clarno Formation (Waters and others, 1951; Fisher and Wilcox, 1960; Hay, 1962). In a later study Fisher (1964) explained the red clay as a continuation, into John Day time, of deep and prolonged weathering that was responsible for the post-Clarno "lateritic" paleosol. No exceptionally iron-rich rocks with evidence of irreversible hardening (plinthites or "laterites" formed in place) were found with the present work.

Association of iron oxides, manganese oxides, kaolinite, montmorillonite, chalcedony, and calcite also has been reported within the same hardpan in the lower John Day Formation (Fisher, 1964). These kinds of hardpans are sometimes found in desert soils (Birkeland, 1984). The present study, however, did not identify calcareous hardpans, either through acid testing in the field or through chemical analysis.

This is not to imply that lateritic and calcareous paleosols are not present but rather to indicate the diversity of prior views on ancient weathering in these rocks and emphasize the need for detailed study of entire profiles. There are many different kinds of paleosols in these rocks (Smith, 1988; Pratt, 1988) as in other alluvial sequences (Retallack, 1983; Bown and Kraus, 1987). The paleosol profile described here is a start at unravelling their complex and changing paleoenvironment through paleosol study.

¹ The word "luca" is the term for the color red in the Umatilla dialect of the Sahaptin language spoken by early inhabitants of this area (Rigsby, 1965).

² For explanations of soil-science terminology, readers are referred to Soil Conservation Service (1975), Brewer (1976), and Birkeland (1984).

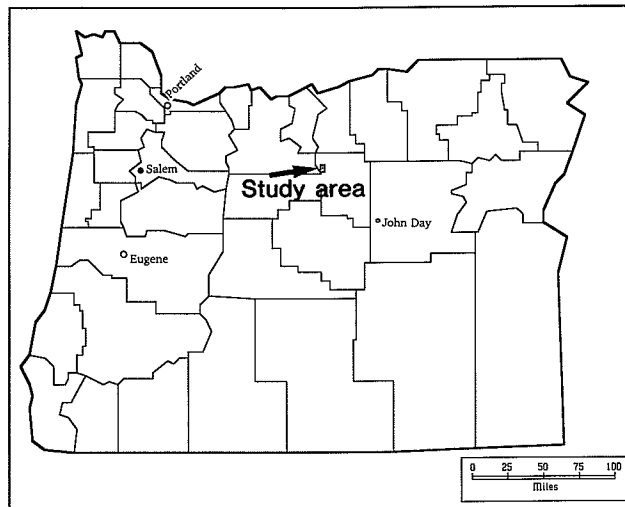


Figure 1. Location of Luca clay paleosol study area in Wheeler County, Oregon.

GEOLOGIC SETTING

The studied profile is located in the north-central part of Wheeler County, Oregon, in the S¹/₂SE¹/₄ sec. 23, T. 7 S., R. 19 E., Clarno 7¹/₂-minute quadrangle (Figure 1). It is some 2.5 mi northeast of the bridge across the John Day River at the small village of Clarno. The outcrop studied is a prominent red knoll capped with white ash, in a grassy slope 1 mi northeast of Camp Hancock (Figure 2). This red outcrop is mapped within the lower John Day Formation, which overlies the basal ignimbrite of the formation, here dated at 37.3±11 million years (m.y.) (Robinson and others, 1984). The basal red part of the formation, which includes the paleosol described here, is poorly fossiliferous. Loose around the base of the outcrop studied were found a fragmentary large canine tooth like that of an entelodont (large piglike mammal) and some permineralized woody branches 12 cm in diameter showing a fracture pattern similar to that of charcoal. Some 50 m south of the outcrop and underlying the paleosol are brown paper shales and tuffs containing fish scales, cones, winged fruits, and leaves, including those of *Ulmus*, *Tetrapteris*, and *Metasequoia*. All of these remains are low in diversity and poorly preserved compared to those of the middle green and upper buff members of John Day Formation, which contain abundant fossil leaves (Manchester and Meyer, 1987), fish (Cavender, 1969), insects (Cockerell, 1927; Peterson, 1964), and mammals (Merriam and Sinclair, 1907; Woodburne and Robinson, 1977).

The John Day Formation of north-central Oregon is a widespread, largely pyroclastic sequence lying between the Clarno Formation of Eocene age and the Columbia River Basalt Group of Miocene age. The formation crops out in a belt along the southern margin of the Columbia River drainage basin, extending nearly 200 km eastward from the central Oregon Cascade Range. The formation provides a well-exposed and relatively continuous record of early Cascade Range volcanism. It consists largely of andesitic to dacitic tuffaceous claystone, air-fall tuff with numerous inter-layered ash-flow sheets, and lava flows of rhyolite and trachyandesite (Woodburne and Robinson, 1977; Dingu, 1979).



Figure 2. General view of the lower John Day Formation, in Wheeler County, Oregon (arrow indicates position of Luca clay paleosol).

METHOD

A trench about 2.30 m deep and 80 cm wide was dug with hoe and shovel to create a better exposure of the various horizons of the paleosol. Dilute hydrochloric acid was used to check the presence of carbonate minerals. Color was identified using a Munsell color chart. Thin sections were made of samples from each horizon, and point counts were done. Chemical composition of each sample was assayed with atomic absorption by Christine McBirney at the University of Oregon. The clay minerals of the paleosol were identified by use of the Rigaku Miniflex X-ray diffraction machine. The detector was set to count over a range of 2θ from 70° to 5° . The X-ray wavelength was 1.54059 \AA ($\text{CuK}\alpha$). The samples analyzed were not pretreated. Quartz and silicon metal standards were used for calibrating the machine.

DESCRIPTION OF THE LUCA CLAY PALEOSOL

The paleosols crop out in a red badlands slope (Figure 2). The top of the paleosol can be identified as a laterally abrupt contact between white ash and red mottled silty claystone. Below that, there is a thick gradational profile of claystone that becomes redder and darker in color as mottles of gray silty claystones become less abundant. The drab mottles are complexly intertwined and tubular, like drab-haloed root traces (Retallack, 1983). The various horizons identified in the trench were a silty claystone surface (A), clayey subsurface (Bt), and a silty tuffaceous claystone parent material (C). Color varies from white (5YR8/1) in the A horizon to dusky red (10R3/4) and dark red (10R3/6) in the Bt and C horizons, respectively.

The A horizon (0-47 cm) is a noncalcareous silty claystone, containing slender, purple root traces surrounded by drab haloes. This horizon is sharply truncated by the overlying tuff unit that defines the top of the paleosol. The A horizon is dominantly clay with lesser silt. Slickensides also were observed. In thin section, it has porphyroscopic skelinseplic plasmic fabric (of Brewer, 1976); with plagioclase, volcanic rock fragments, glass shards, opaques, and a few sesquiargillans.

The Bt horizon (0.47-1.41 m) is a dusky red (10R3/4) claystone with less common drab-haloed root traces than the A horizon (Figure 3). This clayey horizon is riddled with slickensides, randomly arranged. Acid test indicates it is noncalcareous. There is a gradual decrease of the root traces downward into the C horizon. No fossil burrows or biological traces other than roots were found in this horizon. Microtexture is porphyroscopic skelmasepic, with plagioclase, volcanic rock fragments, opaques, and few quartz grains.

The C horizon (1.41-2.16 m) is dark red (10R3/6) and contains no root traces or burrows. The dominant grain size of this horizon is silt. This part of the paleosol gave no indication of a concentration of calcareous nodules or stringers. The lower portion of the horizon contains some recognizable feldspar grains and rock fragments (Figure 3). Microtexture is porphyroscopic skelmasepic in drab areas, isotic with sesquioxide stain elsewhere. Plagioclase, volcanic rock fragment, opaques, quartz, and a few sesquiargillans were also observed. The C horizon gradually passes into a clayey lower portion that

also has been affected by weathering processes. It has the same color as the overlying horizon.

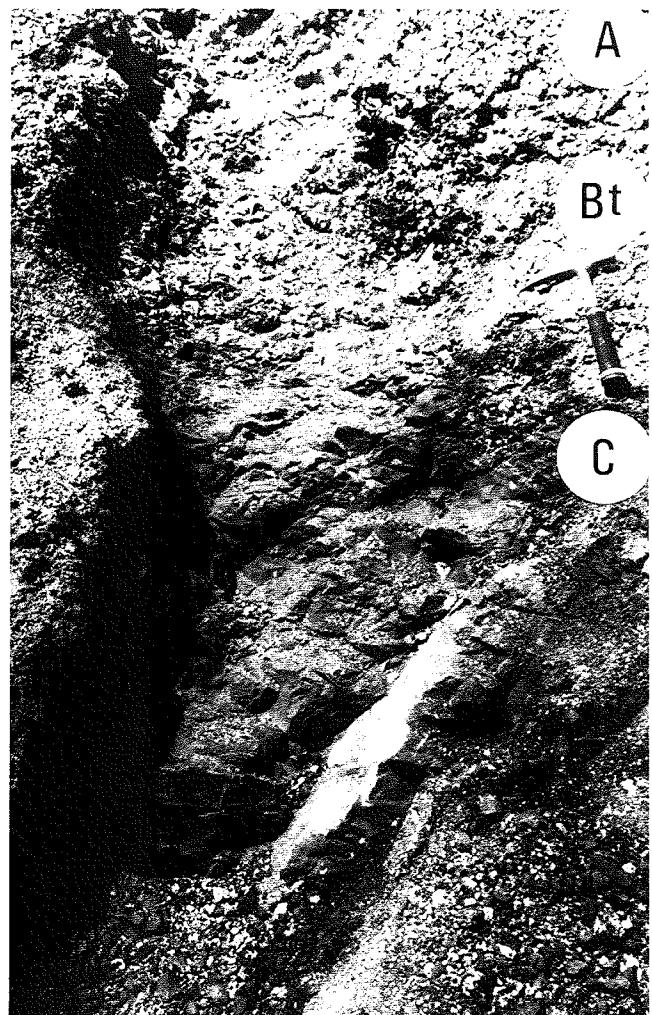


Figure 3. Paleosol horizons exposed after trenching of the Luca clay paleosol.

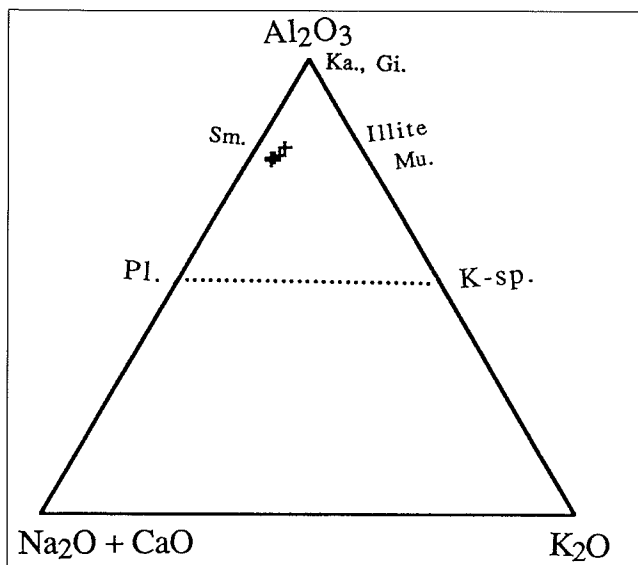


Figure 4. Triangular variation diagram constructed using molar proportions of Al_2O_3 , Na_2O+CaO , and K_2O as end members for the weathering profile of Luca clay paleosol.

CLAY MINERAL COMPOSITION

Smectite is the dominant clay mineral followed by kaolinite, as revealed by X-ray diffraction studies. A triangular variation diagram plotted with Al_2O_3 , K_2O , and Na_2O+CaO (following Nesbit and Young, 1989) as end members also indicates smectite to be the major clay component of the paleosol (Figure 4). Quartz and hematite also were detected in all the X-ray diffraction traces.

CHEMICAL COMPOSITION

Within the profile there is a general increase in the oxide values of SiO_2 , CaO , MnO , Na_2O , and MgO and decrease of Fe_2O_3 , K_2O , TiO_2 , and Al_2O_3 from the lower horizon to the surface of the paleosol (Table 1). Three main patterns appear in the distribution of the trace elements in the paleosol. Co, Ni, and Sr are found in larger abundance in the surface and near-surface horizon; Cr, Rb, and Zn are found in greater abundance in the lower horizon, while Cu and Ba are enriched in the clay-rich Bt horizon.

The concentration of SiO_2 and some mobile elements (alkali and alkaline earth elements) in the A horizon compared to the lower part of the fossil soil may have been due to the addition of volcanic ash, dust, and thin increments of flood-borne silt (which are evident from the profile section; Figure 5). The depletion of potassium from the A horizon could be the result of plant uptake as found in surface soils by Mehlich and Drake (1955) and Tan (1984).

In general, Ba, Cr, and Zn tend to accumulate in clays of soils and other residual materials (Aubert and Pinta, 1977; Wedepohl, 1978). The abundance of these elements and Cu in the clay-rich Bt horizon may reflect the affinity of these trace elements for clay and hydroxides of iron and manganese. The surface enrichment of Sr, generally a mobile element during weathering, may be due to addition of new materials to the soil profile.

MOLECULAR WEATHERING RATIOS

Molecular ratios were employed to understand specific weathering processes in the development of the paleosol. The ratios are calculated by dividing the weight percent of each oxide or element involved by its molecular weight and

Table 1. Major- and trace-element chemical data for the Luca Clay paleosol. Oxides in weight percent, trace elements in ppm; sample numbers indicate vertical position between surface (JD-1) and lower horizon (JD-5)

Sample	JD-1	JD-2	JD-3	JD-4	JD-5
SiO_2	59.46	59.26	57.68	53.20	51.50
TiO_2	1.46	1.52	1.58	1.67	1.58
Al_2O_3	16.13	16.20	16.42	17.17	17.36
Fe_2O_3	5.31	5.59	6.75	8.85	10.20
FeO	0.00	0.00	0.00	0.00	0.00
MnO	0.06	0.05	0.06	0.08	0.08
MgO	0.66	0.63	0.62	0.61	0.57
CaO	2.26	2.12	2.11	2.08	1.84
Na_2O	1.57	1.54	1.51	1.37	1.21
K_2O	0.80	0.82	0.92	1.03	1.08
H_2O^+	3.65	3.60	4.50	4.28	4.36
H_2O^-	8.68	8.56	7.65	9.75	10.34
P_2O_5	0.09	0.10	0.08	0.13	0.07
TOTAL	100.13	99.70	99.88	100.18	100.19
Ba	135	135	145	116	126
Co	78	28	15	20	20
Cr	20	21	23	25	27
Cu	80	112	106	130	45
Li	16	16	16	15	17
Rb	42	41	59	57	70
Sr	134	128	124	100	94
Zn	82	82	86	89	86

then dividing the oxides or elements as specified by the particular ratio.

The ratios of Al_2O_3/K_2O , SiO_2/Fe_2O_3 , SiO_2/Al_2O_3 , $Base/Al_2O_3$, and Ba/Sr all decrease down the profile indicating leaching of bases and iron-rich clay from surface to subsurface horizons (Figure 6). The ratio of FeO/Fe_2O_3 is extremely low in all the horizons, evidence of a highly oxidized paleosol that was probably well-drained throughout. The Ba/Sr ratio of the Luca clay paleosol is also low throughout, an indication of limited leaching.

DIAGENESIS

The drab-colored A horizon, which originally would have been the part of the paleosol richest in organic matter, may have been discolored during burial gleization of the paleosol. Drab-haloed root traces, abundant in both A and Bt horizons, may also have been discolored by anaerobic decay of organic matter soon after burial of the fossil soil (Retallack, 1983). These drab haloes and horizons have none of the features, such as ferruginous concretions or a tabular pattern of carbonaceous root traces, that are found in originally waterlogged soils. The paleosol is also too highly oxidized to have been a gleyed soil.

The red color of the soil matrix is due to the presence of hematite as revealed by X-ray diffraction. Well-drained soils may have hydroxides of ferric iron in the form of gels, or minerals such as goethite, which form a light-brown or yellow stain. These minerals may have been converted to hematite by dehydration during compaction of the fossil soil (Walker, 1967). Thus the paleosol may

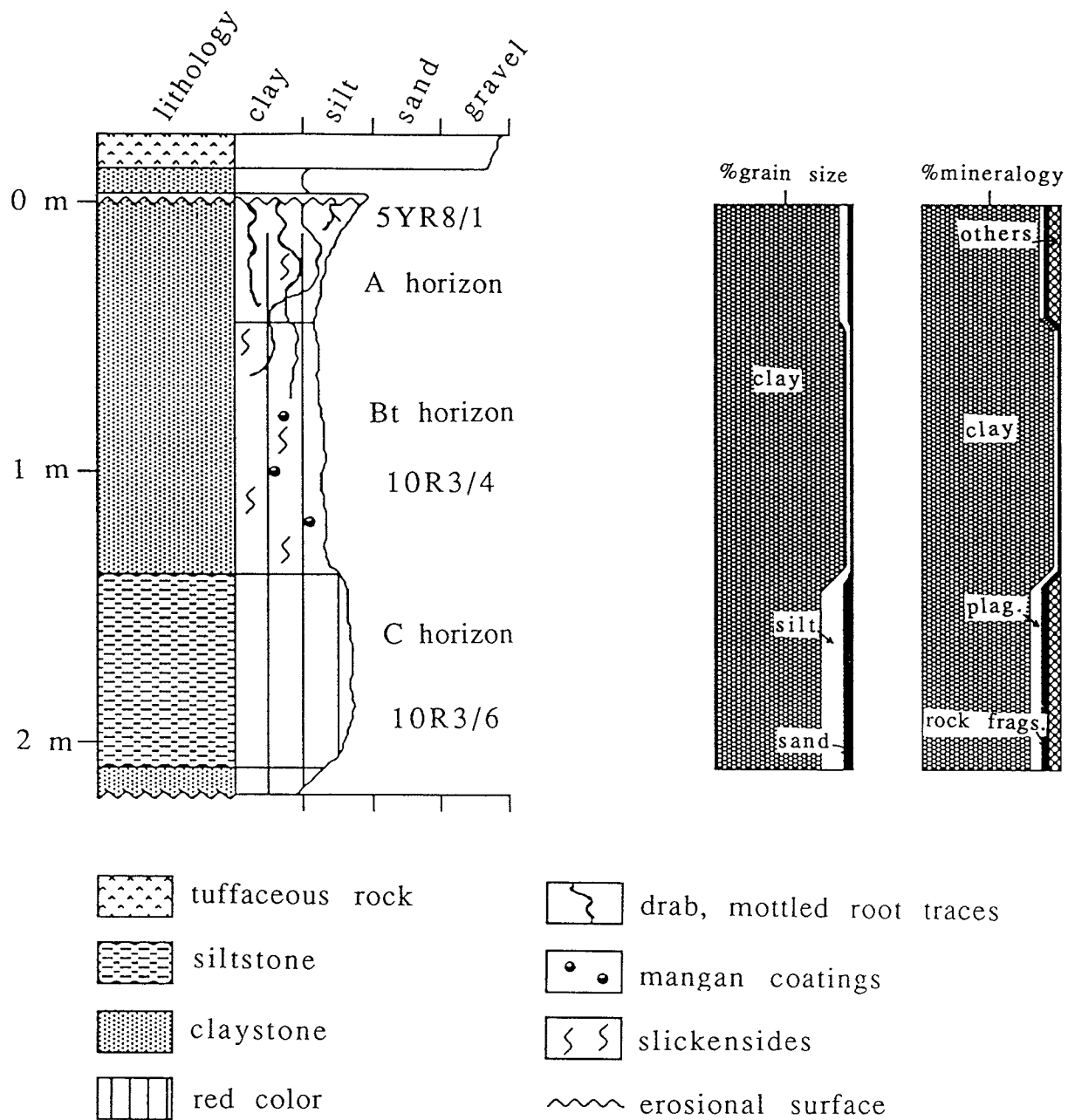


Figure 5. Columnar section (measured in field) and petrographic composition and grain size (from point-counting of thin sections) of the Luca clay paleosol within the lower John Day Formation in Wheeler County, Oregon.

be redder than the original soil by as much as three Munsell hue units, like some Quaternary paleosols compared to similar surface soils (Ruhe, 1969).

Compaction of paleosols by overburden is a common phenomenon that results in a reduction of their thickness. The deformed root traces of the Luca clay paleosol indicate a considerable reduction of thickness of the fossil soil by compaction. Slickensides form in clayey soils where peds are repeatedly heaved past one another or by crushing of peds one against another during compaction following burial (Retallack, 1990). Both of these mechanisms might have been the causes for the abundant slickensides observed in the paleosol. The smectitic nature of the clay (Figure 4) would have facilitated the swelling and shrinking of the soil upon wetting and drying.

IDENTIFICATION

Modern soils with clayey subsurface (argillic) horizons include Alfisols and Ultisols, which are distinguished and classified according to their base status. The greater abundance of smectite than kaolinite indicates a mildly alkaline to neutral pH. The former Eh of the paleosol can be constrained within broad limits from mineral assemblages. Unlike a reducing environment, where soil hue is usually bluish or greenish gray and where root traces are confined to shallow depths and horizontally oriented, the Luca clay paleosol has a red hue and numerous branching and deeply penetrating root traces. This indicates an oxidizing environment during the development of the fossil soil.

From these considerations the paleosol can be classified as an Alfisol of Soil Conservation Service (1975). Considering its

non-calcareous composition and depth of weathering, it probably was a Udalf.

PALEOENVIRONMENT

Climate

The absence of calcium carbonate and degree of leaching and base depletion indicated by molecular weathering ratios (Figure 6) within the horizons indicate humid conditions. The abundance of smectite and slickensides is compatible with moderate seasonality of wet and dry conditions during formation of this fossil soil. There is no pronounced evidence of clay heave (mukkara structure of Paton, 1974) as in Vertisols of strongly seasonal climate.

Vegetation

The Luca clay paleosol is deeply weathered and has a full sequence of horizons (A—Bt—C). These features and abundant root traces that emanate from the surface down into the profile are evidence that it once supported a woodland or forest ecosystem. The drab-colored portions of the A and Bt horizons (Figures 2 and 3) may have formed during burial around areas once moderately rich in organic matter, as already outlined. This would probably have been an ochric epipedon of a well-drained soil rather than a histic one of a swampy soil. The charcoalified wood found near the paleosol may be taken as an indication of occasional forest fires. Fossil plants in a lacustrine deposit underlying the paleosol include *Ulmus*, *Tetrapteris*, and *Metasequoia*. This is similar to forest floras known from lake deposits higher in the John Day Formation (Manchester and Meyer, 1987), but such lakeside vegetation did not necessarily grow in the well-drained paleosol reported here.

Animals

No burrows were recognized in the paleosol. A stout canine tooth like that of an entelodont was found loose on the surface near the base of this paleosol. This fossil is similar to those found higher on the John Day Formation (Merriam and Sinclair, 1907). Such stout teeth are more readily preserved than shells or porous bones, and the noncalcareous Luca clay paleosol would not have been especially favorable for the preservation of bones or teeth. Thus the paleosol may have supported a diverse mammalian fauna that remains poorly known because of preservational biases.

Topographic setting

The Luca clay paleosol was formed on a stable land surface. The deeply penetrating and evenly spread root traces in the fossil soil are indications of high porosity, permeability and drainage. The red hue from hematite pigment of the Bt horizon probably formed by burial dehydration of iron oxyhydrates or gels (Walker, 1967). It is unlikely, however, that such a clayey soil interbedded with coarse-grained gray to white tuffs was oxidized during burial by ground water. Thus the very low molecular weathering ratio of $\text{FeO}/\text{Fe}_2\text{O}_3$ (Figure 6) can be taken as evidence of a strongly oxidized soil. The drab color of the A horizon was not caused by waterlogging but by anaerobic reduction of organic matter as the buried soil subsided below water table. The former water table was probably at least 3 m below the surface during soil formation.

Parent material

The Luca clay paleosol formed on a volcanogenic tuffaceous material that probably had been reworked from preexisting soils and redistributed by rivers. The ratios of $\text{SiO}_2/\text{Al}_2\text{O}_3$, $\text{SiO}_2/\text{Fe}_2\text{O}_3$, and $\text{FeO}/\text{Fe}_2\text{O}_3$ at the base of the profile are unlike those of fresh ash and may have been produced by desilication and ferruginization in the drainage basin. Such processes continued during the development of the fossil soil from its parent material as revealed

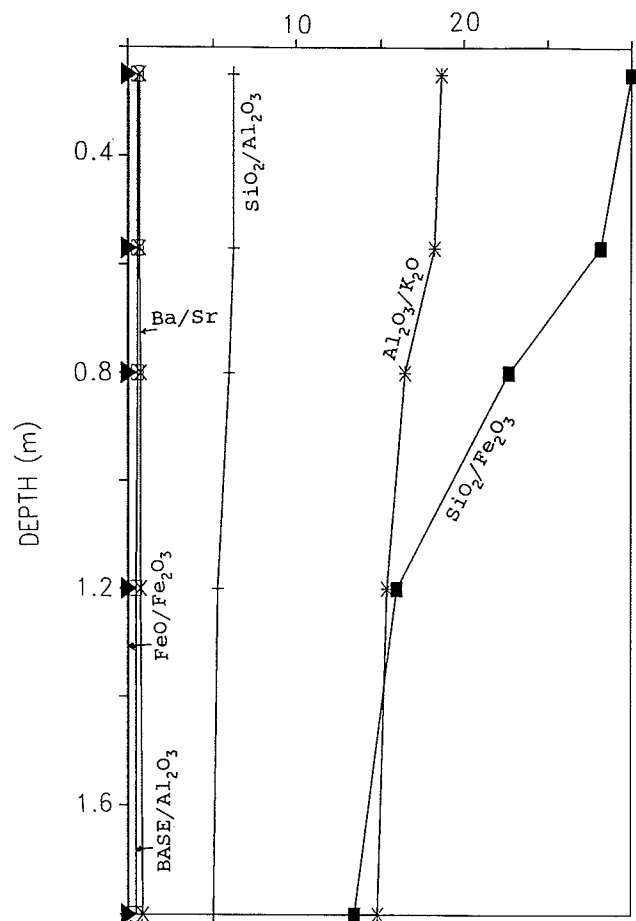


Figure 6. Selected molecular ratios chosen to demonstrate degree of weathering of the Luca clay paleosol.

by these same molecular ratios (Figure 6).

Time for formation

The clayey subsurface (Bt) horizon of the Luca clay paleosol is moderately developed (in the sense of Retallack, 1988). In soils of alluvial terraces of the Merced River in the San Joaquin Valley of central California (Harden, 1982) such differentiated argillic horizons take some 10,000 to 40,000 years to form. Similar estimates are gained by comparison with Bt horizons in a variety of other chronosequences of surface soils, as summarized by Birkeland (1984). Thus the development of the Luca clay argillic (Bt) horizon of the paleosol may also represent a few tens of thousand years.

CONCLUSION

The Luca clay paleosol in the Oligocene lower John Day Formation is a well-preserved and differentiated paleosol with gray to white A horizon and dusky to dark-red clay-rich Bt and silty C horizon. Numerous drab-haloes root traces extend from the A into the Bt horizon. It was formed in a humid to subhumid climate on the well-drained and stable land surface of an extensive alluvial plain downwind of a major volcanic mountain range. These ancient soils were evidently vegetated by large trees, probably forest, similar to that in evidence from associated lacustrine leaf beds.

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DOGAMI to open natural-resource store/information center

The Oregon Department of Geology and Mineral Industries (DOGAMI) will open its new natural-resource information center/store when the new Portland State Office Building is completed in late February or early March of next year. Located on 800 Oregon Street NE near the Lloyd Center, the Convention Center, and MAX, Portland's light-rail system, the new building will house many state agencies, including DOGAMI.

DOGAMI's administrative offices, geologists, and library will be located on the ninth floor of the new structure. The 700-ft² store/information center, however, will be on the first floor, in the southeast portion of the building.

The purpose of the new store/information center is to make natural-resource and outdoor-recreation material readily available to Oregonians and visitors. It will continue to sell U.S. Geological Survey (USGS) maps and DOGAMI publications but will also handle material from other state and federal natural-resource agencies. The USGS has agreed to provide the facility with many of its educational and informational materials and has designated it as an Earth Science Information Center. A committee of representatives from several state agencies has developed the inventory policy for the store, and that policy is available from DOGAMI for anyone who wants to see it.

Several months ago, DOGAMI announced a store-naming contest. Numerous interesting and in some cases unusual names were submitted, and an outstanding winner was selected. The winning name, which we believe really summarizes our vision for the new facility, will be announced in connection with the opening of the store/information center, and the winner will receive the prize at that time.

DOGAMI is looking for volunteers to help in the new store/information center. If you like people, have interest or expertise in some aspect of Oregon's natural resources such as geology, plants, wildlife, birds, or forestry, want to learn more about any such subjects, or would like an opportunity to share your knowledge about Oregon with someone else, contact Beverly Vogt, DOGAMI, 910 State Office Building, Portland, OR 97201, phone (503) 229-5580. Training for the store/information center will start in January, but if you are not available then, we will have an ongoing training program, so our volunteers will be well prepared. If you want to help DOGAMI sooner than that, we have several volunteers working with us now and could use more to help us with the existing store and with planning and organizing the move to the new site.

Watch for more news about us. □