Published?

Mammalian Tracks in the Late Pliocene or Early Pleistocene Beds of Lake County Oregon

Packard, E. L.; Allison, I. S.; and Cressman, L. S.

Mr. _____ Shook of Klamath Falls called L. S. Cressman's attention to a series of Mammalian tracks he had discovered in sedimentary rocks about 20 miles west of Lakeview, Oregon. Under the guidance of Mr. _____ Howard, Cressman and Allison visited the locality. Later Allison, H. P. Hansen and E. L. Packard studied the imprints and procured plaster casts of three of the best preserved tracks.

The locality is on the property of Mr. George Stevens, leased to W. D. Anderson, Bar H Ranch, Lakeview, Oregon, in the NE ¼ of Sec. 20, T. 39 S., R. 18 E and about 500 feet south of the north line of section 20. It can be reached by the Old Dog Lake forest road that leads southeasterly from State Highway 66, from a point about 300 feet west of the highway sign marking the Drews Gap summit. The road passes through a gate on the east-west section line about 3/4 mile from the highway into Section 20, and follows down a slope to the crossing of a shallow channel of an intermittent stream. About 300 feet north of that crossing, the channel is constricted by nearly vertical walls in which a heavy, indurated mud flow is exposed. Not far below that miniature gorge a shallow right hand tributary has exposed a sloping rock surface which reaches to the junction with the larger channel. The fossil tracks occur on that sloping bed at an elevation as determined by aneroid of 5325 feet.

Oct 2-1958 now owned by Douglas Tracy

The region has not been studied by geologists, and it is not covered by topographic maps or aerial photographs. Due to these factors and the very limited time available for a field study, the date of these fossil tracks can only be determined within rather wide limits.

The several imprints occur in a coarse consolidated deposit consisting of angular fragments of a variety of rocks, principally igneous, ranging in size from small grains to masses several centimeters in length, imbedded in finer tuffaceous material. Due to differential weathering, the exposed surface of the fossil bed is quite rough, and the joints have been widened on that portion of the bed that has been exposed for the longest time. Such a sediment unfortunately is too coarse for the preservation of clear-cut imprints and weathering has further impaired the tracks, which lack much desired detail.

The fossil bed grades downward into a much coarser deposit which in the small gorge, higher up on the main stream, contain many large fragments of acidic and basic igneous rocks imbedded in a firmly cemented matrix of finer particles. These deposits evidently represent mud flows which may have accompanied an eruption of some unknown nearby volcano. Above the fossiliferous stratum, the sediments are finer grained, light colored, and contain occasional tuffaceous fluviatile cross-bedded sandstones and siltstones.

The time was not available to determine the detailed character nor thickness of this deposit, nor to discover the relationships to the topographically higher masses of igneous rocks exposed in the region of block-faulted mountains.

The fossiliferous ~~xtrat~~ stratum dips 16 degrees westerly and strikes N. 15-20 degrees W. The tracks extend along the strike for several ~~pad~~ paces and then turn and follow nearly directly down the present dip where they disappear under several feet of tuffaceous siltstones which form the low rock-cut bank of the wash.

The preservation of the tracks was due to the filling of the foot marks in the coarse mud by a deposit of fine-grained brown silt, 5 centimeters in thickness, which still may be seen in the section of the low bank and which still fills of the tracks partially exposed by excavation. Since that deposit is so fine-grained and readily weathered, it has been completely removed from the exposed tracks by rainwash and deflation.

The attitude of these beds, the known presence ~~kf ak~~ of local faults cutting similar deposits nearby along State Highway 66, and the many major fault blocks in the surrounding region indicate that the fossil tracks antedated an epoch of faulting. Two such times of faulting now generally recognized in that part of Oregon include the mid-Pleistocene (?) faulting of pre-Wisconsin lake beds of the Goose Lake Basin, and the previous epoch of more intense faulting during the late Pliocene. At that earlier date, the block faulted ranges of Oregon and such basins as that now occupied by Goose Lake were developed.

If, after detailed study, such supposed ~~dt~~ dates should prove correct, the tracks might prove to be as old as Pliocene and no younger than early Wisconsin. Since no other fossils have been found which might date these tracks, no closer dating is now possible.

The series of tracks extends from the junction of the two stream channels northwesterly for a distance of about 4.5 meters. Beyond that point, the surface has been so deeply weathered that only a number of pits remain that seem to represent claw-like marks. Their distribution and faint imprints of footpads in front of track Number VI, as indicated on the accompanying plat, suggests that the animal took one or two steps beyond the last track, Numbered VII, and then turned abruptly to the left, leaving several very faint single tracks and a number of claw-like marks, before resuming his normal gait in the direction of the present dip of the beds. Only a left (?) double track can be clearly seen in that last group, but a second was partially excavated in that series. It is possible that several more may extend farther down the dip underneath the meter-thick overburden. These tracks are spaced about 15 decimeters (59 inches) apart, a stride longer than that of an average man. Their outside margins are 48 centimeters apart, which gives some indication of the lateral dimensions of the animal.

The first three sets of double tracks are clearly recognizable although only four show the detail which might be expected in such sediments. Only the anterior of each of these three sets of tracks show clear evidence of claw-like marks and none shows any clear indication of the presence of toe pads on the foot. The large oval impression of the sole of the foot in every instance indicates an undivided pad.

The maximum depth of the imprint reproduced in the plaster cast (print Number VI) as measured in the field from the general surface of the bed is about 30 millimeters. The claw-like marks are now shown only as irregular holes, considerably modified by weathering. The posterior margins are rather steep, indicating they were made by a claw rather than the end of a toe or hoof. They reach a maximum depth of 25 millimeters, which, however, does not necessarily indicate the true length of the claw-like process responsible for the imprint.

The anterior track of each series is slightly larger than the posterior. Both are oval in outline, the anterior one having an anterio-posterior diameter of about 14 decimeters and a transferse diameter of 18.

The absence of clear evidence of claw-like marks on the posterior of the double tracks indicates that the hind foot overstepped the forefoot in walking, a habit practiced by bears. Therefore, in all further reference to the front track, which shows the claw-like marks, that print will be called the track of the hind foot.

The disposition of the claw-like imprints of these tracks introduces a special problem in the identification of that ancient animal. Three quite evenly-spaced marks occur in front of the pad impression, the central one marks the anterio-posterior axis of the foot. It occurs about 75 millimeters from the approximate anterior margin of the imprint of the foot pad, or nearly 140 millimeters from a point somewhat arbitrarily taken as the center of the imprint of the sole. Two other claw-like imprints lie not far inside of an arc of a circle centering at the middle of the pad and passing through the anterior mark. The line from the center of the pad to these lateral marks diverges from the line of the axis by as much as 35 degrees. This distribution is characteristic of all of the tracks that are measurable and therefore cannot be attributed to an accidental spreading of the toes.

The position of the two remaining claw-like imprints is even more puzzling. On the right hand side of the foot mark, making an angle of about 80 degrees with the axis of the foot is an imprint, comparable to the anterior ones and located about 95 millimeters from the central point of the pad imprint. This occurs at approximately the same position on both plaster casts brought into the laboratory and was observed on other tracks in the field. On the left side, a less well-defined imprint about 85 millimeters from the center also appears in both casts and several measurements made to the other marks also agree, thus proving the presence of a toe diverging over 80 degrees from the axis of the foot as defined above.

Such a disposition of the toes of a large five-toed mammal was unexpected, combined with the claw-like imprints and an undivided foot pad.

The dimensions of the two imprints as taken on the plaster casts may be shown on the following diagram.

(Diagram here)

(Diagram showing the series of tracks)

From these measurements, it is possible to estimate the length of a digit of the hind foot of <u>A. californicum</u> if one assumes, contrary to fact, that the phalanges of all digits were approximately of the same length. Thus digit III would be 131.7 mm long. To this may be added 113.7 mm, the length of the metatarsal III, which gives a total of 245.4 mm as the approximate total length of the middle toe bones of that species, as measured from the proximal end of the metatarsal. That figure of 245.4 mm might thus represent the approximate distance between the hind margin of the foot pad to the claw of A. californicum. Such a figure exceeds the distance from the posterior margin of the imprint of the pad to the claw mark of the fossil only by about 10 millimeters. This rough estimate indicates that a species of Arctotherium could have made a track as large as that of the fossil specimen.

Regardless of the general bear-like foot mark, the obvious overstepping habit of the animal as it walked, and this rough agreement as to anterio-posterior dimensions of the fossil track with that of ~~sax~~ Arctotherium, there is still lacking an explanation of the spacing of the outside toes as indicated by the claw-like impressions.

The possible amount of spreading of the toes of an arctothere has not, to the writers' knowledge, been determined. Until that has been ascertained by a careful reconstruction of a foot of one of these mammals, ~~thax~~ no reference of these tracks to a known member of the short-faced bear can be made. It does appear possible, however, that the arctotheres, belonging as they do to a group that early diverged from the true ursids, possibly may have had a foot capable of leaving such impressions as have been found.

In view of these uncertainties, one can only suggest that these tracks may have been formed in late Pliocene or the first half of the Pleistocene by an arctothere-like carnivore, larger than modern bears, and possibly markedly different from any known species of arctotherium.

It appears probable that these tracks were made by a very large animal with a single sole pad, and long claws on each of the five widely diverging toes. The only known Later Tertiary or Quaternary large mammal that would even approximately meet those conditions are the bears. Although the imprints are probably larger than those made by living bears or true extinct ursids, they probably are no larger than might have been made by one of the short-faced bears that were then living in the Western Hemisphere. This possibility is worthy of further consideration, although such a spread of the toes may not have been possible in any known member of that group.

Those arctotheres, arose in the Miocene of Eurasia and they were then represented by Hyaenarctos and later by Indoarctos. A possible representative of the latter Pliocene genus occurs in the Rattlesnake Pliocene beds of Oregon and has been named I. (?) oregonesis ~~Merriamx~~ Merriam, Stock, and Moody (1916). The Rattlesnake fossils include teeth, limb bones, a 5th metacarpa, a 2nd metatarsal and several phalanges.

The arctotheres migrated to South America during the late Pliocene and Pleistocene where they were represented by Arcthotherium (Agriotherium) and other related forms. Arctotherium is also known from the Rancho La Brea deposits of mid-Pleistocene Age (Merriam 1911); at Potter Creek Cave of Northern California (Cope 1879, 1891); Port Kennedy Fissure, Pennsylvania (Cope 1879) and from Alaska (Lambe, 1911).

The foot structure of Arctotherium of the Rancho LaBrea and Potter Creek Cave depoits is much better known and measurements of several bones are given by Merriam (Stock and Merriam 1925).

Woods of Fish Lake, Oregon, and Vicinity

1. Conifer type (Edrexylon spp.). Generalized conifer wood types without (1) apparent (diffuse) parenchyma cells, (2) fusiform rays, or (3) resin canals. In cases of very inferior preservation may include some fine-grained gum-like hardwoods.

.............#20. (some 50); #32. (2)

2.

2. Cedar type (Cupressinoxylon spp. ?). Woods very much like the above but cedar-like in general appearance.

.............#3. (some 40)

3. Cedar type (Cupressinoxylon spp.). Woods like the above but diffuse parenclyma apparent.

.............#2. (9); #22. (9); #31. (1)

4. Sequoia type (Sequoioxylon spp.). Like the above but with traumatic canals apparent, and/or very coarse texture.

.............#4. #30

5. Fir type (Abies spp.). No diffuse parenchyma apparent but traumatic canals present.

.............#5. (3); #21. (6)

6. "Japanese" fir type (Keteleeria spp.). Woods with conspicious festoon of longitudinal canals, not accompanied by transverse (ray) canals.

.............#1. (7); #24. (1)

7. Pine type (Pinus spp.). Woods with scattering single resin canals, all of equal diameter.

.............#23 (1)

8. Oaks (Quercus spp.). Hardwood types with occasional broad rays and vessel flames plus parenchyma strands scattering through the annual rings.

.............#6. Red oak type. #7. Live oak type.

9. Elm type (Ulmus spp.). Woods with initial large pores in strands of one to several followed by wavy bands of small vessel clusters.

.............#9. #34. (2)

10. The remaining hardwoods are highly conjectural, the finer ones being lumped together as "gum woods"...#11, #25, #36 (3); the coarser ones as "laurel"...#8, #10, #26, #33, #35, #37.

11. #27 may be amber.

Age Relationship

The specimens appeared to be in three groups which separation has been maintained by the #"s; group 1 (#1-11); group 2 #20-27), group 3 (#30-37). They seem to be of about the same age and origin.

The age reference suggests early Miocine--for the following reasons:

1. Keteleeria not known to occur later.
2. Pines characterize the early Tertiary.
3. Absence of Douglas firs.
4. Presence of oaks eliminates pre-Tertiary.
5. Presence of elms suggest mid-Tertiary.
6. Many of the hardwoods suggest the "exotics" of the earlier Tertiary.
7. On the whole, the age seems to be mid-Tertiary, at about the level of the earlier Miocene--some 30 million years ago.

George F. Beck
1/23/60

Map No.	Locality	Fossil Type	Age	Identified by / Author / Reference
1	Stukel Mt. Wilson Quarry	Vert. - Peccary	Mid Pliocene	Hough, USGS Newcomb, 1958
2	Bodnar Ranch NWNE Sec. 34, T.37S., R. 11½ E.	Fresh water ~~NWNE sec~~ shells and fish	Pliocene	Hanna - in Myers + Newcomb 195 Yen USGS -
3	NWNE Sec. 36, T. 40S., R. 10E. 2 mi north-east of Merrill	Camel	late Pliocene	Letter from J.A.S. 9/12/68
4	State Line Road SE¼ Sec. 14, T.41S R. 10E.	Vert. (?)	late Pliocene	" " " "
~~5~~	~~Fishhole Creek~~ Hunt Ranch	Fossil Wood 10± species	Early Miocene	George F. Beck. letter to Alfred D. Collier Not on Map
6	Dog Mountain Sec. 18, T. 40S., R. 17E.	Vert. Horse astragalas chalicothere patella artiodactyl astragalus Perissodactyl upper teeth	fossils indicate Barstovian or Clarendonian (?)	Repenning - Walker - 1965 E½ Klamath F AMS Shee
7	Willow Creek Hills NE sec. 20, T39S., R. 18E	Bear ? Tracks	suggests late Pliocene or Early Pleistocene.	Packard, Allison, Cressman - Typed report - not dated N 194
8	Thomas Creek	Rhino tooth Diceratherium	"John Day" lower Miocene	Peterson 1958 letter from JAS. Peterson, 1959
9	Thomas Creek SW sec. 27, T. 37S., R18E	Leaves 5 sp.	tentative mid Miocene	Jackwolfe letter to NP 12/1/58 Peterson 1959
10	Thomas Creek NWNE sec. 34, T. 37S., R. 18E	Leaves Trapa Americana - Knowlton	early Pliocene late Miocene	" " " " " " Peterson - 1959
11	Paisley Hills East Center Johnson Canyon	Absolute - Biotite from quartz monzonite	32.6 ± 0.7 m.y. late early Oligocene	R.L. Armstrong - Yale Univ. Muntzert, J.K. OSU M.S. Thesi 1968
12	Coglan Buttes	Vert. ?	? TH L. Miocene	Walker shows 2 localities in T. ~~31, 33S~~ 34S, R20E. E½ K. Falls Sheet.
13	Coglan Buttes	vertebrates mammalian	John Day equivalent	
14	Ten Mile Butte	vertebrates mammalian	Mid Pliocene	sec. 34
~~15~~	~~NE Abert Lake~~	~~vertebrates~~ mammalian	~~late Miocene~~	
16	Moss Creek	vertebrates mammalian	John Day equivalent	
~~17~~ OK	Harvey Creek	vertebrates mammalian	? late Miocene	
18	Malin	vertebrates mammalian	late Miocene	
19	Hildebrand	Fish	? Pliocene	Worden - Plio-Pleist

Map #	Locality	Fossil Type	Age	Identified By	Reference/author
~~20~~	~~Pope~~	~~Fish~~	~~Plio-Pleist(?)~~	~~Wilson~~	~~personal comm~~
20 ~~21~~	Parker Place W. edge of Sec. 32, T.37S., R.11½E.	Fish	Plio + Pleist (?)	Miller	Personal Comm
21	Worden ~~NE~~¼ sec. 4, T41S., R.8E.	Fish	Plio-Pleist (?)	Wilson R. Miller	Personal Communic
22	Pope Sec. 7 + 8 T.40S., R.11E	Fish	Plio-Pleist	Wilson	personal comm

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REPORT OF ANALYTICAL WORK

POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. F-1233

Date Received: 13 January 1969

Your Reference: Sample #1

Date Reported: 29 January 1969

Submitted by:
Mr. R. L. Oakes
Atlantic Richfield Company
1500 Security Life Bldg.
Denver, Colorado 80202

Sample Description & Locality:
Rhyolite vitrophyre, Thomas Creek, W. edge sec. 27, T37S, R18E. Road rock quarry on N.W. flank of small dome.

Material Analyzed:
Sanidine concentrate, -40/+100 mesh. Estimated composition: Sanidine crystals, 65-75%; Glass, 15-25%; Quartz, 10%. The concentrate was leached with HF prior to analysis.

Ar^{40*}/K^{40} = 0.00047

AGE = 8.1 (±0.5) x 10^6 years.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
0.00234	0.291	0.00246
0.00257	0.447	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
4.314	4.257	5.194
4.200		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$\text{AGE} = \frac{1}{\lambda_e + \lambda_\beta} \ln \left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1 \right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.

Geochron Laboratories, Inc.

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REPORT OF ANALYTICAL WORK

POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. B-1234

Your Reference: Sample #2

Submitted by: Mr. E. L. Oakes
Atlantic Richfield Company
1500 Security Life Bldg.
Denver, Colorado 80202

Date Received: 13 January 1969

Date Reported: 29 January 1969

Sample Description & Locality:

Quartz₃ Valley Mountain Vitrophyre Biotite, hornblende (?) rhyo-dacite Center sec. 23, T.37S., R.16E. North fland quartz₃ Valley Mountain.

Material Analyzed: Biotite concentrate, -60/+200 mesh, Estimated composition: Fresh biotite of euhedral aspect, 95+%; Greenish-brown amphibole, less than 5%, others, traces only.

Ar^{40*}/K^{40} = 0.00044

AGE = 7.6 (±0.4) x 10^6 years.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
0.00371	0.278	0.00354
0.00337	0.290	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
6.544	6.534	7.971
6.524		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.

Stearns, H. T., 1936, Origin of the large springs and their alcoves along the Snake River in southern Idaho: Jour. Geology, v. 44, no. 4, p. 429–450.

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136. ALKALIC LAVA FLOW, WITH FLUIDITY OF BASALT, IN THE SNAKE RIVER PLAIN, IDAHO

By Howard A. Powers, Denver, Colo.

Fine-grained alkalic lava of middle Pleistocene age occupies an area about 10 miles long and 1 mile wide near King Hill, Idaho. Three separate sheets of the molten rock, each less than 30 feet thick, flowed down a gentle slope, the gradient of which decreases from 80 feet per mile to 25 feet per mile. The distribution and thickness of the flow units indicate that the fluid lava had as great mobility as that of the common basalt in the area, which contains labradorite plagioclase.

The upper parts of the flow units are black and are aphanitic to glassy; their vesicular texture resembles that of Swiss cheese. The internal and basal parts are holocrystalline but very fine grained. Olivine and plagioclase are the only minerals visible in the hand sample, mostly as microphenocrysts less than 1 mm in greatest dimension. Rare tablets of plagioclase, only a millimeter thick but as much as 2 cm long by 2 cm wide, are characteristic of one flow unit.

The microscopic texture is dominated by stubby tablets of plagioclase, commonly in jackstraw pattern, but locally oriented in flow pattern. Interstitial spaces are occupied by euhedral to subhedral crystals of clinopyroxene, olivine, magnetite, ilmenite, and apatite, and by patches of anhedral alkali feldspar. The plagioclase is sodic andesine, about An_{35}. The olivine ranges from Fo_{40} to Fo_{25} as determined by powder X-ray diffraction pattern (Yoder and Sahama, 1957, p. 484). The clinopyroxene is iron rich and probably also titanium rich because there is not enough visible ilmenite to account for all of the TiO_2 found by chemical analysis.

The rock is too fine grained for modal analysis, but the computed norm has been adjusted to approximate the mineral content, as shown in the table below. Some *ab* was combined with the *or* in orthoclase, and most of the TiO_2 was allotted to pyroxene. The olivine was computed to agree with the composition indicated by X-ray analysis.

Lava of the composition shown by these analyses does not fall within the range of basalt adopted by Green and Poldervaart (1955), because it is too low in lime and magnesia, and too high in potassia and phosphate. Nor does the composition match that of any igneous rock average in the compilation of Nockolds (1954). The ratio of lime to alkalies in the King Hill Rock approximates that of Nockolds' average alkali doreite, but the King Hill rock is lower in total feldspar, and higher in iron, titania, and phosphate. In content of silica and alumina, the King Hill rock compares reasonably with the average alkali andesite. It is significantly higher than average alkali andesite, however, in titania, total iron, potassia and phosphate and it is much lower in magnesia and lime.

TABLE 136.1.—*Chemical and approximate mineral composition of lava near King Hill, Idaho, as determined from five analyses*

[D. F. Powers, U.S. Geological Survey, analyst]

	Results of 5 analyses			Approximate mineral composition	
	Average	Range	Norm		
SiO_2	49.45	47.17–51.23	Q .15		
Al_2O_3	13.71	13.34–14.45	or 14.7	Alkali feldspar	16
TiO_2	3.32	4.15– 2.90	ab 28.8	Plagioclase An_{35}	42
Fe_2O_3	3.07		an 14.6		
		15.45–13.27		Clinopyroxene	31
FeO	11.28		wo 4.1		
				Olivine	2
MnO	.22	.24– .20	fs 13.2		
MgO	3.68	4.42– 3.33	en 9.2		
CaO	6.77	7.68– 6.36	il 6.2	Ilmenite	.5
Na_2O	3.39	3.18– 3.54	mt 4.4	Magnetite	4.4
K_2O	2.43	2.00– 2.60	ap 3.4	Apatite	3.4
P_2O_5	1.40	2.05– .90			
H_2O	.80	.41– 1.09			

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Nockolds, S. R., 1954, Chemical compositions of igneous rocks: Geol. Soc. America Bull., v. 65, no. 10, p. 1007–1032.

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137. A DISTINCTIVE CHEMICAL CHARACTERISTIC OF SNAKE RIVER BASALTS OF IDAHO

By HOWARD A. POWERS, Denver, Colo.

The basaltic rocks, of Pliocene to Recent age, from the Snake River valley in southern Idaho are shown by chemical analyses to have a high degree of consanguinity. These basalts may constitute a *clan* in the sense proposed by Tyrrell (1926, p. 136)—that is a group of rocks with the highest degree of consanguinity within a *kindred*.

Preliminary comparisons have shown, also, that the Snake River basalts differ significantly from other basalts of the northwestern United States. One prominent difference is portrayed in figure 137.1, a three-component plot of the ratios between silica, magnesia, and total iron plus manganese in chemical analyses. The diagram shows these ratios for all available analyses of Snake River basalts (except one of a nepheline basalt and a few that contain less than four percent by weight of magnesia) together with all the available analyses of Columbia River basalts, as compiled by A. C. Waters (1960). To represent the basalts of the Cascades, two sample groups of analyses containing more than three percent magnesia were arbitrarily chosen; one sample group was from near Mount Lassen and the other from near Mount Hood.

The rocks from the Snake River valley are all lower in silica than those from other areas. In the Snake River clan, moreover, the silica generally decreases as the ratio of iron to magnesia increases, whereas the opposite is true of the other rocks. The reasons for these and other differences may become apparent as more data are accumulated.

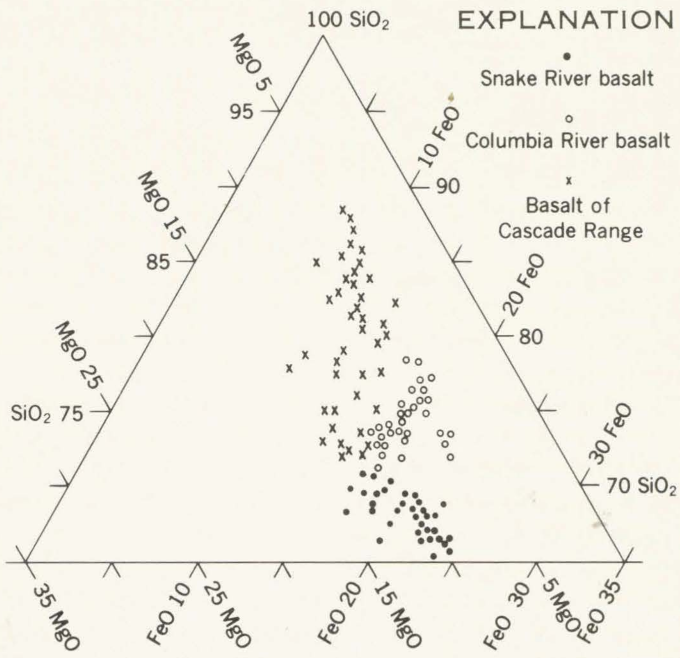

FIGURE 137.1.—Ratios between SiO_2, MgO, and total iron plus manganese in some basalts of the northwestern United States. Data plotted are weight percent of SiO_2, MgO, and sum of $FeO+0.9Fe_2O_3+MnO$ computed to 100 percent.

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Waters, A. C., 1960, Stratigraphic and lithologic variations in the Columbia River basalt: Am. Jour. Sci. (in press)

138. AGE AND CORRELATION OF SOME UNNAMED VOLCANIC ROCKS IN SOUTH-CENTRAL OREGON

By GEORGE W. WALKER, Menlo Park, Calif.

Fragmentary collections of vertebrate fossils from several newly discovered localities in southeastern Lake County, Oreg., (fig. 138.1) indicate that the enclosing rocks are of approximately the same age as certain Miocene volcanic rocks of central Oregon and adjacent parts of Nevada and California.

The fossils, consisting principally of bone fragments and teeth that have weathered out of tuffaceous beds, apparently represent a single fauna including *Merychippus*, Camelidae, *Dromomeryx* sp. (tentative identifications by G. E. Lewis, 1959), and other mammalian genera. According to Lewis, this fauna is comparable to that of the Mascall formation of Grant, Crook, and Jefferson Counties, Oreg., (Downs, 1956); it also resembles the mammalian faunas from Beatty and Corral Buttes, Oregon (Wallace, 1946), and Virgin Valley, Nevada (Merriam, 1910), all of which are considered to be of late middle to early late Miocene age.

Andesitic and rhyodacitic volcanic rocks of comparable age, mapped by Russell (1928) as the upper part of the Cedarville series, are exposed in northeastern California and northwestern Nevada. The age assignment of these rocks and their correlation with the Mascall formation is based on studies of fossil floras by Chaney (*in* Russell, 1928) and LaMotte (1936).

The vertebrate-bearing strata of southeastern Lake County are in a section several hundred feet thick largely composed of fine-grained poorly bedded silicic tuff and tuffaceous sedimentary rocks that range in color from pale yellowish-orange to tan, yellow, and light gray. These strata were probably deposited for the most part on dry land, but to a minor extent in shallow lakes. Near major volcanic centers of south-central Oregon some of the fine-grained tuffaceous rocks grade laterally into coarse pumice lapilli tuffs, and interstratified layers of sintered or welded tuff become more abundant. These pyroclastic rocks rest with angular discordance on an extensive series of basalt flows locally more than 1,000 feet thick. Flows near the top of the series consist of ophitic to subophitic diktytaxitic, locally olivine-bearing, basalt that contains little mafic glass; in some of these flows plagioclase pheno-

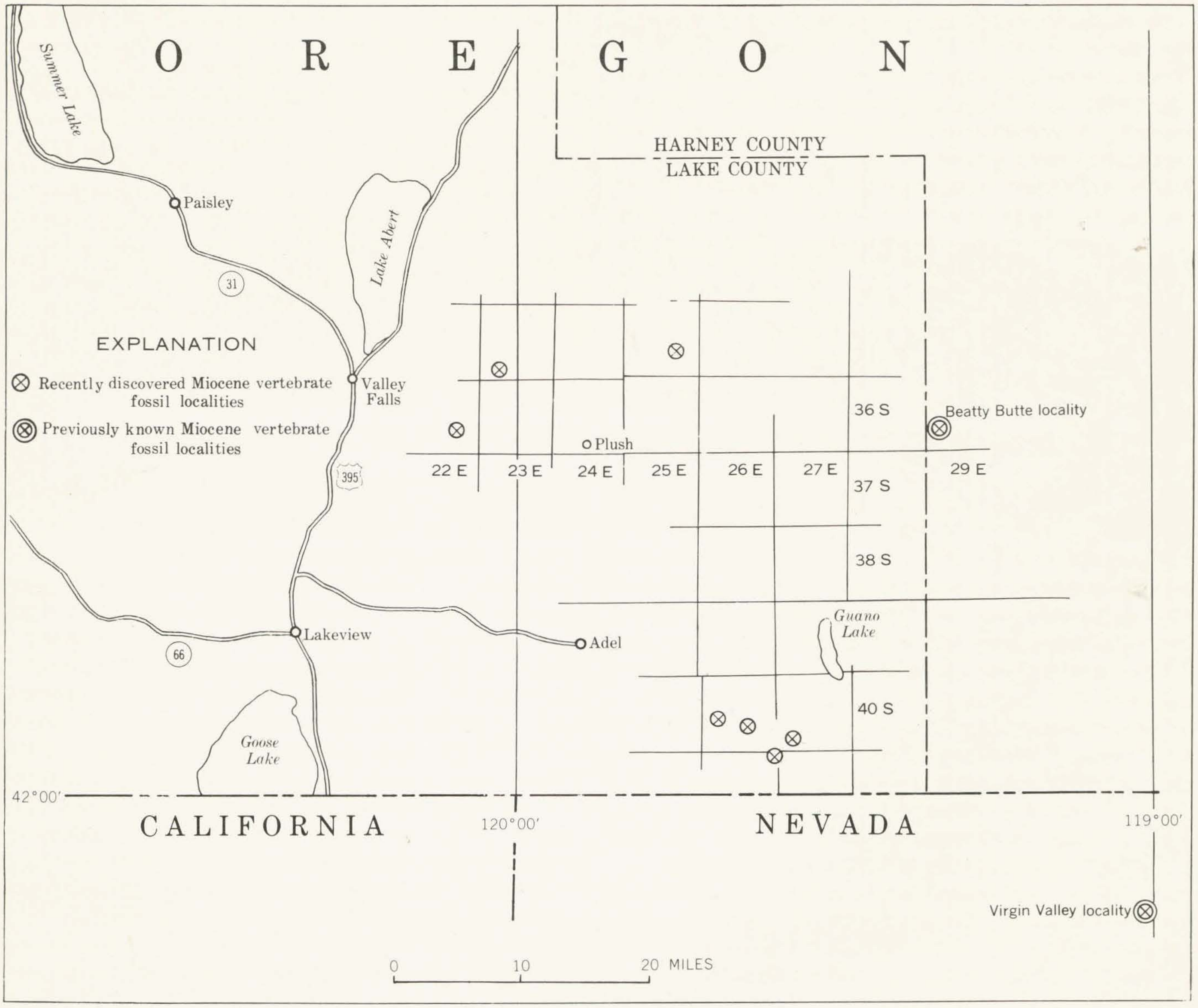

FIGURE 138.1.—Index map showing distribution of Miocene vertebrate fossil localities.

crysts are abundant. These flows are fresh; the constituent minerals reveal only slight evidence of alteration. Other flows, chiefly in the lower part of the basalt series, contain altered phenocrystic and groundmass olivine, altered mafic glass, and zeolites. Dustlike grains of hematite appear on plagioclase cleavage surfaces and surfaces of discontinuity between crystals. Beneath the basalts are silicic pyroclastic rocks lithologically similar to, and probably correlative with, pyroclastic rocks exposed several tens of miles to the west; the latter have been dated as of lower Miocene or John Day age on the basis of a *Diceratherium* tooth, or possibly of middle Miocene (Hemingfordian) age on the basis of fossil plants collected from the same beds that contained the tooth (Peterson, 1959). These rocks in turn are underlain discordantly, south and southeast of Paisley, by andesitic volcanic rocks presumably of pre-Miocene age.

The general sequence of Miocene and older volcanic rocks in southern Lake County is similar to that which comprises the Clarno, John Day, Columbia River, and Mascall formations of central Oregon, but differs from it in some details, particularly in the mineralogy and physical characteristics of the mafic flow units. The late middle to early late Miocene silicic tuff and tuffaceous sedimentary rocks of southeastern Lake County are roughly similar in bulk lithology to rocks of comparable age in Virgin Valley, Nev. Although both these units are apparently of the same age as the upper part of the Cedarville series, exposed in northeastern California and northwestern Nevada, similarities in bulk lithology between the two sections are not obvious.

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139. UPPER TRIASSIC GRAYWACKES AND ASSOCIATED ROCKS IN THE ALDRICH MOUNTAINS, OREGON

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Upper Triassic rocks aggregating 40,000 to 50,000 feet in maximum thickness occupy a triangular area about 35 miles from east to west and 16 to 18 miles from north to south in the Aldrich Mountains, Oregon. These rocks are mainly volcanic graywackes and shales, andesitic tuffs, basaltic lavas, and conglomerates that include boulders and fragments of Upper Triassic sedimentary rocks. Slide breccias consisting largely or entirely of basement rocks characterize parts of the section, and the graywackes are in large part turbidites. Although most individual beds or corresponding volcanic units are lenticular and of relatively small extent, angular unconformities and differences in lithology make it possible to recognize three major stratigraphic divisions.

The oldest of these comprises three members (fig. 139.1). The lowest member, exposed near the western edge of the area, west of the fault which crosses Murderers and Deer Creeks, is at least 8,000 feet thick; it is dominantly conglomeratic but includes some basalt flows near the base. The middle member, which occupies the northwestern part of the map area between Fields and Riley Creeks, is 17,000 to 18,000 feet thick. The lowest 5,000 feet of this member is characterized by slide breccias and volcanic flows and breccias interlayered with mudstone and shale, the middle part by mudstones, shale, and graywackes, and the upper 3,000 to 8,500 feet by massive tuff. The upper member is a wedge of interbedded tuff, graywacke, and shale which lies with its thin edge at Riley Creek Butte, near the center of the map, and thickens to 10,000 or 11,000 feet near Fall Mountain, 8 miles to the east.

The middle division is a relatively uniform sheet, 1,000 to 2,000 feet thick, which forms the only stratigraphic unit that can confidently be traced across the map area. It contains no volcanic rocks, and consists