PETROGRAPHY OF THE RATTLESNAKE FORMATION AT THE TYPE AREA, CENTRAL OREGON

By Harold E. Enlows

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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ABSTRACT

The Rattlesnake Formation of Pliocene age at its type area in central Oregon consists of two fanglomerate members separated by a thin, poorly zoned rhyodacite ignimbrite sheet resulting from a single ash flow. The fanglomerates are the result of fluviatile deposits in the valleys of the ancestral John Day River and its tributaries. The sediments were derived from the highlands adjacent to the river valleys, and the clasts reflect the bedrock geology of these highlands. The Formation is presently found as terrace deposits as much as 1,350 feet above the level of the present river system.

Sediments consist largely of mafic volcanic clasts with minor smectite pseudomorphs after volcanic grains, glass shards, plagioclase, augite and magnetite, and a matrix of glass and mafic volcanic grains and their smectite pseudomorphs, feldspar, magnetite, and augite. The only important cement is authigenic smectite coating grains and filling interstices.

The ignimbrite tongue extends beyond the underlying fanglomerate, resting upon older bedrock at what must have been the edges of the ancestral stream valleys. The less resistant overlying sediments are commonly removed, leaving the ignimbrite as the sole representative of the Formation at many exposures. It consists largely of glass shards, pumice fragments and accidental inclusions picked up from the terrain over which it flowed. The constituents are unwelded to poorly welded in a thin basal and a thicker top zone, and firmly welded in a central columnar zone.

Post ash-flow uplift has folded the Formation into a broad northward-plunging trough.

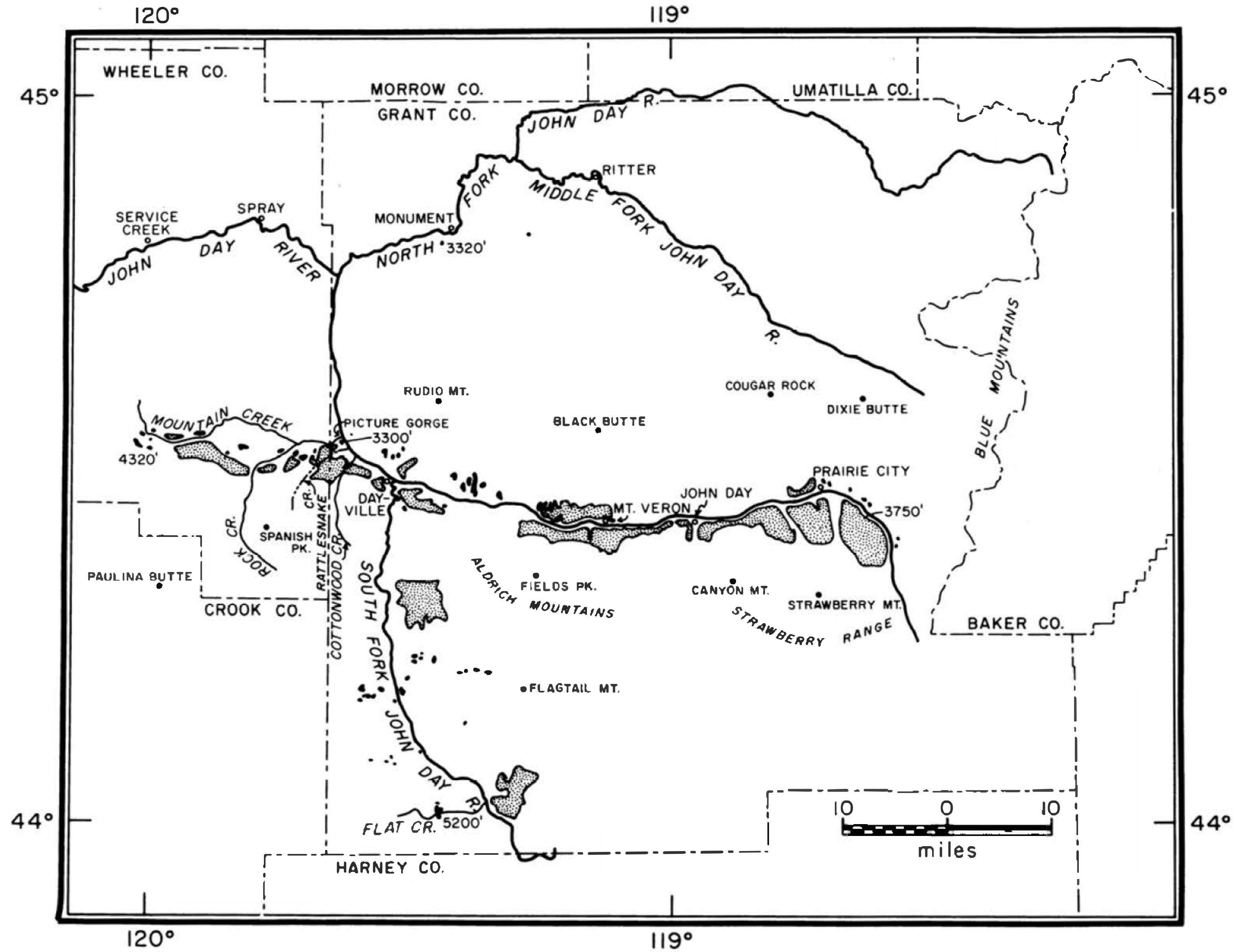

Figure 1. Outcrop of the Rattlesnake Formation in the drainage of the John Day River. Elevations are on the base of the Rattlesnake Ignimbrite Tongue. (Adapted from Brown and Thayer, 1966; Davenport, 1971; Wallace and Calkins, 1956; Oles and Enlows, 1971; and unpublished data of Wilkinson and Enlows.)

INTRODUCTION

J. C. Merriam (1901, p. 301) named the Rattlesnake Formation of the John Day Basin from an occurrence on Rattlesnake Creek, "... about one mile west of Cottonwood." Later, Merriam and others (1925, p. 54-55) stated that, "The area of Rottlesnoke exposed in the butte west of Picture Gorge has generally been termed the type section, and although it really represents but o small port of the entire succession within the formation, it was subjected to more careful study than elsewhere, due to the presence of mammalian fossils in the tuff and in the gravel." Capping the section in the butte west of Picture Gorge is a rock unit they referred to as a "rhyolite flow" or the "Rattlesnake rhyolite." They also stated (1925, p. 55), "On Cottonwood Creek and in practically all Rattlesnake areas east of Picture Gorge, however, a very considerable thickness of grovels overlies the rhyolite." Wilkinson (1950) first recognized the ash-flow origin of Merriam's "rhyolitic lava."

Upon initiation of a restudy of the Rattlesnake Formation (Enlows, 1973; Enlows and others, 1973) it was decided as a first step to locate, measure, and describe the type section of the formation with considerable care. Two locations were chosen, one on Rattlesnake Creek ond one on Cottonwood Creek, and the composite section appearing in Appendix 1 was measured and described. Petrographic examinations were mode of both the sedimentary sequence and the "rhyolite" at these locations.

GEOLOGIC SETTING

The Rattlesnake Formation at the type section has been subdivided by the author into three members as listed in Table 1. Its areal distribution in the John Day drainage is shown in Figure 1.

There seems little doubt but that fluviatile deposition in the ancestral valley of the John Day River and its tributaries resulted in the grovels, sands, and mudstones forming the Rattlesnake Formation. The sediments were derived from highlands adjacent to the river valleys. Alluvial fans built into the valleys coalesced at the foot of the highlands and formed alluvial piedmont plains which merged basinward into the alluvial plain of the ancestral John Day River or the alluvial plains of some of the larger tributaries. The composition of the clasts in the sediments records the bedrock geology of the adjacent highlands.

The down-cutting John Day River and its tributaries have subsequently partially removed the Rattlesnake, leaving remnants behind as terraces high above the present river level. The high-level terraces ore generally remnants of the alluvial piedmont plains of the ancestral depositional basin, whereas the more centrally located alluvial plain of the ancestral John Day River has been largely or completely removed, as hove the alluvial plains of the larger tributaries such as the South Fork and the North Fork of the John Day.

The Rattlesnake Ignimbrite Tongue is the result of a short-lived catastrophic volcanic eruption which momentarily interrupted the period of fluviatile deposition. The ash flow forming the ignimbrite not only covered the deposits of the alluvial piedmont plains and the alluvial plains of the rivers, where the ignimbrite can be seen resting upon Rattlesnake sediments, but it also lapped up onto the bedrock rimming the valleys, where it is observed resting directly upon older bedrock. Erosion following emplacement of the ignimbrite tongue destroyed it locally, furnishing ignimbrite debris for the overlying fanglomerate member, but at other places fan deposition covered it rapidly enough to allow partial or complete preservation.

The Rattlesnake has been observed resting unconformably upon rocks as old as Paleozoic and as young as the Miocene Moscoll Formation. It is difficult to place an upper limit on the age of the formation because it is generally not covered by an easily recognized marker bed of definite age, and the coarse fanglomerate of the upper member seldom contains recognizable fossils. Merriam and others (1925),

Table 1. Field description and thickness of the members of the Rattlesnake Formation in the type area

Member	Thickness Meters	Field description
Upper Fanglomerate Member	112.78	Coarse fanglomerate of remarkably uniform lithology. Boulders 1 m in diameter are encountered; more commonly the framework is composed of smaller boulders, cobbles and pebbles. Framework clasts rounded to sub-angular consisting predominantly of Picture Gorge Basalt; Rattlesnake Ignimbrite also found. A crude bedding is formed of thin discontinuous lenses of coarse sandstone. Poorly cemented, commonly slope-forming.
	disconformity	
Rattlesnake Ignimbrite Tongue	12.46	A single flow unit and a simple cooling unit. Separated into three zones: a thin, light-gray, poorly welded base; a brownish-gray, moderately to firmly welded middle part displaying vertical columnar structure; and a pale red, poorly welded upper zone.
	disconformity	
Lower Fanglomerate Member	66.33	Fanglomerate with thick interbeds of yellowish-gray massive volcanic wacke and grayish-orange massive volcanic mudstone in the ratio of 63% fanglomerate, 21% mudstone, and 16% sandstone. These textural units are thick discontinuous lenses rather than laterally continuous layers.
	angular unconformity	
Total	191.57	

and more recently the author, found fragmentary mammalian fossils in the lower port of the Upper Fanglomerate Member at the type section, and Davenport (1971) found o considerable mammalian fauna in the sediments above the Rattlesnake Ignimbrite Tongue in the Paulina Basin. Little could be determined from the fossils found by the author at the type section but J. A. Shotwell (1969, oral communication) identified the fossils in the Paulino Basin outcrop as typical Rattlesnake fauna of Hemphillian age. Merriam and others (1925, p. 58) stated:

> "Through the accumulated Rattlesnake deposits deep canyons have been cut, and in the lower reaches of these excavations ore deposits containing o Pleistocene fauna. The age of the Rattlesnake Formation is, therefore, limited on one side by a period of erosion and deformation succeeding accumulation of the Moscall Miocene, and on the other side by a period of erosion preceding accumulation of deposits of Pleistocene age."

Thayer (1956 a,b,c) suggested that the uppermost terrace fanglomerates of the Rottlesnake may be of Pleistocene age, and it seems likely that at certain outcrops this age is true. However, the author found no convincing evidence suggesting a Pleistocene cap on the Upper Fanglomerate Member of the type section. On the contrary, the evidence cited by Merriam and others (1925), the lack of a significont stratigraphic break, and the high topographic position of these terrace gravels (locally 1,350 feet above the present river level) indicate that the Upper Fanglomerate Member at the type section should be dated as Pliocene only.

The Rattlesnake was placed in the provincial time term Hemphillian by the Wood committee (Wood and others, 1941), and no information has since been discovered which would alter this decision.

Figures 2 through 7 illustrate the stratigraphy and lithology in the type section.

STRATIGRAPHIC SEQUENCE

Lower Fanglomerote Member

The lower member can best be described in terms of three typical rock types which are not only interbedded but which grade one into the other both vertically and laterally.

Fanglomerate

This rock type is poorly consolidated and extremely porous. Framework clasts correspond in composition to the local pre-Rattlesnake bedrock geology. At the type section, only clasts of Picture Gorge Basalt were identified, but in the John Day Valley west of the type section,Clarno andesites, dark metavolcanics and metasediments, dark chert, and ultramafic to acidic plutonites are common. Basalt textures at the type section range from scoriaceous through dense aphanitic to porphyritic and fine- to medium-grained granulor, and shapes range from well rounded to subangulor. Boulders up to a meter in diameter are present, but the clasts are more commonly in the cobble- to pebble-size range.

The matrix of the type-section fanglomerate consists of yellowish-gray (5Y 7/2) sand, the composition and shape of the groins varying with the grade size as given below.

Very coarse sand: Almost exclusively fresh mafic volcanic grains with occasional quartz or feldspar; well rounded to subangular but mostly rounded.

Coarse sand: Predominantly mafic volcanic grains, many red and altered, many feldspar grains; grains rounded to subangular.

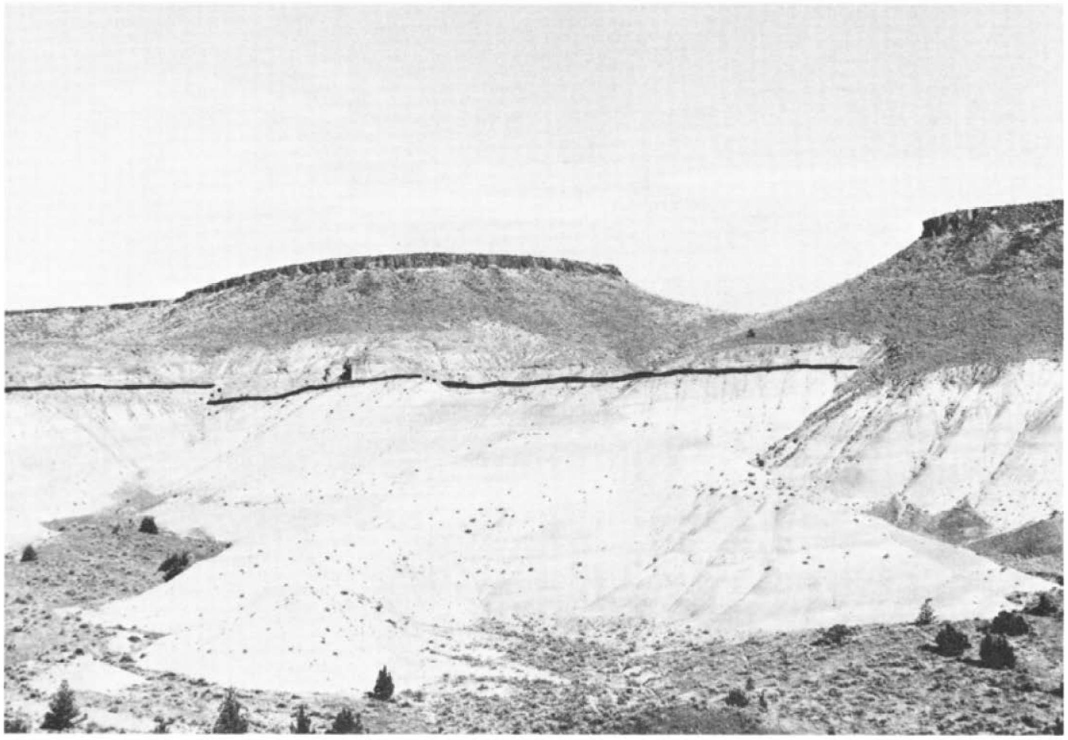

Figure 2. Lower Fanglomerate Member overlying Mascall Formation and capped by Rattlesnake Ignimbrite Tongue, type section on Rattlesnake Creek.

Figure 3. Lower Fanglomerate Member resting on Mascall Formation (contact obscured), type section on Rattlesnake Creek.

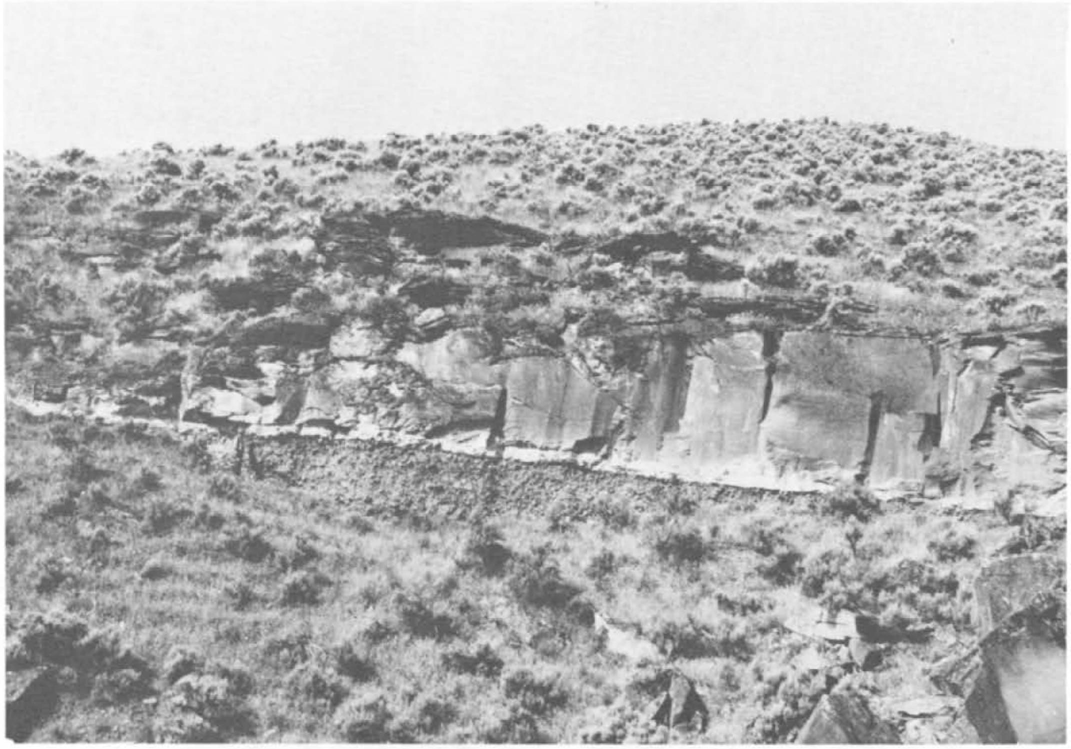

Figure 4. Rattlesnake Ignimbrite Tongue between the Lower Fanglomerate and Upper Fanglomerate Members, type section on Cottonwood Creek.

Figure 5. Contact of the Upper Fanglomerate Member and Rattlesnake Ignimbrite Tongue, type section on Cottonwood Creek.

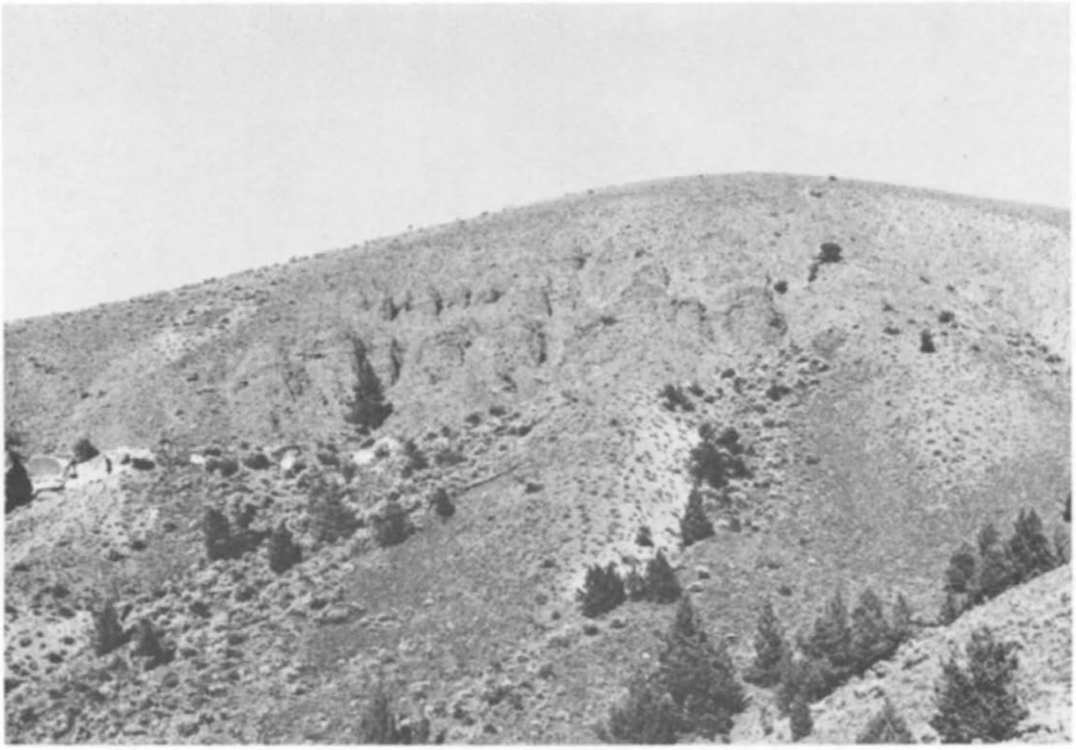

Figure 6. Ninety meters of the Upper Fanglomerate Member resting on Rattlesnake Ignimbrite Tongue, type section on Cottonwood Creek.

Figure 7. Boulders and cobbles of Upper Fanglomerate Member with large shattered boulder of Rattlesnake ignimbrite (on the right), type section on Cottonwood Creek.

Medium sand: Predominantly mafic volcanic groins, many red but some waxy white, green and orange; X-ray analyses of these altered white, green and orange grains yield peaks consistent with smectite, clinoptilolite, and plagioclase; feldspar common; grains subrounded to subangular.

Fine sand: Feldspar and lithics equally abundant, most of the lithics altered to white, green, orange, and red masses of hematite, smectite, and clinoptilolite; augite and magnetite common; grains angular to subangular.

Very fine sand: Altered lithics and feldspar with minor augite and magnetite; groins angular.

Silt and cloy: Smectite, some recognizable as waxy white, green, or orange alterations of volcanic lithics, feldspar, magnetite and augite; X-ray analyses of clay fractions indicate smectite only.

The sparse cement coating some of the grains and filling interstices is smectite.

Volcanic wacke

This rock type makes up a very high proportion of the Lower Fanglomerate Member. It is grayish brown (5YR 3/2), yellowish gray (5Y 7/2), or grayish orange pink (10R 8/2), commonly contains pebbles or granules, and is very porous and poorly consolidated. Mechanical analyses for random samples token from two typical wacke units give the results in Table 2. The composition of the framework varies with the grade size as given below.

Pebbles and granules: Fresh mafic volcanic fragments except for a rare quartz pebble; clasts well rounded to subrounded.

Very coarse sand: Predominantly grains of mafic volcanics, some red but mostly fresh, feldspar common; clasts rounded to subangular.

Coarse sand: Predominantly groins of mafic volcanics, many altered to red, waxy brown, or orange pseudomorphs yielding X-ray patterns of smectite and clinoptilolite, feldspar common; grains rounded to subangulor.

Medium sand: Predominantly mafic lithics or pseudomorphs of lithics, feldspar common; grains subrounded to subangular.

Fine sand: Feldspar, groins of mafic volcanics and smectite pseudomorphs, minor augite and magnetite; clasts angular to subangular.

Very fine sand: Feldspar and smectite pseudomorphs abundant, fresh mafic lithics common, minor augite and magnetite; clasts angular.

Silt and clay: Smectite, some recognizable as pseudomorphs after pyroclastic shards and bubble walls; much glass, some still vitric but mostly devitrified; minor feldspar and magnetite. The cloy fractions, both larger and smaller than 2 microns, are entirely smectite.

The sparse cement in the wacke is smectite.

Table 2. Mechanical analyses of two typical samples of the pebbly volcanic wacke from the Lower Fanglomerate Member.

Grade size	Unit #2	Unit #6
Pebbles	23%	7%
Granules	3	1
VC sand	15	6
C sand	24	32
M sand	19	23
F sand	7	13
VF sand	3	7
Silt and clay	5	10

Volcanic mudstone

Grayish-orange-pink (10R 8/2) to yellowish-gray (5Y 8/1) mudstone, commonly sandy, porous, friable and poorly bedded, forms the third and least abundant lithic variety of the Lower Fanglomerate Member. A mechanical analysis of Unit #5, which was token as a typical mudstone, yielded 18 percent sand, 68 percent silt, and 14 percent clay. The composition and texture of the fragments vary with grade size as follows:

Coarse sand: Mafic volcanic grains, pumice, and minor feldspar. The mafic lithics ore red to orange, altering to hematite and smectite; the pumice is devitrified and partially altered to smectite; grains ore rounded to subangular.

Medium sand: Chiefly devitrified and altered pumice, occasional feldspar and altered mafic volcanic lithics; grains angular to subangular.

Fine sand: Devitrified and altered pumice and glass shards, altered mafic lithics, feldspar, and magnetite, an occasionl fragment of chalcedony; grains angulor to subangular.

Very fine sand: Devitrified and altered pyroclastic shards, some completely altered to smectite; much feldspar and chalcedony; magnetite common; all clasts angular.

Silt: Feldspar, magnetite, chalcedony, and abundant devitrified or completely altered pyroclastic shards and bubble walls.

Cloy: The clay fractions both larger than and smaller than 2 microns give very strong peaks for smectite and a very weak 10 A° mica peak.

Rattlesnake Ignimbrite Tongue

Field relations and source

The Rattlesnake Ignimbrite Tongue of the type area is a single ash-flow unit that appears to have entered the ancestral John Day drainage system from the south by way of the volley of the present South Fork of the John Day River. Originating in the Horney Basin, probably in the Buzzard Creek area according to Parker (1974), the ash flow spread southward into the northern port of Cotlow Valley, onto the flanks of Hart Mountain and Poker Jim Ridge and northward across what is now a mountainous divide separating north-flowing and south-flowing streams and into the drainage of the ancestral Crooked River and the South Fork of the John Day River. (A more comprehensive report on the Rattlesnake Ignimbrite Tongue prepared by Enlows, Parker, and Davenport will appear later.) Remnants can be found in the upper reaches of the John Day River as far east as sec. 17, T. 13 S., R. 34 E. southeast of Prairie City; in the drainage of the North Fork of the John Day River near Monument (SW$\frac{1}{4}$ sec. 2, T. 9 S., R. 28 E. and NW$\frac{1}{4}$ sec. 23, T. 9 S., R. 27 E.); and west as far as the headwaters of Mountain Creek in sec. 7, T. 12 S., R. 23 E. To the south of the present John Day drainage system the ignimbrite can be correlated with the uppermost ignimbrite of the Danforth Formation and certain textural changes can be noted. However, the present discussion will be limited to that part of this huge sheet presently found in the John Day drainage.

The thickness of the ignimbrite sheet was originally controlled by the topography and the distance from the source but was later modified by erosion. The maximum thickness found in the John Day drainage is 36.58 m, but at many localities erosion has reduced it to a few meters or it has been completely removed. Throughout the John Day drainage, except for the outcrop southwest of Prairie City, the ignimbrite corresponds closely to what Martin (1959) termed a "poorly zoned ignimbrite." It is thin, contains abundant pumice lapilli or blocks, and the glass shards are commonly vitreous or very weakly devitrified and plainly visible. There is seldom a zone of dense glass or even a zone of dense welding. It is commonly zoned into a thin, unwelded or poorly welded base of light-gray (N6 or N7) color and unmodified vitroclastic texture, a thick moderately to firmly welded central part which is yellowish gray (5Y 7/2) to pale yellowish brown (10YR 6/2) with eutaxitic texture and columnar structure, and an upper poorly welded zone with poor eutaxitic texture, a pinkish-gray (5YR 8/1) color, and horizontal platy structure. Because of erosion, the poorly welded zone may be missing. Where present it is always thin; a true non-welded upper zone with unmodified vitroclastic texture has not been found.

The pumice fragments found in the ignimbrite are white and when flattened seldom show cross-sections longer than 4 to 5 cm, although serious search in most outcrops will reveal a few 8 to 9 cm long.

The outcrop southwest of Prairie City is thin and non-welded, has a true vitroclastic texture throughout, and the pumice fragments are generally no more than 1 cm in diameter. It is thought to have been deposited near the distal edge of the ash flow, probably formed of the finer, cooler, faster moving material near the top of the flow. The outcrops at Monument and in the headwaters of Mountain Creek, which are also thought to be located close to the edge of the ash-flow sheet, exhibit very small pumice fragments, never over 6 cm in diameter, with the largest always found near the base of the flow.

The entire ignimbrite sheet contains sand grains, pebbles, and cobbles picked up from the surface over which the flow moved (Figures 8 and 9). These accidental inclusions are largely of mafic volcanic composition, but they vary with the composition of the soil and gravel over which the ash flow moved; minor quantities of black chert, quartzite, vein quartz, greenstone, or dark fine-grained metamorphics are found locally. The basal unwelded zone of the ignimbrite is commonly rich in rounded accidental clasts, at places as large as 46 cm in diameter. These rounded inclusions commonly are isolated in a matrix of ash but locally are so numerous as to lie in contact with each other. Isolated lenses of cobbles and pebbles are found far above the base in certain exposures, and one well rounded cobble 7.6 cm in diameter was found 6 m from the base.

Particularly well developed in exposures near Mount Vernon, but seen also in other outcrops, are nearly vertical pockets or tubes of pebbles and cobbles bound in an ashy matrix (Figure 9). The eutaxitic texture of flattened pumice fragments extends through the matrix of these vertical pipes, indicating that they are pre-compaction phenomena. Pebbles and cobbles may be rounded to angular but are most commonly rounded. The vertical tubes are near the base of the ignimbrite sheet but in no case could an actual contact with either the underlying or overlying fanglomerate member be found. One typical tube started 3.65 m from the base, extended upward for 2.5 m and reached a diameter of 41 cm. It contained several well rounded cobbles 6 to 8 cm in diameter. The matrix was in no way different from the rest of the ignimbrite mass. These tubes are considered spiracles formed when the ash flow crossed water-saturated gravel. Explosive steam jets were generated, forcing the gravel upward into the ash flow in a fashion similar to that described by Waters (1960) in lava flows.

Although cobbles are lacking, pebbles and sand-sized grains of accidental origin are found in the top, poorly welded zone of the ignimbrite, where they are much more sparsely distributed than in the

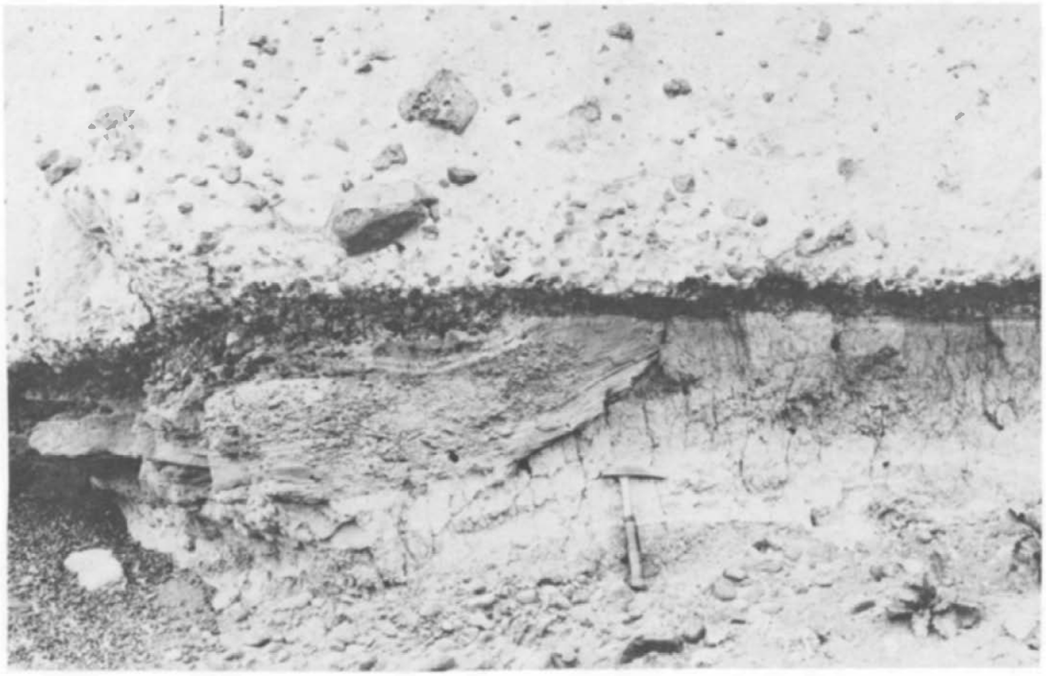

Figure 8. Cobbles and pebbles of basalt enclosed in the poorly welded base of the Rattlesnake Ignimbrite Tongue on Cottonwood Creek.

Figure 9. A vertical tube of basalt and greenstone pebbles and cobbles in the Rattlesnake Ignimbrite Tongue near Mt. Vernon.

lower zones. The presence of so much accidental debris, some found in the uppermost parts of the ignimbrite, suggests a violently turbulent and rapid flow despite the seventy miles the ash flow had traveled from its source prior to arrival in the ancestral John Day Valley.

Present elevations on the Rattlesnake Ignimbrite Tongue indicate differential uplift of what must have been a relatively broad, flat Pliocene drainage system sloping north from a volcanic center in the present Harney Basin. The ash flow apparently moved northward, unobstructed by the present topographic high, down the ancestral John Day Valley. Post-ash-flow uplift has folded that part of the ignimbrite now found in the John Day drainage into a broad northerly plunging trough down the axis of which flows the South Fork of the John Day River and the John Day River itself north of Picture Gorge. Uplift must have been vigorous in immediate post-ash-flow time. The Lower Fanglomerate Member of the type section exhibits a vertical section consisting of 63 percent fanglomerate with clasts seldom coarser than cobbles, 21 percent sandstone, and 16 percent mudstone. The Upper Fanglomerate Member consists of a single fanglomerate unit rich in boulder-size clasts.

Along Flat Creek near the summit of the drainage divide (Figure 1) in T. 18 S., R. 27 E. the base of the ignimbrite lies at 5,200 feet. Thirty-five miles north of Flat Creek at Picture Gorge the elevation is 3,300 feet, and in the drainage of the North Fork of the John Day River 25 miles NNE of Picture Gorge a remnant of ignimbrite is found along Dry Creek at 3,320 feet. The easternmost outcrop on the John Day River is south of Prairie City, 50 miles east of Picture Gorge, and here the ignimbrite lies at 3,750 feet. In the headwaters of Mountain Creek, 20 miles west of Picture Gorge, the ignimbrite is found at 4,320 feet.

Texture

In addition to the vitroclastic texture, good to fair eutaxitic structure can be seen in all specimens except for those collected in the very basal part of the lower zone. Most samples are porous and only moderately welded (Figures 10 - 15). Isolated glossy, completely welded, non-porous masses are found near the base of the central firmly welded zone. The vitroclastic texture is reasonably coarse grained, and pumice lumps, usually in flattened lenses, commonly reach 3 to 4 cm in length; glass shards and bubble walls are often as much as 1½ mm long.

Mineralogy

Pumice and glass shards, bubble walls, and glass dust form 94 percent of the rock with both brown- and clear-glass shards represented in roughly equal proportions. Accidental lithic fragments constitute 5 percent of the rock, and cognate mineral grains one percent.

Glass: Both clear- and brown-glass shards are present. Aside from the color the only consistent difference that could be found in the two glasses was in their chemistry. The brown glass contains much more iron and somewhat more lime but less silica and alumina. All samples of the Rattlesnake Ignimbrite Tongue from the Harney Basin source area to the John Day Valley contain both brown and clear shards except for the Prairie City outcrop, thought to be a distal remnant, which contains only clear glass. Dark pumice, on the other hand, seems to decrease from the source northward into the John Day drainage where it is uncommon.

Feldspar: The feldspar is a high-temperature, soda-rich variety lying between sanidine and high albite to which the name anorthoclase is usually applied. Samples from the John Day drainage average near Or_{33} (Table 3). Crystals are generally subhedral, up to 2.5 mm in diameter, but average closer to 0.5 mm. In many crystals the combination of pericline and albite twinning characteristic of this mineral is apparent. Universal stage measurements on 2V give values ranging from 33° to 45°, and index of refraction measurements using index oils give alpha 1.524 and gamma 1.536. Crystals are fresh and may or may not show corroded borders.

Quartz: The quartz occurs in euhedral dipyramids typical of beta quartz and may reach diameters of 1 mm, although most are smaller. They commonly occur as composites with feldspar or other quartz

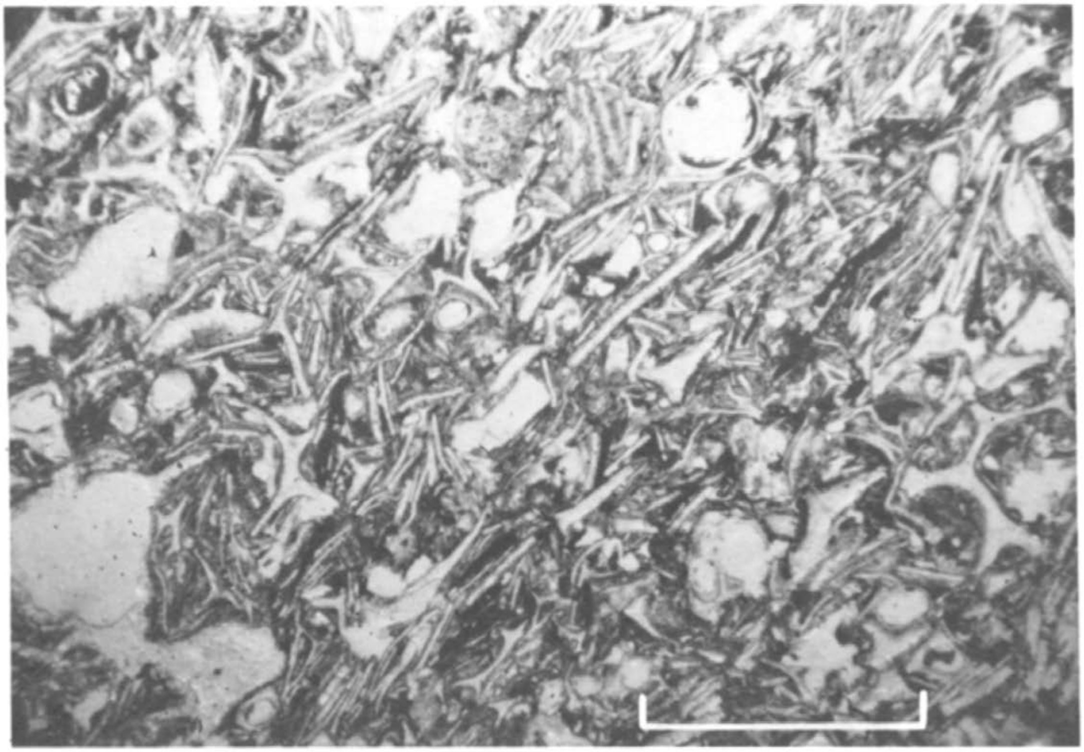

Figure 10. Undeformed glass shards and bubbles in the poorly welded base of Rattlesnake Ignimbrite Tongue. (Bar scale equals 1 mm.)

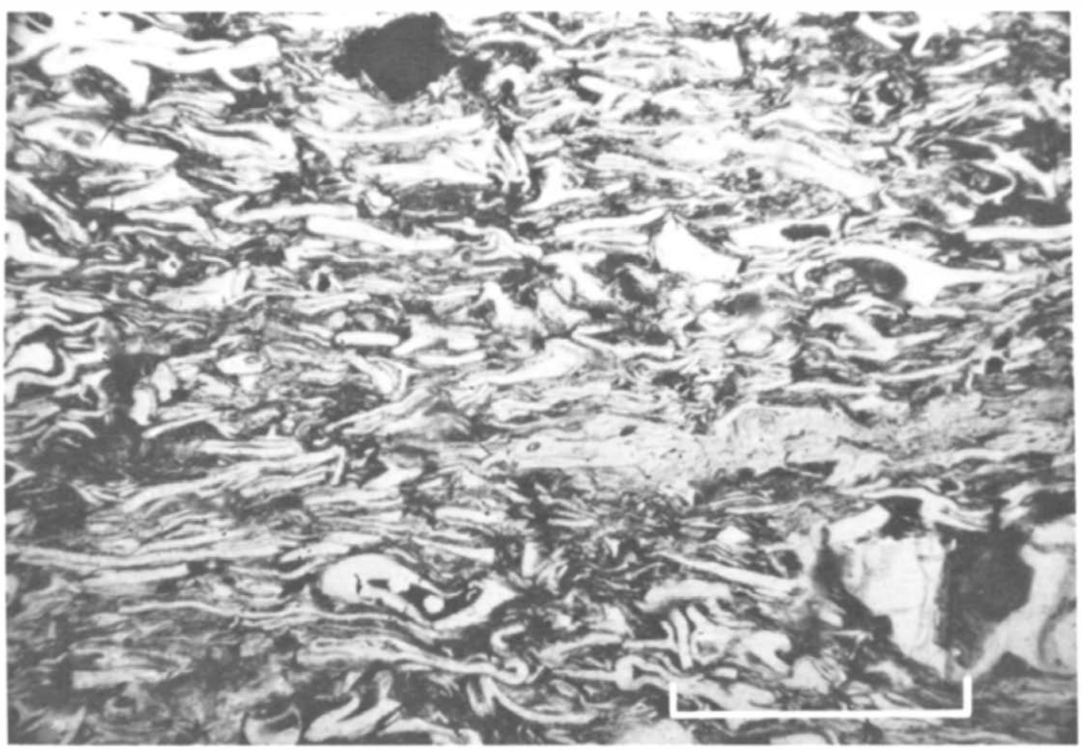

Figure 11. Flattened shards, bubbles, and pumice in a thin vitrophyric zone of the Rattlesnake Ignimbrite Tongue. (Bar scale equals 1 mm.)

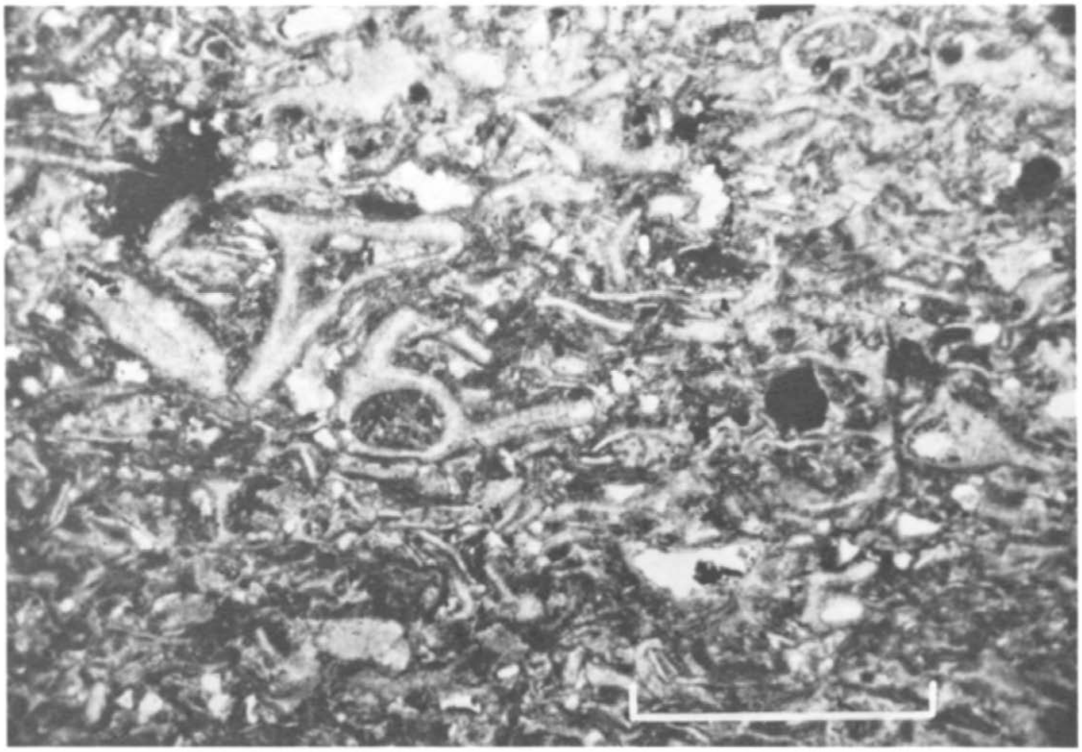

Figure 12. Firmly welded central part of the Rattlesnake Ignimbrite Tongue. (Bar scale equals 1 mm.)

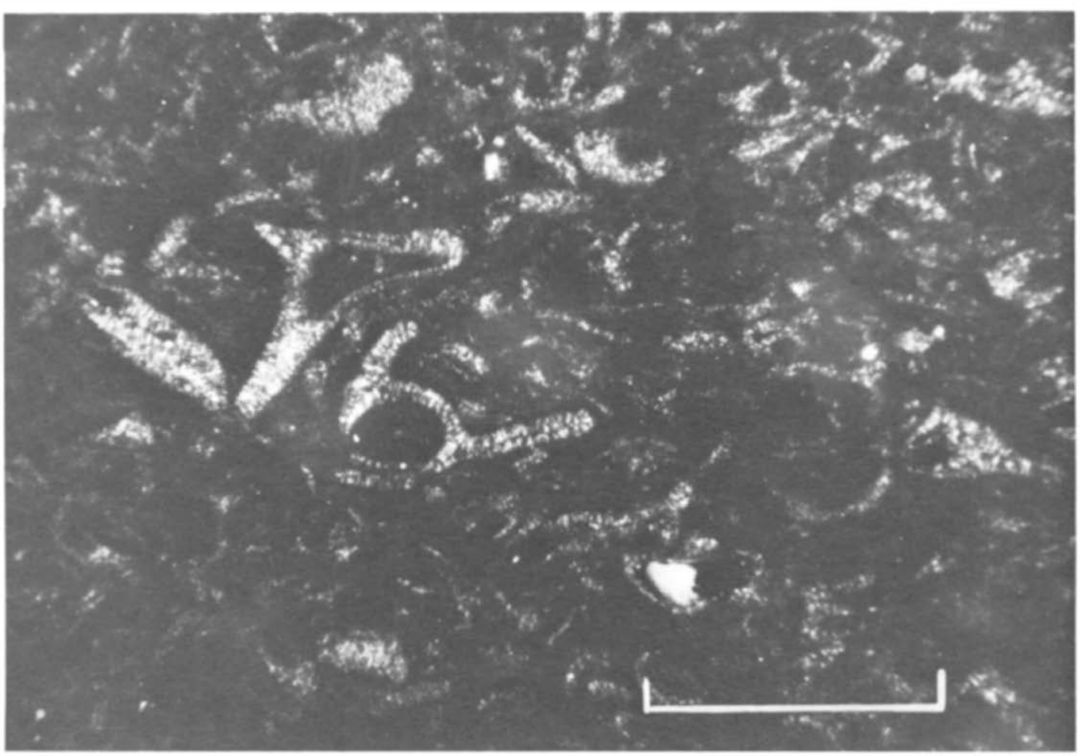

Figure 13. Same as above but with nicols crossed. (Bar scale equals 1 mm.)

crystals and ore characteristically emboyed and fractured. Quartz crystals ore for less numerous than feldspar; groin counts mode from disoggregoted material indicate feldspar groins outnumber quartz by 10 to 1.

Table 3. Orthoclose content of feldspar phenocrysts from the Rattlesnake Ignimbrite Tongue*

Sample Location	Non-homogenized	Homogenized
South fork of the John Day River #	36.0	35.0
Murderers Creek	36.5	38.0
Cottonwood Creek, top	26.0	29.0
Cottonwood Creek, bose	31.5	33.5
Mountain Creek	29.5	34.0
Deer Creek (near Monument)	31.0	----
Prairie City	25.0	32.0
Average	30.8	33.6

* X-ray determinations of weight percent orthoclase using the technique of Wright (1968).

\# Davenport (1971).

Clinopyroxene: In 60 percent of the thin sections, a groin or two of green clinopyroxene is found. Groins range from 0.2 to 1.0 mm in length and ore commonly elongate parallel to the crystallographic C axis. The mineral is weakly pleochroic from pole green to yellowish green, it is biaxial positive with an optic axial angle of 47° to 58°, the maximum extinction angle is near 44°, and the index of refraction for X is 1.726 and for Z, 1.758. The opticol properties suggest an iron-rich augite.

Magnetite: The magnetite groins ore smaller than those of the other cognate minerals, averaging less than 0.2 mm in diameter. They ore variably euhedrol or anhedral and occur alone or as inclusions in the other mineral groins. Most groins are fresh but those in the upper poorly welded zone commonly ore wholly or partially altered to hematite.

Zircon: Small euhedrol to anhedral groins of zircon form isolated groins in the matrix or, more commonly, occur as inclusions in or attached to the other cognate minerals, especially magnetite.

Alteration

The major alteration is devitrificotion of the gloss. For the entire ignimbrite this is modest but it is important at some outcrops. The basal unwelded zone tends to be vitreous always, as is the lower port of the firmly welded middle zone. The upper port of the middle firmly welded zone and the upper poorly welded zone are locally strongly devitrified and rarely exhibit vapor phose mineralization.

Devitrificotion begins with rims of birefringent material about shards, proceeds to a vogue spherulitic type extinction in the whole shard (the brown shards ore always the first to show this), and finally develops a strong oxiolitic texture in the elongate shards. X-ray analysis indicates the minerals of the axiolites are cristobolite and alkali feldspar.

At a few localities where devitrificotion is complete in the upper port of the moderately welded zone or in the upper poorly welded zone, coarse vesicles contain comparatively lorge (0.1 to 0.2 mm long) crystals of tridymite and alkali feldspar, which either hove grown into the opening or rim the opening, forming a zone several millimeters thick.

Figure 14. Unwelded ignimbrite from the Prairie City outcrop; apparently a distal remnant of the Rattlesnake Ignimbrite Tongue. (Bar scale equals 1 mm.)

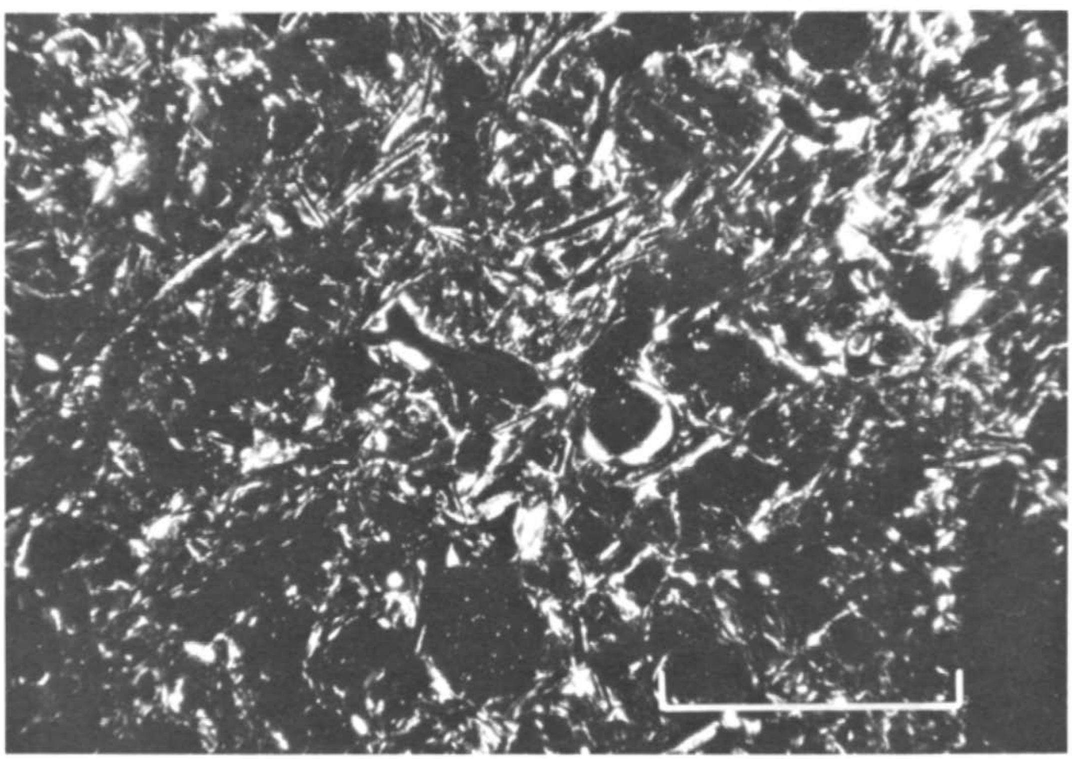

Figure 15. Same as above but nicols crossed. (Bar scale equals 1 mm.)

The brown to red color of much of the ignimbrite is the effect of pigmenting limonite and hematite. Broad red to brown stains are observed around both the mafic volcanic fragments and magnetite grains, especially near the top of the ignimbrite where porosity is high and oxidizing solutions readily penetrate the rock from above.

Geomagnetic polarity

The geomagnetic properties of all outcrop samples of ignimbrite seriously studied in the John Day drainage were investigated with a field model fluxgate magnetometer. The polarity of a few samples was too weak to record, but all others yielded reverse polarity. This is in accord with the results obtained by Dalrymple and others (1967), who determined the polarity of the ignimbrite cropping out along Birch Creek 2 miles east of the type section on Rattlesnake Creek.

Chemistry

Rock samples were carefully checked for purity, but considering the mixture of accidental fragments encountered, it is almost inevitable that a small number of these accidental rock fragments were included. The results of chemical analyses are given in Table 4. As can be seen, sample E-3-65, taken at the base of the ignimbrite in the type area at Cottonwood Creek, differs from the other four analyses. It is thought probable that the lower SiO_2 and higher Fe, Mg, and Co values are the result of admixture of appreciable amounts of accidental groins. Consequently, this sample is not used in calculation of the average chemical analysis.

In a rock consisting of 99 percent glass, but chemically simple, it was thought useful to treat the norm as the mode and classify the rock according to the classification of Johannsen (1939). Such a procedure, using the norm shown in Table 4, places the rock in Class I, Order 1, Family 7 eruptive (117E) and suggests the name leuco-sodaclase-rhyodacite.

Age

Potassium argon age determinations on the Rattlesnake Ignimbrite Tongue were made by Evernden and others (1964) and by Dalrymple and others (1967). The author obtained additional determinations from Geochron Laboratories and Kline Laboratories. Results for age dates in the John Day drainage are given in Appendix 3. Dotes range from a high of 6.69 m.y. to a low of 5.80 m.y., but three of the six are grouped so close to 6.4 m.y. that this figure is thought to be the most likely.

Upper Fanglomerate Member

The Upper Fanglomerate Member at the type section consists of coarse volcanic fanglomerate containing thin, discontinuous lenses of pebbly volcanic wacke. It was deposited under essentially constant physical conditions and is considered a single sedimentation unit. Both the fanglomerate and the discontinuous sandstone lenses are poorly consolidated, porous, and slope forming.

Fanglomerate

Framework clasts range up to boulders 1 meter in diameter, but cobbles and pebbles are far more common. The clasts mirror the ancestral geology of the locality in which the fanglomerates are found. At the type section, Picture Gorge Basalt clasts predominate although Rattlesnake ignimbrite fragments are common near the base. However, off the north flank of the mountains extending east from Fields Peak to Hanscombe Mountain, the high-level terrace gravels of the Upper Fanglomerate Member contain quartzite, dark chert, white vein quartz, and diorite as well as abundant mafic volcanics. North of the Strawberry Mountains, mafic Strawberry Volcanics predominate, with minor serpentinites, ultra-mafics, and rhyolite.

Table 4. Chemical analyses of the Rattlesnake Ignimbrite Tongue and a norm for the average chemical analysis*

Oxide	E-3-65 Cottonwood Ck., Base	E-6-65 Cottonwood Ck., Top	E-45-67 Mountain Creek	E-84-67 Murderers Creek	E-71-67 Prairie City	Average**
SiO_2	75.31	77.45	78.80	78.49	78.15	78.22
TiO_2	.27	.27	.21	.22	.21	.23
Al_2O_3	14.29	12.96	11.71	12.09	12.90	12.41
Fe_2O_3	1.64	1.10	.37	.38	.45	.57
MgO	1.73	.51	.21	.14	.10	.24
CaO	.99	.29	.13	.10	.10	.15
Na_2O	2.50	2.98	4.21	3.75	4.02	3.74
K_2O	3.02	3.70	4.21	4.79	4.02	4.18
P_2O_5	.18	.01	.01	.01	.01	.01
MnO	.06	.72	.01	.03	.02	.19
Total	99.99	99.99	99.87	100.00	98.98	99.94
					Qz	40.08
					Or	24.47
					Ab	31.44
					An	.84
					Il	.45
					Mt	.64
					En	.60
					Total	98.52

*Analyses in dry weight percent, total iron expressed as Fe_2O_3
**Excluding sample E-3-65

The matrix of the Upper Fanglomerate Member at the type section consists of a very coarse sand, about half being in the coarse to very coarse grade sizes (Table 5). The composition and texture of the matrix varies with the grade size precisely as it does with the included lenses of volcanic wacke described later.

The only cement is authigenic smectite coating grains or filling interstices, often found in masses large enough to allow easy physical and optical identification. X-ray examination leads to the conclusion that the cement is a member of the montmorillonite-beidellite series. Properties of this mineral are summarized in Appendix 2.

Table 5. Mechanical analyses of three typical samples of the matrix of the Upper Fanglomerate Member

Grade	Sample 1	Sample 2	Sample 3	Average
Very coarse sand	30%	22%	24%	25%
Coarse sand	17	29	26	24
Medium sand	14	24	21	20
Fine sand	13	15	14	14
Very fine sand	12	5	7	8
Silt and clay	14	5	8	9

Volcanic wacke

The color of the sand in the lenses is always some shade of yellowish brown (10YR 6/2 to 10YR 5/4). It is always coarse-grained, usually contains pebbles and granules of mafic volcanics, and is porous and poorly consolidated. Mechanical analyses for two random samples of the typical sandstone lenses of the Upper Fanglomerate Member are given in Table 6.

Table 6. Mechanical analyses of two samples of sandstone from lenses in the Upper Fanglomerate Member

Grade	Sample 1	Sample 2
Pebbles	4%	1%
Granules	10	8
Very coarse sand	12	21
Coarse sand	17	25
Medium sand	20	16
Fine sand	14	9
Very fine sand	8	6
Silt and clay	15	14

The composition of the framework ond matrix varies with the grade size as given below.

Pebbles: Both Rattlesnake ignimbrite and mafic volcanic pebbles, the mafic volcanics predominating; both lithic types are fresh and the shapes range from subangular to rounded.

Granules: Rattlesnake ignimbrite, mafic volcanics, and pumice, the ignimbrite predominating; occasional smectite pseudomorphs after mafic volcanics; groins subrounded to subangular.

Very coarse sand: Mafic volcanics and Rattlesnake ignimbrite fragments; rounded to subangulor. The lithic fragments may be fresh or partly altered; occasional smectite pseudomorphs.

Coarse sand: Predominantly lithics but much feldspar and on occasional dipyramid of quartz; subrounded to subongular. Mafic volcanics predominate; some are fresh, dark, and dense; some altering to hematitic masses; a few waxy brown to white, almost completely altered to smectite. Rattlesnake ignimbrite fragments ore present along with anorthoclase and quartz dipyramids, but the feldspar is chiefly plagioclase.

Medium sand: Fresh mafic volcanics rare, smectite pseudomorphs after mafic volcanics common. Obvious ignimbrite grains missing but glass shards, both clear and devitrified, are common. A minor amount of severely altered brown mafic glass is present. Feldspar is common, augite and quartz dipyramids rare. Groins subrounded to angular.

Fine sand: Largely smectite pseudomorphs after glass shards or mafic volcanic clasts but some clear glass and fresh mafic volcanic clasts. Minor feldspar and rare augite, quartz, and magnetite. Grains subangular to angular.

Very fine sand: Smectite pseudomorphs or broken fragments of pseudomorphs of both mafic clasts and glass shards; clear glass and feldspar; minor augite and magnetite. The gloss may be clear (probably from the Rattlesnake Ignimbrite Tongue) or dark and magnetite rich. All groins are angular.

Silt: Predominantly smectite pseudomorphs after gloss shards; minor fresh glass, either clear or dark and magnetite filled, feldspar, and magnetite; rare augite.

Clay: Commonly only smectite can be detected but a few samples yielded o weak 10 A° peak, perhaps illite, and one sample contained small amounts of kaolinite.

The only cement noted was smectite.

Smectite cement

The only important cementing material in the Rattlesnake sediments is authigenic smectite. The volcanic debris of the sediments contains a great deal of metastable mafic gloss rich in calcium, magnesium, and aluminum and poor in potassium. Low concentrations of K^+ and abundance of Mg^{++} in what must hove been on $MgO-Al_2O_3-SiO_2-H_2O$ system at low temperature led to the formation of abundant smectite and practically no kaolinite. Roy and Roy (1955) have pointed out that the smectite field in the $MgO-Al_2O_3-SiO_2-H_2O$ diagram covers a large area in the high-silica part of the diagram.

The silica content of the authigenic solutions forming the smectite must hove been very high as indicated by the essential absence of kaolinite. Kittrick (1969) calculates that H_4SiO_4 levels at which gibbsite, kaolinite, and smectite may form range from zero to about 150 ppm SiO_2. The activity of H_4SiO_4 determines which of these minerals will precipitate. High H_4SiO_4 levels appear to be required for smectite formation; kaolinite forms at intermediate and gibbsite at low silica levels. High H_4SiO_4 activities could be maintained by relatively static solutions; the gas vesicles in volcanic cinders or broken fragments seem ideal for holding such solutions. Kittrick (1969) suggests that smectite may serve as a geologic indicator of silica levels at near-saturation with respect to amorphous silica.

CONCLUSIONS

(1) The Rattlesnake Formation consists of a Pliocene sequence of vertically and laterally interfingering fanglomerates, wackes, and mudstones deposited as a valley fill along the course of the ancestral John Day River and its major tributaries. It is separated into two sedimentary units by a rhyodacite ash flow 6.4 millions of years in age.

(2) The ash flow originated from a volcanic center in the present Harney Basin and flowed north into the ancestral John Day Valley by way of the valley of the South Fork of the John Day River.

(3) Minerals which formed in the Rattlesnake sediments during authigenesis include smectite cement and smectite and clinoptilolite pseudomorphs after glassy volcanic clasts. In the ignimbrite, diagenetic change involved only modest devitrification.

(4) Present elevations of the Rattlesnake Ignimbrite Tongue indicate differential uplift of what must have been a broad, rather flat Pliocene drainage system sloping north from a volcanic center in the present Harney Basin. The ignimbrite sheet now appears as a northerly plunging trough, highest along the crest of the present drainage divide, with the axis indicated by the course of the northerly flowing South Fork of the John Day River and by the John Day itself north of Picture Gorge (Figure 1). South of the drainage divide, the ignimbrite descends to the Harney Basin. Collapse of the volcanic center in the Harney Basin following extrusion of the Rattlesnake Ignimbrite Tongue may have much to do with the present low elevation in the basin.

(5) Rejuvenation of the streams in the John Day drainage following the post-ignimbrite uplift brought about widespread erosion of the Rattlesnake Formation, leaving remnants as terrace deposits well above the level of the present stream system.

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APPENDIX

APPENDIX 1. TYPE SECTION OF THE RATTLESNAKE FORMATION

In the SW¼ of sec. 19, T. 12 S., R. 26 E., a steep slope rises from Rattlesnake Creek northwest to an ignimbrite-capped ridge. The lower part of this slope consists of light-colored, fine-grained sedimentary rock of the Mascall Formation, while the upper part consists of an excellent exposure of the basal beds of the Rattlesnake Formation. The entire sequence of basal Rattlesnake is exposed from the angular unconformity at the top of the Mascall to the contact with the capping ignimbrite. Because of the friable nature of all Rattlesnake sedimentary rocks, clean exposures, such as this, are unusual and found only on steep slopes. The unconformable surface separating the Rattlesnake from the Mascall is relatively planar but easily located because the beds above and below exhibit a sharp angular discordance and a marked change in lithology. The Mascall beds strike N. 70° W. and dip toward the southwest at 15° while the Rattlesnake beds strike from E-W to N. 60° W. and dip only 4-5° to the south or southwest. The uppermost Mascall bed is a pale-brown (5YR 5/2), fissile, tuffaceous shale, whereas the lowermost Rattlesnake unit is a darker brown volcanic fanglomerate.

In the SW¼ of sec. 33, T. 12 S., R. 26 E., on the east side of Cottonwood Creek, the Rattlesnake Ignimbrite Tongue is capped by 112.78 m of continuously exposed fanglomerate, the top of which forms the surface of the east ridge bounding the valley. The upper surface of the ignimbrite is irregular with shallow channel cuts indicating some erosion prior to deposition of the overlying fanglomerate.

Upper Fanglomerate Member	Thickness meters
Unit 19	112.78

Volcanic fanglomerate: a single sedimentation unit remarkably uniform in composition and lithology, porous and poorly cemented. Boulders 1 m in diameter are encountered but more commonly the framework is composed of small boulders, cobbles, and pebbles. Clasts range from rounded to subangular and consist predominantly of mafic volcanics in many textures, colors, and degree of weathering. Colors are chiefly moderate red, greyish red, brown and yellowish brown (5R, 5YR, 10R and 10YR), textures are scoriaceous, aphanitic, or porphyritic, some clasts so weathered that they crumble in the hand, others ring under the hammer. Most clasts were identified as Picture Gorge Basalt, but a not inconsiderable number of firmly welded Rattlesnake ignimbrite clasts were encountered, largely in the lower part of the unit. The matrix consists of a moderate yellowish-brown (10YR 5/4) sand composed chiefly of lithic grains of a mafic volcanic, feldspar, smectite grains (formed from altered volcanic lithics), and minor magnetite. The cement is a sparse coating or pore filling of authigenic smectite. A crude bedding is developed by discontinuous lenses, never more than a few centimeters thick, of sand and pebbles interbedded with the predominant small boulder, cobble, and pebble aggregates. No major break in lithology was observed.

Contact - Unit 19/Unit 18: sharp, with local shallow scour-and-fill.

Rattlesnake Ignimbrite Tongue

	Thickness meters
Unit 18	1.52

Upper poorly welded zone: poorly to moderately welded; pale red (10R 6/2); contains flattened white to gray pumice fragments up to 3.5 cm long and sparse rounded to angular mafic volcanic pebbles and sand grains. A poor eutaxitic structure commonly leads to the development of flat slabs of rock on the outcrop.

Contact - Unit 18/Unit 17: gradational but sufficiently sharp to allow a topographic break between the units. Unit 18 is slope-forming, Unit 17 cliff-forming.

Unit 17 — 10.03

Firmly welded zone: moderately to firmly welded, light gray (N8) to brownish gray (5YR 6/1) with good eutaxitic structure and many flattened and aligned gray to white pumice fragments. Mafic volcanic pebbles and sand grains common. Vertical joints with somewhat curved joint surfaces form fair, commonly four-sided, columns 2 to 3 m in diameter.

Contact - Unit 17/Unit 16: gradational; marked by an undercut cliff.

Unit 16 — 0.91

Poorly welded base: very light gray (N8); basal 30 cm very poorly consolidated with unmodified vitroclastic texture, commonly crowded with rounded to angular mafic volcanic pebbles and cobbles up to 12 cm in diameter and white to brown pumice fragments up to 5 cm in diameter which become somewhat flattened and aligned in the upper part of the zone, developing a poor eutaxitic structure.

Contact - Unit 16/Unit 15: remarkably sharp and planar.

Lower Fanglomerate Member

Unit 15 — 5.17

Sandy volcanic mudstone: crudely bedded, grayish orange pink (10R 8/2); subangular to rounded sand grains of mafic volcanics, pumice, feldspar, and minor agate; rich in silt-sized grains of feldspar and glass; clay largely smectite. Contains one 60-cm-thick lens of yellowish-gray (5Y 8/1) sandy fanglomerate 1.8 m from the top, which lenses out laterally within a few meters. Ten cm from the top, fragments of the teeth of *Hipparion* sp. were found along with small root casts lined with carbonaceous material.

Contact - Unit 15/Unit 14: undulatory, shallow scour-and-fill.

Unit 14 — 7.90

Volcanic fanglomerate: framework of cobbles and pebbles of mafic volcanics (Picture Gorge Basalt), well rounded to subangular; scoriaceous, stony aphanitic or porphyritic; fresh to deeply weathered; grayish red to

Thickness meters

yellowish brown (5R, 5YR, 10 R and 10YR); matrix of yellowish-gray (5Y 7/2) sand consisting of subangulor grains of mafic volcanics with minor feldspar and pyroxene; sparse smectite cement coating grains and filling pores.

Contact - Unit 14/Unit 13: undulatory scour-and-fill.

Unit 13 — 2.43

Volcanic wacke: fine-grained, yellowish gray (5Y 7/2), upper 60 cm very silty. Framework of angular to subongulor pumice and mafic volcanics with feldspar; matrix feldspar, magnetite, gloss, and smectite.

Contact - Unit 13/Unit 12: gradational

Unit 12 — 5.47

Volcanic fanglomerate: identical to Unit 14.

Contact - Unit 12/Unit 11: undulatory scour-and-fill.

Unit 11 — 5.17

Volcanic wacke: very coarse-grained, yellowish gray (5Y 7/2), similar to Unit 13 but coarser and partially covered.

Contact - Unit 11/Unit 10: gradational

Unit 10 — 8.51

Volcanic fanglomerate: similar to Unit 14 but contains many lenses of coarse yellowish-gray volcanic wacke.

Contact - Unit 10/Unit 9: undulatory scour-and-fill.

Unit 9 — 3.34

Volcanic wacke: very coarse-grained, yellowish gray (5Y 7/2), massive, lithology similar to Unit 13, becomes finer grained toward the top.

Contact - Unit 9/Unit 8: sharp and planar.

Unit 8 — 12.16

Volcanic fanglomerate: similar to Unit 10. Typical Rattlesnake volcanic fanglomerate with many interbedded lenses of yellowish-gray volcanic wacke.

Contact - Unit 8/Unit 7: very irregular with deep scour-and-fill.

Unit 7 — 2.40

Pebbly volcanic wacke: pebbles of mafic volcanics in a massive yellowish-gray (5Y 7/2), very coarse sand. Becomes finer grained and

Thickness meters

grayish orange pink (10R 8/2) at the top. Framework predominantly mafic volcanics with pumice, rare groins of feldspar, pyroxene, and agate. Clasts ore generally angular to subongulor and fresh. The matrix is feldspar and smectite pseudomorphs after tiny mafic fragments, minor magnetite. The sparse cement is smectite.

Contact - Unit 7/Unit 6: sharp and planar.

Unit 6 — 3.50

Volcanic fanglomerate: similar to Unit 10 but exhibits thick cross-beds dipping due east. Many discontinuous lenses of yellowish-gray (5Y 8/1) volcanic wacke, clasts of mafic volcanics and isolated fragments of grayish-orange-pink (10R 8/2) volcanic siltstone apparently of intraformational origin.

Contact - Unit 6/Unit 5: sharp, undulatory with many small scour-and-fill features.

Unit 5 — 2.89

Volcanic mudstone: massive, grayish orange pink (10R 8/2); much silt consisting of gloss and feldspar with finer particles of limonite, smectite, and minor humus. A thin lens of pebbly volcanic wacke near the center.

Contact - Unit 5/Unit 4: gradational.

Unit 4 — 0.61

Volcanic fanglomerate; similar to Units 8 and 10.

Contact - Unit 4/Unit 3: sharp with local shallow cut-and fill.

Unit 3 — 2.45

Sandy volcanic mudstone: grayish orange pink (10R 8/2); very crude laminations; sparse rounded to angular sand groins of mafic volcanics, feldspar, and pyroxene in a silt consisting of bath clear glass and devitrified gloss, feldspar, and much finer fragments of smectite, limonite and humus.

Contact - Unit 3/Unit 2: gradational.

Unit 2 — 0.58

Pebbly volcanic wacke: yellowish gray (5Y 7/2); crude bedding includes some cross-beds dipping N. 70° E. Pebbles and framework clasts largely rounded to subangulor mafic volcanics but rare groins of feldspar, pyroxene, and agate. Lithics fresh to weathered but minerols ongulor and fresh. Matrix largely volcanic glass; cement sparse smectite which coots groins and fills interstices. Bose very pebbly.

	Thickness meters
Contact - Unit 2/Unit 1: sharp, with local shallow scour-and-fill.	
Unit 1	3.75

Volcanic fanglomerate: framework consists of boulders up to 30 cm in diameter, cobbles and pebbles all of mafic volcanics; well rounded to subangular; stony aphanitic, scoriaceous or porphyritic; fresh to deeply weathered; colors moderate red, grayish red, brown, and yellowish brown (5R, 5YR, 10R and 10YR) in a yellowish-gray (5Y 7/2) matrix. Matrix chiefly sand or silt-sized grains of mafic volcanics, feldspar, pyroxene, and agate. Coating the clasts and packed into the voids of the matrix are glass shards and dust mixed with smectite cement. This gives the light hue to the matrix and serves as the chief binding material in the rock.

Contact - Unit 1/Mascall Formation: angular unconformity, sharp.

Total Rattlesnake	191.57

MASCALL FORMATION

APPENDIX 2. AUTHIGENIC SMECTITE FROM THE UPPER FANGLOMERATE MEMBER OF THE TYPE SECTION

Physical Properties

The larger smectite grains are generally concavo-convex with a botryoidal surface on the convex side and a very smooth concave surface. Masses of this shape often adhere to a smooth grain of sand. Under magnification it can be seen that these grain coatings commonly show growth lines parallel to the smooth surface as if they were applied layer by layer.

The smectite has a waxy luster, is brittle and soft, and is easily scratched and broken by a steel needle. The color commonly is moderate reddish orange (10R 6/6) or grayish orange pink (10R 8/2), more rarely pale greenish yellow (10Y 8/2), light green (5G 7/4), or white (N9).

Optical Properties

Fragments appear to be single crystalline units and some exhibit sharp extinction, but more commonly the extinction is undulatory, moving as a broad bar across the fragment. Certain optical constants were measured as follows:

Biaxial (-)

2V near 20°

Alpha 1.487

Gamma 1.500

X-Ray Properties

Basal spacing A° units

The powder pattern with Ca^{++} saturated samples gives typical broad peaks at about 15.4 A° which increase to 18.1 when treated with glycerol.

060 spacing A° units

The powder pattern indicates an 060 peak at 1.507 A° which, according to Warshaw and Roy (1961), indicates a trioctahedral smectite.

Identification

The data are adequate to identify the mineral as a member of the montmorillonite-beidellite series, but they will not distinguish between montmorillonite and beidellite.

Sample: W 14

Locality: sec. 27, T. 12 S., R. 25 E., ½ mile north of Birch Creek School and ¼ mile west of Birch Creek

Stratigraphy: from a friable white rhyolite tuff (Author's note: Poorly welded base of the Rattlesnake Ignimbrite Tongue)

Data:

K = 5.00, 4.95%

Ar = Sample wt. 0.673 g, 40 Ar rad/g (10^{-11} moles) 4.923

$\frac{40 \text{ Ar rad} \times 100}{40 \text{ Ar total}}$ 39.6

Age: 6.69 $\pm$ 0.20 my

Source: Dalrymple and others (1967)

Sample: W 15

Material: anorthoclase

Locality: sec. 27, T. 12 S., R. 25 E., ½ mile north of Birch Creek School and ¼ mile west of Birch Creek

Stratigraphy: from a red welded tuff overlying W 14 (Author's note: Upper poorly welded zone of the Rattlesnake Ignimbrite Tongue)

Data:

K = 5.69, 5.67%

Ar = sample wt. 1.027g, 40 Ar rad/g (10^{-11} moles) 4.998

$\frac{40 \text{ Ar rad} \times 100}{40 \text{ Ar total}}$ 47.9

Age: 5.95 $\pm$ 0.18 my

Source: Dalrymple and others (1967)

Sample: KA 1206

Material: sanidine from rhyolite (Author's note: anorthoclase)

Locality: 10.6 miles east of Dayville, Oregon; in a road cut on north side of highway 26; 2.4 miles west of UCMP loc. P4129

Stratigraphy: (Author's note: A slide block of Rattlesnake Ignimbrite Tongue; the ignimbrite crops out on the side of the valley one mile north and 450 feet higher)

Data:

K = 3.854%

$A40^{at}$ = 16%

Age: 6.4 my

Source: Evernden and others (1964)

APPENDIX 3. POTASSIUM-ARGON AGE DETERMINATIONS FOR THE RATTLESNAKE IGNIMBRITE TONGUE

Sample: E-3-65

Material: anorthoclase
Locality: Cottonwood Creek, SW¼ sec. 33, T. 12 S., R. 26 E.
Stratigraphy: poorly welded base
Data:
$K = 3.76, 3.75\%$
$Ar^{40} = 0.965 \times 10^{-6}$ cc/gm ($56\% \lesssim Ar^{40}$)
Age: 6.42 ± 0.128 my
Source: Enlows, Kline Laboratories

Sample: E-71-67

Material: anorthoclase
Locality: About 3½ miles SW of Prairie City, Oregon in a road cut in the SE¼ sec. 17, T. 13 S., R. 35 E.
Stratigraphy: a channel sample taken over a vertical interval of 3.5 m from the base of the outcrop upward
Data:
$K = 3.749, 3.908\%$, ave. 3.828%
$Ar^{40} = 0.00157$ and 0.00161 ppm, ave. 0.00159
Age: 5.80 ± 0.50 my
Source: Enlows, Geochron Laboratories

Sample: E-84-67

Material: anorthoclase
Locality: on Murderers Creek, SE¼ sec. 32, T. 14 S., R. 27 E.
Stratigraphy: poorly welded base
Data:
$K = 4.41, 4.43\%$
$Ar^{40} = 1.61 \times 10^{-6}$ cc/gm ($29\% \lesssim Ar^{40}$)
Age: 6.56 ± 0.226 my
Source: Enlows, Kline Laboratories

Sample: E-6-70

Material: anorthoclase
Locality: on Dry Creek, NW¼ sec. 23, T. 9 S., R. 27 E.
Stratigraphy: poorly welded base
Data:
$K = 3.85, 3.83\%$
$Ar^{40} = 0.985 \times 10^{-6}$ cc/gm ($28\% \lesssim Ar^{40}$)
Age: 6.41 ± 0.22 my
Source: Enlows, Kline Laboratories