Character of a columnar jointed erosional remnant, Crawfish Lake Quadrangle, Oregon

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INTRODUCTION

In the Elkhorn Mountains of Eastern Oregon during the summer of 1998, the Crawfish Lake Quadrangle's volcanics were mapped by four others[1] and myself resulting in a composite geologic map of the quadrangle's Tertiary volcanics. I also studied a small but spectacular outcrop of basalt (Hill 6721) which forms a columnar jointed knob. I aimed to determine its origin as either a shallow intrusive feature or an erosional remnant of an inter-canyon extrusive flow by composing an accurately surveyed map of the outcrop.

GEOLOGIC HISTORY AND CONTEXT

This outcrop is located in the Elkhorn Mountains which are part of a cluster of ranges with various orientations and relief collectively known as the Blue Mountains. The Blue Mountains were born when exotic Permian, Triassic, and Jurassic oceanic floor and island arc rocks were accreted to Oregon's prehistoric shores, which at that time lay across eastern Washington and Idaho defining a tectonic continental/oceanic plate boundary and subduction zone. This is a lithology defined as the Baker Terrane in the Elkhorn Mountains (Walker and Robinson, 1990). A long period of volcanism, interspersed with periods of sedimentation and erosion, ensued which is expressed by a Mesozoic granitic intrusive known as the Bald Mountain Batholith which metamorphosed the Baker Terrane rocks. After a period of considerable erosion and deposition of sediments, Tertiary volcanism commenced which is exposed today in 8 miles^2 of the Crawfish Lake Quadrangle (Hazlett, 1998).

STRATIGRAPHY

The oldest identified lava [Tob] is an olivine basalt which tends to be vesicular and amygdaloidal (zeolitic or silica-filled) and occurs almost exclusively as float. The immediately overlying unit [Tpob] is a slope forming basalt that contains up to 5% plagioclase phenocrysts. Following this early volcanism, [Tep], an ash flow tuff breccia was deposited which today, mostly crops out as a weathered yellow-brown vesicular clay. Also included in [Tep] is an epiclastic basinal sequence which shows itself on the slopes of Chicken Hill ridge and up to 3km away often under forest and soil cover. This sequence is made up mostly of tuffaceous sandstones which exhibit cross-bedding and cut-and-fill channel structure in places. Overlying [Tgob] is a largely apheric, magnetic basalt that contains olivine-rich glomeroporphyritic aggregates and weathers into rolling knobs. This unit shows well developed columnar jointing. The particular erosional remnant that I am studying is a part of [Tgob]. A trachitic andesite [Tta] is thought to succeed [Tgob]. However, its age relationship to other volcanic units is ambiguous because of a lack in contact relations. For example, the fact that it is the most weathered and oxidized rock in the area makes one believe that [Tta] may be the oldest unit in the mapped sequence. [Tta] is characterized by highly weathered outcrops and float. A final stage of intermediate volcanism was accented by eruption of the Chicken Hill andesite [Tach], which is certainly younger than [Tta] given the outcrop pattern seen in the area of Middle Trail Creek. The Chicken Hill andesite is clearly the most widespread lava in the quadrangle. It exhibits platy jointing and columns that suggest this andesitic lava flowed over an eroded terrain. Petrographically, [Tach] is as varied as it is widespread. In general, it contains an abundance of plagioclase and pyroxene phenocrysts, the pyroxene crystals being notably smaller and less abundant than the plagioclase (Hazlett, 1998).

[1]Carrie Brugger of Colorado College, Kate Trafton of Carleton College, Kyle McClure, and Rick Hazlett, both of Pomona College.

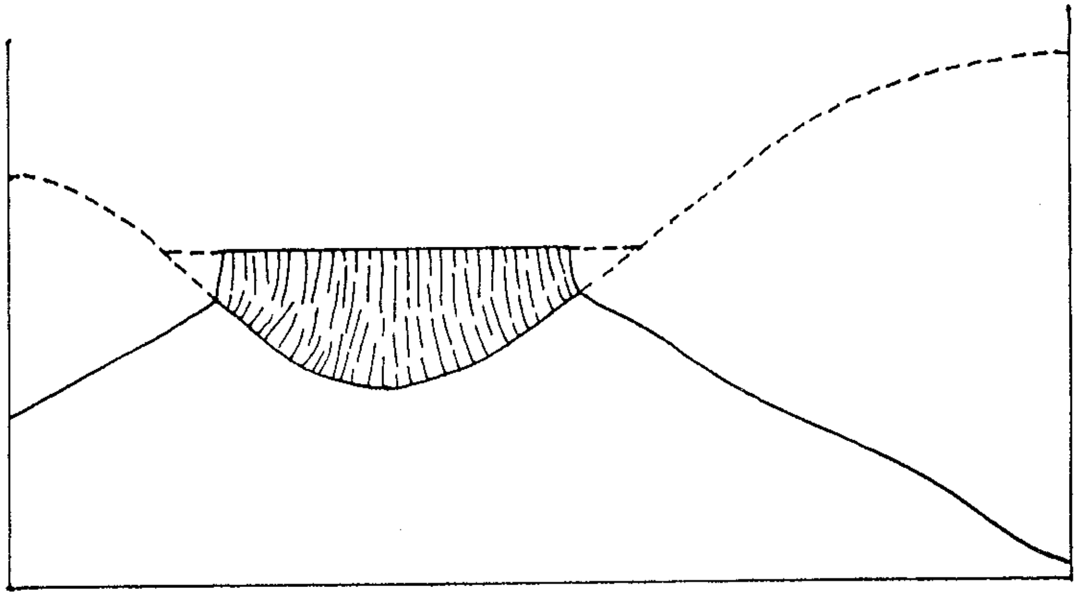

Figure 1
This shows a profile view of a lava flow partly filling a valley. Notice how the joints form normal to upper and lower surfaces of cooling. Erosion of adjoining valley rocks leaves the inter canyon flow standing as a flat topped ridge above its surroundings.

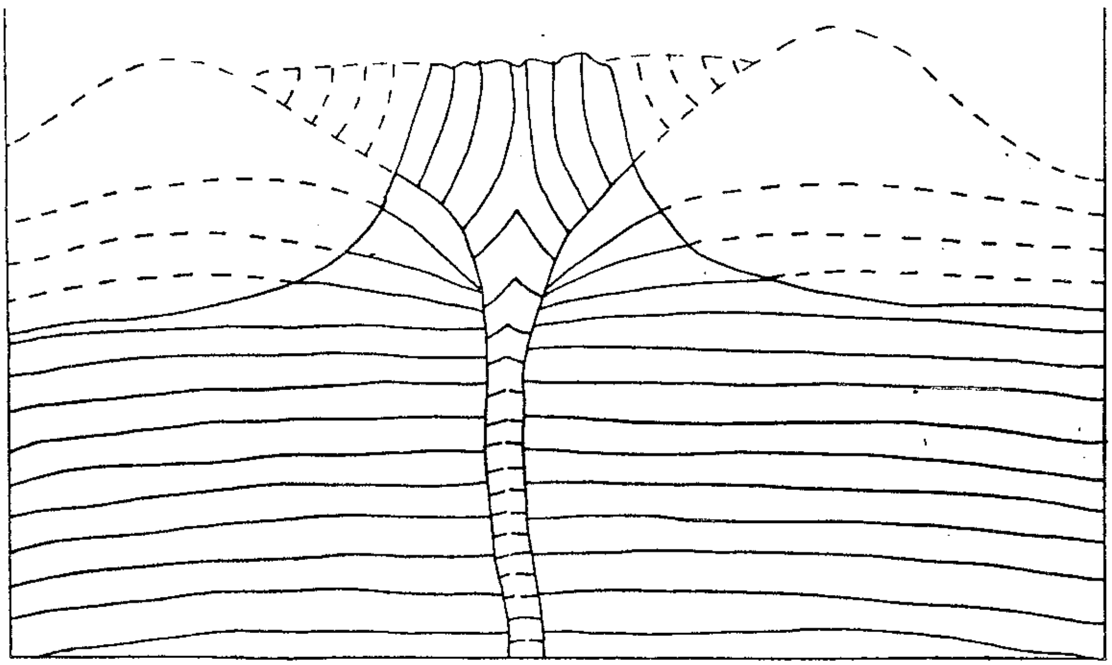

Figure 2
This shows a profile view of a Hopi Butte type lava head. A crater forms atop the conduit stem and is filled with lava that joints normal to upper and lower surfaces of cooling. Erosion of the less resistant surroundings leaves the lava head in high relief. (Figure adapted from Macdonald, 1972).

METHODS

Mapping. Our team of four students and one professor accomplished geologic mapping by moving from one conspicuous outcrop to another, taking samples, and marking their positions on our topographic maps. We were thorough to the point of leaving very few outcrops unobserved on ridges and other elevated terrain. However, much of the field area was heavily forested and subdued causing the need for pace and compass traverses which were done at roughly ½km intervals. In this case, outcrops were stumbled upon by chance and rocks found in tree root boles were observed (Hazlett, 1998). Contributing to the difficulty of finding outcrops in subdued areas was the presence of downed lodgepole pine trees.

Surveying of Hill 6721. This outcrop of [Tgob] is somewhat elongate occupying a rectangular box 100m at its longest point and about 40m wide. The columnar joints in this outcrop are astounding, partly by their wide variation in orientation from one column to the next, and variation within individual columns. Once I decided to study this outcrop in detail, my colleagues and I determined that a precise survey should be done if any sense was going to be made out of it because of its size, shape, and variability of columnar joint orientation. Therefore, I used the tape and compass method of surveying to collect data. One of my mapping partners, Kyle McClure assisted me in this task. In measuring the trend of lines between designated stations on the outcrop, we quickly discovered through a series of cross-checks that the trend was indeterminable using a magnetic Brunton compass because the outcrop was too magnetic itself, thereby interfering with the Bruntons' trend measurement. Because this data set was vital in creating a detailed map of the outcrop, a separate outer group of stations located beyond the talus slope was created from which trend measurements could accurately be made. Through trigonometry, the outcrop was then able to be surveyed. Furthermore, joint orientation information was gathered to be plotted later on the topographic map of the outcrop.

COLUMNAR JOINTING, PLUGS, AND LAVA FLOWS

The columnar jointing pattern was investigated thoroughly to better understand its character and origin. Columnar joints are found in all types of lava flows often resembling a colony of vertical rock towers. They are also found in dikes where the joints for normal to the dike walls often resembling stacked firewood (Macdonald, 1972). Columnar joints can occur in volcanic necks or the margins of any intrusive body as they form normal to the outer surface of cooling, whether above or below ground. Because they arise in relation to the outer edge of the cooling body, one can gain much insight into the body's original shape when the outer edges of the body have been destroyed by erosion or are still buried by subsequent deposition. For example, if lava was extruded over a hilly terrain or within a valley, the bottom surface of cooling would not be horizontal and therefore, the columns would not form vertically, but at right angles to the irregular topography (Figure 1).

The map view of volcanic necks is often circular ranging in diameter from a few yards to a mile. Some plugs are oval in shape and others tend to be more elongate. In Hopi type plugs, the conduit fills with lava and a crater forms atop the conduit stem which can also fill with lava creating a head (Figure 2). The head can resemble an inter canyon lava flow in that the crater above the conduit acts as the valley walls which subsequently fill with lava. The lava cools forming columnar joints normal to the horizontal upper-surface and to the bottom bowl shaped surface. The result is a downward flaring outward of joints (Berthelay, 1980). However, the flaring outward effect occurs continuously in 360° as the bottom surface of cooling is a bowl. Contrarily, inter canyon flow flaring of joints occurs in only two directions, roughly 180° from each other as the bottom surface of cooling consists of two valley walls.

GEOCHEMISTRY AND PETROLOGY

The outcrop's [Tgob] petrology was also investigated thoroughly to better understand its character and origin. One my mapping partners, Carrie Brugger of Colorado College, did a petrographic and geochemical analysis of each Tertiary volcanic unit in the quadrangle. See table 1 for a summary of her results for [Tgob]. This unit's petrology and geochemistry indicate it is an andesite characteristic of extrusive lava flows. If it were a volcanic neck, it could be any type of erupted lava, but would more likely be composed of fragmental material mixed with volcanic rock. This is not the case with [Tgob]. However, its petrology does leave the possibility of being the columnar jointed head of a volcanic neck as described earlier.

Table 1

plagioclase	39.8%	SiO_2	56.93%
opaques	2.9%	Al_2O_3	16.38%
clinopyroxene	16.3%	Fe_2O_3	7.63%
orthopyroxene	5.4%	MnO	0.11%
olivine	- -	MgO	5.74%
plagioclase phenocrysts	11.1%	CaO	7.81%
clinopyroxene phenocrysts	3.1%	Na_2O	3.36%
orthopyroxene phenocrysts	1.4%	K_2O	1.13%
olivine phenocrysts	- -	TiO_2	0.93%
glass	19.5%	P_2O_5	0.15%
		LOI	0.69%

(Brugger, 1999)

DISCUSSION

Well developed columnar jointing and [Tgob]'s petrology indicate that the unit is an extrusive lava flow of andesitic composition. The question as to whether [Tgob] is an inter canyon flow or the head of a Hopi type volcanic plug is answered by the fact that [Tgob] has been shown to exist as extrusive lava flows not associated with a particular volcanic plug elsewhere in the quadrangle. This is sufficient evidence in and of itself to suggest the outcrop's origin as an inter canyon flow. Later, when the outcrop's topographic map is generated, this will be further elucidated.

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