The Spatial Distribution and Origins of Sandstone Monoliths in the Swauk Watershed, Kittitas County, WA

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Abstract

Large groups of gigantic sandstone and conglomerate monoliths populate the Swauk Watershed of northern Kittitas County. These monoliths rest on side slopes in the watershed and distinctively project from their surroundings. The origins of these features are unknown. We studied these monoliths in the field by mapping their spatial distribution, describing their morphology and composition, and measuring their orientation and sizes in order to determine their origins. We used Google Earth and topographic maps to locate the monoliths and map their distribution. Interpretations were based from field work data and past research. Our field results show commonalities between the features related to overall structure, composition, and geomorphology. All monoliths studied were associated with dipping strata. Dip slopes are gently sloping while anti-dip slopes are much steeper. The monoliths also have distinct and traceable conglomerate layers that are highly resistant to erosion, as well as thick sandstone layers and some smaller pebble layers. These features also share similar geomorphology: they are surrounded by channels; fresh surfaces are lichen-free; honeycomb weathering and overhangs dominate the anti-dip slopes; and prominent vertically aligned jointing parallels the dipping beds. These results indicate that geologic composition and structure play a significant role in the initial shaping of these landforms. Differential weathering, fluvial erosion, and mass movement weakened the sandstone to cause low bedrock escarpments to retreat on the slopes, which carved out vertically aligned joints. The repetitive cycle of weathering, mass movement, and stream erosion has ultimately been the cause of the isolation of the sandstone monoliths over time.

Introduction

- The Swauk Watershed lies in a structural basin in the Eastern Cascades of Washington state, in northern Kittitas County (see Figure 1).
- The Swauk Watershed is a mountainous region bordered by Blewett Pass to the north, Teanaway Ridge to the west, and Table Mountain to the east.
- Throughout the Swauk Watershed lie numerous, noticeably tilted "monoliths" composed of sandstone & conglomerate. These monoliths rest on side slopes in the watershed and distinctively project from their surroundings.
- Similar features have been found elsewhere. In the Carpathian Mountains of Poland, these remnants have been defined as products of subsurface water erosion and selective weathering (Alexandrowicz and Urban 2005). In Somerset Island, Canada, similar features are products of differential weathering and mass movement (Dyke 1976).
- These monoliths have been discussed in the literature as *tors.* The definition of a tor is an individual rocky form separated from the slope and other landforms and characterized by walls sculpted by weathering processes. They are predominantly located in the upper parts of mountain ranges (Alexandrowicz and Urban 2005).

Questions

- What led to the formation of the Swauk Watershed monoliths? Fluvial erosion, geologic structure, mass wasting, selective weathering, or a combination of all of the above?
- What does their spatial distribution suggest about their origins?

Study Area

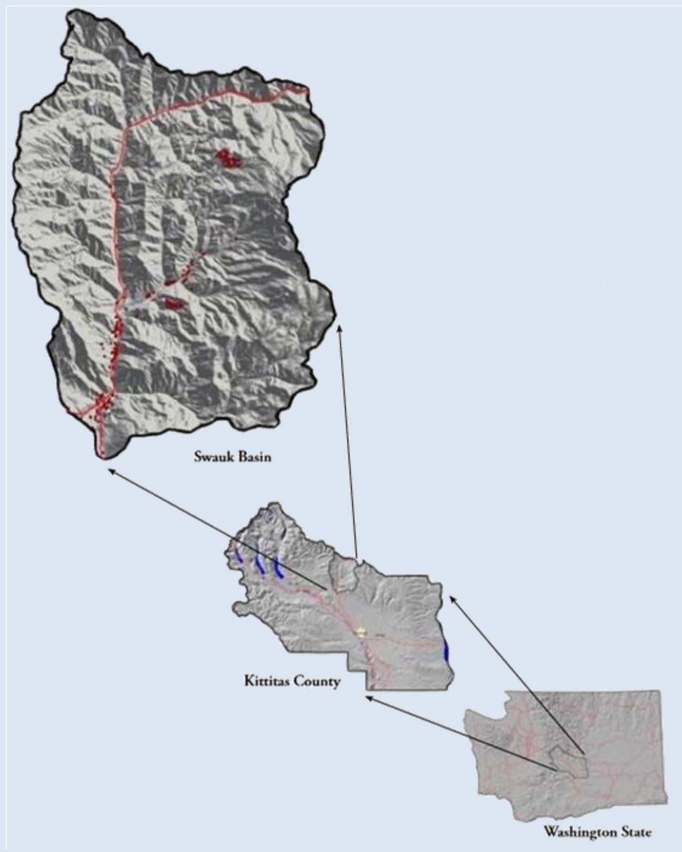

Figure 1. The Swauk Watershed in Kittitas County, Washington (Engstrom 2006).

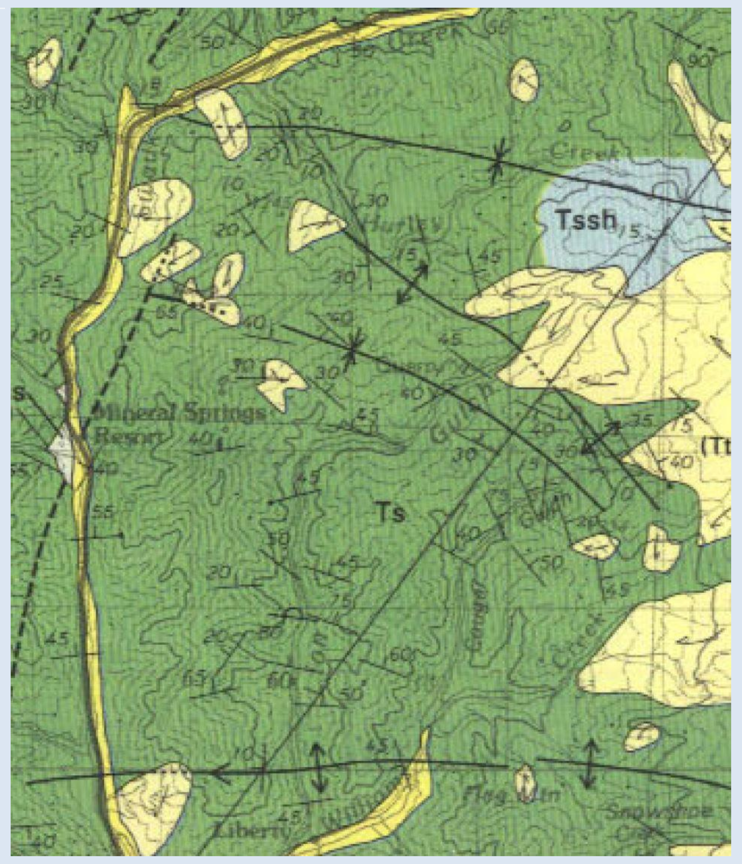

Figure 2. Geologic map of part of the Swauk Watershed (Tabor et al., 1982).

Methods

1. Map the spatial distribution of the monoliths (see Figure 3):
   - Google Earth ID based on color and shape
   - Monolith plotting onto topo maps
   - Final map on Google Earth
2. Describe and measure the monoliths in the field (see Figure 4):
   - Focus on the different sizes, shapes, orientations (aspect), compositions, geologic structure, and stratigraphic relationships of each
   - Measure strike & dip of the sandstone and conglomerate beds (see Table 1)
   - Measure trend & plunge of the joints (see Table 2)
3. Determine the origin of the monoliths:
   - Based on spatial distribution, field descriptions, strike and dip, trend and plunge, and past literature on the topic

Results

Descriptive properties of the monoliths

- Sizes: Heights ranged from 3-57 m tall
- Shapes: tilted, asymmetrical, cliff-like, and/or pillar-shaped
- Compositions: sandstone and conglomerate beds with pebble lenses and rip-up clasts of various sizes
- Joints ranged from 0.02-3 m wide and often extended through monoliths
- Honeycomb weathering and potholes dominated the anti-dips and tops
- Weathered material from the monoliths blanketed the surroundings

Measurements

- Strike and dip measurements plotted in alignment with the crests and troughs of synclines and anticlines (see Figure 3)
- The spatial distribution of monoliths also aligned with the local geologic structures (see Figure 3)

Feature Name	Strike	Dip
LG1	300	31
LG2	307	26
	309	19
	320	21
LP1	339	20
LP2	276	27
LP3	265	38
CT1	140	32
	145	42
CT2	135	33
LR1	290	16
CG1	300	71
CG2	300	71
BMJ1	340	25
	340	21
HC1	325	14
HC2	200	20
	200	20
	250	10
	190	20
SCG1	85	54
SCG2	63	41
SCG3	330	12
	345	10

Table 1. Field measurements of strike and dip (plotted in figure 3).

Table 2. Field measurements of trend and plunge.

Feature Name	Trend	Plunge
LR1	290	61
HC1	183	69
	318	36
	328	84
	359	21
HC2	260	95
	160	80
	250	87
	150	75
	255	87
SCG1	135	77
SCG2	305	35
	295	42
	230	62
SCG3	105	80
	55	90

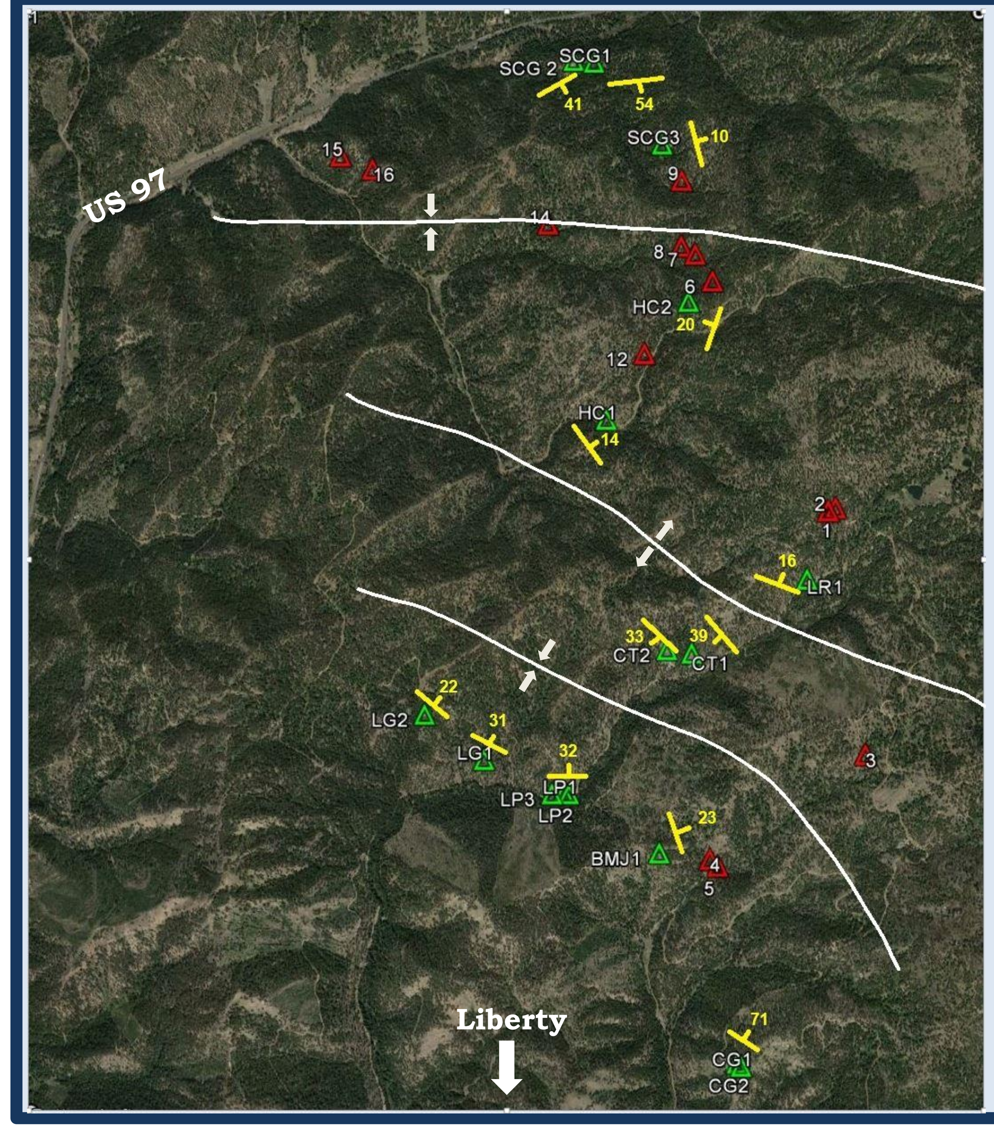

Figure 3. Monoliths in the Swauk Watershed, overlain onto Google Earth image. Green triangles indicate monoliths visited. Numbered red triangles indicate monoliths mapped from Google Earth. Yellow strike and dip symbols measured from the monoliths.

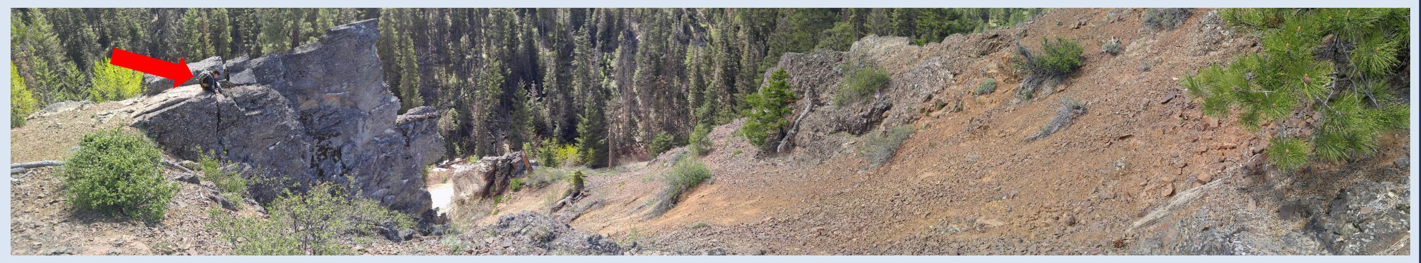

Figure 4. Rebeca taking trend & plunge measurements of joints at site HC1. View SW.

Origin Model

1. Swauk Formation deposition began 59.9 million years ago (Ma) as W to SW flowing streams laid down sands & gravels (Eddy et al., 2015). Evidence: rip up clasts, cannonballs, sedimentary structures, and calcite veins
2. Intrusion by Teanaway dikes 47 Ma (Miller 2014)
3. Tectonic uplift and folding further complicated geology. Evidence: jointing & tectonically influenced drainage reorganizations (Miller 2014)
4. Weathering. Evidence: grus (i.e., gravel-sized debris), honeycombs & weathering pits created by exfoliation & hydrolysis
5. Mass Movement. Evidence: removal of grus; rockfall from the anti-dip surfaces & sides
6. Fluvial erosion I. Evidence: extinct channels and potholes located on anti-dip slopes
7. Fluvial erosion II. Evidence: backwasting of the features; pillar & cliff-like shapes

Conclusions & Future Research

- Although these features have been explained as products of either subsurface water erosion and selective weathering (Alexandrowicz and Urban 2005), or differential weathering and mass movement (Dyke 1976), our field investigations support a combination of all the above processes. A series of tectonic uplift, mass movement, weathering, fluvial erosion, and backwasting have together influenced the genesis of the monoliths in the Swauk Watershed.
  There is no doubt in our minds that the monoliths are tors, as they match the definitive criteria: they are individual rocky features that form separated from the slope and other landforms, and are characterized by walls sculpted primarily by weathering processes.
- In the future, our data can be applied to adjacent Peshastin Creek and Teanaway River watersheds in order to construct a regional map of the monoliths. Further, future researchers can see how the origins of these monoliths are related to others in surrounding basins.

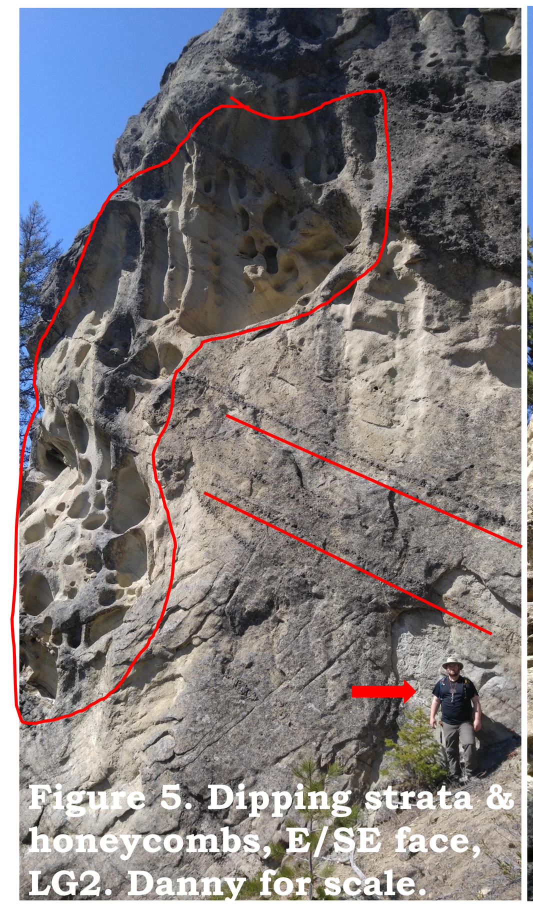

Figure 5. Dipping strata & honeycombs, E/SE face, LG2. Danny for scale.

Figure 6. Pillar form & joints, S/SW face, LG2. Danny for scale.

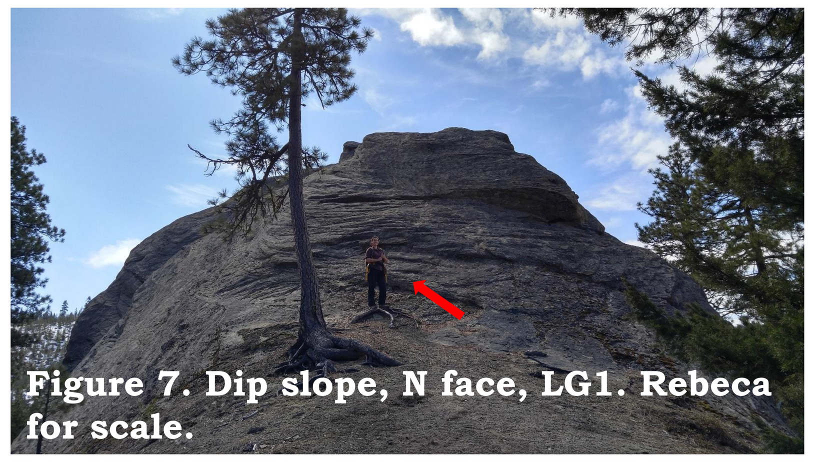

Figure 7. Dip slope, N face, LG1. Rebeca for scale.

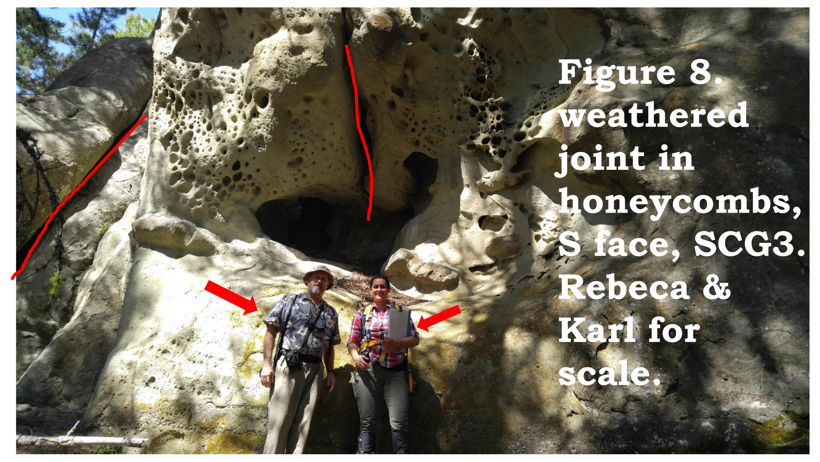

Figure 8 weathered joint in honeycombs, S face, SCG3. Rebeca & Karl for scale.

References

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