Tremendous Erosion of the Cascade Anticlinorium near Mount St. Helens

Part 1: Structure and Calculations

Edward A. Isaacs*

Abstract

The Cascade Anticlinorium is a prominent feature from southern British Columbia to northern California that formed from regional folding during the Cascade Orogeny. Extensive research has been conducted across the anticlinorium and its parasitic folds, but little focus has been given to the erosion surface that truncates the anticlinorium. Outcropping along parasitic folds on the western flank of the Cascade Anticlinorium, Mount St. Helens is an excellent location to assess erosion. An examination of regional stratigraphy and structure of the anticlinorium, as well as the parasitic folds that comprise the deformed basement underlying Mount St. Helens, reveals that at least 7,850 m of strata were eroded along the truncated Lakeview Peak Anticline, while exhumed intrusives in the adjacent Pole Patch Syncline suggest a greater value. Because this erosion surface can be traced across the entire Cascade Anticlinorium, significant erosion occurred across the entire anticlinorium, much of which happened after regional folding. Such massive denudation is only explicable by the Genesis Flood.

Introduction

A profound irony in the geosciences is the unintended demonstration of phenomena best explained by the Genesis Flood. Though first nurtured in a biblical heritage, geology has become the flagship for deep time and its accompanying uniformity of rates punctuated by a preponderance of cataclysms (Reed, 2010; Reed and Williams, 2012). Despite this elevated position, geology has repeatedly bewildered pure naturalistic explanation. Geomorphology, the systematic study of landforms and their origin, is one such discipline not only documenting the numerous mysteries of secular naturalism (Akridge and Froede, 2000; Oard, 2011) but also detailing the impact of the Genesis Flood on Earth and its reverberations throughout history (Oard, 2008a; 2016; Clarey, 2017b). Recent geomorphological studies have shown a growing interest in anticlines as show-

* Edward A. Isaacs, Portland, OR, CreationGeoExplorer@outlook.com
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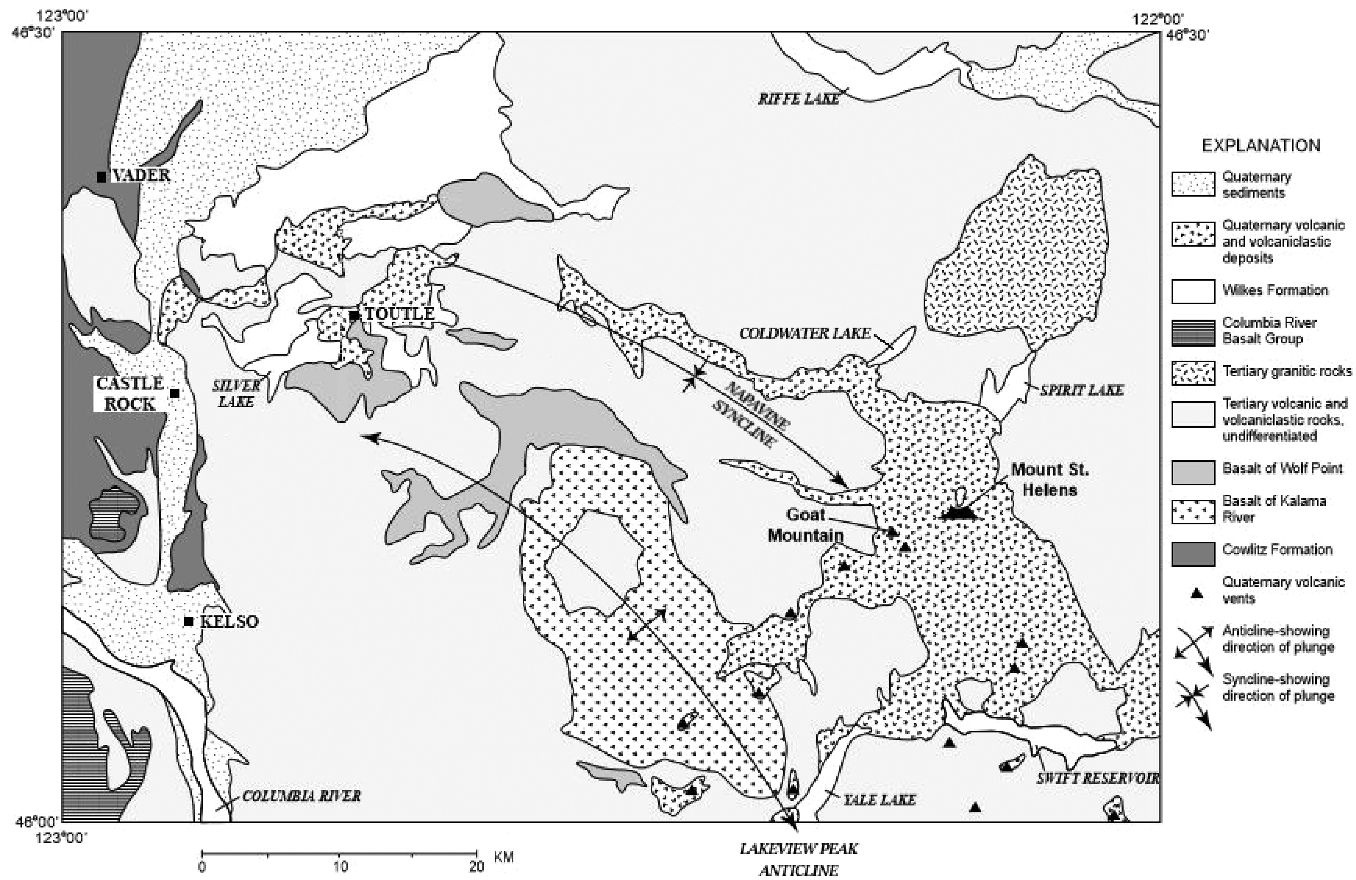

Figure 1. A geologic map of the region contiguous to Mount St. Helens detailing the stratigraphy and structural features of the region. First striking towards the southeast, the Lakeview Peak Anticline strikes easterly before trending south beyond the edge of the diagram, while the Pole Patch Syncline strikes north-south a few km east of the mapped area (c.f. Figure 7). Both Coldwater Lake and Spirit Lake are on the western flank of the Pole Patch Syncline (Evarts and Ashley, 1993b), although the structure of the Pole Patch Syncline in the northwestern region of the diagram is complicated by the lesser Napavine Syncline, which surfaces along the Lakeview Peak Anticline northwest of Goat Mountain. Modified from Figure 1 of Evarts (2001).

cases of prodigious erosion (Oard, 2012; 2013c; Matthews and Oard, 2015; Oard and Matthews, 2015). Ranging from the southern tip of British Columbia to the northern regions of California, the Cascade Anticlinorium is a north-south anticlinal composite fold composed of numerous anticlinal and synclinal parasitic folds. One of several major anticlinoria in the northwestern United States, the Cascade Anticlinorium is a member of a complex fold belt just beginning to be understood (Cheney and Hayman, 2007; Cheney, 2014). One of its features commonly overlooked by secular researchers is the erosion surface truncating the anticlinorium (Cheney, 2016b), which provides the deeply dissected platform hosting several Pleistocene volcanic cones such as Mount St. Helens (Figure 1). The geology surrounding Mount St. Helens shows evidence for diluvial-scale erosion of the Cascade Anticlinorium.

Structure and stratigraphy of the Cascade Anticlinorium

Along the western coast of North America, the Cascade Arc is a belt of continental foreshortening (folding) and increased volcanism that spans British Columbia to California (Cheney, 1997). Dominating the northern region of the arc are north-south anticlinoria, defined as "composite anticlinal structure[s] of regional extent composed of lesser folds" known as parasitic folds (Jackson,

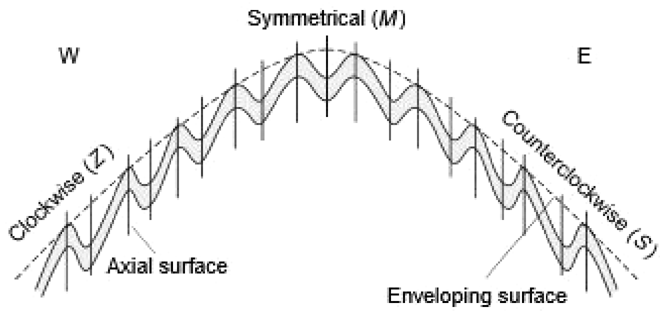

Figure 2. The general structure of a symmetrical anticlinorium, a "composite anticlinal structure of regional extent composed of lesser folds" termed parasitic folds (Jackson, 1997, p. 28); the inverse of an anticlinorium is termed a synclinorium. Figure after van der Pluijm and Marshak (2004). For further information, consult Chapter 10 (Folds and Folding) of van der Pluijm and Marshak (2004).

1997, p. 28, brackets mine; see Figure 2). These anticlinoria are intermittently interrupted by younger, more subdued east-west synclinoria, which are "composite synclinal structure[s] of regional extent composed of lesser [parasitic] folds." (Jackson, 1997, p. 645, brackets mine). This pattern of east-west synclinoria superposed upon the more extensive north-south anticlinoria cumulatively produces the 'egg-crate' topography of the northwest United States (Cheney and Sherrod, 1999). Besides the various anticlinoria such as Hog Ranch-Eagle Creek Anticlinorium and Eocene metamorphic core complexes in Eastern Washington and Idaho, two major north-south anticlinoria are found in Washington State, namely the Coast Range Anticlinorium along the coastline and the Cascade Anticlinorium up to two hundred kilometers inland. The most spectacular of these anticlinoria, the Cascade Anticlinorium exceeds 3.6 km from the structural base of the Pasco Basin in Eastern Washington to the present crest of the Cascade Anticlinorium (Cheney, 2016b).

Although this north-south tending anticlinorium spans the British Columbia border to northern California, the Cascade Anticlinorium is interrupted in northern Oregon by the westerly-striking Dalles-Umatilla Synclinorium, which causes the southerly plunge of the Cascade Anticlinorium in southern Washington and the northerly plunge of the Cascade Anticlinorium in northern Oregon (Cheney, 2016b, pp. 208–209). Within Washington, the Cascade Anticlinorium reaches its highest elevation in the northern portion of the state where it is dominated by igneous and metamorphic bedrock, while further south stratigraphically younger deposits dominate the more subdued topography (Cheney and Hayman, 2007). An impressive erosion surface truncates the Cascade Anticlinorium and its smaller parasitic folds, forming the platform which hosts the region's Pleistocene composite cones.

In total, the fold belt exhibits four major unconformity-bounded sequences (Table 1), termed *synthems*, that define the structural features of the region (Cheney, 2016a). Dated to the Early to Late Eocene, the lowermost sequence is the Challis Synthem, predominately arkosic in lithology (e.g., Wenatchee and Roslyn formations) with interbeds of basaltic to rhyolitic flows (e.g. Teanaway and Taneum formations) and volcaniclastics. Above the Challis Synthem is the primarily volcaniclastic Kittitas

Table 1. The Cascade Anticlinorium is comprised of four unconformity-bounded sequences, termed synthems, composed of a variety of lithologies dated from Early Eocene to recent.

Synthem	Age	Primary lithologies
High Cascade	Pliocene to Present	Alluvial, laharic, volcaniclastic, glaciogenic, and mass wasting deposits
Walpapi	Early Miocene to Pliocene	Flood basalts with interbeds of volcaniclastics, siliciclastics, and lithics
Kittitas	Late Eocene to Early Miocene	Andesitic and felsic volcaniclastics
Challis	Early to Late Eocene	Primarily arkosic with interbeds of basaltic to rhyolitic flows and volcaniclastics

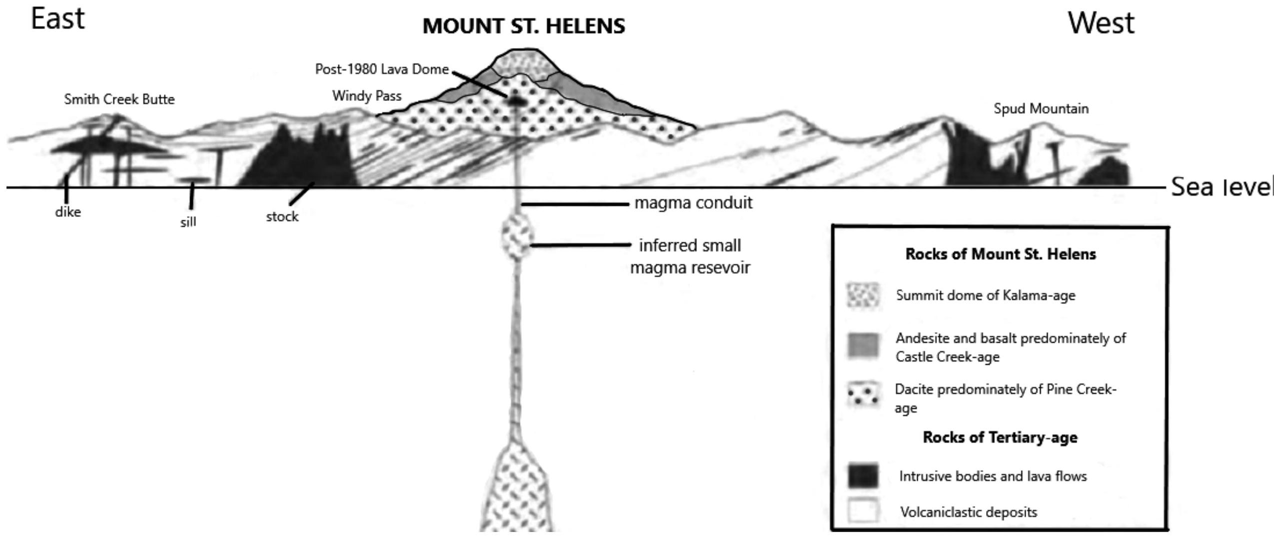

Figure 3. A cross section of Mount St. Helens and the underlying crust clearly depicting the eastward dipping formations of the Lakeview Peak Anticline and adjacent Pole Patch Syncline to the east. Interestingly, the intrusive suite along Spud Mountain has not been greatly deformed by tectonics despite a naturalistic age of 31 Ma, allegedly preceding regional folding by more than 10 Ma. Observe that the dips decrease gradationally towards the west (right) as one nears the Napavine Syncline just beyond the western edge of the diagram. This Napavine Syncline surfaces along the Lakeview Peak Anticline a few km southward, as shown in Figure 1. Modified from Pringle (2002).

Synthem representing the Late Eocene to Early Miocene, which is overlain by the younger Walpapi Synthem of Early Miocene to Pliocene age.

The Walpapi Synthem is exemplified by the Columbia River Basalts, particularly evident in the Columbia River Gorge along the Dalles-Umatilla Synclinorium. Found predominately in structural lows, the Columbia River Basalts have been the subject of much contention over whether they predate or postdate the Cascade Orogeny. Tolan and Beeson (1984) proposed that the Columbia River Basalts were intracanyon flows formed in precursory structural lows through the Cascade Range, but recent research suggests that the Columbia River Basalts were merely *preserved* within structural lows, such as the Dalles-Umatilla Synclinorium (Newcomb, 1967), and thus predate regional folding during the Cascade Orogeny (see Cheney, 2014; 2016a; 2016b and references therein).

Sparsely overlying the Walpapi Synthem, the High Cascades Synthem dated Pliocene to recent is the youngest unconformity-bounded sequence. Dominated by alluvial, laharic, volcaniclastic, glaciogenic, and mass wasting deposits, localized deposits of the High Cascades Synthem dot the erosion surface truncating the Cascade Anticlinorium.

Geology of the Mount St. Helens Region

Towering 1,400 m above the deeply dissected topography in southwest Washington, Mount St. Helens is the westernmost Pleistocene composite cone along the Cascade Anticlinorium (Figure 1). With an extensive history of volcanism and geomorphological evolution, Mount St. Helens is "a living laboratory to document, visualize, and understand a changing landscape" (Austin, 2009). However, this stratovolcano is merely a minor volcanic feature following a long trend of volcanism that both preceded and later succeeded the Cascade Orogeny.

On the western flank of the Cascade Anticlinorium, several truncated parasitic folds comprise a significantly deformed basement that is unconformably overlain by the deposits of Mount St. Helens (Figures 1 and 3). The deeply dissected topography offers spectacular exposures of the internal structure (Figure 4), as Evarts et al. (1987) explain:

Figure 4. The deforestation along the northern regions of Mount St. Helens during the 18 May 1980 eruption left the eastwardly dipping formations (denoted by arrows) of the west limb of the Pole Patch Syncline strikingly visible around Spirit Lake.

> The Tertiary rocks beneath Mount St. Helens strike roughly north-south and dip east at an average of…, forming the northeastern limb of a broad regional anticline that plunges gently south. The axis of the corresponding syncline lies several kilometers east of the mapped area. Such broad open folds are the dominant structures in the Cascade province of southern Washington.

This regional anticline is the Lakeview Peak Anticline (Phillips, 1987a), a doubly plunging antiform that strikes eastward before trending southerly to the west of Mount St. Helens until it is displaced along the younger Chelatchie Prairie fault zone north of Vancouver, Washington (Phillips, 1987b; Evarts and Ashley, 1991; Evarts, 2005). The adjacent syncline east of Mount St. Helens is the,

> broad Pole Patch syncline, a gentle fold in the crustal rocks whose axis is located about 15 mi (25 km) east of the Coldwater Ridge Visitor Center [several km northwest of Mount St. Helens]. (Pringle, 2002, p. 51, brackets mine.)

Complicating the structure of these parasitic folds is the Napavine Syncline to the northwest (Figure 1). This syncline traces along the eastern limb of the Willamette-Puget-Fraser Synclinorium west of the Cascade Anticlinorium before striking eastwardly to the north of the Lakeview Peak Anticline until surfacing along the eastern limb of the Lakeview Peak Anticline northwest of Goat Mountain (Evarts and Ashley, 1990). With amplitudes ranging from an estimated 1–5 km (Swanson et al., 1989), these folds are a sample of the extensive continental foreshortening during the Cascade Orogeny.

Geologic mapping of the region surrounding Mount St. Helens has identified a complex agglomeration of Oligocene to Early Miocene volcanogenic strata correlating to the Kittitas Synthem, although neither the lower nor upper contacts of the Kittitas Synthem have been identified in the region contiguous to Mount St. Helens (Evarts et al., 1987). While this assemblage includes the "remains of basaltic cones and shields, andesitic composite cones, dacite domes, and possibly a small caldera, all intruded by a myriad of subvolcanic to epizonal intrusions" (Evarts et al., 1987), lithified pyroclastics of varying qualities dominate the lithology (Figures 5a and 5b). These volcanogenic beds are assumed to have resulted from subaerial emplacement (Evarts and Ashley, 1993a), although work in recent decades questions that interpretation (Froede, 2000; Oard, 2002; Woodmorappe and Oard, 2002; Froede, 2003). The Kittitas Synthem is locally unconformably overlain by the High Cascades Synthem, which in this locale primarily resulted either directly or indirectly from the Mount St. Helens eruptive cycles.

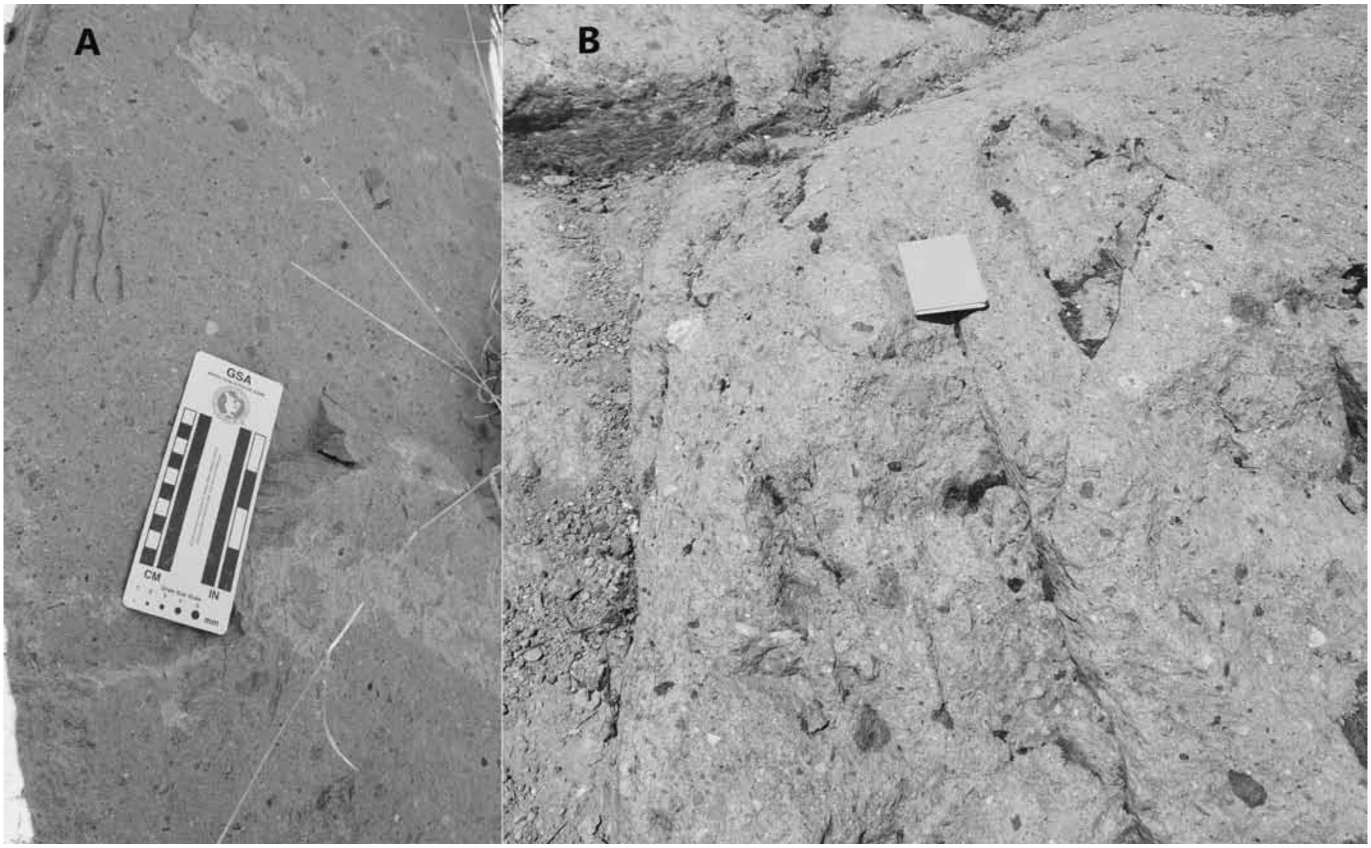

Figure 5. Lithified volcaniclastics are a dominating feature of the Kittitas Synthem throughout the regions contiguous to Mount St. Helens.
A—Roadcuts often expose welded tuff in cross section or contain boulders such as the depicted block.
B—A volcanic breccia (dated approximately 30 Ma) exposed along the Harmony Trail on the northern shores of Spirit Lake.

Intrusives: chronological indicators

Intrusive complexes across the region have been used to decipher the chronology of regional folding. Potassium-Argon dating by Evarts et al. (1987) defined four discrete periods of magmatism dating from the Oligocene to Quaternary. Their first, and most extensive, period commenced with plutonic intrusions, such as the granitic Spirit Lake Pluton, accompanied by extensive extrusion of lava and pyroclastics from the Oligocene to Early Miocene. Evarts et al. postulate local magmatism briefly stalled while regional folding during the Cascade Orogeny (20–15 Ma) formed the Cascade Anticlinorium and its parasitic folds (e.g. Lakeview Peak Anticline and Pole Patch Syncline) until magmatism renewed in the Middle Miocene.

Another episode of magmatism resumed in Late Miocene, although more recent radiometric dating suggests an Early Miocene age (Evarts, 1993a). Intrusives from the "Late Miocene" and subsequent magmatism have remained relatively undeformed and exhumed while their corresponding extrusives were eroded (Hammond, 1980; Evarts et al., 1987), suggesting that these intrusions preceded regional truncation. Evarts et al. (1987) suggest that a final episode of volcanism continued locally through the Quaternary, resulting in numerous intrusions that correspond to their extrusive rocks of the High Cascades Synthem.

The flaws of radiometric dating, however, force us to view this chronology with caution. Drastic revision is not uncommon as new dates are obtained, and they often contradict previous work or alternative radiometric dating schemes. No method is presently available for radiometrically-based relative dating for the Late Cenozoic. Despite the lively debate among diluvialists regarding the use of relative dates (e.g., Humphreys, 2000; Baumgardner, 2012; Froede and Akridge, 2012; Oard, 2013a; Clarey, 2016), examples tend to focus predominately on the pre-Cenozoic or Early Cenozoic strata, and thus lack an

Table 2. Summary of the major stages of intrusives at Mount St. Helens. Because of the questionable dating of these intrusives to specific epochs of the Geologic Timescale, they are here arranged by their relation to the Cascade Orogeny and subsequent erosion. Type localities are also noted, although not all intrusives will always correlate to their faulty radiometrically-assigned date.

Stage	Generally Corresponding Epoch	Type locality
Pre-uplift	Oligocene to Mid-Miocene	Spirit Lake Pluton
Post-uplift/pre-erosion surface	"Late Miocene" to Early(?) Pliocene	Smith Creek Butte Intrusive Complex Kidd Creek Suite
Post-erosion surface	Late(?) Pliocene to Holocene	Goat Rocks Dome

adequate scale of resolution for practicality in the Late Cenozoic.

These challenges to the Evarts et al. (1987) narrative are exacerbated by conflicting chronologies based on intrusives. Although the intrusions of "Late Miocene" (8–12 Ma) postdate regional folding, later radiometric dates (Evarts and Ashley, 1993b) suggested that the intrusions were up to 12 Ma *older* than regional folding (20–15 Ma) despite no evidence of deformation from folding (Evarts et al., 1987). Similarly, the Spud Mountain intrusive suite west of Mount St. Helens, notwithstanding a postulated age of 31 Ma, has not been greatly deformed or tilted by the regional folding that allegedly postdates it by 10 Ma (Evarts and Ashley, 1993b). On a broader scale, the secular construct based on radiometric dating is complicated by the mutually exclusive narratives proposing that the Cascade Orogeny terminated anywhere between 15 Ma to 3 Ma (Appendix). Indeed,

> Stratigraphic details and geologic relationships should be viewed as more factual compared to age-dates, and yet, age-dates seem to always trump any other data sets, *regardless of conflicts*. (Clarey, 2017a, emphasis mine.)

Such is common when dating the Cascade Orogeny, forcing us to rely not on radiometric dating and chronostratigraphy but on empirical stratigraphy to broadly differentiate these various eruptive periods of the Kittitas and High Cascades synthems at Mount St. Helens. These episodes, summarized in Table 2 as pre-uplift, post-uplift/pre-erosion surface, and post-erosion surface, generally correlate to the eruptive cycles of Oligocene to Early Miocene, "Late Miocene" to Early(?) Pliocene, and Late(?) Pliocene to Quaternary, respectively, although there are exceptions which will require further research.

Calculating the magnitude of erosion

The broad open folds of the Cascade Anticlinorium, like any foreshortened region, are analogous to a massive sinusoid whose crests represent antiforms and troughs exemplify synforms. While a fold system can be more complex than a sinusoid, particularly where folding was superposed upon a previously deformed region, the geometry between the axis of the trough and the adjacent crest remain analogous to that of a sinusoid. This allows us to produce a conceptual model to quantify the erosion along the Lakeview Peak Anticline. Extensive mapping of the area contiguous to Mount St. Helens and elsewhere has revealed the fold belt to be shallow and nearly symmetrical without overturned or heavily faulted folds to complicate the structure, making a simple sinusoid a particularly cogent analogy for our calculations.

Like a sinusoid, a fold has a mathematically predictable morphology. Both the crest and trough have their own axial plane that intersects the axis, while the inflection point (midpoint) bisects the sinusoid horizontally. The slope at any point (or pair of infinitely close points) along the sinusoid is measured using a tangent line. As the tangent line measures the slope at a point using a linear function, the tangent line will intersect the antiformal axis either above (higher y-value) or below (lower y-value) the axis depending upon the slope of the tangent line and the position of the point it measures. We may observe from Figure 6 that the intersection of the tangent line and the axial plane produces an angle complimentary to the angle produced by the tangent line intersecting the horizontal plane of the reference point, while the horizontal plane intersects the axial plane at a right angle. This produces a right triangle, simplifying our study to a simple trigonometric calculation.

First, the 20º–25º dip of the strata mapped by Evarts et al. (1987) provides the slope of our tangent line, which constitutes the hypotenuse of our right triangle. Second, the horizontal distance between the arbitrary reference point (from which we can measure relative distance) along the sinusoid to the anti-

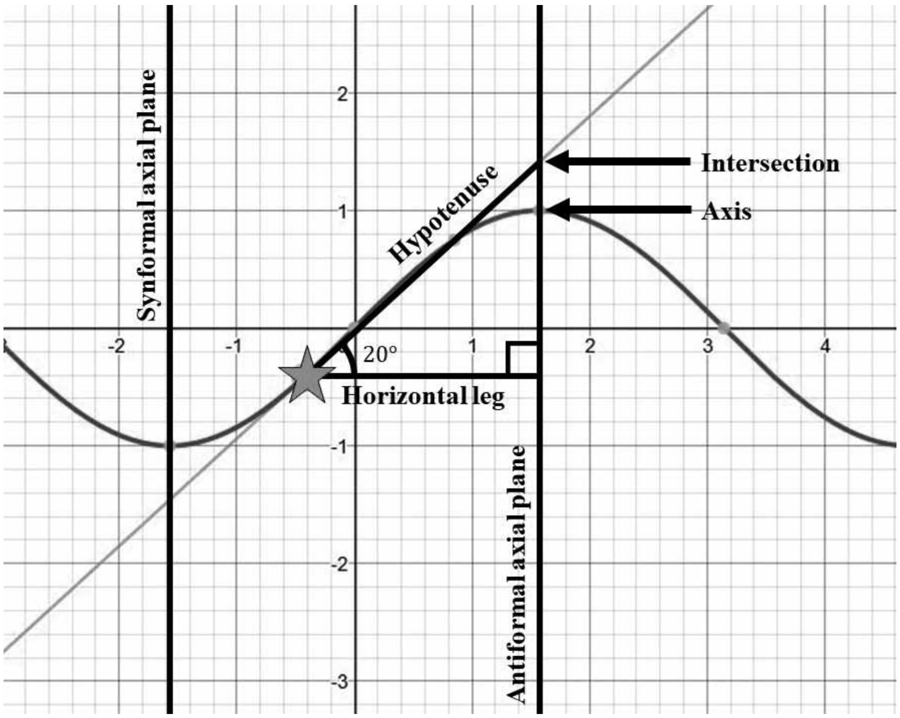

Figure 6. A fold belt is analogous to a sinusoid, which we may use to calculate the height of the Lakeview Peak Anticline before it was truncated. The star denotes an arbitrary reference point, while the slanted line coincident with the line termed 'Hypotenuse' is the tangent line, which in this case is 20° above the horizon. The tangent line intersects the antiformal axial plane (vertical line) at the point denoted as 'Intersection.' The resulting triangle allows us to calculate the vertical distance between the reference point (star) and the 'Intersection,' which we may multiply by a certain value to obtain the vertical distance between the reference point and the axial crest.

formal plane constitutes the horizontal leg. Knowing the slope of the tangent line (and thus the other two angles) and the length of the horizontal leg, we can easily calculate the vertical leg of our right triangle. Because the point at which the tangent line intersects the antiformal axial plane will vary depending on its slope, one must multiply the length of the vertical leg by a certain percentage to yield the vertical distance between the reference point and antiformal axis, as can be seen in Figure 6. Using an arbitrary point for reference, we may easily find this value by examining the structural geology.

Our reference point (Figure 7) lies just west of Smith Creek Butte along the eastern flank of the Lakeview Peak Anticline, as seen in Figure 3. This reference point is approximately 16 km west of the Pole Patch Syncline axis and 28 km east of the Lakeview Peak Anticline axis, placing our reference point approximately 36.7% (16.2/44.2) of the distance from the axis of the Pole Patch Syncline to the Lakeview Peak Anticline. This indicates that the vertical distance from the present topography to the peak of the pre-eroded anticline will be 77% of the length of the vertical leg of our right triangle (see above and Figure 6).

Knowing the minimum slope of our tangent line and the length (28 km) of the horizontal leg *b*, we may calculate the length of the hypotenuse:

$$\cos 20° = \frac{28.0 \text{ km}}{h}$$

Solving for *h* yields 29.8 as the length of the hypotenuse or extrapolated strata. To solve for the vertical leg *a*, or the vertical distance between the present topography to the anticlinal crest, we input this information into the Pythagorean theorem:

$$\sqrt{a^2} = \sqrt{29.8\ldots^2 - 28.0^2}$$

This leads to a = 10.2 km, which we multiply by the 77% (see above) to yield 7.85 km (7,850 m). This value is the anticipated height of the anticlinal crest above the present erosion surface, and thus a likely estimate of the thickness of strata eroded. However, this is a minimal value based on using the lower estimate for the slope. If we used the 25° slope value, the pre-erosion thickness would be 10.1 km.

How extensive is the erosion?

This extensive truncation has greatly altered the topography such that any anticlinal crest is scarcely visible above the adjacent syncline, dictating that the anticline was eroded below the midpoint (inflection point) of this fold system. This has caused the regional fold belt to be nearly invisible on topographic maps because erosion has nearly leveled the structural relief, although geologic maps allow the three-dimensional extrapolation of the pre-eroded structure.

Not only has erosion nearly obliterated any topographical trace of the anticlines, but the synclines have similarly been truncated. After investigating the Kidd Creek Intrusive Suite northeast of Mount St. Helens in the Pole Patch

Syncline, Swanson (1992) noted that this complex postdates regional folding but was solidified at depths between 1 to 5 km before being exhumed by the erosion surface. Because the topographic relief is 1 km, Swanson (1992) proposed that 1 to 4 km has been removed from the Pole Patch Syncline, which would by extension suggest that the Lakeview Peak Anticline was eroded by 1 to 4 km in addition to our calculated 7.85 km (bringing our calculation to 8.85–11.85 km). This local truncation is merely a small segment of the vast erosion surface truncating the entire Cascade Anticlinorium, suggesting that much of the Cascade Anticlinorium was eroded by a similar, if not greater, value.

A preliminary calculation suggests a minimum of 34,000 cubic kilometers of eroded material has been removed from the truncated Cascade Anticlinorium in Washington State alone—greater than the cubic volume of North America's Great Lakes combined (23,000 cubic kilometers). Further research across the Cascade Anticlinorium is required for more specific results.

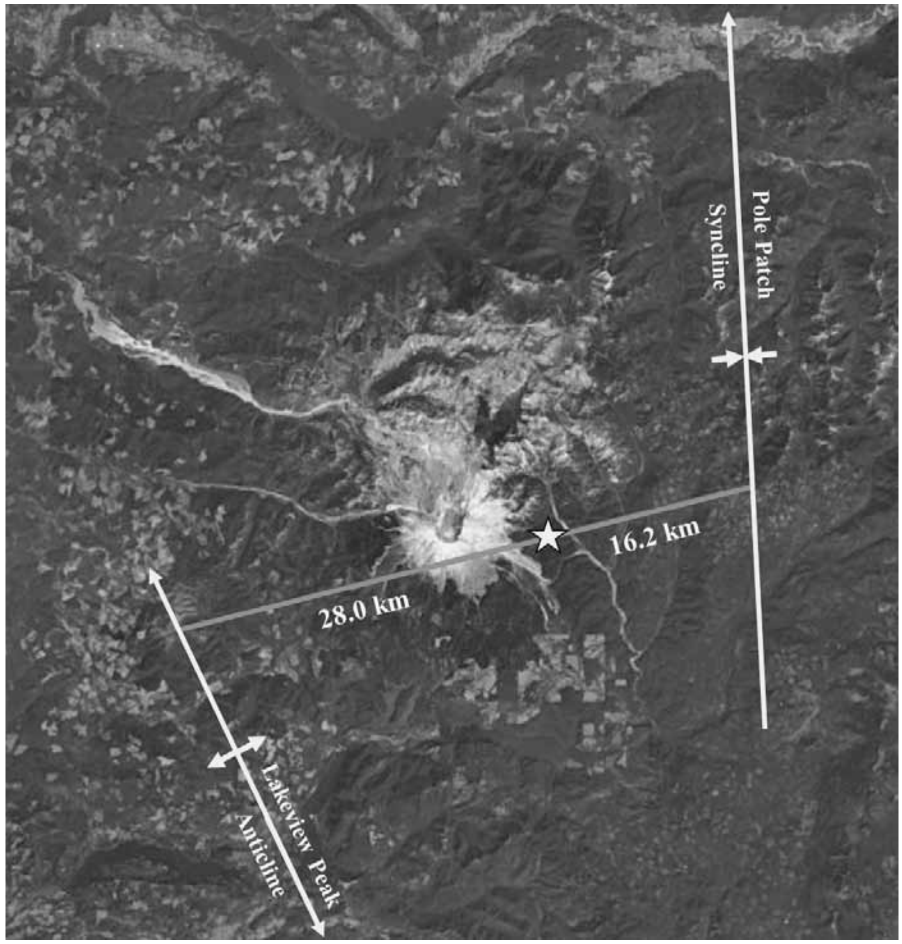

Figure 7. A simplified diagram depicting Mount St. Helens and structural features of the Lakeview Peak Anticline and Pole Patch Syncline; arrows denote direction of plunge (compare with Figure 1 for a more comprehensive examination). The line connecting both Lakeview Peak Anticline and Pole Patch Syncline is a 44.2 km transect representing the distance between axes. The star denotes our reference point west of Smith Creek Butte (shown in cross section in Figure 3), while distances between that point and the axes are also shown.

An enigmatic challenge to secular geology

The formation of this vast erosion surface has long been ignored by secular geologists, no doubt from its challenging implications. Naturalistic geology invokes only gradual processes and the occasional cataclysm; it must rely solely on wind, glacial, fluvial, and mass wasting processes to transform Earth's surface. Options are further restricted when we consider that wind lacks the necessary power, while there is no evidence of glaciers forming such an extensive erosion surface. Similarly, mass wasting would form no such erosion surface and would deposit the sediments in the adjacent valleys, which generally lack extensive basin fill. Such fill would be easily discernable on geologic maps, but many basins in the region are relatively shallow, the obvious exception being the Willamette Valley west of the Cascade Anticlinorium. The Willamette Valley can have tens of meters of surficial deposits but is too far south to contain the vast eroded products of Washington's Cascade Anticlinorium. Furthermore, such sediments pale in comparison to that eroded from the Cascade Anticlinorium (see Plate 15.2 in Cheney, 2016b).

Forced to rely solely on fluvial processes, secular geologists have proposed three primary erosional models (Oard, 2018):

1. Superimposed stream hypothesis
2. Stream piracy hypothesis
3. Stream antecedence hypothesis

Frequently applied to transverse drainages, these models are riddled with assumptions (Oard, 2008b), the first two assuming that the erosion surface formed at the present elevation without significant subsequent uplift, while the third suggests that diastrophism uplifted the erosion surface to the present elevation. Nonetheless, secular geologists must assume that the stream(s) would plane the region rather than transect or circumnavigate the structural barrier, as actually observed today.

The superimposed (or superposed) stream hypothesis postulates that certain structural barriers (e.g., antiforms) were buried by sediment and gradually exhumed by stream erosion, although this model has been discarded by naturalistic geologists chiefly because it assumes that such vast sediment now removed had once buried the underlying topography. Indeed, it posits sediment that is not presently observable anywhere! This problem is magnified by the erosion surface truncating the Lakeview Peak Anticline being a small segment of the erosion surface across the *entire* Cascade Anticlinorium. This forces the conclusion that the entire Cascade Anticlinorium was once buried, but if that happened, the eroded sediment has not been found in any nearby valleys.

Similarly, stream piracy postulates that at least two streams coalesced when one stream eroded more quickly than the other(s) and thereby consolidated the collective discharges into one stream. Although more appropriate for water gaps, one could argue that stream piracy potentially explains the erosion surface, but stream piracy would not create an extensive erosion surface like that extending across the *entire* Cascade Anticlinorium. Instead, it would erode laterally, rounding the folds into ridges separating vast peneplains, as supposed by naturalistic thought, rather than generating a planar erosion surface leveling the folds.

Stream antecedence, the most popularly invoked of the three, is particularly common in the literature on the Columbia River Gorge (Tolan and Beeson, 1984; Tolan et al., 2002), although it has not been proposed for the truncated Cascade Anticlinorium. This model postulates that the stream eroded the substrate at the same rate as the basement rock was being uplifted, opining that erosion and uplift continued in equilibrium. This continued equipoise is highly unlikely to produce transverse drainages (Oard, 2018), so how much more difficult would it be for any stream(s) to erode along vast stretches of the uplifting Cascade Anticlinorium and its parasitic folds, especially maintaining such a perfect equilibrium? Furthermore, the undeformed intrusives near Mount St. Helens were formed at depth subsequent to regional folding, and only later became exhumed by erosion. This indicates that the Cascade Anticlinorium had already been uplifted before extensive truncation commenced.

Not only do these models individually fail to explain the field data, but there is no conceivable combination of them that would explain it. Remember that both anticlinal crests and synclinal troughs have been leveled below the original floor of the synclinal valleys. These naturalistic interpretations furthermore fail to explain how the resulting sediment was transported from the region into the surrounding valleys, which lack the required basin fill. Therefore, two important questions that any model must explain are:

1. How was such an extensive area eroded?
2. Where is the resulting sediment?

Tremendous erosion during the early to late Flood

The Genesis Flood offers mechanisms that can explain the erosion of this region. Deciding which phase of the Flood corresponds to the erosion of the Cascade Anticlinorium requires a combination of various disciplines (Whitmore and Garner, 2008; Oard, 2016), particularly through the application of geomorphology, paleontology (Cowart and Froede, 1994; Whitmore, 2006; Ross, 2012), stratigraphy (Reed, 2005; Clarey and Werner, 2019), and the requisite geologic energy (Reed et al., 1996). While paleontology cannot be applied directly to this locality, the remaining three criteria suggest a dynamic high-energy water event of regional extent produced the ubiquitous erosion surface. Although substantial post-Flood catastrophism negates some of the problems encountered by the gradual processes of naturalistic geology, post-Flood catastrophes appear insufficient to produce the erosion surface due to the scale, as such local events would produce features very similar to the uniformitarian interpretations discussed previously.

Because some undeformed intrusive complexes postdate the onset of regional folding during the Cascade Orogeny but preceded the erosion surface, the formation of the erosion surface would require a prodigious cataclysm. As mentioned above, mass wasting would merely relocate the sediment to a nearby basin, but adequate rock eroded from the region cannot be found in the adjacent synclinoria. Furthermore, the scale of the Cascade Anticlinorium alone is beyond the potential reach of regional catastrophes such as post-Flood lakes or Ice Age floods, which were largely confined to already existent basins rather than traversing major structural barriers. Instead, what is required is a cataclysm that not only encompasses the immediate region but also the adjacent basins. Such a scale could only be achieved during the Genesis Flood.

The truncation of the Cascade Anticlinorium could have occurred during one or a combination of three distinct phases of the Genesis Flood (Figure 8):

1. The initial energy peak of Reed et al. (1996) at the Flood's onset
2. The Zenithic Phase of Walker (1994) at the Flood's climax
3. The recessive Sheet Flow Stage of Oard (2001a; 2001b) during the Late Flood

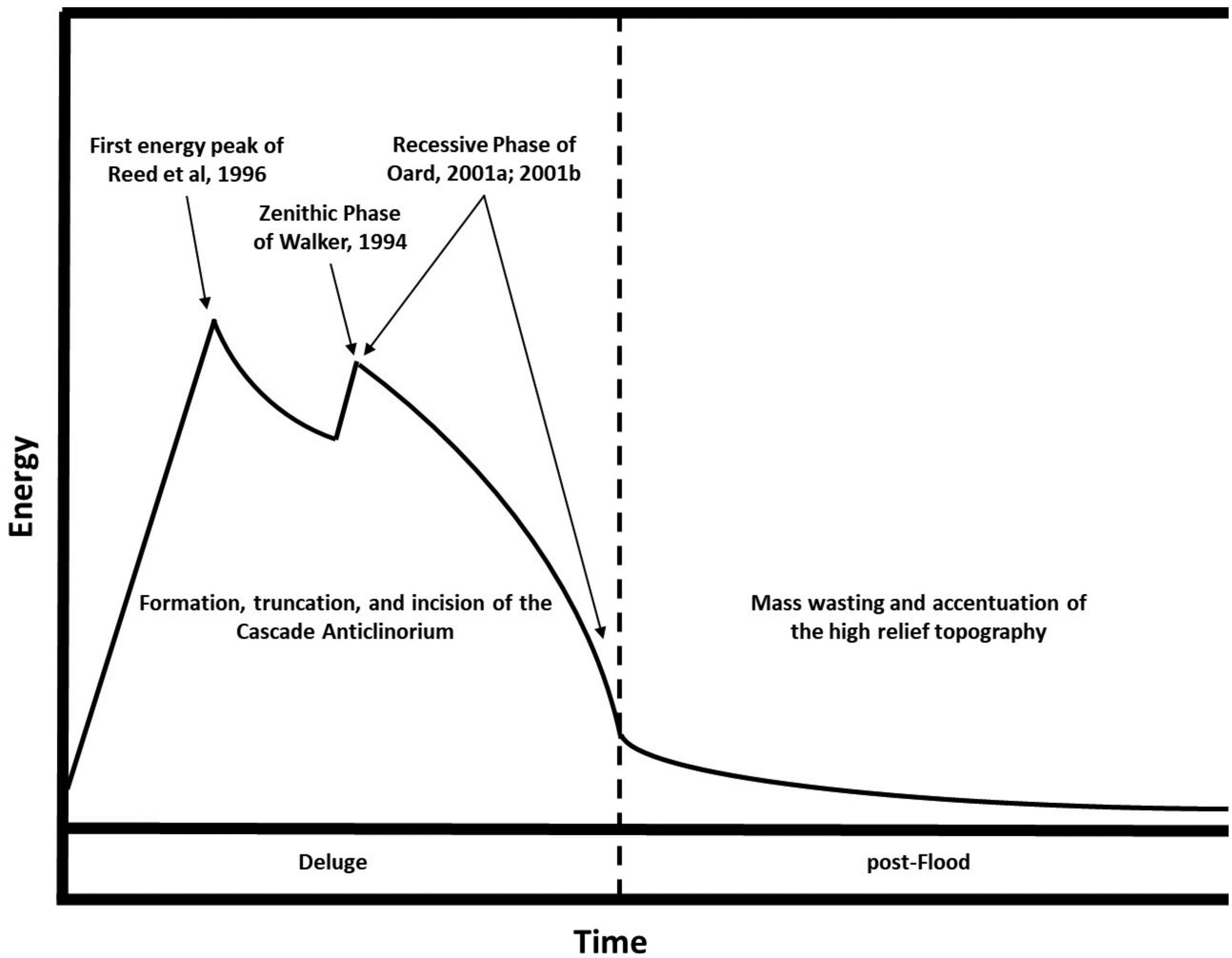

Figure 8. There are three potential phases during which the Cascade Anticlinorium could have been truncated, being: 1) the energy peak of Reed et al. (1996) at the Flood's onset; 2) the Zenithic Phase of Walker (1994) at the Deluge's climax; and 3) the Sheet Flow Stage during the Recessive Phase of Oard (2001a; 2001b) in Late Flood. As Earth gained a quasi-equilibrium state in the post-Flood era, processes such as mass wasting, glaciation, and others would accentuate and sculpt the high-relief topography. Designed after the energy curve in Reed et al. (1996; their Figure 1); not to scale. Similarities between models does not imply complete agreement between the chronologies of Walker (1994), Reed et al. (1996), and Oard (2001a; 2001b).

Determining which stage the truncation occurred must be accomplished through the application of various disciplines, as discussed above. Vertebrate ichnofossils in the Chuckanut Formation and Puget Group of the Challis Synthem (Mustoe, 2002; Mustoe et al., 2012; Mustoe and Hopkins, 2013) indicate an Early Flood or prior origin of the Challis Synthem (Cowart and Froede, 1994; Oard, 2013b), but few fossils in younger synthems make direct dating of the later deposits and subsequent Cascade Orogeny difficult. Stratigraphic analysis of the Cascade Anticlinorium could produce a relative chronology of regional tectonism which in certain locales may be dated directly. For example, determining the age of the Columbia River Basalts (which predate the Cascade Anticlinorium, as discussed above) would help determine the timing of the Cascade Orogeny.

Despite this uncertainty, a general chronology may be inferred. Regardless of the stage, the Cascade Orogeny would overlap with other tectonic regimes across the region, such as rifting in Eastern Washington and uplift of the nascent Rocky Mountains, as attested by the Columbia River Basalts (Woodmorappe and Oard, 2002). Although irregularities would develop, the receding floodwaters would generally trend westward across the Cascade Anticlinorium towards the Pacific Ocean, which would be strengthened by floodwaters receding westward from the nascent Rocky Mountains to the east. Some of the eroded lithics would be deposited in the Willamette-Puget-Fraser Synclinorium west of the Cascade Anticlinorium, but the lack of extensive basin fill suggests that much of the sediment was transported into the Pacific Ocean Basin. Following truncation, further erosion of the Cascade Anticlinorium would continue on a diminished scale during the Late Flood channelized erosion phase and into the post-Flood period, sculpting and accentuating the deeply dissected topography (Walker, 1994; Whitmore, 2013).

Additional research is necessary to properly ascertain the complexities of the regional diastrophism and denudation of the Cascade Anticlinorium during the Genesis Flood and subsequent volcanism and accentuation during the post-Flood era. Such study should ascertain: (1) when during the Genesis Flood was the Cascade Orogeny and subsequent truncation; (2) what volume of material was eroded from the Cascade Anticlinorium; and (3) where the resulting sediment was deposited, as further work in this series will endeavor to answer.

Implications for the Western Coast of the United States

Such tremendous erosion across the Cascade Anticlinorium has major implications on our understanding of receding floodwaters throughout the western United States. Before extensive erosion, the Cascade Anticlinorium would pose a great barrier along much of the Western Coast during the Genesis Flood, temporarily impeding the recession of floodwaters flowing westward from tectonic adjustments along the Rocky Mountains. Both the uplift of the Cascade Anticlinorium to the west and the Rocky Mountains to the north and east would funnel the receding floodwaters southward through Eastern Washington and Oregon toward the present provinces of basin and range (Nevada), Colorado Plateau (Arizona), and others. Further research may use these currents, resultant deposits, and erosive features to decipher a relative geologic chronology for the Western United States.

Conclusions

Once again, empirical geology continues to contradict uniformitarian geohistory. The development of such a widespread erosion surface, in addition to both the calculated depth of erosion along the fold belts and the estimated volume of sediment it represents, collectively suggest hydraulic energy and scale that can only be satisfied by the Genesis Flood. Mount St. Helens straddles the massive erosion surface that truncates a belt of parasitic folds, including the Lakeview Peak Anticline and Pole Patch Syncline. Using various mathematical models, this study has estimated that a minimum of 7,850 m of strata was eroded from the Lakeview Peak Anticline, while now exposed intrusive suites in the adjacent Pole Patch Syncline indicate even greater erosion. The consistency of this extensive truncation suggests vast erosion across much of the Cascade Anticlinorium. Some undeformed intrusive complexes postdating the Cascade Orogeny were exhumed during the formation of the erosion surface, demonstrating that much of the erosion across the anticlinorium postdates the Cascade Orogeny. This severely challenges the naturalistic paradigm.

That this erosion surface probably developed in the Late Flood is suggested by the timing of the Cascade Orogeny relative to other regional geologic events. A post-Flood erosion event is rejected because of the scale and nature of the erosional surface, while post-Flood local catastrophic models also fail to explain the transport of the resulting debris beyond the immediate basins. While baffling to both secular and post-Flood models, the Cascade Anticlinorium is a testimony to the Genesis Flood.

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Appendix

Naturalistic geologists have proposed various conflicting chronologies of the Cascade Orogeny that continue to be debated. Bretz (1917) suggested that the Cascade Orogeny commenced merely 3 Ma, while later research by Tolan and Beeson (1984) on the Columbia River Basalts suggested a minimum date of 15 Ma, similar to that of Evarts et al. (1987), Swanson et al. (1989), and Evarts and Swanson (1994) who suggested the Cascade Orogeny occurred between 20–15 Ma. Recent work by Cheney (2014; 2016a; 2016b) suggests a return to a younger date of approximately 4 Ma, which was corroborated by Mustoe and Leopold (2014) using paleobotany.

To resolve these conflicting dates, Mitchell and Montgomery (2006) proposed that the Cascade Range of Northern Washington was uplifted before 15 Ma while the Cascade Range of Southern Washington was uplifted after the emplacement of the Columbia River Basalts (17 to 4 Ma). However, they did not address the anomalous features that reside wholly within the Southern Washington Cascade Range, which cumulatively necessitate uplift either between 20–15 Ma or approximately 4 Ma. Such a multi-million-year disparity is unusual, considering that naturalistic geologists opine to be capable of dating geologic events with a resolution of one hundred-thousand years! Debate over these various naturalistic chronologies of the Cascade Orogeny will persist until a reevaluation using sound stratigraphical and geomorphological principles is proposed.

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