

Volcanic Ash Identification at Saltese Flats, Eastern Spokane County, Washington

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Image courtesy of Spokane County

PROJECT OVERVIEW

Saltese Flats, in eastern Spokane County, is a wetland marsh area underlain by extensive peat deposits. In 1958, a study evaluating peat resources in Washington State reported a significant buried tephra horizon from a series of soil bore holes (Rigg, 1958). The tephra was not described in detail, and a volcanic source was not correlated. In 2019, the Spokane County wetlands restoration project at the site afforded direct examination of the tephra (ash), via excavation. This study presents the results of trench mapping, sampling, and tephra characterization from the Saltese site along with the volcanic source identification and correlation using glass shard geochemistry.

INTRODUCTION

The Cascade Range consists of nearly twenty active or recently dormant volcanoes along the western portions of California, Oregon, Washington, and British Columbia. The modern Cascade volcanoes, known as the “High Cascades”, are dominated by composite volcanoes and have been erupting for at least the last 1 million years. In the last 4,000 years alone, the United States Geological Survey (USGS) has identified multiple major eruptions from 13 separate Cascade volcanoes (Myers and Driedger, 2008). Volcanic ash from Alaskan volcanoes and the Yellowstone caldera have also been identified. Needless to say, significant amounts of volcanic ash from multiple sources and different dates have been deposited over the western United States and Canada.

Volcanic ash layers can be seen around Spokane County, such as along Interstate 90 at Sunset Hill and just north of Qualchan Golf Course adjacent to Highway 195. Longtime residents of the Inland Northwest remember well the ash deposited from the May 18th, 1980 Mt. St. Helens eruption. Yet another layer of volcanic ash, which is the subject of this paper, was recently exposed during construction of the Spokane County Saltese Wetlands Restoration Project.

Prior to 1890, Saltese Flats was a swampy shallow lake to peat bog wetland (Saltese Lake). In the 1890’s Valley pioneer Peter Morrison homesteaded the area and began draining the lake as part of a larger plan to create agricultural land for growing Timothy Hay used for horse and cattle feed (Lambeth, 2021, Edelin, 2018). Spokane County acquired the land from the Morrison family for purposes of restoring the area to wetlands, and for educational opportunities and recreation. The restoration project began in 2019 with an estimated completion date in 2021 and completion of the Doris Morrison Learning Center in early 2022.

During the wetland restoration process, excavation exposed a layer of light-gray powdery material approximately 6 feet (190 centimeters) below the surface. The layer, about 2 feet thick (71 centimeters) was recognized by local resident and retired geologist Jerry Booth as a potentially significant volcanic ash horizon. Further field and preliminary lab examination by Spokane Community College (SCC) Geology instructor, Andy Buddington, confirmed the material as a relatively clean volcanic ash. This report presents the findings of the resulting undergraduate research project performed by SCC students Alan Belasco, Jalyn Osgood, and Katlin Gamache.

SITE LOCATION AND LOCAL GEOLOGY

Saltese Flats occur within a small, NNW-trending basin (2.5 miles by 1 mile) located between bedrock ridges at the northern base of Mica Peak, approximately 2 miles west of the Liberty Lake basin along the southern edge of the Spokane Valley (see Figure 1a). Adjacent to the Flats on the east is the Saltese Uplands Conservation Area, which is underlain by metamorphic bedrock, the Hauser Lake Gneiss, and consists of gneiss, schist, and amphibolite (Buddington, et al., 2015). The prominent N-S trending ridge directly west of Saltese Flats is composed of rusty-colored Hauser Lake Gneiss. Farther west are scattered exposures of Columbia River basalt and Missoula Flood sediments (Weis, 1968). The Saltese Flats are part of the Saltese Creek watershed in which surface streams and groundwater flows northward into the Spokane Valley-Rathdrum Prairie Aquifer system (Figure 1a). Saltese Creek drains the northern slopes of Mica Peak, which is underlain by metamorphic gneiss and schist. The study site is located along the southwestern margin of the Saltese Flats wetland area, which is now administered by Spokane County (Figure 1b).

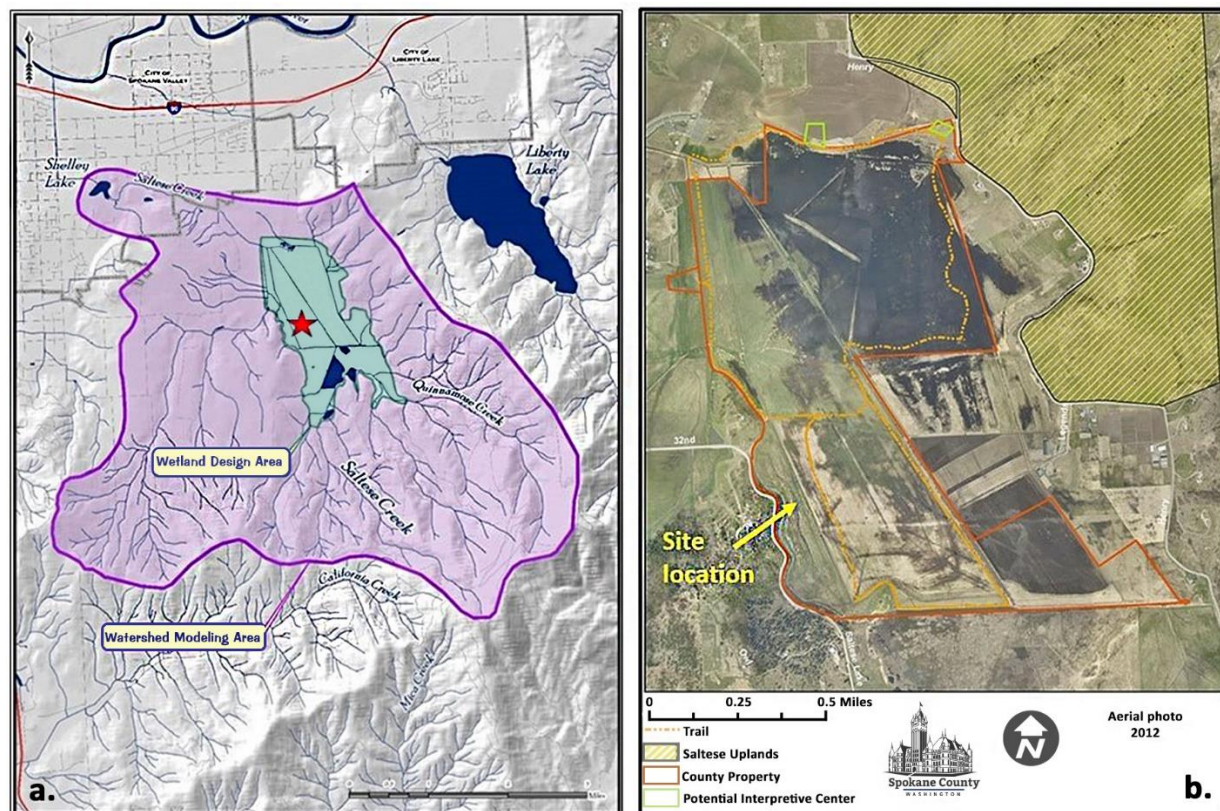


Figure 1. Location maps of Saltese Flats and site study area. (a) Saltese Flats, pre-restoration (green outline) within the Saltese Creek watershed (purple outline), with the study site indicated by the red star (image courtesy of SCC Environmental Sciences Department); (b) Saltese wetlands restoration area and study site location (image courtesy of Spokane County Environmental Services).

SALTESE FLATS PEAT, PALEOLAKE SALTESE AND WETLAND RESTORATION

In 1958, a Washington Division of Mines and Geology study done by Dr. George Rigg examined the peat resources of Washington State. Peat is a carbon-rich, sedimentary deposit composed of partially decayed plant matter with variable amounts of water, and forms in bogs, wetlands,

and shallow lakes. Peat is generally heterogeneous and comprised of fibrous materials including leaves, stalks, grasses, moss, roots, and other organic matter. As part of his extensive study, Rigg investigated peat deposits at Saltese Flats, Liberty Lake, and Newman Lake, along with other peat occurrences throughout Spokane County. Rigg mapped the surface area of each peat occurrence along with borehole mapping and sampling. The borehole work allowed for subsurface determination of peat thicknesses and depths, as well as developing the stratigraphy of the subsurface peat, soils, and sediments such as lacustrine (lake) and fluvial (stream) deposits. Rigg diligently recorded the presence and thicknesses of what he termed pumicite (volcanic ash) along with diatomite and woody material.

The report identifies, via a west-to-east subsurface borehole transect, a continuous light-gray pumicite horizon under Saltese Flats ranging up to several feet in thickness, with depths to the top of the pumicite layer at just under 5 feet on the western side to approximately 13.5 feet (to the top of the pumicite) in the central and eastern portions of the basin (Figure 2). The pumicite thickens from approximately 1 foot (30 cm) on the west to just over 2 feet (65 cm) in the central portions. Although borehole #7 doesn't completely penetrate the pumicite, it appears that the top of the horizon is beginning to shallow toward the eastern side of the basin as would be expected. The profile shows sedimentary peat directly underlying the pumicite, and in hole #4, lake mud and sand underlies the sedimentary peat then diatomite to a depth just under 20 feet. It should be noted that borehole #8, located approximately 3700 feet north of the transect line, shows the top of the pumicite unit at approximately 9 feet depth, indicating a shallowing of the basin to the north.

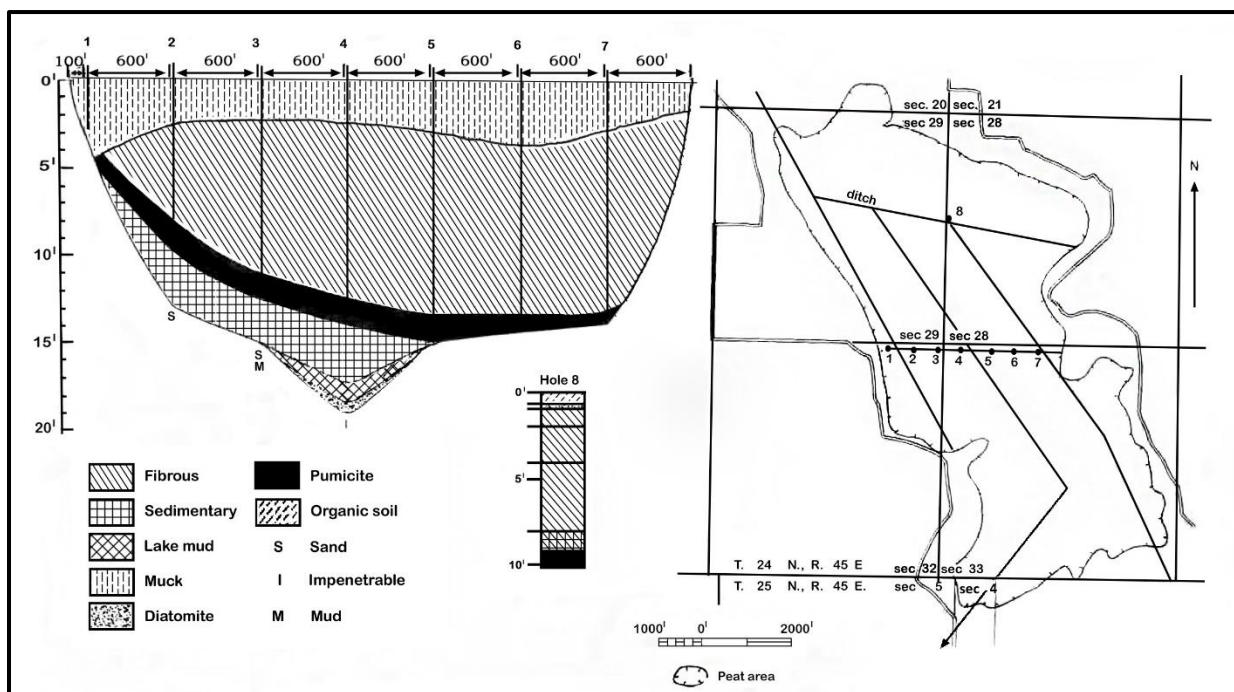


Figure 2. Saltese Flats subsurface profile from boreholes and surface map of area and the borehole profile line, taken from Rigg, 1958.

Our study site in this report is approximately 500 feet south of Rigg's profile line. Based on the transect profile, the pumicite unit is continuous and significant in thickness, portraying the paleotopography of the prehistoric lake (Saltese Lake) bottom. Pumicite, as used by Rigg, is a

term no longer in use, but in this case represents volcanic ash. Regardless of terminology, the continuous nature and thickness of the pumicite suggests the potential of a significant volcanic airfall deposit blanketing the entire lake bottom. An alternative origin for the horizon could have been deposition via reworking of surface ash either from runoff by local streams into the basin, or redeposition of ash into the basin by wind. The 1958 study did not describe the ash horizon beyond its color, depth, and thickness.

It should be noted that Rigg reported significant gray to white pumicite at the two Newman Lake peat occurrences he studied, but interestingly, no discernable pumicite layer at Liberty Lake. Rigg suggested there may be pumicite within the Liberty Lake peat but “scattered in other materials”.

In 2019, Spokane County Environmental Services began a wetland restoration project at Saltese Flats. Parts of the area underwent shallow excavation for the development of a surface feature, “Pete’s Pond” named after the late Pete Morrison. During the excavation a significant horizon of light-gray colored, fine volcanic ash was exposed in the southwestern portion of the area (Figure 3).



Figure 3. Saltese Flats light-gray ash horizon with initial exposure during excavation of wetland pond.

TRENCH STRATIGRAPHY

With permission from Spokane County Environmental Services, a temporary trench was excavated for the purpose of subsurface mapping and sampling of the ash layer (Figure 4). The trench was excavated during the wetland restoration process but, due to safety concerns, was not entered. General descriptions, thickness measurements, and sampling were performed at the surface.

The trench stratigraphy is shown in Figure 5. From the top of the trench down to 190 cm is dark brown to blackish peat. The ash, encountered at 190 cm depth, exhibits a light-gray color, and

occurs to a depth of 260 cm (103 in) with a thickness of approximately 71 centimeters (28 in). Directly below the ash is a thin (14 cm) layer of bluish-colored, fine sand, with dark brown peat to the trench bottom (365 cm).

The upper and lower contacts of the ash are sharp, displaying no signs of mixing, interbedding or gradation with the underlying blue sand or overlying peat. The ash layer is very uniform, and no obvious stratification was observed.



Figure 4. Field photos of study site. (a) trench with ash exposure, (b), close-up of ash layer near base of trench. Note that the trench is in-filling with groundwater.

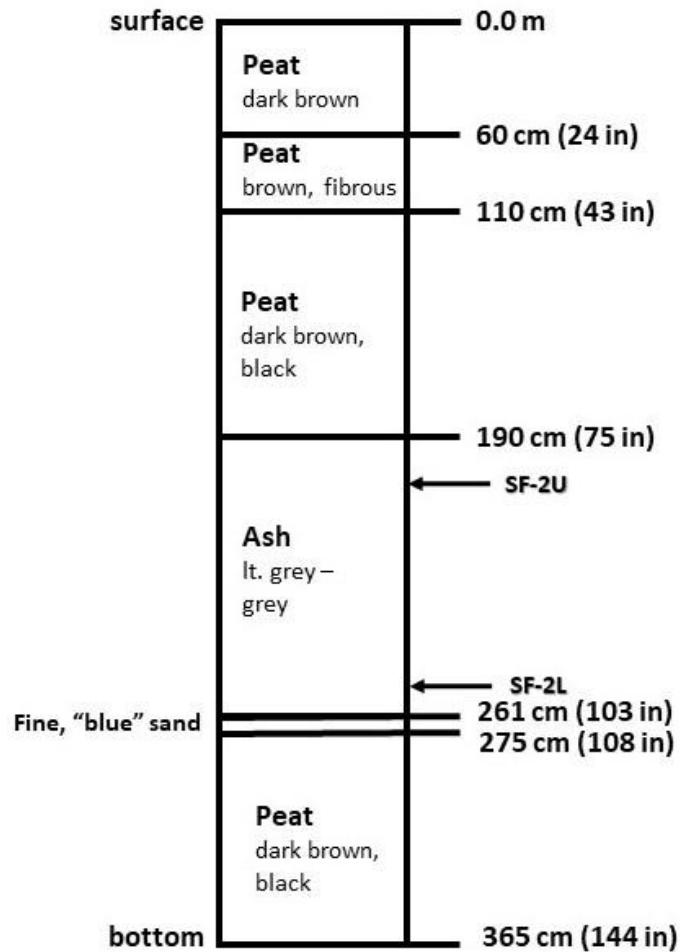


Figure 5. Stratigraphic column of the Saltese Flats site trench of this study. Ash samples are indicated by SF-2U and SF-2L.

ASH CHARACTERISTICS AND COMPOSITION

Three ash samples were collected for examination and analysis. SF-1 is a grab sample from the trench pile. Sample SF-2U is from the upper 20 cm of the ash layer taken in situ, and SF-2L is from the lower 20 cm of the ash layer. Samples were dried, then examined via grain mount petrography and Scanning Electron Microscope (SEM) imagery.

Ash Components and Mineralogy

The ash is composed of fine (<150 microns) glass shards, with micro-crystals (microlites) and lithic (rock) fragments. In general, the samples were dominated by glass shards (~85-90%) with up to 10-15% microlites (microcrystals) and lithic fragments. Mineralogically, the microlites are composed of lath-shaped plagioclase with possible amphibole, Fe-Ti oxides, and pyroxene. Glass shards can be platy to tricuspidate, with vesicles, and volcanically-derived lithic fragments can contain ultra-fine microlites (Figure 6). No detrital mineral grains or significant organic components were observed.

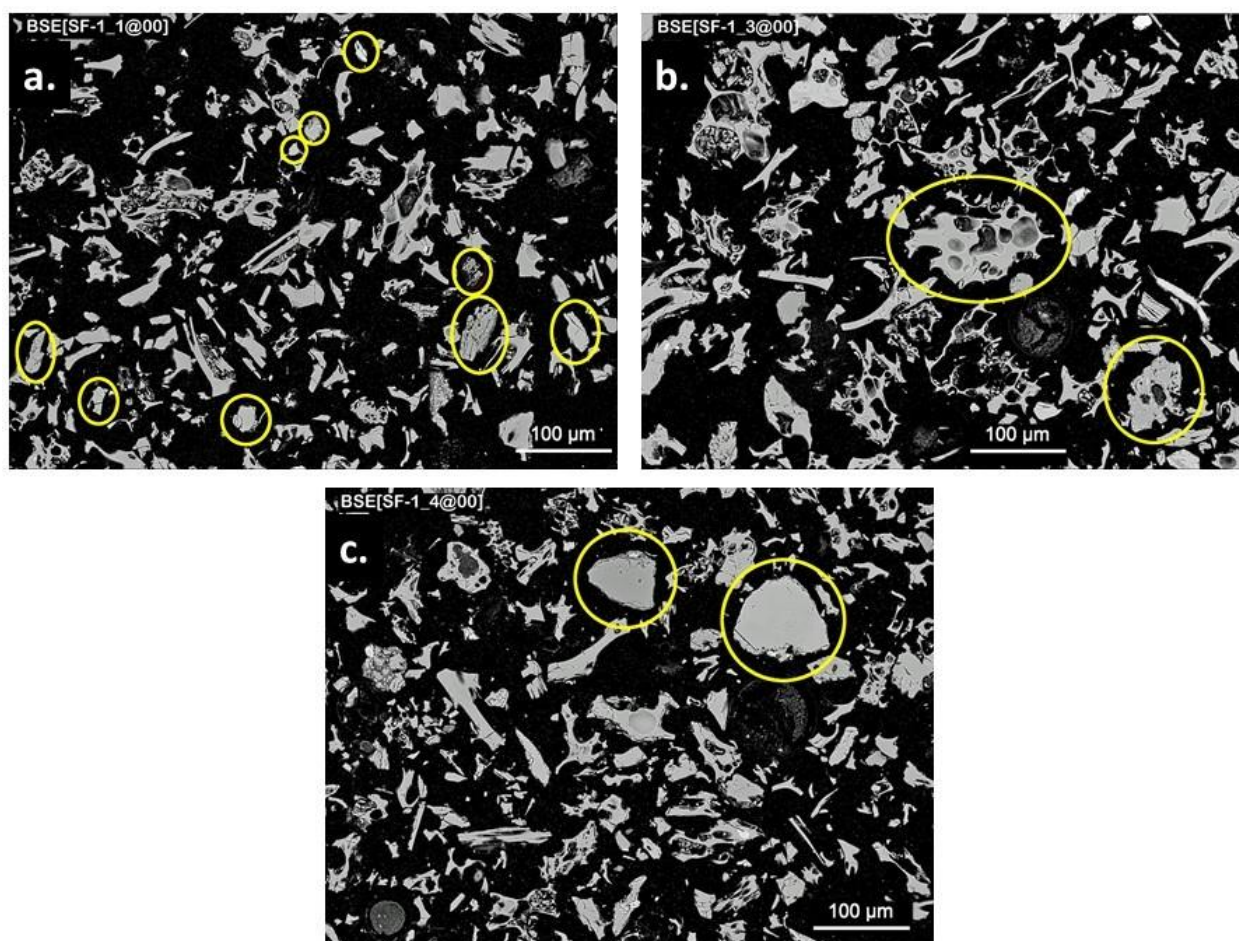


Figure 6. SEM images of Saltese Flats ash. (a) SF-1_1, showing vesicular glass shards with mineral and rock fragments (circled), (b) SF-1_3, volcanic rock fragment containing ultra-fine microlites (lower right, circled) and large vesicular glass fragment (center, circled), (c) SF-1_4, showing two large mineral fragments (circled).

Blue Sand

Directly below the ash is a thin layer (~14 cm) of fine, bluish-colored sand. The contact between the sand and the overlying ash is sharp. The sand is well-sorted and consists of subangular (to rare subrounded) grains ranging from 0.250 to 0.125 mm in size. The mineral composition of the sand consists of quartz, feldspar, muscovite, biotite, with accessory amounts of epidote, chlorite (after mica) and zircon. There are also grains of polygranular quartz and several unidentified components, including opaques.

Upon excavation of the trench, the sand exhibited a defined light-blue coloration, but after one to two weeks in the lab after drying, the sand turned gray to brownish-gray in color.

Ash Chemistry

The three Saltese samples were sent to the Peter Hooper Geoanalytical Laboratory at Washington State University for microprobe glass shard analysis (n=25 shards per sample) for major element compositions using a JEOL JXA8500F field emission electron microprobe. The elemental analyses were then averaged with standard deviations calculated (Table 1). SiO₂

compositions range from 72.78-72.97%, with Na₂O and K₂O compositions ranging from 5.39-5.53%, and 2.74-2.79%, respectively.

In general, the glass shard major element oxide analyses were very consistent indicating no significant weathering or chemical variation within the Saltese ash layer.

Table 1. Summary of averaged major element oxide, glass shard analyses of the Saltese ash.

Glass compositions in weight % oxides						
	SF-1		SF-2U		SF-2L	
	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
SiO ₂	72.97	0.31	72.78	1.07	72.89	0.31
Al ₂ O ₃	14.23	0.19	14.21	0.39	14.32	0.24
Fe ₂ O ₃	2.04	0.07	2.08	0.46	2.03	0.06
TiO ₂	0.4	0.04	0.4	0.08	0.4	0.04
Na ₂ O	5.44	0.21	5.53	0.17	5.39	0.2
K ₂ O	2.74	0.14	2.79	0.14	2.77	0.12
MgO	0.45	0.03	0.46	0.1	0.44	0.03
CaO	1.55	0.1	1.59	0.32	1.58	0.11
Cl	0.18	0.02	0.17	0.02	0.17	0.02
Total	100		100		100	
# shards	25		25		25	
Similarity Coefficient	0.98*		0.98*		0.98*	

VOLCANIC SOURCE CORRELATION

The 1958 study by Rigg conclusively indicated the presence of a significant tephra layer underlying Saltese Flats. But a volcanic source or event date was not directly addressed for the Saltese ash. Rigg suggested, generally, that pumicite (ash) deposits within the many peat areas of Washington State, and specifically eastern Washington, likely originated from Glacier Peak approximately 6700 years ago. He based his correlations on a 1957 study (Rigg and Gould) that compared grain size and mineral content of ash deposits from peat areas across the state to a prominent tephra horizon at two sites in western Washington. At the western Washington sites, peat directly beneath the tephra was dated by radiocarbon (C14) at 6700 years. In a later study, Powers and Wilcox (1964) reexamined the tephra samples of Rigg and Gould, and correlated them to tephra samples of Mount Mazama at Crater Lake. More recent studies (Egan, et al., 2015) confirm the Powers and Wilcox conclusions and show that the Rigg and Gould C14 date when calibrated to a cybp (calendar years before present) age, correlates with the 7700 cybp “climactic” eruption of Mount Mazama.

Volcanic ash, due to its fine-grained nature, can travel great distances upon eruption into the atmosphere. Because individual volcanic events typically have specific geochemical compositions unique to the event (and volcano) of origin, specific far-distanced eruptive events can be correlated by glass shard major element geochemistry. Volcanic glass shards are erupted microscopic glass particles and represent the magmatic composition of the specific source event from which they originated. Although composite volcanoes such as those of the Cascade Range can have variations in magmatic chemical compositions over time, typically individual

eruptive events are chemically uniform. Therefore, glass shard analysis can be very helpful in correlating an unidentified ash layer to its source.

The major element oxide data obtained from glass shard microprobe analyses (25 shards per sample) were compared to the WSU Pacific Northwest tephra database (1726 records) for correlation analysis to ash chemistries of known events. Based on this statistical comparison, the Saltese Flats ash matches the Mount Mazama “*climactic*” eruption at 7700 cybp (calendar years before present). The correlation is based on matches to twenty-two known Mazama (7700 cybp) samples with a similarity coefficient of 0.98 (Table 1). The correlation analysis and similarity coefficient determination is that of Borchardt et al., 1972.

The Saltese data were then compared to other known Holocene tephra occurrences in southern Canada including Mount Mazama, Mount St. Helens, Bridge River (Mount Meagher), and Glacier Peak (Figure 7), as well as dated rock samples in the Crater Lake area of southwestern Oregon (Figure 8). In all cases, the Saltese Flats ash correlates very closely to the Mazama 7700 cybp climactic eruption.

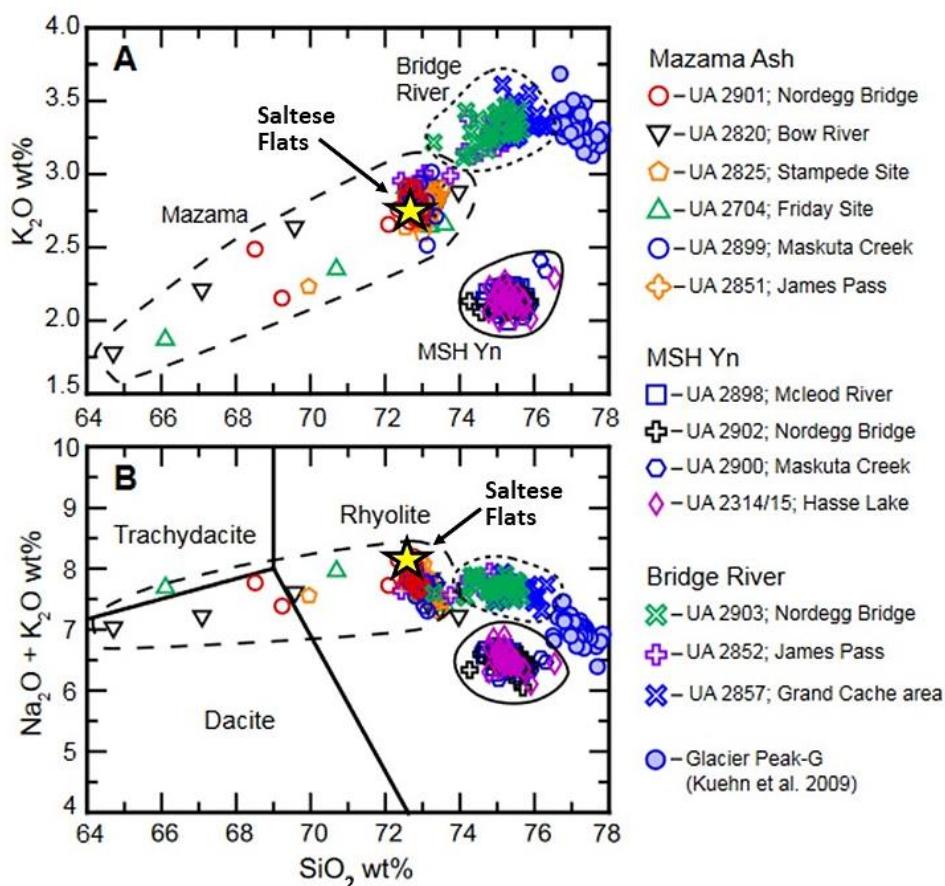


Figure 7. Major element vs. SiO_2 plots for event correlation (modified from Jensen et al., 2019). (a) plot of wt.% K_2O vs. SiO_2 with averaged Saltese values for comparison (yellow star), (b) wt.% $\text{K}_2\text{O} + \text{Na}_2\text{O}$ vs. SiO_2 . Mazama data are from the 7700 cybp climactic eruption. Note the Glacier Peak-G samples are from the 13,710 – 13,410 cybp eruptions.

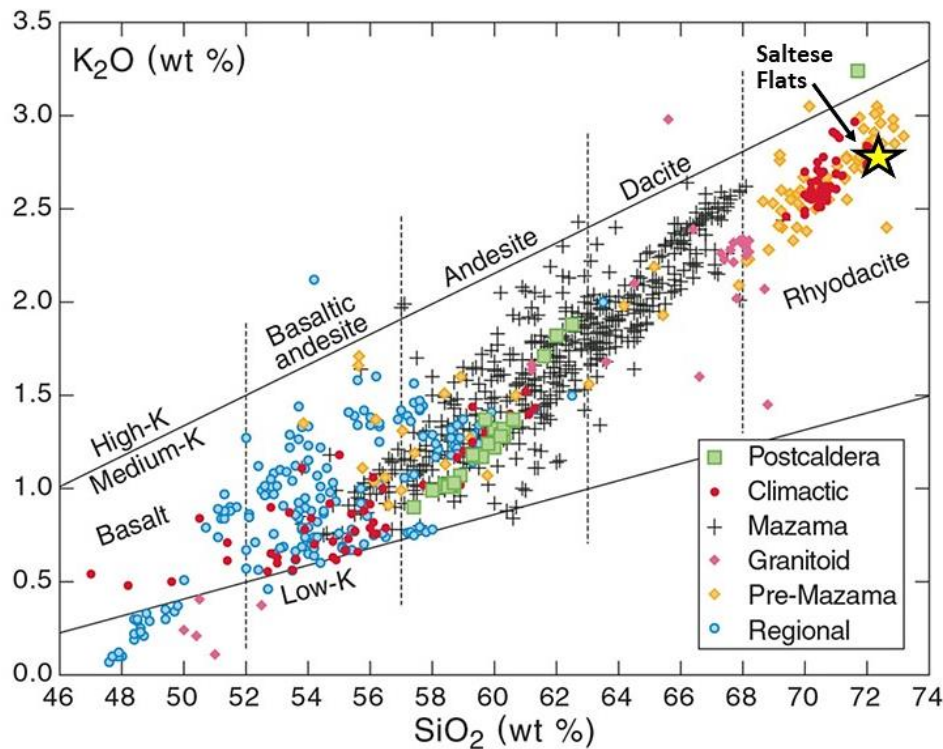


Figure 8. Plot of K_2O vs. SiO_2 (wt.%) of volcanic rocks from the Crater Lake area; modified after Bacon and Lanphere, 2006. The averaged Saltese Flats data shown as yellow star.

MOUNT MAZAMA CLIMACTIC ERUPTION

Mount Mazama is a major Cascade volcano but has not been significantly active since the climactic eruption (7700 cybp) and has not erupted in the last 4000 years (Myers and Driedger, 2008). Mount Mazama was thought to rival, in size and height, today's large Cascade composite volcanoes such as Rainier and Shasta (Bacon and Lanphere, 2006, USGS, 2021). The 7700 cybp eruption was the largest Cascade eruption in the last 1 million years, and one of the largest on Earth over the last 12,000 years (USGS). The climactic eruption resulted in the total collapse of the upper portions of the volcano and development of the 8 x 10 km caldera now partially filled by Crater Lake. An estimated 50 km³ of ejected rhyodacite tephra (Bacon and Lanphere, 2006) was ultimately distributed across much of the Pacific Northwest. Mazama ash has been documented as far north as central Alberta, Canada, east into central Montana, and south into central Nevada (Kimsey, et al., 2007). The presence of a 71 cm thick Mazama ash layer approximately 400 miles from its source testifies to the magnitude of the climactic eruption (Figure 9).

Other significant Mazama ash (7700 cybp) occurrences have been recognized in the Spokane area (Figure 10). Along Interstate 90 at Sunset Hill is an impressive display of Mazama ash, which has been interpreted as "reworked" ash, occupying an eroded channel into the underlying Wanapum basalt (Gene Kiver, oral commun.). The Sunset Hill occurrence in Figure 10 is thus a secondary deposit that accumulated within an old stream channel due to remobilization of the ash by either wind or water and is thicker than the initial airfall deposit.

Along US 195, just north of the Qualchan golf course, is another exceptional exposure of Mazama ash occurring above a sequence of layered Missoula Floods and glacial Lake Columbia sediments.

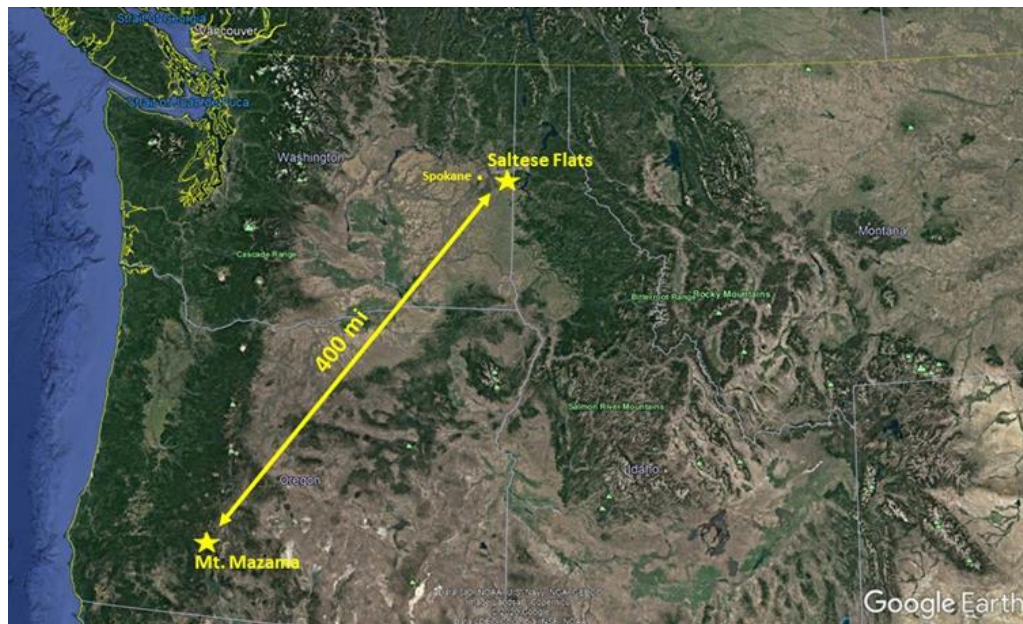


Figure 9. Google Earth image showing Saltse Flats site relative to the Mount Mazama volcano in the south-central Oregon Cascades.



Figure 10. Local Mazama ash (7700 cybp) occurrences. (a) Sunset Hill, Interstate 90, looking north, exposure of Mazama ash (light) filling an eroded channel in Wanapum Basalt (dark), (b) Latah Creek, Mazama ash exposure (light-colored layer), US 195 looking east.

DISCUSSION

Saltse Flats was a lacustrine depositional setting at the time of the climactic Mazama eruption. The thick accumulation of peat and organic materials is consistent with a shallow lake or boggy marshland. Based on the borehole data of Rigg (1958), prehistoric Saltse Lake was not excessively deep, likely less than 20 feet.

The presence of a fine, blue-colored sand between the ash and lower peat deposit is worthy of note because it is so unusual. Such a deposit of fine, well-sorted sand suggests an influx of slow-moving water prior to the ash deposition. Furthermore, the subangular, immature clasts indicate erosion from a relatively close source, such as the adjacent Hauser Lake Gneiss bedrock. The mineral grain compositions confirm this. Together, these observations suggest that the sand layer may represent a channel of slow flowing water through the shallow marsh or bog.

The blue coloration of the initially excavated fine sand is interesting. Blue “clays” have been reported from boreholes at Newman Lake (Rigg, 1958), but no details on textures or mineral compositions are available. It should be noted that the blue sand turned brownish-gray upon drying within a period of about one to two weeks. We attribute the blue coloration of the fine sand to a process known as “gleying”. Gleys, or gleyed subsurface materials, are associated with water saturated, anaerobic (low oxygen) conditions, where subsurface water is restricted in flow. The bluish coloration is the result of the reduction of ferric to ferrous oxides in the material. With the relatively impermeable ash directly above the sand layer and peat below, groundwater within the sand likely had restricted flow, and due to the high amount of organics present, reducing (low oxygen) conditions dominated. The blue “gleyed” sand turned brownish-gray upon exposure to oxygen during the drying process.

One very compelling aspect to the Saltese/Mazama occurrence is its significant thickness (71 cm). This raises the question of whether this is a primary or secondary deposit. A primary tephra deposit is one that can be clearly shown to have originated and deposited directly from the eruption. Secondary, or reworked deposits, are the result of remobilization and redeposition of the original erupted materials. Remobilization can be initiated by several processes including fluvial (rivers & streams), aeolian (wind), or gravitational (landslips) processes. The end result can be erosion and removal in one area or region and overthickening of the original tephra materials in another region due to remobilization and redeposition. Ash is particularly susceptible due to its relatively low density. Discerning between primary vs. secondary deposits can often be difficult for a variety of reasons, which are beyond the scope of this report.

A recent study by Buckland et al. (2020) addresses the significant thickness variabilities of over 250 Mazama tephra occurrences reported in the literature. The Buckland study has produced the most up-to-date “isopach” (thickness) map for Mazama ash distribution throughout the Pacific Northwest into southern Canada, and shows areas of over-thickening with respect to the primary thickness distributions. Based on the comprehensive study of Buckland and her colleagues, the area of eastern Spokane County likely received a total of approximately 10 to 20 cm from the main airfall event of Mount Mazama. The 71 cm of accumulated ash is well above the calculated isopach values.

Could the Saltese Flats occurrence be an anomaly within the region in that it is a primary deposit as a result of unique wind pattern distribution and fall out? Or is the 71 cm thick layer the result of secondary processes of ash remobilization, redeposition, and over-thickening? The vegetative cover of eastern Washington 7700 cybp was similar to today, a semi-arid vegetative zone, susceptible to ash resuspension from prevailing west-to-east wind patterns. There was

clear redistribution of St. Helens ash for weeks to months following the May 18th, 1980 eruption. Resuspension and redistribution of Mazama ash was inevitable and Saltese Flats was likely a recipient of that windblown ash. How much was primary vs over-thickened? This study cannot answer that specifically, but it was probably considerable. And, if we are to use the Buckland study as our guide, somewhere close to 50 cm of redeposited ash filled the Lake Saltese basin.

Regardless of the likely overthickening possibility, Saltese Flats preserves an important record of downwind ash deposition from the Mazama eruption. The ash was deposited into a shallow lake or wetland bog and based on the borehole study of Rigg (1958), the deposit is extensive and consistently thick across the paleolake bottom. It was not concentrated into a single stream paleochannel but blankets the basin. The deposit composition appears uniform with little to no contamination of detrital sediment grains or organics while exhibiting sharp upper and lower contacts. Determining the extent of potential reworking and overthickening within the Saltese occurrence will take further detailed study.

The Mazama air-fall event was undoubtedly a cataclysmic time for the Saltese Flats, and the entire Inland Northwest region as far east as central Montana. Consider that the last major Cascade eruption, the May 18th, 1980 Mount St. Helens eruption, deposited a total of 0.25 to 0.50 mm of uncompacted ash in the Spokane area (Sarna-Wojcicki, et al., 1981). This relatively low amount of deposited St. Helens ash caused significant disruption to transportation and everyday lives throughout the region. It presented a significant human respiratory health threat as well. An airfall event of 10 to 20 cm of ash, representing 200 to 400 times the thickness of airfall ash as that from the Mt. St. Helens eruption can only be imagined, but indeed Saltese Lake must have been a hellish, inhospitable place during the eruption of Mount Mazama in 7700 cybp!

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