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Article abstract

The May 18, 1980, eruption of Mount St.Helens comprised a complex series ofevents that started with a magnitude 5.1 earthquake. Studies of eye witness photographs and observations provided important information in determining the chronology of events. The eruption has been subdivided into six phases, based on evidence provided by this chronology and detailed stratigraphiework. The first phase, which included thelateral blast, has come under the closest scrutiny, but even here observations of the eye witnesses have provided useful information that must be accounted for in any model of the phenomena.

The May 18, 1980, Eruption of Mount St. Helens, Washington State: A synopsis of events and review of Phase I from an eyewitness perspective

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Summary

The May 18, 1980, eruption of Mount St. Helens comprised a complex series of events that started with a magnitude 5.1 earthquake. Studies of eyewitness photographs and observations provided important information in determining the chronology of events. The eruption has been subdivided into six phases, based on evidence provided by this chronology and detailed stratigraphic work. The first phase, which included the lateral blast, has come under the closest scrutiny, but even here observations of the eyewitnesses have provided useful information that must be accounted for in any model of the phenomena.

Introduction

The paroxysmal eruption of Mount St. Helens on the morning of May 18, 1980, quickly entered the annals of volcanological history. The eruption was, in global terms, comparatively small, but its significance to science was not a consequence of eruption size but rather the completeness with which the eruption was monitored and observed. Phenomena associated with the eruption were studied and witnessed by observers both on the ground and in the air, and by radar, satellite and other techniques. The observed phenomena could be documented and correlated with the resulting deposits. In this way, a synthesis began between the physical processes that occurred during the eruption and the concomitant results of those processes, such as change in eruption style, vigour, or products. This synthesis is perhaps most visible in the literature analyzing the processes and deposits of the catastrophic landslide and ensuing lateral blast, both of which had been relatively unstudied phenomena prior to the May 18 eruption of Mount St. Helens.

Despite the considerable technology focussed on the volcano, it was the eyewitness accounts that provided the detail and chronology of many of the events that were occurring in rapid succession. For example, the inundation of the southern slopes of the mountain by the lateral blast, some minutes after the onset of the eruption, was noted by observations, but scant evidence is preserved in deposits on the southern slope — nevertheless the "rim topping" aspect of the blast must be accounted for in any model explaining the phenomena. Other aspects of the lateral blast noted by observers include the morphology of the flow front, destruction of timber, periods of heat and cold and density of airborne particles. These observations must also be accommodated in any model.

The presence of juvenile pumiceous grey tephra, less than an hour after the start of the eruption, was also noted by observers, but not accounted for in early analyses of the eruption events. The lahar that travelled down the Muddy River, along the east side of the volcano, occurred within minutes of the start of the eruption. These observations provided details of the eruption that were not readily apparent from later field observations, but which must be integrated into the chronology of events to gain a more complete understanding of all aspects of the eruption.

Chronology of Events

Criswell (1987) produced a synthesis of the first day of the eruption by taking eyewitness observations, radar, satellite and seismic data and combining them with field mapping, stratigraphic and geochemical studies to develop a detailed chronology of the eruption. He subdivided the eruption into six phases (Figure 1) and showed how subtle (and not so subtle!) observed changes in plume morphology, colour and height could be correlated with changes in the resultant deposits. Phase I, the paroxysmal phase, lasted from 08:32 Pacific Daylight Time (PDT) to 09:00 PDT and included the lateral blast; phase II, the early plinean phase, lasted from 09:00 PDT to 12:15 PDT; phase III is termed the early ash flow phase and lasted from 12:15 PDT to 15:00 PDT; phase IV, the climactic plinean phase, extended from 15:00 PDT to 17:15 PDT; phase V was typified by ash flows and commenced at 17:15 PDT, lasting for one hour; phase VI, the post-eruption phase, started at 18:15 PDT and lasted into May 19. Criswell (1987) has correlated each phase with specific pyroclastic and tephra deposits (Figure 1).

Phase I, Paroxysmal Lateral Blast: Surge or Flow?

Perhaps the most dramatic event of the eruption occurred in the first 2 minutes of phase I, the lateral blast. This event has been the focus of numerous studies resulting in a variety of rather diverse conclusions (Table 1). However, as stated by Peterson (1986, p. 14), "This is healthy progress because subsequently these workers and others, stimulated by opposing conclusions, are forced to reexamine observations, search for new evidence, seek flaws within each line of reasoning and thereby build improved interpretations. Thus will the understanding of the eruption advance."

The photographic and eyewitness accounts (Rosenbaum and Waitt, 1981; Neilsen *et al.*, 1989) are critical to interpretation of the first few minutes of the eruption. Using these data, Moore and Rice (1984) developed a chronology of the events of the first five minutes of the eruption (Figure 2).

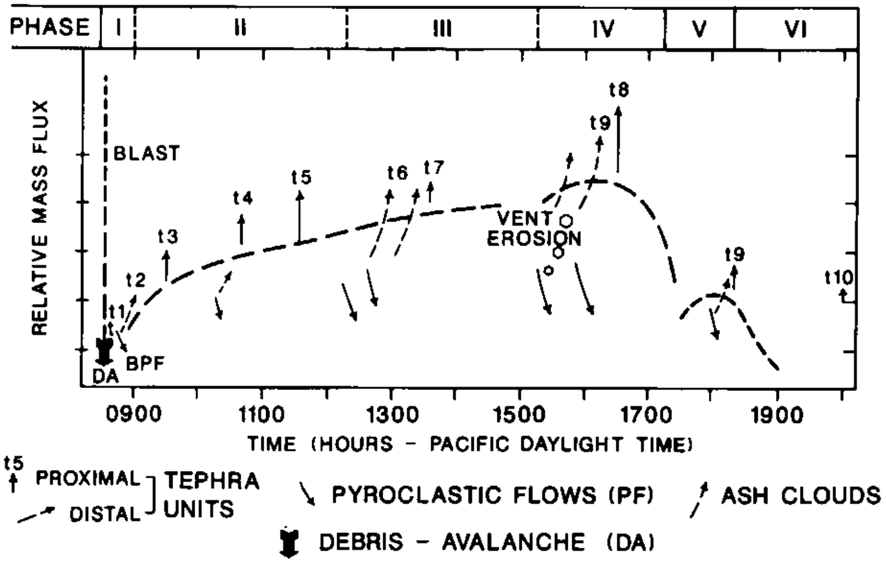

Figure 1 *Phases (noted in roman numerals at the top of the diagram) of the May 18 eruption. Modified from Criswell (1987, fig. 25, p. 10,264).*

They proposed that a second explosion occurred approximately two minutes after the start of the eruption (Figure 2). Further refinements were offered later by Sparks *et al.* (1986).

The photographic sequence taken by P. Hickson (Figure 3) shows the details of the first minutes of the eruption. Slide block I can be clearly seen moving down slope of the flank explosion, and slide block II, moving between the flank and summit explosions. The steep front of the lateral blast is clearly visible in Figure 3e. Figures 3e and 3f show the front advancing over the east slopes. The eastern flow front was considerably thinner than the northern. Moore and Rice (1984) plotted the advance of the blast front (Figure 2) and timing of the failure of avalanche block III using photographs taken from Mount Adams. Sparks *et al.* (1986) later suggested that the 25-km-high plume and mushroom cloud (Figure 4) formed from the lateral-blast cloud by ingestion of air and decreasing density. The lateral blast-cloud covered an area of 600 km^2 and then lifted as a unit, producing the spectacular mushroom cloud.

The model of Sparks *et al.* (1986) does not, however, account for all of the phenomena associated with the eruption plume. Evidence from the east side of the volcano suggests that the lateral blast continued several kilometres past the edge of destroyed timber. It had coherence such that, while finally coming to rest, it hung in valleys to the east as a pall of ash (Figure 5), well below the mushroom cloud advancing high overhead. Accretionary lapilli appeared to be falling from the overhead mushroom cloud, but the view eastward to the flanks of Mount Adams was not obscured by falling tephra (Figure 5).

Evidence suggests that the secondary explosion proposed by Moore and Rice (1984) likely had a major impact on formation of the eruption cloud described by Sparks *et al.* (1986). This second explosion, two minutes after the first (Figure 2), appeared to emanate from landslide block II which had formed from a large part of the cryptodome (Moore and Rice, 1984). This proposed second explosion does, however, remain controversial and is not accounted for in other models such as proposed by Kieffer (1981, 1984). Criswell (1987) found stratigraphic evidence for this explosion in a pyroclastic deposit which contains juvenile clasts and lithic debris, but differs from the lateral-blast deposit in that the juvenile clasts are more expanded (pumiceous). Hoblitt (1989) has found further evidence to support the two explosion hypothesis. He suggests the initial explosion was largely magmatic and the second explosion had a significant hydrothermal contribution (Hoblitt, 1989).

Questions that have not been fully addressed include the nature of the second explosion, how it may have influenced the extent of destruction and what the implications of this second explosion might be on the resulting "lateral-blast" deposits? These deposits have perhaps been more closely scrutinized than any others resulting from the eruption (Table 1).

Scrutiny of the lateral-blast deposits has led to differing interpretations and models of the physical processes under which the deposits formed (Table 1 and references there in, also Hoblitt, 1989, 1990; Hickson and Barnes, 1986; Hoblitt and Miller, 1984; Waitt, 1984; Walker and Morgan, 1984). Much of this debate has centred around whether or not the lateral-blast represented a pyroclastic surge or a pyroclastic flow, or some combination of these.

The lateral-blast at Mount St. Helens was unequivocally a density flow (Figure 3e) and it was witnessed and photographed from many different angles — in fact, some people actually experienced the event and lived to report their observations (Rosenbaum and Waitt, 1981; Neilsen *et al.* 1989). Within hours, the consequences and deposits of the lateral-blast were observed in the field. The picture of the event is remarkably complete, in spite of its power, short duration and complexity. A model that uses flow dynamics to account for many puzzling aspects of the deposits has been published by Valentine (1987). He showed how it is possible to form the observed deposits from a stratified flow in which the particles are held aloft and transported by turbulence within the flow — a surge *sensu stricto*. In recent work, Hoblitt (1989, 1990) has suggested that the multiple explosion aspect of the initial phase of the eruption may have played a significant role in the resulting stratigraphic unit. He suggests that deposition and erosion by density currents, resulting from the two explosions following in rapid succession, may account for many aspects of the deposit (Hoblitt, 1989, 1990).

Table 1 **Nomenclature used in various studies when referring to the lateral blast.**

Reference	Nomenclature
Hoblitt *et al.* (1981)	Directed Blast
Kieffer (1981)	Blast; Lateral Blast
Kuntz *et al.* (1981)	Pyroclastic Surge
Moore and Sisson (1981)	Pyroclastic Surge
Waitt (1981)	Pyroclastic Density Flow
Hickson *et al.* (1982)	Pyroclastic Surge
Walker and McBroome (1983)	Pyroclastic Flow/LARI
Fisher and Heiken (1983)	Pyroclastic Flow/Blast Flow
Moore and Rice (1984)	Pyroclastic Surge
Sparks *et al.* (1986)	Pyroclastic Surge/Flow
Criswell (1987)	Pyroclastic Flow/Surge
Fisher *et al.* (1987)	Pyroclastic Surge
Valentine (1987)	Pyroclastic Surge/Blast Surge

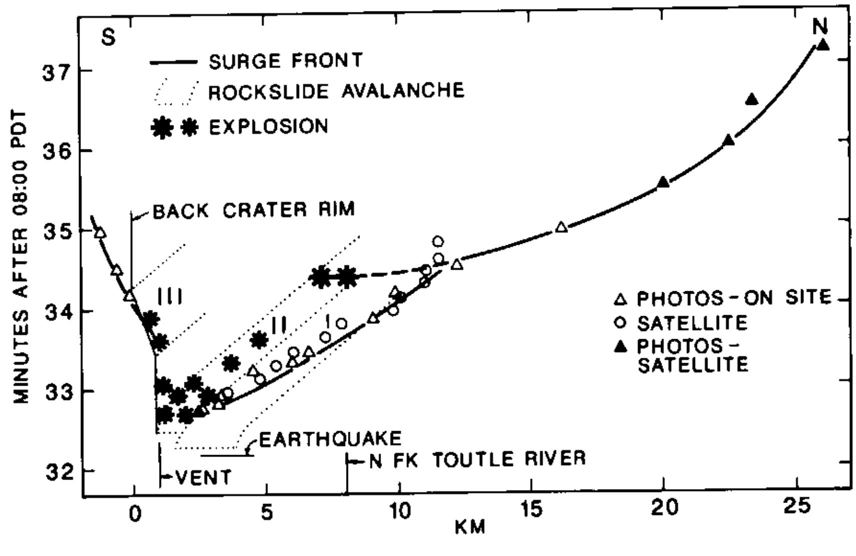

Figure 2 *Time-travel plot of events occurring during the first five minutes of the eruption. From Moore and Rice (1984, fig. 10.5, p. 137).*

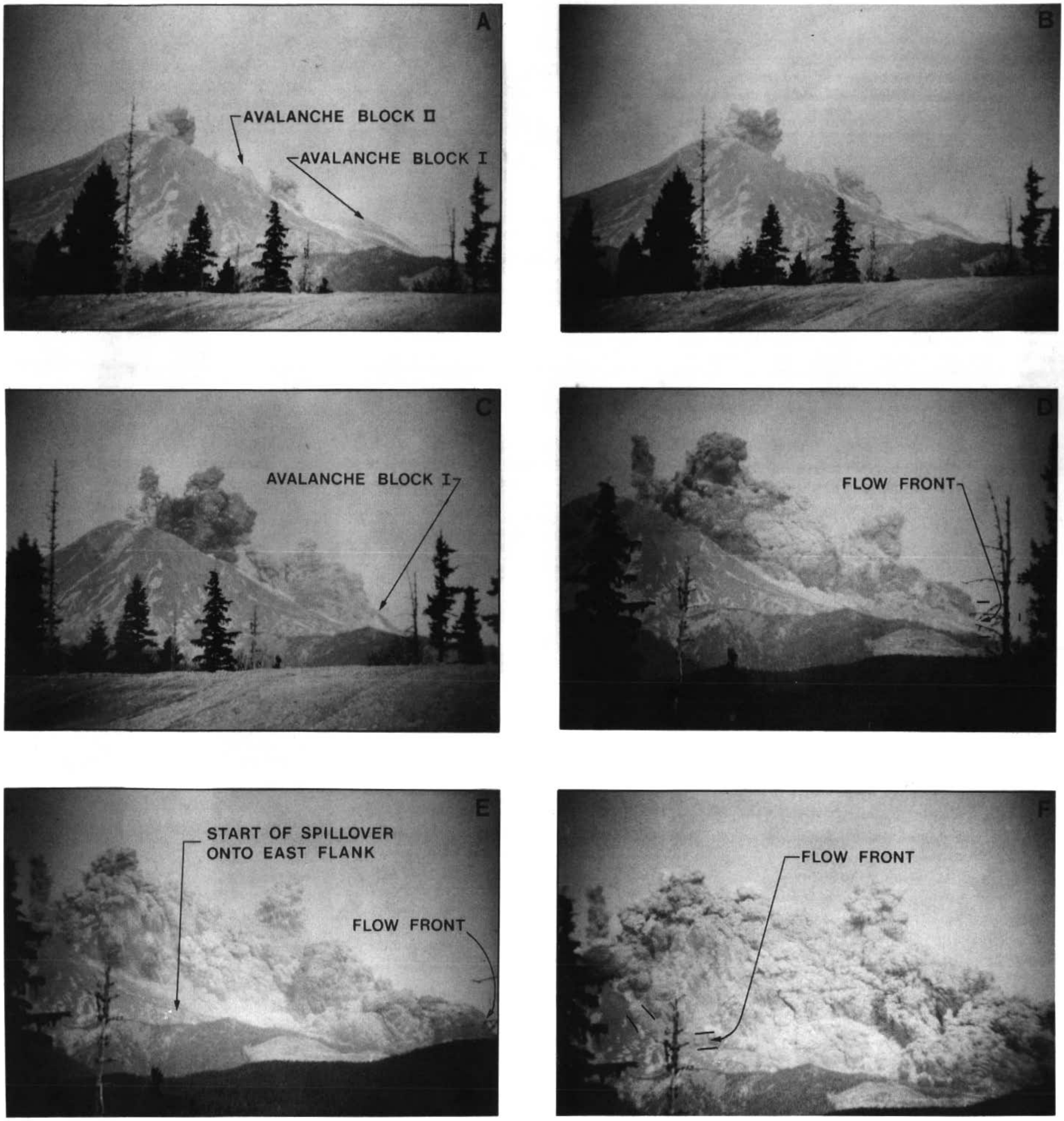

Figure 3 *Sequential photographs of the initial two minutes of the May 18 eruption (Figure 2). Timing is based on Voight (1981, written communication 1990) which differs slightly from that used by Moore and Albee (M&A)(1981). All times are Pacific Daylight Time.* **(a)** *08:32.79 PDT (08:32.39 M&A);* **(b)** *08:32.83 (08:32.8 M&A);* **(c)** *08:33.0;* **(d)** *8:33.3;* **(e)** *08:33.5;* **(f)** *08:33.7. Critical features of this eruption period have been noted on the photographs. Photographs by P. Hickson.*

Figure 4 *Eruption column approximately 08:42 PDT from 20 km southeast of Mount St. Helens. Note summit has now been reduced to its post-eruption height by the failure of avalanche block III. A small pyroclastic flow (arrow) can been seen descending the southwest flank. The edge of the mushroom cloud is visible above the column. Expansion velocity of the mushroom cloud has been estimated in excess of 50* $m \cdot s^{-1}$ *(Sparks* et al., *1986). Photograph by P. Hickson.*

Figure 5 *View eastward across Clear Creek drainage toward flanks of Mount Adams (arrow). Ash from passage of lateral-blast cloud can be seen hanging in valleys as mushroom cloud expands overhead. Photograph by P. Hickson.*

Conclusion

Perhaps the most important lesson taught by the eruption of Mount St. Helens is the value of visual observations to our interpretations of the eruption processes. The May 18, 1980, eruption of Mount St. Helens was a complex series of events that cannot be described in a few simple words or sentences. Likewise, it should not be surprising that the resulting deposits are also complex, and show significant variation, both vertically and laterally. The observations must be compatible with the stratigraphic evidence; often they are not. Therefore, we must modify our existing models accordingly, with new explanations where demanded by the observations. Perhaps what is most noticeable in the volcanological literature since the eruption of Mount St. Helens is the increasing use of "facies" in describing deposits. We know from observations that these deposits have a complex history, but can be related to a specific event, albeit one that may have a duration of several minutes or even hours. Variations within the deposit can best be described as facies, implying a genetic relationship between parts of the deposit and the actual event. The use of facies helps account for the complexity of the deposits and links them to the events that generated them.

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My presence at Mount St. Helens on May 18, 1980, was fortuitous. However, many people have been instrumental in subsequent work at Mount St. Helens and on volcanoes elsewhere. Among these are P. Hickson, D.W. Peterson, C.D. Miller, W.C. Barnes, W.H. Mathews and J.G. Souther. Reviews of the manuscript by J.A. Roddick and D.W. Peterson improved it greatly.

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Compositional Trends and Eruptive Cycles at Mount St. Helens

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Summary

The 40,000-year eruptive history of Mount St. Helens reveals an overall compositional trend from rhyodacite to andesite, with basalt at ~1.9 and ~1.6 ka. A cyclic eruption pattern is superimposed on this trend. Cycles comprised a repose interval, when compositional and thermal gradients developed in the underlying magma body, followed by an eruption interval in which progressive tapping of magma beheaded these gradients. Recovery of gradients varied with duration of the ensuing repose period. Eruption sequences follow the pattern: (1) ***eruptive progression*** from Plinian eruptions to dome growth accompanied by pyroclastic flows and tephra, followed (in some cases) by lava flows punctuated by pyroclastic outbursts; (2) a ***mineralogic progression*** from hydrous Fe-Mg phenocrysts (hb, cm, bi) toward pyroxenes; (3) a ***magmatic compositional progression*** from rhyodacite or dacite to andesite. Progressions 1 and 2 stem mainly from volatile gradients in the magma reservoir whereas progression 3 (and to some extent 2) reflects gradients of melt composition and crystal content. Three eruption cycles within the last 4,000 years follow this pattern. Earlier cycles are probable but only dimly perceived, mainly from the partial record of tephras and pyroclastic flows.

Introduction

This paper stems from a talk given at the GAC—MAC Special Symposium on the Tenth Anniversary of the May 18, 1980, eruption of Mount St. Helens (MSH). Our assignment was to present an overview of some aspect of the eruptive history of MSH prior to 1980. The eruptive history itself has already been established and is now well known. Little has been said as yet, however, about pre-1980 compositional variation of the MSH magmas with time, which is important petrogenetically. We therefore chose to look at compositional trends and eruptive patterns over the lifetime of the MSH volcanic center, and to suggest some possible interpretations. Perhaps this will help to stimulate much-needed future work on these problems.

Eruptive History of Mount St. Helens

The eruptive history of MSH has been established primarily by Dwight R. Crandell and Donal R. Mullineaux. Their detailed, elegant work sets the standard for such studies everywhere.

The eruptive history of the MSH volcanic center spans >40,000 years; that of the present mountain, about 3,000 years (Crandell *et al.*, 1975; Crandell and Mullineaux, 1978; Mullineaux and Crandell, 1981; Crandell, 1987). Crandell (1987) divides the eruptive history of MSH into four ***eruptive stages*****, each separated by long intervals of dormancy: the Ape Canyon stage, >40-36 ka; the Cougar stage, ~21-18 ka; the Swift Creek stage, 13-11 ka, and the Spirit Lake stage,** 4 ka to present. Shorter ***eruptive periods***, separated by repose periods, are recognized within the Spirit Lake eruptive stage. These are: the Smith Creek period, 4.0-3.3 ka; the Pine Creek period, 3.0-2.5 ka; the Castle Creek period, 2.2-1.6 ka; the Sugar Bowl period, 1.15 ka; the Kalama period, ~500-370 years B.P.; the Goat Rocks period, 190-133 years B.P.; and the eruptions that began in 1980. Figure 1 shows the eruptive stages and periods and the dormant intervals that separate them.

The first three eruptive stages and early part of the fourth stage (Smith Creek and Pine Creek periods) produced abundant dacitic tephras and pyroclastic flows (Mullineaux, 1986; Crandell, 1987). Dacitic (to siliceous andesite) dome and lava flow remnants related to these pyroclastics probably lie buried beneath the modern volcano, judging from a few exposed remnants and from the common occurrence of pyroclastic flows bearing nonvesicular clasts of dacitic dome lavas. Remnants of a cluster of dacitic domes mostly from the Pine Creek period are exposed in the lower part of the 1980 crater wall of MSH (Hopson and Melson, 1982). The modern stratovolcano, built mainly from lavas (flows and domes) and pyroclastic deposits of andesite, dacite, and lesser basalt, grew above the pedestal of earlier dome remnants during Castle Creek and later time.

The eruption of olivine basalt during the Castle Creek eruptive period is a unique event in the history of MSH, and it figures prominently in hypotheses concerning the petrogenetic evolution of the volcano. Two basaltic events at ~1.9 ka (Greeley and Hyde,