Section I

Volcanic Events and Successional Responses

Spirit Lake and Mount St. Helens (July 26, 1980)

Introduction

Although we know a lot about how, when and why volcanoes erupt, it often feels like they vent capriciously, as if at the whim of some minor deity. Many societies did believe that volcanoes represent deities or symbolic mythological figures. Vulcan, whose eponymous Sicilian island home gave us the name for all tumultuous mountains, is joined by the Greek god of blacksmiths and volcanoes Hephaestus and by the far more lovely, but just as dangerous, Hawaiian goddess Pelé.

What we call Mount St. Helens is known to local Native American people as Louwala-Clough, home to the divine maiden Loowit. It is another indication of European hubris that the cone was named by George Vancouver, ignorant of its true name, for an obscure British aristocrat, Alleyne Fitzherbert (1753-1839). The good captain knew Fitzherbert, who, by negotiating a treaty between Spain and Great Britain in 1791, made it possible for British ships to explore the northwestern waters without Spanish interference. It was for this feat that Fitzherbert was raised to the peerage as Baron St. Helens.

This stratovolcano, once the most beautiful in North America, now bears the scars of its traumatic eruption on May 18, 1980. Volcanologists spent many years prior to the eruption studying its past. Based on their detailed investigations, Crandell and Mullineaux (1978) predicted that Mount St. Helens would soon erupt. When it started rumbling, a battalion of volcanologists and geologists jumped into action. Virtually all aspects of this volcano's activities, before, during and since the first cataclysmic events, have been studied in exquisite detail, setting new standards in volcanology. Predicting volcanic eruptions has become much less uncertain (and much more certain than predicting the behavior of volcanic deities (See Sidebar I.1).

Ecologists also swarmed to Mount St. Helens, lured by the potential to study at first hand and in considerable detail how ecosystems reassemble after a major trauma. For several years, you could not spend a summer day without seeing a group of ecologists hunched over a field plot, carefully measuring seedling distributions or engaging in some other arcane behavior. The air was filled with helicopters transporting field teams on their sundry missions. Over the years, most of those ecologists moved on. Some, like Lawrence C. Bliss, Michael F. Allen, Estella Leopold and Donald Zobel, retired. The careers of others drew them elsewhere. Still others, such as Virginia H. Dale, return occasionally to monitor slow moving developments. I continued to lead a research project on plant recovery through 2010.

Sidebar I.1. *The Kentucky prophet*

Kentucky is lovely in May. I was doing training workshops concerning preserving diversity when managing National Forests. One workshop took me to Lexington, and I visited with my friends at the University of Kentucky, Carol and Jerry Baskin. That evening, after dinner, we returned to their home, where I was their overnight guest. In their study was a Sierra Club calendar. Now, I know that you will find it hard to believe, but the mountain of the month was none other than Mount St. Helens. It was May 15, and there it was in all its "Fuji of North America" grandeur. Carol, naturally, asked me whether I thought the volcano was going to explode. Of course, my colleagues had been laying plans to start reconnaissance studies if it erupted, but I was too young to hedge my bets. "Sure, Carol, real soon…and it's going to be big," I told her with more certainty than was merited. On the 16th of May, I moved on, and early Sunday, I boarded a plane for Seattle. Somewhere over eastern Montana, the pilot informed us that Mount St. Helens had erupted and that we were making a detour. We diverted south 150 miles, then out to sea, then around back to Seattle from the north. The ash plume was astonishing. The next morning at work, my answering machine was flashing ominously. The message, from Jerry: *Sir, you are a prophet in the State of Kentucky.*

There have been waves of younger ecologists working on Mount St. Helens, often trained by the old guard. The most prominent is John G. Bishop, who continues to conduct inventive studies of nutrient effects and herbivory. Others have conducted important studies over several years, before moving on to other pursuits. Notable among these was David M. Wood, who periodically returned to conduct monitoring until his death in 2012. Jonathan H. Titus, Shiro Tsuyuzaki and Roger N. Fuller subsequently developed broader interests in ecological processes, conservation and restoration. These and many others have contributed insights concerning how vegetation reclaims the land after traumatic disturbances.

Background

The study of succession often uncovers unexpected lessons about the tenacity of life and quirks by which biological communities develop. Newly created or sterilized habitats may soon be invaded by plants and animals, sometimes in unexpected ways. Usually, successful invasions are delayed until physical processes like erosion and soil development help to prepare the site to support colonists. Unusual associations among plant often develop and we are beginning to understand that there are no narrow prescriptions for how a successional story must unfold.

This lack of predictability follows because many steps in the recovery of an ecosystem are subject to chance. It also results from sensitivity to local factors, including soil fertility, soil moisture and the environmental limits to establishment and growth. The proximity to potential colonists is a variable that has profound influence on early succession. On many kinds of new volcanic substrates, physical processes may prepare the way for biological processes. Rain may compact loose surfaces thus limiting erosion that otherwise would have removed the first wave of seeds. Surface heterogeneity is created on this hostile surface, often just tiny crannies only slightly better suited to seedling germination than are others. These safe-sites are vital. Wind deposits organic matter in the form of dust, spores, invertebrates and the like, thus improving site fertility. Water erosion re-works surfaces and removes newly emplaced materials. This too enhances site heterogeneity. Seeds and spores that find favorable sites start a self-augmenting process that initiates local succession. Without these forms of physical preparation, the first invaders, nearly always dominated by small seeded species not very tolerant of stress, would stand no chance. As small colonies become established, other species eventually arrive, grow and expand. Among such species on Mount St. Helens are nitrogen-fixing lupines. Once lupines become common, succession accelerates, but it may take unexpected directions. The story of how vegetation continues to develop on this volcano is the focus of Section I.

Good Viewing

Throughout Section I, I refer to locations where particular events or specific research efforts occurred. Several kinds of volcanic disturbances or of successional recovery may be seen from one location (See Fig. I.1). The great virtues of Mount St. Helens are that it is so close to so many people and that it is so appealing.

Research Sites

Study sites that illuminate the processes of recovery surround the cone. One strategy I used to establish study sites was to find places with contrasting degrees of isolation from colonists and that exemplified different impacts. The realities of logistics forced compromises and the perverse dynamics of the mountain itself resulted in the abandonment or destruction of some sites. I conducted additional monitoring and experiments near most of these places. Descriptions of my monitoring studies are augmented by the work of several other groups.

On the south side of the volcano, there were several impacts. Tephra fell during the first few eruptions and covered vegetation (and snow) with coarse deposits rarely deeper than 15 cm. The first permanent plots were established on tephra-impacted sites. Two small lahar deposits were accessible near an early campsite, so as soon as any plants were observed on them, permanent plots were established. Subsequently, extensive grids of plots were placed on both deposits. Scoured sites created by lahars were discovered on benches and on steeper slopes. Permanent plots established there as well. Thus, three types of impacts could be monitored within a few km of each other.

Two ridges extend down the crater on the western slope of the cone. One divides the two forks of the Toutle River. It is barely within the blast zone. Soil and remnants of the forest persisted. Studebaker Ridge, a dramatic feature that helped to direct the force of the initial eruption to the north, angles to the northwest. It suffered from the blast during the early stages of the eruption that removed all plants and most soil to reveal a basement of old lava rocks. This exposed ridge presented a hostile environment and a very limited seed rain. Conditions become increasingly stressful as one proceeds up the ridge towards the crater. A southeast trending ridge separated Pine Creek from the large Muddy River lahar. On each ridge, I established transects of permanent plots.

I studied the Muddy River Lahar intensively and I was rewarded with important insights into the effects of distance on establishment. Vegetation was surveyed intensively in 2002 and 2007. East of the cone is a large, relatively barren site called the Plains of Abraham? I established both a grid and an array of permanent plots on this level terrain that had been devastated by the blast, lahars and pumice deposits.

On the north side of the cone is the Pumice Plain. The initial lateral eruption removed most plants and soils and certainly killed all larger animals. The central area (pyroclastic zone) received several pyroclastic flows and substantial areas were reworked by floods and lahars that have prevented much vegetation development. A sampling grid was established here by David Wood. The eastern part of this area (pumice zone) escaped pyroclastic flows but did receive deep pumice deposits. These were sampled by a grid and several transects of permanent plots. On north-facing slopes in this area, some species survived by virtue of being buried in snow. I established permanent plots, a grid and a long- term study of depressions that I came to call "potholes" in the pumice zone. The entire Pumice Plain was surveyed, first in 1993 and then in 2004, in order to understand how vegetation developed on a broad scale. Wetlands are scattered throughout the Pumice Plain. They have been studied over the years by Jon Titus and by me.

The geological events preceding the great 1980 eruption were described by Mullineaux and Crandell (1981), while those immediately following the eruption were admirably described by Foxworthy and Hill (1982). The book edited by Dale, Swanson and Crisafulli (2005) provides chapters on virtually all aspects of the geological and ecological recovery of this volcano. Del Moral and

Fig. I.1. Location map. Main study locations are indicated directly on the map. Trails and roads mentioned in the text are marked. (Map was modified from a digital map provided by the Mount St. Helens National Volcanic Monument, used by permission).

Grishin (1999) described the processes of recovery from volcanic eruptions in general and gave an overview of the scope and importance of volcanism to human affairs. Walker and Del Moral (2003) offered a detailed analysis of primary succession that relied heavily on findings from Mount St. Helens. How volcanism and other natural disasters have affected human affairs was outlined by Del Moral and Walker (2007). These books and reports may offer more details for the interested reader than I can provide in this book.

Overview of Section I

8:32 A. M. on Sunday, May 18, 1980 is a moment certainly etched in my mind and in the minds of many others who lived in the Pacific Northwest at that time. At that moment, triggered by a magnitude 5.1 earthquake, the fragile, unstable bulging north side collapsed. An unprecedented landslide-debris avalanche slowly began to descend and within seconds, the landscape surrounding the mountain changed radically. The north face crashed through part of Spirit Lake and then flowed west, filling the North Fork of the Toutle River valley and blocking its tributaries. A very few seconds later, as the avalanche released the bottled up forces within the cone, a massive lateral steam-driven eruption occurred. This blast extinguished life near the cone, toppled forests many kilometers away and seared trees even more distant. The blast quickly overtook the debris avalanche and converted most of Spirit Lake to steam. The cone had lost 400 m elevation to form an amphitheater. Intensely hot, glowing clouds of gas called pyroclastic flows began to roil directly from the throat of the volcano thus sterilizing the land. Very soon after the lateral blast, a cloud of pumice began to ascend, reaching 20 km high, and started drifting to the northeast. Near the cone, pumice rocks fell on the new surfaces. The texture of deposits became increasingly fine with distance so that a dust called ash coated the landscape over several hundred km. The intense heat rapidly melted glaciers and snowfields on the remaining sides of the crater. Great mudflows (called lahars) started sweeping down valleys. The Muddy River Lahar wreaked havoc on the southeast side of the cone, with deposits flowing into the Swift Reservoir to the southeast.

In this section, I will describe these volcanic events in more detail and sketch their broad impacts on the land. In each case, I will place them in an historical context. I will provide images of what these landscapes looked like at that time and where to see them now. I will outline how vegetation has developed since the eruptions, based on the studies of several research groups, including my own. This section is largely descriptive, but hints at the mechanisms to be explored in Section II.

Each landscape surrounding Mount St. Helens received unique disturbances that resulted from the combination of impact type, distance from the crater and landscape context(Swanson and Major 2005). These disturbances produced many succession pathways, or trajectories. In addition, later disturbances (e.g., small lahars spawned by torrential rain, surface erosion that dissected unconsolidated deposits and elk trampling) caused portions of each trajectory to regress so that at any time, adjacent vegetation could express different ecological ages.

The distribution of the major impacts is shown in Fig. 1.2. It shows the pyroclastic zone emanating from the crater and overriding some of the debris avalanche. This massive avalanche realigned Spirit Lake and moved rapidly down the North Fork of the Toutle River, leaving behind thick deposits and blocking several streams to form new lakes. As this avalanche deposited materials, it became more liquid and developed into a lahar. This lahar reached the Columbia River; other lahars created havoc as they flowed down many canyons. The blast zone includes three areas. Closest to the cone, and extending in a wide arc, is a zone from which most vegetation and soil was removed. Further away and where protected by ridges, is the blown-down zone. As the force of the eruption attenuated, trees were killed by the searing heat, but left standing. At still greater distances, the major impacts were those associated with the fall of ash.

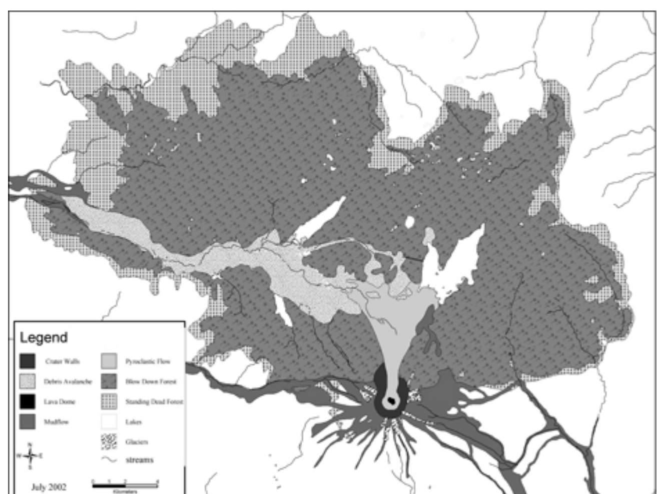

Fig. I.2 Impact map. (Map was modified from a digital map provided by the Mount St. Helens National Volcanic Monument).

Chapter 1 centers on the impacts caused by air-fall tephra, often erroneously called ash, a fine-textured form of tephra. This impact is the most extensive volcanic impact. Ash clouds can shut down air traffic and adversely affect the weather. They can cause great inconvenience, economic loss and even mortality to humans, livestock and wild life. Tephra from major eruptions have altered landscapes and probably have had effects on evolution.

Chapter 2 discusses the blown-down and standing dead tree zone found in a large arc centered north of the crater. Near the crater, standing trees were snapped or uprooted and slammed into the ground. Further away, the force attenuated, but the heat remained intense. This created a narrow seared zone that became the standing dead zone. While the blast destroyed the trees, many herbs and animals survived either being dormant beneath snow or protected by topography. As snow melted, many plant and animal survivors emerged to start the redevelopment of these forests. The importance of nurse logs to the rate of recovery and to ecosystem complexity was demonstrated by studies in these areas. This region has demonstrated the importance of surviving vegetation and capricious events in determining the rate of recovery.

Chapter 3 is concerned with lahars (mudflows) and the debris-avalanche spawned by the great eruption. These devastating mixtures of water, mud, boulders, trees and anything else caught up in the tumult can rumble down from the volcano (debris-avalanche), move swiftly along river canyons, picking up large objects like trees (debris-flow) and, as larger material settles out, become a lahar. Lahars scour riverbeds and can fill in lakes and block tributaries. Once the lahar subsides, erosive forces create steep-sided channels that may take decades to stabilize. Lahars, because they are lined by relatively intact vegetation, allowed me to investigate how isolation alone affects the species composition of recovering vegetation. Studies along the course of the Muddy River Lahar demonstrated the importance of environmental stresses and distance combine to affect the rate of vegetation development.

Chapter 4 covers the terrain northwest, northeast and east of the crater, which is the vegetation removal zone. This zone is so close to the cone that the blast blew obliterated trees, soil and everything else. To the northeast, the pumice zone provides some of the best examples of primary succession to be found here, or anywhere. Small areas on steep north-facing slopes were protected from the brunt of the blast by snow. While trees were annihilated, soil and dormant plants survived, eventually to offer important lessons about recovery processes. To the northwest, Studebaker Ridge offers a stunning example of how impact intensity has affected recover rate. This ridge is the only place where we have studied recovery on older lava flows. Finally, on the east side of the cone, a broad, relatively flat plain was denuded by the blast, swept by lahars and buried by coarse pumice. Discovering reasons for the slow recovery on the Plains of Abraham led to better understanding of habitat stresses and dispersal limitations.

Chapter 5 concerns the pyroclastic zone, where unimaginably hot, incendiary (i.e., pyroclastic) flows of gas, molten rock and pulverized magma destroyed all life, scrubbed the south slopes of Mount Margaret, plunged through and reshaped Spirit Lake. The pyroclastic deposits, comprised of very fine, deep powder, were subsequently eroded by wind and water, in many places leaving coarse pumice gravel surfaces. Wetlands have developed in many portions of this region from springs and snowmelt, and streams flowing off the crater continue to rework broad areas that remain essentially devoid of vegetation.