

## CHAPTER 5

### The Zone of Pyroclastic Deposits



*The Pyroclastic Zone (September 10, 1980).*

#### What is a pyroclastic flow?

Pyroclastic flows are searing, superheated blasts of gas that turbulently entrain incandescent rock fragments surging from a cone or vent at horrifying speeds. The name derives from Greek, “broken by fire.” They are also known in French as *nuée ardentes*, “glowing cloud.” Temperatures in these deadly volcanic explosions can soar above 800 °C, and hurtle down slope at speeds in excess of 700 km per hour. They are usually spawned by an eruptive explosion, but the collapse of a Plinian eruption column or even collapsing dome can eject masses of incendiary gas and associated rocky debris surging down the slope. The structure of a pyroclastic flow includes a mass of rapidly flowing fragmented rocks at ground level (the basal flow) that engulf all in its path. Above it, a turbulent ash cloud rises to herald the inevitable, imminent devastation. Low-density pyroclastic flows (more gas, less pumice) raced far up the south slope of Coldwater Ridge.

The eruption of Krakatau in 1883 was a turning point in the history of communications. For the very first time,

a major event was described and communicated almost instantaneously around the world using the newly laid sub-marine telegraphic cables. Even before this fifth most powerful eruption in recorded history had turned sunsets red, the news of the cataclysm taking place in the remote Sunda Strait (between Java and Sumatra) was known in London. The eruption blasted away most of the island. The resultant landslide, the collapse of the northern part of Krakatau into the sea created a mammoth tsunami (Francis 1985) that peaked at 40 m when it struck land. It destroyed many villages on nearby islands and killed more than 36,000 people.

Pyroclastic flows are the swiftest and often the most devastating of volcanic events. Without a doubt, they are the most dangerous volcano spawn. Pyroclastic flows have killed more people directly than any other volcanic process. The rare killer lahar and deep tephra deposits are exceptional. You cannot outrun a pyroclastic flow. You cannot even survive a close encounter. You will die even if you only inhale some super-heated air. And if the heat didn't sear your lungs, the noxious sulfurous gasses would

surely kill you. You should not plan to observe from a short distance because you will be bowled over by the blast of heated air heralding the approach of the flow. Nothing survives a pyroclastic flow, and its deposits are, without question, sterile. Because of their origin in the throat of a volcano and their intense heat, they lack nitrogen or any semblance of soil. Thus, there was no better place to investigate primary succession on Mount St. Helens, once the substrate has cooled and stabilized.

### Pyroclastic flows in history

The pyroclastic flows on Mount St. Helens were unique because so many were photographed. This provided a much better understanding of how they are formed, how they work and the devastation they can wreak. Certainly, pyroclastic flows were associated with most large historic eruptions, but in the cataclysmic chaos of most titanic eruptions, pyroclastic flows often escaped noticed in the din of blast, persistent tephra bombardment, flowing lava and lahars. The terrified are poor witnesses.

No historic eruption demonstrated how volcanoes changed history more than did that of Thera, today known as Santorini (about 1623 B.C.). This date was determined by carbon dating of horse bones and is a bit earlier than that determined by historical methods. Today, the remnant islands form an archipelago that includes a major Greek resort (Santorini); volcanic activity on a much smaller scale continues. The stupendous eruption had many effects, but the most significant appears to have been the tsunamis caused by pyroclastic surges from the caldera collapse into the eastern Mediterranean. The largest tsunami may have exceeded 50 m when it struck Crete and while Crete suffered greatly, the entire eastern Mediterranean basin was devastated by the tsunamis and by thick ash deposits. This event certainly crippled the thriving Minoan culture and led to the shift in power to Greece (Fig. 5.1).

Over 1700 years later, and a short sail west across the Mediterranean, pyroclastic flows helped seal the fate of Pompeii and Herculaneum. Pliny the Younger described many of catastrophic events that had killed his uncle. Most notably, the younger Pliny accurately described pyroclastic flows for the first time. From A.D. 79 on, volcanoes began to get some respect. However, volcanism remained poorly understood, and mountains sometimes had to erupt before their true nature was revealed. Pyroclastic flows in Japan, Indonesia, the Philippines, Mexico and many other places claimed many lives over the centuries. In 1815, Tambora produced the largest eruption in 2000 years. Its pyroclastic flows killed 12,000 people, in-



*Fig. 5.1. Nea Kameni, an uninhabited island in the caldera of Santorini (May, 2014). This island first appeared in 47 A.D., after the devastating 1623 B.C. eruption. It has erupted repeatedly in the last three centuries. Four boats shelter at night.*

cluding every speaker of the recently encountered Tamboran language. The climate cooling effects of Tambora led to the deaths of several million people.

The true characteristics of pyroclastic flows were poorly understood until 1902. It was then that La Montagne Pelée (French = Mount Baldy) on the northern edge of the Caribbean Island of Martinique produced deadly pyroclastic flows. The town of St. Pierre, only 6 km from the crater was having an election. Despite a killer lahar and a warning tsunami, officials urged complacency and encouraged everyone to come to the safety of the town, vote and then go back home when Pelée settled down. Although Krakatau had erupted less than 20 years earlier, scientists had yet to come to appreciate the potential destructive force of a volcanic eruption. Many people did scurry to the safety of the south part of the island (having little faith in their political leaders); many more came from the countryside to what was thought to be the safety of St. Pierre. The scientific commission investigating the eruption minimized the danger and issued sanguine bulletins. Pelée really turned up the heat after the lahars and in the next two days, ash eruptions and dome building accelerated. Several small pyroclastic flows surged down the slopes. Then, inevitably, early on Thursday morning of May 8, the thunderous eruption was heard. Two minutes later, a huge pyroclastic surge crashed down the valley to incinerate St. Pierre, killing 29,000 people. Now, geologists understood nature of pyroclastic flows. Two people survived in the town, a shoemaker and a prisoner locked in a stifling dungeon. He was in solitary confinement and was severely burned when pyroclastic flows surged through town. In the four days before his

rescue, he is said to have gone mad. The authorities wisely released him and he spent his remaining days as the LONE SURVIVOR of St. Pierre in a circus.

Mount Pinatubo, Philippines, produced an eruption second only to Katmai during the 20<sup>th</sup> Century. It occurred in a densely populated region and killed in several ways. The pyroclastic flows moved down several valleys, filling the Marcella River to depths in excess of 200 m. This flow traveled 14 km from the cone and buried villages along the way.

Pyroclastic deposits are very unstable and soon erode. The ability of plants to invade and establish is affected by the stability, texture and fertility of the material left after erosion has settled down. The pyroclastic surfaces on Mount St. Helens provided an unparalleled opportunity to explore how plants establish under harsh conditions.

### The pyroclastic zone of Mount St. Helens

The Mount St. Helens pyroclastic zone was outlined within a few hours on May 18, 1980; there were known 17 flows on that day, some reaching at least 8 km from the cone (Swanson and Major 2005). Additional flows occurred later during the summer of 1980 and a few were noted in subsequent eruptions. As the landslide started at 8:32 A.M. on that fateful Sunday morning in May, internal explosions caused by the sudden release of pressure, quickly blasted through the tail of the landslide. It was composed of pumice from new lava and pulverized older rock. This moving torrent accelerated down slope and spread out over the Pumice Plain, removing all vegetation in its path. Much of Spirit Lake was turned to steam and the debris avalanche displaced most of the remaining water. Its shape and base elevation were substantially altered by the debris avalanche deposits. Later that day pyroclastic flows seared the over 15 km<sup>2</sup> of the Pumice Plain, leaving behind a very fine powder mixed with a mixture of coarser rocks (Fig. 5.2 Top, Bottom) that sometimes filled the air and at other times blanketed the landscape. These deposits came to define the pyroclastic zone.

The trees swept away by the debris avalanche ended up floating on the surface of the reconstituted Spirit Lake (Fig. 5.3), and the resulting scars on the face of Coldwater Ridge persist (Fig. 5.4). Large pumice rocks left behind with the passage of the flow form part of the deposit. Many other pyroclastic flows covered this area on May 25, June 12, July 22 and August 7. Much of the initial surface has been eroded, first by wind, then by water, leading to a form of desert pavement. Therefore, pyroclastic surfaces are frequently very coarse, providing a surface that is very difficult for plant survival.



*Fig. 5.2. Aerial view of pyroclastic zone, including hummocks: Top, Dusty morning view; Bottom, little dust is evident in the evening (both views taken on July 26, 1980).*



*Fig. 5.3. Spirit Lake showing the massive log jam that persists, albeit much smaller, to this day (September 8, 1980).*



**Fig. 5.4.** The “steps” leading up Coldwater Ridge above Spirit Lake retain evidence of scouring of these slopes by receding lake water (August 16, 2011).



**Fig. 5.5.** Region west and north of the insipid Spirit Lake: Top, hummocks and sinkholes cover the landscape and new pyroclastic deposits cover the flank Coldwater Ridge (July 26, 1980); Bottom, hummocks and unusually level and pristine pyroclastic deposits west of Spirit Lake (September 9, 1980). These views were the source of my comment picked up by the media that “When we first got to the mountain, we didn’t need to have color film. Everything was all grey and black.”



**Fig. 5.6.** Pyroclastic zone: a strong westerly wind blows ash to the east, allowing a view of early erosion features, while Spirit Lake is partially obscured (September 8, 1980);

Flying over the landscape provided an insight as to what Dante might have imagined: a dusty expanse of large, hot mounds and deadly sinkholes. The slopes above Spirit Lake showed newly emplaced pyroclastic flows on the south flank of Coldwater Peak (Fig. 5.5Top). Sinkholes and hummocks dot the landscape to the west of what was to become Spirit Lake (Fig. 5.5Bottom). Sink holes are depressions in the original debris avalanche that had collected Spirit Lake water and glacial ice. As a pyroclastic flow hit the water, steam-driven explosions erupted. The speed with which the landscape altered daily can be seen from two images of the pyroclastic zone taken on successive days in September 1980 (Fig. 5.6Top, Bottom). Once a pyroclastic flow has cooled, the surface consists of a fluffy white powder that resembles the ash from burning coal. It is subject to rapid and intense wind and water erosion. The fine dust of the original deposits was slowly removed by wind and water, leaving behind a sandy to gravelly surface that resembles desert pavement.

The depth of the pyroclastic deposits insulated the intensely hot buried rocks. Where rainwater seeped down and contacted these hot zones, steam formed. It escaped, forming fumaroles (Fig. 5.7) that persisted for several years and around these fumaroles, small, ephemeral moss communities formed. As the rocks cooled, fumaroles ceased, and the communities were extinguished. The pyroclastic deposits collected July 26, 1980 were later shown in the greenhouse to be infertile and very acidic, but rapid weathering reduced their acidity (del Moral and Clampitt 1985). Collecting this material was a challenge (Fig. S5.1; Sidebar 5.1). Erosion modified the pyroclastic zone more so than other sites, removing much of the pyroclastic material and forming deep, steep-walled canyons. Secondary disturbances, including small lahars, have further sculpted

the landscape and kept succession



*Fig. 5.7. Fumaroles can result when pyroclastic flows engulf large ice masses. Steam clouds escape over a few months (July 26, 1980).*



*Fig. 5.8. Periodic snowmelt created flash floods across the pyroclastic zone, setting back recovery. Here, reworked old lava rocks form the*

**Sidebar 5.1. The straw men**

Memories of July 26, 1980 are etched in my mind. It was a most wearying day, compounded by intense physical discomfort, and exciting beyond my experience. By then, Mount St. Helens had provided four major eruptions, including one just four days earlier that added a fresh dusting of ash. A new dome began to build shortly after our trip and more eruptions soon followed. Jerry Franklin and I knew that an ecological reconnaissance was required. Surely, we thought arrogantly, Louwala-Clough, the smoking mountain, would wait before further venting (the next eruption occurred 12 days later). Our mission: to find as many study sites as we could. This meant by helicopter, a government-contracted machine. And that meant that flight rules were scrupulously followed. We had to wear hot flame retardant jump suits when temperatures ranged in the 90s. I asked the crew chief if jump suits would save us in a fiery crash. “No,” he drawled, “but they’ll be able to identify your body.”

We lifted from Vancouver’s airfield at dawn, subsequently



*Fig. S5.1 Pyroclastic surface overlain by a slightly more recent pyroclastic flow (July 26, 1980). Author is collecting two buckets of material that would be tested for its ability to sustain seedling growth. Jerry Franklin (foreground) looks on. The substrate temperature was 50°C at the time.*

landing on the Toutle debris avalanche, the Muddy lahar, above Butte Camp, on the Plains of Abraham, above Spirit Lake in the pyroclastic zone (Fig. 5.7) and other sites. The region was dusty, so every landing went like this: find a possible spot; circle to find safe landing spot; circle upwind; tilt the chopper to blow the surface clear of ash; land; do NOT turn off the machine. This last procedure was mandated by the thought that in case of an eruption, rapid take off was imperative. Our procedure: jump out; slip the jump suit off our shoulders; take pictures and note; grab soil samples for later testing. Because the rotors kept turning, it was dusty. The ash was highly abrasive...after all; it is essentially finely ground glass.

By mid-afternoon, we were covered in ash and parched. Fortunately for us, the chopper had to refuel, so we landed at the tiny Kelso airfield for a desperately needed respite. There, we pretty much emptied the soft drink machine, then mentally restored, and emotionally stabilized, we returned to business, covered with the dust from a mountain that would consume the rest of my professional life. I was ghostly pale, scarcely recognizable and my hair was as stiff as straw.

in an early state in much of the area. Large portions of this



**Fig. 5.9.** Barren floodplain on the western edge of the pyroclastic zone (2003). Very few plants survive from year to year.

area remained scarcely vegetated due to frequent flooding and scouring during winter storms and dominated by dry streambeds of large cobbles (Fig. 5.8). Decades later, much of the pyroclastic zone remains barren due to frequent spring floods (Fig. 5.9).



**Fig. 5.10.** Active spring-fed stream suffers frequent flooding. Vegetation is dominated by sun-adapted herbs such as Lewis's monkey flower and young willows and alders (1998).

### Life returns to the pyroclastic zone

*Physical development.* Initially rocky, with much powdery and unstable particles, pyroclastic deposits were soon shaped by physical processes. Rain and melting snow compressed the deposits while wind removed the powder. These deposits were compacted by heavy rains and winter snows. Wind removed fine particles and left behind pumice rocks that stabilize the surface, mulch the surface and create safe-sites for germination. Wind erosion also created favorable microsites and introduced organic matter from dust, spores and insects. Other pyroclastic flows occurred during each of the main subsequent eruptions (May 25,

June 12, July 22, August 7 and October 16), yet the sterile landscape that was the pyroclastic zone changed rapidly in the months following the first eruption. Pumice rocks created some topographic variation that eventually would allow seeds to germinate and establish. Within three years, much of this landscape stabilized, and started to develop lush wetlands where water persisted (Fig. 5.10). Stabiliza-



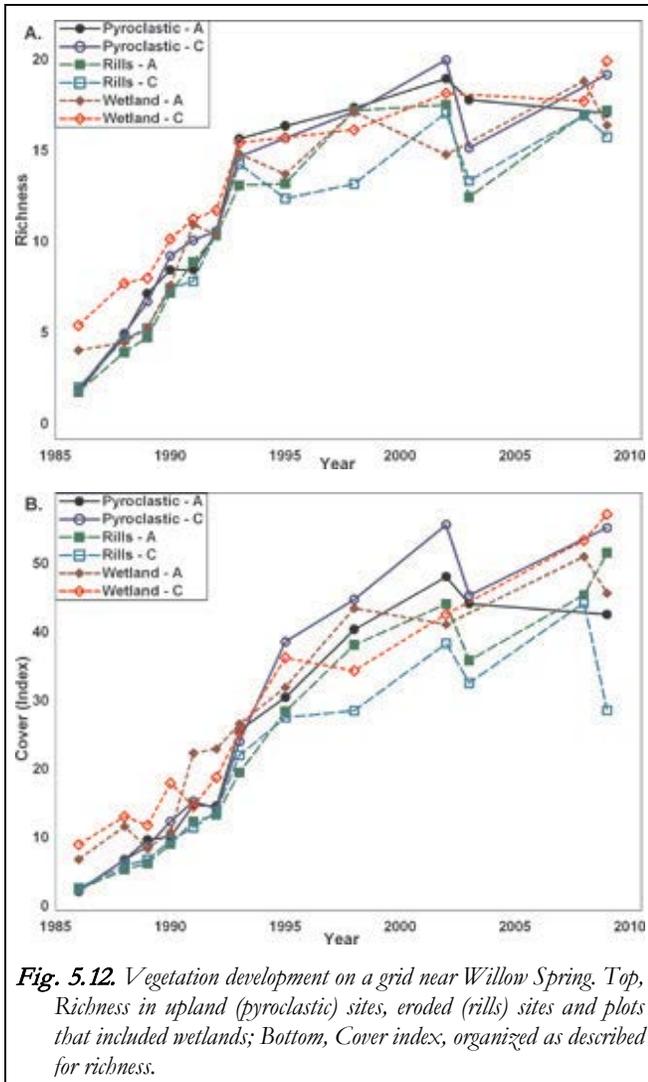
**Fig. 5.11.** Willow Springs, 1986. This natural spring was augmented by the U.S. Army Corps of Engineers while they were drilling the drainage tunnel for Spirit Lake. Willows, fireweed and willow herbs, have started succession. This view is typical of the vegetation when the first grid survey was undertaken in this area.

tion and oases allowed the invasion of plants and animals to begin the reassembly of biological communities.

*Faunal development.* The fauna of the pyroclastic zone was studied by several groups. Insects proved crucial to the initiation of primary succession (Edwards and Sugg 2005). The wind (aeolian) deposition of predators and scavengers, although doomed, led to the development of a resource base for both subsequent animals and immigrating plants. A continual rain of spiders and insects made it possible for plants to begin to establish on Mount St. Helens. These studies reinforced what was beginning to be appreciated: aeolian inputs are crucial to sustaining ecosystems in many situations.

Amphibians were another taxon that has received much attention (Crisafulli et al. 2005a). Because salamanders, newts, frogs and toads require water, they did not occupy much of the landscape, but where they did occur, they formed important parts of the community. Recolonization followed the development of wetlands around Spirit Lake, around springs and in creeks sustained by seeps and springs.

Small mammals provided many important interactions during the development of vegetation on the pyroclastic



**Fig. 5.12.** *Vegetation development on a grid near Willow Spring. Top, Richness in upland (pyroclastic) sites, eroded (rills) sites and plots that included wetlands; Bottom, Cover index, organized as described for richness.*

zone (Crisafulli et al. 2005b). Thus far, rodents appear to interact primarily through seed predation and herbivory. Common species in this area included the deer mouse, mountain shrew, golden-mantled ground squirrel and Pacific jumping mouse.

*Vegetation development.* Vegetation development over a portion of the pyroclastic area was followed by Wood (Wood and del Moral 1988; del Moral and Wood 2012) in a 16 ha grid near Willow Spring (Fig. 5.11), a natural feature that appeared shortly after the eruption. The source has shifted 100 m south since 2004, after the 2004 eruption. The grid sampling method used this index: 1 = < 0.05%; 2 = 0.06 to 0.25%; 3 = 0.26 to 1.0%; 4 = > 1 to 5%; 5 = > 5 to 20%; 6 = 21 to 50%; 7 = 51 to 90%; and 8 = 91 to 100%. The index scores were transformed to their mid-points to describe the cover changes directly.

Wood categorized the plots into stable uplands (pyroclastic surfaces), eroded uplands and wetlands. Not all

plots were sampled in all years. Therefore, I grouped data into blocks and present only two of the four regions in each habitat. Richness reached relatively high values in all sites by the mid-1990s (Fig. 5.12, A). Thereafter, some increases were noted, but significant secondary disturbances reduced richness in most plots after 2002 and wetlands after 2008. Cover developed more slowly, reaching a peak in undisturbed pyroclastic plots in 2002 and again in 2009 (Fig. 5.12, B). Wetland plots were affected by winter storms during 2008 and declined substantially in 2009 and 2010 (not shown due to reduced sample size).

Species patterns demonstrated the general increase in vegetation in stable pyroclastic sites, eroded sites and wetlands. On pyroclastic sites, lupines became overwhelmingly dominant from 1995 to 2003, after which they stabilized at respectable cover. At its peak, lupines covered over 50% of the pyroclastic plots (Fig. 13Top). Thereafter, it declined sharply in response to herbivory and its population dynamics (Bishop et al. 2005). The dune bentgrass developed more typically, reaching dominant values after 2003. Beardtongue is a persistent species that is not subject to significant fluctuations. Although it developed slowly, it occurred in nearly every plot. Indian paintbrush developed slowly, but once other vegetation became common, it thrived. Yarrow and cat’s ear are two species that elsewhere rarely occur at the levels observed on pyroclastic sites. They also demonstrated consistent increases.

Vegetation in rills and eroded sites developed more slowly due to episodic disturbances (Fig. 13 Mid). The lupine pattern was like that of the pyroclastic sites, with a major crash noted in 2003. Lupines have not fully recovered. Sitka willow is typically a wetland species, but in the pyroclastic zone, it developed widespread populations. In the rill habitat, it developed slowly through 2002, and then suffered the general population crash noted in many species and the vegetation in general. However, it recovered strongly. Its decline in 2010 was due to winter disturbances and to herbivory. Cat’s ear increased steadily over the years and remained remarkably abundant in 2010. It responds to nitrogen inputs from lupines (Gill et al. 2006). The remaining species shown in Fig. 13 Mid increased steadily, then most decreased in 2010. The decline may be due to resurgent elk populations (J. G. Bishop, pers. comm.).

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**Fig. 5.14.** Upland pyroclastic zone site with prairie lupines in foreground and Indian Paintbrush in background (2003).

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**Fig. 5.15.** Spring-fed wetland (1999) showing young willows, willow herbs and upland species such as cat's ear. Hydrophytic mosses and several species of rush are common in such habitats.

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The wetland plots often included some upland vegetation because wetlands were often more narrow than the plots. Lupine dominated until 2002, after which willows and Sitka alder dominated (Fig. 5.13 Bottom). After the lupine crash, Indian paintbrush became abundant for several years. It declined as wetland shrubs became denser, and possibly, due to elk effects.

By 2010, the pyroclastic zone contained wide areas dominated by low willow with lupines and a variety of

other species (Fig. 5.14) and developing wetlands (Fig. 5.15). Scattered throughout this area are saplings of several conifer species. As these plants can overcome infertility, drought and the lack of mycorrhizae, the pyroclastic zone will develop into an open conifer forest.

*Upland vegetation patterns.* Vegetation patterns across the pyroclastic zone were studied in 1993 and 2004. Suggested by Wood's grid data, the region is heterogeneous. A major goal of the surveys was to determine if predictable relationships between habitat factors and species composition could be found. The details of these studies are in Chapter 8. Here I will summarize the descriptive aspects to provide a better idea of the nature of this region.

As can be inferred from the grid, the vegetation of the pyroclastic zone remains heterogeneous. Erosion, repeated disturbances from small lahars, variable moisture conditions and variable terrain all contribute to this mosaic. Working across 15 km<sup>2</sup> does not allow for detailed, repeat survey of permanent plots as has been presented for other, more homogeneous regions. However, I can provide several snapshots based on earlier studies of the uplands. In 1993, we conducted a broad-scale survey of the entire Pumice Plain, including the pyroclastic zone (Del Moral et al. 1995). At that time, vegetation was poorly developed and plots on the pumice zone resembled those of the pyroclastic zone. The relationship to environmental factors was weak, and the location of the plot was the best (but not very good) indicator of species composition. That landscape factors were of paramount importance suggested that stochastic (random) factors play a key role in assembly of plant communities. The richness in the pyroclastic zone in 1993 was 9.9 species per plot, about half that of refugia at that time. Refugia, in addition to supporting survivors, had relatively fertile soil and had been invaded by additional species. Diversity was also low, but greater than lupine-dominated areas, where competitive effects produced communities with only one or two dominants and several subordinate species. This vegetation was in the early stages of species assembly and dominated by the typical wind-dispersed pioneer species: in descending order, pearly everlasting, fireweed, prairie lupine, cat's ear, hawkweed and dune bentgrass. Cover was sparse, with many sub-samples lacking any plants. Associations of species that rarely occur together elsewhere were common.

In 2004, we again surveyed the Pumice Plain, including refugia, pumice sites, pyroclastic sites and drainages (del Moral and Lacher 2005). The vegetation had developed substantially since the earlier survey. Taking only those plots in the pyroclastic zone, I determined that there were

seven communities. Cover was dominated by a pulse of prairie lupine. In addition, while mosses had been rare in 1993, they were dominant where substrates were stable. Vegetation, represented by five communities, varied in response to environmental stress. All communities had prairie lupine and rock moss, with various associates (Fig. 5.16). Percent cover ranged from 85% to 9%, while the average number of species dropped from 19 to 13. Bentgrass, willows, broadleaf lupine were more abundant in denser communities, cat's ear, pearly everlasting and fireweed were common in barren plots. In addition, one lush meadow community occurred along drainage corridors. It was characterized by strong dominance of broadleaf lupine, paintbrush, cat's ear and slide alder. The final community also occurred in moist habitats, but was drier than the previous one. It was distinguished in that both lupine species were dominant, a situation that is rare in mature vegetation.

*Wetland patterns.* Wetlands in the pyroclastic zone are obviously new structures, so their development is clearly primary succession. There was little vegetation along intermittent streams fed by melting snow because the stream banks are too dynamic and unstable. Any plants establishing during the summer of one year are washed



**Fig. 5.17.** Young wetland developing along a permanent stream formed by an upland spring. Margins are dominated by willows, which will persist, and a variety of willow herbs, that will be excluded from the developing wetland woodland.

away by the spring of the next. Wetlands did develop wherever there was a stable substrate and dependable water. Many became oases that supported a rich flora and fauna. Wetlands that are associated with spring-fed streams or, closer to Spirit Lake and supported by groundwater, have developed nicely (Fig. 5.17).

The debris avalanche, having temporarily displaced Spirit Lake, emplaced a natural dam across its outlet down

the Toutle River. The new higher level of the lake and weakness of the dam created by the avalanche gave rise to fears that the dam would fail, unleashing a new lahar down the river. Such failures occur frequently with devastating results. Spirit Lake has experienced one such failure (Major et al. 2009) and models indicated that if the current debris dam had failed, the flood would have been 20 times that of the 1980 lahar. Therefore, the U.S. Army Corps of Engineers excavated a tunnel through bedrock to lower Spirit Lake. The tunnel, completed in May 1985, connected Spirit Lake directly to Coldwater Creek. The result was that the level of Spirit Lake dropped several meters, revealing new land suitable for the development of wetlands. These wetlands therefore started to develop six growing seasons after many of the spring-fed ones at slightly higher elevations.

Several studies of wetlands have concentrated in this area. Titus et al. (1999) and del Moral (1999b) published studies of wetlands over the entire Pumice Plains (studies from 1994 and 1998, respectively). Most of the wetlands were in the pyroclastic zone. Jon Titus and Jennifer Griffith (unpublished 2004 data) surveyed the wetlands and found many more species than had any other investigators. As part of a study of productive habitats, Del Moral and Eckert (2005) characterized transitions from wetland to upland and provided detailed description of typical wetlands near Spirit Lake.



**Fig. 5.16.** Lush vegetation was very common across the pyroclastic zone in 2004. Here, the remains of an elk are surrounded by lupines and Indian paintbrush (photo courtesy of Tara F. Ramsey).

The Titus and Griffith study included 73 plots on pyroclastic surfaces. I classified these data into five communities. Two lowland wetland communities occupied isolated depressions near Spirit Lake that had been submerged until 1985. Willows, alders, horsetails, rushes and wetland mosses dominated one (A). Collectively the plots in this community were diverse; there were 51 species

found, with an average of only 16 per plot. The other (B) had a denser overstory of the same shrubs, but was more heterogeneous, having 75 species, but an average of 20 species per plot. Wetland mosses dominated the understory at the expense of horsetails and rushes. These two communities were five years younger than others in the area. Their heterogeneity suggests that the competitive effects of a strong canopy have yet to impose some regularity on the species composition.

The remaining communities occurred along moving streams. Where erosion was common, as near springs and steep slopes, there were few shrubs to cast shade and there was little sediment to support mosses. This commu-



**Fig. 5.18.** *A bizarre island of common horsetail persists on the lower pyroclastic zone (1999). There was no obvious source of water, but it is likely that the horsetails established when Spirit Lake was at its maximum size, then the rhizomes grew down as the lake level was lowered artificially (1982-84).*

nity (C) was poorly developed and frequently suffered erosion from the associated streams. Cover was 25%, with 17 species per plot and 55 species in total. It was dominated by willow herbs, Lewis' monkey flower and several wetland rushes, all adapted to sunny conditions. Stable sites had a community (D) of dense willows forming a canopy with giant horsetails and mosses dominating the understory. Total cover exceeded 68%; there were 49 species, averaging 18.9 species per plot. Community E was dominated by mosses, horsetails and rushes, with scattered willows. Total cover was 92%, but willows covered only 27% of the area. The moss layer limited the ability of willows to develop. There were only 28 species in total, with an average of 15.0 species per plot. These plots were in stable habitats.

These results are consistent with those of del Moral and Eckert (2005). That study, based on 16 wetlands sam-

pled in 2002, found that wetlands near Spirit Lake in stagnant conditions were dominated by several species of mosses, horsetails, several rush species, willow herbs, sedges, liverworts and a limited canopy of willows and Sitka alder. We also found three orchid species, hardly surprising since orchids are adept at long-distance dispersal. This heterogeneity in similar habitats, combined with the strong dominance by wind-dispersed species, implied that chance establishment was common. Over time, it is likely that wetlands will demonstrate greater consistency because wetland species have good long-distance dispersal ability and can demonstrate strong competitive ability. Together, wetlands greatly enhance the overall floristic richness of the Pumice Plains, and provide habitats and resources for many animals that otherwise would be excluded from this area.

An unusual feature was encountered during the study that served to emphasize that summaries and generalizations should not be relied upon to provide the entire story. Near the wetland described above, I chanced upon a small island of field horsetail emerging from what appeared to be a dry pyroclastic surface (Fig. 5.18). This encounter occurred during the 1999 wetland survey. The habitat was distinctly not wetland, but the dominance of horsetails and a fringe of willow herb and Sitka alder suggested that it once had been. I surmised that the community established during the high water times that lasted to the spring of 1986. As the water table dropped, horsetail rhizomes and alder roots were able to keep pace, sustaining this odd patch of vegetation.

### Importance of pyroclastic habitats

Pyroclastic surfaces comprised a small part of the devastated landscapes of Mount St. Helens, yet they offer unique insights into succession. All life was obliterated and all deposits were fresh from the bowels of the volcano. Such purity is rare and even lahars and pumice falls often may retain some biological signal from the past. Lahars can entrain old soil and rhizomes that may start succession immediately in relatively fertile conditions. Some organisms may survive tephra deposits and emerge onto barren substrates supported by older ones. Neither case holds for the pyroclastic zone. Further, potential colonists were at best several km distant. The stark, infertile plain eroded rapidly, retarding development. It was clear that succession would not proceed until surfaces had stabilized. Unstable stream courses persist, and episodic debris flows erode large areas, so much of this area remains nearly devoid of vegetation. Such sites are no longer dominated by pyroclastic materials, long since removed, but by a jumble of rocks ejected from earlier eruptions.

### Where to see the pyroclastic zone

**Johnston Ridge:** Distant views are to be seen here, but by taking Boundary Trail #1 to the east, down into the Hummock area and beyond, you will gain an appreciation of the pyroclastic zone. You can reach Willow Springs and other features of the pyroclastic zone.

**Windy Ridge:** From this site, take Truman's Trail #207 to the small parking area and then continue to the west. Willow Springs offers a welcome respite. From here, either continue to the west, or turn uphill (Trail #207A) to join the Loowit Trail (#216). At the junction, you can turn back to the east to make a nice loop.

### Summary

Pyroclastic flows are intense disturbances that initiate recovery that can only be primary succession. External forces, including erosion, compaction and the constant rain of organic matter, helped to stabilize and enrich these new surfaces, preparing the surface for vegetation establishment. The biological input accelerated as a few plants establish and animals are drawn to the developing communities, forming a positive feedback loop.

Vegetation structure developed as on the other surfaces. First species accumulated relatively quickly and then vegetation cover developed as the colonists expanded. Development was accelerated by biotic facilitation in the form of nitrogen fixation, carbon deposition, amelioration of the microclimate and other factors. Herbivory by mammals and insects may retard succession by limiting growth and carbon accumulation, but it also can lead to enhanced seed dispersal, wider distribution of nutrients and the creation of safe-sites. Stability and the assured presence of water led to the rapid development of wetlands. Chronically disturbed sites had little vegetation. The heterogeneity found in wetlands implied that establishment had a strong component of chance.