

Ascending ash cloud from Redoubt Volcano, Alaska, 1990. The cloud is reflected in the waters of Cook Inlet. View to the west from the Kenai Peninsula. Photograph by J. Warren. Courtesy U.S. Geological Survey (hereafter cited as USGS).

# **In the Thirty and Fourth Year: A Geologist's View of the Great Destruction in 3 Nephi**

*Geological studies and eyewitness accounts of volcanic activity show the likelihood that the massive destruction reported in 3 Nephi was caused by an explosive volcanic eruption.*

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About three hundred years ago, a cataclysmic volcanic eruption occurred off of the northeastern coast of Papua New Guinea. No written history of this eruption exists, but local legends abound concerning the event. In 1970, Russell Blong began collecting many of these legends and piecing together the effects of the eruption.<sup>1</sup> The native legends refer to this period as the “time of darkness”:

I am going to tell the story of darkness. I am going to tell the story of the great darkness which appeared on this ground/area. I did not see it. People told me and so I know it.

It was while they were asleep, in the night, that it was so dark on this earth, and they slept/lay for about three nights. And when they took flares and went up the hills and made signs, going with flares in the pitch blackness, they said: Can you see my flare? But the flares did not light up the place! So they said: No!

This went on many times. And when they were sleepy and it should have been night they slept. And when it should have been light they woke and got up, and kept looking and looking and lit flares and went up the hills saying: Do you see my flare? And others said: Do you see? And they looked all around. But they didn't see them.<sup>2</sup>

The legends recount that after the eruption other phenomena occurred along with the darkness, which most of the legends

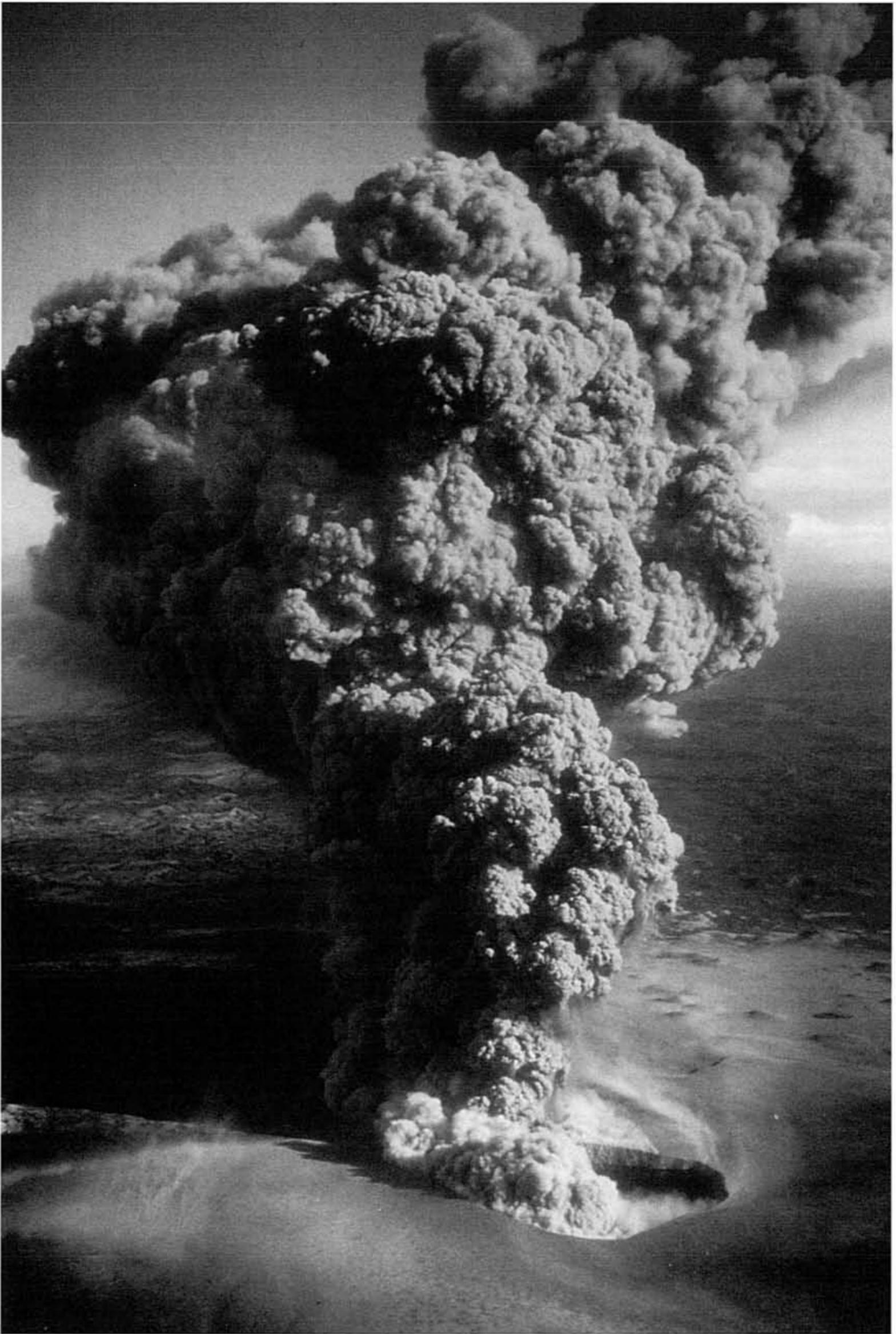
describe as lasting two to four days.<sup>3</sup> One describes “thunder, lightning, and tremors”<sup>4</sup> as heralds to the darkness. Another reports that “a storm was on its way and there was a rustling and whistling in the air.”<sup>5</sup> Others describe winds, earthquakes, floods, loud noises, fumes, and unusual changes in temperature.<sup>6</sup> Many people died from collapsing huts, fumes, sores inflicted by hot falling ash, falling stones, starvation, and other causes.<sup>7</sup> Along the coastal areas, trees and crops were destroyed by floods of water.<sup>8</sup> One account said that “all bad men, trouble makers, people with bad thoughts, thieves, etc.” died during the darkness.<sup>9</sup>

The native accounts are amazing, according to Blong, not only because they have survived for three hundred years, but also because, aside from a little exaggeration and embellishment, “the veracity of the stories can be tested against physical reality.”<sup>10</sup> None of the accounts gives a complete picture of the event, but taken together they provide a good idea of the conditions that occur during an explosive volcanic eruption. The distribution and thickness of ash from this eruption, the only physical evidence that survives, provide a way to estimate the size of the eruption and the associated effects that presumably would have accompanied it. All of the conclusions based on this physical evidence agree well with the oral traditions.

A second, much older account of a time of darkness is found on the remains of an Egyptian stele that has been connected with a great volcanic eruption (ca. 1500-1450 B.C.) on the island of Santorini (Thera) located about seventy miles north of the island of Crete.<sup>11</sup> The inscription on the stele reads in part:

The gods [caused] the sky to come in a tempest of r[ain], with darkness in the western region and the sky being / unleashed without [cessation, louder than] the cries of the masses, more powerful than [. . .], [while the rain raged (?)] on the mountains louder than the noise of the / cataract which is at Elephantine. Every house, every quarter that they reached [. . .] / floating on the water like skiffs of papyrus opposite the royal residence for a period of [. . .] days, / while a torch could not be lit in the Two Lands.<sup>12</sup>

One other historical account is very similar in detail to the New Guinea legends of the time of darkness and also to the Egyptian



Alaska, 1977. Cloud of ash, steam, and volcanic gas rising from the east Ukinrek Maar crater. Photograph by R. Russell. Courtesy USGS.

account. This account is almost two thousand years old and is recorded in 3 Nephi in the Book of Mormon:

And it came to pass in the thirty and fourth year, in the first month, on the fourth day of the month, there arose a great storm, such an one as never had been known in all the land. And there was also a great and terrible tempest; and there was terrible thunder, insomuch that it did shake the whole earth as if it was about to divide asunder. And there were exceedingly sharp lightnings, such as had never been known in all the land. And the city of Zarahemla did take fire. And the city of Moroni did sink into the depths of the sea, and the inhabitants thereof were drowned. And the earth was carried up upon the city of Moronihah, that in the place of the city there became a great mountain. And there was a great and terrible destruction in the land southward. But behold, there was a more great and terrible destruction in the land northward; for behold, the whole face of the land was changed, because of the tempest and the whirlwinds, and the thunderings and the lightnings, and the exceedingly great quaking of the whole earth; And the highways were broken up, and the level roads were spoiled, and many smooth places became rough.

. . . And behold, the rocks were rent in twain; they were broken up upon the face of the whole earth, insomuch that they were found in broken fragments, and in seams and in cracks, upon all the face of the land. And it came to pass that when the thunderings, and the lightnings, and the storm, and the tempest, and the quakings of the earth did cease—for behold, they did last for about the space of three hours . . . and then behold, there was darkness upon the face of the land. And it came to pass that there was thick darkness upon all the face of the land, insomuch that the inhabitants thereof who had not fallen could feel the vapor of darkness; And there could be no light, because of the darkness, neither candles, neither torches; neither could there be fire kindled with their fine and exceedingly dry wood, so that there could not be any light at all; And there was not any light seen, neither fire, nor glimmer, neither the sun, nor the moon, nor the stars, for so great were the mists of darkness which were upon the face of the land. And it came to pass that it did last for the space of three days that there was no light seen. . . .

And it was the more righteous part of the people who were saved, and it was they who received the prophets and stoned them not; and it was they who had not shed the blood of the saints, who were spared—And they were spared and were not sunk and buried up in the earth; and they were not drowned in the depths of the sea; and they were not burned by fire, neither were they fallen upon and crushed to death; and they were not carried away in the whirlwind; neither were they overpowered by the vapor of smoke and of darkness. (3 Ne. 8:5-13, 18-23; 10:12-13; hereafter quoted without further citation)



**Spirit Lake, Washington.** The lake is filled with trees stripped from the mountain slopes by the “tempests” generated from the eruption of Mount St. Helens, 1980. The “face of the land”—the once lush, green mountains surrounding Spirit Lake—was completely changed by the eruption. Defoliated remnants of the thick forest float on the surface of the lake. The only visible water appears as dark patches. Photograph by Lyn Topinka. Courtesy USGS/Cascades Volcano Observatory.

This account of destruction in 3 Nephi has always fascinated me, from my first reading of the story as a young boy to the present time. It is an account of what, at first glance, appears to be a complex event or group of events that would be difficult to explain in terms of any single cause. In fact, I have often heard my fellow Latter-day Saints describe how all the physical features of North, Central, and South America that we see today were formed at this time, so great was the destruction. A reshaping of the entire surfaces of these continents, however, goes against all available geologic evidence. I believe that as we look at the 3 Nephi account in detail, we will find that it is describing a more localized event—an event that fits with the restricted geographic views of many Book of Mormon scholars.<sup>13</sup>

However, the 3 Nephi account cannot be explained solely as a massive earthquake or storm, for neither of these natural disasters can account for all the features described. All of the features of

the account can, however, be explained by a specific type of natural phenomenon occurring only in certain geologic settings—an explosive volcanic eruption, similar to the eruption in Papua New Guinea and to the eruption on Santorini. I am certainly not the first who has recognized this event for what it is, but I hope here to more completely outline the events that occurred and demonstrate that all of these events can be explained in the context of a single explosive volcanic eruption.<sup>14</sup>

### **Events Occurring during the Destruction**

The diversity of phenomena and locales mentioned in the account in 3 Nephi is considerable, indicating that the event probably affected a fairly large area and that the writer must have waited and accumulated information from around the land before making his record; it is unlikely that he witnessed all of the events himself. Some knowledge of the type of destruction that would occur had been preserved in the Nephite record. The prophet Zenos foretold the physical phenomena that would occur at the death of the Savior (1 Nephi 19: 10–13). Written hundreds of years before the events recorded in 3 Nephi, 1 Nephi preserves Zenos’s prophecy that “there would be thunderings and lightnings, tempests, fire and smoke, a vapor of darkness, the earth opening, mountains being carried up, rocks rending, and the earth groaning,” and three days of darkness.<sup>15</sup> Evidently with this prophecy specifically in mind, the terminology used in 3 Nephi becomes more specific and descriptive, clearly defining the kinds of events that occurred in fulfillment of this prophecy. For example, phrases such as “exceedingly sharp lightnings,” “earth was carried up upon the city,” “rocks . . . found in broken fragments . . . upon all the face of the land,” “thick darkness [that you] could feel,” “not any light seen,” “vapor of darkness,” and “vapor of smoke” are key phrases in interpreting these passages of scripture. The writer wants us to know that the lightning was not the ordinary kind of lightning, but rather extraordinary; that somehow earth was moved uphill (an unusual occurrence); that the rocks were not just broken up along a narrow fault, but were scattered across the land; that the darkness was unusual—a darkness that could be felt and that was so intense, light could not be seen; and that there were vapors of smoke associated with the darkness.

A complete listing of the events recorded in 3 Nephi as having occurred during the destruction includes the following:

1. A great storm (8:5)
2. A strong and terrible tempest (8:6, 12, 17; 10:14)
3. Terrible thunder (8:6, 12, 17)
4. Shaking of the whole earth (8:6, 12, 14, 17, 19; 10:9)
5. Exceedingly sharp lightning (8:7, 12, 17)
6. Burning of cities (8:8, 14, 24; 9:3, 9-10; 10:13-14)
7. Sinking of cities into the sea (8:9; 9:4, 7; 10:13)
8. Earth carried up on cities (8:10, 14, 25; 9:5; 10:13)
9. Sinking and burial of cities (9:6, 8; 10:13-14)
10. Changing of whole face of the land (8:12, 17)
11. Whirlwinds (8:12, 16; 10:13-14)
12. Breaking up of highways and earth (8:13)
13. Breaking up of cities, destruction of inhabitants (8:14, 15)
14. Breaking and scattering of rocks (8:18; 10:9)
15. Three-hour duration of initial events (8:19)
16. Three-day duration of thick darkness (8:19, 22, 23; 10:9, 13)
17. Palpable darkness (8:20)
18. No fires or lights (8:21)
19. Very dry wood (8:21)
20. Vapors of smoke (10:13-14)
21. Falling objects crushing people (10:13)

### **Explosive Volcanism**

Each of these events listed above have been documented in historic explosive volcanic eruptions and will be discussed later in detail. First, however, it is important to establish where the type of volcanic eruption required to produce these effects occurs and to determine if these locations are compatible with current ideas about Book of Mormon geography.

Volcanoes are usually found in three very different geologic settings around the world. These are (1) along the margins of two tectonic plates where they are moving apart—geologists call these *rifts* or *spreading boundaries*, (2) along the margins of two plates where they are moving together—called *subduction zones* or *collision boundaries*, and (3) within tectonic plates at locations called *hot spots*. Volcanoes that form at spreading boundaries are

usually made up of numerous fluid lava flows that spread out to form a broad, shieldlike shape, which gives these volcanoes their name—shield volcanoes. Their eruptions are rarely violent and are most often gentle enough that a family could gather together, climb a hill to get a good view and avoid the hot, incandescent lava flows, and sit and watch in safety.

The volcanoes that form in subduction zones, however, are quite different. The magma below the surface in these volcanoes is thick and viscous and contains more water and other gases than the quiet flows of the shield volcanoes. This thick, pasty, molten rock is so viscous that when it is forced to the surface it does not flow far but instead builds up conical, steep-sided volcanoes called *strato-volcanoes*. These volcanoes are often very beautiful and are greatly admired by sightseers. Mountains such as Mount Fuji, Mount Ranier, Lassen Peak, and Mount St. Helens fall into this class of volcanoes.

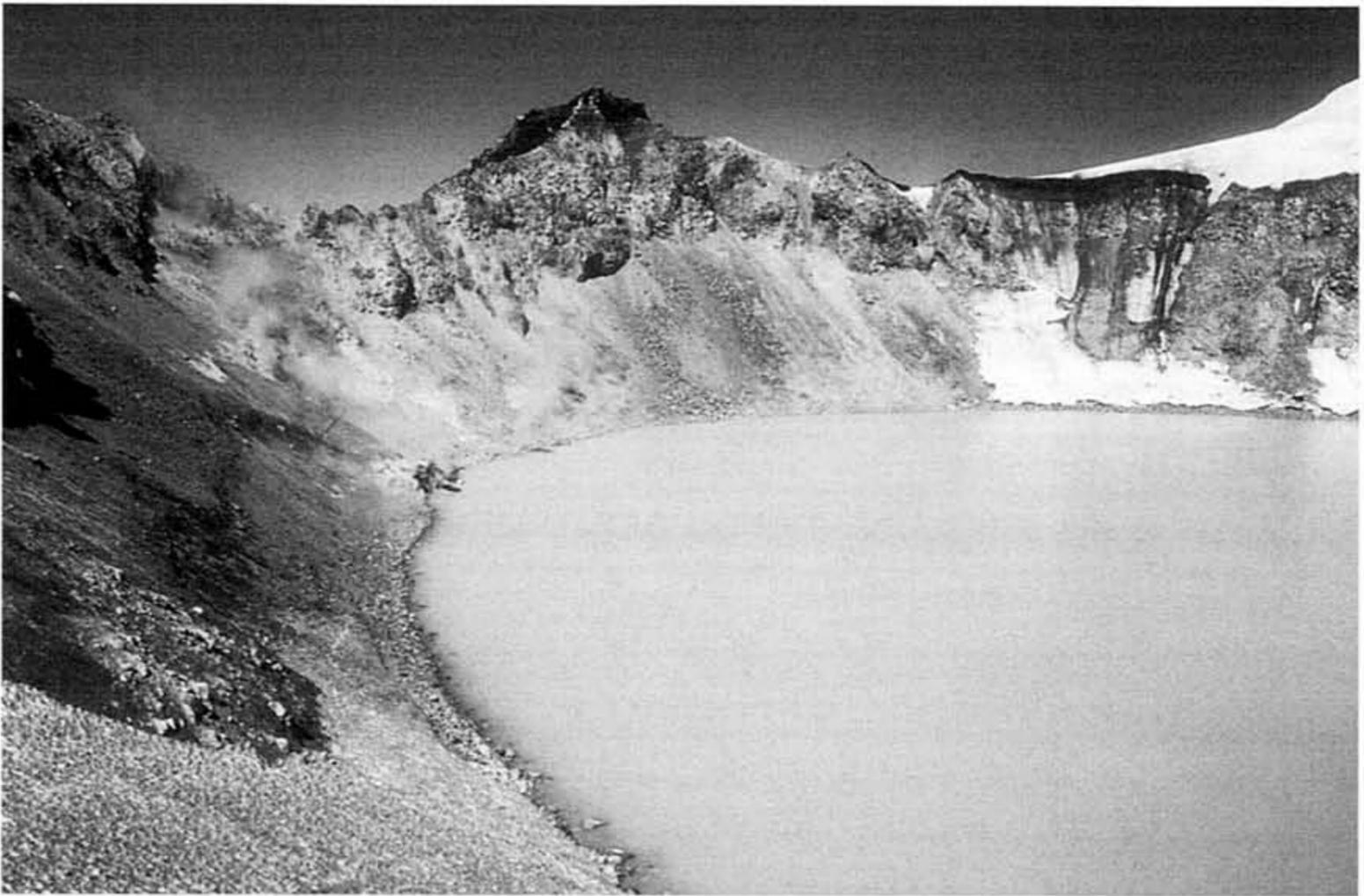


Steam rising from Augustine Volcano in Alaska, 1982. The lava dome, which formed within the crater after the main eruption, acts as a plug in the volcano's vent, preventing the release of pressure. Photograph by C. Nye. Courtesy USGS.

But even though these mountains are beautiful, they are extremely violent and dangerous. At times the pasty, viscous magma in the volcano plugs up the volcano's vent, preventing the release of pressure from the underground magma chamber. Over time the pressures exerted by the gases in the subsurface become so great that the mountain collapses or blows its top, just as a pressure cooker will explode if the release valve is clogged and the pressure that builds up as the pot is heated is not allowed to escape. As the pressure is released from the underground chamber, the gases separate out of the liquid magma and swell in volume, causing the volcano to explode in a raging fury. In many cases, the venting of magma occurs so rapidly that the underground chamber cannot support the weight of the overlying rock. This rock collapses into the underground chamber, forcing out more molten rock and creating a depression, termed a caldera, where the volcano once stood. Crater Lake in Oregon is a good example of a caldera left after a mountain has blown its top.

Hot-spot volcanoes may produce either quiet fluid lava eruptions or very violent, explosive eruptions depending on whether the eruption occurs in an ocean basin or on a continent. If the hot spot is in an ocean basin, the eruption is generally quite mild, as in the Hawaiian Islands. But if the hot spot is located under a continent, the eruptions are generally much more violent, similar to those at subduction zones.

It is the violent, explosive eruptions from subduction-related volcanoes or continental hot spots that can explain the events of 3 Nephi. In historic times, several of these explosive eruptions have occurred and have been well documented. The eruptions of Mount St. Helens (1980, Washington State), El Chichón (1982, Mexico), Nevado del Ruiz (1985, Colombia), Mount Pinatubo (1991, Philippines), and other volcanoes of this type during the past several decades have given scientists a chance to document more accurately and completely the phenomena associated with them. All of these recent eruptions have been fairly small, however, when compared to some other historic eruptions. Mount St. Helens, for example, erupted a volume of rock equivalent to a block one mile wide by one mile long by three-quarters of a mile deep. Mount Pinatubo erupted eight to ten times that amount. However, during



A crater lake on Mount Douglas, Alaska, 1982. This lake occupies a caldera, a large depression formed from a violent volcanic eruption. Photograph by C. Nye. Courtesy USGS.

the eruption of Tambora in April 1815 on the island of Sumbawa in Indonesia, a volume one hundred times the size of the 1980 Mount St. Helens eruption was ejected.<sup>16</sup>

A bit more should be said here, as a side note, about the eruption of Tambora. In 1815, Joseph Smith's family had just suffered through a second year of drought in Norwich, Vermont,<sup>17</sup> and were in desperate need of a good crop in 1816. This, however, was not to be. The dust and ash that had been injected into the atmosphere the previous year by the eruption of Tambora cooled the world's climate and caused the summer of 1816 in New England to be the coldest on record. Snow fell in June, and killing frosts occurred as late as July 12. Then a series of unusually early frosts hit again after August 20.<sup>18</sup> The year 1816 became known as "the year without a summer."<sup>19</sup> This third successive year of crop failures in New England drove many farmers from the area,<sup>20</sup> including the Smith family.<sup>21</sup> It is interesting that a volcano in a far-off corner of the world could have been instrumental in motivating Joseph's family to move where they needed to be for the restoration of the gospel to occur.

Now let us go back to the main questions asked at the start of this section. Could these kinds of explosive volcanoes have occurred in the area where the Book of Mormon peoples were living, and could an eruption have occurred at the time of Christ's death? The answer to both of these questions is yes. If, as most Book of Mormon scholars believe, the people lived in southern Mexico or Central America, then they would have been living in a very active belt of explosive volcanism located where the North American and Cocos tectonic plates are colliding. In fact, based on the volume of eruptive material and the length of the volcanic belt, the Central American volcanic zone is ranked as the most productive volcanic region anywhere on earth.<sup>22</sup> The Book of Mormon people had probably witnessed smaller eruptions throughout their history, but they are not mentioned in the Book of Mormon possibly because they were not damaging or devastating enough to be of concern and because they were not related to a specific prophecy.

That any earlier, smaller eruptions are not mentioned is not really unusual. For example, on the island of Martinique, prior to the devastating eruption of Mount Pelée in 1902, the local newspapers hardly mention the volcano even though it had been gurgling and spewing forth small quantities of ash and steam for days before the main eruption. The papers and the local people were more concerned about the upcoming elections. When the volcano was mentioned, it was to soothe and reason with the populace and convince them that no disaster was imminent.<sup>23</sup> The reason for this disregard of the mountain was simply because the mountain had done this type of thing many times before without any large, damaging eruption. From all around the world, similar stories can be told of people living for centuries around and on the flanks of active volcanoes. They live there without fear because the massive, cataclysmic eruptions are not common. Such was probably the case as well among the Nephites. They lived with the volcanoes, they farmed on their slopes in the rich soil, they witnessed occasional small eruptions, blasts of steam, and small earthquakes, but they had not experienced a large, devastating eruption.

The eruption described in 3 Nephi, however, was apparently a major eruption with such massive devastation that it would be hard to ignore it in a historical record, and the events that

followed—namely, the coming of the Savior—made this a particularly important historic event. My personal opinion is that the Book of Mormon peoples lived in a relatively small area, probably in southern Mexico or Central America as described in John Sorenson's book *An Ancient American Setting for the Book of Mormon*. This area is located along a subduction zone tectonic boundary with many active volcanoes and a record of volcanic eruptions—for example, the eruptions of El Chichón, Mexico, in 1982; Cerro Negro, Nicaragua, in 1968; and Coseguina, Nicaragua, in 1835.<sup>24</sup> More eruptions, both small and large, are expected here in the future. At the present time, a particular layer of ash or a particular volcano has not been tied to the 3 Nephi disaster, but I believe that it is there, as the following points demonstrate little doubt that this disaster was an explosive volcanic eruption.

### **Storm, Tempest, and Whirlwinds**

Large explosive volcanic eruptions are often accompanied by violent winds and whirlwinds.<sup>25</sup> The winds are caused by the movement of clouds of volcanic ash, either hugging the ground as hot, fast-moving, enormously destructive clouds called *nuées ardentes*, or as blast clouds, moving at even higher velocities. For example, during the eruption of Mount St. Helens, the explosion was “almost beyond comprehension, five hundred times greater than the twenty-kiloton atomic bomb that fell on Hiroshima”<sup>26</sup> and the blast cloud is estimated to have moved at velocities of over three hundred miles per hour.<sup>27</sup> Three eyewitnesses who viewed the blast reported the following accounts:

I looked east toward Hanaford Lake and Fawn Lake and that area—it looked like that whole mountain range had just exploded. As the blast cloud approached it looked like a boiling mass of rock—and just as high as you could see. Trees were picked up and thrown into the air at the leading edge of the cloud. . . .

The cloud approached with a roaring noise. As it passed overhead, a cedar tree began to fall and within seconds there were no trees left.

A very strong wind, which blew flames from the campfire flat along the ground and held braids of hair out horizontally, preceded the blast cloud by about 10-15 seconds.<sup>28</sup>



**Flattened trees.** On the slopes of Smith Creek Valley, trees were snapped off by the winds following the eruption of Mount St. Helens, 1980. The direction of the blast is evident from the alignment of the trees. Over four billion board feet of usable timber was damaged or destroyed. Photograph by Lyn Topinka. Courtesy USGS/Cascades Volcano Observatory.

Trees hundreds of years old were snapped off like toothpicks and flattened out, all pointing the same direction, away from the blast. With the wind howling at what these witnesses estimated to be nearly two hundred miles an hour, some “old giants” were torn out by their roots and tossed into the air, as if they were mere trifles, up and over nearby ridges fifteen hundred feet high.<sup>29</sup> Here it must be mentioned again that the eruption of Mount St. Helens was a fairly small one by geologic standards.

Even more impressive are the accounts of the destruction wreaked on the city of St. Pierre on the island of Martinique in the Caribbean during the eruption of Mt. Pelée in 1902. St. Pierre was a city of over thirty thousand people. Only two people who were in the city survived the eruption, along with a handful of others in the near vicinity. One of the survivors, a Monsieur Albert, owner of an estate near St. Pierre, recounts in his experience how suddenly and violently the winds caused by the eruption began and the magnitude of their destructive power:

Mont Pelée had given warning of the destruction that was to come, but we who had looked upon the volcano as harmless did not

believe that it would do more than spout fire and steam, as it had done on other occasions. It was a little before 8 o'clock on the morning of May 8 that the end came.

I was in one of the fields of my estate when the ground trembled under my feet, not as it does when the earth quakes, but as though a terrible struggle was going on within the mountain. A terror came upon me, but I could not explain my fear.

As I stood still, Mont Pelée seemed to shudder and a moaning sound issued from its crater. It was quite dark, the sun being obscured by ashes and fine volcanic dust. The air was dead about me, so dead that the floating dust seemingly was not disturbed.

Then there was a rending, crashing, grinding noise, which I can only describe as sounding as though every bit of machinery in the world had suddenly broken down. It was deafening, and the flash of light that accompanied it was blinding, more so than any lightning I have ever seen.

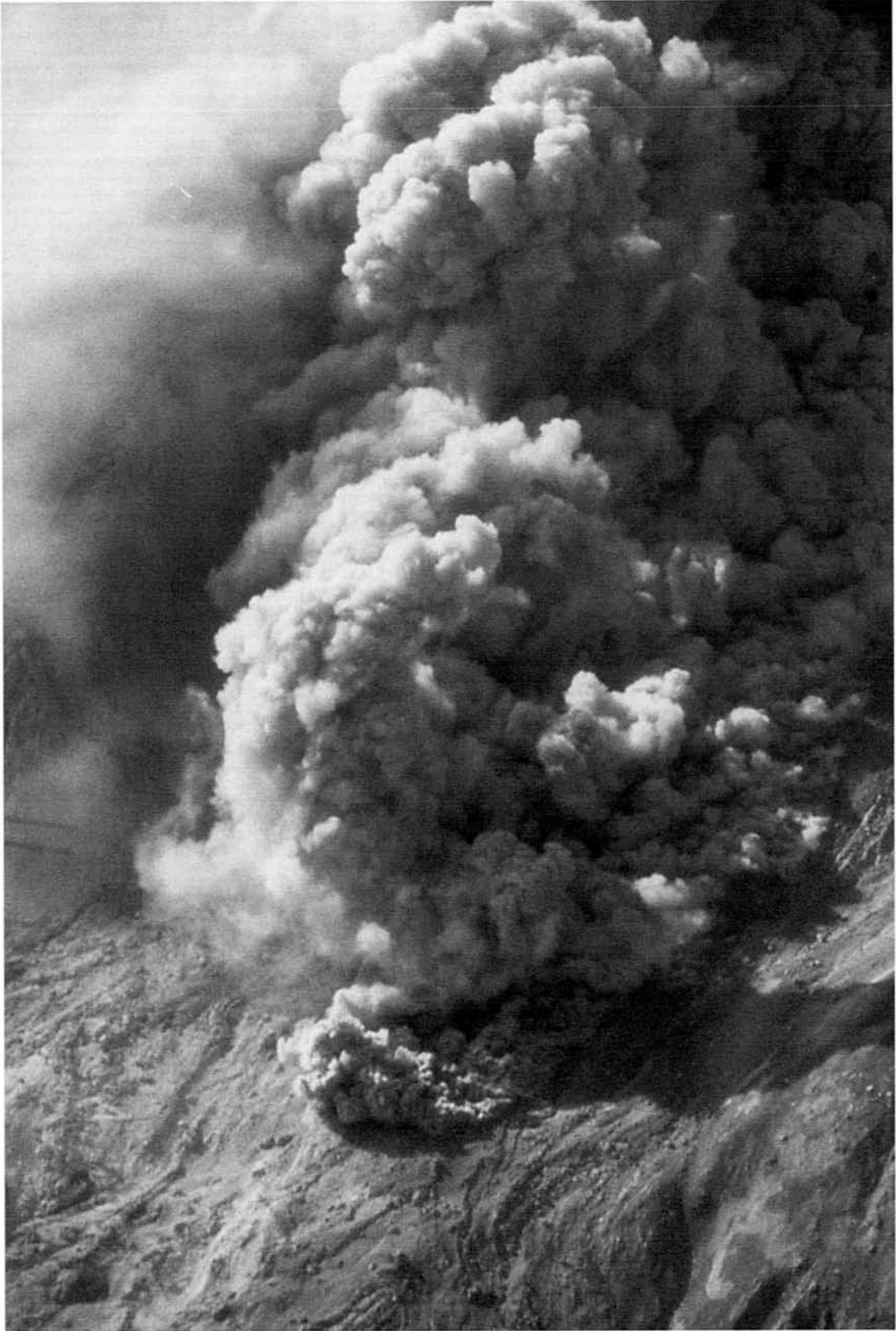
It was like a terrible hurricane, and where a fraction of a second before there had been a perfect calm I felt myself drawn into a vortex and I had to brace myself firmly. It was like a great express train rushing by, and I was drawn by its force.

The mysterious force leveled a row of strong trees, tearing them up by the roots and leaving bare a space of ground fifteen yards wide and more than one hundred yards long.

Transfixed I stood, not knowing in what direction to flee. I looked toward Mont Pelée, and above its apex formed a great black cloud which reached high in the air. It literally fell upon the city of St. Pierre. It moved with a rapidity that made it impossible for anything to escape it.

From the cloud came explosions that sounded as though all of the navies of the world were in titanic combat. Lightning played in and out in broad forks, the result being that intense darkness was followed by light that seemed to be of magnifying power.<sup>30</sup>

The "great black cloud" seen by Monsieur Albert was a blast of superheated steam filled with even hotter ash particles. This cloud, it is estimated, traveled with a velocity of at least one hundred miles per hour. This speed was possible because the ash particles gave the cloud a greater density than normal atmospheric gases, causing the cloud to flow low along the ground. As it moved, the cloud was buoyed up enough by the hot, compressed gases at the base of the flowing mass that it traveled in a near frictionless state down the mountain and into St. Pierre. The great density, velocity, and ground-hugging nature of the cloud increased



**Augustine Volcano, 1986.** An enormously destructive cloud of rapidly moving volcanic ash, called a *nuée ardente*, rolls down the north side of the volcano. Photograph by M. E. Yount. Courtesy USGS.

its destructiveness, which was much greater than that of a hurricane of the same wind velocity.<sup>31</sup> Fred Bullard, in his book *Volcanoes of the Earth*, describes the power of this rush of ash and volcanic gas on and over the city of St. Pierre:

All the houses in St. Pierre were unroofed and otherwise demolished either in part or totally. The trees were stripped of leaves and branches down to the bare trunks. The force of the blast is shown by the fact that walls of cement and stone, three feet in thickness, were torn to pieces as though made of cardboard, six-inch cannon on the Morne d'Orange Battery were sheared from their mountings, century-old trees were uprooted, and a statue of the Virgin Mary, weighing at least three tons, was carried 50 feet from its base.<sup>32</sup>

During the eruption of Krakatoa, an island volcano off the coast of Java, in 1883, high velocity winds, again arising quite suddenly to hurricane levels (as at St. Pierre), were reported by several ships sailing near the island. The first officer aboard the ship *W. H. Besse* describes the winds as they impacted his ship:

At 6 a.m. . . . got under weigh, having a fair wind, was in hopes to get out clear of the straits before night; at 10 a.m. were within 6 miles of St. Nicholas Point, when we heard some terrific reports also observed a heavy black bank rising up from the direction of Krakatoa Island, the barometer fell an inch at one jump, suddenly rising and falling an inch at a time, called all hands, furled all sails securely, which was scarcely done before the squall struck the ship with terrific force; let go port anchor and all the chain in the locker, wind increasing to a hurricane.<sup>33</sup>

Whirlwinds, or tornados, appear to be a fairly common feature of many explosive volcanic eruptions. The hot ash erupted into the air is a concentrated source of heat that causes severe updrafts, providing ideal conditions for the formation of whirlwinds. Only a few accounts, however, actually report whirlwinds, perhaps because they often cannot be seen due to the incredible darkness that usually accompanies eruptions. Nonetheless, whirlwinds were an important feature of several eruptions, such as the 1815 eruption of Tambora when "violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air, tore up the largest trees by the roots, and covered the whole sea with floating timber."<sup>34</sup> Lieutenant Owen Phillips reported that the town of Saugar, located about twenty-five miles

from Tambora, was devastated by a violent whirlwind that blew down nearly every house.<sup>35</sup>

After a preliminary eruption of Krakatoa in May 1883 (prior to the main eruption in August), a group of dignitaries and scientists visited the island out of curiosity and a desire to assess the damage. They report that

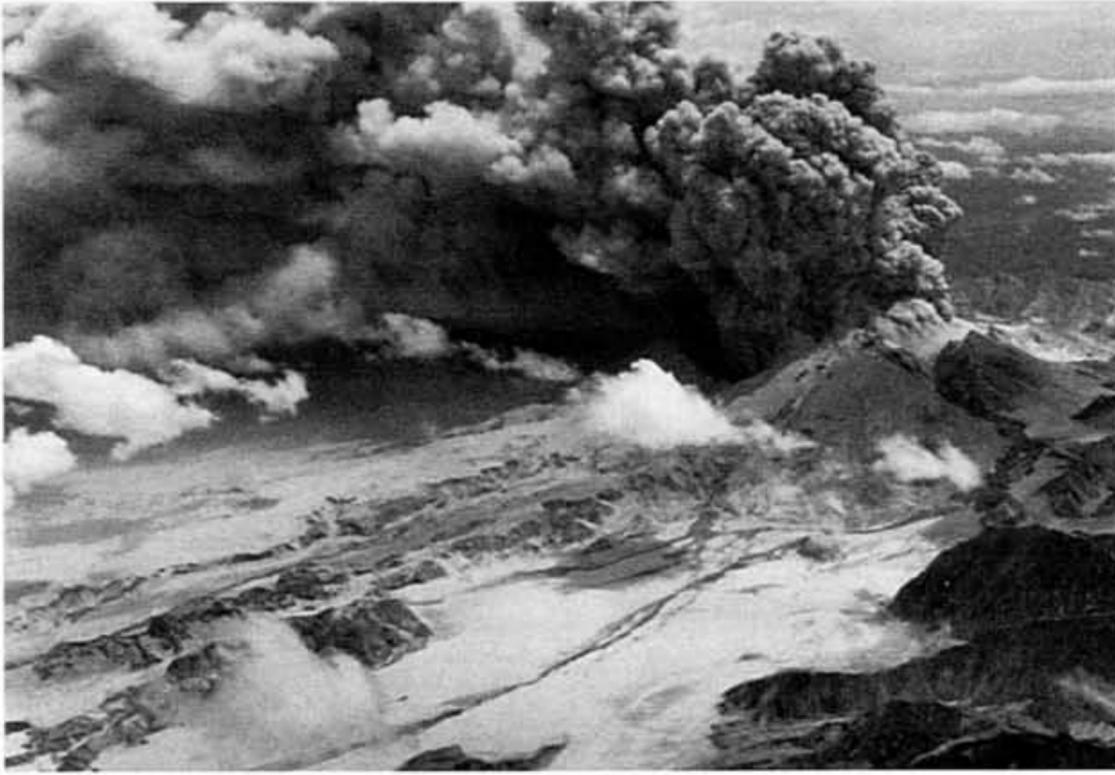
some trees showed through the ash as bare stumps several meters high, and from which the branches seemed to have been torn off by force. The wood was dry, without signs of burning or charring; no leaf or branch could be found in the ash, and it is therefore likely that the deforestation must be attributed to a whirlwind, as it often develops in turbulent air during volcanic eruptions as a result of local heating of the atmosphere.<sup>36</sup>

When the Mayon volcano in the Philippines erupted in 1766, it was accompanied by “tornadoes, called baguios in that country.”<sup>37</sup> Whirlwinds have also been reported from the 1947 eruption of Hekla, the 1963 eruption of Surtsey, and the 1973 Eldfell eruption, all in Iceland.<sup>38</sup> From these accounts, it is apparent that strong winds and whirlwinds are common features of explosive volcanic eruptions and that there is no need to call upon other types of storm activity, such as hurricanes or cyclones, to explain these events.

One more piece of evidence is important here as well. The Book of Mormon mentions that their wood was “exceedingly dry.” It is not likely that their wood would be exceedingly dry if they had just experienced a hurricane or some other type of large tropical storm. But the winds and storms associated with volcanic eruptions, although they may be accompanied by rain, are often dry. The above account of the excursion to Krakatoa after one of its eruptions describes the trees and wood as dry. Another account from Mount St. Helens indicates that no rain accompanied that eruption:

The lightning-streaked cloud rolling northeast from Mount St. Helens at nearly 60 miles an hour looked exactly like a towering thunderhead—but it was bigger and blacker than any in memory. Most people in its path, as yet unaware of the volcano’s eruption, braced for a storm. But no rain fell. Instead, the cloud descended like a shroud, cloaking the landscape in a blackness of volcanic ash that even automobile headlights could not penetrate.<sup>39</sup>

The “exceedingly dry wood” described in the Book of Mormon indicates a dry storm with violent winds and whirlwinds—all



Mount Pinatubo in the Philippines, 1991. Aerial view of ash cloud from the eruption of the volcano. Photograph by E. W. Wolfe. Courtesy USGS/Cascades Volcano Observatory.

of which are consistent with a large volcanic eruption. Certainly violent winds and whirlwinds can occur without rain in other circumstances and under other conditions, but few other settings would be as spectacularly violent as a large volcanic eruption. Even a major hurricane could not produce the kind of destructive wind, for example, that destroyed the city of St. Pierre in 1902.

### **Terrible Thunder and Sharp Lightning**

Most of our experience with thunder and lightning comes from the thunderstorms that are quite common throughout the world. Occasionally these may be extremely violent storms with spectacular displays of lightning and blasts of thunder. Nephi's description of the thunder and lightning that occurred was not of this ordinary kind, however, for he describes them as "such as never had been known in all the land." The thunder was also unusual in that it is correlated with the shaking of the "whole earth as if it was about to divide asunder," implying that earthquakes were occurring along with the lightning and thunder. Lightning displays and associated thunder, along with other noises caused by explosions near a volcano, can be of this extraordinary kind

described by Nephi. The lightning is caused by the friction between the exploding ash and the air. This friction generates enormous quantities of static electricity that is then discharged as lightning. The thunder from the lightning is supplemented by the explosions from the volcano and the earthquakes that occur almost continuously during some eruptions. One of the earliest accounts of these types of volcanic lightning displays comes from Pliny the Younger, who observed the eruption of Mount Vesuvius in A.D. 79. Pliny writes:

A fearful black cloud was rent by forked and quivering bursts of flame, and parted to reveal great tongues of fire, like flashes of lightning magnified in size.<sup>40</sup>

Peter Francis interprets Pliny's description of magnified lightning as the discharge of "static electricity accumulating in the ash cloud."<sup>41</sup>

The air at times during a volcanic eruption is so charged with static electricity that unusual things may happen. For example, during an eruption in Kamchatka in eastern Russia, the electrical activity played tricks with modern electric appliances:

Together with the cloud came also and was growing a rumble of loud thunder accompanying incessantly flashing lightnings. . . . People returning from work were wandering about the village in search of their homes. Peals of thunder were crashing with deafening loudness without any interruption. The air was saturated with electricity, telephones were ringing spontaneously, loudspeakers of the radionet were burning out.<sup>42</sup>

The thunderous noises produced by an eruption may carry for distances of several hundred miles. The 1815 eruption of Mount Tambora demonstrates how far-reaching these effects can be:

In April, 1815, one of the most frightful eruptions recorded in history occurred in the mountain Tambora, in the island of Sumbawa. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of nine hundred and seventy geographical miles in a direct line, and at Ternate in an opposite direction, at the distance of seven hundred and twenty miles. . . . The area over which tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca islands, Java, a considerable portion of Celebes, Sumatra, and Borneo.<sup>43</sup>

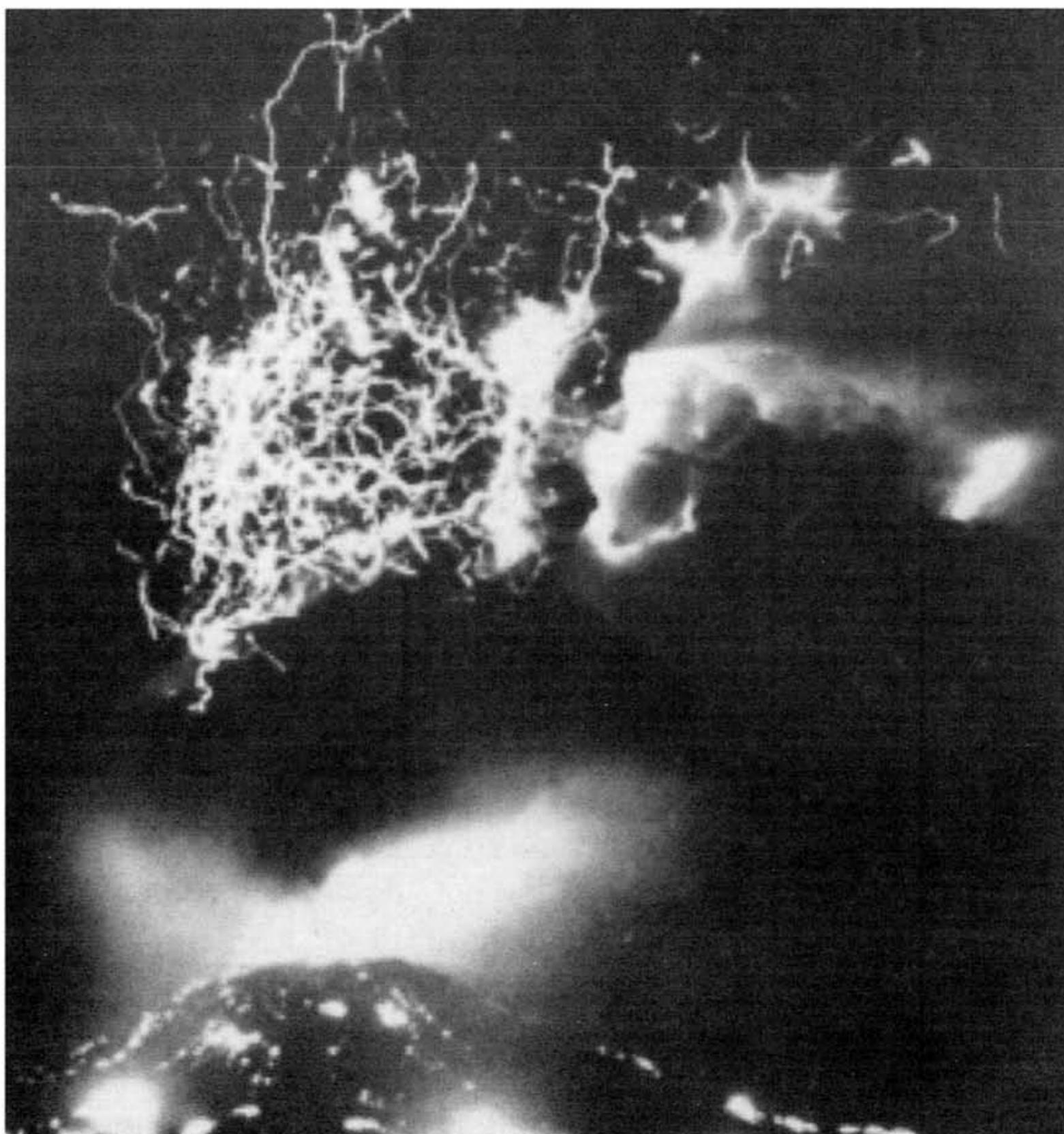
From Captain Logan's account of the eruption of Krakatoa, which he witnessed from on board the ship *Berbice* in the Sunda Straits, we see again the spectacular nature of the displays of electrical activity occurring during an eruption. The ship's log at midnight begins:

The ash shower is becoming heavier, and is intermixed with fragments of pumice stone. The lightning and thunder became worse and worse; the lightning flashes shot past and around the ship; fire-balls continually fell on the deck, and burst into sparks. We saw flashes of lightning falling quite close to us on the ship; heard fearful rumblings and explosions, sometimes upon the deck and sometimes among the rigging. The man at the wheel felt strong electric shocks on one arm. The copper sheathing of the rudder became glowing from the electric discharges. Fiery phenomena on board the ship manifested themselves at every moment. Now and then, when any sailor complained that he had been struck, I did my best to set his mind at ease, and endeavoured to talk the idea out of his head, until I myself, holding fast at the time to some part of the rigging with one hand, and bending my head out of reach of the blinding ash shower which swept past my face, had to let go my hold, owing to a severe electric shock in the arm.<sup>44</sup>

During the eruption of Mount St. Helens,

lightning and other electrical phenomena associated with the eruption were so spectacular that many witnesses mentioned them. . . . Some observers witnessed unusual forms of lightning. Some of the lightning appeared red. It wasn't normal lightning—"first a white dot appeared in the cloud, and then a bolt would shoot out from it." The lightning was in ball form "streaking toward the ground, connected neither with the cloud nor with the ground. . . ." After the cloud passed overhead, lots of lightning started 600-800 ft in the air and formed "big balls, big as a pickup and just started rolling across the ground and bouncing."<sup>45</sup>

Photos of volcanic lightning displays have been published in several places. For example, Simkin and Fiske have a photo of lightning around Anak Krakatoa (the new island that emerged in place of Krakatoa) taken during an eruption in 1933;<sup>46</sup> Decker and Decker show a five-minute time-lapse photo of lightning over an erupting volcano in Nicaragua;<sup>47</sup> Lambert has a picture of lightning in the skies over Surtsey during an eruption;<sup>48</sup> Nuhfer and others have a photograph of lightning over the Galunggung volcano in Indonesia;<sup>49</sup> and *Discover* magazine published a spectacular



Mount Vesuvius, 1944. Static electricity crackles over the volcano during an eruption. Courtesy Corbis-Bettmann.

seven-minute time-lapse photo of lightning over the Sakurajima volcano in Japan.<sup>50</sup>

The descriptions of thunder and photos of lightning around explosive volcanic eruptions show that these phenomena often occur without rainfall, so that the wood for fires could still be “exceedingly dry,” ready for the unsuccessful attempts to build fires. These historic descriptions also record the unusual nature of the lightning—that it comes, not only as bolts, but as balls of lightning and that the electricity may permeate the air, creating other

interesting effects. The lightning displays associated with volcanic eruptions are certainly of the unusual and extraordinary type and fit very well with Nephi's description of "exceedingly sharp lightnings, such as never had been known in all the land." The thunder, earthquakes, and other sounds associated with an explosive volcanic eruption also concur with Nephi's terminology of "terrible thunder, insomuch that it did shake the whole earth as if it was about to divide asunder." These features of the destruction in 3 Nephi do not alone define the event as a volcanic eruption; just as with the winds described in the previous section, spectacular lightning and thunder can be produced in other ways, but an explosive volcanic eruption is certainly the simplest explanation that satisfies all of the criteria.

### **Shaking and Quaking**

Large tectonic earthquakes (those with Richter magnitudes greater than about seven) do not occur frequently around the world—perhaps ten to twenty every year, mostly in unpopulated areas. They do occur frequently enough, however, for scientists to have a very good idea of their characteristics. The energy released during large earthquakes comes from two blocks of earth moving rapidly past each other while years of accumulated strain is released. At most, the shaking of the earth during these massive earthquakes may last for a few minutes. For example, during the Alaskan earthquake of 1964, one of the largest earthquakes ever recorded (Richter magnitude between 8.3 and 8.6), the shaking lasted for three to four minutes, an extraordinarily long period of time.<sup>51</sup> The San Francisco earthquake of 1906 lasted only about forty seconds.<sup>52</sup>

These short periods of shaking, however, give plenty of time to accomplish the destruction that large earthquakes produce, but they are far short of the three hours of continuous or near continuous shaking described in 3 Nephi. The destruction produced during an earthquake is also fairly localized, along the line of slippage (called the fault line) and in regions quite close to this line. Other phenomena associated with large earthquakes are aftershocks that come intermittently for several days after the main quake, landslides or rock falls off of steep slopes, liquefaction of sandy soils

causing the collapse of buildings, tidal waves or tsunamis in coastal areas, rare displays of lightning or other electrical phenomena, thunderlike noises, and the spread of fires through cities or towns with concentrated housing made of wood.<sup>53</sup>

Although these phenomena are similar to some of those mentioned in 3 Nephi, some glaring differences are apparent. I have already mentioned one, namely, that, in the 3 Nephi account, the shaking lasted for about three hours—too long a time period for the shock from a single large earthquake and too short for the period during which aftershocks following a major earthquake usually take place. However, it is a very reasonable amount of time for the initial stages of a volcanic eruption. We might call this the “throat-clearing stage” of the eruption, which occurs as the mounting pressure cleans the volcano’s vent of the rock and debris that have plugged it up. During this time, frequent explosions and earthquakes occur. Once the vent is cleared, the volcano may continue to erupt for several hours or days without additional significant earthquakes.

Other problems with ascribing the destruction described in 3 Nephi to a major tectonic earthquake include (1) the three days of darkness—this phenomenon has never been reported in association with a large earthquake; (2) the winds and tempests—although it may be windy during an earthquake, just as it may be windy at any other time, no correlation between wind and earthquakes has been demonstrated, even though one of the old, now-abandoned theories of earthquake production was the idea that wind was trapped in the earth and released during an earthquake;<sup>54</sup> (3) whirlwinds—I know of no report of a whirlwind or tornado caused by an earthquake; and (4) the inability to light a fire—which, again, has never been reported as an effect of a major earthquake. Nephi’s description of the whole face of the land being changed is also not typical of an earthquake. Although the devastation can be enormous during an earthquake, most landmarks survive and are recognizable. On the other hand, a major volcanic eruption often produces scenes so strange and unnatural that it seems as if the landscape has been remade.

The kinds of quaking and shaking described in 3 Nephi are typical, however, of the descriptions from historical accounts of

explosive volcanic eruptions.<sup>55</sup> During the eruption of Krakatoa, the shaking of the earth lasted throughout the night of August 26, 1883, and on into the next morning.<sup>56</sup> Earthquake vibrations rose to thirty to forty times the normal background level during the eruption of a volcano on Raoul Island, northeast of New Zealand in 1964, continuing throughout the eruption.<sup>57</sup> Reports from the 1902 eruption of the Santa Maria volcano in Guatemala tell of earthquake activity that lasted for several hours, rising to several peaks of shaking during the climax of the eruption. The eruption of ash and debris continued on for another day or two without any significant earthquake activity.<sup>58</sup>

When the Coseguina volcano in Nicaragua erupted in 1835, it was reported that the sounds accompanying the shaking were alarming and heard up to four hundred miles away and that “the roar was practically continuous for seven hours.”<sup>59</sup> Even though most of the noise and shaking caused by the eruption of Coseguina ceased after a few hours, the eruption itself and the darkness caused by the ashfall continued on for three to four days.<sup>60</sup> All of these accounts are quite similar to the 3 Nephi account in which the initial part of the eruption lasted for three hours with violent shaking and thunder, followed by quiet and darkness for three days.

### **Cities Burned, Drowned, and Buried**

The destruction of people and buildings may occur in a variety of different ways during an explosive volcanic eruption, and the devastation may be widespread, reaching up to a few hundred miles from the erupting volcano. The destruction in the Book of Mormon account appears to have been quite widespread, for, in addition to the cities mentioned in the passage above, the cities of Jacobugath, Laman, Josh, Gad, and Kishkumen and their inhabitants were burned; the cities of Onihah, Mocum, and Jerusalem were covered by water; and the cities of Gilgal, Gadiandi, Gadiomnah, Jacob, and Gimgimno were sunk and buried in the earth.

**Fire.** The cities mentioned in the 3 Nephi account were all destroyed in ways understandable in terms of a massive volcanic eruption. The fires that started in Zarahemla and other cities could easily have been ignited by hot ash falling onto wooden and thatch

structures that probably made up most of the buildings in the cities (Hel. 3:10-11), by a fast-moving, hot cloud of ash traveling along the ground, or by the unusually violent lightning accompanying the eruption. Accounts of similar occurrences can be found in historical records. For example, many fires were started in the city of Stabiae by the fall of hot rocks and ash from the eruption of Mount Vesuvius in A.D. 79.<sup>61</sup> A firestorm swept through the city of St. Pierre during the 1902 eruption of Mt. Pelée. Many of the houses in tropical St. Pierre were wooden structures with no windowpanes, only shutters, so that the highly heated gas and ash from the eruption easily penetrated into every part of the buildings. The city was almost instantly and completely engulfed in flames. A ship from Fort de France tried to approach the burning city three and one-half hours after the eruption but had to turn away because the heat was still so intense.<sup>62</sup> An assistant purser by the name of Thompson on board the ship *Roraima*, which was just approaching the St. Pierre harbor at the time of the eruption of Mt. Pelée, gives the following description:

I saw St. Pierre destroyed. It was blotted out by one great flash of fire. Nearly 40,000 people were killed at once. Of eighteen vessels lying in the Roads, only one, the British steamship *Roddam* escaped and she, I hear, lost more than half on board. It was a dying crew that took her out. Our boat, the *Roraima*, arrived at St. Pierre early Thursday morning. For hours before we entered the roadstead, we could see flames and smoke rising from Mt. Pelée. No one on board had any idea of danger. Capt. G. T. Muggah was on bridge and all hands got on deck to see the show. The spectacle was magnificent. As we approached St. Pierre, we could distinguish the rolling and leaping red flames that belched from the mountain in huge volumes and gushed high into the sky. Enormous clouds of black smoke hung over the volcano. The flames were then spurting straight up in the air, now and then waving to one side or the other a moment, and again leaping suddenly higher up. There was a constant muffled roar. It was like the biggest oil refinery in the world burning up on the mountain top. There was a tremendous explosion about 7:45 soon after we got in. The mountain was blown to pieces. There was no warning. The side of the volcano was ripped out, and there hurled straight towards us a solid wall of flame. It sounded like a thousand cannon.

The wave of fire was on us and over us like a lightning flash. It was like a hurricane of fire. I saw it strike the cable steamship *Grappler* broadside on, and capsize her. From end to end she burst into flames and then sank. The fire rolled in mass straight down on St. Pierre and the shipping. The town vanished before our eyes.

The air grew stifling hot and we were in the thick of it. Wherever the mass of fire struck the sea, the water boiled and sent up great clouds of steam. The sea was torn into huge whirlpools that careened toward the open sea. One of these horrible, hot whirlpools swung under the *Roraima* and pulled her down on her beam end with the suction. She careened way over to port, and then the fire hurricane from the volcano smashed her, and over she went on the opposite side. The fire wave swept off the masts and smokestacks as if they were cut by a knife.

I saved my life by running to my stateroom and burying myself in the bedding. The blast of fire from the volcano lasted only for a few minutes. It shriveled and set fire to everything it touched. Thousands of casks of rum were stored in St. Pierre, and these were exploded by the terrific heat. Burning rum ran in streams down every street and out into the sea.

Before the volcano burst, the landings at St. Pierre were crowded with people. After the explosion, not one living being was seen on land. Only twenty-five of those on board [out of sixty-eight] were left after the first blast.<sup>63</sup>

Another cause of fires in a volcanic disaster can be related more to the effects of the earthquakes accompanying an eruption than to the eruption itself. Lamps, torches, cooking fires, and other open flames disturbed by the shaking may ignite fires. In the confusion and darkness, these fires may burn out of control and create havoc in populated areas.

**Flood.** The flooding of cities and villages is also a common occurrence during large, explosive volcanic eruptions. Explosions, earthquakes, and massive landslides around a volcano, particularly if the volcano is near the ocean, create huge waves of water that travel outward from the source until they collapse on coastal communities. These waves, called *tidal waves* or more properly *tsunami*, are one of the major causes of death in some volcanic eruptions. During the 1883 eruption of Krakatoa, 165 villages were completely destroyed and 132 partly destroyed by tsunami, killing approximately thirty-three thousand people. Waves crashing on the shores near Krakatoa reached heights of over 130 feet.<sup>64</sup>

Several eyewitnesses recorded accounts of the Krakatoa tsunami and their destructive power. An elderly Dutchman reported:

I have lived in Anjer [Java] all my life, and little thought the old town would have been destroyed in the way it has. I am getting on in years, and quite expected to have laid my bones in the little cemetery



St. Pierre, Martinique, prior to the eruption of Mount Pelée, ca. 1902. St. Pierre was a prosperous seaport with a population of almost 40,000. Courtesy Bart J. Kowallis.



The remains of St. Pierre, 1902. Following the eruption of Mount Pelée, a firestorm swept through the city. Only the foundations of the buildings survived the devastation. Courtesy Bart J. Kowallis.

near the shore, but not even that has escaped, and some of the bodies have actually been washed out of the graves and carried out to sea. The whole town has been swept away, and I have lost everything except my life. The wonder is that I escaped at all. I can never be too thankful for such a miraculous escape as I had.

The eruption began on the Sunday afternoon. We did not take much notice at first, until the reports grew very loud. Then we noticed that Krakatau was completely enveloped in smoke. Afterwards came on the thick darkness, so black and intense that I could not see my hand before my eyes. It was about this time that a message came from Batavia inquiring as to the explosive shocks, and the last telegram sent off from us was telling you about the darkness and smoke. Towards night everything became worse. The reports became deafening, the natives cowered down panic-stricken, and a red fiery glare was visible in the sky above the mountain. Although Krakatoa was twenty-five miles away, the concussion and vibration from the constantly repeated shocks was most terrifying. Many of the houses shook so much that we feared every minute would bring them down. There was little sleep for any of us that dreadful night. Before daybreak on Monday, on going out of doors, I found the shower of ashes had commenced, and this gradually increased in force until at length large pieces of pumice-stone kept falling around. About six A.M. I was walking along the beach. There was no sign of the sun, as usual, and the sky had a dull, depressing look. Some of the darkness of the previous day had cleared off, but it was not very light even then. Looking out to sea I noticed a dark black object through the gloom, traveling towards the shore.

At first sight it seemed like a low range of hills rising out of the water, but I knew there was nothing of the kind in that part of the Soenda Strait. A second glance—and a very hurried one it was—convinced me that it was a lofty ridge of water many feet high, and worse still, that it would soon break upon the coast near the town. There was no time to give any warning, and so I turned and ran for my life. My running days have long gone by, but you may be sure that I did my best. In a few minutes I heard the water with a loud roar break upon the shore. Everything was engulfed. Another glance around showed the houses being swept away and the trees thrown down on every side. Breathless and exhausted I still pressed on. As I heard the rushing waters behind me, I knew that it was a race for life. Struggling on, a few yards more brought me to some rising ground, and here the torrent of water overtook me. I gave up all for lost, as I saw with dismay how high the wave still was. I was soon taken off my feet and borne inland by the force of the resistless mass. I remember nothing more until a violent blow aroused me. Some hard firm substance seemed within my reach, and clutching it I found I had gained a place of safety. The waters swept past, and I found myself clinging to a cocoanut palm-tree. Most of the trees near the town were uprooted and thrown down for miles, but this one fortunately had escaped and myself with it.

The huge wave rolled on, gradually decreasing in height and strength until the mountain slopes at the back of Anjer were reached, and then, its fury spent, the waters gradually receded and flowed back into the sea. The sight of those receding waters haunts me still. As I clung to the palm-tree, wet and exhausted, there floated past the dead bodies of many a friend and neighbor. Only a mere handful of the population escaped. Houses and streets were completely destroyed, and scarcely a trace remains of where the once busy, thriving town originally stood.<sup>65</sup>

Another report describes the devastation following the tsunami:

As far as the eye can reach, the only thing that remains standing is a solitary tree, a gigantic durian, maimed, branchless and leafless. It forms the gravemark of a heap of corpses and carcasses lying under roofs, houses, and trunks of trees. Hundreds of such graves, though of smaller dimensions, may be seen over and over again on the plain. The turned-up earth often merely covers a corpse, alongside which a cocoanut branch or bamboo is stuck upright for the guidance of the authorities. Thousands of corpses of human beings and also carcasses of animals still await burial, and make their presence apparent by an indescribable stench. They lie in knots and entangled masses impossible to unravel.<sup>66</sup>

Even for communities located along the shores of lakes, the flooding hazards are significant during a volcanic eruption. A child generates waves in the bathtub by sliding to one end of the tub, taking the water with him, then sliding back along with the water to the other end until eventually the water waves in the tub begin to slop over the sides. In the same way, large water waves can be generated in lakes by the wave energy produced by earthquakes moving back and forth through the water. The waves created by this movement are called *seiche* waves and, although not usually as large as tsunami, they can cause severe damage and death. Water levels in lakes can also change dramatically during an eruption due to landslides collapsing into the lake or blocking a lake's outlet. Spirit Lake at the foot of Mount St. Helens was two hundred feet higher in elevation after the eruption in 1980.<sup>67</sup> Lodges, cabins—everything near the previous lakeshore—were buried deeply under water, mud, and debris.

The kinds of flooding and burial by water that is associated with explosive volcanic eruptions could certainly fit the descriptions in 3 Nephi when the Lord, referring to the cities of Jerusalem,

Onihah, and Mocum, says, “The waters have I caused to come up in the stead thereof,” or when Nephi describes the city of Moroni sinking “into the depths of the sea.” Moroni is described in the Book of Mormon as being “near the east sea” (Alma 50:13), while Sorenson has suggested that Jerusalem was perhaps located on the shores of a lake.<sup>68</sup> These locations are both ideal for the types of destruction by water that occur during an eruption.

**Burial.** The Book of Mormon also describes the destruction of several cities by either being buried in the earth or, as in the case of the city of Moronihah, having the earth carried up upon the city. Burial in the earth is a common occurrence in explosive volcanic eruptions. The large quantities of ash and pumice that are produced blanket the landscape for many miles around the volcano. A heavy fall of ash and pumice destroyed the town of Pompeii during the eruption of Mount Vesuvius. The accumulation of ash and pumice averaged a depth of about twenty feet<sup>69</sup> and left



Building buried by lahars (volcanic mudflows), 1990. This structure, located near the mouth of the Drift River in Alaska, is twenty-two miles from Redoubt Volcano, the source of the eruption. Photograph by C. Gardner. Courtesy USGS.

only the tops of the taller buildings protruding above it. Because the town was completely abandoned after the eruption and the building tops that remained above the ash eventually weathered away, Pompeii was for a time completely lost. Modern excavations have uncovered the town and, by pouring plaster into molds left in the solidified ash, have shown the tragic final moments of some of the inhabitants who were trapped in the ashfall.<sup>70</sup>

Cities or towns are also buried when the ash from an eruption combines with rain or with rapidly melting snow to form a thick slurry of hot mud that flows rapidly downslope.<sup>71</sup> These volcanic mudflows are called *lahars*. The town of Herculaneum escaped the heavy fall of ash that destroyed Pompeii, but as the ash and pumice continued to accumulate on the higher slopes of the volcano and were then saturated by rain, a wet slurry of mud formed, became fluid, and quite suddenly swept down the sides of the volcano. One or more of these lahars flowed through Herculaneum and completely engulfed it. Buildings were smothered, crushed, and buried sixty to seventy feet deep in the mud. The burial was complete enough that a new town, Resina, was constructed on top of buried Herculaneum.<sup>72</sup>

Another example of burial by mud, but with a slightly different twist, occurred in 1886 when the Tarawera volcano on the North Island of New Zealand erupted. Many towns and villages around the volcano were buried by falling mud produced when part of the eruption blew out through the bottom of Lake Rotomahana, located adjacent to the volcano. The mixture of volcanic ash, water, and mud that had accumulated on the bottom of the lake for centuries fell from the sky. The village of Wairoa was buried in seven feet of this mixture, and the villages of Moura and Te Ariki disappeared, along with all of their inhabitants, under seventy-five feet of mud.<sup>73</sup>

A recent example of a city being buried by a volcanic mudflow occurred in Colombia in 1985. On November 13 of that year, a relatively small eruption occurred from the Nevado del Ruiz volcano. The ash, however, was hot enough to melt part of the snow and ice cap at the top of the volcano. The water from the melted snow mixed with ash at the top of the volcano and picked up other debris as it flowed swiftly down the mountain and into the river valleys. At about 11 P.M., the mudflows swept over the

defenseless city of Armero, killing about twenty-five thousand people. Asleep in their beds, most of the inhabitants had no warning and were buried alive. It was all over in just a few minutes.<sup>74</sup>

In addition to burial by falling ash and burial by lahars, a third method of burial is also possible around an erupting volcano. This phenomenon was not well understood until the eruption of Mount St. Helens in 1980. This eruption was triggered when the swollen north side of the volcano collapsed. The ensuing landslide, or debris avalanche, traveled out across the valley at the base of the mountain, burying Spirit Lake, then flowed up and over an intervening ridge more than three hundred feet high, down across the next valley, and then halfway up the next mountain, leaving deposits as much as six hundred feet thick.<sup>75</sup> This debris avalanche traveled as far as twenty-five miles from the volcano at speeds in excess of 150 miles per hour.<sup>76</sup> Since 1980, geologists have learned that occurrences of massive landslides such as this are actually quite commonly associated with explosive eruptions.<sup>77</sup>



Lahars accumulated in the Drift River Valley. Large lahars from the eruptions of Redoubt Volcano in 1989 and 1990 covered the entire Drift River Valley floor and extended twenty-two miles to the Cook Inlet. Photograph by T. Miller. Courtesy USGS.

Returning once more to the words in 3 Nephi, we read that “the earth was carried up upon the city of Moronihah, that in the place of the city there became a great mountain.” From this description, it seems possible that Moronihah might have been buried by a debris avalanche similar to the one that occurred at Mount St. Helens—an effective way to carry earth up upon a city. In any case, Moronihah and the other cities buried in the earth (or the ash) would have to have been quite close to the eruption (probably within fifty miles and perhaps much closer). Avalanches such as these do indeed dramatically alter the local topography so that it is not unreasonable to believe that where there had been a city nestled in a valley, there was, after the eruption, a hill or mountain formed by the avalanche deposits. It is hard to imagine “a great mountain” being formed by these avalanche processes, but it may be that the author is using a bit of hyperbole here, as is not uncommon in accounts of any disaster. It is also true that the term “great mountain” may be relative—what people in one area refer to as a mountain may to others be simply a hill. An alternative hypothesis, however, is that the city was very close to the volcano and was initially buried by an avalanche deposit, then later it *became* a great mountain as the volcano rebuilt itself over the buried city.

### **Whole Face of Land Changed**

This description from 3 Nephi almost sounds as if, after the destruction, no mountains or valleys or other topographic features were recognizable—as if the face of the entire earth had been changed. And yet a careful reading makes it obvious that the basic geography of the Book of Mormon land was not changed after the destruction and that there were cities, especially around the land of Bountiful, that were probably not severely damaged.<sup>78</sup>

One of the keys to understanding these passages of scripture is to understand the meaning of “whole face of the land” or “face of the whole earth.” What did Nephi mean? Certainly, he did not mean literally the whole earth, for we know from historical records that no massive destruction occurred at this time in the Mediterranean region, nor in Asia, Europe, or the Middle East. So if we cannot interpret “the whole earth” as being literally the whole earth, what did the writer mean? I think it is obvious that he meant



Drift Glacier at Redoubt Volcano, 1991. A geologist examines deep volcanic flow and deposits. Photograph by C. Gardner. Courtesy USGS.

*his* whole earth, or the whole land that was known and inhabited by the Book of Mormon peoples. Here again one must not get carried away into thinking that all of North and South America were deformed, because, as has been shown by other authors, the area over which the Book of Mormon peoples roamed was most likely only a few hundred miles long and wide.<sup>79</sup> It is only in this context that the great destruction makes sense and can be supported by scientific reasoning and, hopefully at some point in the future, some concrete evidence of the disaster.<sup>80</sup> If we insist on holding to the claim that all of the topographic features of two great continents were formed at this time, we cannot count on any support from geology, and we will probably alienate anyone with even a rudimentary understanding of the subject.

How do people who have witnessed one of these eruptions or who have visited the area after an eruption describe what they see? This comparison, I believe, is a good measure of how Nephi would react to the same event. Pliny the Younger describes his reaction upon seeing the landscape after the eruption of Mount Vesuvius:

At last the darkness thinned and dispersed into smoke or cloud; then there was genuine daylight, and the sun actually shone out, but yellowish as it is during an eclipse. We were terrified to see everything changed, buried deep in ashes like snowdrifts.<sup>81</sup>

From accounts of the eruption of Mount St. Helens come the following descriptions of the devastated landscape after the eruption:

Within minutes . . . the upper Toutle River Valley below St. Helens was a barren landscape of total desolation. A 156-square-mile swath extending northwest from the volcano lay devastated.

A billion board feet of timber were blown down; animals were buried in ash or roasted by gases; and scores of persons were dead or missing. . . . Harry Truman, his lodge and all of Spirit Lake disappeared in a cataclysmic cauldron. The once-rounded mountain top was shorter by 1,300 feet, and a mile-deep horseshoe of hell was gouged out of the north side.<sup>82</sup>

They call the land an alien moonscape, a blighted badlands. President Carter flew over it in late May and called it "indescribable." Dirty rivulets seem to flow uphill as they wind through the bizarre terrain. . . . At ground zero in the hellish landscape is what is left of Mount St. Helens. It sits like a resting monster.<sup>83</sup>

After a violent eruption, the volcano and the area surrounding it often appear completely foreign. The volcano itself may have changed from a towering, symmetrical peak to a blackened stump, stripped of foliage and unrecognizable as the mountain it used to be. Local officials who went to investigate the eruption of Tambora found that the thirteen-thousand-foot mountain was now flattened into a broad plateau and surrounded by a scene of utter devastation.<sup>84</sup> About ninety thousand people died from the eruption and the famine and disease that followed.

Volcanic landslides and mudflows may also significantly alter the terrain, creating hills and ridges where valleys and lowlands had previously existed. The account in 3 Nephi describes four cities as having sunk and "made hills and valleys in the places thereof" (3 Ne. 9:8). Tsunamis along the coast may obliterate not only towns and villages but other familiar landmarks. After a night of terror during the eruption of Krakatoa and the tsunamis that followed the eruption, one resident described the scene: "At last morning came. In front of us was what was once a town, but there was no destruction. There was simply . . . nothing."<sup>85</sup>

Perhaps the most significant change is due to the gray blanket of ash covering everything, casting a ghostly pall over the entire scene, killing most of the vegetation, and creating the feeling of a new and alien landscape. In 1991, Mount Pinatubo erupted in the Philippines. The amount of ash erupted was about the same as during the Krakatoa eruption. The ash buried Clark Airbase, fifteen miles from the volcano, so deeply that the United States government later abandoned it. It also destroyed, at least temporarily, over two hundred thousand acres of farmland and two dozen towns and displaced 1.2 million Filipinos from their homes.<sup>86</sup> It truly changed the whole face of the land.



Eruption plume from Mount Pinatubo, 1991. This picture was taken from Clark Airbase control tower. Clark Airbase was buried in ash so deep that it eventually had to be abandoned. Photograph by J. N. Marso. Courtesy USGS/Cascades Volcano Observatory.

### **Broken and Scattered Rocks**

Nephi's description of the effects the cataclysm had on the rocks might at first glance be ascribed to a great earthquake. Certainly during a great quake the earth is rent and broken, and rocks may afterward be found in "seams and cracks" and in "broken fragments." However, Nephi states that the rocks were found in this manner scattered over the whole face of the land. This is not typical of earthquakes, where the zone of actual breakage of rock is usually fairly narrow and confined, even in the greatest earthquakes. On the other hand, an explosive volcanic eruption commonly produces large quantities of broken and shattered rocks that are frequently scattered over a very wide area. Geologists call

deposits of these broken, fragmented rocks *pyroclastic* rocks. *Pyro* is derived from Greek and means fire, while *clastic* means broken or fragmented.

The size of the fragments of rock produced by a volcanic eruption ranges from small sand-sized fragments of ash and dust, to larger lumps of pumice and other rock, and even to very large house-sized blocks. The largest fragments of rock generally fall back to the earth near the eruptive source, but fairly large fragments may still be found some distance from the volcano. During the violent 1669 eruption of Italy's Mount Etna, "huge boulders, some weighing as much as three hundred pounds, were shot several miles through the air."<sup>87</sup> Volcanic bombs over three feet in diameter were thrown over three miles during the 1938 eruption of Asama in central Japan.<sup>88</sup> In Tambora's 1815 eruption, fist-sized stones fell up to twenty-five miles away from the eruption.<sup>89</sup> In



Impact craters from volcanic bombs, 1992. The craters, formed from large rocks ejected during a volcanic eruption, dot the surface of avalanches of volcanic debris that blanket the slopes of Crater Peak on the Mount Spurr volcano in Alaska. Photograph by C. Neal. Courtesy USGS.

describing two phases of the eruption of the Taal volcano in 1754 in the Philippines, one eyewitness describes the scattering of rocks and boulders, along with some of the other volcanic phenomena we have already discussed:

On November 15, it [Taal volcano] vomited enormous boulders. More intense earthquakes than had been experienced before tottered those houses which still stood. Immense waves of water in the lake threatened the low-lying villages along its shores.

At 7 in the morning of November 28 occurred a new paroxysm, during which the volcano vomited forth such masses of fire and ejecta that in my opinion, all the material ejected during so many months, if taken together, would not equal the quantity which issued at that time. The columns of fire and smoke ascended higher than ever before, increasing every moment in volume, and setting fire to the whole island, there not being the smallest portion of the latter which was not covered by smoke and glowing rocks and ashes. All this was accompanied by terrific lightning and thunder above, and violent shocks of earthquakes underneath.<sup>90</sup>

The reports of the distribution of rock fragments from the 1883 eruption of Krakatoa are probably typical for a moderately large eruption. Aboard the ship *Sir Robert Sale*, located approximately forty miles from the main blast, it was recorded that lumps of pumice the size of pumpkins fell onto the deck.<sup>91</sup> Captain Watson, on board the *Charles Bal* ten miles from the volcano, gives this account:

At 2:30 P.M. we noticed some agitation about the point of Krakatoa, clouds or something being propelled from the N.E. point with great velocity. At 3:30 we heard above us and about the island a strange sound, as of a mighty crackling fire, or the discharge of heavy artillery at one or two seconds' interval. At 4:15 . . . we observed a repetition of the noise noted at 3:30, only much more furious and alarming; the matter, whatever it was, being propelled with amazing velocity to the N.E. . . . At five the roaring noise continued and was increasing; darkness spread over the sky, and a hail of pumicestone fell on us, of which many pieces were of considerable size and quite warm. . . . About six the fall of larger stones ceased, but there continued a steady downpour of a smaller kind, most blinding to the eyes, and covering the deck to a depth of three to four inches very speedily. While an intense blackness covered the sky and land and sea, we sailed on our course.<sup>92</sup>



A large fragment of the lava dome from Augustine Volcano, 1986. This rock fragment was carried about three miles in a thick, fast-moving wall of volcanic ash (*nuée ardente*) during the eruption of Augustine Volcano. Photograph by M. E. Yount. Courtesy USGS.

The fall of stones during an eruption is one of the more selective ways in which people are injured or killed. Two people may be standing together and one will be hit and killed while the other may be spared. In 1779, the volcano Sakurajima erupted in southern Japan. One woman caught in the eruption describes her experience trying to escape the island:

I, myself, held a four year old child in my arms and led another of seven, and, so impeded, was forsaken by the boats. As I groped through the night, a stone, large as a hand-ball, struck the baby in the neck and killed her. She gave one cry and lay quite still, and all my efforts to revive her were in vain. I prayed she might live a thousand generations, but all prayers failed, and the body became colder and colder. So I covered her face with a cloth, and wept over my dead. Just then a weary old man came creeping near and told of other people killed by falling stones, others dragging themselves along with broken legs, and some buried alive under sand drifts.<sup>93</sup>

Volcanic eruptions are, as can be seen from the above accounts, very efficient at scattering broken rock fragments over a wide area and in causing great destruction and death due to this ejected material. This scattering of ejected rock could easily explain the broken rock fragments found over the whole land after the disaster in 3 Nephi.

### **Thick Darkness**

One of the common themes that can be found in almost all accounts of explosive volcanic eruptions is the darkness created by the fall of ash. This darkness may last for a few hours or a few days, and the historical descriptions mimic the terminology used in the Book of Mormon. In the following accounts, the darkness is referred to as “thick,” “impenetrable,” “profound,” and “total.” It is also described as a “darkness that might almost be felt.” Some accounts even record that fires cannot be lit or can only be started with great difficulty. The following are a representative cross section of the numerous records that describe the darkness associated with explosive volcanic eruptions.

Pliny the Younger had the opportunity to witness and describe in vivid detail the eruption of Mount Vesuvius in A.D. 79. His uncle, Pliny the Elder, was a naturalist and wanted a closer view of the eruption. He was prepared to sail across the Bay of Naples to better see the eruption when he received word of the devastation that was occurring at the mountain’s base. The elder Pliny decided to still travel across the bay but to try to rescue people rather than investigate the volcano, although he was probably still hoping for a better view. During the rescue attempt, Pliny the Elder was either overcome with fumes or died of a heart attack. Others with him returned to his nephew, reported what had happened, and described the eruption. Pliny the Younger later recorded his impressions in two letters to the historian Tacitus:

Elsewhere there was daylight by this time, but they [the elder Pliny and his companion] were still in darkness, blacker and denser than any night that ever was.<sup>94</sup>

Ashes were already falling, not as yet very thickly. I looked round: a dense black cloud was coming up behind us, spreading over



Eruption cloud rising over the summit of Augustine Volcano, 1986. The cloud, with tendrils of ash extending downward, darkens the daytime sky. Courtesy USGS.

the earth like a flood. . . . We had scarcely sat down to rest when darkness fell, not the dark of a moonless or cloudy night, but as if the lamp had been put out in a closed room.<sup>95</sup>

During the 1980 eruption of Mount St. Helens, Sgt. Larry Gamache of the Yakima County Sheriff's office reported that it was "just like midnight" in the middle of the afternoon. "All the street lights and neon signs have turned on."<sup>96</sup> The darkness during the eruption of Bezymianny Volcano in eastern Russia is described as "so impenetrably dark that one could not see his own hand, even if brought up to the very face," and the cloud of darkness described as "very thick and almost tangibly heavy."<sup>97</sup> Mount Tambora was reduced in height by over four thousand feet when it erupted in 1815, and "the darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night,"<sup>98</sup> making it "impossible to see your hand when held up close to the eye."<sup>99</sup> "There was total darkness by day for three days within 200 miles of the volcano."<sup>100</sup>

The most detailed eyewitness accounts come from the eruption of Krakatoa. The first officer on board the ship *W. H. Besse* recorded these impressions:

Sunday, August 26, 1883.—The day commenced with strong breezes and thick cloudy weather; at 4 A.M. hove short; at 6 A.M. got under weigh, wind SW; at 4 P.M. wind hauling ahead, came to anchor; the sky at this time having a threatening appearance; atmosphere very close and smoky, at 5 P.M. heard a quick succession of heavy reports sounding like the broadside of a man-of-war only far louder and heavier; heard these reports at intervals throughout the night; the sky was intensely dark, the wind having a dull moaning; through the rigging also noticed a light fall of ashes. The sun when it rose next morning . . . had the appearance of a ball of fire, the air so smoky, could see but a short distance; at 6 A.M. thinking the worst of the eruption was over as the reports were not so frequent or heavy as during the night, got under weigh, having a fair wind, was in hopes to get out clear of the straits before night . . . let go starboard anchor, it had gradually been growing dark since 9 A.M. and by the time the squall struck us, it was darker than any night I ever saw; this was midnight at noon, a heavy shower of ashes came with the squall, the air being so thick it was difficult to breathe, also noticed a strong smell of sulphur, all hands expecting to be suffocated; the terrible noises from the volcano, the sky filled with forked lightning, running in all directions and making the darkness more intense than ever; the howling of the wind through the rigging formed one of the wildest and most awful scenes imaginable, one that will never be forgotten by anyone on board, all expecting that the last days of the earth had come.<sup>101</sup>

Another witness to the Krakatoa eruption recounted that they were “inclosed in a darkness that might almost be felt,” and that “at noon the darkness was so intense that we had to grope our way about the decks [of the ship].”<sup>102</sup>

One of the interesting features of the “thick darkness” described in 3 Nephi was the difficulty, at least in some locations, of starting fires even with their fine, dry wood. This was obviously not a general feature of the destructive event, because several cities were burned—so some fire was possible. Although I have not found many accounts of this phenomenon in historical records of volcanic eruptions, it has been reported as something that does occasionally occur. For example, dozens of fires kindled by the fall of hot ash around Mount St. Helens were quickly extinguished by

the heavy fall of ash.<sup>103</sup> Rapidly falling ash can accumulate to several inches thick in a few minutes, even at considerable distances from the erupting volcano. The ash even finds its way into buildings and homes in tropical areas where windowpanes are normally absent. When Krakatoa erupted, the Beyerinck family was living in a village about fifteen miles from the island. Their home was the only one still standing after the eruption. Mrs. Beyerinck describes their difficulty starting a fire:

Someone burst in shouting 'shut the doors, shut the doors.' Suddenly it was pitch dark. The last thing I saw was the ash being pushed up through the cracks in the floorboards, like a fountain. . . .

There was still deep darkness. We couldn't light a fire, as matches went out immediately. At last the head boy, the only remaining male servant, managed to start a small fire.<sup>104</sup>

In the case of the Nephites, we do not know how they started fires during normal times; presumably it required some skill and patience. One can only imagine the difficulty in trying to start a fire during a heavy fall of ash.

Not only will the ashfall extinguish fires, but the gases erupted from a volcano can have the same effect. These gases are usually heavier than normal atmospheric gases, are very poor in oxygen, and commonly create acids in the atmosphere. These gases would also prevent the lighting of fires, but seldom is anyone alive to make the attempt, as the gases tend to quickly suffocate or poison those who are unfortunate enough to be caught under the blanket.<sup>105</sup> In 1986 an unusual release of CO<sub>2</sub> from a volcanic lake, Lake Nyos in Cameroon, created a dense near-surface cloud that flowed down and over several villages, asphyxiating 1,746 people and eighty-three hundred livestock. In the village of Nyos, less than 1 percent of the villagers survived.<sup>106</sup> Asphyxiation was also a common cause of death during the 1911 eruption of the Taal volcano in the Philippines.<sup>107</sup> One of the two survivors found in the city of St. Pierre after its destruction by the eruption of Mount Pelée records the suffocation of several people around him:

On the 8th of May at about eight o'clock of the morning, I was seated on the door-step of my house, which was in the southeastern part of the city. . . . All of a sudden I felt a terrible wind blowing, the

earth began to tremble, and the sky suddenly became dark. I turned to go into the house, made with great difficulty the three or four steps that separated me from my room, and felt my arms and legs burning, also my body. I dropped upon a table. At this moment four others sought refuge in my room, crying and writhing with pain, although their garments showed no sign of having been touched by flame. At the end of ten minutes one of these, the young Delavaud girl, aged about ten years, fell dead; the others left. I then got up and went into another room, where I found the father Delavaud, still clothed and lying on the bed, dead. He was purple and inflated, but the clothing was intact. I went out and found in the court two corpses interlocked: they were the bodies of the two young men who had . . . been in the garden when I returned to my house at the beginning of the catastrophe. Crazy and almost overcome, I threw myself upon a bed, inert and awaiting death. My senses returned to me in perhaps an hour.<sup>108</sup>

### Reactions of Terrified People

After the destruction and death described in 3 Nephi, the people “cry and mourn, saying: O that we had repented before this great and terrible day, and had not killed and stoned the prophets, and cast them out” (3 Ne. 8:25). These Book of Mormon people, having been warned by the prophets, were perhaps more justified but not unique in their reaction. The violence of explosive eruptions with their accompanying shaking, ashfall, darkness, and other phenomena often seem to bring those trapped within the zone of these terrifying effects to a state of humility and repentance, a contemplation of death, and sometimes a belief that the end of the world has arrived. Pliny reports, “People bewailed their own fate or that of their relatives, and there were some who prayed for death in their terror of dying. Many besought the aid of the gods, but still more imagined there were no gods left and that the universe was plunged into eternal darkness for evermore.”<sup>109</sup>

Ivan Orloff, an Alaskan Eskimo, wrote to his wife the following during the 1912 eruption of Katmai:

We are awaiting death at any moment. A mountain has burst near here. We are covered with ash, in some places ten feet and six feet deep. All this began on June sixth. Night and day we light lanterns. We cannot see daylight. We have no water, the rivers are just ashes mixed with water. Here are darkness and hell, thunder and noise. I do not know whether it is day or night. The earth is trembling, it lightens every minute. It is terrible. We are praying.<sup>110</sup>

During the eruption of Coseguina in 1835, the terror of the inhabitants of Alanchó, Nicaragua, was so great that anticipating the final judgment was upon them, “three hundred of those living out of wedlock were married at once.”<sup>111</sup> Deathbed repentance, however, is not always effective. In Sicily in A.D. 1169, Mount Etna had one of its most lethal eruptions, killing fifteen thousand people. A large group had crowded into Catania’s cathedral “to pray for divine intercession when the earth heaved and the building collapsed,” killing them all.<sup>112</sup>

### **A True Record**

A question that might be asked by those who doubt the truth of the Book of Mormon account is, “What is so remarkable about the account of a volcanic eruption?” “No doubt,” they would say, “Joseph Smith had read an account of a volcanic eruption and thought it would make a nice backdrop for the destruction he envisioned occurring at Christ’s death.” I would answer that the account is remarkable for its detail and accuracy and that such an account would have been impossible for an uneducated young man to have published in 1830. Volcanoes were neither well understood nor well documented in the early 1800s. Geology was a science still in its infancy. The first real textbook of geology was published the same year as the Book of Mormon, 1830, by Charles Lyell in Great Britain.<sup>113</sup> But his descriptions of volcanic eruptions, as well as the few other accounts available in Joseph Smith’s day, are incomplete and do not include all the features found in the Book of Mormon account, features that are now known to occur with large explosive eruptions.

The eruption of Tambora in 1815 was probably the most spectacular eruption in historic times, and it occurred when Joseph Smith was about ten years old. “Surely,” Book of Mormon detractors would say, “Joseph must have read or heard about this eruption? He could easily have modeled his 3 Nephi account after Tambora.” Although it is possible that Joseph read an account of the Tambora eruption somewhere, it is much more probable that Joseph never knew about the eruption of Mount Tambora. The eruption was almost completely unreported at the time it occurred, and

detailed available accounts of the eruption are still rare.<sup>114</sup> The only substantial accounts that survived from this time were assembled by Sir Thomas Stamford Raffles, British lieutenant governor of Java, and published in 1817.<sup>115</sup> Raffles's *History of Java* does include a few pages describing the eruption, and some of the features of the description are similar to the Book of Mormon account (as are the accounts of all volcanic eruptions of this type), but again the account does not mention some of the features of the Book of Mormon account. For example, no mention is made of lightning of any kind, nor of the inability to light fires. Nor does Raffles mention all the types of destruction found in the Book of Mormon account. It was not until 1847 that a scientific expedition penetrated to the crater and scientists were able to gain some understanding of what had occurred.<sup>116</sup> Even then, the information gathered was not widely distributed.

Although our testimonies of the Book of Mormon do not or should not depend upon physical evidences, such evidences can add greater depth, understanding, and faith as we read and study. The gospel of Jesus Christ asks us all to “study and learn” (D&C 90:15) and teaches us that it is “impossible for a man to be saved in ignorance” (D&C 131:6). The events in the Book of Mormon are more personally meaningful and I feel a greater compassion and kinship for the people of the Book of Mormon as I gain a greater understanding of their way of life, their problems, and their environment.

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## NOTES

<sup>1</sup>Russell J. Blong, *The Time of Darkness* (Seattle: University of Washington Press, 1982), 69-70.

<sup>2</sup>Blong, *Time of Darkness*, 70.

<sup>3</sup>Blong, *Time of Darkness*, 104.

<sup>4</sup>Blong, *Time of Darkness*, 5.

<sup>5</sup>Blong, *Time of Darkness*, 4.

<sup>6</sup>Blong, *Time of Darkness*, 103.

<sup>7</sup>Blong, *Time of Darkness*, 116.

<sup>8</sup>Blong, *Time of Darkness*, 151.

<sup>9</sup>Blong, *Time of Darkness*, 116.

<sup>10</sup>Blong, *Time of Darkness*, 7.

<sup>11</sup>John Gee, "Another Note on the Three Days of Darkness," *Journal of Book of Mormon Studies* 6, no. 2 (1997): 2. Some people have argued that this eruption corresponds with the plagues and darkness in Egypt described in Exodus.

<sup>12</sup>Claude Vandersleyen, "Une tempête sous le règne d'Amosis," *Revue d'Égyptologie* 19 (1967), from the translation by Robert K. Ritner, in Karen Polinger Foster and Robert K. Ritner, "Texts, Storms, and the Thera Eruption," *Journal of Near Eastern Studies* 55, no. 1 (1996): 11. Ellipses enclosed in brackets indicate illegible material.

<sup>13</sup>See, for example, John L. Sorenson, *An Ancient American Setting for the Book of Mormon* (Salt Lake City: Deseret Book; Provo, Utah: FARMS, 1985), 415. This book, in my view, is the best analysis of Book of Mormon geography available and provides us with a very plausible setting.

<sup>14</sup>Other works suggesting a volcanic eruption as a possible cause of the destruction in 3 Nephi include the following:

James L. Baer, "The Third Nephi Disaster: A Geological View," *Dialogue: A Journal of Mormon Thought* 19 (spring 1986): 129-32. The author mentions the possibility of volcanic eruptions as the cause of the destruction, but focuses mostly on the event being caused by one or more large earthquakes. Earthquakes certainly do accompany large volcanic eruptions, sometimes occurring in swarms of quakes as the eruption proceeds. The reverse, however, is not true: volcanic eruptions do not usually occur with large earthquakes, and large earthquakes of even the largest magnitudes do not last for more than a few minutes and certainly not for the three hours described in 3 Nephi.

Russell H. Ball, "An Hypothesis concerning the Three Days of Darkness among the Nephites," *Journal of Book of Mormon Studies* 2, no. 1 (1993): 107-19. Ball also believes that the event can be entirely explained by an explosive volcanic eruption.

E. L. Peay, *Nephi's Promised Land in Central America*, vol. 2 of *The Lands of Zarahemla: A Book of Mormon Commentary* (Provo, Utah: By the author, 1994), 168-69. Peay suggests that a combination of hurricane, volcano, and great earthquake could account for the destruction, although he focuses on the volcanic eruption to explain most of the features.

Marlon A. Nance, "Can the 'Days of Darkness' Be Documented?" FARMS Seminar, October 26, 1996. Nance has taken the study one step further. He is trying to identify ash layers in oceanic sediments near Mesoamerica to try to identify the eruption responsible for the 3 Nephi destruction.

Hugh W. Nibley, *Since Cumorah* (Salt Lake City: Deseret Book, 1988), 231-38. Nibley first tries to explain everything in terms of events that occur during a great earthquake, but as he proceeds also includes the idea that a volcanic eruption may have been involved. He cites several examples of the different phenomena from historic accounts of large earthquakes and volcanic eruptions. In general Nibley's analysis is quite good and fairly close to my own, although I would argue that no large earthquakes, outside of those naturally occurring with an explosive volcanic eruption, are needed to explain the text in 3 Nephi.

David A. Palmer, *In Search of Cumorah, New Evidences for the Book of Mormon from Ancient Mexico* (Bountiful, Utah: Horizon, 1981), 38-41. Palmer does a very nice job of outlining the basic evidences for a volcanic eruption at the time of the great destruction. However, I would disagree with him on the following

points. First, he states that “it appears that there was eruption of at least one and probably several volcanoes” (39). I see no need for the eruption of more than one volcano, an event that would be highly unlikely in most natural settings for the time frame given in the Book of Mormon. Secondly, he states that “there was obviously a devastating earthquake, and its aftershocks lasted for three days” (39). The Book of Mormon account indicates that after three hours the shaking ceased, not three days. Lastly, Palmer says, “The description given in the Book of Mormon suggests an abnormally large shift in the plates at the time of the Crucifixion. That would have caused earthquakes and simultaneously sent magma to the surface in several places, unleashing terrible destruction” (40). However, according to geologic understanding, it is not likely that an unusually large shift in the plates would send magma to the surface. Only if the magma were already near the surface, primed for an eruption, could a large earthquake trigger a volcanic eruption. Again, however, no large movement along the plate boundary is necessary to explain the events of 3 Nephi.

Sorenson, *Ancient American Setting*, 318–23. My only comments on his analysis are that he calls on hurricanes or tropical storms as the likely cause of the flooding of cities near the sea, while I would suggest that it is far more likely that this flooding was caused by tsunami. He also states that nothing is surprising about the phenomena associated with the destruction except that the scale or magnitude was unprecedented (323). I would agree that this is probably true among the Book of Mormon peoples, but the magnitude of this destruction, I would suggest, is not unique in historical times (certainly the eruptions of Krakatoa and Tambora are possibly of the same scale), and this event would have been dwarfed by some of the eruptions we observe to have occurred in the geologic record, such as the last three eruptions out of the Yellowstone area, which were hundreds of times bigger than Krakatoa and Tambora. See Robert B. Smith and Lawrence W. Braile, “Topographic Signature, Space-Time Evolution, and Physical Properties of the Yellowstone-Snake River Plain Volcanic System: The Yellowstone Hotspot,” in *Geology of Wyoming*, ed. Arthur W. Snoke, James R. Steidtmann, and Sheila M. Roberts, Geological Survey of Wyoming Memoir no. 5 (Laramie, Wyo.: Pioneer Printing and Stationery, 1993), 718, figure 14. This article mainly discusses the pre-historic eruptions around the Yellowstone hotspot, which were bigger than any historic eruptions. The authors estimate that the largest of the Yellowstone eruptions was perhaps two thousand times as large as the Mount St. Helens eruption.

John A. Tvedtnes, “Historical Parallels to the Destruction at the Time of the Crucifixion,” *Journal of Book of Mormon Studies* 3, no. 1 (1994): 170–86. Tvedtnes points out that natural phenomena correlate well with the 3 Nephi events, but he also tries to relate this to movement of the tectonic plates and perhaps a major earthquake as well as volcanic eruption. I do not believe that any major plate movement or earthquake was necessary to produce the 3 Nephi events other than the earthquakes that normally occur during a volcanic eruption.

<sup>15</sup>John W. Welch, ed., *Reexploring the Book of Mormon* (Salt Lake City: Deseret Book; Provo, Utah: FARMS, 1992), 23. Zenos did not mention a whirlwind nor specifically a shaking of the earth.

<sup>16</sup>Smith and Braile, “Topographic Signature: The Yellowstone Hotspot,” 718, figure 14.

<sup>17</sup>James B. Allen and Glen M. Leonard, *The Story of the Latter-day Saints*, 2d ed., rev. and enl. (Salt Lake City: Deseret Book, 1992), 18.

<sup>18</sup>Kaari Ward, ed., "The Year without a Summer," in *Great Disasters: Dramatic True Stories of Nature's Awesome Powers* (Pleasantville, N. Y.: Reader's Digest, 1989), 108-11.

<sup>19</sup>Henry Stommel and Elizabeth Stommel, "The Year without a Summer," *Scientific American* 240 (June 1979): 176-80. See also Henry Stommel and Elizabeth Stommel, *Volcano Weather* (Newport, R. I.: Seven Seas, 1983).

<sup>20</sup>Ward, "The Year without a Summer," 111.

<sup>21</sup>Allen and Leonard, *Story of the Latter-day Saints*, 18.

<sup>22</sup>Thomas A. Jaggar, *Volcanoes Declare War* (Honolulu: Paradise of the Pacific, 1945), 129; Fred M. Bullard, *Volcanoes of the Earth* (Austin: University of Texas Press, 1984), 93.

<sup>23</sup>George G. Daniels, ed., *Volcano*, The Planet Earth Series (Alexandria, Va.: Time-Life Books, 1982), 22, 25.

<sup>24</sup>Bullard, *Volcanoes of the Earth*, 93-96. Bullard indicates that the Central American volcanoes are so explosive that liquid lava is rarely erupted. Instead, almost all (99 percent) of the magma erupted out of Central American volcanoes is in the form of ash and pumice. This would perhaps explain why there is no mention in the 3 Nephi account of anything that sounds like lava flows.

<sup>25</sup>M. B. Lambert, *Volcanoes* (Seattle: University of Washington Press, 1978), 32. Lambert includes a photograph of a whirlwind produced during the 1963 Surtsey Volcano eruption in Iceland.

<sup>26</sup>Staffs of the *Longview (Wash.) Daily News* and the *Bellevue (Wash.) Journal-American*, *Volcano: The Eruption of Mount St. Helens* (Longview, Wash.: Longview Publishing, 1980), 26.

<sup>27</sup>J. G. Rosenbaum and Richard B. Waitt, "Summary of Eyewitness Accounts of the May 18 Eruption," U. S. Geological Survey Professional Paper 1250, 1981, 62.

<sup>28</sup>Rosenbaum and Waitt, "Eyewitness Accounts," 59-60.

<sup>29</sup>Staffs, *Volcano*, 26.

<sup>30</sup>William A. Garesché, *Complete Story of the Martinique and St. Vincent Horrors* (New York: L. G. Stahl, 1902), 50-51. Garesché had been the American consul to Martinique for several years prior to the eruption and was well acquainted with many of the victims of the disaster.

<sup>31</sup>Bullard, *Volcanoes of the Earth*, 125.

<sup>32</sup>Bullard, *Volcanoes of the Earth*, 125.

<sup>33</sup>R. D. M. Verbeek, *Krakatau* (Batavia, [Indonesia]: Imprimerie de l'état, 1885), 480-81. This account and many others reported by Verbeek are also found in a comprehensive study of Krakatoa: Tom Simkin and Richard S. Fiske, *Krakatau 1883: The Volcanic Eruption and Its Effects* (Washington, D. C.: Smithsonian Institution, 1983), 98-99.

<sup>34</sup>Charles Lyell, *Principles of Geology* (London: John Murray, 1830), 403-5.

<sup>35</sup>Daniels, *Volcano*, 58.

<sup>36</sup>Simkin and Fiske, *Krakatau 1883*, 64.

<sup>37</sup>Jaggar, *Volcanoes Declare War*, 61.

<sup>38</sup>Lambert, *Volcanoes*, 32; and Sigurder Thorarinsson and Bernard Vonnegut, "Whirlwinds Produced by the Eruption of the Surtsey Volcano," *Bulletin of the American Meteorological Society* 45, no. 8 (1964): 440-44.

<sup>39</sup>Daniels, *Volcano*, 157.

<sup>40</sup>Pliny, *Letters and Panegyricus*, The Loeb Classical Library (1969), 1:443.

<sup>41</sup>Peter Francis, *Volcanoes: A Planetary Perspective* (New York: Oxford University Press, 1993), 68.

<sup>42</sup>Georgievich S. Gorshkov, "Gigantic Eruption of Volcano Bezymianny," *Bulletin Volcanologique*, series 2, 20 (1959): 86-87.

<sup>43</sup>Lyell, *Principles of Geology*, 403.

<sup>44</sup>Simkin and Fiske, *Krakatau 1883*, 102.

<sup>45</sup>Rosenbaum and Waitt, "Eyewitness Accounts," 63.

<sup>46</sup>Simkin and Fiske, *Krakatau 1883*, 104.

<sup>47</sup>Robert W. Decker and Barbara B. Decker, *Mountains of Fire: The Nature of Volcanoes* (Cambridge: Cambridge University Press, 1991), 39.

<sup>48</sup>Lambert, *Volcanoes*, 31.

<sup>49</sup>Edward B. Nuhfer, Richard J. Proctor, and Paul H. Moser, *The Citizen's Guide to Geologic Hazards* (Arvada, Colo.: American Institute of Professional Geologists, 1993), 58. The photograph was taken by Ruska Hadian of the Volcanological Survey of Indonesia.

<sup>50</sup>Mark Kemp, "Power Surge," *Discover* 9 (April 1988): 40-41. This photo was taken by Tsuyoshi Nishinoue on November 17, 1987. It has since been used on postcards, one of which I purchased on a visit to Japan.

<sup>51</sup>Konrad B. Krauskopf and the Committee on the Alaska Earthquake, *The Great Alaska Earthquake of 1964, Summary and Recommendations* (Washington, D. C.: National Academy of Sciences, 1973), xi.

<sup>52</sup>Bruce A. Bolt, *Earthquakes* (New York, W. H. Freeman, 1988), 18.

<sup>53</sup>Bolt, *Earthquakes*, 21; John Milne, *Earthquakes and Other Earth Movements* (Philadelphia: P. Blakiston's Son, 1939), 15.

<sup>54</sup>The idea of "earthquake weather" was probably first proposed by Aristotle. He put forth the theory that earthquakes were caused by winds trapped in large subterranean caverns. This idea was still being taught as late as 1755, when John Winthrop lectured at Harvard on the strengths of Aristotle's thesis. Winthrop proposed that the weather prior to an earthquake needed to be hot and windless because large quantities of air needed to be trapped underground. During an earthquake, this air would be released in a fury of wind. G. Lennis Berlin, *Earthquakes and the Urban Environment*, vol. 1 (Boca Raton, Fla.: CRC, 1980), 13. Even Shakespeare borrowed the idea: "Diseased nature oftentimes breaks forth in strange eruptions; oft the teeming earth is with a kind of colic pinch'd and vex'd by the imprisoning of unruly wind within her womb; which for enlargement striving, shakes the old beldame earth, and topples down steeples and moss-grown towers." William Shakespeare, *Henry the Fourth, Part I*, quoted in Berlin, *Earthquakes and the Urban Environment*, 13.

<sup>55</sup>Raymond R. Dibble, "Seismic and Related Phenomena at Active Volcanoes in New Zealand, Hawaii, and Italy" (Ph.D. diss., Victoria University, Wellington, N. Z., 1972), 557; Lambert, *Volcanoes*, 33.

<sup>56</sup>Simkin and Fiske, *Krakatau 1883*, 32-40.

<sup>57</sup>R. D. Adams and Raymond R. Dibble, "Seismological Studies of the Raoul Island Eruption, 1964," *Bulletin Volcanologique* 29 (1966): 5.

<sup>58</sup>Stanley N. Williams and Stephen Self, "The October 1902 Plinian Eruption of Santa Maria Volcano, Guatemala," *Journal of Volcanology and Geothermal Research* 16 (1982): 33-56.

<sup>59</sup>Bullard, *Volcanoes of the Earth*, 95.

<sup>60</sup>Bullard, *Volcanoes of the Earth*, 95-96.

<sup>61</sup>Francis, *Volcanoes: A Planetary Perspective*, 68.

<sup>62</sup>Bullard, *Volcanoes of the Earth*, 125.

<sup>63</sup>Lewis D. Leet, *Causes of Catastrophe* (New York: Whittlesey House, 1948), 8; Satis N. Coleman, *Volcanoes New and Old* (New York: John Day, 1946), 80-81. Both Leet and Coleman use this same account given by Assistant Purser Thompson, but there are some minor differences between the two. I have combined parts of the accounts from both sources here.

<sup>64</sup>Simkin and Fiske, *Krakatau 1883*, 15.

<sup>65</sup>Simkin and Fiske, *Krakatau 1883*, 73.

<sup>66</sup>Simkin and Fiske, *Krakatau 1883*, 117.

<sup>67</sup>Tom Koenninger, ed., *Vancouver! Vancouver! This Is It!* (Lubbock, Tex.: C. F. Boone, 1980), 36.

<sup>68</sup>Sorenson, *Ancient American Setting*, 222-23. Sorenson places Jerusalem on Lake Atitlan in Guatemala. It may be that the other cities mentioned with Jerusalem, Onihah and Mocum, were also on this lake. These three cities would have probably been quite distant from the main volcanic eruption because they are located far into the land southward, and the Book of Mormon makes it clear that the most wicked people and the greatest destruction were in the land northward. Lake Atitlan, however, is surrounded by high volcanoes over twelve thousand feet high, and steep mountain slopes continue down to the lake shore (see photos in Sorenson, *Ancient American Setting*, 177). Such slopes are often unstable, and earthquake activity, induced by even a distant volcanic eruption, could certainly be sufficient to trigger landslides down into the lake, causing the lake level to rise and cover cities or towns near the shore.

<sup>69</sup>Decker and Decker, *Mountains of Fire*, 104.

<sup>70</sup>Francis, *Volcanoes: A Planetary Perspective*, 63. During an excavation in 1812, several bodies were uncovered only a few inches below the upper surface of the ash layer. One of them was holding a decomposed bag that had held 360 silver coins, 42 bronze pieces, and 8 imperial gold medallions. Egon C. C. Corti, *The Destruction and Resurrection of Pompeii and Herculaneum*, trans. K. and R. Gregor Smith (London: Routledge and Kegan Paul, 1951), 171.

<sup>71</sup>Lambert, *Volcanoes*, 47.

<sup>72</sup>Francis, *Volcanoes: A Planetary Perspective*, 68.

<sup>73</sup>Jaggar, *Volcanoes Declare War*, 32.

<sup>74</sup>David K. Chester, *Volcanoes and Society* (London: Edward Arnold, 1993), 292-93; Kaari Ward, ed., "The Wrath of Nevado del Ruiz," in *Great Disasters*, 108-11.

<sup>75</sup>Daniels, *Volcano*, 154.

<sup>76</sup>Francis, *Volcanoes: A Planetary Perspective*, 93.

<sup>77</sup>Decker and Decker, *Mountains of Fire*, 112.

<sup>78</sup>See Sorenson, *Ancient American Setting*, 318-23. Sorenson interprets the phrase "face of the land" to mean that the changes to the land were mostly cosmetic surface changes, and that the basic geography was unchanged. I would agree in general with this statement, although near the eruption site the changes may have been very dramatic and not necessarily simple cosmetic ones. See also Nibley, *Since Cumorah*, 232.

The sixteen destroyed cities mentioned by name in 3 Nephi were in lands away from Bountiful. For example, Gid and Mulek (mentioned in Helaman 5:15, sixty years prior to the destruction), located near the city of Bountiful, are not mentioned in the lists of cities that were destroyed. Other cities “remained,” even though “the damage thereof was exceedingly great” (3 Ne. 8:15). Some time after the three days of darkness, “there were a great multitude gathered together, of the people of Nephi, round about the temple which was in the land Bountiful” (3 Ne. 11:1).

<sup>79</sup>Sorenson, *Ancient American Setting*, 8-23; Palmer, *In Search of Cumorah*, 29-31.

<sup>80</sup>If a large explosive volcanic eruption did occur in Mesoamerica at the time of Christ’s death, then the ash may still be present and might be found in some places. A significant ash layer of approximately the right age (ca. A.D. 100-200) has been described in Payson D. Sheets, “An Ancient Natural Disaster,” *Expedition* 14, no. 1 (1971): 24-31; and in Payson D. Sheets, “Environmental and Cultural Effects of the Ilopango Eruption in Central America,” in *Volcanic Activity and Human Ecology*, ed. Payson D. Sheets and Donald K. Grayson (New York: Academic, 1979), 525-64. Sheets describes how the eruption of Ilopango Volcano in El Salvador essentially destroyed the cultures in this region, and they did not recover for almost two hundred years. However, if we accept the Book of Mormon geography as interpreted by Sorenson, then this eruption may be too far south to have caused much destruction around Zarahemla, although it is still close enough to have caused the darkness. It certainly is too far south to have caused much destruction in the land northward, where the Book of Mormon describes the destruction as being the worst.

Palmer, *In Search of Cumorah*, 102, points out that an ash layer possibly dating to about the time of Christ’s death was also found at Tres Zapotes, an important archaeological site north of the Isthmus of Tehuantepec. Tres Zapotes is near to several active volcanoes. El Chichon, a volcano located about seventy-five miles north of Sorenson’s Zarahemla in southern Mexico, erupted violently in 1982. It had previously erupted around A.D. 800 according to Chester, *Volcanoes and Society*, 277-78, and undoubtedly had earlier violent eruptions.

The problem is that there are so many active volcanoes in Mexico and Central America and there have been many eruptions in the last few thousand years. Wenkam wandered through many prominent archaeological sites in Central America and Mexico and claimed to find volcanic ash almost everywhere. He puts forward the hypothesis that volcanic eruptions may have been a common cause of destruction in this region. Robert Wenkam, *The Edge of Fire* (San Francisco: Sierra Club Books, 1987), 29-43.

For our purposes in understanding this Book of Mormon event, and using Sorenson’s geography as a guide, I would suspect the eruptive center to have been north of the Isthmus of Tehuantepec (in the land northward where destruction was greatest) and probably along the coast where the eruption could generate a tidal wave. However, more geologic and geochronologic information is needed before any further speculations can be made. Marlon Nance, in a talk presented at a FARMS seminar on October 25, 1996, proposed the most comprehensive plan for locating an ash bed associated with this eruption. He proposed to chemically fingerprint and date ash beds found in deep-sea cores taken from areas

near to Mesoamerica. This would be a fascinating project, and one I hope he is able to carry out.

<sup>81</sup>Pliny, *Letters and Panegyricus*, 1:445.

<sup>82</sup>Koenninger, "Vancouver!" 24.

<sup>83</sup>Staffs, *Volcano*, 52.

<sup>84</sup>Daniels, *Volcano*, 58.

<sup>85</sup>Simkin and Fiske, *Krakatau 1883*, 89.

<sup>86</sup>Andrew Robinson, *Earthshock: Hurricanes, Volcanoes, Earthquakes, Tornadoes, and Other Forces of Nature* (London: Thames and Hudson, 1993), 115-16.

<sup>87</sup>Kaari Ward, ed., "Mount Etna Erupts—Again," in *Great Disasters*, 91.

<sup>88</sup>William E. Scott, "Volcanic and Related Hazards," in *Volcanic Hazards*, ed. Robert I. Tilling (Washington D. C.: American Geophysical Union, 1989), 17-18.

<sup>89</sup>Daniels, *Volcano*, 58.

<sup>90</sup>M. S. Maso, *The Eruption of Taal Volcano* (Manila: Manila Bureau of Printing, 1911), 9. Important parts of this account are reprinted in Kent H. Wilcoxson, *Volcanoes* (London: Cassell, 1966), 166-67.

<sup>91</sup>Francis, *Volcanoes: A Planetary Perspective*, 80.

<sup>92</sup>E. W. Sturdy, "The Volcanic Eruption of Krakatau," *Atlantic Monthly* 54, no. 321 (July 1884): 387-89.

<sup>93</sup>Jaggar, *Volcanoes Declare War*, 67.

<sup>94</sup>Pliny, *Letters and Panegyricus*, 1:433.

<sup>95</sup>Pliny, *Letters and Panegyricus*, 1:445.

<sup>96</sup>Koenninger, "Vancouver!" 25.

<sup>97</sup>Gorshkov, "Gigantic Eruption," 86-87.

<sup>98</sup>Lyell, *Principles of Geology*, 404.

<sup>99</sup>Haraldur Sigurdsson and Steven Carey, "The Eruption of Tambora in 1815: Environmental Effects and Eruption Dynamics," in *The Year without a Summer*, ed. C. R. Harrington (Ottawa: Canadian Museum of Nature), 20.

<sup>100</sup>Stommel and Stommel, *Volcano Weather*, 12.

<sup>101</sup>Simkin and Fiske, *Krakatau 1883*, 98-99.

<sup>102</sup>Sturdy, "Volcanic Eruption of Krakatau," 387-89.

<sup>103</sup>Koenninger, "Vancouver!" 24.

<sup>104</sup>Simkin and Fiske, *Krakatau 1883*, 84-85. The Beyerinck family later had to put out their fire because it began to attract many natives who were crazed with thirst and quite desperate.

<sup>105</sup>Scott, "Volcanic and Related Hazards," 19-20.

<sup>106</sup>Alan E. Kehew, *Geology for Engineers and Environmental Scientists* (Englewood Cliffs, N. J.: Prentice Hall, 1995), 75-77.

<sup>107</sup>Wilcoxson, *Volcanoes*, 171.

<sup>108</sup>Angelo Heilprin, *Mount Pelée and the Tragedy of Martinique* (Philadelphia: J. B. Lippincott, 1905), 119.

<sup>109</sup>Pliny, *Letters and Panegyricus*, 1:445.

<sup>110</sup>Wilson F. Erskine, *Katmai* (London: Abelard-Schuman, 1962), 55. The same quote is also found in Katia Krafft and Maurice Krafft, *Volcanoes* (Maplewood, N. J.: Hammond Inc., 1980), 58.

<sup>111</sup>H. Williams, "The Great Eruption of Coseguina, Nicaragua, in 1835," *University of California Publications in Geological Science* 29, no. 2 (1952): 33.

<sup>112</sup>Ward, "Mount Etna Erupts—Again," 90-91.

<sup>113</sup>Lyell, *Principles of Geology*.

<sup>114</sup>Richard B. Stothers, "The Great Tambora Eruption in 1815 and Its Aftermath," *Science* 224, no. 4654 (1984): 1191-98.

<sup>115</sup>Thomas S. Raffles, *History of Java*, 2 vols. (London: Black, Parbury, and Allen, 1817), 1:29-33.

<sup>116</sup>Robinson, *Earthshock*, 94.