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PHOTOGRAPHS OF THE 1992 ERUPTIONS OF CRATER PEAK, SPURR VOLCANO, ALASKA

by

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INTRODUCTION

Spurr is an active volcano located 125 km (78 mi) west of Anchorage, the state of Alaska's largest city and an important transportation hub in the North Pacific. This large, ice- and snow- covered stratovolcano underwent a massive collapse followed by an explosive eruption approximately 10,000 - 20,000 years ago to form a 5 x 6 km (3.7 x 3.1 mi) summit caldera (Riehle, 1985; Nye and Turner, 1990). Subsequent eruptions built an andesite lava dome that is now the 3374-m- (11,070 ft) summit of Mount Spurr, and Crater Peak, a 2309-m- (7576 ft) high satellitic cone on the south margin of the caldera. Crater Peak has been the source of at least 35 explosive eruptions in the last 5000 years including the only other historic eruption of Mount Spurr in 1953 (Riehle, 1985; Wilcox, 1959; Juhle and Coulter, 1955).

After 39 years of quiescence, Crater Peak reawakened with a series of three, short-lived but violent eruptions on June 27, August 18, and September 16-17 of 1992 (Alaska Volcano Observatory, 1993). Each eruption lasted between 3.5 - 4.0 hours and produced a cloud of gas and ash that reached altitudes of more than 15 km (49,000 ft) above the volcano. Near the volcano, avalanches of debris tumbled down the flanks of Crater Peak and large blocks were hurled as far as 3 km (1.8 miles) away. Two of the three 1992 events blanketed populated areas northeast and east of the volcano, including the city of Anchorage, with as much as 3 mm (1/8 inch) of sand-sized ash. The fallout closed airports, schools, and businesses for a day or more, interrupted air traffic over southcentral Alaska, and caused respiratory problems for people with breathing disorders. The clean-up cost the city of Anchorage alone an estimated $2 million. Resuspended ash was an intermittent problem more than a year later.

The Alaska Volcano Observatory (AVO), a cooperative effort involving the U. S. Geological Survey, the University of Alaska Fairbanks, Geophysical Institute and the Alaska Division of Geological and Geophysical Surveys is the principal organization responsible for volcanic hazards assessment and eruption notification and monitoring in Alaska. As part of this program, AVO maintains a seismic network at Spurr and four other active Alaskan volcanoes (Brantley, 1990; Wright and Pierson, 1992). Analysis of earthquake patterns in the months prior to the June 27, 1992 eruption prompted AVO to formally declare concern about the possibility of an eruption at Spurr several weeks before the onset of activity. Emergency call-downs and timely written information releases from AVO transmitted critical hazards information to appropriate federal, state, and municipal agencies as well as other parties vulnerable to the effects of volcanic ash.

Photography of the 1992 eruptions of the Crater Peak vent at Spurr volcano illustrates a number of phenomenon related to explosive volcanism and associated volcanic hazards. These slides depict selected highlights of this eruption series.

SLIDE CAPTIONS

1. View to the north of the 3374-m (11,070 ft) summit of Mount Spurr (background) and 2309-m (7576 ft) Crater Peak (foreground), the site of eruptions in 1953 and 1992. Crater Peak is a satellitic vent perched in the southern breach of the volcano's caldera which formed 10,000 - 20,000 years ago, truncating an ancestral stratovolcano. Mount Spurr proper is an ice-covered, andesite lava dome complex that has not erupted in historic times. Crater Peak, which has been active for at least the last 5,000 years, is a basaltic-andesite stratocone with a summit crater approximately 800 m (2624 ft) across at its rim. The volcano lies 125 km (78 mi) due west of Anchorage, the principal population center in the state of Alaska. (photo by R G McGimsey, USGS, 10/9/91)

2. Within the Crater Peak basin, a warm, blue-green lake, approximately 500 m (1640 ft) across, developed some time after the 1953 eruption. On June 11, 1992, the lake temperature was 50^{o} C and its pH was 2.5. A darkening of the lake color and upwelling zones - the largest about 5 m (16.4 ft) across is visible to the right in this view - indicated a possible addition of sulfur and an increased heat flux below the lake. In addition, new geysers of superheated water were observed streaming through talus on the north shore of the lake (far shore in this view). These signs, combined with an increased number of earthquakes detected below the volcano since August 1991, prompted scientists from the Alaska Volcano Observatory to issue a notice on June 17, 1992 of the increased likelihood of eruptive activity. (photo by R G McGimsey, USGS, 6/11/92)

3. An overflight on June 26 revealed that the lake in Crater Peak had drained away. After 4 hours of energetic seismicity, Crater Peak erupted explosively at 7:04 am ADT (Alaska Daylight Time) on June 27. The eruption occurred under heavy cloud cover and was not photographed; fallout from the 15-km- (49,000 ft) high eruption column darkened the snow and ice of the surrounding mountains and ash fell as far away as Manley Hot Springs, 425 km (264 mi) north of the volcano. In this view, looking north-northwest towards Crater Peak, the fallout-mantled summit of Spurr is visible behind Crater Peak and to the right. A column of steam rises from the Crater Peak vent. During the eruption, avalanches of hot debris cascading down the south flank of Crater Peak mixed with snow to form debris flows, or lahars, which reached the Chakachatna River, not visible in this view. (photo by T P Miller, USGS, 7/3/92)

4. A seismometer had been installed on the rim of Crater Peak in August of 1991. Signals from this instrument allowed AVO to track the build up of seismicity prior to the eruption. Several hours into the eruption on June 27, the seismometer stopped transmitting. This twisted steel pipe with 6 mm (1/4 in) thick walls and a melted, blasted piece of corrugated, galvanized steel was all that remained of the geophone, batteries, culvert, and antenna. (USGS photo, 7/6/92)

5. The volcano quieted down dramatically after the June 27 eruption, and it appeared as if, similar to the 1953 eruption, this phase of activity had ended. However, at 4:41 pm ADT on August 18, without significant seismic precursors, Crater Peak again erupted, suddenly and explosively, sending pulverized rock to more than 14 km (46,000 ft) altitude. Winds blowing east over the volcano carried the gas and ash cloud across upper Cook Inlet and over the city of Anchorage. AVO observers on board a small aircraft documented the violent eruption column roiling over the vent. In this view, steam rises around the base of the column where hot debris has fallen on and vaporized snow and ice. Crater Peak is obscured by clouds; the summit of Mount Spurr is to the left of the eruption column (photo by R G McGimsey, USGS, 8/18/92)

6. A lighter-toned cloud of ash rising off the south flank of Crater Peak, visible in the lower right, resulted from avalanches of hot debris, or pyroclastic flows, that had traveled down the side of the cone towards the Chakachatna River. The spreading eruption cloud at this time has reached at least 14 km (46,000 ft) altitude and formed a wide, anvil-shaped cloud. (photo by R G McGimsey, USGS, 8/18/92)

7. As shown in this oblique view of the south flank of Crater Peak, successive pyroclastic flows formed overlapping tongues of coarse debris that coursed down the slopes of Crater Peak and funneled into preexisting drainages. The farthest-traveled pyroclastic flows moved about 3 km from the crater rim, descending more than 1000 m (3280 ft) in elevation. (photo by C A Neal, USGS, 9/3/92)

8. Newly-erupted material within the pyroclastic-flow deposits consists of these brown, cauliflower-shaped cobble- and boulder-sized clasts. The chemical composition of most of the newly erupted material is that of basaltic andesite with a SiO_2 content of about 57%, a rock type typical for Crater Peak. Under the microscope, these rocks are only slightly vesicular and contain the minerals plagioclase, pyroxene, and hornblende in a micro-crystalline matrix with very little glass. Also ejected in smaller quantities were fragments, up to several meters across, of old volcanic material from the edifice of Crater Peak, smaller pieces of deeper, possibly plutonic and metamorphic rock, and partially melted and remobilized basement rock (next slide). (photo by C A Neal, USGS, 9/3/92)

9. A spectacular product of this eruption includes this example of inflated metamorphic rock which was ejected in small quantities during each of the three eruptions in 1992. This material appeared in various states of vesicularity and is believed to represent partially melted, frothed fragments of basement rock plucked from deep beneath Crater Peak. It is found as separate clasts of ejecta and also as inclusions within blocks of the 1992 andesite. (photo by T P Miller, USGS, 10/23/92)

10. Each eruption also violently ejected large bombs along a narrow ballistic trajectory from the vent. This view looking down the south flank of Crater Peak

shows the fall-colored tundra and 1992 pyroclastic-flow deposits dotted with numerous impact craters formed when these bombs slammed into the ground. These bomb showers probably occurred during explosions of superheated water that gained access to hot rock within the eruptive conduit below Crater Peak. Blocks 1 m (3.3 ft) across were thrown as much as 3 km (1.9 mi) from the vent. (photo by C A Neal, USGS, 9/3/92)

11. A geologist stands near one of the bomb craters on the south flank of Crater Peak. Measurements of the orientations of some of the craters indicate that many of the impacting bombs were spinning like a curveball when they hit the ground. (photo by C A Gardner, USGS, 9/26/92)

12. Fallout of coarse material during the eruption resulted in a narrow zone of deposition on the ground. This is a photograph of the fallout deposit from the August 18 eruption. Sixteen cm (6.3 in) of lapilli and coarse sand representing about 3.5 hours of eruption accumulated 8 km (5 mi) downwind of the vent. Note the different colors within the deposit: the light colored clasts at the base are about 23% less dense than the dark clasts at the top. This may mean that the first material to be erupted was richer in dissolved gases. (photo by R G McGimsey, USGS, 9/9/92)

13. Ash from Crater Peak mantles a car hood in Anchorage. By the time the August 18 eruption cloud passed over Anchorage, 125 km (78 mi) distant, the fallout consisted of coarse to fine sand-sized particles which accumulated to a thickness of 3 mm (1/8 in) in parts of the city. Residents were able to observe the oncoming eruption cloud which appeared as a dark storm cloud moving steadily overhead. (photo by R G McGimsey, USGS, 8/19/92)

14. Ash on the ground in Anchorage became resuspended in the air with the slightest breeze; vehicular traffic also contributed to unhealthy particulate levels in the air over the city. Many residents resorted to particle masks and had to take precautions to protect sensitive electronic equipment, car engines, etc. People with respiratory sensitivities were warned to stay indoors and keep physical activity to a minimum. (photo by R Emanuel, 8/19/92)

15. The Anchorage International Airport was closed to air traffic for 20 hours due to the ash blanketing runways. Clean-up took several days and was best accomplished by wetting down the ash followed by grading and sweeping trucks. Around the city, residents hosed down homes, driveways, and cars. (photo by R Emanuel, 8/19/92)

16. Following the August eruption, the inside of Crater Peak was mantled with pyroclastic debris and coarse talus from rock avalanches from the steep crater walls. The actual vent for the eruptions is located at the back left (NW) corner of the crater, here steaming profusely. Other "rootless" fumaroles emit steam through the thick blanket of debris on the crater rim and where banked against the crater walls. (photo by T P Miller, USGS, 8/20/92)

17. Crater Peak erupted for the final time in 1992 during the night of September 16-17. Like the first two eruptions, this event was brief and explosive, sending a cloud of gas and ash to 15 km (49,000 ft) in altitude over the volcano. Hot debris cascaded onto the surface of the Kidazgeni Glacier, adjacent to Crater Peak, causing extensive melting of the ice. This view shows the debris-mantled glacier and channels newly incised by meltwater. Downslope, avalanches of hot debris became increasingly water-rich and formed lahars that rushed down a steep-walled canyon and temporarily dammed the Chakachatna River. The eruption cloud from the September 16-17 eruption traveled east-northeast just missing Anchorage but heavily impacting the communities in the Matanuska-Susitna and Copper River basins. (photo by C A Gardner, USGS, 9/23/92)

18. The lahars of the September eruption were cold and dark when photographed only hours after emplacement. They formed these steep-sided lobate tongues of poorly sorted debris. Note person standing on lahar deposit. (photo by R G McGimsey, USGS, 9/17/92)

19. During the September 16-17 eruption, the interior of Crater Peak was once again mantled by many layers of fragmental debris varying in size from very fine ash to large blocks meters across. In this view, taken after the eruption, the vent is marked by the column of steam. Through the series of eruptions, the location of the vent appeared to have migrated somewhat further to the NW against the wall of the crater. Compare with slide # 1, pre-eruption. (photo by C A Neal, USGS, 9/24/92)

20. In early October, 1992, a period of intense tremor-like seismicity later interpreted to be related to vigorous degassing of the hydrothermal system beneath Crater Peak sent AVO to Level of Concern Color Code RED, the highest level of concern. Although no eruption ensued, a robust column of magmatic gas and steam, shown in this slide, was startlingly visible from Anchorage. In early November, an earthquake swarm probably related to a shallow intrusion of magma was recorded at shallow levels beneath Crater Peak. Although seismicity slowly declined, AVO scientists continued to measure detectable amounts of sulfur dioxide and carbon dioxide over Crater Peak into the early part of 1993. This probably reflects the continued degassing of magma stored beneath the vent. (photo by M P Doukas, USGS, 10/2/92)

REFERENCES

Alaska Volcano Observatory, 1993, Mt. Spurr's 1992 eruptions, EOS, Transactions, American Geophysical Union, v. 74, no. 19, p. 217-222.

Brantley, S., editor, 1990, The eruption of Redoubt Volcano, Alaska, December 14, 1989 - August 31, 1990, U.S. Geological Survey Circular 1061, 33 p.

Juhle, W. and H. Coulter, 1955, The Mt. Spurr eruption, July 9, 1953 (abstract); Transactions, American Geophysical Union, v. 36, p. 199-202.

Nye, C. J. and D. L. Turner, 1990, Petrology, geochemistry, and age of the Spurr volcanic complex, eastern Aleutian arc, Bulletin of Volcanology, v. 52, p. 205-226.

Riehle, J.R., 1985, A reconnaissance of the major Holocene tephra deposits in the upper Cook Inlet region, Alaska, Journal of Volcanology and Geothermal Research, v. 26, p. 37-74.

Wilcox, R.E., 1959, Some effects of recent volcanic ash falls with special reference to Alaska, U.S. Geological Survey Bulletin 1028, p. 409-476.

Wright, T.L., and Pierson, T.C., 1992, Living with volcanoes: The U.S. Geological Survey's Volcano Hazards Program, U.S. Geological Survey Circular 1073, 57 p.

GLOSSARY OF SELECTED TERMS

ash: fine fragments (less than 2 millimeters across) of lava or rock formed in an explosive volcanic eruption

andesite : volcanic rock with about 52% to 63% silica (silica is SiO_2, an essential constituent of most minerals found in rocks)

basalt: volcanic rock with less than 52% silica

basement rock: rock that is generally buried deeply beneath a surficial cover of sedimentary or volcanic rocks; usually plutonic or metamorphic

caldera: a large, roughly circular depression usually caused by volcanic collapse or explosion

clast: an individual fragment of rock produced by mechanical weathering or volcanic explosion

dome complex: an overlapping series of generally rounded piles of lava extruded onto the Earth's surface (see *lava dome*)

ejecta: a general term for anything thrown into the air from a volcano during an eruption; synonymous with *pyroclast* which means "fire" and "broken piece"

fallout: fragmental material ejected from a volcano and deposited on the ground; includes everything from blocks near the volcano to fine ash at great distances downwind

fumarole: a small opening or vent from which hot gases are emitted

hydrothermal: of or pertaining to the movement and chemical action of hot water in the ground

inclusion: a fragment of older rock entrained within newly erupting material

intrusion: an injection of molten material into a volcano or into the upper part of the Earth's crust; the "feeder pipe" for an eruption

lahar: a water-saturated mixture of mud and debris that flows rapidly downslope; often formed when hot volcanic material falls on snow and ice or when rain saturates loose volcanic debris

lapilli: ejected rock or pumice fragments between 2 and 64 millimeters across *lava dome*: a steep sided mass of viscous and often blocky lava extruded from a vent; normally has a rounded top and roughly circular outline

magma: molten rock within the earth; molten rock that erupts onto the surface is called "lava"

metamorphic rock: a rock that has been chemically and physically changed by being subjected to heat and pressure, usually deep within the earth

plutonic rock: a rock that forms from the cooling of molten material at great depth below the earth's surface

pyroclastic flow: a dense, hot, chaotic avalanche of rock fragments, gas, and ash that travels rapidly away from an explosive eruption column, often down the flanks of the volcano

satellitic cone: a volcanic cone that forms on the side of a volcano; a secondary vent

seismometer: an instrument that measures earthquake activity

seismicity: any earthquake activity

stratovolcano: (also called a *stratocone* or *composite cone*) a steep-sided volcano, usually conical in shape, built of lava flows and fragmental deposits from explosive eruptions

talus: rock fragments, usually coarse and angular blocks, that accumulate into a loose pile at the base of a steep slope or rock wall

tremor: a type of volcanic earthquake activity characterized by continuous vibration of the ground; often signifies movement of magma

vesicular: the texture of a volcanic rock characterized by abundant holes that reflect escaping gas (pumice is very vesicular)

vent: an opening in the earth's surface through which volcanic eruptions occur

volcanic rock: a rock formed by the cooling of molten material at or very near the surface of the earth