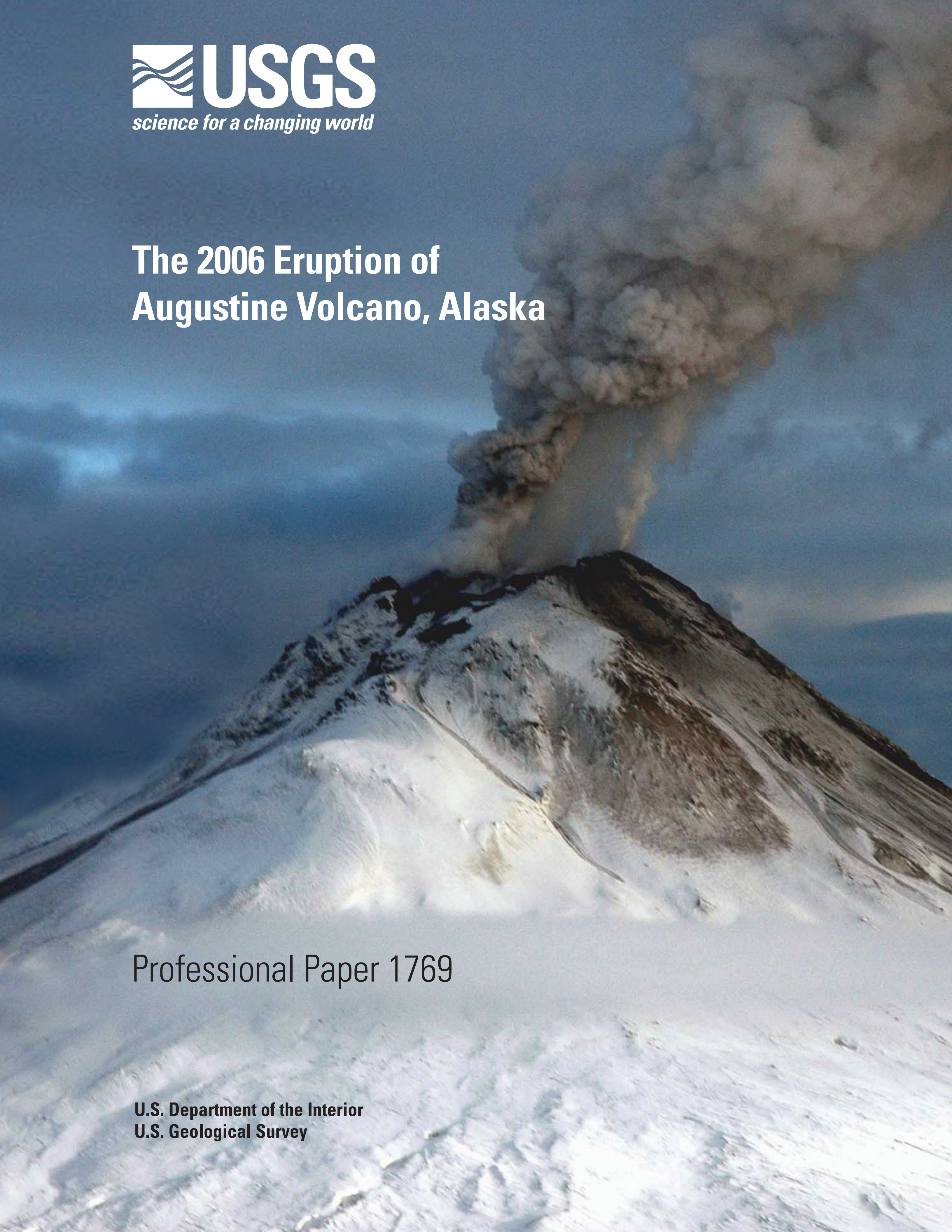

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The 2006 Eruption of Augustine Volcano, Alaska

Professional Paper 1769

U.S. Department of the Interior
U.S. Geological Survey

COVER

The west side of Augustine Volcano on January 12, 2006, with minor ash plume in progress. Ash and lahar deposits from explosions on January 11 are visible on volcano’s flanks. The original USGS/AVO photograph by Game McGimsey is shown below.

The 2006 Eruption of Augustine Volcano, Alaska

Edited by John A. Power, Michelle L. Coombs, and Jeffrey T. Freymueller

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

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Foreword

The 1986 explosive eruption of Augustine Volcano, Alaska, prompted the creation of the Alaska Volcano Observatory (AVO), a cooperative program of the U.S. Geological Survey (USGS), the University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological and Geophysical Surveys. Since then, this effective long-term partnership has led the way in monitoring Alaskan volcanoes, communicating the hazards associated with volcanic activity, and furthering our knowledge of volcanic processes at work in Alaska. The unrest at Augustine that began in 2005 and culminated in eruption in 2006 showcased the advancement of monitoring technology over the past two decades. Such developments, including broadband seismometers, continuous GPS receivers, infrared imagery, remote web cameras, atmospheric pressure sensors, and digital data transmission, greatly improved our observations and understanding of the processes driving the 2006 eruption of this island volcano. In addition, this was the first Alaskan eruption that the public could track in real time via the Internet, as seismic data and Webcam images were available to followers all over the world.

To ensure that public officials, key government agencies, affected industries, the news media, and the general public were well informed and able to take appropriate actions to deal with the hazards associated with the reawakening volcano, AVO did not work alone. Other scientists from the USGS Volcano Hazards Program provided their time and expertise. NOAA's West Coast Alaska Tsunami Warning Center, the National Weather Service, the Federal Aviation Administration, the Department of Homeland Security, and the EarthScope/Plate Boundary Observatory also contributed significantly to the effective response to the 2006 eruption of Augustine.

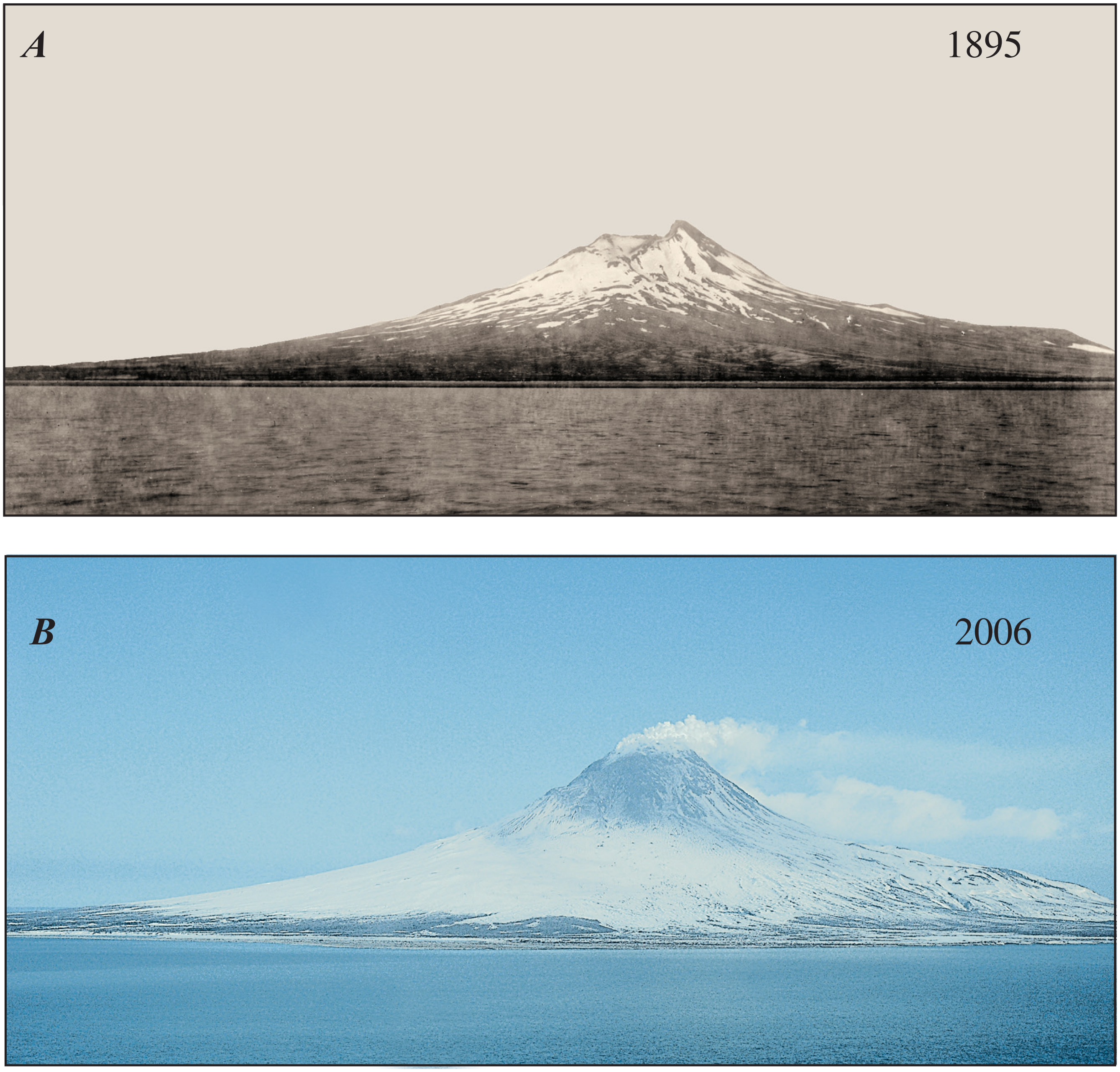
The scientific response to this eruption involved an even larger pool of talent that included researchers from collaborating government agencies, universities, and private research institutions, as well as contributions from citizens in south-central Alaska who collected ash samples and provided visual observations and photographs. The result of these efforts is a comprehensive picture of Augustine as a volcanic system—magma generation deep in the crust; magma mixing and ascent in the shallow crust and volcanic conduit; pyroclastic flows, lahars, and lava that greatly altered the landscape of Augustine Island; and eruptive plumes that deposited ash in south-central Alaska and traveled hundreds of kilometers downwind.

The hazard-communication protocols and scientific insights developed at Augustine in 2006 were quickly applied at explosive eruptions of Okmok Volcano (2008), Kasatochi Volcano (2008), and Redoubt Volcano (2009), Alaska. This quick succession of explosive eruptions in the Aleutian Arc highlights the need for programs that provide both long-term surveillance and warnings of the hazards presented by active volcanoes, as well as increase our knowledge of the underlying physical processes so that future eruption forecasts can be more accurate. Although these eruptions all occurred far from major population centers, each presented a serious hazard because of the far-reaching effects of airborne volcanic ash.

The unprecedented impacts of volcanic ash on air travel in Europe from the 2010 eruption of Eyjafjallajökull Volcano in Iceland serves as a further reminder of the importance of understanding and communicating the hazards associated with explosive volcanism. This collection of papers studying the 2006 eruption of Augustine Volcano will serve as an important reference for scientists responding to future volcanic unrest, whether in Alaska or anywhere else where people's lives can be placed in harm's way when volcanoes awake.

Marcia McNutt

Director
U.S. Geological Survey



Two views of the southwest side of Augustine Volcano showing changes in summit morphology over a 111-year period. *A*, Top image shows the Augustine volcanic cone taken from a ship in 1895 (USGS photo by C.W. Purington). *B*, A similar image taken from an airplane flying at an altitude of roughly 500 feet at approximately the same position on March 29, 2006 (AVO photo by Dan Cervelli).

Preface

Augustine Volcano, the most historically active volcano in Alaska's Cook Inlet region, again showed signs of life in April 2005. Escalating seismic unrest, ground deformation, and gas emissions culminated in an eruption from January 11 to mid-March of 2006, the fifth major eruption in 75 years. The eruption began with a series of 13 short-lived blasts over 20 days that sent pyroclastic flows; snow, rock, and ice avalanches; and lahars down the volcano's snow clad flanks; ash clouds drifted hundreds of kilometers downwind. Punctuated explosive activity gave way to effusion of lava and emplacement of thick block-and-ash flows on the volcano's north flank that continued through mid-February. In mid-March renewed extrusion resulted in the building of a new, higher summit lava dome and two blocky lava flows on the north and northeast flanks of the cone. The eruption resulted in ash fall on many south-central Alaskan communities and disrupted air traffic in the region.

Augustine's frequent eruptions and relatively easy access have long drawn volcanologists to study the accumulation, ascent, and eruption of andesitic to dacitic magma. Studies of the most recent activity before 2006, in 1976 and 1986, revealed that the volcano lately produces explosive eruptions that are preceded by months of unrest and injection of new magma into a storage region in the upper several kilometers of the crust. Each of these eruptions then followed a similar progression from explosive to effusive behavior over several months. Petrologic and geophysical observations suggest that these three eruptions were triggered by similar magma mixing events and that the subsequent ascent and eruption of magma was governed by processes that were roughly constant from one eruption to the next. Geologic studies of the island show that in the more distant past parts of Augustine's edifice have failed repeatedly, resulting in debris avalanches that entered the sea and, at least once, in 1883, caused a tsunami that hit surrounding Cook Inlet coastlines. Such edifice failures and resultant local tsunamis should be expected in the future.

Recognition of Augustine's frequent activity and hazardous nature led to the installation of a network of telemetered seismometers beginning in 1971, the establishment of a geodetic network in 1988, and the installation of other new instrumentation such as pressure sensors, broadband seismometers, and cameras by the Alaska Volcano Observatory (AVO), and the selection of Augustine for geodetic instrumentation through the EarthScope/Plate Boundary Observatory program in 2004. In addition, remote sensing techniques, such as airborne thermal imaging and the advanced spaceborne thermal emission and reflection radiometer (ASTER), provided novel and often critical information as the 2006 eruption progressed. The combination of a long-term seismic network and an array of new monitoring techniques has provided a breadth and depth of understanding of Augustine's most recent activity that was not possible in the past.

This volume contains 28 chapters reporting on a diverse suite of new scientific observations and investigations that were motivated by the 2006 eruption. Understanding the magmatic processes that drive eruptions, identifying eruptive events, tracking the movement of ash clouds, and communicating the resultant hazards to other government agencies and the public are all critical tasks for AVO, and chapters touch upon all of these topics. One goal in this compilation is to synthesize the diverse information into as complete an understanding of the magmatic and eruptive processes as possible.

An equally important goal is to provide a framework for diagnosing periods of unrest and formulating forecasts of eruptions that will certainly take place at Augustine in the future. This latter goal is especially important, as Augustine's frequent eruptive activity suggests that another eruption can be expected within the next several decades. Consequently, the investigations in this volume are intended to provide both a means to better forecast future eruptive episodes and also an opportunity to formulate and test future hypotheses for magmatic and eruptive processes. Future eruptions may follow a course similar to those observed in 1976, 1986, and 2006. However, a major perturbation that upsets conditions within the magmatic system could occur, owing perhaps to the rise of a much larger or different parental magma or to a large edifice failure similar to the 1883 sector collapse. In such events, the comprehensive study of past eruptions will provide data critical to assessing the current state of the magmatic system.

In assembling this volume we have sought as consistent and accurate a portrayal of the 2006 eruption as possible. We have asked all authors to refer to the same basic eruption chronology, unless their observations and data require alternative explanations. Naturally, not all techniques or methodologies produce a completely consistent set of observations, nor do the precise conclusions in every paper support one another. We have grouped chapters on the basis of discipline. Papers that focus on specific techniques, methodology, or instrumentation are placed throughout the volume where they best fit with others that rely on their results.

We gratefully acknowledge the contributions of many reviewers and editorial assistance from Jim Hendley, Peter Stauffer, George Havach, Judy Weathers, Manuel Nathenson, Jan Zigler, and many others.

John A. Power, Michelle L. Coombs, and Jeffrey T. Freymueller

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Petrology and Geochemistry

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Remote Sensing and Volcanic Emissions

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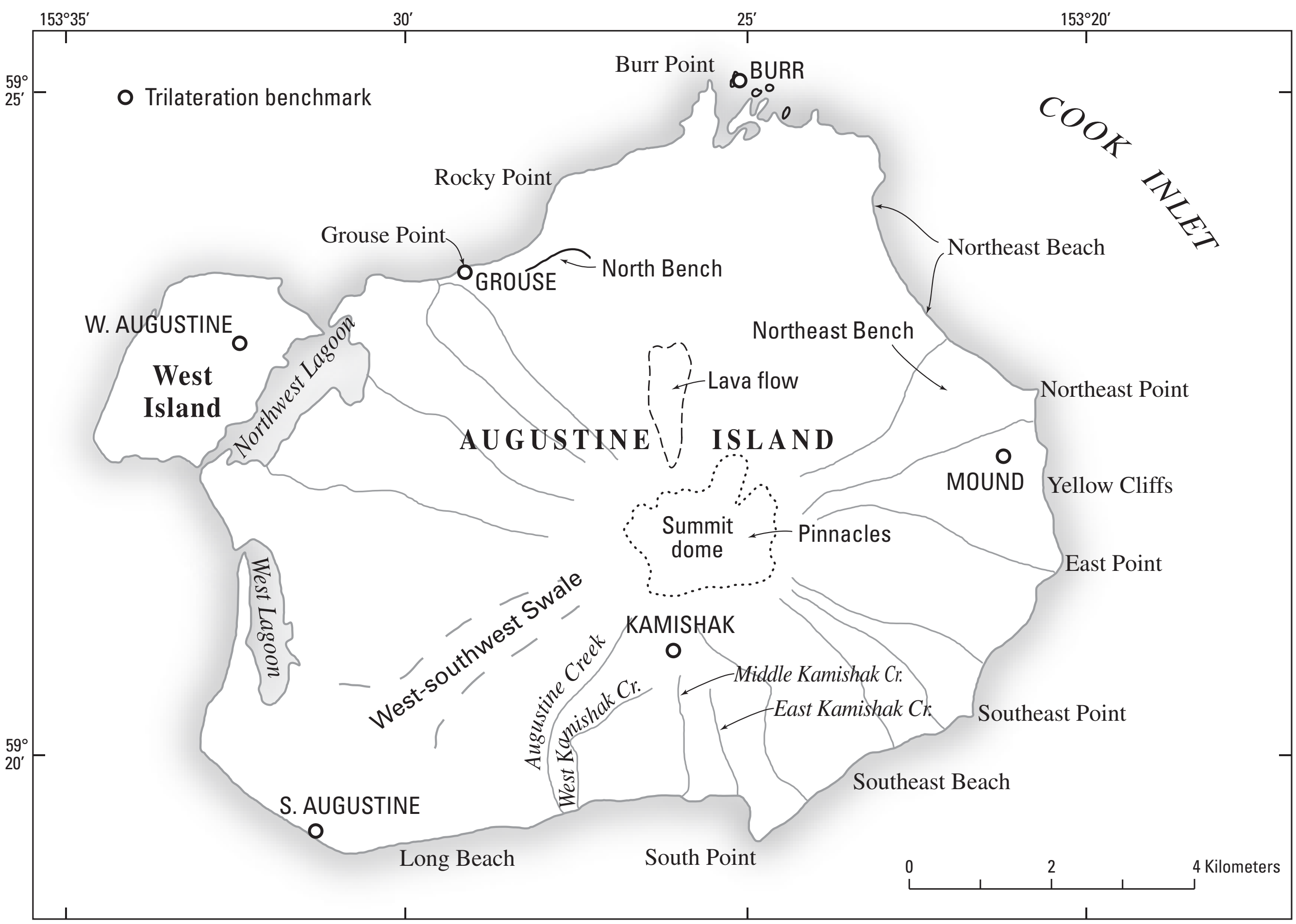
Note on Geographic Names on Augustine Island

Few place names on Augustine Island are formally recognized by the U.S. Board on Geographic Names (http://geonames.usgs.gov/). All place names associated with Augustine are informal with the exception of Burr Point, Augustine Creek, Augustine Island, and Augustine Volcano.

With the exception of the place names noted above, place names on Augustine Island are unofficial and only have capitalization for clarity. Within U.S. Geological Survey Professional Paper 1769 efforts have been made to consistently use place names on Augustine Island. The use of erroneous and unofficial names for Augustine Volcano—Mount Augustine and Mount Saint Augustine—has not been permitted except in historical quotations.

The map below shows many of the place names, both official and unofficial, used on Augustine Island.



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The 1986 explosive eruption of Augustine Volcano, Alaska, prompted the creation of the Alaska Volcano Observatory, a cooperative program of the U.S. Geological Survey, the University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological and Geophysical Surveys. Since then, this effective long-term partnership has led the way in monitoring Alaskan volcanoes, communicating the hazards associated with volcanic activity, and furthering our knowledge of volcanic processes at work in Alaska. The unrest at Augustine that began in 2005 and culminated in eruption in 2006 showcased the advancement of monitoring technology over the past two decades. Such developments, including broadband seismometers, continuous GPS receivers, infrared imagery, remote web cameras, atmospheric pressure sensors, and digital data transmission, greatly improved our observations and understanding of the processes driving the 2006 eruption of this island volcano. In addition, this was the first Alaskan eruption that the public could follow in real time via the Internet, and seismic data and Web-cam images were available to followers all over the world.

From the Foreword by Marcia K. McNutt