Geomorphology 246 (2015) 123–145

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Review

Geomorphic consequences of volcanic eruptions in Alaska: A review

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ARTICLE INFO

Article history:
Received 18 November 2014
Received in revised form 29 May 2015
Accepted 2 June 2015
Available online 6 June 2015

Keywords:
Alaska eruptions
Geomorphology
Impacts
Lahars

ABSTRACT

Eruptions of Alaska volcanoes have significant and sometimes profound geomorphic consequences on surrounding landscapes and ecosystems. The effects of eruptions on the landscape can range from complete burial of surface vegetation and preexisting topography to subtle, short-term perturbations of geomorphic and ecological systems. In some cases, an eruption will allow for new landscapes to form in response to the accumulation and erosion of recently deposited volcaniclastic material. In other cases, the geomorphic response to a major eruptive event may set in motion a series of landscape changes that could take centuries to millennia to be realized. The effects of volcanic eruptions on the landscape and how these effects influence surface processes has not been a specific focus of most studies concerned with the physical volcanology of Alaska volcanoes. Thus, what is needed is a review of eruptive activity in Alaska in the context of how this activity influences the geomorphology of affected areas. To illustrate the relationship between geomorphology and volcanic activity in Alaska, several eruptions and their geomorphic impacts will be reviewed. These eruptions include the 1912 Novarupta–Katmai eruption, the 1989–1990 and 2009 eruptions of Redoubt volcano, the 2008 eruption of Kasatochi volcano, and the recent historical eruptions of Pavlof volcano. The geomorphic consequences of eruptive activity associated with these eruptions are described, and where possible, information about surface processes, rates of landscape change, and the temporal and spatial scale of impacts are discussed.

A common feature of volcanoes in Alaska is their extensive cover of glacier ice, seasonal snow, or both. As a result, the generation of meltwater and a variety of sediment–water mass flows, including debris-flow lahars, hyperconcentrated-flow lahars, and sediment-laden water floods, are typical outcomes of most types of eruptive activity. Occasionally, such flows can be quite large, with flow volumes in the range of 10^7–10^9 m^3. A review of the lahars generated during the 2009 eruption of Redoubt volcano will illustrate the geomorphic impacts of lahars on stream channels and riparian habitat. Although much work is needed to develop a comprehensive understanding of the geomorphic consequences of volcanic activity in Alaska, this review provides a synthesis of some of the best-studied eruptions and perhaps will serve as a starting point for future work on this topic.

Published by Elsevier B.V.

Contents

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http://dx.doi.org/10.1016/j.geomorph.2015.06.004
0169-555X/Published by Elsevier B.V.

1. Introduction

Volcanic eruptions in the Aleutian arc of Alaska have had a profound impact on the landscape, and throughout this region (Fig. 1) volcanic activity of various magnitudes and frequencies have exerted an important influence on hydrologic, biologic, atmospheric, and geomorphic systems (Vanderhoek and Nelson, 2007; DeGange et al., 2010). Volcanic activity over long time scales (tens to hundreds of thousands of years) has resulted in the growth of many of the major mountains in parts of the Alaska Range, the Aleutian Range, and the Wrangell Mountains. It could be argued that eruptions and their aftermath have played a dominant role in shaping the ecosystems and landscapes of southern and southwestern Alaska, and the Aleutian Islands, as volcanoes and their eruptive products are the principal landforms of these regions. Volcanoes within the Aleutian arc (Fig. 1) have exhibited a wide variety of eruptive styles, ranging from mild effusive eruptions to catastrophic caldera-forming events associated with voluminous ash flow sheets and tephra fallout over broad areas of Alaska and the Yukon (Miller and Smith, 1987; Preece et al., 2000). Some of the largest documented eruptions of late Quaternary age worldwide have occurred in Alaska, and some of the most historically active volcanoes in North America also are found here. Given the significant magnitude of many Alaska eruptions and the high frequency of occurrence of eruptive activity, it is worthwhile to examine how eruptive activity and the products of this activity have affected the geomorphic evolution of landscapes throughout the Aleutian arc. This task is practical and academic because of the obvious implications for hazards to people, infrastructure, and the environment and for understanding how volcanic systems evolve in an area that is as geologically dynamic as Alaska.

Although much of Alaska and the Aleutian arc are remote and unpopulated, the frequency of modern eruptions (average of 1–2 per year) presents a unique opportunity to observe and evaluate geomorphic processes that operate on newly formed volcanic deposits. In addition to their frequent eruptive activity, most active volcanoes in Alaska are large stratocones with significant relief (several thousand meters), and therefore, ample potential energy associated with steep flanking slopes is available as a driving mechanism for geomorphic processes. As a result of their high relief and northern location, nearly every volcano in Alaska has some amount of ice and snow cover. This means that water is readily available, and as a result, a variety of flowing sediment–water mixtures (lahars) can form on the flanks of volcanoes and in surrounding valleys during eruptive activity.

Volcanoes that are characterized by frequent explosive eruptions typically have a mantling cover of loose, fragmental pyroclastic debris that is easily eroded by water-rich mass flows. Eruption-related introduction of large volumes of water and sediment into river systems

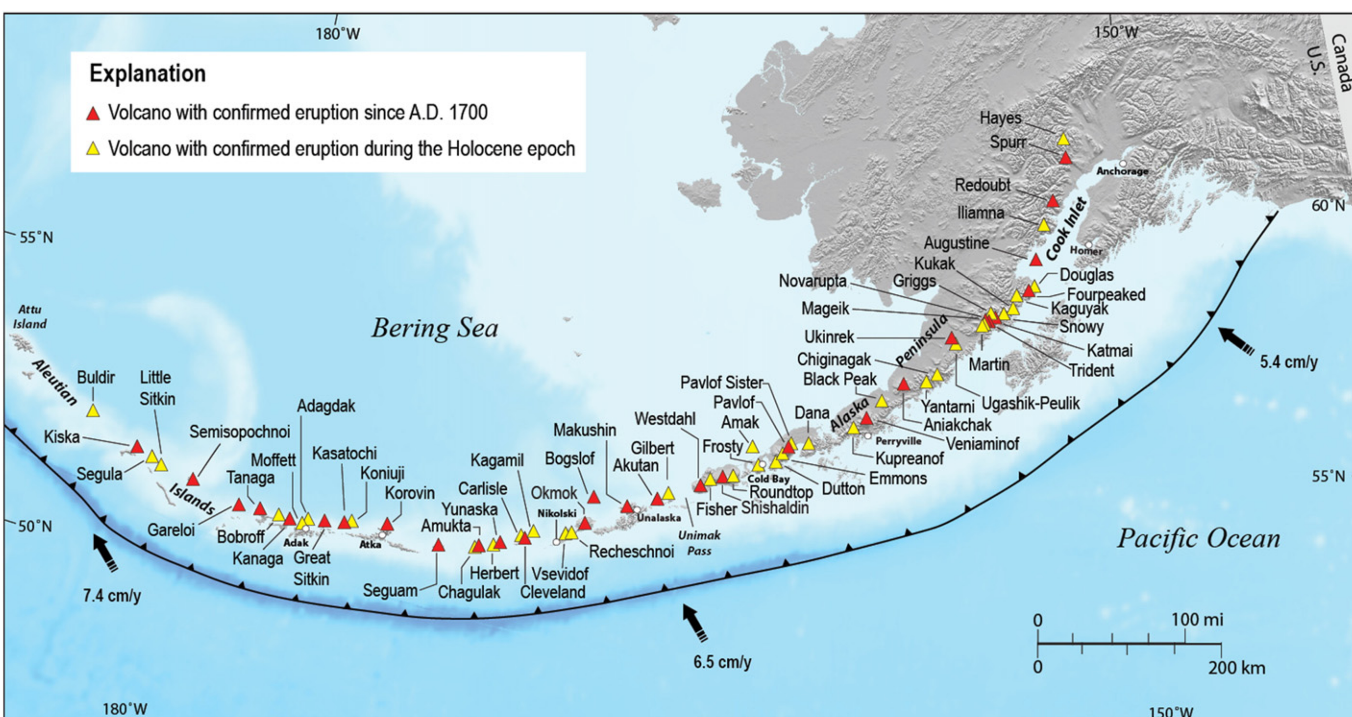

Fig. 1. Major volcanoes and volcanic fields of the Aleutian arc. The red triangles indicate volcanoes that have experienced eruptive activity since A.D. 1700 and are considered historically active. The yellow triangles indicate volcanoes that have had confirmed eruptive activity within the past 10,000 years. Also shown are the location of the Aleutian trench and the rates of plate motion for the Pacific Plate.
From Freymueller et al. (2008).