Quaternary Science Reviews 168 (2017) 101–122

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

A full holocene tephrochronology for the Kamchatsky Peninsula region: Applications from Kamchatka to North America

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ARTICLE INFO

Article history:
Received 30 October 2016
Received in revised form
15 March 2017
Accepted 28 April 2017
Available online 19 May 2017

Keywords:
Holocene
Paleogeography
Tephrochronology
Northern Pacific
Kamchatka
Data analysis
Volcanic glass chemistry
Age modeling

ABSTRACT

Geochemically fingerprinted widespread tephra layers serve as excellent marker horizons which can directly link and synchronize disparate sedimentary archives and be used for dating various deposits related to climate shifts, faulting events, tsunami, and human occupation. In addition, tephras represent records of explosive volcanic activity and permit assessment of regional ashfall hazard. In this paper we report a detailed Holocene tephrochronological model developed for the Kamchatsky Peninsula region of eastern Kamchatka (NW Pacific) based on ~2800 new electron microprobe analyses of single glass shards from tephra samples collected in the area as well as on previously published data. Tephra ages are modeled based on a compilation of 223 ^{14}C dates, including published dates for Shiveluch proximal tephra sequence and regional marker tephras; new AMS ^{14}C dates; and modeled calibrated ages from the Krutoberegovo key site. The main source volcanoes for tephra in the region are Shiveluch and Kliuchevskoi located 60–100 km to the west. In addition, local tephra sequences contain two tephras from the Plosky volcanic massif and three regional marker tephras from Ksudach and Avachinsky volcanoes located in the Eastern volcanic front of Kamchatka. This tephrochronological framework contributes to the combined history of environmental change, tectonic events, and volcanic impact in the study area and farther afield. This study is another step in the construction of the Kamchatka-wide Holocene tephrochronological framework under the same methodological umbrella. Our dataset provides a research reference for tephra and cryptotephra studies in the northwest Pacific, the Bering Sea, and North America.

1. Introduction

Tephra layers are widely used for correlation and dating of various deposits and landforms and for the synchronization of disparate paleoenvironmental archives. These applications are in high demand in paleoclimatology, paleoseismology, archaeology, and other Quaternary science disciplines (e.g., Alloway et al., 2007; Lowe, 2011). Regions located within 100 km of active volcanoes often host sequences of visible tephra layers which permit the construction of detailed tephrochronological frameworks for dating deposits and landforms formed by various geological events (e.g., Braitseva et al., 1997; Shane, 2005; Fontijn et al., 2016; Nakamura, 2016). For instance, in eastern Kamchatka deposits left by catastrophic events such as tsunami, co-seismic subsidence, liquefaction, and faulting form distinct silt, sand and debris layers or wedges sandwiched between tephra layers which can be differentiated by thickness, color, grain size, stratification, grading and physical properties (Figs. 1–3). In paleotsunami research, for example, tephra layers have been a major tool for correlation between and among sites along the Japan-Kuril-Kamchatka subduction zone (e.g., Bourgeois et al., 2006; Sawai et al., 2009; MacInnes

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http://dx.doi.org/10.1016/j.quascirev.2017.04.031
0277-3791/

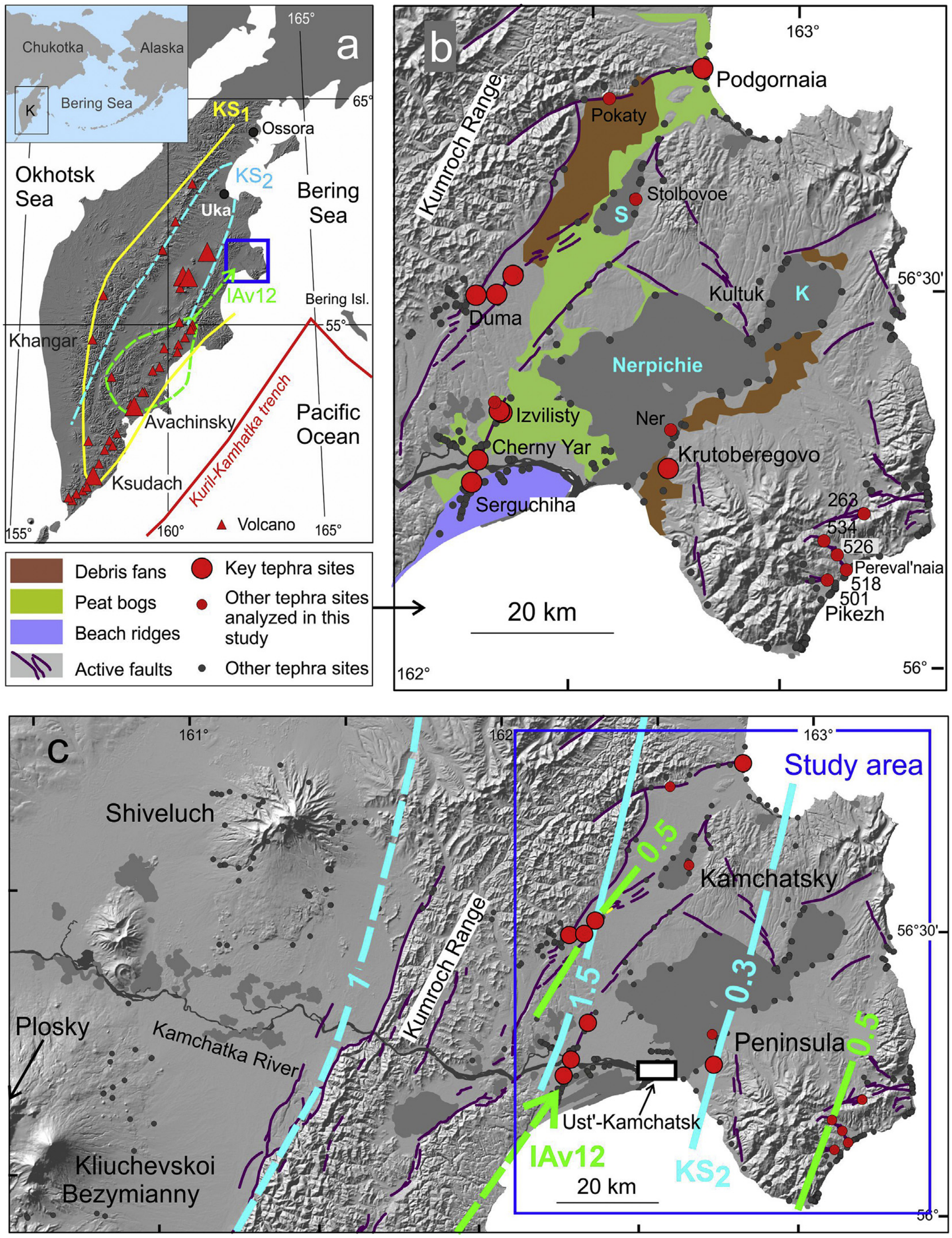

Fig. 1. Locations of the study area (dark blue frames on **a** and **c**), volcanoes, and main tephra sites shown on SRTM global digital elevation model (spatial resolution is approx. 90 m; data available from the U.S. Geological Survey). Inset in **a** shows position of the Kamchatka Peninsula (K). **a** – position of the study area relative to the Kamchatka-Aleutian junction. Holocene volcanoes are shown with red triangles, larger triangles show source volcanoes for tephras in the study area. Volcanoes mentioned in the text are labeled here and in **b** and **c**. Volcanic chain along the eastern coast of Kamchatka forms the Eastern Volcanic Front. Dispersal area (1 cm outline) of the main regional tephras known to have reached the study area is shown with lines and labels of matching colors: KS$_1$ and KS$_2$ according to Braitseva et al. (1997) refined after Kyle et al. (2011) and Plunkett et al. (2015); IAv12 (AV$_4$) – outline according to Braitseva et al. (1998) with an arrow to the Cherny Yar site where this tephra was mentioned by Bazanova et al. (2005). **b** – detailed map for the study area showing major morphological features and active faults (Pinegina et al., 2014), and research sites; legend for **b** is located left of the map. Lakes are in dark-gray and labeled with blue: S – Stolbovoe Lake, K – Kultuchnoe Lake; **c** – position of study area relative to closest active volcanoes: Shiveluch, Plosky, Kliuchevskoi, and Bezymianny. Location of Ust'-Kamchatsk village is labeled. Newly determined positions of isopachs for IAv12 and KS$_2$ tephras are shown in solid lines, thickness in cm. Other symbols as in **a** and **b**. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2016); tsunami deposits themselves are often lacking unique features and therefore cannot be differentiated on their own (Bourgeois et al., 2006). Tephra layers have also been used to determine landslide and turbidity-current frequencies, which may be correlated with paleoseismic events (e.g., Adams, 1990; Moernaut et al., 2014; Pouderoux et al., 2014). Paleoseismological studies of active faults use tephra layers to date faulting events and correlate them over the fault system, and also to evaluate the rate of