Global and Planetary Change 134 (2015) 26–40

Contents lists available at ScienceDirect

Global and Planetary Change

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

Distal tephrochronology in volcanic regions: Challenges and insights from Kamchatkan lake sediments

Gill Plunkett [a,*], Sarah E. Coulter [a], Vera V. Ponomareva [b], Maarten Blaauw [a], Andrea Klimaschewski [a], Dan Hammarlund [c]

[a] School of Geography, Archaeology and Palaeoecology, Queen's University Belfast, Belfast, Northern Ireland, UK
[b] Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russia
[c] Quaternary Sciences, Department of Geology, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden

ARTICLE INFO

Article history:
Received 31 October 2014
Received in revised form 20 March 2015
Accepted 1 April 2015
Available online 10 June 2015

Keywords:
Distal tephra
Tephrochronology
Age-modelling
Kamchatka
Holocene

ABSTRACT

Kamchatka is one of the world's most active volcanic regions and has hosted many explosive eruptions during the Holocene. These eruptions had the potential to disperse tephra over wide areas, forming time-synchronous markers wherever those tephras are found. Recent research in Kamchatka has begun to focus on the geochemical analysis of individual glass shards in order to characterise tephra layers. We have applied this approach to the study of visible tephras from three lakes – one in central and two in northern Kamchatka – with the aim of identifying key tephras and potential issues in the application of distal (>100 km from an active volcano) tephra in volcanically complex regions. In total, 23 tephras from 22 tephra beds have been geochemically analysed, representing products from at least four volcanic systems in Kamchatka. We demonstrate that distal lake sediments in the region can yield reliable tephrostratigraphies, capturing tephra from eruptions that have the greatest potential to disperse volcanic ash beyond the region. We draw attention to issues relating to correlating and distinguishing key marker horizons from the highly active Shiveluch Volcano, namely the need to ensure inter-lab comparability of geochemical data and good chronological control of the proximal and distal tephras. Importantly, we have also extended the known distribution of two key tephra isochrons from the Ksudach volcano. Our work contributes valuable glass geochemical on data several key marker beds that will facilitate future tephra and palaeoenvironmental research within and beyond Kamchatka.

1. Introduction

Tephrochronology is a well-established technique for reconstructing volcanic histories and dating past environmental change. Proximal tephrochronology in areas close to volcanic sources has traditionally focused on characterising the morphology, whole rock geochemistry and mineralogy of visible tephra beds, and mapping their extent (e.g. Thorarinsson, 1967; Braitseva et al., 1997). Increasingly, characterisation of the glass component is becoming standard practice in volcanic regions (e.g. Larsen, 1981; Gehrels et al., 2006; Fontijn et al., 2014), opening up opportunities to extend the reach of tephrochronology well beyond the confines of the immediate tephra fallout zone. In more distal locations (100s–1000s km), visible or microscopic tephra horizons comprise ash beds that cannot usually be identified reliably by their petrological or morphological features but instead rely on the geochemical characterisation of the glass, the tephra component that is most widely dispersed. Although applied principally as a dating method, distal tephrochronology also enables the extent of volcanic ash dispersal and the possible environmental, economic and societal impact of given eruptions to be assessed (Lane et al., 2013; Jensen et al., 2014; Sun et al., 2014). The distal tephra record is essentially biased towards eruptions that were sufficiently powerful to disperse ash over long distances, but can nevertheless capture events that have not been documented or preserved in the proximal record (de Fontaine et al., 2007; Payne et al., 2008).

This paper describes the analysis of distal tephras in three lakes in Kamchatka (western Beringia) as an aid to dating the lakes' Holocene sediment sequences and as a means of assessing the value and challenges of integrating distal and proximal tephra records in a highly active volcanic region. A detailed tephrostratigraphical framework for Kamchatka has previously been established on the basis of extensive visible tephra layers, all of which derive from Kamchatkan volcanic systems (e.g. Braitseva et al., 1992, 1997; Ponomareva et al., 2007). Visible Kamchatkan tephra beds have aided the dating of palaeoenvironmental change on the Peninsula (e.g. Savoskul and Zech, 1997; Bäumler and Zech, 2000; Dirksen et al., 2013) and centimetre-thick ash beds have been identified in sedimentary sequences from the Sea of Okhotsk (Gorbarenko et al., 2002; Derkachev et al., 2012), the Asian mainland (Melekestsev et al., 1991; Ponomareva et al., 2013b), the Kuril Islands

* Corresponding author.
E-mail address: g.plunkett@qub.ac.uk (G. Plunkett).

http://dx.doi.org/10.1016/j.gloplacha.2015.04.006
0921-8181/

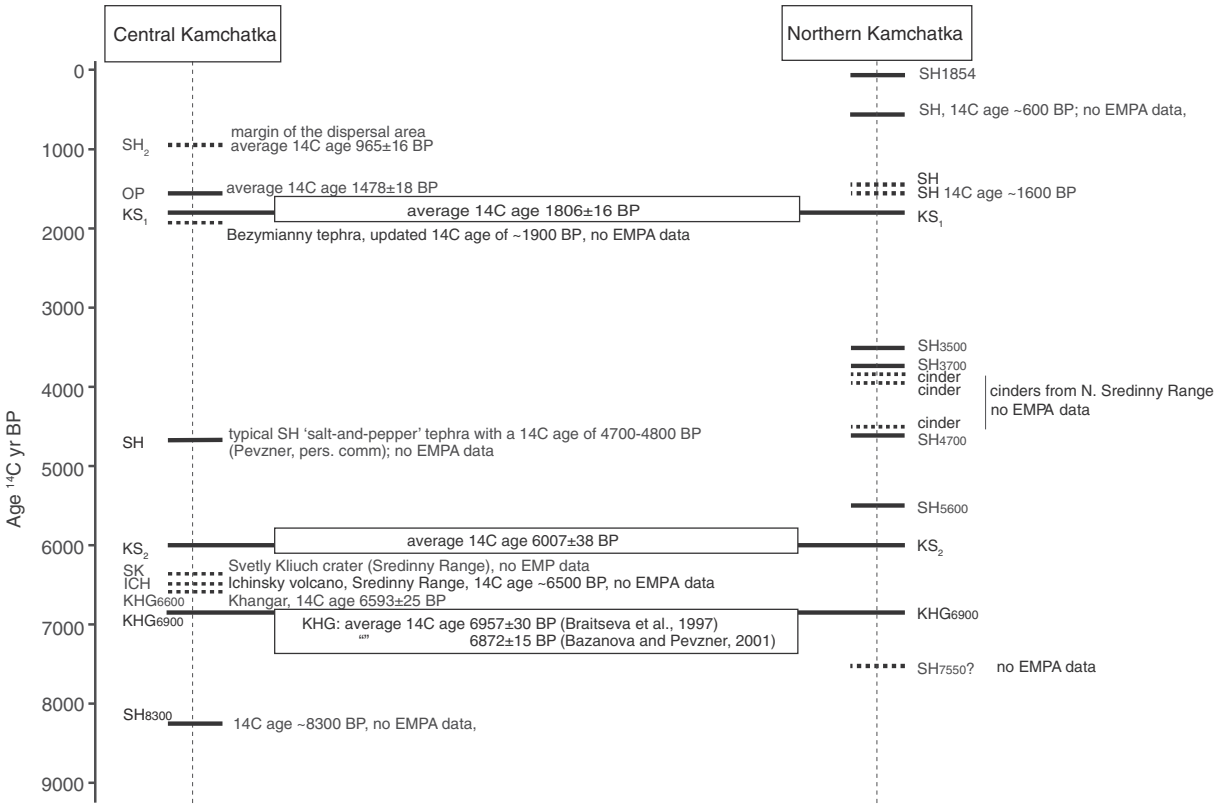

Fig. 1. Schematic expected tephrostratigraphy for northern (Pechora and Lifebuoy Lakes area) and central Kamchatka (Olive-backed Lake area) shown on a ^{14}C timescale, based on published tephra isopachs (Braitseva et al., 1997; Kyle et al., 2011), published sections through Holocene sediments (Pevzner, 2010, 2011; Dirksen et al., 2013), and ^{14}C ages (Braitseva et al., 1997; Bazanova and Pevzner, 2001; Pevzner, 2004, 2010, 2011; Ponomareva et al., in press). Only half of the shown tephra layers have been geochemically analysed (Kyle et al., 2011); for others their relation to proximal tephra beds is not confirmed. Solid lines show major regional tephra layers; dashed lines show smaller tephras. Codes for tephra layers: SH — general code for all tephra layers from Shiveluch volcano; OP — Baranii Amphitheater crater (Opala volcano); KS — general code for all tephra layers from Ksudach calderas; KHG — code for tephras from Khangar volcano; SK — Svetly Kliuch crater; ICH — Ichinsky volcano. Numbers after the tephra codes shown in subscript are approximate ^{14}C ages.

to the south of Kamchatka (Hasegawa et al., 2011; Kyle et al., 2011), the western Aleutian islands (Kyle et al., 2011), the Bering Sea (Ponomareva et al., 2013a, in press) and the NW Pacific Ocean (Cao et al., 1995). The first comprehensive attempt to characterise glass chemistries from major Holocene marker beds was published by Kyle et al. (2011). An extensive programme of electron probe microanalysis

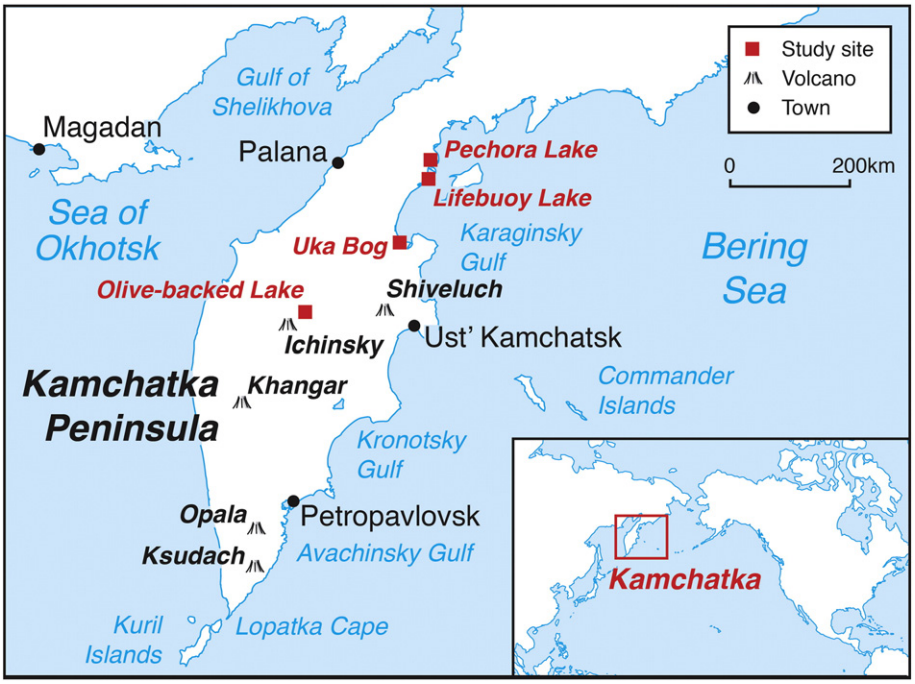

Fig. 2. Location of Pechora, Lifebuoy and Olive-backed lakes in Kamchatka. The locations of the main volcanoes discussed in the text and Uka Bog are also indicated.