Journal of Volcanology and Geothermal Research 314 (2016) 169–181

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

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

Lake-floor sediment texture and composition of a hydrothermally-active, volcanic lake, Lake Rotomahana

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ARTICLE INFO

Article history:
Received 7 August 2015
Revised 22 February 2016
Accepted 25 February 2016
Available online 3 March 2016

Keywords:
Lake Rotomahana
Lacustrine sediment
Volcanic lake
Hydrothermal system
Silica

ABSTRACT

Young volcanic lakes undergo a transition from rapid, post-eruptive accumulation of volcaniclastic sediment to slower pelagic settling under stable lake conditions, and may also be influenced by sublacustrine hydrothermal systems. Lake Rotomahana is a young (129 year-old), hydrothermally-active, volcanic lake formed after the 1886 Tarawera eruption, and provides a unique insight into the early evolution of volcanic lake systems. Lake-bottom sediment cores, 20–46 cm in length, were taken along a transect across the lake and characterised with respect to stratigraphy, facies characteristics (i.e., grain size, componentry) and pore water silica concentrations. The sediments generally comprise two widespread facies: (i) a lower facies of light grey to grey, very fine lacustrine silt derived from the unconsolidated pyroclastic deposits that mantled the catchment area immediately after the eruption, which were rapidly reworked and redeposited into the lake basin; and (ii) an upper facies of dark, fine-sandy diatomaceous silt, that settled from the pelagic zone of the physically stable lake. Adjacent to sublacustrine hydrothermal vents, the upper dark facies is absent, and the upper part of the light grey to grey silt is replaced by a third localised facies comprised of hydrothermally altered pale yellow to yellowish brown, laminated silt with surface iron-rich encrustations. Microspheres, which are thought to be composed of amorphous silica, although some may be halloysite, have precipitated from pore water onto sediment grains, and are associated with a decrease in pore water silicon concentration. Lake Rotomahana is an example of a recently-stabilised volcanic lake, with respect to sedimentation, that shows signs of early sediment silicification in the presence of hydrothermal activity.

1. Introduction

Volcanic lakes undergo dynamic sedimentological changes in the few months to decades after their eruptive origin (e.g., Smith, 1991; Larson, 1993, and references therein). Re-established, or new hydrothermal systems are also a common feature of young volcanic lakes (e.g., Casadevall et al., 1984; Brantley et al., 1987; Christenson and Wood, 1993; Pasternak and Varekamp, 1997). Physical evidence for early sedimentation and environmental change within old volcanic lakes is often preserved in lake cores through volcaniclastic-lacustrine successions within maar-diatremes (e.g., Pirrung et al., 2003; Németh et al., 2008; Kaulfuss, 2013; Fox et al., 2015; Marchetto et al., 2015). Lake-bottom sediment core can also be used to infer the effects of volcanic tephra on the limnology of modern lakes (e.g., Rawlence, 1985; Fish, 1979). Lake Rotomahana, in the North Island of New Zealand, is an important example of a very young volcanic lake, in the classification of Christenson et al. (2015), which formed within a valley cut by a chain of craters, then dammed by volcanic material during and shortly after the June 10, 1886 Mount Tarawera eruption. Previous sediment cores from this lake (e.g., Trolle et al., 2008) have intersected both the modern pelagic lacustrine sediments and underlying volcaniclastic deposits associated with the 1886 eruption. This succession records significant process changes during the evolution of the lake. Active sublacustrine hydrothermal activity has also been detected on the lake floor (e.g., Walker et al., 2016; de Ronde et al., 2016). Thus, cores of lake sediment are likely to record near-surface physical evidence of this activity. This paper describes the physical characteristics of the sediments below the floor of Lake Rotomahana and discusses the post-eruptive sedimentological and hydrothermal processes associated with the young history of this volcanic lake.

2. Geological and hydrothermal setting

Lake Rotomahana is located within the southeastern margin of the Okataina Volcanic Complex, at the edge of the structural caldera boundary (Seebeck et al., 2010; de Ronde et al., 2016). The country rock geology surrounding Lake Rotomahana was mapped and discussed by Nairn (1989, 2002) and Pittari et al. (2016), and comprises predominantly rhyolite lava domes and associated pyroclastic deposits, intra-caldera ignimbrites and outflow ignimbrites from other calderas. Localised

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http://dx.doi.org/10.1016/j.jvolgeores.2016.02.025
0377-0273/

basaltic scoria deposits have been documented on the northern and southern lake shores (Nairn, 1979, 1989, 2002), and associated basaltic dikes have been identified by a magnetic survey of the lake (Caratori Tontini et al., 2016).

The modern geomorphology and hydrology of Lake Rotomahana (Figs. 1 and 2) are a consequence of landscape modifications from the June 10, 1886 Mount Tarawera eruption (e.g., Cole, 1970; Nairn, 1979; Keam, 1988, 2016). The modern lake is 6.2 km long, oriented in a southwest to northeast direction, and is up to 2.5 km wide at its southwestern end, where it reaches a maximum depth of 130 m. Fig. 1 shows the catchment streams for the lake, however there is no natural surface outlet; water seepage to Lake Tarawera occurs on the northern side. The Rotomahana lake level (337 m above sea level, a.s.l.) is 38 m higher than the level of Lake Tarawera (299 m a.s.l.). The lowest point on the rim between the two lakes is 343 m a.s.l. (Fig. 1) and an overflow pipe and culvert were constructed across this saddle in 1974 (R. Keam, personal communication). de Ronde et al. (2016) have identified fourteen phreatomagmatic maar and/or hydrothermal eruption craters on the lake floor, originating from the 1886 eruption. Prior to the eruption, the area was a swampy valley with two significantly smaller lakes, Lake Rotomahana and Lake Rotomakariri, to the northeast (Keam, 2016). These lakes were drained to Lake Tarawera through the Kaiwaka Valley, which was subsequently filled by volcanic debris during the eruption creating a natural dam.

During the climactic phase of the Mount Tarawera eruption, which lasted for about 4 h, a succession of craters was excavated along a 16 km-long, northeast-trending linear structure across Mt. Tarawera, the lower-lying old lakes Rotomahana and Rotomakariri, and extending into the Waimangu Valley. Eruption vents across Mount Tarawera produced a basaltic plinian eruption column that dispersed a scoria fall deposit (Tarawera Pyroclastics Member, Nairn, 2002) largely to the northeast; scoria deposits surrounding Lake Rotomahana ranged from 3 cm (SE end) to 50 cm (NW end) (Walker et al., 1984). Eruption vents that formed along the extension of the linear structure to the southeast, across the low-lying lake region, produced a phreatomagmatic eruption column and pyroclastic base surges (Nairn, 1979), which were largely directed to the northwest. A lithic lapilli ash deposit, up to 20 m-thick (Rotomahana Pyroclastics Member, Nairn, 2002), mantled the landscape around the lake (Nairn, 1979; Pittari et al., 2016).

Shortly after the eruption, the Rotomahana craters began to fill with cold water, which quenched much of the steam discharges associated with these by late 1887, and the lake had filled to its present level by the mid-1890s (Healy, 1975). Much of the post-eruptive sediment fill has accumulated in the largest craters of the central lake basin, up to 37 m in thickness (de Ronde et al., 2016), and was probably transported here by lake bottom currents. Trolle et al. (2008) estimated a net sedimentation rate of 0.8 mm y^{-1} (0.08 kg m^{-2} y^{-1}) over the period 1886–2006, based on the depth to the Tarawera tephra in lake-bottom

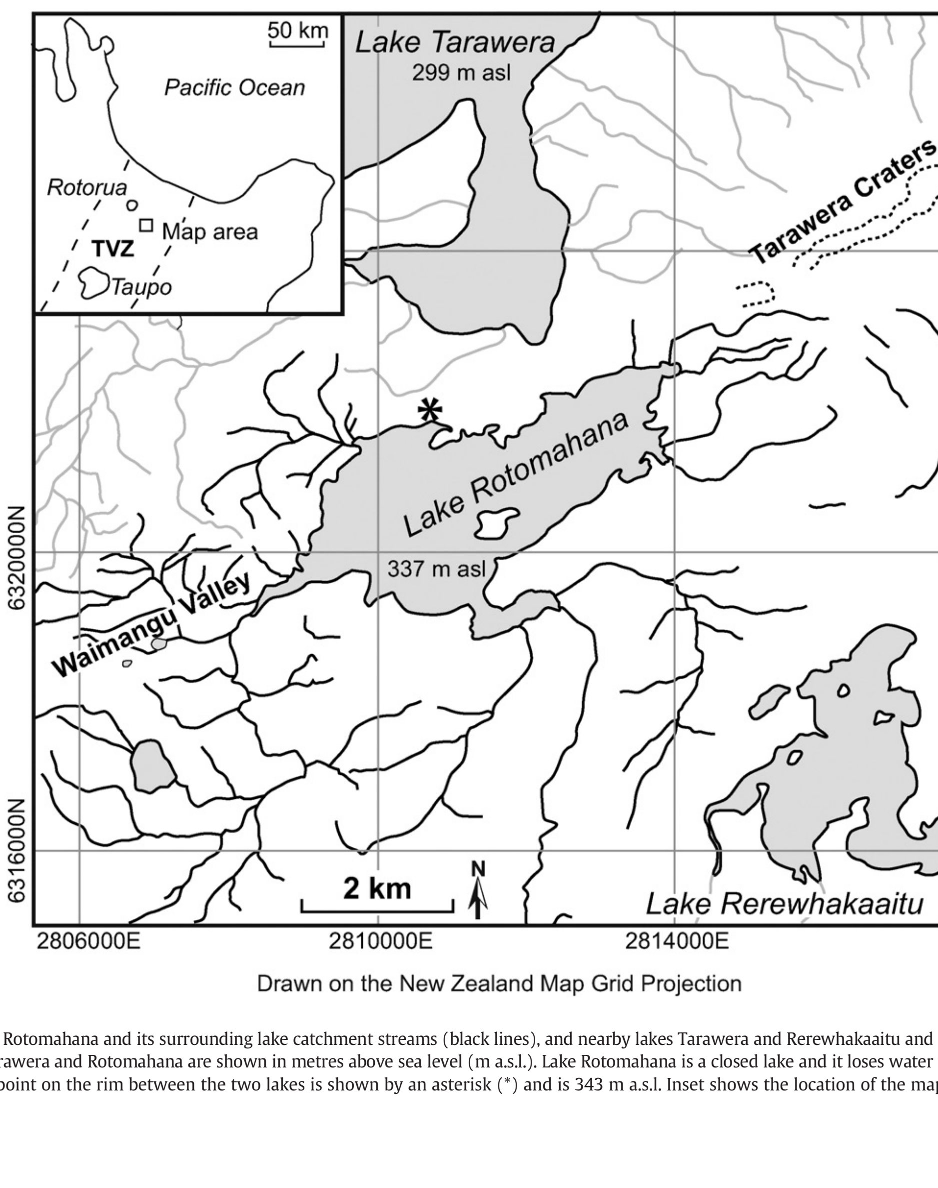

Fig. 1. Regional map of Lake Rotomahana and its surrounding lake catchment streams (black lines), and nearby lakes Tarawera and Rerewhakaaitu and their catchment streams (grey lines). The levels of lakes Tarawera and Rotomahana are shown in metres above sea level (m a.s.l.). Lake Rotomahana is a closed lake and it loses water through subsurface seepage to Lake Tarawera; the lowest point on the rim between the two lakes is shown by an asterisk (*) and is 343 m a.s.l. Inset shows the location of the map area in context of the Taupo Volcanic Zone (TVZ).