Quaternary International xxx (2017) 1–11

Contents lists available at ScienceDirect

Quaternary International

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

Radiocarbon dating of coastal boulders from Kouzushima and Miyake islands off Tokyo Metropolitan Area, Japan: Implications for coastal hazard risk

Akihisa Kitamura [a, b, *], Takafumi Imai [a], Yosuke Miyairi [c], Yusuke Yokoyama [c], Yasufumi Iryu [d]

[a] Institute of Geosciences, Shizuoka University, 836 Oya, Suruga-ku, Shizuoka, 422-8529, Japan
[b] Center for Integrated Research and Education of Natural Hazards, Shizuoka University, 836 Oya, Suruga-ku, Shizuoka, 422-8529, Japan
[c] Atmosphere and Ocean Research Institute, University of Tokyo, Chiba, 277-8564, Japan
[d] Institute of Geology and Paleontology Graduate School of Science, Tohoku University, Sendai, 980-8578, Japan

ARTICLE INFO

Article history:
Received 14 February 2017
Received in revised form
21 April 2017
Accepted 24 May 2017
Available online xxx

Keywords:
Coastal boulders
Emerged marine sessile assemblage
^{14}C dates
Holocene
Tsunami
Storm surge
Kouzushima
Miyakejima
Izu island

ABSTRACT

Over the last two decades, two giant tsunamis generated by earthquakes of approximately Mw 9 (the 2004 Sumatra–Andaman and 2011 Tohoku earthquakes), and a large storm surge associated with the 2013 Super Typhoon Haiyan, have caused catastrophic damage to infrastructure, property, and industry in many areas of the western Pacific. If we are to improve coastal hazard assessment for the Pacific coast of the southwestern Japanese mainland, a reconstruction of the history of tsunamis and storm surges during the late Holocene is required.

This study surveyed coastal boulders to determine whether such events have previously affected the islands of Niijima, Shikinejima, Kouzushima, and Miyakejima that lie offshore from the Tokyo Metropolitan Area. Coastal boulders on Kouzushima and Miyakejima were found with marine organisms attached. Radiocarbon dating of these organisms indicates that the boulders were emplaced during the periods AD 1694–Modern and Modern, respectively. The boulder on Kouzushima (13.3 ton at 1.4 m ground elevation) was transported by historical tsunamis or severe storm surges, whereas the boulder on Miyakejima (33.4 ton at 7.1 m ground elevation) was probably transported by a storm surge associated with Typhoon 7920 in 1979. An emerged marine sessile assemblage on Miyakejima (2.31–3.06 m above mean sea-level (amsl)) was dated to ca. 3900–3500 years BP. This high relative sea-level can be explained by a mid-Holocene highstand and uplift associated with volcanic activity.

1. Introduction

Over the last two decades, coastal areas in the western Pacific have experienced two devastating tsunamis, which were generated by the approximately Mw 9 2004 Sumatra–Andaman and 2011 Tohoku earthquakes, as well as a major storm surge associated with the 2013 Super Typhoon Haiyan. Following the Tohoku Earthquake in particular, coastal hazard assessments have become increasingly important for the Pacific coast of the southwestern Japanese mainland. The Tohoku Earthquake occurred off the Pacific coast of northeastern Japan, and was the largest earthquake (Mw 9.0) ever recorded in Japan. It generated a mega-tsunami with a run-up height of 10–40 m in the coastal areas of Iwate, Miyagi, and northern Fukushima prefectures, and resulted in ~19,000 deaths. Based on lessons learned from this disaster, the Central Disaster Management Council (CDMC, 2011), has defined two types of tsunamis (i.e., Level 1 and Level 2 tsunamis), which could be generated in the Suruga and Nankai troughs, where the Philippine Sea Plate is subducting beneath the Eurasian Plate. Level 1 tsunamis, with wave heights of 5–10 m in coastal areas, have occurred every 100–150 years in the region since the 684 Hakuho Earthquake (e.g., Ando, 1975; Ishibashi and Satake, 1998; Watanabe, 1998; Sangawa, 2001, Fig. 1). Most of these tsunami events were caused by earthquakes of around Mw 8. Level 2 tsunamis are considered to be the

* Corresponding author. Institute of Geosciences, Shizuoka University, 836 Oya, Suruga-ku, Shizuoka, 422-8529, Japan.
E-mail addresses: kitamura.akihisa@shizuoka.ac.jp (A. Kitamura), t_imai_10165@yahoo.co.jp (T. Imai), miyairi@aori.u-tokyo.ac.jp (Y. Miyairi), yokoyama@aori.u-tokyo.ac.jp (Y. Yokoyama), iryu@m.tohoku.ac.jp (Y. Iryu).

http://dx.doi.org/10.1016/j.quaint.2017.05.040
1040-6182/

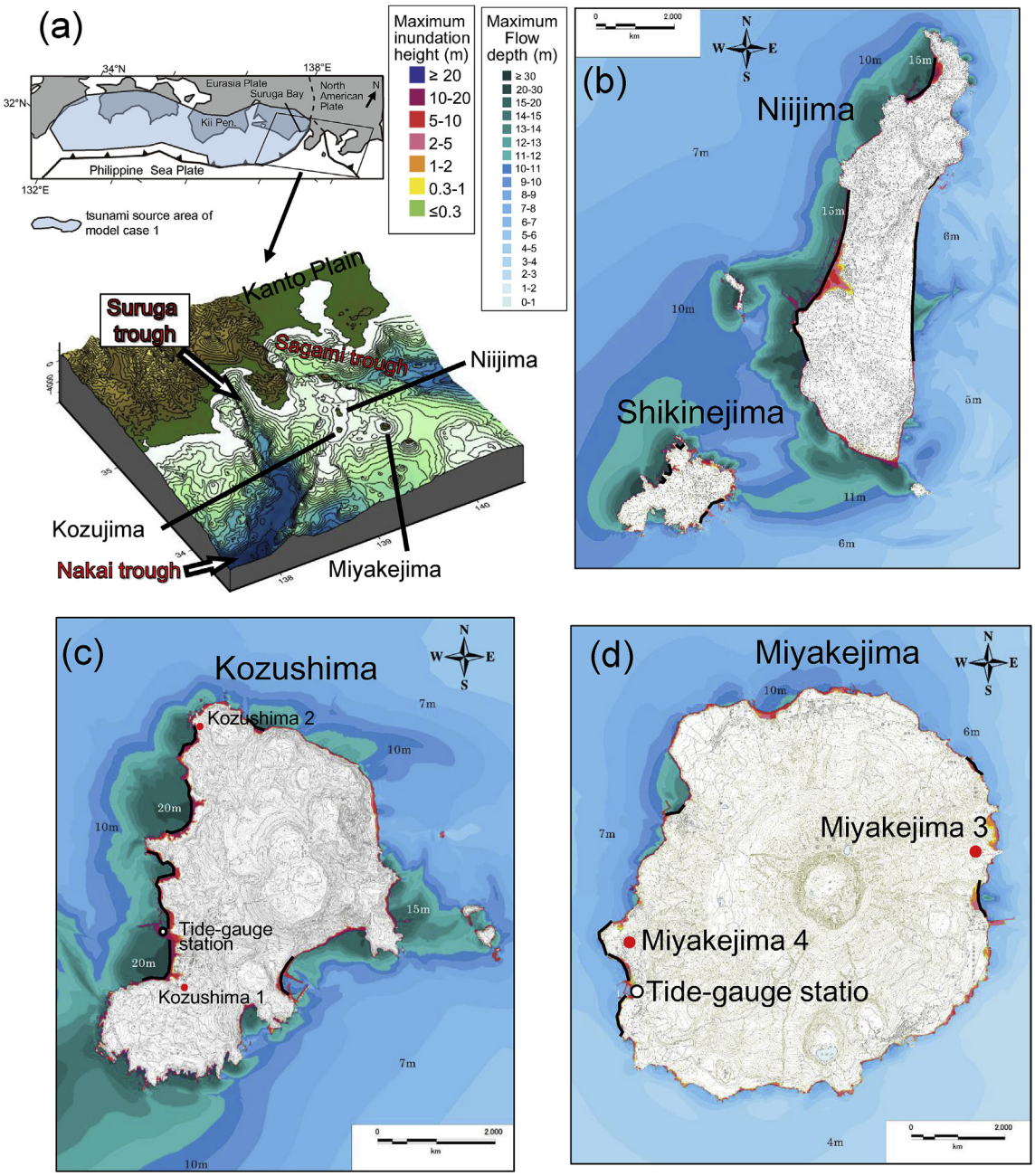

Fig. 1. (a) General view of the Suruga and Nankai troughs and the study area. Distribution of tsunami height and tsunami run-up (Tokyo Metropolitan Government Disaster Prevention, 2013) and ground survey areas in Niijima (b), Shikinejima (b), Kouzushima, (c) and Miyakejima (d), showing tide-gauge station, and GPS observation. Black lines along the coast are surveyed areas.

largest possible, and are caused by the largest conceivable earthquakes (Mw 9.1) that could occur along the megathrusts of the Nankai Trough (CDMC, 2012). Such events are infrequent but have the potential to cause widespread damage. CDMC (2011) noted that "*… when conducting earthquake and tsunami hazard assumptions in the future, the largest-possible mega earthquakes and tsunamis should be considered from every possible angle. … in order to verify the occurrence of mega tsunamis over a time scale of several thousand years it is vital that further enhancement be made not only to seismological research but also to the comprehensive geological, archaeological and historical research, including research into tsunami deposits on land and the ocean floor, geological research into coastal terraces, and research into biological fossils etc.*".

The government of Japan (2012) presented eleven model cases of Level 2 tsunami wave heights. The wave heights of Level 2 tsunamis for model cases 1, 6, and 8 were higher than for the other cases when applied to the Tokyo Metropolitan Area, and the Kanagawa and Shizuoka prefectures, of central Japan. Fig. 1 shows predicted tsunami source area and wave heights of case 1. It is important to note that this tsunami model is not based on historical or geological evidence, and that it far surpasses the largest known historical event (e.g., Goto et al., 2014).

CDMC (2011, 2012) initiated studies of tsunami deposits and boulders along coastal areas of Shizuoka Prefecture to determine whether Level 2 tsunamis had previously occurred over time-scales of several thousand years (Abe and Shirai, 2013; Fujiwara et al.,

Please cite this article in press as: Kitamura, A., et al., Radiocarbon dating of coastal boulders from Kouzushima and Miyake islands off Tokyo Metropolitan Area, Japan: Implications for coastal hazard risk, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.05.040