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History of Phreatic Eruptions in the Noboribetsu Geothermal Field, Kuttara Volcano, Hokkaido, Japan

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A 6.3-m-deep trench was dug in the Noboribetsu Geothermal Field, Kuttara Volcano, Hokkaido, Japan, to clarify the history of phreatic eruptions in the field. The stratigraphic section in the trench consists of (from lower to upper): the Kt-1 pyroclastic surge deposit, nine phreatic fall deposits (Nb-l to Nb-d), the B-Tm tephra, two phreatic fall deposits (Nb-c, Nb-b), the Us-b tephra, and a phreatic fall deposit (Nb-a). The 12 phreatic fall deposits (Nb-l to Nb-a) are 3−100 cm thick and consist of altered dacitic lithic fragments in a clay-rich fine-grained matrix. These deposits are inferred to have been erupted from the Noboribetsu Geothermal Field. Buried soil layers occur between the deposits. Radiocarbon dating of buried soil samples from immediately below each of the phreatic fall deposits suggests that phreatic eruptions occurred at *ca.* BC 6450, BC 5370, BC 3980, BC 3440, BC 1990, BC 1710, BC 1280, BC 900, BC 200, AD 980, AD 1480, and after AD 1663, corresponding to an average eruption interval of ～700 years.

Key words: eruptive history, phreatic explosion, Noboribetsu Geothermal Field, Kuttara Volcano, trench survey

1. Introduction

Geothermal fields are common in active volcanic regions and have become major sites for tourism and for extracting geothermal energy. Although there have been few historical volcanic eruptions in geothermal fields, geological studies suggest that phreatic eruptions (here, the term 'phreatic eruptions' is used for steam-driven explosions that do not involve fresh magma, following Barberi *et al*., 1992 and McPhie *et al*., 1993) in such settings occur at intervals of 100−1000 years (Lloyd, 1972; Hedenquist and Henley, 1985; Ito, 1999; Kudo *et al*., 2000; Miyabuchi and Watanabe, 2000; Browne and Lawless, 2001; Okuno, 2002; Ohba and Kitade, 2005; Kobayashi *et al*., 2006; Mannen, 2007). Therefore, an understanding of the eruptive history of a geothermal field is essential in evaluating the volcanic hazard in the region.

The Noboribetsu Geothermal Field at Kuttara Volcano, southwestern Hokkaido (Fig. 1), is one of the major geothermal fields in Japan. The existence of small explosion craters in this field suggests that phreatic eruptions have occurred in recent geological time (Yamazaki, 1986; Katsui *et al*., 1988; Goto *et al*., 2011a, 2011b). However, the history of eruptions remains unknown, because this field is generally covered with thick vegetation, and there are few exposures of phreatic deposits. To address this shortcoming, we conducted a trench survey and performed radiocarbon dating of phreatic deposits erupted from the field. This paper reports on the stratigraphy and radiocarbon ages of the phreatic deposits and discusses the eruptive history of the geothermal field.

2. Noboribetsu Geothermal Field

The Noboribetsu Geothermal Field lies in the western part of Kuttara Volcano (Fig. 1), an andesitic to rhyolitic composite volcano (elevation, 549 m above sea level) with a small caldera at its summit (Lake Kuttara). The volcano evolved over the period 80−45 ka, involving early silicic explosive activity and subsequent stratovolcano building associated with caldera collapse at about 40 ka (Katsui *et al.,* 1988; Yamagata, 1994; Moriizumi, 1998; Moriya, 2003). The geothermal field, which is inferred to have formed after the collapse of the caldera (Katsui *et al.,* 1988), is approximately 1 km wide (NE–SW) and 1.5 km long (NW–SE).

The Noboribetsu Geothermal Field is characterized by a dacitic cryptodome (Hiyoriyama Cryptodome), a volcanic lake (Oyunuma Lake), and a fumarolic valley (Jigokudani Valley) (Fig. 2). The Hiyoriyama Cryptodome, located in the northern part of the geothermal field, is 350−550 m in diameter and rises 130 m above the surrounding area (Fig. 3; Goto *et al*., 2011a). Fission-track analyses indicate that the dome formed at 15±3 ka (Goto and Danhara, 2011). Oyunuma Lake (115 × 210 m in area), located in the central part of the geothermal field, is the largest lake in the field and is filled with hot acidic water (Fig. 3). The Jigokudani Valley, in the southern part of the geothermal

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