

## Field survey report on Zao Volcano (2012–2018)

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We have been conducting field surveys on Zao volcano since 2012, such as temperature monitoring and water sampling on Maruyama-sawa geothermal area, ruin of Niizeki hot spring and Okama crater lake, based on the expectation that Zao volcano may be activated by 2011 Great East Japan Earthquake. Geophysical observation network by Japan Meteorological Agency, which has started 24-hour monitoring in September 2010, detected volcanic tremor in January 2013 for the first time, and a tremor and preceding tilting occurred in April (JMA, 2013). Since then Zao volcano sustains its higher activity than usual. Volcanic warning, Level 2: Do not approach the crater, were issued in April 2015 due to the increase in volcanic earthquake and in January 2018 due to the occurrence of volcanic tremor with largest-ever amplitude and continuous tilt motion. In harmony with these activities our field surveys also detect some changes in surface activities. Here we review our field survey results since 2012, especially focusing on the 2017-2018 results which has not reported yet.

Temperature of over 20 fumaroles has been measured repeatedly on Maruyama-sawa geothermal area, where small phreatic explosion occurred in 1940 (Toraishi and Tominaga, 1940; Anzai, 1941). The highest temperature exceeded 102 °C in 2012, but decreased over 7 °C within four months in 2013; fumarole temperature overall fell lower than 95 °C by 2014. After the first volcanic warning in 2015, the highest fumarole temperature reached nearly 100 °C temporarily, and then overall temperature rise occurred in 2016. In 2018, after volcanic warning was issued for the second time in January, the highest fumarole temperature exceeded 100 °C in June and reached 104 °C in July, which is the highest record in our survey since 2012.

We have paid attention to ruin of Niizeki hot spring, where high temperature and high concentration hot springs gushed as a result of activation in the past, but no activity was recognized between 2012 and 2014. In September 2015, five months later from the first volcanic warning, we found that Niizeki hot spring resumed welling up with multiple hot springs at around 32°C. But in 2016 surveys, Niizeki hot spring had only a few weak cold-water springs, and no remarkable activity was recognized after the second volcanic warning in 2018.

In contrast with Maruyama-sawa and ruin of Niizeki hot spring, no thermal activity has been recognized on Okama crater lake thus far. The bottom temperature was around 4 °C in late May and early June (2014 and 2016), and around 7 °C in early September (2014, 2015, 2017 and 2018). We installed thermocouples in 2017 and 2018 on the bottom of Okama crater lake to record the temperature change one hour interval. We found that 3-4 °C temperature rise occurred in early October in 2017 and 2018, which is probably not be the results of thermal activity of Zao volcano but seasonal variation, because the degree of temperature change and the time of the year were identical. In 2018 other research group conducted topography survey of Okama crater lake bottom using a multiple-frequency sonar system and

detected vertically extending reflection over a small mound on the center of the lake bottom, which may be caused by a chain of rising volcanic gas bubbles or hot water plume (Yamasaki et al., 2018). One of our thermocouple is set within 10 m from the reflection source. Our thermocouple may catch the temperature change if thermal activity occurs there.

キーワード：蔵王火山、表面活動

Keywords: Zao volcano, surface activity