

## Activization of Zao volcano within the past 100 years and the present activity

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In the recent 100 years major activities occurred on Zao volcano in 1918, 1939, 1966 and continued several years. After the 2011 Tohoku Earthquake increase in seismic activity was reported on 21 active volcanoes in Japan (JMA, 2014). While Zao volcano was out of them, volcanic tremor was observed for the first time in Jan. 2013, and a tremor and preceding tilting occurred in April (JMA, 2013). In addition, partial turbidity was found on Okama crater lake in Oct. 2014. We have started temperature monitoring of fumaroles and springs on Maruyama-sawa geothermal area (hereafter indicated as Maruyama-sawa), 1.5 km NE of Okama in 2012, temperature monitoring and chemical analysis of Okama and Maruyama-sawa water in 2013. We also have watched the confluence of Nigori-kawa and Firiko-zawa (Niizeki-onsen), 1.6 km east of Okama, where hot dense springs appeared in the past activity. Here we review the last three major activities focusing on Okama, Maruyama-sawa and Niizeki-onsen to compare with the present activity.

In 1918 Okama changed its color and then gas emitted from bottom (Omori, 1918), which lasted until 1928. The depth in 1928 was 61 m (Anzai, 1961). Some change accompanied an earthquake at Maruyama-sawa on 12 Aug. 1918 (Imada et al., 1985), although the detail is unclear. Tori-jigoku, killing animals by dense volcanic gas, had formed by 1935 (Anzai, 1961). Niizeki-onsen, developed by tunneling between 1907 and 1908 (sanitation department of Miyagi prefecture, 1969), lowered its temperature in 1917 winter and decreased the discharge by 1/3 in Jun. 1918. Although the temperature recovered temporarily, it was closed due to dry up in 1921.

In 1939 Okama changed its color on the end of July, followed by gas emission and temperature rise. Temperature in the bottom mud was >250 °C in Aug. 1940 (Anzai, 1941). The last turbidity was on Sep. 1942. Maruyama-sawa had weak fumarole activity in Jul. 1939 (Toraishi and Tominaga, 1940), but small explosion occurred on 10 Feb. (Toraishi and Tominaga, 1940) or 16 Apr. (Anzai, 1941), 1940. Niizeki-onsen recovered effusion 18 m away from the old vent in Jun. 1939, and new hot spring appeared 500 m upstream along Nigori-kawa (Ueno, 1940). Temperature was 88 °C on Feb. 1940 (Toraishi and Tominaga, 1940) and ph was 0.3 on May 1940 (Anzai, 1941). A 2 m wide and over 100 °C solfatar was found on the northern slope of the riverside.

No anomaly occurred on Okama in 1966 activity: no gas emission, unchanged depth (27 m line) between 1955 and 1968 (Shida et al., 1969) and monotonous decrease in Ca<sup>2+</sup> and SO<sub>4</sub><sup>2-</sup> concentrations between 1955 and 1983 (Shida et al., 1969; Sato and Kato, 1985). In contrast Maruyama-sawa activated its fumarole. At Niizeki-onsen steaming ground appeared on the slope and highly acidic hot spring effused along Nigori-kawa, whose temperature, ph, electrical conductivity (EC) were 77 °C, 0.3, >5 S/m on Oct. 1967 (Shida, 1968).

Based on our observation the present activity seems to be similar to that from 1966 so far. Except <sup>129</sup>I/<sup>127</sup>I ratio that may relate to seismic activity (Matsunaka et al., 2014), no obvious change has been observed on Okama; the depth is around 25 m, and Ca<sup>2+</sup> is 60-70 mg/kg which is almost equal to or slightly lower than that in 1983. Temperature of Maruyama-sawa fumarole is almost constant, but the fumarolic steam has become prominent gradually, especially since autumn of 2014. In addition a trace of mud effusion was found in Oct. 2015. We confirmed in Sep. 2015 that Niizeki-onsen has reactivated upwelling. Temperature, ph and EC on 3 Sep. and 28 Oct. were 32.1 °C and 34.1 °C, 2.3

and 2.0, 0.126 S/m and 0.789 S/m.

Imada et al. (1985) pointed out the center of the activity had moved from Okama to Maruyama-sawa. Except Okama the present activity also resembles that from 1939. We should continue the survey with having the 1940 Maruyama-sawa small explosion in mind.

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