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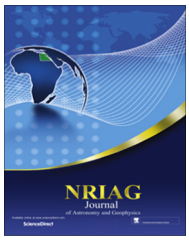

Anomalous geomagnetic variations associated with the volcanic activity of the Mayon volcano, Philippines during 2009–2010

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Abstract Local anomalous geomagnetic variations preceding and accompanying the volcanic eruptions had been reported by several researchers. This paper uses continuous high-resolution geomagnetic data to examine the occurrence of any anomalous geomagnetic field variations that possibly linked with the volcanic eruption of the Mayon volcano, Philippines during 2009–2010. The nearest geomagnetic observing point from the Mayon volcano is the Legazpi (LGZ) station, Philippines; which is located about 13 km South of the Mayon volcano. The amplitude range of daily variations and the amplitude of Ultra Low Frequency emissions in the Pc3 range (Pc3; 10–45 s) were examined at the LGZ station and also were compared with those from the Davao (DAV) station, Philippines as a remote reference station. Both the LGZ and DAV stations belong to the MAGDAS Network. The result of data analysis reveals significant anomalous changes in the amplitude range of daily variations and the Pc3 amplitude at the LGZ station before and during the volcanic eruption of the Mayon volcano. From the obtained results, it appears that the observed anomalous variations are dependent on the change in the underground conductivity connected with variation in the physical properties of the Earth's crust due to the activity of the Mayon volcano. Therefore, these anomalous geomagnetic variations are considered to be of a local volcanic origin.

1. Introduction

Observations and analysis of geomagnetic field measurements have been carried out in the vicinity of some active volcanoes in order to observe and detect any anomalous geomagnetic signals in association with the volcanic activities (Yukutake et al., 1990; Uyeda et al., 2002; Sasai et al., 2002; Okubo et al., 2006). Noteworthy observed geomagnetic field variations had been

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considered as anomalous signals associated with some volcanic eruptions. These variations have small amplitudes, generally a few nTs; 5–15 nT (Rossignol, 1982). In addition, these previous studies are aimed to understand the generation mechanisms of the observed anomalous geomagnetic signals (Stacey et al., 1965; Johnston and Stacey, 1969; Tanaka, 1993; Uyeda et al., 2002). Generally, three mechanisms are widely accepted for explaining the occurrence of anomalous geomagnetic field variations associated with volcanic phenomena. The first mechanism is the Piezomagnetic effect that is related to changes in rock magnetization under varying crustal stress conditions accompanying the volcanic activities. The second one is the Electrokinetic effect due to the motion of electric charges associated with the underground fluid flow. The last one is the thermal effect related to thermal demagnetization/remagnetization of the volcanic rocks, which could be observed on the ground as anomalous geomagnetic signals (Yukutake et al., 1990; Tanaka, 1993; Okubo et al., 2006).

Continuous measurements of the geomagnetic field by ground magnetometer array are regarded as a powerful tool for monitoring volcanic activities. During the last few decades, a number of successful and promising results have been obtained from analyzing geomagnetic data recorded nearby some active volcanoes. Generally, short and long-term anomalous geomagnetic signals had been reported in association with geodynamic activities such as earthquakes and volcanoes. However, the number of observed anomalous signals related to volcanic activities is still small but some of these works are worth to be mentioned (Johnston and Stacey, 1969; Tanaka, 1993; Kotsarenko et al., 2005; Fujinawa et al., 2006).

The main aim of the present study is to analyze reliable geomagnetic data in the vicinity of the Mayon volcano at the Legazpi (LGZ) station, Philippines (Fig. 1), during the period from August 2009 to December 2010 to look for geomagnetic anomalies that could be related to the activity of the Mayon volcano during that period. Conventionally, the comparison of geomagnetic field measurements near volcanoes and remote reference measurements can be used to observe and detect the anomalous signal associated with volcanic activities. Therefore, geomagnetic data from the Davao (DAV) station, Philippines were used as a remote reference station in the present study as shown in Fig. 1.

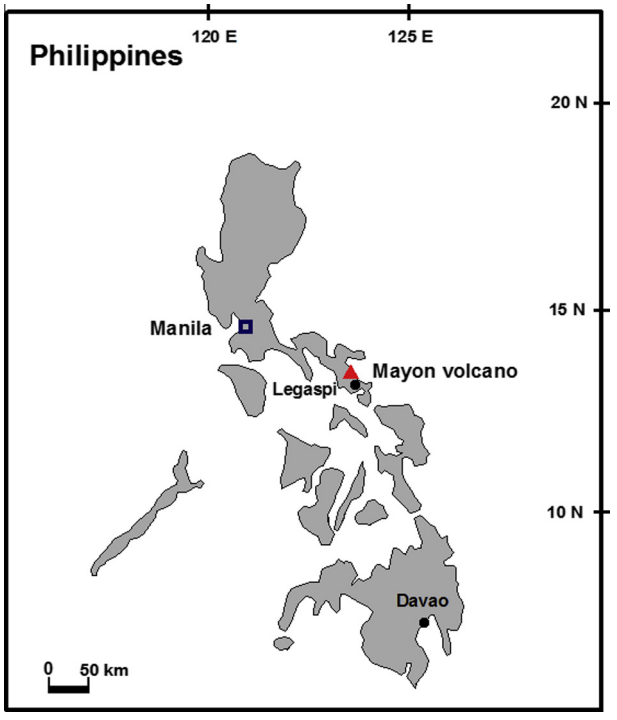

Figure 1 Location map shows locations of both the LGZ and DAV stations, and also the Mayon volcano, Philippines.

2. The geology and tectonics of the Mayon volcano

The Mayon volcano (13.26°N/123.69°E) forms the northern boundary of Legazpi City, the largest city in terms of population in the Bicol Region, Philippines, see Fig. 1. The Mayon volcano is the main landmark of Albay Province. In addition, the Mayon is the most active volcano in the Philippines having erupted over 48 times in the past 400 years (*The Philippine Institute of Volcanology and Seismology [PHIVOLCS]*; Catane et al., 2003).

The Mayon volcano is a symmetrical stratovolcano type capped by a small central summit crater. The cone is considered to be the world's most perfectly formed volcano for its symmetry, which was formed through layers of pyroclastic and lava flows from past eruptions and erosion. The upper slopes of the basaltic-andesitic volcano are steep averaging 35–40 degrees. It has frequent eruptions producing pyroclastic flows, mudflows and ash falls that repeatedly triggered large-scale evacuations. The Mayon's most violent eruption, in 1814, killed more than 1200 people and devastated several towns. Historical records of eruptions date back to 1616 and range from strombolian to basaltic plinian, with cyclical activity beginning with basaltic eruptions, followed by longer-term andesitic lava flows. Eruptions occur predominately from the central conduit and have also produced lava flows that travel far down the flanks. Pyroclastic flows and mudflows have commonly swept down many of the approximately 40 ravines that radiate from the summit and have often devastated populated lowland areas (*PHIVOLCS*).

Mayon volcano is part of the Pacific Ring of Fire. It is located on the eastern side of Luzon, near the Philippine Trench which is the convergent boundary where the Philippine Sea Plate is driven under the Philippine Mobile Belt. When a continental plate or belt of continental fragments meets an oceanic plate, the lighter continental material overrides the oceanic plate, forcing it down into the Earth's mantle. Magma may be forced through weaknesses in the continental crust caused by the collision of the tectonic plates. One such exit point is Mayon (*PHIVOLCS*).

3. The 2009–2010 eruption of the Mayon volcano

The PHIVOLCS raised the status from Alert Level 1 to Alert Level 2 on August 2009. On Wednesday, 28 October 2009 and 11 November 2009 minor ash explosions lasting for about one and three minutes respectively occurred in the summit crater.

Early in the morning of Tuesday 15 December 2009, a moderate ash explosion occurred at the summit crater. On 17 December 2009, there were five ash ejections with one reaching 500 ms above the summit, lava flows reached down to 1500 m below the summit, and incandescent fragments from the lava