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Insight Into The 2024-2025 Eruption of Lewotobi Laki-Laki Volcano in Flores Island, Indonesia: An Overview

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Abstract - Between November 2024 and April 2025, Lewotobi Laki-laki Volcano (1,584 m a.s.l.), situated in Flores Regency, East Nusa Tenggara, Indonesia, exhibited eruptive activity that significantly impacted the surrounding environment. Volcanic ash was extensively deposited across residential areas, agricultural land, and forested regions. Two major eruptive events occurred on 3rd November 2024 and 20th March 2025. Historical records indicate that Lewotobi Laki-laki has been active since 1861 CE, typically characterized by mild eruptions involving ash emission, lava flows, and dome formation. However, in the beginning of November 2024, the volcano activity intensified, culminating in a directed blast eruption on 3rd November at 23:57 Central Indonesian Time from its northwestern upper flank (Kushendratno *et al*., 2024). This event ignited fires in nearby villages, and resulted in nine fatalities due to exposure to blast material. Subsequently, on 20th March at 22:56 Central Indonesian Time, a vertical explosive eruption occurred from the central vent, generating an eruption column that ascended to approximately 8,000 m (Kristianto *et al.*, 2025), and produced column collapse predominantly affected the west–northeastern flank, causing three reported injuries. These incidents highlight the critical need for proactive eruption forecasting and the implementation of corresponding mitigation strategies. The eruption on 3rd November 2024 prompted a revision of the Lewotobi Laki-laki hazard map, reflecting a newly observed eruptive style with a pronounced northwestern trajectory.

Keywords: explosive eruption, directed blast, column collapse, eruption style, mitigation strategy, hazard mapping

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Introduction

Lewotobi Volcano comprises two adjacent volcanic edifices: Mount Lewotobi Laki-laki (1,584 m a.s.l.) and Mount Lewotobi Perempuan (1,703 m a.s.l.), both located in Flores, East Nusa Tenggara, Indonesia. Based on historical records and observed volcanic activity, Lewotobi Laki-laki exhibits greater eruptive frequency and intensity compared to Lewotobi Perempuan. The last eruptions of this volcano were in 1021 CE and 1935 CE, characterized by lava dome formation. In contrast, Lewotobi Laki-laki experienced its most recent major eruptions on 3rd November 2024 and 20th March 2025.

Following its previous eruption in 2003, Lewotobi Laki-laki was classified under the lowest alert level (Level I/Normal). However, increased seismic activity particularly deep volcanic earthquakes (VA) on 20th December 2023

prompted The Centre for Volcanology and Geological Hazard Mitigation (CVGHM), Geological Agency (GA), to elevate the alert status to Level II (Waspada/Advisory) (Magma Indonesia). This escalation was followed by an eruption on 23rd December 2023, which produced an ash column reaching 1,000–1,500 m, and triggered rockfalls extending up to 300 m along the north–northwest flank.

Figure 1 illustrates the progression of volcanic activity and corresponding alert levels for Lewotobi Laki-laki from 1st January 2023 to 30th April 2025. CVGHM employs a four-tier alert system: Level I (Normal), Level II (Waspada/Advisory), Level III (Siaga/Watch), and Level IV (Awas/Warning) (Andreastuti *et al*., 2019; Andreastuti *et al*., 2023). During the observation period, Level IV was declared on four times, January 2024, November 2024, February 2025, and March 2025, coinciding with heightened eruptive activity. A total of eleven eruptions occurred, some accompanied by lava flows, notably on 10th January 2024 (northeast flank) and 9th–10th November 2024 (northeast and west flanks; see Figure 2). As of the latest update, Lewotobi Laki-laki remains at Level III (Siaga/Watch).

This report focuses on the eruptive events of 3rd November 2024 and 20th March 2025, which represent significant shifts in the volcano eruptive behaviour.

Eruption History

Lewotobi Laki-laki has been documented as active since 1861 CE, with a Volcanic Explosivity Index (VEI) ranging from 1 to 3 (Kusumadinata, 1979; Badan Geologi, 2011). Its eruptions have varied from effusive to explosive, with a total of twenty events recorded between 1861 and 2024. The recurrence interval ranges from one to thirty years (Figure 3). Several eruptions have caused damage to agricultural areas, infrastructure, and forest ecosystems. Fatalities were reported during the eruptions of 1869, 1907, and most recently in 2024.

Figure 2 presents imagery from the 10th November 2024 eruption, showing lava flow deposits on the west flank and vegetation damage resulting from the 20th March 2025 eruption. The image was captured using a Mavic 3T drone.

The eruptive character of Lewotobi Laki-laki has evolved over time. In 1932, a lava dome formed, followed by pyroclastic flow generation. Subsequent activity became predominantly effu-

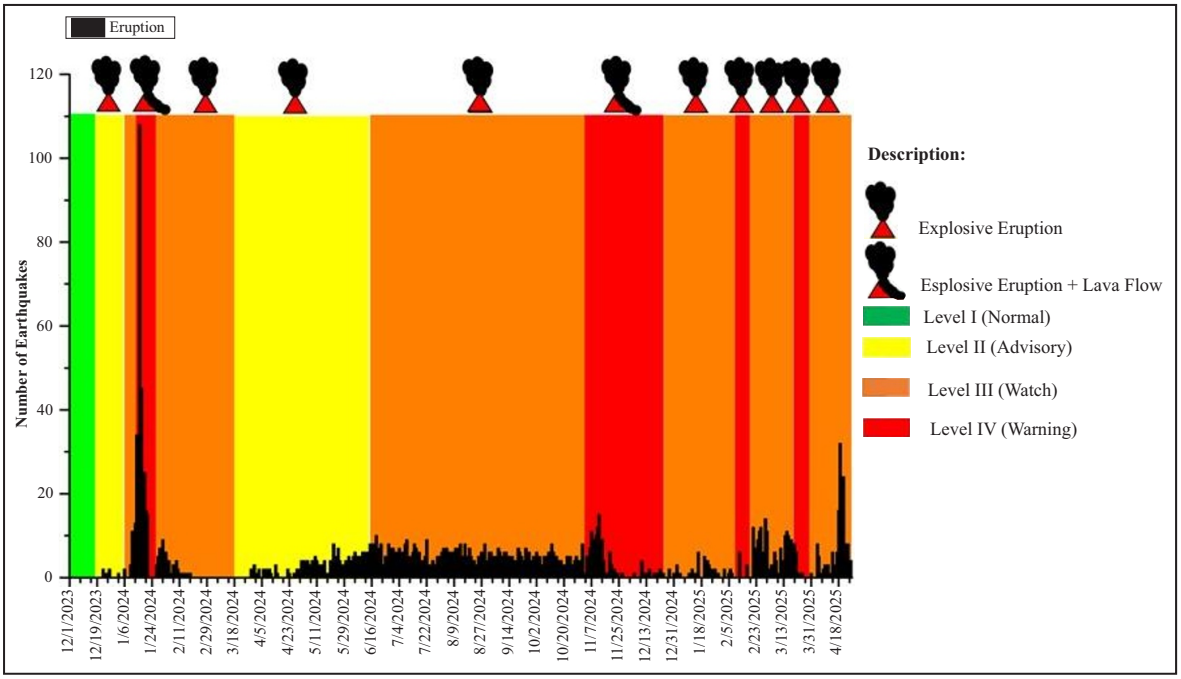

Figure 1. Volcanic activity of Lewotobi Laki-laki Volcano from 1st January 2023 to April 2025.

Figure 2. Image of the 10th November 2024 eruption, lava flow (black colour) of Lewotobi Laki-laki in the west flank resulting from the eruption activity on 10th November 2024. The burnt plants and the smoky areas because of eruption on 20th March 2025 (yellow line). The image was taken using the Mavic 3T drone.

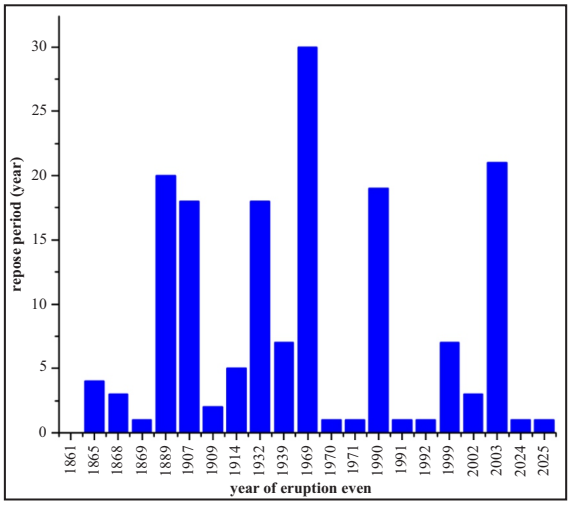

Figure 3. Graph of eruption events and its intervals of Lewotobi Laki-laki volcano eruptions.

sive, producing lava flows. Since 1990, however, the volcano has exhibited a more explosive-magmatic style, characterized by pyroclastic fall deposits. Figure 3 depicts the temporal distribution and intervals of Lewotobi Laki-laki eruptive events.

On 3rd November 2024 at 23:57 local time, a directed blast eruption occurred from the northwestern upper flank (Kushendratno *et al*., 2024), igniting fires in nearby villages and resulting in nine fatalities. Seismic monitoring revealed a marked increase in shallow (Type B) and deep (Type A) volcanic earthquakes two-day prior, peaking on the day of the eruption with 41 and 124 events, respectively.

On 20th March 2025 at 22:56 local time, a vertical explosive eruption from the central vent produced an ash column reaching 8,000 m (Kristianto *et al.*, 2025). The subsequent column collapse affected the west−northeastern flank and caused three injuries. Unlike the November event, this eruption was preceded by deep volcanic earthquakes on the day itself, totaling 202 recorded events.

Geochemical analysis of lava samples from the 1914 and 1933 eruptions revealed silica (SiO_2) content ranging from 52–63 % (Sukhyar and Mawardi, 1990). The 2024 lava sample contained 58.44 % SiO_2 (Primulyana, 2024, personal communication), classifying it as intermediate andesitic rock. This relatively acidic magma, derived from silica-rich sources, exhibits high viscosity, which impedes gas escape and facilitates pressure accumulation, conditions contributing to explosive eruptions.

The 3rd November 2024 Eruption

The eruption on 3rd November 2024 significantly affected two administrative districts: Wulanggitang and Ile Bura, encompassing eight villages. In Wulanggitang District, the impacted villages included Klatanlo, Hokeng Jaya, Pululera, Boru, Boru Kedang, and Nawokote, while Dulipali and Nobo were affected in Ile Bura District. According to the National Disaster Management Agency (BNPB), the eruption displaced approximately 11,553 residents from six of these villages: Klatanlo, Hokeng Jaya, Boru, Nobo, Nawokote, and Dulipali (https://news.detik.com/berita/d-7634434/bnpb-pengungsi-erupsi-gunung-lewotobi-11-553-orang-tersebar-di-8-titik). Evacuees were accommodated in eight temporary shelters, six located in East Flores and two in Sikka Regency.

The eruption commenced with a directed blast from the upper northwest flank of Lewotobi Laki-laki. The explosion ejected volcanic bombs and large ballistic projectiles, which caused extensive structural damage and fatali-

ties. These high-energy rock fragments, some of which were boulder-sized, penetrated rooftops, collapsed buildings, and ignited fires, severely damaging schools, government offices, roads, and agricultural areas. Casualties occurred among residents who were unable to evacuate prior to the blast. Figure 4 depicts the impact of eruption event as observed from The Lewotobi Laki-laki Observatory Post, while Figure 5 illustrates the damage on school, located approximately 5,5 km northwest of the summit.

To assess the spatial distribution of ballistic ejecta and ash deposits, high-resolution aerial imagery was acquired using the DJI Mavic 3T Enterprise drone. Ballistic projectiles, capable of traveling several kilometers from the vent, created impact craters up to 15 m in diameter and contributed to structural collapse and widespread debris dispersal. Figure 6 presents the post-eruption imagery of Hokeng Jaya Village, showing ash-covered infrastructure and vegetation, as well as directional mapping of blast trajectories.

The 20th March 2025 Eruption

A subsequent major eruption occurred on 20th March 2025 at 22:56 Central Indonesia Time. This event was characterized by a vertical explosive eruption from the central vent, generating an eruption column that reached an altitude of approximately 8,000 m above the summit (Figure 7). The column collapse produced pyroclastic flows and surges that predominantly affected the northeast flank, with secondary impacts extending toward the northwest.

Three individuals sustained injuries due to pyroclastic surges within a 4.7 km radius of the summit, as shown in Figure 8. These casualties occurred within the hazard zone, although the recommended exclusion radius was 6 km. The red-filled circles in Figure 8 indicate the precise locations of the injured individuals.

Impact of The Eruption

Volcanic activity at Lewotobi Laki-laki during the 2024–2025 period produced a diverse array of eruptive materials, including fine ash, volcanic blocks, lava flows, rockfalls, pyroclastic flows, and pyroclastic surges. Monitoring data from The Meteorology, Climatology, and Geophysic Agency (BMKG) and the Darwin Volcanic Ash Advisory Centre (VAAC) indicated that ash dispersal was predominantly directed westward and northwestward, reaching altitudes of approximately 11,000 ft. (~3.3 km). Consequently, five regional airports, Soa (Bajawa), Frans Seda

Figure 4. The impact of Lewotobi Laki-laki eruption on 3rd November 2024, at 23:57 Central Indonesia Time in the form of spot of fire on Goleriang and Klatanlo Hamlets, Klatanlo Village (taken from Lewotobi Laki-laki Observatory Post).

Figure 5. The impact of blast material of Lewotobi Laki-laki eruption on 3rd November 2024, at 23:57 Central Indonesia Time on school building.

(Maumere), Komodo (Labuan Bajo), Hasan Aroeboesman (Ende), and Frans Sales Lega (Ruteng), were temporarily closed due to ashfall. Additionally, several flights to and from Bali and West Nusa Tenggara (NTB) were canceled as a precautionary measure to mitigate aviation hazards associated with volcanic ash.

Pyroclastic flows generated directly from eruptive activity extended 1,500 to 2,000 m from the summit, primarily toward the northeast sector. Whereas, pyroclastic flows resulting from column collapse and associated pyroclastic surges reached distances of 500 to 2,000 m, with dispersal patterns spanning north to northeast. Incandescent lava avalanches were observed within a range of 100 to 2,000 m, directed toward the west, northwest, north, and northeast sectors. Ballistic projectiles were ejected around the summit area, and several eruptions produced lava fountains reaching heights of up to 1,000 m above the crater rim.

The eruption on 3rd November 2024 produced ballistic materials in the form of large blocks, some of which created ground impact cavities up to 15 m in diameter. These impacts were concentrated in the northwest sector, approximately 4.6 km from the summit, with the farthest ballistic reach recorded at 7 km. Pyroclastic surges affected the summit and northern slopes, covering an estimated area of 10 km². Figure 9 illustrates

Figure 6. A post-eruption landscape around Lewotobi Laki-laki Volcano (Hokeng Jaya Village) showed ash-covered buildings and vegetation (top left, above). White lines showed the direction of blast to points of material locations (above). Below showed zoom of Hokeng Jaya Village impacted by directed blast.

Figure 7. The eruption that occurred on 20th March 2025 at 22:56 Central Indonesia Time showed an eruption column as high as 8,000 m above the summit, followed by pyroclastic flows produced by column collapse, and incandescent material.

Figure 8. The impact of 20th March 2025 eruption of Lewotobi Laki-laki to the northeast flank of the volcano. Red filled circles represent the locations of injured people due to the surge that accompanied the eruption.

the spatial distribution of eruptive materials and ballistic impact zones resulting from the November 2024 eruption series. In addition to altering the volcano morphology, these events caused fatalities, extensive damage to vegetation and agricultural land, and structural destruction, particularly in the northwest sector.

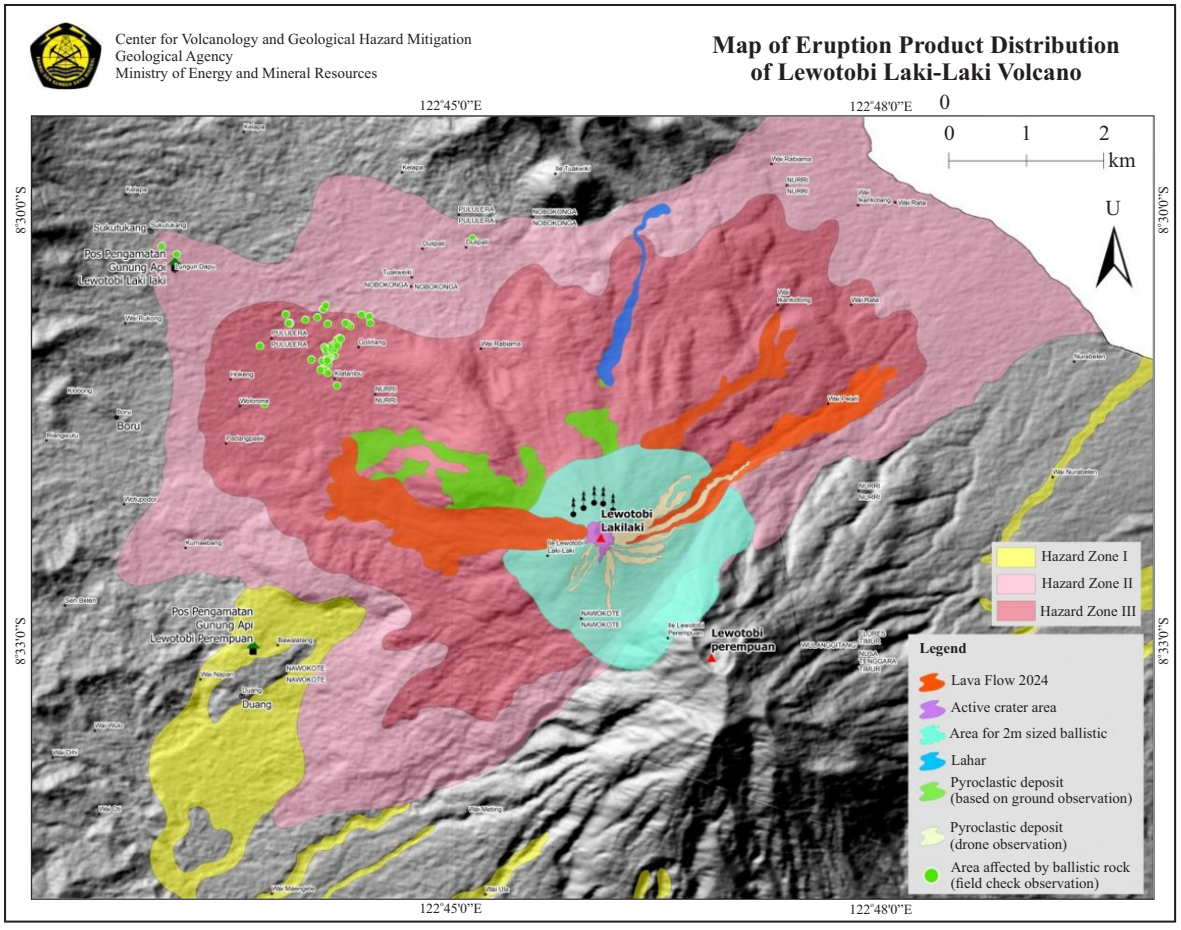

Figure 9. Map showing the distribution of eruption material and area affected by ballistic at northwest sector as result of November 2024 eruption series.

Post-eruption morphological assessments revealed substantial changes to the summit of Lewotobi Laki-laki. Satellite imagery captured on 6th November 2024 identified an elongated incision along the upper flank, extending approximately 4 km from the northern to southwestern sectors, attributed to a lateral eruptive event. A sector collapse on the northern to northwestern crater wall resulted in a breach approximately 140 m wide. The crater area expanded to roughly 90,000 m^2. Furthermore, a pre-existing gas vent on the upper southwestern slope was eroded and merged into a newly formed elongated crater structure, consistent with the morphological transformation induced by the eruption. Figure 10 presents visual documentation of these changes, captured via drone and observatory post imaging.

Figure 10. Morphological changes at the summit of Lewotobi Laki-laki Volcano impacted by eruptions in November 2024. Taken by drone except for 4th November 2024 was visualized from Observatory Post.

Conclusion

The eruptive behaviour of Lewotobi Laki-laki during the 2023–2025 period transitioned from effusive to explosive styles, following a nine-year dormancy. Initial activity resumed with a mild eruption on 23rd November 2023, escalating to a directed blast on 3rd November 2024, followed by vertical explosive eruptions. Intermittent dome formation and lava flows were observed between explosive episodes.

The directed blast on 3rd November 2024 predominantly impacted the northwest sector, prompting a revision of the volcano hazard map to accommodate future eruptive scenarios. The hazard zone radii were adjusted from 2 km (Zone III), 5 km (Zone II), and 7 km (Zone I) in the previous map (Mulyana *et al*., 2009) to 4 km, 6 km, and >9 km, respectively, in the updated version (Kartadinata *et al*., 2025).

A subsequent explosive eruption on 20th March 2025, followed by column collapse, affected the northeast and northwest flanks. The impact remained within the hazard parameters recommended by CVGHM, GA. From December 2023 onward, intensive eruptive activity has led to significant morphological changes at the summit, including the development of cracks, alteration zones, and persistent fumarolic activity—features that may serve as precursors to future eruptions.

Continuous and detailed monitoring of Lewotobi Laki-laki is essential to understand its evolving activity and to provide timely, accurate information to stakeholders and communities residing in the vicinity of the volcano.

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