Volcanic seismicity beneath Chuginadak Island, Alaska (Cleveland and Tana Volcanoes): Implications for magma dynamics and eruption forecasting

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Cleveland and Tana are remote volcanoes located in the central Aleutian volcanic arc on the eastern end of the Islands of Four Mountains. The persistently active Mount Cleveland volcano, located on the western side of Chuginadak Island, is surrounded by several closley spaced Quaternary volcanic centers including Carlisle, Herbert, Kagamil, Tana, and Uliaga, and numerous small satellite vents on Chiginadak, between Cleveland and Tana (Fig. 1). The Alaska Volcano Observatory (AVO) installed two permanent broadband seismometers on Chuginadak Island near Cleveland in 2014, and we operated a temporary broadband network on the western side of the island in 2015-2016. Collectively, these stations provided the first seismic observations of this frequently active volcano and the surounding Holocene-aged volcanic vents. During the study period (July 2014-January 2019), eruptive activity at Cleveland was characterized by small explosions separated by periods of lava effusion that fomed small domes in the volcano's summit crater. We characterize seismicity beneath Chuginadak Island through automated analysis of event waveform frequency content, development of a one-dimensional P-wave velocity model, calculation of earthquake hypocenters, magnitudes, focal mechanisms, and identification of earthquake families. This analysis reveals the full range of seismic event types expected in a highly active volcanic environment and includes Volcano-Tectonic (VT) earthquakes, Long-Period (LP) events, and explosion signals. LP events appear to cluster at shallow depth beneath the active crater of Mount Cleveland and almost all of the explosions occur without identifiable short-term (hours to days) seismic precursors. VT earthquakes beneath Mount Cleveland occur at depths of 2 to 8 km BSL and range in magnitude from -0.2 to 1.8. VT focal mechanisms indicate have horizontal P-axes that align with the regional axis of maximum stress. These observations, and a relatively slow one-dimentional seismic velocity model, suggest are consistent with a shallow body of magma that is fed through a deeper conduit system. The time-history of VT earthquakes and shallow LP events suggest their occurrence may track the transfer of magma and fluids from the mid-crust to the shallow portions of the conduit system and may provide a means to anticipate future explosions and periods of dome growth. VT hypocenters also occur ~7 km to Cleveland's northeast at depths of 5 to 10 km BSL, below a group of Holocene-aged vents between Mount Cleveland and Tana. These earthquakes have vertically-oriented P-axes and a greater percentage occur in families. These observations, combined with observations of vent orientation and morphology and gas flux, suggest the area between Cleveland and Tana represents a zone of complicated volcano-tectonic interaction, similar to calderas elsewhere in the Aleutian arc. The presence of a larger volcanic system in the IFM could influence magmatism and account for the multiple closely-spaced volcanic centers in this region. ■

References

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Figure 2 (right). Sketch of the major components of the Chuginadak Island magmatic system defined by observed seismic activity after the conceptual model proposed by Werner et al. (2020). The principal seismic components of this model include the inferred source of LP seismicity likely within the Cleveland cone, the VLP explosion source zone at 300 - 600 m ASL (Haney et al., 2019), a modeled seismo-acoustic source zone that extends from the summit to sea level (Iezzi et al., 2020), VT earthquake hypocenters that range in depth from 2 to 8 km BSL, The zone of VT hypocenters under the Isthmus cones that range from 5 to 10 km depth BSL, and the deeper low velocity anomaly from 10 to 20 km depth identified by seismic receiver functions (Janiszewski et al., 2020).

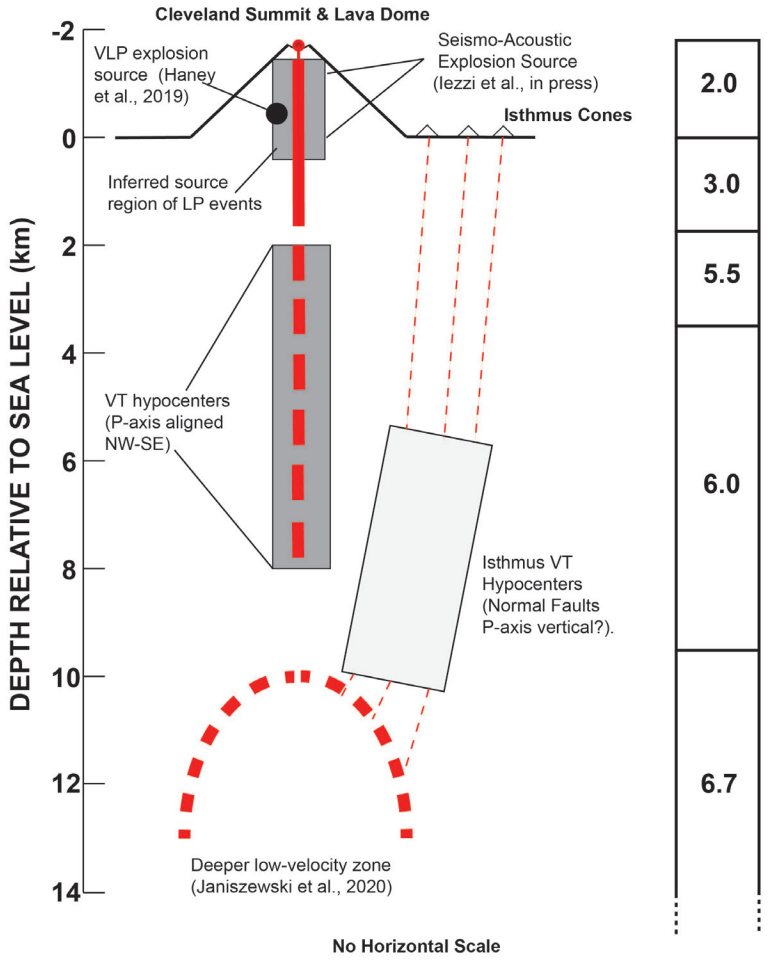

Figure 1. (bottom) Location of Mount Cleveland volcano, ~70 km west of the settlement of Nikolski, Alaska, in the Central Aleutian arc. Volcanoes are shown with triangles and settlements with plus symbols. Modified after Werner et al. (2020).