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Tuyas (subglacial volcanoes): an underutilised tool for paleo-ice reconstruction

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The landforms resulting from subglacial volcanic eruptions represent an underutilised resource for paleoglaciological reconstructions. These "glaciovolcanoes" interact intimately with their eruption environment to produce a wide range of unique edifice morphologies and characteristic deposit lithofacies. The physical properties of glaciovolcanic deposits directly reflect the nature of their subglacial eruption environment (i.e. ice thickness, ice surface elevation and glacier basal hydrology), which results in confinement or impoundment by ice, as well as, accelerated cooling of the lavas and tephras by contact with ice, snow or melt water. Glaciovolcanic deposits are also physically robust and are highly susceptible to radiometric dating (e.g. 40Ar/39Ar), giving them a distinct advantage over studies of glacial drift. Recognising and characterising glaciovolcanic eruption processes has powerful potential for advancing the understanding of ancient subglacial environments and reconstructing palaeo-ice masses. More than 65 years ago, W.H. Mathews (1951) published a seminal paper describing the Table; an iconic, flat-topped volcano in southwest British Columbia (BC), Canada. He ascribed a glaciovolcanic origin, making the Table one of the first globally recognised examples of intermediate (i.e. andesitic) glaciovolcanism. The Table is now established as the type example of a lava-dominated tuya.

We revisit this iconic volcano with a detailed field-based study that is supported by forensic volcanological mapping, 3D photogrammetry, high-resolution photography and geochronology. Our work shows the Table to be a steep-sided, flat-topped mass of dense andesitic lava that preserves a near-original outer surface of glassy, finely-jointed lava. The lavas comprising the upper surface are pervasively oxidised, suggesting that the volcano penetrated the upper surface of the ice, and interacted with the atmosphere. The edifice entirely lacks evidence for sequential upward growth and preserves an overarching morphology that strongly resembles a series of sub-parallel, coalesced vertical sheets of lava (dikes). We propose a new conceptual model for the eruption, involving dikes injected directly into an ancient, 350–450 m thick ice mass with an upper ice surface elevation of 2000–2100 m. The injected dikes were inflated endogenously outwards, within a tightly-confined, but well-drained subglacial cavity. By combining the critical ice sheet parameters established through our volcanological analysis with a new, high-resolution estimate of age, we quantitatively recover the existence of an ancient, continental-scale ice mass (i.e. the Cordilleran ice sheet) that existed in the southwest Canadian Cordillera during Marine Isotope Stage (MIS) 5b–5d. At this magnitude, the level of ice cover in SW BC is discordant with the volume that is suggested by established global paleoclimate proxies (i.e. the MIS), and suggests, that at this time, the paleoclimate in southwest BC was somewhat colder and/or wetter than the global average.