Pyroclastic passage zones in glaciovolcanic sequences

Kelly Russell[1], Ben Edwards[2], Lucy Porritt[3]

[1]Universtiy of British Columbia, Canada, [2]Dickinson College, USA, [3]University of Bristol, UK

E-mail: lucyporritt@hotmail.com

Passage zones are diachronous surfaces marking transitions between subaqueous and subaerial depositional environments during volcanic eruptions. The elevations of passage zones have long been considered to record unequivocally the heights and depths of paleo-lakes at a specific point in time and space, and are particularly useful in glaciovolcanic settings. However, previous workers have only identified glaciovolcanic passage zones within effusive volcanic sequences where the passage zone separates subaqueous lava-fed delta lithofacies from overlying subaerial lavas. Here we present the first documented description of a new type of passage zone within an entirely explosive glaciovolcanic sequence in a subglacial volcano (i.e. tuya) near Kawdy Mountain in NW British Columbia, Canada. Kima'Kho tuya is a highly dissected, small volume (4-6 km^3), early Pleistocene (1.82 Ma $\pm$40 ka) basaltic volcano. The edifice forms a high relief structure covering 28 km^2 and rising to an elevation of 1946 m.a.s.l. on a regional plateau situated at 1470 m.a.s.l. The volcano features a 476 m high, 3 km diameter, eroded tephra cone (1.1-1.5 km^3) formed by an initial phase of explosive eruption through an enclosing ice sheet. The cone comprises mostly vent-proximal (<1 km from vent) volcaniclastic deposits; distal deposits are absent or not preserved. The pyroclastic cone comprises massive to crudely bedded lapilli tuffs deposited subaqueously below the level of the englacial lake, overlain by coarsely to well bedded subaerial deposits, characterised by abundant armoured lapilli, that were deposited once the cone became emergent. The transition between subaqueous and subaerial facies occurs at 1850 m.a.s.l. and defines a passage zone within pyroclastic deposits. Subsequent eruptions formed an onlapping lava-fed delta comprising steeply-dipping (5 to 30°) beds of pillow lava, pillow breccias and pillow lava derived hyaloclastite capped by subaerial lava sheets. Our discovery requires extension of the passage zone concept to accommodate explosive volcanism and should guide future studies of hundreds of terrestrial and non-terrestrial glaciovolcanic edifices. We suggest that the geometries of pyroclastic passage zones will be sensitive recorders of dynamic changes in englacial lake levels, and will differ fundamentally from effusive passage zones. Edifice growth and lake level fluctuations will be recorded by the morphology of the pyroclastic passage zone surface, e.g. a concave upwards surface represents the simultaneous growth of the edifice whilst the lake level is rising due to trapped meltwater. Our recognition of pyroclastic passage zones increases the potential for recovering transient paleo-lake levels, improving estimates of paleo-ice thicknesses on Earth and Mars, and providing new constraints on paleoclimate models that consider the extents and timing of planetary glaciations.