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Darwin's triggering mechanism of volcano eruptions

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Charles Darwin wrote that '... the elevation of many hundred square miles of territory near Concepcion is part of the same phenomenon, with that splashing up, if I may so call it, of volcanic matter through the orifices in the Cordillera at the moment of the shock;... ' and '... a power, I may remark, which acts in paroxysmal upheavals like that of Concepcion, and in great volcanic eruptions,... '. Darwin reports that '... several of the great chimneys in the Cordillera of central Chile commenced a fresh period of activity ....' In particular, Darwin reported on four-simultaneous large eruptions from the following volcanoes: Robinson Crusoe, Minchinmavida, Cerro Yanteles and Peteroa (we cite the Darwin's sentences following his The Voyage of the Beagle and researchspace. auckland. ac. nz/handle/2292/4474).

Let us consider these eruptions taking into account the volcano shape and the conduit. Three of the volcanoes (Minchinmavida (2404 m), Cerro Yanteles (2050 m), and Peteroa (3603 m)) are stratovolcanos and are formed of symmetrical cones with steep sides. Robinson Crusoe (922 m) is a shield volcano and is formed of a cone with gently sloping sides. They are not very active.

We may surmise, that their vents had a sealing plug (vent fill) in 1835. All these volcanoes are conical. These common features are important for Darwin's triggering model, which is discussed below. The vent fill material, usually, has high level of porosity and a very low tensile strength and can easily be fragmented by tension waves. The action of a severe earthquake on the volcano base may be compared with a nuclear blast explosion of the base. It is known, that after a underground nuclear explosion the vertical motion and the surface fractures in a tope of mountains were observed. The same is related to the propagation of waves in conical elements. After the explosive load of the base. the tip may break and fly off at high velocity.

Analogous phenomenon may be generated as a result of a severe earthquake. The volcano base obtains the great earthquake-induced vertical acceleration, and the compression wave begins to propagate through the volcano body. Since we are considering conic volcano, the interaction of this wave with the free surface of the volcano may be easily analysed. It is found that the reflection of the upward-going wave from the volcano slope produces tensile stresses within the volcano and bubbles in conduit magma. The conduit magma is held at high pressure by the weight and the strength of the vent fill. This fill may be collapsed and fly off , when the upward wave is reflected from the volcano crater as a decompression wave.

After this collapse the pressure on the magma surface drops to atmospheric, and the decompression front begins to move downward in the conduit. In particular, large gas bubbles can begin to form in the magma within the conduit. The resulting bubble growth provides the driving force at the beginning of the eruption. Thus, the earthquake-induced nonlinear wave phenomena can qualitatively explain the spectacular simultaneity of large eruptions after large earthquakes.

The pressure difference between a region of low pressure (atmosphere) and the magma chamber can cause the large-scale eruption. The beginning and the process of the eruption depend on many circumstances: conduit system and its dimension, chamber size and pressure, magma viscosity and gas concentration in it may be the main variables .

The resonant free oscillations in the conduit may continue for a long time, since they are fed by the magma chamber pressure (Galiev, Sh. U., 2003. The theory of nonlinear trans-resonant wave phenomena and an examination of Charles Darwin's earthquake reports. Geophys. J. Inter., 154, 300-354.). The behaviour of the system strongly depends on the magma viscosity. The gas can escape from the bubbles more easily in the case of low viscous magma. However, if the magma is very viscous, so the gas cannot escape so easily, then the bubbles grow very quickly near the vent only. Effects of this growth can resemble an explosion.