Geophysical Research Abstracts, Vol. 9, 08044, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-08044

A CO_2-rich gas trigger of explosive paroxysms at Stromboli volcano (Italy)

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Stromboli, in the Aeolian island arc, is one rare basaltic volcano on Earth displaying persistent explosive activity at same crater vents for hundreds of years. Two main types of explosions are observed: (a) Recurrent (every 10-20 mn) Strombolian-type outbursts, tapping the crystallised upper magma column, which are driven by the periodic ascent and bursting of gas slugs that form through bubble coalescence and accumulation in the volcano conduits; and (b) Discrete ($\sim$2 per year on average) explosive paroxysms which constitute a major hazard for visitors and volcanologists because they can impact wide areas of the volcanic cone and have no obvious precursory signals [1,2]. Their triggering mechanism is still unclear. However, they are unique events during which the aphyric volatile-rich HK-basalt feeding the volcano is directly erupted as highly vesiculated pumice [2-4], which means that they must originate from below the volcano conduits in which degassing-induced magma crystallisation occurs essentially. The fast ascent of discrete magma blobs of the primitive basalt has been suggested as a possible deep triggering mechanism [2-4]. Here I'll show that a more plausible alternative source mechanism for these explosions is the catastrophic uprise of CO_2-rich gas pockets generated from intermittent gas accumulation in the sub-volcano plumbing system [5]. Airborne measurements of the SO_2 and CO_2 crater plume emissions [6,7] demonstrate that carbon dioxide is highly abundant (2.2$\pm$0.2 wt%) in Stromboli parental magma and, hence, should start exsolving at mantle depth. At $\sim$10 km in the arc crust, where the parent magma differentiates into the erupting HK-basalt, 2.5 wt% of CO_2-rich gas, with high CO_2/S ratio ($\sim$40), already coexists with the low viscosity basaltic melt. Modelling shows that the high gas volume fraction (increasing from 10% at 10 km to $\sim$30% at the base of the volcanic pile) and the bubble size should easily permit bubble segregation and temporary bubble foam

growth at deep feeder discontinuities, even though closed-system magma ascent prevails on a time-average basis. Foam collapse [8] should intermittently trigger the fast uprise of large CO_2-rich gas pockets whose expansion constitutes the main driving force of paroxysmal explosions. The size of the gas pockets was estimated. Such a gas-driven mechanism well reconciles (i) the dynamics of the paroxysms (sudden occurrence, lack of short-term geophysical forerunners, strikingly minor effects on the shallow conduit system and the magma composition), (ii) their petrologic singularities (decompressive extrusion of moderate amount of the aphyric basalt as pumice, carrying of deeply derived Mg-rich olivine crystals by the melt envelope of the gas pockets), and (iii) the gradual decrease or low level of seismic tremor in the several (average: $\sim$4) months preceding 90% of the paroxysms [9], here demonstrated to reflect a reduced gas transfer across the volcano conduits due to partial gas retention and pressure build up at depth. One key warning signal of forthcoming paroxysms could be increasing CO_2/S ratio in crater gas emissions, due to enhanced leakage of CO_2-rich bubble foam prior to collapse. Precursory leakage of deeply derived gas is indeed supported by the anomalous S/Cl peak ratio detected a few tens of hours prior to a powerful explosion on 5 April 2003 [10]. Continuous gas survey with remote sensing tools is thus of highest priority to forecast these events in future. The present interpretation of Stromboli paroxysmal explosions may apply to other basaltic volcanoes displaying similar activities.

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