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Deciphering magmatic reservoir failure using differential stress, driving pressure ratio and tensile strength – implications for eruption forecasting

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In this study a relation is established between differential stress (σ_d), driving magma pressure ratio (R') and tensile strength (T) of a rock mass in a volcanic system. It is shown that in σ_d vs. R' space, the T curve follows equation of rectangular hyperbola. For dyking or volcanic eruption to occur, this T curve must be exceeded. It is proposed that this theoretical relation can be exploited to understand magma reservoir failure and for volcanic eruption forecasting. Applicability of this theoretical relation is demonstrated on Santorini volcanic system (Greece) for which considerable background information is available from previous studies. Published dyke orientation and aspect ratio data from Santorini yield σ_d and R' values of 8.04 MPa and 0.22 respectively. Considering weak quality host rock mass in Santorini, tensile strength curve for T=1.5 MPa is plotted in σ_d vs R' space. Taking into account past magma reservoir volume and rock physical property estimates, and assuming σ_d and absolute stress to be constant, it is argued that change in reservoir dynamics would be controlled by variation in volume of magma released from the deeper magma reservoir to shallow reservoir (V_r) in Santorini. Values of R' and V_r for the events of non-dyking in Santorini are also calculated. Minimum R' and V_r required to induce diking and eruption are estimated and it is concluded that the proposed theory can be generally applied for eruption forecasting.