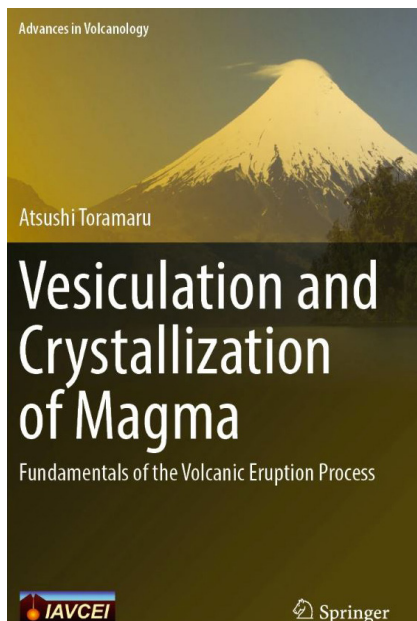


**Vesiculation and crystallization of magma: fundamentals of the volcanic eruption process**, by Atsushi Toramaru, 2022. Springer [Advances in Volcanology]; xxxii + 427 pages; hardcover price €149.79, paperback price €149.79; eBookprice €117.69, ISBN 978-981-16-4208-1



The present tome is a continuation in the ‘Advances in Volcanology’ series, as produced by the IAVCEI, the world organisation of volcanologists, and constitutes the English edition of a Japanese book that appeared in 2018 and written by Atsushi Toramaru, professor in the Department of Earth and Planetary Science at Kyushu University. The primary focus of the present volume revolves around the processes of vesiculation (involving formation of bubbles) and crystallisation (pertaining to solidification of magma into well-structured solid matter). These processes take place primarily under endogenous conditions, occurring in both the magma chamber and the eruptive conduit. Furthermore, they play a significant role in shaping eruptive mechanisms and in influencing the overall style of volcanic eruptions. The texture of bubbles and crystals is impacted by temperature and pressure paths that the magma has undergone; this can be investigated by applying either the equilibrium theory or thermodynamics, and the disequilibrium

theory or kinetics. Toramaru does not wish to take shortcuts when dealing with these topics, in that he prefers not produce an easy-to-understand book that may become popular but fails to delve into the necessary physical concepts needed to address these processes quantitatively. The author quantitatively describes all the processes discussed through detailed explanations of the derivation of equations and the underlying fundamental physics. The present volume is divided into four parts (inspired by nature, vesiculation of magma, crystallisation of magma and application, respectively) and ten chapters. A useful list of symbols precedes the first chapter and short lists of references conclude each chapter. Throughout the chapters, readers will find numerous fact sheets that offer in-depth studies or historical notes. These fact sheets are distributed plentifully, all characterised by a consistent format and accompanied by clear titles.

The behaviour of volcanoes is introduced by examining recent eruptions in Japan as case studies. By studying these eruptions and the rocks resulting from them, we can gain insights into the entire process of an eruption, from the magma chamber to the deposition of volcanic products. While this approach enhances the reading experience, it is important to note that certain considerations are impacted by the specific events that are described. For instance, the description of pyroclastic flows focuses mainly on the Heisei eruption of the Unzen volcano, in which the collapse of a lava dome resulted in this particular phenomenon. However, it is worth noting that while this case represents one instance of pyroclastic flows, most of such flows are actually formed by the collapse of an eruptive column.

The second chapter explains the equilibrium theory related to the formation of bubbles of volatiles (water and carbon dioxide) in silicate melt as a result of changes in temperature and pressure. In cooling, crystallisation of magma proceeds and becomes supersaturated with volatiles, then vesiculates (a phenomenon known as second boiling) and overpressurised.

Chapter 3 focuses on the formation and behaviour of bubbles in liquids, exploring both theoretical perspectives and experimental findings. Homogeneous and heterogeneous nucleation are described. The growth and expansion of bubbles are illustrated in Chapter 4. Bubbles nucleating in supersaturated liquids grow by  $H_2O$  diffusion into bubbles and expand by decompression. The comprehension of bubble growth and expansion processes involve the simultaneous solution of the following equations: (1) an equation governing the diffusion flux for the rate of molecule increase within bubbles, (2) the Rayleigh-Plesset equation, which describes the change in bubble radius by conservation of momentum, (3) an equation concerning the diffusion field of  $H_2O$  in the melt, (4) an equation encompassing the conservation of mass of  $H_2O$  in the entire system, as well as (5) an equation representing the gas state within bubbles, known as the equation of state.

Chapter 5 explores the temporal evolution of vesiculation and begins by deriving temperature, pressure and volatile concentration, followed by successive calculations of bubble nucleation rate and growth rate. Vesiculation experiments under a pressure of 1 atm were hardly ever conducted until the 1990s. They are basically conducted with gas-medium high-pressure apparatus. The process of decompression is achieved by regulating the opening and closing of the pressure valve. Once the desired pressure is attained, the sample is rapidly cooled by transferring it to a lower temperature. The quenched sample is then analysed in order to measure its vesicularity, distribution of bubble radii, number density of bubbles and water content in the melt. For the homogeneous nucleation of rhyolitic melt, experiments demonstrate good consistency with theory.

Chapter 6 discusses the various phenomena experienced by bubbles within magma, including secondary growth, deformation, coalescence, detachment, collapse and oscillation. Gas permeability is a factor that determines whether an eruption will be explosive or effusive. An open system behaviour is expected for magma providing lava flows and lava domes, with effective occurrence of out-gassing. In Part III, decompression-induced crystallisation is described. The kinetics of the cooling crystallisation of magma is illustrated in Chapter 7. In the 1970s, laboratory investigations into crystallisation commenced as part of endeavours to elucidate the source of lunar rocks retrieved through the Apollo space programme. Numerous experiments have since been carried out by employing liquids with a composition similar to basalt found on the moon. The nucleation rate, which depends on the extent of

undercooling, plays a crucial role in the process of crystallisation.

Chapter 8 provides a summary of the similarities and distinctions between cooling crystallisation and decompression-vesiculation-induced crystallisation. Magma vesiculation refers to the release of water from the melt; a reduction in water content results in an elevation of the melting point of crystal phases. As a result, the majority of groundmass crystals in volcanic rocks are formed through crystallisation induced by decompression. Experimental investigations have been conducted to replicate the groundmass texture of eruptive materials and have provided insights into the relationship between decompression conditions and various factors such as nucleation rate, growth rate, crystal size distribution, crystallinity, crystal morphology and composition.

Chapter 9 discusses how crystal size distribution serves as a means to reconstruct the kinetics of nucleation and growth. In 1988, Cashman conducted measurements on the crystal size distribution (CSD) of microlites from Mount St. Helens. The present study considered precursory events, including pre-eruption earthquakes, as indicators of magma ascent. By analysing the timing of these signals, an appropriate crystallisation time was determined. Toramaru starts and concludes his presentation of volcanic processes with natural examples with a large interlude that elucidated the governing laws behind these processes. Finally, he utilises these physical equations to interpret the texture of volcanic products in Chapter 10, presenting examples of recent eruptions in Japan and concerning various eruptive styles: Plinian and sub-Plinian, Vulcanian, lava domes and lava flows. The application of the models presented above makes it possible to estimate the dynamics in volcanic conduits or to provide long-term predictions, i.e., when precisely a volcano will erupt.

A note on nomenclature is called for: I disagree with the use of negative terminology such as 'non-explosive' rather more appropriate terms such as 'effusive'. The aim of the present book is to offer a comprehensive understanding of the physical principles that govern magma behaviour within volcanic conduits. Toramaru's explicit intention is to include all necessary procedural details, enabling readers to analyse eruptive mechanisms quantitatively. Consequently, it serves as a valuable guide, presenting and providing insightful commentary on the gradual progression of vesiculation and crystallisation processes in magmas.

*Claudio Scarpati*  
*University of Naples Federico II, Italy*  
*e-mail: claudio.scarpati@unina.it*