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Pyroclastic density currents and the sedimentation of ignimbrites

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Preface

Ignimbrites are vast, landscape-modifying deposits composed mainly of pumice fragments and ash. They derive from the most hazardous types of explosive volcanic eruptions and record rapid sedimentation from catastrophic pyroclastic density currents that sweep across the ground. Since early work on ignimbrites by P. Marshall (1935), H. Kuno (1941), R. L. Smith (1960) and R. V. Fisher (1966), there has been a dramatic increase in research into these enigmatic deposits. Particularly instructive field studies include those of ignimbrites from the large caldera volcanoes of the western USA, from the arc volcanoes of the Mediterranean region, Japan, Southeast Asia, South America and New Zealand, and from intraplate volcanoes such as the Canary Islands. Experimental-analogue and numerical modelling of pyroclastic density current behaviour and sedimentation have recently complemented the field-based work. Now there is a bewildering plethora of ignimbrite classification schemes, emplacement models and deposit interpretations. It is therefore timely to take stock, to synthesize modern understanding, and, in particular, to consider how field investigations of ignimbrite lithofacies can best be used both to infer actual pyroclastic density current behaviour and to constrain or test the various models. A fresh look at ignimbrite emplacement is all the more important with the recognition that ignimbrites can relate to eruptions with magnitudes sufficient to impact global climate and biota.

This Memoir reviews what is known about pyroclastic density currents and presents a new *conceptual framework* for investigating the deposition of all types of ignimbrite lithofacies. After introducing some key concepts in Chapter 1, we review important observations and experiments that bear on the nature and behaviour of pyroclastic density currents (Chapter 2), and on the mechanisms by which diverse particles are supported and variously segregated within them (Chapter 3). In Chapter 4 we present the conceptual framework that we have devised to comprehend how different ignimbrite lithofacies are deposited. In this framework, ignimbrite sedimentation is treated as a sustained flow-boundary process in which the sorting and bed-form characteristics of the deposit relate to different types of concentration and shear distributions within the *flow-boundary zone* that spans the basal part of the current and the uppermost part of the aggrading deposit. Chapter 5 describes and illustrates a wide variety of common ignimbrite lithofacies, including examples from around the world, and in it we apply the flow-boundary zone approach to provide some insights into how they may have formed. In Chapter 6, we elaborate the paradigm developed in earlier chapters to consider how the various architectures of ignimbrites may be used to reveal how flow-boundary zones of sustained currents evolved through time and space. We consider the diverse vertical and lateral lithofacies sequences exhibited by ignimbrites with reference to a temporal framework provided by time-surfaces called *depochrons* and *entrachrons*. Such sheet-scale analysis is important because an individual lithofacies provides information primarily only about the local flow-boundary zone, whereas the properties and behaviour of the current as a whole may only be deduced when the sheet-scale depositional history is understood.

The flow-boundary zone approach to interpreting ignimbrite sedimentation, linked with the scheme for analysis of ignimbrite lithofacies architecture, provides a powerful means to constrain the overall behaviour and evolution of unseen pyroclastic density currents. The approach begs further research into the mechanisms and rates of the various processes that are inferred. It also has applications for the interpretation of deposits from lahars, turbidity currents, and other types of granular, liquefied or fluidized sediment gravity flows. We hope that this Memoir both stimulates and facilitates further research into pyroclastic density current deposits and into experimental quantification of physical conditions and process rates.

KEY WORDS: density current, sedimentation, ignimbrite, pyroclastic flow, pyroclastic surge, granular flow, fluidization, hindered settling, granular segregation.

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Dedication

We dedicate this book to the memory of R. V. Fisher (1928–2002).