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Weathering and the Riverine Denudation of Continents

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Preface

Continental denudation has been the center of attention of a reduced and select group of outstanding specialists for several decades. The foci have been placed in queries such as how much solid and dissolved material is annually removed from the continents by rivers and how much water is involved in the process?; which are the forcing variables and processes in continental wearing away?; is climate more important than lithology in defining the rate of denudation?, where and when?; how much height do continents recuperate through isostatic rebound as a consequence of denudation?; are weathering and denudation connected in a straightforward way? These and other similar questions became particularly important several years ago, when it turned out that weathering and denudation were linked to climate change, nowadays or in the geological past. The joint action of weathering and denudation has played, for example, a significant role in the formulation of the amazing hypothesis of the "Snowball Earth," which appears to have occurred occasionally about 650 million years ago. On the other hand, there exists the additional anthropogenic impact that adds complexity to the current scenario because it may amplify erosion in ill-managed areas and, hence, increase sediment retention behind dams.

We have written this Brief Monograph, using classic references and case studies, trying to direct the reader's attention to the simple fact that continental denudation begins with weathering. Rivers constitute the amazingly efficient conveyor belt system that performs the main task in transferring most of the solid debris and dissolved substances thus produced, to the coastal ocean. At the same time, we must not disregard the fact that, in so doing, they contribute to sustain a very dynamic and diverse life-supporting system, in the rivers themselves as well as in estuaries and the adjacent marine environment.

On account of its conciseness, this brief book should be viewed as a stepping stone for those who wish to pursue this subject further on and, also, as an invitation to some deeper digging into the weathering-denudation system in a multidisciplinary way.

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Several editors have kindly granted the necessary permission to reproduce graphic material and thanks are extended to all. The authors are specially obliged to Australia's CSIRO (http://www.publish.csiro.au/pid/5955.htm) and to the UK's Cambridge University Press (http://www.cambridge.org/ar/academic/subjects/earth-and-environmental-science/geomorphology-and-physical-geography/river-discharge-coastal-ocean-global-synthesis?format=PB).

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Chapter 1
Introduction

Abstract Denudation, volcanism, and tectonics are intertwined Earth system processes that constitute the main driving forces intervening in shaping the Earth's landscape. Clearly, the wearing away of the Earth's surface cannot occur unless a series of synergistic processes, collectively known as "weathering," are initiated. This term, in use for a long time, promotes the idea that climate (weather) always plays a major role in rock breakdown; since this is not the case in every instance the change for "rock decay" has been proposed recently. At any rate, the linkage between weathering and denudation is not straightforward because the latter may be limited by the former ("weathering-limited denudation") or, in contrast, it may be restricted by the hindered transport of the weathering-produced debris ("transport-limited denudation"). In addition to these possible scenarios, two new approaches have been gaining growth in the recent past: one is the study of the "regolith" as a convenient research framework, and the other is the notion of "the critical zone," where the dynamic interaction with the atmosphere and vegetation is emphasized and added to the materials collectively defined as regolith.

Keywords Denudation · Climate · Rock decay · Regolith · Saprolite · Colluvium · Alluvium · Aeolian deposits · Weathering-limited · Transport-limited · Critical zone

1.1 On Weathering and Denudation

The Earth's surface is perceived as dynamic because the remarkable effects of denudation, coupled with tectonics, are constantly changing its landscape. Weathering, erosion, and mass wasting must act before one can appreciate the effects of denudation; sometimes, they are spectacular and sometimes they are subtle, almost imperceptible. At any rate, the weathering of rocks is the preliminary process which modifies and destabilizes the uppermost layers of the Earth's land surface.

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Mineral and rock weathering is clearly the term that has been used for a long time, which describes the initiation of continental wear away. It refers to a series of processes that collectively interact and contribute in variable proportions to shape up the Earth's landforms and landscapes and, hence it has been a central concept in geomorphology.

We use in this monograph the traditional approach that divides the notion of mineral/rock decay into mechanical (or physical), biological, and chemical processes, but we tackle the problem in this way because we still lack a more evolved approach that collates all the processes that participate in the alteration of the exhumed Earth's crust. Dictionaries describe the term "*weathering*" as the action of the weather on any kind of material which is exposed to it. In geology, the term is used specifically to describe the breaking down of minerals and rocks through direct contact with the Earth's atmosphere, and waters. In the geological sense, however, the "long-term action" of weather is implied, as it happens in many definitions used in the Earth Sciences. At any rate, the ultimate action of weathering is to free materials (Fig. 1.1).

The difficulties involved in what is understood by *weathering* are currently being considered, and new ways are being explored. For example, the term itself has had a commanding influence on the evolution of research, particularly when one considers the implication that the weathering of any rock type will follow closely the path set by climate. It is more likely that the weathering of a particular rock, with a relatively constant composition, will be invariable in nature but variable in rate, given the changeability of climate forcing (Hall et al. 2012). To

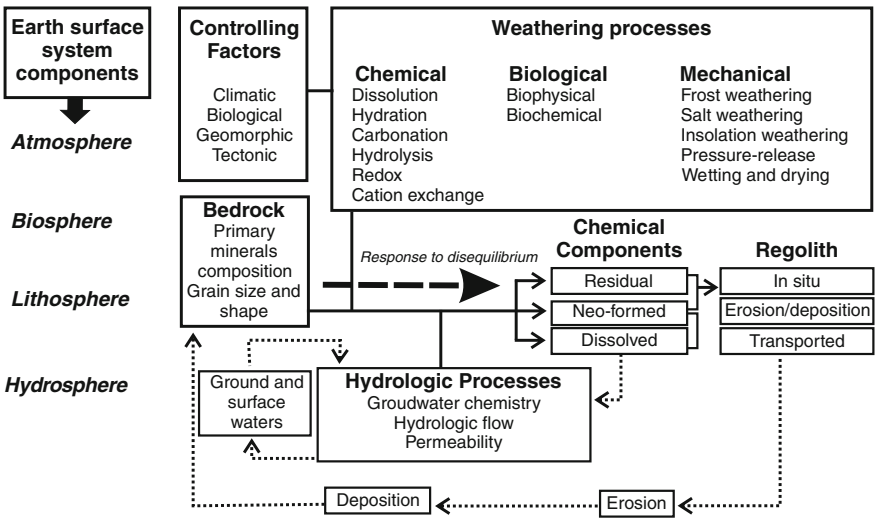

Fig. 1.1 The foremost controls on weathering and the chemical composition of the regolith. Modified from McQueen (2009). © CSIRO 2008. Published by CSIRO publishing, Collingwood, Victoria, Australia, http://www.publish.csiro.au/pid/5955.htm. Reproduced with permission