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INTRODUCTION: CONCEPTS AND GEOMORPHOLOGY

Any discipline has concepts that are key for its progress. For geomorphology these need to be explicitly stated and consistently understood for what they are. We set them within the evolving history of geomorphology and the changing techniques and understanding that have been involved. This demonstrates the fashioning surges that have characterized the discipline and which complicate identification of those concepts which endure and which remain basic to the present and future study of geomorphology.

Geomorphology is the science concerned with the forms and processes on the Earth's land surface. Even with the fascinating challenges of explaining large-scale features such as the distribution of major mountain belts, spectacular landforms such as the Grand Canyon in the southwestern USA (**Figure 1.1**), or process events such as the Iceland volcanic eruption of Eyjafjallajökullin in 2010, geomorphology more generally has not captured the imagination of the general public as it could and should have done. There is today a need to advance geomorphic literacy in the way that climate literacy is being proposed (Climate Literacy, *Global Change Program 2009),* to some extent redressing a lack of student knowledge (Theissen, 2011). It is arguable that practitioners of geomorphology have not sufficiently emphasized the interesting and important underpinning concepts of the discipline as much as they might have. Nonetheless, recent heightened awareness of global environmental change, including the effects of both rapid climate change and increasing human impacts on the Earth's surface, underlines the need to do so. A particular merit of geomorphology is that it has long recognized that our world is a changing one, and so the discipline has devised the means for interpreting sets of phenomena in terms of how they have developed in the past, and may develop in the future, beyond the timescales of individual human experience.

Geomorphology deals mostly with landforms on a human scale, although it may at the same time depend on comprehending physical, chemical and biological processes that range in their dimensions from the continental to the microscopic; forms range in size from minor slope features up to continent-scale landmasses. It also deals in timescales ranging from wind or water turbulence occurring in seconds to slow geological processes operating over millions of years: this poses rather obvious observational difficulties. There is a need to visualize happenings beyond everyday sensory appreciation, though no more so than for modern cosmologists studying the form and origins of the universe, or microbiologists deciphering the functioning of DNA. Landforms are also developed in complex spatial patterns that may be difficult to recognize at first sight. Over recent years many sciences have benefitted from the vastly greater availability of observational and analytical technologies. For geomorphology, this allows such things as the dating of Earth materials, the rapid assessment of sediment chemistry, the survey of river flows, computer modelling of emergent forms, and remote sensing of the Earth's surface. Key ideas can now be rigorously subjected to what in the business world are called 'proof of concept' (POC) procedures, using prototype field studies, laboratory analysis, and physical or numerical modelling; much contemporary published research is of this kind. Necessarily highly technical, this may initially prove alarmingly incomprehensible for many readers. But underlying it all, whether in the minds of researchers to start with or developed as observations proceed, there are key ideas that have come to crystallize our present understanding of the world's land surface.

The challenge for students of geomorphology, indeed of any discipline, is to find a comprehensible way into, and to become conversant with, modern research and its antecedents. With the advent of the internet and improved access to many sources, the research literature has burgeoned rapidly (with suggestions that the total amount of knowledge now doubles every 18 months), so it is easy to become overwhelmed with information and baffled by detail. In 2013 alone, the journal *Geomorphology* published 369 research papers, most of a highly technical nature. Consequently, many students have difficulty in distinguishing between basic underpinning concepts and useful but essentially research level technical material. This is not to belittle what are now indispensable techniques, or their on-going development that forms the focus for much dedicated present research. But for newcomers to the field without much technical knowledge, these can form an impenetrable initial barrier to understanding the things that the science is trying to do. One way of assisting such understanding is first to focus on **key *concepts***, which can be defined as **those abstract ideas, general notions or units of knowledge that are vital to the development of a reliable science**. There is a series of connections (Harvey, 1969: 19) between sense perceptions (percepts), mental constructs and images (concepts) to linguistic representations (terms). Although hitherto concepts have not featured prominently in any one geomorphology book it is important that we consider which concepts actually do underpin geomorphological thought (major concepts are shown in **bold** in subsequent chapters), and how such abstract or general ideas have been deduced or inferred from specific empirical data. Knowledge of these concepts, and their development, can provide the gateway to a more general understanding of what landform science is currently able to tell us.

Philosophy is the discipline concerned with an a priori analysis of concepts, as ideas are sought, possessed or understood, in coming to formulate beliefs (and ultimately knowledge) about the real world. Philosophers have given considerable attention to concepts, since Immanuel Kant (1724–1804) characterized those resulting from experience as *a posteriori*, and Arthur Schopenhauer (1788–1860) contended that concepts are 'mere abstractions from what is known through intuitive perception'. Philosophers and others have recognized several types of concept although Machery (2009) argued that the dominant psychological theories of concepts have yet to be organized within a coherent framework. Laurence and Margolis (1999) suggested that there is still much controversy about what kinds of things concepts are, how they are structured and how they are acquired. For many, one of the traditional tasks of analytic philosophy is that of providing analyses of concepts which can be thought of as mental representations, as abilities peculiar to cognitive agents, or as abstract objects. *Frames*, which originated in logic-based artificial intelligence (AI), have been suggested as the basic format for concept formation in cognition because they are an excellent tool for the investigation of conceptual frameworks underlying scientific *theories* (hypotheses related by logical or mathematical arguments explaining a variety of connected phenomena) and their respective *ontologies* (the set of entities presupposed by theories) (Schurz and Votsis, 2007). A dynamic frames approach was developed by Lawrence Barsalou (1992) for the representation of concepts and the addressing of issues about conceptual change (see Andersen and Nersessian, 2000). Thus *Key Concepts in Geography* (Holloway et al., 2003) listed concepts including space, time, place, scale, physical systems, landscape and environment. Subsequently in a second edition Clifford et al. (2009) added nature, globalization, development, sustainability and physical geography, and risk. The breadth of things that could be regarded as underpinning concepts, explicit or implicit, is extremely wide.

For this book, we focus on concepts necessary for our current understanding of geomorphology as landform science. Those selected are less general than time and space, but also less specific than individual logical or mathematical theories linking entities (such as the relationship between river channel dimensions and discharge variables). Other expressions used for over-arching approaches are *paradigms* (Kuhn, 1962) and *research programmes* (Lakatos, 1970), but here we focus on concepts that relate specifically to geomorphology. In the remainder of this introduction we outline the development of geomorphology as a discipline, and its relationship to physical geography and to geology, ecology and environmental science (1.1). Subsequently we indicate the broad categories of techniques employed by geomorphologists (1.2), and then explain the chapter structure for the presentation of concepts in four major sections, indicating why the specified concepts have been selected (1.3).

1.1 Geomorphology as a discipline

In addition to four books in a series on the history of the study of landforms (Chorley et al., 1964; 1973; Beckinsale and Chorley, 1991; Burt et al., 2008) other works have traced the antecedents of the science of geomorphology in detail so that only a synopsis of the development of the science is provided here. The first use of the word geomorphology was in 1858 in the German literature (see Roglic, 1972; Tinkler, 1985). **Table 1.1** suggests some of the founding assumptions prior to that date and indicates others that were subsequently influential. In geomorphology, as in any other discipline, the foundations of the discipline are significantly shaped by the contributions of single individuals, but similar ideas can emerge in more than one country. Whereas in the 19th and early 20th centuries ideas diffused relatively slowly, by the late 20th and early 21st centuries the speed of technical communication was so rapid that it is no longer easy to identify a single influence or the origin of ideas. Hence **Table 1.1** is an approximation, compiled as a series of indicator milestones, to suggest the influences affecting the shaping of a discipline from the mid 19th century to the present day. Many ideas are cross disciplinary so that terms such as 'evolution', which would have been without great scientific meaning before about 1800, are now used (though with different technical definition and process underpinnings) from astrophysics to biology. In addition to individuals, there are wider influences: broader scientific ideas, researchers' experience of particular regions, diverse publications and journals, the work of academic societies and technological developments, as well as the constraints set by financial limitations or the public policy demands of particular societies. The selection in **Table 1.1** tells much about our perception but it can be supplemented by the reader. A different example reflecting writer perception is the cast of principal characters listed by Kennedy (2006) which omits some that we include but includes others that we do not.

In the light of developments summarized in **Box 1.1** three particular motivational trends now recognized are: the need for more multidisciplinary research and investigations; the question about how far geomorphology can extend; and the potential to make further progress in relation to the management and design of environments (Gregory and Goudie, 2011b). However, a paradox now appears: despite the obvious importance of, and interest in, geomorphology as concerned with explaining the land surface of the Earth, the discipline itself 'remains little known and little understood, certainly in relation to other academic disciplines, and especially outside university circles' (Tooth, 2009). Appreciating the way that the science of landforms has grown as a discipline, and being mindful of the potential that it now has, mean that this is a particularly appropriate time to focus upon basic fundamental concepts. **Table 1.1** provides the background for such concepts against the timeline of the development of geomorphology.

1.2 Techniques employed by geomorphologists

Technical advances are arguably enabling great progress to be made in the 21st century. In fact since 1960 changes in geomorphology are reminiscent of the way in which Chemistry and Physics were changed by the technological breakthroughs in the early 20th century. Thus Summerfield (2005b) described the subject as having 'major research frontiers ranging in scale from the transport paths of individual particles over a river bed to the combined tectonic and surface processes responsible for the 100 million year history of sub-continental scale landscapes'. Before the 1960s geomorphology paid little explicit attention to techniques but used time-consuming methods of field surveying, field sketching, and mapping as appropriate. The way in which the scope of techniques available for the geomorphologist has changed is demonstrated by the content of books written to summarize those available (Table 1.2); to demonstrate the consequences of this explosion of techniques, Table 1.3 presents six categories, with an indication of those available fifty years ago, key developments since that time, and an outline of the contemporary range. **Table 1.4** summarizes the range of dating techniques now available.

Many examples could be given of recent dramatic progress made possible, but DEMs of difference (DoDs), which quantify volumetric change between successive topographic surveys, and Structure for Motion (SfM) methods, which estimate three-dimensional structures from two-dimensional image sequences, illustrate the progress now possible. Overviews from space both allow geomorphologists not only to see and measure the characteristics of large landforms, but also to

Table 1.2 Examples of publications reflecting the development of techniques in geomorphology

Year	Publication	Major Contents
1966	*Techniques in Geomorphology* C.A.M. King	Observation of form and character; Observation of processes in action; Experiment and Theory (models); Cartographic and morphometric analysis; Sediment analysis and statistical analysis
1969-	*Technical Bulletins* British Geomorphological Research Group	Aim was to 'have a source of standardized information relating to increasingly sophisticated methods of data collection' 26 published by 1980
1981	*Geomorphological Techniques* A. Goudie	In five parts: 1. Introduction, 2. Form, 3. Material properties, 4. Process, 5. Evolution
1990	*Geomorphological Techniques* A. Goudie (2nd edition)	
1983	*Geomorphological Field Manual* R. Dackombe and V. Gardiner	Chapters: 1. Topographic survey, 2. Geomorphological mapping, 3. Slope profiling, 4. Mapping landscape materials, 5. Geophysical methods of subsurface investigation, 6. The description of landscape forming materials, 7. Fluvial processes, 8. Glacial processes, 9. Aeolian processes, 10. Coastal processes, 11. Slope processes, 12. Sampling, 13. Miscellaneous aids
2003	*Tools in Fluvial Geomorphology* M. Kondolf and H. Piégay	21 chapters in seven sections: I. Background, II. The Temporal Framework, III. The Spatial Framework, IV. Chemical, Physical and Biological Evidence: Dating, V. Analysis of process and forms, VI. Discriminating: simulating and modelling processes and trends, VII. Conclusion: Applying the tools
2010	*Geomorphological Techniques* (Online Edition) British Society for Geomorphology ISSN 2047–0371	Organized in five sections: Composition of Earth Materials Topographic and Spatial Analysis Processes, Forms and Materials in Specific Environments Long-term Environmental Change (dating techniques, etc.) Modelling Geomorphic Systems

Table 1.3 A view of techniques for geomorphology

Methods, Tools and Techniques	1960s	Subsequent Key Developments
Field techniques	Field mapping, some examination of sediments and deposits, few process measurements	Electronic distance measurement (EDM) Global positioning systems (GPS) Geographical information systems (GIS) automatic loggers Analysis in real time Remote access recording of continuous measurements Geomorphological mapping revived
Numerical techniques	Pre-high speed electronic computers, very basic mathematical and statistical models	Quantitative and statistical analysis Focus on the general rather than the individual characteristics of a particular area Progress from linear to non-linear methods, chaos, and nonlinear dynamical systems approaches, GIS
Remote sensing	Air photographs	Remote sensing providing frequently repeated imagery Sensing of many aspects not previously possible LiDAR gives major advances Prospects of global DEMs at better than 10 m resolution and complete image coverage of the Earth at better than 50 cm Google Earth
Laboratory analysis	Limited to time consuming chemical analysis and size analysis of deposits by sieving and titration	Laboratory analysis of samples of water and sediments rapidly achieved Great range of new instruments available for analysis of rock, sediment, and fluid samples
Modelling	Qualitative models of long-term landscape development	Advances in numerical modelling, geochronology and remote sensing quantitative techniques used to model earth surface process and interpret the landscape
Dating techniques	Some ^{14}C	Great range of new dating methods, some very innovative Quaternary chronology refined Cosmogenic dating enabled great advances in deducing rates of erosion

focus on metre scale forms in remote environments. Geomorphology is becoming far less concentrated on those landforms which are easily accessible in mid-latitude long-populated environments.

1.3 A structure for concepts

Many concepts in geomorphology have been generated following the empirical study of specific instances or occurrences of phenomena. These can be used to encapsulate the commonality between seemingly disparate localised phenomena, so that one would expect geomorphological texts to be concerned with linking concepts as basic to the discipline. **Table 1.5** collates works that cite concepts but it is striking that relatively few are explicitly conceptual in format; geomorphological research appears to have been empirically rather than theoretically driven. What **Table 1.5** does show is the implicit conceptual guidelines – the ideas, assertions and hypotheses that have accumulated and evolved during the development of the discipline. We are well aware that many concepts could be considered as 'key' for the discipline in detail, but we believe our selection is appropriate for understanding the overall nature, and the attraction and challenge, of modern geomorphology. Complementary information on geomorphological concepts is provided through texts of several kinds (**Table 1.6**).

Recent years have seen the transformation of geomorphology with the advent of substantial advances in techniques available, but unlike the physical sciences the provision of general laws may be considered an unrealistic dream in view of the contingent factors that are people-, place- or time-dependent. It has been suggested that this is as important or even more important than general laws in determining how the world works (Phillips, 2004). Phillips (2004) therefore sees a future requirement as confronting the creative tension between *nomothetic* (concerned with general theories) and *idiographic/interpretive* (concerned with individual cases) science, and integrating the two approaches.

So what is the most appropriate way of organizing geomorphological concepts for the discipline in the 21st century? Any structure has to reflect the way in which geomorphology has evolved, it has to be capable of embracing the range of concepts which are now the basis for geomorphological study, and it should form an appropriate platform for taking on the challenges of the 21st century. The first group of concepts (A in Table 1.7) focuses on system contexts involving the methodology of the discipline and the way in which investigations are approached. Systems have provided the most durable conceptual approach since promoted by Chorley (1962) fifty years ago, so that the three subsequent categories are concerned with the functions

Table 1.7 Book Structure

1. Introduction: Concepts and Geomorphology
SECTION A: System Contexts
2. The Systems Approach
3. Uniformitarianism
4. Landform
5. Form, Process and Materials
6. Equilibrium
7. Complexity and Non-linear Dynamical Systems
SECTION B: System Functioning
8. Cycles
9. Force-Resistance
10. Geomorphic Work
11. Process-form Models
SECTION C: System Adjustments
12. Timescales
13. Forcings
14. Change Trajectories
15. Inheritance
16. The Anthropocene
SECTION D: Drivers for the Future
17. Geomorphic Hazards
18. Geomorphic Engineering
19. Prediction and Design
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(B in Table 1.7), adjustments (C), and present and future management (D) of the geomorphic system. These four categories provide a logical sequence which, when explored, can prove challenging and thought-provoking. In subsequent chapters, as in this one, tables are employed, both within the text and available online, to give additional detailed information. These are not essential to an understanding of the text but provide more detailed background information that the enquiring reader may require.

FURTHER READING

Gregory, K.J. and Goudie, A.S. (2011) Introduction to the discipline of geomorphology (pp. 1–20), Conclusion (pp. 577–85). In K.J. Gregory and A.S. Goudie (eds), *The SAGE Handbook of Geomorphology.* London: Sage.

Murray, B., Lazarus, E., Ashton, A., Baas, A., Coco, G., Coulthard, T., Fondstad, M., Haff, P., McNamara, D., Paola, C., Pelletier, J. and Rheinhardt, L. (2009) Geomorphology, complexity, and the emerging science of the Earth's surface, *Geomorphology*, 103: 496–505.

Phillips, J.D. (2012) Storytelling in the Earth sciences: the eight basic plots, *Earth Science Reviews,* 115: 153–62.

Tooth, S. (2009) Invisible geomorphology, *Earth Surface Processes and Landforms,* 34: 752–54.

TOPICS

1. In the light of the philosophy background to concepts, the history of the development of geomorphology and the list suggested in Table 1.7, where would you position concepts of evolution, and what other concepts would you expect to be included?

WEBSITE

For this chapter the accompanying website **study.sagepub.com/gregoryandlewin** includes Figure 1.1; Tables 1.1, 1.4, 1.5, 1.6; Box 1.1; and useful articles in *Progress in Physical Geography*. References for this chapter are included in the reference list on the website.