Alan Clowes and Peter Comfort

Process and Landform

Conceptual Frameworks in Geography

CONCEPTUAL FRAMEWORKS IN GEOGRAPHY
GENERAL EDITOR: W.E.MARSDEN

Process and Landform:

An Outline of Contemporary Geomorphology

Second edition

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Maps and diagrams drawn by Tim Smith

Oliver & Boyd

Contents

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Editor's Note

An encouraging feature in geographical education in the 1970s was the convergence taking place of curriculum thinking and thinking at the academic frontiers of the subject. In both, stress was laid on the necessity for conceptual approaches and the use of information as a means to an end rather than as an end in itself. The value of such convergence is still evident.

The central purpose of this series is to bear witness to this convergence. In each text the *key ideas* are identified, chapter by chapter. These ideas are in the form of propositions which, with their component concepts and the interrelations between them, make up the conceptual frameworks of the subject. The key ideas provide criteria for selecting content for the teacher, and in cognitive terms help the student to retain what is important in each unit. Most of the key ideas are linked with *assignments,* designed to elicit evidence of achievement of basic understanding and ability to apply this understanding in new circumstances through engaging in problem-solving exercises. Each of the major themes presented invites an extension of understanding through additional study. Such activities are suggested throughout the text, some of which encourage research and investigation, a current and desirable requirement in many programmes of work at this level.

Although the series is not specifically geared to any particular 'A' level examination syllabus, indeed it is intended for use in first-year geography courses in polytechnics, universities and colleges of education as well as in the sixth form, it is intended to go some way towards meeting the needs of those students preparing for the more radical advanced geography syllabuses.

It is hoped that the texts contain the academic rigour to stretch the most able of such candidates, but at the same time provide a clear enough exposition of the basic ideas to provide intellectual stimulus and social and/or cultural relevance for those who will not be going on to study geography in higher education. To this end, a larger selection of assignments and readings is provided than perhaps could be used profitably by all students. The teacher is the best person to choose those which most nearly meet his or her student's needs.

W.E. Marsden
University of Liverpool

Preface

Nature goes her own way, and all that to us seems an exception is really according to order. (*Goethe, 1824*)

In writing this book, we have been aware throughout that the physical landscape is an environment of immense diversity and considerable complexity. We have attempted to study the landscape by looking at its individual components. The processes that operate within each system evoke a response which produces a particular landform, and our aim in this book is to examine this interaction between process and landform.

Inevitably, it is impossible to be comprehensive with such a wide field to cover, but we hope we considered those aspects of geomorphology which will help to unravel many of the problems presented by the working of the British landscape. We have tried to do this as simply as possible, bearing in mind the requirements of sixth-form students but, we hope, not dodging the more difficult and less easily comprehensible interrelationships. We have drawn material from both the more familiar descriptive and the newer analytical sources in an attempt to illustrate a variety of methods of approach. Deliberately, whenever possible, we try to relate the concepts we identify to the real world and we have chosen examples to illustrate these from the British Isles where possible. The scale of our study varies widely from micro to macro scale landforms.

Throughout, we encourage students to investigate for themselves the processes and resulting landforms. In the text we have indicated some areas where research, even at a relatively simple level, could provide an interesting and valuable insight into the complexity of geomorphological systems.

Our thanks must go to many friends and colleagues who have contributed ideas, made suggestions and loaned material for inclusion in the book. In particular, we owe much to Bill Marsden, whose editorial eye, watchful as ever, improved the structure and systematised the contents of the chapters.

The second edition includes a chapter on desert processes and landforms. Also, we have taken the opportunity to modify the text in places; mostly this involves only minor changes and we hope readers will agree that they add to the usefulness of the book. We appreciate all the comments made by teachers, lecturers and students who have used the first edition, and we have tried to incorporate their suggestions whenever appropriate.

Alan Clowes
Peter Comfort

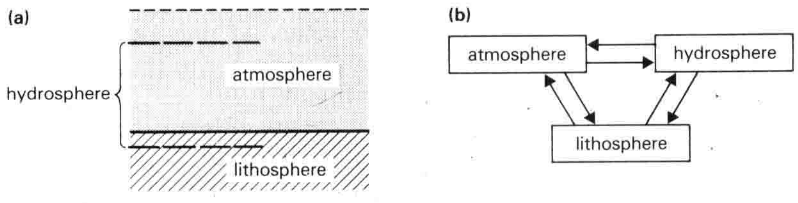
1 Introduction

A. Geomorphology

If we break the word *geomorphology* down into its component parts, its meaning quickly becomes apparent: *geo* means earth, *morph* means shape or form, and *ology* means study. A literal translation would give us 'the form of the earth', but the word is specifically used to mean the form of the earth's *surface*. We intend to look not only at form, but also at the *processes* that have been responsible for the formation of that particular form. Geographers in the past have been anxious to catalogue and describe the earth's surface and the features on it. Today, we have switched the emphasis to try to answer questions about why particular forms have developed.

The surface of the earth is the meeting point or *interface* between the gases of the *atmosphere* and the rocks of the *lithosphere* (lithos = rock) (Fig. 1.1a). Across this interface pass gases, liquids and solids. Probably the most important of these substances is water. It is present in rocks and in the atmosphere. It forms a zone which lies across the rock–atmosphere boundary and is often referred to as the *hydrosphere*. Each of these areas interacts with the others and we will investigate something of the processes of each (Fig. 1.1b).

Figure 1.1 The earth–atmosphere system



B. Scale

Over the 150 million km^2 of the earth's land surface there is a perceptible variation in shape and process. Ben Nevis and the Norfolk Broads are two very different places to spend a holiday. Yet if we were to see Britain from a satellite, the differences between these two places would be less evident. If we looked at the whole of the northern hemisphere, the differences between Ben Nevis and the Norfolk Broads would be even more difficult to detect, although those between the Alps and the Sahara would be noticeable.

If we were to go the other way and narrow down our field of vision, differences would become more evident. Deposits dumped by glaciers in Norfolk and Scotland might at first sight look rather similar. Closer inspection, however, might reveal that the minerals in the Norfolk deposit could only have originated in Scandinavia, whereas those on Ben Nevis could only have come from that area. Perception of differences and similarities depends to some extent, therefore, on scale. The matter of the universe is composed of a few types of subatomic particles, mainly electrons, protons and neutrons. It is the way these particles are grouped together to form atoms of the elements, and the way elements combine to form compounds of elements that makes up the variety of the universe. To try to represent the size of the universe and that of the subatomic particle on the same diagram creates a problem. Relative to an atom, 1 mm is a very long way, but on the scale of the universe it is totally insignificant. The problem of the representation of scale is one we will encounter frequently. There are ways around this problem.

Take the diameter of a sand grain, for convenience 1 mm, and the diameter of the earth, approximately 12 000 km. The ratio between these two values is 12 billion to one. If we double each, the ratio remains the same. In Figure 1.2, the process of doubling is represented by a uniform increase in the distance along the scale; the distance between 1 mm, and 2 mm is exactly the same as that between 12 000 km and 24 000 km. These scales are *logarithmic*. It is the ratio between values, not the values themselves, which are important.

The scale of the subject of this book extends from that of the earth down to the smallest movable fragment of rock, a clay particle. These are shown on Figure 1.2. However, occasionally, we need to stretch these boundaries to include the sun, where the energy of most of our systems comes from. We also need to include atomic-sized particles in order to look at the chemistry of some processes. The boundaries are not really very clear. At one end we begin to move into the field of astronomy and at the other to that of physics. The main area of concern is indicated in Figure 1.2.

A more practical use of logarithmic scales is in the classification of the sizes of particles of rock. Some of these particles are house-sized, occasionally even larger; others are nearly molecular-sized. Figure 1.3 shows the sizes of particles graphically, from clay, 1/1000 mm across, to cobbles, boulders and even larger fragments. Notice how the scale works by a factor of two so that each jump halves the value or doubles it. The phi (Φ) scale uses this system to make the numbers simple. There are twenty steps covering the whole size range.

Figure 1.2 The scale of natural phenomena

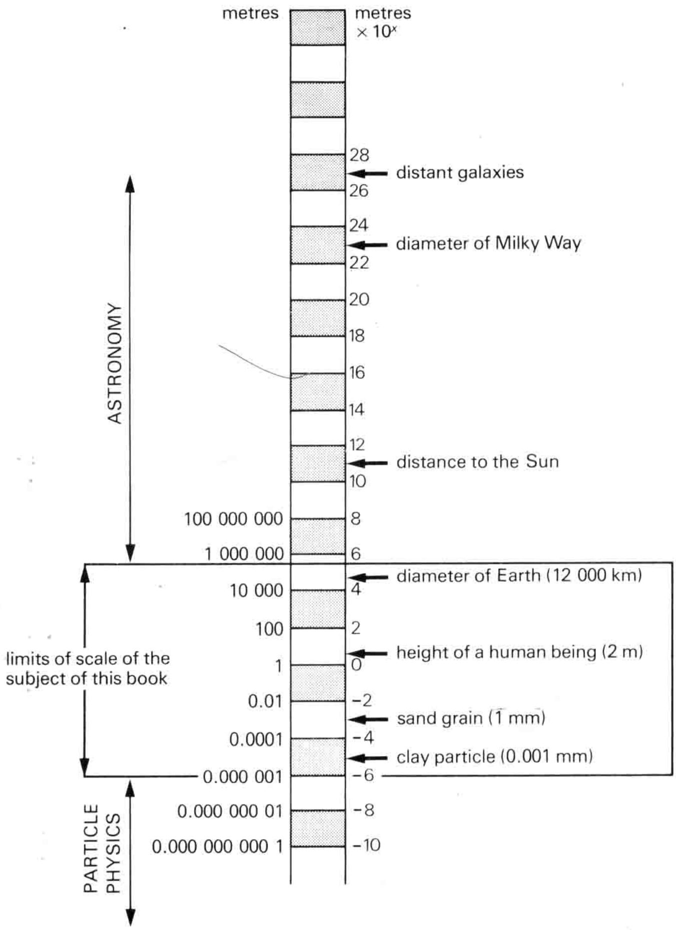
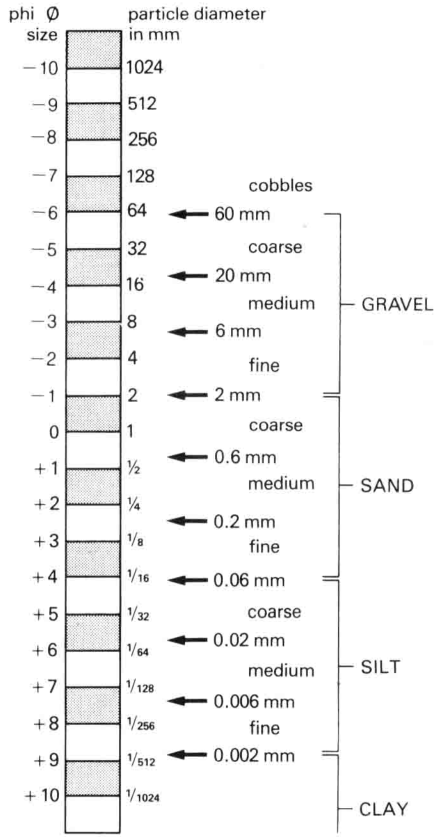


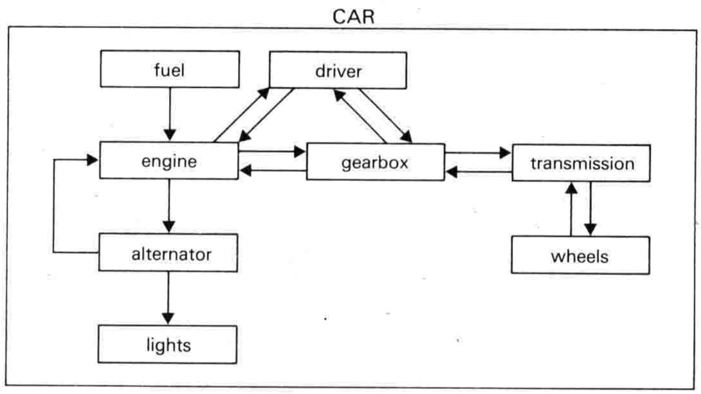
Figure 1.3 The size of particles



C. Systems

The problem of examining the whole of the natural universe is evidently immense. We have narrowed down the field to look at one compartment, geomorphology. Each chapter of this book represents a further subdivision in which one geomorphological environment of the earth's surface is examined. *Systems analysis* has given us a similar approach, breaking down reality into *elements* and identifying the *linkages* between them. A very simple example of this is a car (Fig. 1.4). Fuel drives the engine which produces changes in the other elements of the system. Ultimately the wheels, in contact with the road, are driven. Most of the links in this system operate in both directions. For instance, a car rolling down hill turns the transmission (axles) round. Particularly, interesting is the alternator, which is driven by the engine and produces electricity, which is returned to the spark plugs in the engine. In systems terms this is known as *feedback*. The driver receives feedback from the engine when listening to how fast the engine is running and deciding whether or not to change gear.

Figure 1.4 The car as a system



If fuel were fed continuously to the engine, it would go faster and faster and demand more and more fuel. In the end it would break down. This is the example of *positive feedback* which, unless regulated in some way, leads to a breakdown in the system. *Negative feedback* occurs when an increase in the acitivity of one element of the system induces a decrease in the activity of another. In the case of the engine, this is the driver taking pressure off the accelerator, thus restricting the fuel flow. Feedback regulates the system and tends to maintain a *steady state.* Examples of these types of system are detailed in later chapters.

The labels on the boxes in Figure 1.4 tell us nothing about the complexity of the internal combustion engine. From the diagram, we know only that fuel goes in and is changed to another form of energy, which is passed on to the gearbox. The engine is regarded as a *black box.* It is not necessary to know how the engine functions in order to drive the car. However, it is possible to look inside the box and examine the engine system. The box becomes transparent as we begin to understand the operation of the systems within it. In systems terms, this is a *white box.* I suspect that for many of us it remains only partly understood, a *grey box!*

D. Systems in Geomorphology

The way in which the atmosphere, lithosphere and hydrosphere interact was outlined at the beginning of this chapter. The only significant input into this system in *energy* in the form of electromagnetic radiation from the sun. Essentially the system is *closed* off from the rest of the universe. On a short time scale, the car is a closed system, which carries its own energy source, petrol; in the longer term it needs injections of fuel, if the engine is to function and output energy to the driving wheels. It can therefore be regarded as an *open system,* with inputs and outputs of both energy and mass in the form of fuel and exhaust.

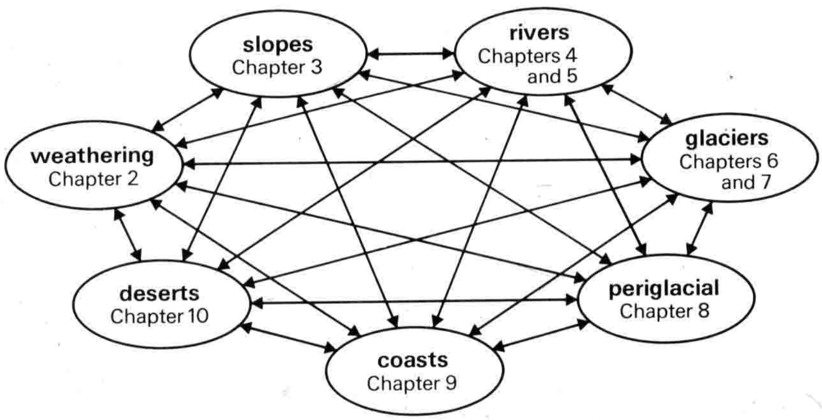
Each chapter of this book looks at an open system which receives inputs, often of rock or water, from other systems (Fig. 1.5). All of these systems are operating within the closed system of the earth–atmosphere. Rivers are a familiar example of an open system. They receive inputs of water mainly from precipitation flowing down slopes, and of sediment derived from the rocks over which the river flows. In populated areas, human activity increases sediment and effluent input to the river. The output of the river is often into the ocean, where water, sediment and effluent are deposited. They are generally changed in nature, so the river acts as both a transporting and processing system. Some water evaporates from the river and some may seep into the rocks beneath. There are outputs, therefore, to both the atmosphere and the lithosphere. In Chapters 4 and 5 we take a much closer look at how the river system processes its inputs and outputs.

E. Humans in the System

The surface of the earth is affected by humans to a remarkable extent. Large areas are farmed or grazed, river valleys are often densely populated, roads are built through mountain areas, and coasts are used as ports and harbours. Humans act as an additional element, putting a variety of materials into different parts of the geomorphic system. Coal dust from mining has been a significant part of the sediment in rivers on coal fields. The coast has been used as a dumping ground for waste from domestic refuse to toxic chemicals. Not all this input is deliberate; as a result of poor farming practice, soil has been washed from the land surface. Humans have also taken from the system: gravel has been taken from rivers and estuaries for building; slopes have been changed to accommodate roads, and coastlines altered as part of reclamation schemes.

The appearance of humans as another element in the system has often changed the balance achieved by feedback within the natural system. Whole systems, because of their closely interlinked nature, have reacted and changed or have started to change towards a new steady state

Figure 1.5 The geomorphological system and its subsystems



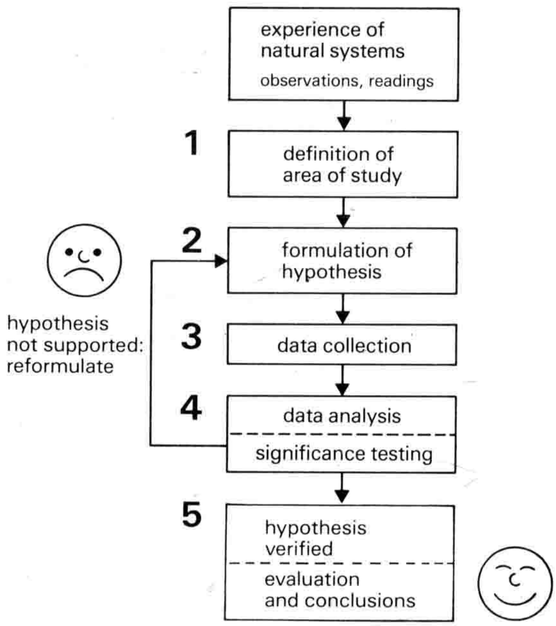
incorporating humans. Examples of such changes are dealt with in this book. It is important that we understand how these systems operate so that we do not produce changes which may have dramatic and dangerous repercussions. The removal of woodland in one part of a river valley may, for example, cause flooding in another. The Vaiont Dam disaster, which is explained on page 57, shows how such consideration of only one part of the system can lead to catastrophic changes in others.

F. The Scientific Method

Many of the ideas in geomorphology originated in the nineteenth century. Pioneer geographers collected information about areas or regions and as the information accumulated they classified it in various ways. This type of activity is characteristic of the early stages of a science. The classifications led to the formulation of '*laws*' and *theories*, many of which have stood the test of time. A number of objections can be made to this method of investigation. It is easy to collect information which is too voluminous to handle and often it is inapplicable, since it leads to no valid conclusion.

The *scientific method* was evolved mainly in physics-based science, and this provides a more logically acceptable and more concise way to solve problems in science. The starting point is a *hypothesis*, which may be *accepted* or *rejected* by testing in the real world. Information is collected to evaluate the hypothesis. It is therefore much more particular

Figure 1.6 The scientific method



than the general observations which result from the first method of inquiry.

The scientific method is shown diagrammatically in Figure 1.6. There are roughly five formal stages in the process. They are preceded by one similar in form to the first method of inquiry followed by the early geographers, and which consists of personal experiences and informal observations of the earth's surface from which you build up your own mental image of the real world.

1. Defining the problem

Many students find this stage difficult in framing their own investigations. Finding an area of study which interests you is dependent on what you have read, or on your acquaintance with a particular area. For example, you may notice that the beach you visit changes in height. You decide to find out *why*.

2. Erecting the hypothesis

Every investigation needs a starting point. By reading about beaches you will be able to identify important elements in the system which cause the beach to change. Observation may lead you to think that the speed of the wind is the most effective of these. Thus you arrive at the *hypothesis* or theory that 'there is a relationship between beach height and wind speed'.

3. Data collection

To test the hypothesis, information or *data* about the beach height and the wind must be collected. It is impossible to measure the height of the whole beach, so a small part or *sample* of the whole beach (referred to as the *population*) must be used. The selection of a sample should be unbiased. If the narrowest part of the beach were chosen because it would be easier to survey, then the sample would be unrepresentative of the beach as a whole. *Bias* in sampling can be eliminated by using some random method, for example by spinning a coin or throwing a dice. This cuts down the work to manageable proportions. Sometimes someone else will collect the data for you. Wind direction can be obtained from meteorological stations nearby. These are *secondary sources* of information which themselves may have to be sampled.

4. Analysis of data and interpretation

This part of the procedure is determined by your hypothesis. The relationship between beach height and wind speed can be shown graphically as in Figure 1.7. The arrangement of the points in an almost straight line shows that there is some *correlation* between the two variables. In general, the graph shows that as wind speed increases so

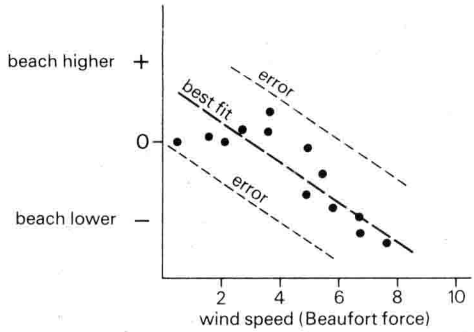


Figure 1.7 A simple correlation of wind speed and beach changes

beach height falls. But not all the points lie in a straight line, implying that there is some degree of vagueness or randomness about the relationship. It is possible that the relationship you have recorded could have occurred by *chance*. This would be more likely if only a small number of points were used in the investigation. If you tossed a coin and recorded two consecutive 'heads', you would not be unduly surprised. If you went on recording heads, your suspicions would grow. In general, the larger the sample, the more significant are the results. There are statistical tests of *significance* which could be applied to the beach data. If such a test were to show that your results were significant, then you would be able to verify the initial hypothesis. In Figure 1.6, this is shown as a positive feedback. If the results were not significant, indicating that they could have occurred by chance, then you need to return to step 2 and revise your views as to the most important variable in determining beach height.

5. Conclusions and evaluation

The conclusion of this investigation may confirm your ideas or those of others about the beach. Perhaps your beach behaves differently than might be expected from the researches of others. The reasons for this are for you to explain and to erect new hypotheses about.

By following the pattern of the scientific method, you can be certain that your arguments are well founded and backed up with solid observation.

G. Using this Book

In this chapter, we have indicated some of the ideas we think are important and which lie behind the more specific material presented in the rest of this book. In order to help your understanding of the ideas within a chapter, each is followed by two components which are an essential element of the book:

(a) A summary of the *key ideas* contained in the chapter. These are statements of the basic concepts which form the substance of each chapter. Understanding of these indicates an intelligent, thinking, rather than rote learning approach to study.

(b) *Assignments,* which occur both in the body of the text and at the end of each chapter. These are to check your understanding and to help you remember the ideas in the chapter. They vary from short questions, topics for discussion and essay questions to new sets of data for analysis and indications of different ways of thinking about the subject in the chapter.

In addition, there is a References and Further Reading section at the end of the book, which is divided by chapter. The references supplement the material in the chapters. In general, the books are easily accessible and fairly easy to understand. Some take you a little further into the subject and may be more useful if you are faced with a particular problem in field work or while conducting your own investigation. These have been marked with an asterisk (*).

It is important to emphasise that the summaries of the key ideas, the assignments and the suggested reading are not intended as additional extras or time-consuming luxuries. They are intended to be an integral part of this introductory course in geomorphology.

ASSIGNMENTS

1. (*a*) *Explain what is meant by the terms morphology and process.*
   (*b*) *Describe the morphology of a sand castle. Explain the processes which lead to the formation of sand castles.*

2. *Explain briefly the nature of the links shown in Figure 1.1 between atmosphere, lithosphere and hydrosphere.*

3. *Draw a 'systems diagram' to represent the generation of electricity. The main elements are fuel, dynamo, steam, turbine, water, transformer and national grid. There may be more.*

Key Ideas

A. *Geomorphology*

1. The objective of geomorphology is to explain the form of the earth's surface.
2. Processes operating at the air–rock interface are the mechanisms of change in geomorphology.

B. *Scale*

1. The perception of differences between phenomena is in part a function of scale.
2. Logarithmic scales represent size differences as *ratios.*

C. *Systems*

1. A system is a set of *elements* with *linkages* between them.

2. Systems emphasise the interrelatedness and integration within and between various environments.
3. Many natural systems are self-regulating, having *feedback mechanisms.*

D. *Systems in Geomorphology*

1. The earth–atmosphere system is closed and within it a variety of subsystems, both open and closed, operate at different scales.

E. *Humans in the System*

1. Natural systems must adjust to a new *steady state* when humans appear as a significant element within them.

F. *The Scientific Method*

1. The scientific method provides the foundation for investigation of natural systems.