GEOGRAPHICAL GEOMORPHOLOGY:
HISTORICAL DEVELOPMENT, CONTEMPORARY PROBLEMS,
AND FUTURE PROSPECTS

by

Gary L. Beach

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Geographical geomorphology is a young science with a long, complex history closely paralleling the growth and development of geology. From an enthusiastic beginning under the tutelage of William Morris Davis, geographical geomorphology rapidly lost its influence and stature in geography. Today there is a sense of purpose and direction that has been missing for nearly half a century. Having traversed through the rise and fall of numerous paradigms, the discipline has become fragmented into a number of nationally oriented sub-fields, including: quantitative, process, applied, climatic, and regional geomorphology. Operationally, geomorphology can be characterised as functioning in a theoretical vacuum without a unifying paradigm. Because of the pluralistic state and acknowledged theoretical vacuum, contemporary geomorphology is presently in the midst of a period of enormous intellectual, technical, and conceptual change. Considerable debate continues to be generated concerning the methodological objective differences that exist between geographical and geolog-
cal geomorphology. New journals and professional associations have become established within the last five years in an effort to provide additional communication forums for geomorphic thought and research. The future of geographical geomorphology lies primarily in the direction of assessing landform processes, identifying the spatial distribution of landform features, and collecting geomorphic information that can be utilized in providing predictions in applied situations.
APPROVED:

Associate Professor of Geography in charge of major

Head of Department of Geography

Dean of Graduate School

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I. INTRODUCTION

Beyond the general acceptance that geomorphology is the study of landscapes, there is little agreement amongst geomorphologists as to what constitutes their sub-discipline. As this paper will attempt to illustrate, the reasons for this disagreement are extremely complex. Questions are continuously being raised concerning departmental affiliation, methodological approaches, and conceptual frameworks within which geomorphic studies should be considered. In part, this situation exists because geographical geomorphology is a relatively young science with a long tradition that overlaps into and derives subsistence from many other disciplines.

At the turn of this century most geographers were specialists in geomorphology. Confined by the idea of geographical cycles of erosion, however, geomorphology languished during the next fifty years behind the growth and development that was taking place in the various sub-disciplines of human geography. Over the last three decades the nature and scope of geomorphology has been radically changed. The discipline has become increasingly diversified. Geomorphologists, both in terms of training and professional interests, reflect a multi-disciplinary background, while geomorphological studies range across and borrow extensively from
such disciplines as hydrology, geology, pedology, and climatology. As a result of these changes, there has been a veritable explosion of new ideas, new questions, new research techniques, and new applications for our accumulating knowledge of landforms. If measured in terms of individuals, productivity, and intellectual expansion, the field of geomorphology has never been stronger or more vital than it is today.

This period of rapid growth and expanding intellectual horizons (1945 to the present) has also brought with it significant problems. Butzer (1973, p. 39) has observed that:

Despite a certain amount of philosophical or methodological discussion, the many streams of geomorphological study have never been fully rationalized, either within an historical perspective or in terms of the spectrum of contemporary trends.

Butzer refers to this condition as "pluralism in geomorphology."

**Pluralism in Geomorphology**

The pluralistic condition in which geomorphology finds itself today is in large measure a reflection of the problem associated with defining the boundary limits of the science. These boundary limits are elusive because landforms represent a complex assemblage of interactions. Physical laws and theoretical constructs which explain their forms, their spatial distribution, and their formative processes are not as easily defined as in other sciences such as physics and chemistry. In fact, geomorphology has been described as a "pseudo-science with a largely unscientific tradition"
(Chorley, Dunn, and Beckinsale, 1964, p. 4).

While acknowledging the increasingly problematic nature of the discipline, most geomorphologists look upon this trend toward pluralism as being ultimately beneficial; i.e., diversity is considered to be a source of strength (Peltier, 1954; Butzer, 1973; Graf, Trimble, Toy, and Costa, 1980). Geomorphologists, for example, have been taking advantage of ideas engendered from the "quantitative revolution", developing new techniques and tools designed to solve old and new problems, participating in interdisciplinary investigations concerned with surface forms and processes, and shifting towards research questions of an applied nature that address the interface between geomorphological processes and human activity.

If the above examples represent positive advantages that can be obtained from geomorphic fragmentation, then the following serve to dramatize a few of the potentially negative aspects.

(1) Departmental affiliation. Academic geomorphology is dangerously divided between geography and geology. Although our accumulated knowledge and understanding of landforms has been derived from different disciplines, geographical geomorphology has closely paralleled the growth and development of geology. In the United States, geomorphology is still taught in both geography and geology departments, reflecting the difficulties geomorphology has had in finding a definite academic home (Ritter, 1978, p. 2).

(2) Methodological approaches. Geomorphology does not have
the scope of a major discipline, such as geology, and is best described as "a specialized sub-discipline" (Butzer, 1973, p. 41). Since geomorphology continues to be primarily a derivative science, borrowing techniques and generalizations from other disciplines, it becomes apparent that there are unusual methodological problems which need to be resolved.

(3) Conceptual framework. The science of geomorphology has traversed through the rise and fall of numerous paradigms. In general, the present theoretical basis of geomorphology can be characterized as being largely a complex collection of residual philosophies. Yet despite the continuous influx of ideas designed to provide coherence and direction for geomorphology, many geomorphologists consider the discipline to be operating today in a theoretical vacuum without a unifying paradigm.

Due in part to this lack of unity, geomorphology in the last three decades has tended to become fragmented into loosely associated national schools of geomorphic thought. The methodological approaches these national schools have developed to study landforms have included climatic geomorphology, process geomorphology, and denudation chronology. In other words, even as geographers, geologists, and engineers have looked upon landforms from different perspectives, various groups of geomorphologists have approached the study of landforms with different sets of questions.
Purpose and Organization

In light of the problems identified above, the purpose of this paper is to critically review and assess the development of geomorphology as a sub-discipline of geography. Through an interpretative analysis of the roots of geomorphology, it is hoped that a clearer understanding of the present pluralistic character of the discipline will emerge.

In order to meet this broad goal, special emphasis is placed on: (1) tracing the aims, methods, and critical ideas of geomorphology as they have changed over time; (2) assessing the role geomorphology has played in contributing to and/or has changed the domain of geography; and (3) evaluating the current problems and future prospects of geographical geomorphology. Throughout the paper, notable themes and key persons responsible for significant changes in the direction of geomorphic thought and methodological approaches to landform investigations will be illustrated by means of diagrams, figures, and flow charts.

Although the object has been to present a balanced portrait that encompasses all the major sub-fields of geomorphology, the reader will note a certain bias towards fluvial geomorphology. This orientation was taken because of personal preferences, and because many of the fluvial examples described and illustrated in this paper are applicable to the other sub-fields.
II. HISTORICAL DEVELOPMENT OF GEOMORPHIC THOUGHT

Geomorphology has had a long history of development. The story began when man first attempted to formulate questions concerning landform features. Why were mountains, valleys, deserts, and the vast oceans located where they were? What were the processes responsible for their evolution? The answers were elusive.

A lengthy adolescence period followed these first interpretive questions; a period marked by limited observations and numerous deductive speculations. It was not until the late Renaissance and the development of geologic theory that a more explicit understanding of the Earth and the spatial distribution of landforms began to come into focus. Since then, modern geomorphology has been building upon or regressing from such ideas as catastrophism, uniformitarianism, cycles of erosion, dynamic equilibrium, and plate tectonics.

Each of these new paradigms has been born of a need to comprehend and explain the physical properties and laws associated with landforms. At times, the field of geomorphology advance by great bounds as a new theory or concept was proposed and many pieces of the landscape puzzle appeared to momentarily fall into place. More often, however, progress towards a clearer understanding of landform evolution and landform processes has proceeded step by step. Scratch the surface of any great geomorphic theory or concept and one will invariably reveal that the foundation had previously been laid through the thankless contributions
of innumerable individuals.

In an attempt to synthesize the variable paths the science has taken since the first recorded observations of landforms, the historical development of geomorphology is presented in Figure 1. This flow chart represents what the author considers to be the significant persons, ideas, and time periods related to the development of geomorphic thought.

In order to further summarize and complement this historical flow chart, Table 1 highlights the most significant milestone dates, geomorphic time periods, scholars, ideas, and publications that have in some way altered the direction and progress made in geomorphology. As this figure and table illustrate, most of the changes and advancements made in the designated "ancient" and "classical" geomorphic epochs were brought about by philosophers, natural scientists, and by trained or amateur geologists. Until the time of William Morris Davis, geographers were not at the fore-

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Figure 1. The historical development of geomorphic thought. This flow chart has been constructed based on an interpretive review of the geomorphic literature. Three major epochs have been identified; ancient, classical, and modern. As described in the text, each epoch represents a significant milestone in the development of geomorphic thought. Geomorphic periods are characterized by the introduction of an important new theory or concept that altered the way in which landforms were viewed. These periods are delineated by the year in which the idea was published. Solid interconnecting flow lines between ideas, scholars, or geomorphic groups represent the dominant paradigm(s) of that time period. Dashed lines, on the other hand, represent backwater or secondary paradigms. Note that the lines change within and between geomorphic time periods. This change reflects the general acceptance or rejection of the idea over time.
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front of landform studies. Since then, however, an increasing number of geographical geomorphologists have been contributing to the continued development of the discipline. Throughout this chapter, emphasis will be placed on those individuals or groups whose ideas either substantially altered the study of landforms, or who concentrated their efforts on surface processes and the spatial distribution of landform types.

The flow chart and table are by no means complete. Many geomorphic ideas and most of the geomorphic players have not been acknowledged. Nevertheless, in combination, they do help to provide a graphical means by which the composite narrative about to be told can be followed and understood.

**Early Observations of the Earth (Ancient-1669)**

Man's first interpretations of the earth were visionary. Gods and fables were created that could adequately explain the evolution of the earth's surface. To the Christian peoples of the West, for example, the story of creation and the "great flood" in the Bible's Book of Genesis provided all the answers necessary to account for the existence of different types of landforms in different parts of the world. Eastern cultures have similarly produced their own versions concerning earth's evolution. Chorley, Dunn, and Beckinsale (1964, p. 5) note that all the stories taught that:
the world was created by supernatural persons or forces in a relatively short space of time and that it had since retained to a substantial extent, its original form.

In many cultures of the world, these traditional explanations have continued up to the present unaltered by centuries of scientific discoveries.

Geomorphology had its beginnings amongst the scholars of ancient Greece. Herodotus (484-425 B.C.), for example, was the first to hypothesize that mud from the Nile River had built the Nile Delta into the Mediterranean Sea (James, 1972, p. 29). Aristotle (384-322 B.C.) is another example of a philosopher attempting to reconcile observable earth processes with the use of logic to formulate and give support for theory. Chorley, Dunn, and Beckinsale (1964, p. 5) identified Aristotle as one of the earliest erosionists. Having formulated his concepts from empirically derived observations, Aristotle theorized that cold mountain temperatures condensed atmospheric moisture which, in turn, gave rise to the origin of streams. These, and other early attempts at landform explanation, were primarily concerned with water as an eroding or depositional medium. In each instance, symmetry, logic, and theory became so fundamental as a guiding paradigm for scholarship that if fact conflicted with theory, the fact was ignored and the theory pursued.

None of the Greek scholars progressed in the natural sciences to extent attained by Arab philosopher and physician Avicenna (979-
1037 A.D.). Ahead of his time, and isolated from the ideas of Aristotle and other unassailable Greek philosophers, Avicenna formulated the idea that landforms could result from the action of running water. In other words, once mountains were raised up they were immediately exposed to the processes of fluvial erosion that would ultimately wear them down. James (1972, p. 66) observed that it would take an additional eight centuries before James Hutton presented to Western civilization similar ideas concerning the ability of running water to erode the earth's surface and transport the material to the ocean.

During the Medieval and Renaissance periods, the generally accepted theory concerning earth evolution was based on the account presented in the Bible. The first to cast serious doubts on the biblical explanation was Leonardo da Vinci (1452-1519). Not only did da Vinci suggest that landforms evolved due to local erosion, but he disbelieved that the "great flood" could account for marine fossils he had observed widely distributed far inland from an ocean source (Mather and Mason, 1939, pp. 1-6; Geikie, 1962, p. 50).

**Development of Geologic Theory (1669-1787)**

Despite the earlier philosophical stirrings from the Greeks to the Renaissance, the date at which geology and geomorphology emerged as distinctive sciences with principles and theories of
their own can be set at 1669. It was in this year that the Danish priest Nicolas Steno (1636-1686) published his *Prodromus* (Cloud, 1970, p. 9) (Table 1). Steno believed that fossils and rock strata formed a catalogue of the earth's history. From his observations, Steno developed the first three fundamental concepts of geology: the law of superposition; the principle of original horizontality; and the principle of original lateral extension. The publication of Steno's treatise thus signaled the end of the "Ancient Geomorphology Epoch" and the beginning of the "Classical Geomorphology Epoch" in which paradigms were developed that tested whether what was rational was also true based on facts (Figure 1).

Although 1669 has been designated as signifying a watershed year in the historical development of geomorphology--then closely aligned with the academic growth of geology--the first few decades of the "Classical" epoch can be more accurately described as a period of gradual transition. Steno lived during a time when Europe was being flooded with new observations and discoveries from world-wide explorations. From these observations came both a desire and a need to formulate hypotheses and classification systems that could adequately account for a multiplicity of newly discovered plants, animals, and natural phenomena. It was also about this time that a separation of the academic world was beginning to take place. The various fields of science were in the process of being born with the physical sciences taking the lead.

These new systematic methods of thinking, experimenting, and
recording observations, however, had not yet "broken free from the traditions inherited from ancient Greece and from the accounts of the creation in the Bible" (James, 1972, p. 126). Most geological thinkers of the late seventeenth and early eighteenth centuries felt compelled to reconcile their new theories of geology and geomorphology with biblical history. Groups of scholars taking the first important steps in the use of scientific method were driven towards a catastrophic explanation as being the most likely process in accounting for the nature of observable stratigraphic deposits and other landform features. Early catastrophic reconcilers such as Thomas Burnt (1635?-1715), John Woodward (1665-1728), and Comte de Buffon (1707-1788) were, thus, concerned with justifying the "great flood" as the main agency in the formation of landforms (Chorley, Dunn, and Beckinsale, 1964, p. 15).

The Beginnings of Modern Geomorphology (1787-1830)

The beginnings of modern geomorphology was embedded in a period of revolution—political, social, economic, and intellectual revolution. It was a period of colossal change. Politically, the United States was in the process of experimenting with a new form of democratic government. France was being shaken to its foundation by an enormous social revolution designed to eliminate societal inequities and bureaucratic ineptitude. Great Britain, meanwhile, thanks to its lucrative trading establishment, geographic
isolation, and uniquely uncensored social structure, was in the throes of an enormous economic upheaval resulting from industrialization and urbanization. To a significant degree, the modern Western world can be viewed as principally a product of these late eighteenth and early nineteenth century changes.

On the intellectual front, there was an uneasy co-existence between scientific and medieval ideas. Enlightenment philosophers such as Montesquieu, Voltaire, Rousseau, Hume, and Kant, in their quest for answers regarding natural and social order, had helped to generate provocative debates within the intellectual community, including individuals who considered themselves to be geologists. Many European scholars had been vastly impressed with Sir Isaac Newton's apparent reduction of the universe to orderly relationships. To them, Newton (1642-1727) had completed what Copernicus, Kepler, and Galileo had begun—the supersession of Ptolemy's and Aristotle's scientific sphere of influence (Cunningham, 1973, p. 34). Still, the tendency to resist these and other new avenues of thought and cling steadfast to old, comfortable ideas remained strong. This was especially true whenever new scientific evidence concerning landform evolution and earth surface processes were interpreted by individuals such that they conflicted with the Bible or with acceptable church doctrine.
Progress towards the establishment of a modern school of geomorphology began in 1787 with the publication of Abraham Werner's ideas concerning a universal ocean (Table 1). Werner (1749-1817) hypothesized that the origin of the earth's crust was formed by sediment deposited from a vast ocean in a regular sequence of layers (Beckinsale and Chorley, 1968, p. 410). This idea fired the imagination and gave rise to followers called "neptunists". Their influence in the development of landform studies and geomorphic thought was to last for well over a century.

What particularly characterized Werner's work was his orderly pattern of ideas that lead to one final conclusion (Geikie, 1962, p. 210), and the fact that the theory had the contemporary advantage of not conflicting directly with theological doctrines related to the "great flood". When viewed in retrospect, the weaknesses of Werner's hypothesis lies: (1) in the picture of a gigantic ocean which contained in solution the totality of material that was later to constitute the earth's crust; (2) in the assumption that all rocks were of sedimentary origin; and (3) in the inability to satisfactorily explain the disappearance of the universal ocean.

Although most of Werner's geomorphic and geologic ideas have had little intrinsic value in current landform studies, his contributions to science were, nevertheless, important. First, Werner indirectly helped to define the academic boundaries of the fledg-
ling sciences of geomorphology and geology through his efforts in classifying collected earth data, and in defining methodological approaches to landform investigations; especially those concerned with understanding rock strata. Second, by developing a holistic picture of the world, he furnished other scientists with an orderly, systematic method for observing the earth. Finally, since Werner and his students were extremely adamant concerning their view of earth evolution, numerous arguments and counter-arguments were generated for and against the neptunist point of view. The net effect of these arguments was the stimulation of further interest and research in landform related questions.

The stepping-stone between Werner's "Universal Ocean" and Hutton's "Uniformitarian" concepts was a Swiss, Horace Bénédict de Saussure (1740-1799). De Saussure supported Werner by suggesting that the alpine valleys he had observed in the western Alps "had been cut by the violent torrents when the floods drained off into the present ocean basins" (James, 1972, p. 129). Although de Saussure conceived of landforms resulting initially from titanic floods, on the subject of glaciers he provided an essentially modern description of their formation and movement. Chorley, Dunn, and Beckinsale (1964, p. 30) described de Saussure's geological and geomorphological ideas as an "interesting mixture of medieval and modern."
James Hutton and Uniformitarianism

From the fifteenth to eighteenth centuries, the general opinion had been that landforms were either the result of divine creation, or that they were formed by cataclysms of nature and the slow process of erosion caused by the retreat of a vast ocean. James Hutton (1726-1797) entered at this stage of geomorphic (geologic) development with a simple, but radically new and unifying concept. He believed that the cause of the earth's formations and underlying strata should be sought not in presupposed cataclysmic processes of creation or destruction, but in processes which had always existed and could actually be seen in daily operation. Unlike Werner, Hutton ascribed the formation of mountains and valleys almost exclusively to the action of streams and rivers as they erode the surface and carry the material to the ocean.

Hutton maintained that the present is the key to the past. He viewed the earth as an ever-changing succession of forms that to be understood must be based on the observation of landform processes.

A theory of the earth...can have no retrospect to that which had preceded the present order of this world.... A theory, therefore, which is limited to the actual constitution of this earth, cannot be allowed to proceed one step beyond the present order of things (Hutton, 1795, I, pp. 280-281).

Not only are no powers to be employed that are not natural to the globe, no action...except those which we know the principle, and no extraordinary events to be alleged in order to explain a common appearance, the powers of nature are not to be em-
ployed in order to destroy the very object of those powers... (Hutton, 1795, II, p. 547).

Chorley, Dunn, and Beckinsale (1964, p. 37) note that it was Hutton's denial of catastrophic forces that "made his theory so distinct from all the others that had preceded it." In contrast to the "catastrophists", Hutton's theory was not only to give birth to the school of "uniformitarianism", but to the discipline of geomorphology as well.

When Hutton's ideas were first printed in 1788, he was either ignored or intermittently discredited. He was criticized by both the "neptunists" (who adhered to the universal flood hypothesis) and the "catastrophists" (who, in following biblical accounts, believed that floods, volcanism, and earthquakes were the agents responsible for the various landscape forms) for conceiving of an idea that suggested fluvial processes had shaped the earth since the beginning of time, that the earth was constantly changing, and that there was "no vestige of a beginning--no prospect of an end" to these processes and landform changes (Hutton, 1788, p. 304 in King, 1976, p. 4).

Hutton defended his theories concerning uniformitarianism in a two volume work entitled Theory of the Earth, With Proofs and Illustrations published in 1795 (Table 1). In essence, his was a cyclic view of landform evolution; the same conclusion that would be arrived at by William Morris Davis one hundred years later. To Hutton, there was an orderly succession of mountain uplift, intervals of erosion and deposition, followed again by mountain uplift
generated from below the earth surface. His was a vision of slow, continual change throughout time. Thornbury (1969, p. 7) observed that many of our modern, fundamental concepts of fluvial processes and earth sculpture can be traced back to Hutton's revolutionary theory.

Despite these publications, Hutton was not widely read by his contemporaries. Hutton wrote in an obscure style of prose which made reading and comprehension difficult. Geikie (1962, pp. 310-311) and Chorley, Dunn, and Beckinsale (1964, p. 48) note that to describe metamorphism, for example, he used a sentence one hundred and thirty-six words long. In 1802, this problem of comprehension and understanding of Hutton's ideas was remedied when John Playfair (1747-1819) published his book Illustrations of the Huttonian Theory of the Earth. Playfair rewrote the ideas of Hutton with brilliant clarity and this set off a new round of theoretical debate.

Playfair embraced nearly every aspect of Hutton's ideas. In explaining, amplifying, and expanding upon Hutton's various geomorphic and geologic notions, Playfair stressed the importance of moving water in sculpturing landforms. According to Playfair, not only did streams and rivers create their own valleys, but within each drainage basin, there existed a perfect adjustment between the main trunk and each tributary of the stream and river system. This acknowledgment of an entire drainage system being integrated by the natural adjustment of its parts became known as Playfair's
The idea of uniformitarianism, as developed by Hutton and clarified by Playfair, provides an important postscript concerning the advancement of science in general and geomorphology in particular. By formulating and fostering a controversial idea, not only did Hutton and Playfair provide a basic new premise for understanding the enormous complexity associated with landforms, but they revealed fresh new fields of study that had previously never been explored. James has accurately stated that:

nothing promotes progress more rapidly than presenting a hypothesis that meets with a highly critical reception. This leads scholars to make new observations and to formulate new hypotheses (James, 1972, p. 130).

William Buckland and Diluvialism

Hutton and Playfair lead the way in discrediting the neptunist ideas that all rocks were deposited beneath a universal ocean. Their efforts, however, did not lead to a noticeable weakening in the popularity of neptunism or catastrophism during this geomorphic time period. The final erosion and dominance of these extremely popular ideas would not take place until after the published findings of the Great Western Surveys at the turn of the twentieth century. Considering that Archbishop James Ussher had dated earth's creation as having occurred in 4004 B.C. (Coates and Vitek, 1980, p. 4), for the world to assume its present shape in
the brief time interval allowed, this meant that the application of catastrophic ideas was inevitable. And yet, the fossils that were being collected pointed to slow processes and immense intervals of time. Once again, a gigantic deluge seemed the only possibility that could explain the characteristics of the earth's surface if a literal translation of the Bible was to be incorporated with the scientific findings being made during this time period.

Picking up the threads of previous catastrophists, William Buckland (1784-1856) embarked on a crusade designed to convince the scientific community of the various advantages of the "great flood" idea. As a true representative of what was then perceived to be geomorphology of his day, Buckland genuinely believed that there was no conflict between science and religion. Buckland argued that when the flood occurred, giant waves and tremendous currents covered the whole earth except for isolated peaks and mountain ridges. The retreating water thus sculptured the surface of the earth.

Buckland's arguments were not new. They were preached in an effort to provide a reasoned explanation of the creation along catastrophic lines and would, at the same time, oppose the ideas generated by Hutton and Playfair. Given the zeal and logic of their arguments, Buckland and his associates largely displaced the neptunists during the 1820's and raised "diluvialism" to its high-water mark (Chorley, Dunn, and Beckinsale, 1964, p. 124).

The early nineteenth century was a period of active field
work. The ruling principle of the day was to gather from actual observations sufficient data to form the basis for a reasonable hypothesis. The early objections to Buckland's diluvial theory came from two main groups who were in the field collecting new landform-related data—the fluvialists, and the structuralists.

Following the ideas of Hutton and Playfair, the fluvialists argued that fluvial erosion and deposition were the primary processes responsible for landform development. These ideas were countered by structuralists who insisted upon the importance of structural controls and bedrock composition.

During the decade 1820-1830, with so many new ideas being generated in such a relatively short span of time, geomorphologists for the first time began to orient themselves along nationalistic philosophies. In Germany, neptunists continued to control geomorphic thinking. One of their strongest supporters was Alexander von Humboldt (Chorley, Dunn, and Beckinsale, 1964, p. 138). Geomorphologists in the United States had slowly shifted support from the neptunists to Buckland's diluvialism approach. In Great Britain, on the other hand, uniformitarianists and diluvialists were arguing and rationalizing the virtues of their respective paradigms. At this time of conflicting theories, there entered onto the scene a veritable giant—the most imposing figure in geomorphic thought up to that time—Charles Lyell.
Age of Lyell (1830-1875)

...when seeing a thing never seen by Lyell, one yet saw it partially through his eyes.
- Charles Darwin

Charles Lyell and the Principles of Geology

With the publication of his book *Principles of Geology* in 1830 (Table 1), Charles Lyell (1797-1875) became the great exponent of uniformitarianism (Thornbury, 1969, p. 8). Like Hutton and Playfair before him, Lyell (Figure 2) saw the world evolving and changing by a series of continuous processes and in the total absence of any but the most local cataclysms. It was Lyell who assured the acceptance of uniformitarian principles and largely rid geomorphic thinking of its catastrophic outlook.

The emphasis of Lyell was on the gradual but inexorable changes of landforms and on the value of modern scientific findings as the key to understanding the past. Beginning slowly in Great Britain, then sweeping on to the continent and the United States, uniformitarianism by 1845 was the dominant theory in geomorphology and Lyell was its acknowledged leader.

Unfortunately for the continued growth of geomorphic thought, much of Lyell's geomorphic work is filled with the idea of marine erosion (Thornbury, 1969, p. 8). Lyell questioned the efficiency of running water as an erosional agent, and therefore placed greater emphasis on marine denudation processes. Because of his
Lyell effectively and eloquently argued that landforms are the result of contemporary processes operating over long time spans rather than from biblical catastrophes (Chorley, Dunn, and Beckinsale, 1964, p. 142).

Influence as a writer and a speaker, his ideas concerning marine erosion attracted a large following and undoubtedly delayed the abandonment of marine erosion in favor of fluvial erosion as the major geomorphic process. Lyell's overemphasis on the capacity of marine erosion to dissect landforms and his views on the importance
of iceberg transport were to be challenged by Huttonians and by a new school of glaciologists (Beckinsale and Chorley, 1968, p. 411). Chorley, Dunn, and Beckinsale (1964, p. 146) summarized Lyell's contributions to geomorphic thought in these words:

The beauty of Lyell's geological philosophy, the majesty of its presentation, and the high quality of his stratigraphic observation, caused his geomorphic ideas to exercise a control for the succeeding half century far in excess of their intrinsic value.

Louis Agassiz and the Glacial Theory

In addition to the contributions made by Lyell, another significant development during this period was the recognition of an ice age during which continental ice sheets covered much of northern Europe. The man who is generally given credit for establishing this fact is Louis Agassiz (Thornbury, 1969, p. 8). Agassiz (1807-1893) postulated that the extension of glaciers was not a local circumstance, but part of a climatic change which had affected the whole of Europe. He discussed erratics, polished rocks, stria-tions, and moraines in Switzerland, illustrating from his evidence that at one time the Swiss glaciers had been extensively larger and thicker in size and had a greater areal extent than at the present (King, 1976, p. 20).

It must then be admitted, the author argues, that great sheets of ice, resembling those now existing in Greenland, once covered all the countries in which unstratified gravel is found... (Agassiz, 1840-41, p. 331).

Glaciology, freed increasingly from confusion with a great
flood, grew slowly after about 1845 as a separate branch of science. In the same way, geomorphology, freed from the shackles of diluvialism and gradually enriched by the acceptance of glacial action, returned to the uniformitarian approach in which fluvial and marine processes were considered the primary agents responsible for landform evolution.

Andrew Ramsay and Marine Planation

In Europe after 1845, the most powerful group of geomorphologists were supporters of Lyell's marine erosion theory. They considered themselves to be true uniformitarians. Against them were the structuralists, the fluvialists, and the neptunists. To these rival schools of thought were added the followers of Andrew Ramsay.

Ramsay (1814-1891) postulated a new idea of erosion based on marine planation. This theory associated each main summit-level of the land surface with an ancient sea level. Ramsay's ideas concerning marine planation laid the foundation for later studies in denudation chronology; the methodological approach that attempts to explain landform development by dating sequences of geological events.

The postulating of Ramsay's marine planation theory and the emphasis Lyell and his supporters placed on marine erosion were in large measure a function of physical geography. Most of the land-
form studies that made their way into the literature during this and in the previous geomorphic time periods, were conducted in England and on the European continent. Because of the close proximity to the sea, it was only natural for these European scientists to place a greater emphasis on the capacity of the ocean to erode landforms and deposit sediments rather than in the action of running water.

Beginnings of American Geomorphology

During the Age of Lyell, American geomorphology had rested on European roots. Werner and neptunism followed by Buckland and diluvialism dominated geomorphic thought. Huttonian theories concerning fluvial erosion had made little progress and the uniformitarianism of Lyell was only just making headway. Chorley, Dunn, and Beckinsale (1964, pp. 235-247) suggest that American geomorphologists had too little knowledge of the American landscape to formulate independent theories and therefore borrowed from European scholars their experiences and prejudices. They also suggest that in America, as in Europe, scientists were still constrained within the limits of religious beliefs. This European dominance would remain throughout the next period of geomorphic thought—the Great Western Surveys. After this period, American ideas were to dominate.

Perhaps the most original work by an American during this
period were the ideas concerning fluvial geomorphic processes developed by James Dana (1813-1895). He did for America what Lyell had done for Great Britain in stimulating research, fostering new ideas, and encouraging students to explore the fascinating realm of landform processes.

Retrospectives on the Age of Lyell

In retrospect, the Age of Lyell was not merely a period in which Lyell's marine erosion theory predominated. It was, in reality, a period of heated discussion coupled with a mass infusion of new observations, hypotheses, and theories. For example, during this geomorphic period the faint beginnings of two other aspects of landform studies could be detected. The first idea involved comparing the nature of similar landforms throughout the world. Here, in the middle of the nineteenth century, is the first true glimmer of geographical geomorphology. The second idea had to do with expressing the relationship between a landform and its possible age; i.e., its particular stage of development.

The early geographical classification of surface features and the comparison of their morphology is especially connected with Oscar Peschel (1826-1875). Peschel's aim was to discover a satisfactory causal classification system of the earth's relief features. Because of his early work with landform distributions, Peschel is generally regarded as being one of the founders of

In addition to the ideas already mentioned, there was also introduced during this time period Darwin's concept of evolution. So compelling was the idea of evolutionary change, it was applied by analogy to many other fields besides biology. Applied to the study of landforms, it would eventually appear as Davis' cycle of erosion theory (James, 1972, pp. 182-183).

The scope of landform study had advanced to the state where complexity was becoming the norm. In modern jargon, landform studies were rapidly assuming a "polycyclic and multi-genetic basis" (Chorley, Dunn, and Beckinsale, 1961, p. 1156). Geomorphic thought, in short, was in a muddled state.

From this point in time, there were many lines of possible advances in the development of geomorphic thought. As it turns out, the continued advancement of geomorphology was to be significantly influenced by an expansion of the geographical horizon.

The Great Western Surveys (1875-1899)

Historically, the explorations of the American West marked the end of a geomorphic epoch. Thanks to the dogged determination of John Wesley Powell and the genius of Grove Karl Gilbert, "the enigmatic relationships between form and process began to unravel" (Ritter, 1978, p. 3). Along with the penetrating insights provided by other members of the survey teams, their collective
contributions helped to lay the foundation for the modern American school of geomorphology.

This new period of geomorphic investigation brought with it a freshness of approach and opinion that is unique in the annals of geomorphic thought. Outside the humid setting of Europe and the eastern United States, these intrepid explorers and surveyors were able to view the evidence of nature in a new environment, devoid of an obscuring vegetative cover, with minds that were largely free of foreign preconceptions. Here in tremendous magnification were the answers to the many questions and doubts that had been troubling European geologists and geomorphologists for over a century. After the Great Western Surveys, there could be no more uncertainty regarding the ability of rivers to erode, or confusion concerning structural controls, marine erosion, and marineplanation. As Chorley, Dunn, and Beckinsale (1964, p. 500) have noted, "here was river erosion at its grandest, creating topographic forms on a gigantic scale."

The labor of surveying the vast, unknown areas of the American West was undertaken by several independent parties. They were sent out at the behest of the United States government to gather information and knowledge concerning the nation's natural resources in the western one-third of the country. Four main surveys were organized under the leadership, respectively, of Ferdinand Hayden, Clarence King, George Wheeler, and John Wesley Powell. Except for Hayden, none were trained geologists. Of all the men who partici-
pated in exploring this uncharted region of the United States, Powell comes first to mind.

John Wesley Powell: Western Pioneer Geologist

John Wesley Powell (1834-1902) gained initial fame in his conquest of the Grand Canyon (Figure 3). Later, as one of the

Figure 3. John Wesley Powell (1834-1902). Powell exemplified the combination of exploration with geomorphic investigation that so characterized this period of the "Great Western Survey." His major contributions to geomorphology were: (1) the principle of base level; (2) descriptions on the nature and importance of fluvial erosion processes; and (3) the development of classification systems for river and landform types (Powell, 1961, frontispiece).
principal driving forces in the western survey expeditions, he was also to leave a significant mark on the future of geomorphic development. Aside from his many scientific contributions, Ritter (1978, p. 4) suggests that perhaps his greatest service:

was in creating the scientific climate...and organizing (a) team of extraordinary geologists who worked with him in the western surveys.

The principal scientific discoveries of Powell were presented in his reports on the exploration of the Colorado River (Powell, 1875) and the geology of the Uinta Mountains (Powell, 1876). In these reports, Powell devoted much of his attention to the results of stream erosion. From his observations, Powell proposed two classification systems for streams and landforms. The first was based upon the relationships between streams and the bedrock strata over which they flowed. The second was a genetic classification that described streams and stream valleys according to their origin. In this latter classification he recognized antecedent, consequent, and superimposed streams; terms still widely used today.

Probably the most important and widely applied of Powell's ideas was his concept of base level. Powell felt that there was a limiting level of land reduction beyond which erosion could not continue. Under this concept, the oceans of the world represented ultimate base level. Local base levels, such as those found in the Basin and Range Province, could also exist but were temporary over long periods of geologic time.
In addition to his interest in geology and geomorphology, Powell also provided excellent geographical descriptions of the arid environment he discovered and explored in the American West. Powell realized that arid conditions produced their own special landforms owing to sporadic precipitation and a slow rate of chemical weathering (King, 1976, p. 22). Powell further recognized the influence vegetation has on geomorphic processes, suggesting that sediment yield would increase proportionately with an increase in precipitation whenever the damping effect of a protective vegetation cover was not present.

Powell was a man of action--the preeminent archetype of the western pioneer geologist. With indomitable spirit he had tackled an unknown landscape, learned many of its secrets, and in doing so had helped to change the character and direction of geomorphic thought. A man gifted with imagination and foresight, yet tempered by a scientist's appreciation for the facts, Powell became one of the country's most vigorous proponents for the orderly development of the public domain and the wise use of its natural resource wealth (W. T. Pecora in U. S. Geological Survey, 1969, p. v).

Despite Powell's many diverse accomplishments, in the fields of geology and geomorphology he was destined to be overshadowed by the monumental contributions of his assistant--Grove Karl Gilbert.
Grove Karl Gilbert: Father of American Geomorphology

Of all the men who contributed to our knowledge of landforms from the Great Western Surveys, none can equal the brilliant insights provided by Grove Karl Gilbert (1843-1918). Some of the most striking advances in geomorphology during the last fifty years had been foreseen by Gilbert (Figure 4). Unfettered by doctrinaire explanations or philosophical arguments, Gilbert's major contribution was his enunciation of general principles and laws, as well as in defining the role of deductive and inductive reasoning in geomorphic analysis (King, 1976, p. 24). To a considerable degree, a large part of modern geomorphology is today founded on his conceptual ideas. Thornbury (1969, p. 11) recognized Gilbert as the "first true geomorphologist produced in this country," while Ritter (1978, p. 4) identified him as "the father of modern American geomorphology."

During his association with the Powell survey party, Gilbert studied the geology and geomorphology of the Henry Mountains throughout the summers of 1875 and 1876. His Report on the Geology of the Henry Mountains, Utah (Gilbert, 1877) laid the basis for modern theories of denudation and for fundamental laws of erosion. This report is today considered a classic in landform studies. It represented the first major treatment by any geomorphologist up to this time concerning the mechanics of fluvial processes and the intricate relationship of these processes to the origin of land-
Figure 4. Grove Karl Gilbert (1843-1918). Gilbert's theory of grade and associated concept of dynamic adjustment have provided geomorphologists with an important framework by which to comprehend the linkages between landform features and landform processes. In addition, Gilbert made a significant contribution to geomorphic methodology by pointing out that facts must be used to overthrow theories (U. S. Geological Survey in Fenton and Fenton, 1952, facing p. 270).
forms.

From his empirical observations, Gilbert produced the first clear statement pertaining to the concept of grade. This was a formative notion whereby a stream was determined to reach an equilibrium between slope gradient, volume and velocity of flow, and sediment load. In addition to this major advance in the comprehension of geomorphic processes, Gilbert took the idea an important step further. Because Gilbert always thought in terms of equilibrium and ratios, particularly between force and resistance, he emphasized that all parts of the landscape are mutually adjusted and interdependent. In other words, the character and effectiveness of processes operating to create distinctive landforms could change with time in a continuous process Gilbert called "dynamic adjustment." Unfortunately, the fields of geology and geomorphology at the time were not yet ready for such complex and penetrating ideas.

In 1890, Gilbert relinquished many of his administrative duties, including that of Chief Geologist of the U. S. Geological Survey, in order to complete some of his earlier studies. In the history of Lake Bonneville (Gilbert, 1890), considered by himself to be his magnum opus (Mendenhall, 1919), Gilbert traced the chronology of the Great Salt Lake in Utah through various phases of climatic change. Other works on landforms included a discussion of the reversal of drainage of the Great Lakes, a history of the Niagara River and the development of its gorge by the recession of
falls, a hypothesis that the pattern of ridges and valleys in the Basin and Range Province had been produced by block-faulting, the first recognition of terminal and recessional moraines in the United States, and the introduction of the idea that hanging valleys were caused by alpine glaciation. Many of his earlier ideas on the importance of fluvial processes in landform development were brought together and amplified in his paper *The Transportation of Debris by Running Water* (Gilbert, 1914).

In addition to his many contributions in geomorphology, Gilbert also contributed to the developing American school of geography. In 1904, Gilbert was one of the charter members of the Association of American Geographers (James, 1972, p. 364). He was chosen president in 1908, just as he was chosen president of nearly every learned society of which he was a member. Like so many other geologists and geomorphologists of his time, and since, he also produced an elementary textbook on physical geography (Gilbert and Brigham, 1902). Finally, while an administrator in the federal government, he had much to do with the adoption of principles of nomenclature and cartography for the U. S. Geological Survey's topographic map work.

The common denominator of all successful theories is the author's ability to synthesize an assortment of separate parts and consolidate them such that they become integral components of a major unified scheme or paradigm. Hutton did it with his theory of a succession of worlds; Agassiz achieved it with his theory of
glaciation; Powell succeeded with his theory of base level. Gilbert’s contribution to a unifying geomorphic paradigm lies in his explanation of physical processes that were derived from his substantial theories of grade and dynamic adjustment. The merit of Gilbert’s work comes not merely from his descriptions and observations of landform features and processes, but from his ability to formulate hypotheses that inductively explained their formation and development. Thanks to Gilbert’s fruitful source of ideas, the science of geomorphology has had a solid foundation upon which to build. An excellent biography on Gilbert and his many contributions to geomorphology has recently been completed by Pyne (1980).

Not since the time of Lyell did a new body of thought have such an immediate affect on geomorphologists and geomorphic research as did the work of the Great Western Surveys. Although there remained considerable belief in marine planation and marine erosion during this period, by the turn of the twentieth century most geomorphic thought in the United States and Great Britain was strongly affected by these new ideas and scientific discoveries.

**Davisian Geomorphology (1899-1945)**

**William Morris Davis and the Cycle of Erosion**

If Gilbert had been ahead of his time, then William Morris Davis (1850-1934) was the right man at the right time (Figure 5).
Figure 5. William Morris Davis (1850-1934). Father of modern geography and founder of the Davisian school of geomorphology, Davis developed and preached the concept of geographical cycles of erosion. His philosophical and methodological approach was limited to descriptive explanations of landforms. This approach effectively threw a qualitative veil over geomorphic investigations that was to last for nearly fifty years (Chorley, Beckinsale, and Dunn, 1973, p. 438).
The impact of Davis on geomorphology has been greater than any other one man, including Lyell. The Davisian school of geomorphology grew rapidly in popularity after the turn of this century until it eliminated almost every other school of geomorphic thought. It was Davis who finally led American geomorphology away from its geologic roots and into the domain of geography. His descriptive interpretations of landforms were to dominate the discipline for nearly a half century.

Davis rose to dominate geomorphology and geography on the strength of one over-powering idea; the cycle of erosion (also referred to as the geographical cycle of erosion). By providing new terms and synthesizing an assortment of seemingly unrelated facts and concepts, Davis was able to spark renewed life and interest into the study of landforms. He was also responsible, because of the irresistible strength of his magical generalizations, to lull the geomorphic community into a temporary slumber. Inductive studies concerned with measurements and the mechanics of landform processes were almost totally overshadowed by geomorphologists who were content to follow the more fashionable philosophically deductive landform model developed by Davis.

Incorporating Darwin's idea of evolution, Davis theoretically deduced a cycle of erosion in which a landmass develops through a systematic sequence of landform stages; i.e., youth, maturity, and old age (Figure 6). The cycle begins once a landmass has been raised and progresses through a predestined series of forms until
Figure 6. Example of the Davisian cycle of erosion. Through sequential stages of development, a landform, in this case a tilted fault block mountain, evolves from initial uplift (youth) to old age (Strahler, 1975, p. 498).

In old age a peneplain is achieved or the landmass is affected by other events such as climatic change or renewed uplift. In actuality, Davis and most of his followers devoted much of their time and effort explaining why landforms were not allowed to complete the idealized cycle.

In developing his landform model, Davis suggested that landforms were a function of structure, process, and time (Davis, 1954, pp. 279-280). Emphasis was clearly placed on the time (or stage) that had elapsed in the erosional history of the landform. According to this model, by evaluating the present stage of development, the history of the landform could then be explained by deducing the sequence of evolutionary changes it had undergone in
the past and would likely undergo in the future. Ritter (1978, p. 8) has observed that since under this approach the past becomes the key to the present, it represents a one hundred and eighty degree twist on the previously accepted uniformitarian principle in which the present provides the key to the past.

Davis published his most polished and complete account of the "cycle" concept in 1899 (Table 1). This paper immediately received a great deal of attention. In the years that followed, Davis applied the concept to arid regions (Davis, 1905), to mountainous regions sculptured by glaciers (Davis, 1906), and to islands bordered by coral reefs (Davis, 1928). Davis defended the cycle of erosion concept, his terminology, and its application in each of the above situations with such vigor and persuasiveness that they were almost universally accepted (James, 1972, p. 356). Chorley, Beckinsale, and Dunn (1973, p. 355) suggested, tongue-in-cheek, that:

Surely no man did more for his own cause than Davis. He wrote his own play, chose the scenery, collected the audience, and acted most of the parts.

Intertwined during this period in which he was actively advocating the cycle of erosion theory, Davis was also concerned with defining the subject matter of physical geography. The purpose of this activity was to: (1) distinguish physical geography from geology; (2) demonstrate that physical geography was a science; and (3) relate physical geography to human geography. Davis defined physical geography as the physical, rational, explanatory
study of those existing features of the earth that enter into the relation between the earth and life in general, and man in particular (Davis, 1954).

In his efforts to define physical geography and popularize his explanatory system of landform analysis, Davis also played a prominent role in founding clubs, societies, and journals in the United States. It was entirely through his efforts, for example, that the Association of American Geographers was founded in 1904 (James, 1972, p. 364; Chorley, Beckinsale, and Dunn, 1973, p. 417). By raising geomorphology to a dominant role in American geography, Davis constantly advanced the cause of geography as a whole.

One of the reasons why Davis was able to so dominate geomorphology and geography during this period was because of the support he received from his students and colleagues. In the United States, apart from isolated pockets of resistance such as Rollin D. Salisbury (1858-1922) at the University of Chicago (James, 1972, p. 386), the disciples of Davis' ideas on geographical geomorphology ruled the field. His students included some of the most notable geographers of the early twentieth century: A. P. Brigham (1855-1932); Curtis Marbut (1863-1935); Robert De C. Ward (1867-1931); Ellsworth Huntington (1867-1947); Mark Jefferson (1863-1949); Isaiah Bowman (1878-1950); and Douglas Johnson (1878-1944) to mention but a few (James, 1972, p. 363). Colleagues outside the United States who advocated Davisian ideas included Henri Baulig (1877-1962) and Paul Vidal de la Blache (1845-1918) in

In summarizing this period and the geomorphic ideas advanced by Davis, Thornbury (1969, p. 13) states that:

Despite the objections which have arisen to some of Davis' ideas, it can hardly be denied that geomorphology still retains his stamp more than that of any other single person.

Walther Penck and the First Breach of the Cyclic Theory

The greatest skepticism concerning the cycle of erosion model came from the German school of geomorphology. Davis' four principal antagonists were Albrecht Penck (1858-1945), Walther Penck (1888-1923), Siegfried Passarge (1867-1958), and Alfred Hettner (1859-1941) (Chorley, Beckinsale, and Dunn, 1973, p. 501). They objected primarily on the grounds that Davis had not carefully considered the role of erosion during the initial uplift of a landmass. Steeped in a tradition based on empirical field observations, they also objected to an approach that was directed towards theoretical models and to deductive methods.

The only significant revolt during Davis' lifetime came in 1924 with the publication of Die Morphologische Analyse by Walther Penck (Table 1). Objecting to the notion of rapid initial uplift, Penck maintained that landforms evolve slowly and could not progress through stages of sequential development that would terminate in a region of low relief that Davis had referred to as a peneplain.
According to Penck, denudation of a landmass begins simultaneously with initial uplift. Denudation is caused by the relationship between endogenetic forces acting within the earth and exogenetic forces such as weathering and erosional processes sculpturing the earth's surface (Penck, 1953, pp. 1-2). Thus, under Penck's hypothesis, a landscape assumes a particular form depending on the ratio of endogenetic intensity (e.g., mountain uplift) and the exogenetic displacement of material (e.g., weathering, erosion, transport, and deposition) (Penck, 1953, p. 11). This idea significantly conflicted with Davis' youthful stage in which initial uplift is rapid and no erosion takes place (see Figure 6).

Penck's ideas also included an alternative slope retreat model. According to Davis, slope retreat would take place gradually and uniformly through each sequential stage in landform development. The final landform feature at the end of erosional climax would be a peneplain. Penck, on the other hand, expressed the idea of parallel slope retreat. According to this opinion, concave slopes would increasingly become predominant, with the resulting landform features being expressed by what King (1953) called inselbergs and pediplains.

With the death of Davis in 1934, the cyclic theory lost its driving force. Critics were becoming more vociferous. Serious weaknesses in Davis' ideas and methodological approach were being raised. For the most part, however, geomorphologists in the United States basically felt obliged to accept the conceptual structure
that had been proposed and left behind by Davis within which to conduct research. Although there was rejection to many of his fundamental tenets, there was also no satisfactory substitute for this unifying theory.

Two important factors were to change this confusing state of affairs. First, the ideas of Gilbert were rediscovered and given new meaning. Second, the spill-over effects of the "quantitative revolution" were interjected into the development of geomorphic thought.

Contemporary Geomorphology (1945-Present)

Although the cyclic theory was still common in the geomorphic literature until the mid-1950's, the pendulum was slowly but inexorably swinging away from the basic tenets of Davis. By the end of the 1960's almost every basic assumption in the cyclic theory had been seriously challenged. Out of this theoretical vacuum came a new host of ideas designed to replace the old, inadequate foundation that Davis had built for geomorphology. A modified cyclic model was proposed by King (1953). New statistical approaches for examining landforms were introduced by Strahler (1950, 1952a) and his students. Meanwhile, Hack (1960) was suggesting a return to Gilbert's ideas and introduced the concept of dynamic equilibrium.

What typifies the contemporary period is a major shift in the
ways of approaching landform studies. Deductive reasoning has been replaced with inductive observations and experimentation. Landforms are now being viewed according to their spatial differentiations rather than on their evolutionary history through time. Geomorphologists have thus shifted their attention away from theoretical models to process-oriented analyses. Numerous subfields, as a result of this reorientation in thought, have appeared with nationalistic overtones: United States and Great Britain with processes; France and Germany with climatic geomorphology; Russia with applied geomorphology, and so on (Garner, 1974, p. 32).

Although it can be argued that a theoretical and conceptual framework void exists today in geomorphology (Garner, 1974, pp. 32-33; Ritter, 1978, p. 9; Rosenfeld, personal communication), perhaps it does not matter. The multivariate nature of landform features and processes may well defy our attempts to develop a unifying theory for geomorphology. One thing seems clear though, until we fully comprehend the intimate relationship between process and form, we will never be able to adequately develop a theoretical model that completely fits the complex nature of geomorphology. Today, the search is on for new answers to old questions. A new foundation in geomorphology is being built; not from the top down as envisioned by Davis whereby geomorphologists assume to know what the landform processes are by observing the particular stage of a landform, but from the bottom up as expressed by the
work of contemporary geomorphologists in the field collecting landform-related data from which predictions can be made and hypotheses tested.

The contemporary period was ushered in, not by a geographer nor a geologist, but by a hydrologic civil engineer. In 1945, Robert E. Horton (1875-1945) published an influential article on drainage basin measurement and analysis. As well as any other, this paper signaled an end to the Davisian era and the dawn of a new era that insisted upon: (1) the incorporation of quantitative methods into the geomorphic paradigm—whatever that body of thought and methodological framework might be; and (2) the practical applications of geomorphic understanding. No longer would geomorphologists be content to assume that we knew the processes involved in the development of landforms. Henceforth, measurements and experimentation would be required in the development of geomorphic theory.

But if the Davisian era was characterized by a general unification and complacency of purpose, the contemporary period can be described as fragmented into a multitude of sub-fields that lack a unified direction. The fact that a civil engineer and not a geomorphologist was selected to represent the transition to the contemporary period indicates the increasing diversification that has occurred in recent decades. This is not to say that different schools of thought have not tended to characterize the field of geomorphology in the past. As figure 1 suggests, the history of
geomorphic development is a history steeped in conflicting ideas and methodological approaches. But in the present contemporary period, this pluralism in geomorphology has intensified.

Table 2 summarizes what several authors have identified as the various sub-fields of geomorphology that have evolved since 1945. Clearly there is little agreement amongst the authors. From this list, five have been chosen as representing the current major thrusts geomorphologists have been taking (primarily in the United States) in their search for geomorphic understanding. The five selected sub-fields are quantitative geomorphology, process geomorphology, applied geomorphology, climatic geomorphology, and regional geomorphology.

Quantitative, process, and applied geomorphology appear to be closely allied under the general heading of "dynamic geomorphology." The term was first proposed by Strahler (1952a). Contrasting these sub-fields are climatic and regional geomorphology. These two sub-fields have had a longer tradition, dating back to the Great Western Survey period. They are generally associated with descriptive methodological approaches; i.e., "descriptive geomorphology."

Quantitative Geomorphology

Since 1945, the scope and purpose of geomorphology has been greatly extended by the use of quantitative methods. The post-war
### Table 2.
Various Opinions Concerning Contemporary Schools of Geomorphic Thought

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quantitative revolution that has swept into nearly all the sub-disciplines of geography, including geomorphology, has left an indelible mark. In part, this transformation from qualitative to quantitative methodological approaches has been the result of computer availability, model building, and a significant increase in recently measured data; not to mention a certain fascination with substituting numbers for words in geomorphic analyses.

One area in which quantitative work in geomorphology started earliest and has gone the farthest is that of morphometric analysis of drainage basins. Robert E. Horton, as suggested earlier, was the pioneer. His paper in 1945 had a remarkable and immediate impact on geomorphic science. Horton graphically illustrated that analysis in geomorphology could be applied in both numerical and objective terms. In this paper, Horton suggested a method of stream ordering and developed a set of laws that connects various morphometric characteristics of a drainage basin.

One of the most influential quantitative geomorphologists in the United States has been Arthur N. Strahler (1918- ). Strahler (1950, 1952a, 1952b, 1954, 1956, 1957, 1964) has been particularly energetic in applying and extending Horton's principles (Dury, 1969, p. 28). Throughout his work, Strahler has emphasized the necessity of quantifying geomorphic research whereby processes can be measured accurately and compared effectively. For example, Strahler (1952b) developed an analysis procedure that could provide an indication of the total volume of earth material that has been
removed by erosion in any given basin. Called the hypsometric analysis, it is simply a relationship calculation involving elevation and basin area values.

Other methods that have been useful include trend-surface analysis which can deal with data distributed over an area, and time-series analysis which provides a means of studying phenomena that vary over time. Thus, on the one hand, quantification, statistical analysis, and stochastic models provide an effective means of unifying geomorphology with other natural and physical sciences (Scheidegger, 1970). On the other hand, Cuchlaine A. M. King suggests that there also dangers concerning the increased reliance and applications of quantitative methods because:

in some instances the numerical method seems to become the goal of the study rather than merely the means to a fuller understanding of the genesis of the landforms (King, 1976, p. 142).

Process Geomorphology

One of the most important developments in geomorphology has been the growing number of sophisticated studies concerned with processes that operate to shape the earth’s surface. Although there were notable early studies related to processes (e.g., Gilbert, 1914), much of the work in this sub-field has been taking place only recently. Now, all types of geomorphic processes are being monitored world-wide; the flow of glaciers, periglacial processes, the movement of sand, slope movements, rates of erosion,
transport and deposition of sediment, and many others.

The contemporary interest in process geomorphology began in 1960 when Hack suggested an alternative to the Davisian cycle. Returning to the ideas first proposed by Gilbert (1877), Hack introduced the concept of dynamic equilibrium into the geomorphic literature.

The concept of dynamic equilibrium provides a more reasonable basis for the interpretation of topographic forms in an erosively graded landscape. According to the concept every slope and every channel in an erosional system is adjusted to every other. When topography is in equilibrium and erosional energy remains the same all elements of the topography are downwasting at the same rate (Hack, 1960, p. 80).

Hack regarded the landscape and the processes molding it as part of an open system in a steady state. In such an open state, dynamic equilibrium is dependent upon the continuous transport of materials and energy into and out of the system, and is basically independent of time. Ritter observed that the dynamic equilibrium model diverges so radically from the Davisian cycle that the two may:

logically represent end members of a spectrum of geomorphic possibilities ranging from complete dependence to total independence of time (Ritter, 1978, p. 9).

The dynamic equilibrium concept was given structure in Chorley’s (1962) application of the so-called "general systems theory", and in Leopold and Langbein’s (1962) concept of entropy. In drawing attention to the dynamic qualities of open systems, Chorley stressed its time independent characteristics, while Leopold and Langbein discussed the spatial distribution of energy into and out
of an open system. In other words, landforms are considered to be operating in an open system in which mass and energy are constantly supplied and removed. Losses and gains of mass and energy are kept in a steady state by continuous adjustment of landform processes within the system (Ritter, 1978, p. 10).

Although rates and magnitude-frequency aspects of geomorphic processes in general remain inadequately understood (Wolman and Miller, 1960), recent publications have been constantly expanding our horizons. In addition to those already mentioned, a few of the more significant process oriented articles and texts that have been published, include: Langbein and Schumm, 1958; Leopold, Wolman, and Miller, 1964; and Carson and Kirkby, 1972.

Applied Geomorphology

There has been a heightening interest in the past twenty years over the human exploitation of the natural environment. Passage of the National Environmental Policy Act (NEPA) by Congress in 1969 and the Water Pollution Control Act Amendments of 1972 are a reflection of the public's growing awareness and concern over adverse impacts to the environment.

During the first half of this century, the main stream of academic geomorphologists tended not to consider an applied orientation as being a potentially fruitful basis for geomorphic research. With a change in public and academic attitudes, the
necessity to understand geomorphic processes has recently been demonstrated in situations involving floods, landslides, earthquakes, volcanic eruptions, and soil erosion by wind and water. Geomorphologists are becoming increasingly aware of the value their work has in the solution of applied problems (Cooke and Doornkamp, 1974, p. 2).

Applied geomorphology is the application of geomorphological techniques and analyses to solve man-related environmental problems. The term is synonymous with environmental geomorphology. The greatest potential for applied geomorphology exists in the investigation and prediction of geomorphic processes and their possible effects. The major problem is that little is yet known about the speed of most geomorphic processes (Wolman and Miller, 1958). Taken in the context of an exploding world population and an ever-increasing pressure on the land, applied geomorphologists are being forced to examine processes that occur on a human time scale. Gone is the dominance of historical investigations in the Davisian mode that dealt with landform evolution involving millennia. Applied questions are far more concerned with identifying and understanding short-term temporal and spatial variations in landform processes that may be critical for sensible land management.

In addition to the growing need to understand landform processes in applied situations, geomorphological research has also been concerned with the development of land classification systems.
Publications by Mabbutt (1968), Mitchell (1973), and Bailey, Pfister, and Henderson (1978) provide summary reviews of the general concepts involved in selecting variables and collecting data, morphological mapping techniques, and terrain analysis procedures. In addition, some attention has been directed towards a more comprehensive scheme for mapping land surface forms, materials, and processes as a basis for planning (Demek, 1972).

From these fundamental changes in geomorphic research there is the realization that physical systems of an area can never be fully understood in isolation from social, political, and economic considerations. Applied geomorphologists are more likely today than ever before to be establishing contacts with a variety of environmental managers and technicians, engineers, farmers, planners, foresters, and politicians. In addition, his staple reading material is likely to be expanded to include economics, planning, engineering, management, environmental perception, and law. In short, disciplinary boundaries are likely to have little meaning to the applied geomorphologist, except insofar as they are recognized and crossed with caution (Cooke and Doornkamp, 1974, p. 5).

Because of its short developmental history, no philosophy of applied geomorphology has yet emerged. Nevertheless, Brunsden, Doornkamp, and Jones (1978, pp. 254-255) have acknowledged five abilities that geomorphologists can contribute to applied situations (modified):
(1) Ability to think in spatial terms. Geomorphologists are trained to think about distributions; not only one phenomenon at a time, but several at a time.

(2) Ability to detect spatial correlations.

(3) Ability to change scales of reference in accordance with the nature of the problem. Situations in which flood hazards, landsliding, or avalanching come from outside the boundaries of a site investigation area suggest a few examples.

(4) Ability to comprehend the significance of the time-dimension. Examples include:
   (a) Recurrence intervals of natural events and potential hazards.
   (b) Rates of change under current processes.
   (c) Predicting the occurrence or reoccurrence of a process due to human action(s).

(5) Ability to use research tools and techniques. These acquired skills and knowledge include the use of remote sensing, field monitoring and use of associated equipment, mapping, statistical and laboratory analysis.

In the coming years, applied studies in geomorphology can be expected to become more prolific. Since geomorphology is concerned with landforms, materials, and their related processes, every environmental management decision involving these physical attributes will require scientific input. Therefore, the potential for applying geomorphic knowledge will depend not only on the problem, but also on the willingness of the environmental manager and planner to appreciate the value of this knowledge. Education is the key.
Climatic Geomorphology

The striking contrasts between landforms found in humid, arid, tropical, and glaciated regions have long been recognized. This fact has given rise to the notion that landforms in some way vary with climate. For example, slopes found in humid regions of sandstone bedrock origin appear more convexly rounded with gentler slope gradients than do their distinctively angular counterparts found in arid regions.

There are two basic concepts underlying the study of climatic geomorphology. Büdel (1973, pp. 220-221) has distinguished these by the terms "climatic geomorphology" and "climatogenetic geomorphology." Under the climatic geomorphology approach, it is assumed that different climates, by producing different rates and intensities of weathering and erosional processes, will develop unique landform assemblages (Stoddart, 1969, p. 163). It is dependent for its precise definition on results derived from process geomorphology. Climatic geomorphology thus represents an attempt at systematically analyzing geomorphic processes in order to classify morphologic terrain units.

The second approach, climatogenetic geomorphology, postulates that climatically controlled landform features have been continuously superimposed upon each other during the Tertiary and Pleistocene. In this historical analysis approach, the importance of climatic changes have had over time and the effects on both current
and past geomorphic processes are recognized. The central thread common to both concepts is the extent to which variations in the elements of climate, notably solar radiation energy and precipitation, reflect differences in geomorphic processes; which in turn, produce distinctive landforms or morphogenetic regions (Derbyshire, 1976, p. 1).

The earliest roots of climatic geomorphology have been traced back to Louis Agassiz and the development of the glacial theory (Derbyshire, 1973, p. 12), and to William Morris Davis' essays on the cycle of erosion (Peltier, 1950, p. 214; Stoddart, 1969, p. 161). Davis, in particular, unwittingly helped to lay the foundation for future theoretical developments by recognizing, through qualitative observations and implication, the importance a particular climatic region had on his cyclic model. Davis' theory of structure, process, and stage defined regions outside the humid (or normal) climatic regime, such as in arid and glacial areas, as being the result of climatic accidents. In addition to the arid cycle (Davis, 1905) and the glacial cycle (Davis, 1906), the deductive ideas expressed by Davis were later extended to the savanna by Cotton (1961) and to periglacial regions by Peltier (1950).

Since the turn of the century, the most productive research and greatest support for the ideas embodied in climatic geomorphology have come from the more empirically minded German and French geomorphologists. In Germany, one of the earliest to approach
Geomorphologic investigations from a climatic perspective was Albrecht Penck (1910). From his travels and observations, Penck surmised that climate acts as a steering agent for exogenous processes and the "pure" climatically controlled landforms would be found in centers of climatic zones. Penck reasoned that where boundaries between zones approached each other, then polygenetic landforms would develop. From these observations came one of the first modern attempts at an areal classification of surface morphology based on climatic areas (Holzner and Weaver, 1965, p. 593; Stoddart, 1969, p. 162). The leading German climatic geomorphologist today is Julius Büdel (1948, 1963). His work continues the ideas of those concerned with climatic control on landform development, and he is considered to be the leading proponent of the historically oriented, climatogenetic geomorphology philosophy.

In the French school of geomorphic thought, the ideas behind climatic geomorphology were first used by de Martonne (1913) and later by Birot (Derbyshire, 1973, p. 15). Today, Tricart and Cailleux (1972) have added the ingredients of soils and vegetation cover as additional factors into the traditional climatic orientation approach.

Current discussions of climate and process are intimately intertwined with the delineation of climatic-morphologic regions (Wilson, 1968; Stoddart, 1969; Thorp, 1970). Working within the tradition of the Davisian cyclic theory, the article by Peltier (1950) has become perhaps the best known and most widely refer-
enced paper on this subject. Through a purely deductive assessment, Peltier considered mean annual rainfall and temperature as being the most significant climatic parameters and examined the hypothetical effects of each on five dominant weathering and erosional processes: chemical weathering, frost action, pluvial erosion, mass movement, and wind action (Peltier, 1950, p. 135).

Peltier hypothesized that each of these factors would explain the principal geomorphic processes at work within well-defined climatic regions. This clearly does not reflect reality since such factors as seasonality, intensity, and frequency are not considered in the differentiation of geomorphic processes. Despite the obvious weaknesses, Peltier's approach represents an important step toward classifying and comprehending the complexity of geomorphic processes.

Despite explicit recognition of direct cause and effect relationships between climate and geomorphic processes, for the most part climatic geomorphology today still lacks the methodological framework needed to build quantifiable, reproducible response models which can be subjected to field and laboratory testing. Rather than attacking the problem at the source, from the perspective of process, climatic geomorphologists have made repeated attempts to correlate, on small-scale maps, the world-wide distribution of vaguely defined landform types with chosen climatic parameters thought to be significant in sculpturing the earth's surface. Generalizations that relate climate and landforms should
be approached with caution. Since most climatic-morphologic studies do not take into account bedrock lithology, different rates of erosion and deposition, plate tectonics, and climatic fluctuations, it is easy to fall into a quagmire in which one set of climatically controlled processes is equated with producing a uniform set of landform types. They do not. On the other hand, neither should geomorphic philosophies go to the other extreme as expressed by Lester King (1957), who holds that landforms are essentially independent of climate.

Further quantitative research efforts which are concerned with process, geomorphic dynamics, interrelationships of physical factors, and large-scale mapping of landscape morphometry will likely prove to be the most significant approaches in establishing the importance climatic components have in landscape evolution. With a rational set of developed procedures and techniques, questions as to why and how landforms are where they are can be answered with the same degree of certainty that we now express where landforms are where they are.

Regional Geomorphology

The sub-field of regional geomorphology dates back to the Great Western Surveys of the late nineteenth century. During this period and into the first half of this century, regional studies dealing with the distribution and geomorphic histories of land-
scapes were referred to using the term "physiographic regions". The first attempt to divide the entire United States into geomorphic regions was made by Powell (1895) in a paper entitled "Physiographic Regions of the United States" (Thornbury, 1965, p. 5). This was followed in 1911 by the first regional textbook, Forest Physiography by Isaiah Bowman.

In the years that followed, numerous regional geomorphic studies were undertaken by both geographers and geologists, including: Fenneman (1931, 1938); Loomis (1937); Lobeck (1939); Atwood (1940); Thornbury (1965); and Hunt (1967). The current trend is toward traditional areal studies defined by a particular set of geomorphic processes rather than those defined by political boundaries; e.g., deserts (Cooke and Warren, 1973), glacial and periglacial areas (Embleton and King, 1968).

Regional landform studies continue to be an integral part of geomorphology (Thornbury, 1969, p. 14). Examples of current regional research include: (1) landform assessments for environmental impact statements; (2) mapping of a specific landform type (e.g., playas, landslides, loess) or landform processes (e.g., floods, landslides, glaciers); and (3) morphological regionalization associated with land classification systems.

Finally, Butzer (1973, p. 41) argues the need to initiate systematic, regional studies of landform changes that have and will occur in the wake of environmental changes. The linkage in this regard must be the cooperation amongst the process, applied, and
regional geomorphic sub-fields, a situation that does not exist at the present time.

**Summary**

As this section has attempted to illustrate, geomorphic thought has had a long history of development. Traversing through paradigms which have embodied creationism, diastrophism, diluvialism, uniformitarianism, Davisianism, and a multiplicity of additional "isms", geomorphology has evolved into a fragmented state. As a result of this pluralism, there is currently no unifying body of geomorphic thought, and scientific research is largely operating in an acknowledged theoretical vacuum.

In an attempt to rationalize and systematize the science, geomorphology is presently in the midst of a period of enormous intellectual, technical, and conceptual change. Most of these radically new alterations in thought and approach alluded to earlier, have taken place since 1945. Most of these changes will ultimately be beneficial for the continued growth and development of the sub-discipline. Whether the existing divergence into isolated sub-fields will retain its advantageous state, as many geomorphologists argue, remains to be seen. In an attempt to help clarify this current, complex situation, several of the specific problems facing geomorphology will be addressed in the following two sections.
In order to recapitulate the historical development of geomorphology, two additional summary graphs are provided. Figure 7 is a simplified flow diagram indicating the various paths the identified geomorphic sub-fields have taken in their evolution (compare with Figure 1). From a long adolescence period distinguished by earth observations and preliminary theoretical developments, the academic disciplines of geology and physical geography have emerged. Geology has tended to concentrate its efforts on historical analyses and vertical descriptions of the earth; i.e., subsurface to surface morphological investigations. Sub-fields have included sedimentology, stratigraphy, seismology, volcanology, and paleontology. In contrast, geographical emphasis has been placed on understanding the horizontal differentiation of landform features, and recent or active morphological processes.

At the turn of this century two distinct wings of geomorphology could be identified. The descriptive wing, under the tutelage of William Morris Davis, dominated the science until 1945. Since then, the principal concentration of research has been in the dynamic wing, with geomorphologists building upon the ideas first enunciated by Grove Karl Gilbert. This re-direction toward quantitative, process, and applied questions and techniques can be expected to continue well into the next century.

Finally, figure 8 presents an intellectual tree of the key individuals who have forged the development of geomorphic thought
Figure 7. The Historical Development of Geographical Geomorphology.
### Figure 8. Intellectual Tree of Geomorphology: 1810-1980

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- **Dana**
- **Agassiz**
- **Lyell**
- **Ramsey**
- **Humboldt**

- **Powell**
- **Gilbert**
- **W. Penck**
- **A. Penck**
- **Hunt**
- **Thornbury**
- **Tricart**
- **Peschel**
- **C. King**
- **Chorley**
- **Leopold**
- **Coates**
- **Cooke**
- **Doornkamp**
- **Bailey**
- **White**
- **Leopold**
- **Cotton**
- **Büdel**
- **Wilson**

- **Great Western Surveys**
- **Davison Geomorphology**
- **Contemporary Geomorphology**

- **Epoch**
- **Time**

- **Quantitative Geomorphology**
- **Applied Geomorphology**
- **Descriptive Geomorphology**
- **Regional Geomorphology**
- **Climatic Geomorphology**
- **Process Geomorphology**
- **Dynamic Geomorphology**

- **1810-1980**
from 1810-1980. In addition to portraying most of the names already mentioned in the text, additional names have been added to help provide the continuity required to illustrate the interrelationships between scholars. Delineation of the geomorphic time periods and evolving sub-fields have also been incorporated. For example, since 1945 the five major recognized geomorphic sub-fields and those individuals responsible for their elaboration are acknowledged.
III. THE ROLE OF GEOMORPHOLOGY IN THE SCIENCE OF GEOGRAPHY

When geography departments were being established in the United States at the turn of this century, the first appointments were scholars who had never been trained in a graduate school of geography. Each had to define the field to his or her own satisfaction. The majority of these first geographers were geomorphologists and climatologists educated largely in the physical sciences, especially geology (Bryan, 1950, p. 196). Physical geography was the dominant curriculum. Thus, in the formative years, it was the physical geographer who on the whole controlled the growth and development of the emerging discipline. This situation at the turn of the century contrasts dramatically with the present fellowship of professional geographers in which the dominant pool is drawn from the social sciences.

Just as the discipline of geography in the United States has changed over the course of the past eighty years, so to has the influence and impact brought about by geomorphologists. The purpose of this chapter is: (1) to discuss the various contributions that have been made by geomorphologists to the academic discipline of geography; (2) to review a few of the problems currently facing geographical geomorphology; and (3) to assess and comment on, through an examination of geomorphic publications, the role geomorphology is presently playing within the science of geography.
The Influence of Geomorphology on Geography

The influence of geomorphology on the directional development of geography was at its apex at and for a short period following the turn of this century. The initial leadership and guidance was provided by William Morris Davis. The publication of Davis' "The Geographical Cycle" in 1899 marked the establishment of the first recognized paradigm for geographical study in the United States. This influential paper was published at a time when geography departments were being established throughout the country. The blueprint pattern generally followed was the university concept that had been developed in Germany in 1874 (James, 1972, p. 350). Many of these new geography departments were at first associated with the already recognized and accepted discipline of geology. During this institutionalizing period, most of these fledgling geography departments were to adhere to and follow the ideas being so effectively preached by Davis.

The high degree of dominance wielded by Davis began to evaporate during the 1920's and 1930's with the rise of cultural geography. For reasons that will be elucidated upon later, the low ebb for geomorphology and the other sub-disciplines of physical geography occurred in the mid-1950's (Marcus, 1979, p. 524). The late 1950's and early 1960's became a period of major change and self-examination. Geomorphologists and other physical geographers began to question their position and contributions to geography.
A debt is owed to the so-called quantitative geographers as they inadvertently helped to rejuvenate the physical wing of geography. Today there is a sense of purpose and direction that has been missing for nearly half of this century.

From an enthusiastic beginning with Davis and his unifying idea concerning cycles of erosion, geomorphology rapidly lost its influence and stature in geography. Why? The following explanations are but a few of the principal reasons for this change.

(1) Geomorphic methodologies lagged behind the development and application of spatial techniques being formulated by human geographers.

(2) The rush to and from environmental determinism undoubt- edly weakened the perceived role of geomorphology (Marcus, 1979, p. 524).

(3) Human (cultural) geography, with its emphasis on pressing human problems, attracted far greater numbers of new graduate students.

(4) Prominent geographers, such as Harlan Barrows (1924), aggravated an already significant schism between human and physical geographers by advocating that all the physical geography sub-disciplines should be dropped from the geography curriculum.

(5) The cycle of erosion theory was justifiably being criticized as untenable and incapable of resolving practical problems.

Associated with this disenchantment by most human geographers and some physical geographers with the cycle of erosion theory were
the arguments made by Russell (1949, p. 2) that:

(6) Landform methodologies were too abstract and unrealistic in answering critical environmental questions of human significance.

(7) Landform investigations were excessively geologic in scope and purpose in that they dealt with landform evolutions rather than current landform processes such as flooding and landsliding.

When viewed in combination, these perceived problems led to a rapid shift away from interest in physical geography and landform studies by most geographers. Whereas European universities retained an active interest in geomorphology during the 1920 to 1950 doldrum period, American geomorphologists found it increasingly necessary to rationalize their existence within the orthodox geography curricula (Russell, 1949; Kesseli, 1950; Hammond, 1962; and Zakrzewska, 1967). Philosophical debate eventually became focused on two fundamental dichotomies: the physical-human geography schism; and the division between geographical and geological geomorphology.

Physical Geography Versus Human Geography

The so-called physical-human dichotomy in geography has been described by James (1967, p. 20) as being one of the worst of our persistent errors. It is absurd to think of physical geography as
being separate from human geography. Geomorphology and all the other specialized sub-disciplines of physical geography are, by definition of geography, intimately tied to man.

Geography seeks to explain how the subsystems of the physical environment are organized on the earth's surface, and how man distributes himself over the earth in relation to physical features and to other men (National Academy of Science, 1965, p. 1).

Geography is concerned to provide an accurate, orderly, and rational description of the variable character of the earth's surface (Hartshorne, 1959, p. 21).

In an obvious attempt to lessen the dualism between man and nature, geomorphologists in the past twenty years have made concerted efforts to redirect their methodological approaches along more geographical lines. If viewed from the perspective of the four acknowledged traditions in geography as expressed by Pattison (1964), geomorphology has played a significant role in at least two; the earth science tradition, and the man-land tradition. The earth science tradition was particularly influential shortly before and immediately after the founding of the Association of American Geographers (AAG) in 1904. Since then, geomorphologists have tended to be adherents of the man-land tradition in both geographical instruction and research. This inclination towards man-land relationships can be seen in the following examples.

Modern geomorphologists, dissatisfied with the classical "cycle" research approach that emphasized the history and evolutionary development of landscapes, have become more interested in
landform processes that interface with human activities. Human geographers, on the other hand, have become acutely aware that man is intricately tied to his physical environment. Until only recently the problem had been that landforms and the human elements were, for the most part, studied in isolation. The importance of understanding landform processes in applied situations are finally being recognized. More than ever before, information concerning landforms are intimately being tied to decisions regarding the location of transportation systems, the establishment of industries, and the wise use of our natural resources, agricultural land, forest land, and urban areas.

Since the passage of NEPA in 1969, this loosely defined dichotomy has become less significant. Physical and human geographers are working together in an increasing number of situations in order to solve common geographical problems. Although most geographers can accept the proposition that the physical-human geography schism does not—or at least should not—exist today, a far more persistent problem for geomorphology does continue to exist: the debate over geographic versus geologic geomorphology.

Geographical Geomorphology Versus Geological Geomorphology

The development of geomorphology as a distinct science began in the late nineteenth century following the general rise in prestige of the natural sciences. Becasue of the more rapid
development of geology than of geography, the study of landforms was inextricably interwoven with the academic discipline of geology (Hartshorne, 1959, p. 86). Geomorphologists, having been trained in geology, used geologic methods to help explain the origin of landscapes. These studies were genetic in emphasis and cloaked in descriptive terminology. Geomorphology began to split into geologic and geographic camps as knowledge accumulated and as perceived interests diverged. Considerable concern and debate continues to be generated over the two approach philosophies. One example of this dichotomous situation is reflected, as alluded to earlier, in the difficulties geomorphology has had in finding a permanent academic home.

This is not to say that the identifiable dichotomy between geographical and geological geomorphology is either an isolated or unique case. An analogous situation exists in the life sciences where the emerging discipline of ecology has experienced similar problems. Ecology and geomorphology both approach scientific research from an interdisciplinary perspective. In order to comprehend the environmental complexity of their respective fields of interest, both must utilize at times data, theories, and techniques developed in more narrowly defined disciplines. This interdisciplinary orientation, coupled with loosely defined and recognized academic boundaries, have in combination led to the acknowledged dichotomies between disciplines. In the case of geomorphology, however, the problem has persisted for a longer
Arguments and counter-arguments for or against geographical geomorphology have punctuated the literature periodically since the mid-1940's. Bryan (1950), for example, advocated an extremely limited role for geomorphology in the geographic discipline.

Fortunately for us in the United States geomorphology has attained a place as a geologic science and most geomorphologists hold positions on geologic faculties (Bryan, 1950, p. 198).

In addition, he stated:

> The first and most natural application of geomorphic study is to the history of the earth. From this standpoint geomorphology is a working method inside of the mother science of geology... (Bryan, 1950, p. 199).

This sentiment towards the role of geomorphology has also been echoed by Thornbury (1969). Bryan and Thornbury are just two examples of geologists who are opposed to the European tradition in which geomorphology is associated with geography departments. As one might expect, views expressed by geographers support an entirely different assessment.

Russell (1949), in his presidential address to the AAG, attacked what he termed "classical geomorphology" or the geological methodology. He suggested that geomorphology, along with the rest of the physical geography sub-disciplines, should focus on answering questions having to do with what? where? and how much?

> When geomorphology really tells us what is present in a landscape and tells us exactly where each form is to found, it becomes geographical (Russell, 1949, p. 10).
In 1950, Kesseli advocated a search for geomorphic landscapes; i.e., regions of similar or of different landform types using geographic methodologies. He went so far as to say "the search for geomorphic landscapes...demanded no thorough geologic training" (Kesseli, 1950, p. 8). These ideas were later championed by his student Edwin Hammond (1962).

In contrast, Zakrzewska (1967, p. 131) was convinced that the field of geomorphology could only be adequately covered when both geographers and geologists provided their own unique contributions, each investigating the field from their own point of view. She advocated the restriction of geographical geomorphology, under the title of "landform geography", to investigations concerned with the spatial variations of landform features. Such an orientation would restrict geographers to studying the functional role of landforms in their relationship to man and other elements of the physical environment. She suggested regulating laboratory and field analysis of surface material and geomorphic processes to geologic geomorphology, while leaving geographical geomorphology with morphometric map analysis and regional field studies (Zakrzewska, 1967).

In examining these various philosophical statements, one can argue that the difference between geographers and geologists working in the area of landforms lies not in their working methodologies, but in their objectives. Geologic geomorphology is historical in approach in that it deals with the past, particularly
with the conditions of the past that lie hidden beneath the earth's surface. Geographical geomorphology deals primarily with the present, particularly with the spatial distribution of current land surface forms and processes and how these forms and processes interrelate with man. In breaking away from the historical objectives,

the geographer need study genesis only as far back as will enable him to attain greater comprehension of existing relationships of phenomena in areal variation... (Hartshorne, 1959, p. 85).

Given this general background, it is this author's opinion that the evolution of landforms should essentially be the labors of geologists and only of indirect concern for geographical geomorphologists. The realm of the geographer should be primarily directed toward understanding the spatial interrelationships of active or recently active processes on the earth's surface, how this knowledge can be beneficial to human activities, and answering questions as to what? where? and how much? This is the current trend. Geographers, whatever their individual specialities, will ultimately profit from this new era of increased geographical geomorphology.

Observations From AAG Presidential Addresses

In the United States, most of the presidents of the Association of American Geographers (AAG) have utilized the annual address to the membership as a forum for expressing their ideas about the
scope and method of geography. Usually, the topic has been confined to a particular sub-discipline. In the seventy-five years of the AAG history (1904-1979), 35 of the speech-giving presidents have been practicing physical geographers with a minimum of 43 of the 75 trained as physical geographers (Marcus, 1979, p. 526).

Of these presidential addresses, only Russell (1949) specifically addressed the field of geomorphology and its role in geography. Other geomorphic-related addresses dealt with particular aspects of the science; i.e., the relationship of physical and human geography through an examination of earthquakes (Gilbert, 1909), glaciation (Tarr, 1912), physiographic provinces (Jefferson, 1917), and physical geography in general (Marcus, 1979).

One of the difficulties with understanding the areal variation of landforms has not been the lack of significant problems, but rather their baffling complexity. In 1924, Barrows suggested that we eliminate this problem altogether by dropping geomorphology, as well as climatology and biogeography, entirely from the geographic discipline. In an attempt to distinguish geography from other disciplines, he introduced the idea of human ecology as a unifying theme. He felt geographers should limit themselves to describing the environment, not the study of it. This influential address, of course, occurred at a time when representation by geomorphologists in the AAG was at a record low (see the following section). It was not until Russell (1949) and Thornthwaite (1961) used the presidential address to reinforce our belief that
"the task ahead" required vigorous attention to processes and a more thorough, quantitative understanding of environmental systems, not less, that this descriptive attitude was dispelled.

In 1979, Marcus used the presidential address to examine the role physical geography has had in the affairs of the AAG and in the development of American geography. Marcus presented a case which suggested that the physical sub-disciplines have come almost full circle in the past seventy-five years with regards to influence. From a geomorphic perspective, the cycle began when geography was initially being established. Geomorphology, as we have seen, was a principal founder. This influential beginning was followed rapidly by a lengthy period of relative obscurity. Today, geomorphologists and other physical geographers are once again taking a more active role in shaping the identity and course of geography. As the next section will show, inequalities within the discipline, unfortunately, still exist.

Analysis of Geomorphic Publications

Butzer (1973, p. 42) has recently observed that the publication of geomorphic articles continues to be a vexing problem. Stifled by restrictive editorial policies of the Annals and Geographical Review, geomorphologists have turned increasingly to specialized journals in the United States as well as to a number of overseas journals. Because of insufficient journal outlets for
research findings, a relatively recent phenomenon has been the production of a cavalcade of anthology textbooks and symposiums on a variety of geomorphic research themes. These two characteristics, inadequate journal availability and an increasing number of collected papers bound in book form, are symptoms of a simmering communication crisis in geomorphology.

Problems Associated With Geomorphic Communication

Geomorphological papers are scattered over an incredible array of topical and regional journals—mostly geological and hydrological. This situation has persisted since the development of the science because of: (1) the wide diversity of subject matters being researched; (2) the close evolutionary association with geology and a continued interest in fluvial geomorphic processes; (3) editorial prejudices towards a perceived peripheral sub-discipline; and (4) an insufficient number of journals that cater exclusively to geomorphic topics.

For scholars and students alike, the most prominent geomorphic journals are: Zeitschrift für Geomorphologie (Germany); Revue de Géomorphologie Dynamique (France); Geomorfoloia (U.S.S.R.); and Earth Surface Processes (Great Britain). In addition to these geomorphic journals, there are also a few physical geography journals that are strongly oriented towards geomorphology, such as: Geographiska Annaler, Series A (Sweden); and Physical Geography
Except for Physical Geography, the United States has had only one other geomorphic periodical; the Journal of Geomorphology published from 1938 to 1942. This abortive journal died during World War II, a victim of its time and the slow death of the Davisian tradition (Butzer, 1973, p. 40).

Despite the lack of identifiable journal outlets in the United States, there are indications that communication amongst geomorphologists is slowly improving. For example, since 1960, an invaluable aid for scholars and students in search of widely scattered geomorphological articles has been the Geo-Abstracts, Section A. On a more personal level, communication is being facilitated by the recent formation of the AAG Geomorphology Special Interest Group. The specialty group has established a team of regional correspondents who will function as coordinators for geomorphic sessions at national and regional meetings. They will also provide reports and news items for the Geomorphology Section Newsletter which is published and distributed three times a year to those members of the AAG interested in geomorphology. In addition to these developments, discussions have recently begun concerning the formation of a new geomorphology interest organization in the United States. The idea has been to perhaps pattern it after the influential and extremely successful British Geomorphological Research Group. In total, these recent activities point to a healthy resurgence on the part of geomorphologists to
communicate and share their ideas, methodological developments, and experiences as fully participating members of the geographic community.

Geomorphic Articles in the Annals and Geographical Review

In the United States, the principal journals for professional geographers are the Annals and Professional Geographer of the Association of American Geographers and the Geographical Review of the American Geographical Society. An analysis of the Annals and Geographical Review has been made from volume one of each journal up to 1980. The purpose was to assess the total number of geomorphic or closely related articles that appeared in these two journals when compared to the total number of articles published each year. The results of this analysis are graphically provided in figures 9 and 10.

In addition to a graphical portrayal of the totals, a supplementary analysis was conducted that related the total number of geomorphic articles as a percentage of the total number of geographic articles (Figure 11 and Table 3). This analysis reveals the changes that have occurred over time with regard to geomorphology and the acceptance of geomorphic articles to these two journals.

Editorial policies concerning geomorphic articles in the Annals are characterized by a greater number of peaks and valleys
Figure 9. Geomorphic Articles in Relation to the Total Number of Articles in the Annals, 1911-1980
Figure 10. Geomorphic Articles in Relation to the Total Number of Articles in the Geographical Review: 1916-1980
Figure 11. Geomorphic Articles as a Percent of the Total Number of Articles in the Annals and Geographical Review
(feast or famine) from year to year. The first seven years, up to 1918, reflected the strong physical orientation of the newly formed association. From 1918 to 1945 the influence of human geographers became predominant. Only 15 geomorphic articles were published; with one five year period occurring (1923-1927) when no geomorphic articles were accepted. Despite an increase in the total number of articles between 1945 and 1970, the proportion of geomorphic articles has remained relatively constant at 10 percent.

The Geographical Review has had a more consistent policy
toward geomorphic articles over the years when compared to the Annals. During the 1920's, a significantly higher percentage of geomorphologists were publishing in the Geographical Review. Since then, the percentage rate has steadily declined (Table 3). If the current trend continues into the next decade, only one of every twenty-three articles published will be related to a geomorphic topic.

When the totals are averaged over the life of these two journals, they reveal an average 10 percent publication rate for geomorphic articles. The significance of these numbers, when applied to the Annals, has recently been assessed (with some bias) by Marcus (1979, p. 522). He points out that some 36 percent of the members of the AAG are physical geographers. Physical geographers are assumed to have either a direct or indirect interest concerning geomorphic topics. He also notes that 42 percent of all students enrolled in geography courses in the United States were taking physical geography courses. Since the Annals is only producing geomorphic articles at a 10 percent rate, what these numbers suggest is that the Annals is not adequately serving the needs of physical geographers in general and geomorphologists in particular.

Although numbers such as these can be twisted and arranged to substantiate just about any argument raised, they do tend to reveal that existing geographical journals have not kept pace with the exponential growth of research conducted by geomorphologists.
Instead, these journals appear to reflect outmoded notions and vested interests from limited segments of the geographic discipline.

What this chapter has attempted to show is that geographical geomorphology is alive and well. There are several identifiable problems that continue to persist for geomorphologists, but they are not insurmountable. Internal and external adjustments are being made on a wide variety of fronts to correct these inequities, while at the same time, improving the contributions made to geography and society.
IV. FUTURE PROSPECTS FOR GEOMORPHOLOGY

Until the end of this century, geographical geomorphology will continue to be characterized by diffusion and infusion. Diffusion refers to the fragmentation of geomorphology into a multitude of separate, identifiable sub-fields, five of which have been outlined in this paper. These sub-fields will continue to have nationalistic centers of thought. The infusion or introduction of ideas, techniques, methodologies, and interdisciplinary cooperation from other disciplines and sub-disciplines can also be expected to continue. In order to prevent the dissolution of the science and maintain at least a vague delineation of the academic boundaries, improved communication linkages will need to be established.

The dissemination of information via articles and professional meetings will slowly improve over the next couple of decades. Geomorphological research, as has already been discussed, is published mainly in geological and hydrological serials. Most existing geographical journals have simply not kept pace with the recent developments taking place in geomorphology. The initiation of *Earth Surface Processes* and *Physical Geography*, as well as the formation of the AAG Geomorphology Special Interest Group, indicates a growing awareness by geomorphologists in the past few years of the need to improve the imbalance that exists in the geographic literature. The primary purpose of these new journals
and professional associations has been to provide additional forums for geomorphic thought and research.

The dichotomy that exists between geographical geomorphology and geological geomorphology will become less pronounced. In the United States, geomorphology can be expected to be taught in, and associated primarily with, geography departments. Several reasons can account for this shift in the existing schism. First, geologists are tending to concentrate more and more on endogenetic processes associated with the search for mineral resources and the all-encompassing theories of the restless earth, such as: (1) determination of the earth's age and evolutionary history; (2) forces involved in orogeny; and (3) the mechanisms of plate tectonics, to mention but a few examples. Geomorphologists, on the other hand, will be concentrating their efforts not so much on landform evolution in the long term ($10^3 - 10^6$ years), but on exogenetic landform processes in the short term ($<10^3$ years) that occur on the earth's surface. Geographical geomorphology has returned to the physical functionalism of Grove Karl Gilbert in which an association was attempted between measured forms and processes, albeit with pushing and prodding by the quantitative wave of geography.

One can expect to see a continuation of the study of process mechanics and why landforms and their respective processes are spatially varied. In this regard, geomorphologists will be giving morpho-genetic regionalization increasing attention. There is
still much to be learned about the differences of geomorphic and hydrologic processes that take place amongst various climatic regions of the world.

We can readily enough identify ideas and research themes whose time has come: quantitative and process geomorphology; systems description and analysis; and plate tectonics. For example, quantification has allowed more precise comparison and generalizations than had previously been possible using descriptive methodological approach procedures. Quantification, i.e., the use of statistics, models, and computers, also brought with it significant problems. For a period of time, quantitative methods in geography was considered by many to be a new concept rather than a new, powerful research tool. The result was that in many instances the methodology obscured the problems it was intended to solve. Geographers working in geomorphology in the future will require considerable training in quantitative methods. Not only will it be necessary to extract the inferences from one's own data, but it will be equally important that one be able to read and understand the literature and comprehend the limitations of the methodology (Graf, Trimble, Toy, and Costa, 1980, p. 281).

In addition to the above cited ideas and research themes, future attention increasingly will be given to spatial problems involving landforms and man; i.e., applied geomorphic studies. In a concerted effort to help solve social problems--usually those of pressing economic significance--an increasing number of geomorph-
ologists will be applying existing techniques and methodologies that are designed to provide useful predictions of land surface processes and interrelationships. In addition,

With increasing frequency, geomorphologists will be called upon to testify at planning meetings, comment on environmental assessments, organize research efforts around current issues, and attempt to improve public knowledge of natural hazards and landscape resources (Graf, Trimble, Toy, and Costa, 1980, p. 283).

Several aspects of this trend can be expected: (1) new research techniques will be developed; (2) basic principles of geomorphology will be re-examined; (3) greater cooperation between disciplines and amongst geographers will be facilitated; and (4) pure research that leads to fundamental discoveries and theoretical development will be reduced.

At least for the time being, the science of geomorphology seems poised on the threshold of considerable advancement regarding the theory of landform processes. Giant steps are now being taken on a wide variety of process-related fronts. With each new step forward will come a more comprehensive understanding and perhaps even a few additional answers to the classical yet perplexing questions related to landform distributions, evolution, and dynamics. Out of these research discoveries will emerge a more unifying process-oriented paradigm that will gradually result in the demise of the existing theoretical vacuum. This expected progress in thought will lead to an explosion in the application of geomorphic techniques and methodologies requiring an ever-
increasing demand for field surveys and greater attention to resource-environmental issues. In short, given the rapid changes taking place today, at the turn of the twenty-first century, geomorphologists can be expected to be doing things quite differently from a wide variety of standpoints.

The future of geographical geomorphology appears to be extremely bright and promising. Rapid change and development will continue to be the norm rather than the exception. Geography and geomorphology are daily being strengthened and enhanced because of these activities. Geomorphologists adjusted quickly and surprisingly well to the quantification, systems, and process ideas that have either been introduced, or re-introduced, into the sub-discipline within the past thirty years. The Davisian doldrum period is now history. Pluralism has been accepted as the current state of affairs. The forthcoming changes for geographical geomorphology will not only be challenging, but at the same time, fundamentally rewarding.
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