GEOMORPHOLOGY

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Summary

Geomorphology, the study of landforms, is an integrative science since it includes soils, country rock, climate, water, and vegetation as controlling factors. It is therefore a good basis for geoecological research on a medium and large scale. A morphogenetic analysis in particular allows a better evaluation of many detailed paleoclimatic studies. Advances will come from correlation of landforms with soils and sediments inclusive of laboratory analyses and absolute datings. Increasingly, applied geomorphology is helping with questions of land degradation (soil erosion and desertification) and engineering (flood, landslide damage, and coastal erosion). Geomorphology is helpful for many geoecological problems, such as underground water movement, soil distribution, and vegetation patterns.

1. Introduction

Geomorphology is the study of landforms and of the processes shaping them. Exogenic forces act from above the surfaces (i.e. are climate controlled) and endogenic forces, mainly tectonic movements, are considered relevant for shaping landforms. They change in quality and quantity in space and time. Rock resistance or lithology is the third component. As all three cover a wide field of individual constituents, investigations that apply all three components in detail are possible only for a limited area. Often single landforms are studied, such as a lakeshore, where the three components can be isolated. Obviously which constituents and to what extent they are incorporated varies, so that a distinction is made between micro- (weathering of a bloc), meso- (evolution of a valley), and megageomorphology (subcontinental fault scarps).

But it is not only the spatial scale that characterizes geomorphological investigations. They differ rather more in the extent to which they take into account other geoecological sciences like climatology, hydrology, soil science, and biology; geology is always borne in mind. This results in a comprehensive approach, which seems to be less determinable than the measurement of, for example, erosion rates. But increasingly, the interdependence of geoecological factors is realized and the isolation of single factors is considered incomplete. The surface of the earth, or landforms, is not only the basis for all processes in ecology, the evolution of landforms is also responsible for the depth of weathering and the sediment cover, for example, and therefore for hydrological pathways, the distribution of soils, and the availability of nutrients. This in turn forms the vegetation pattern and the natural resource for land use. Landform evolution is the best control for geoecological budgets on a medium scale, especially to distinguish between natural and human-induced processes.

2. Development of Geomorphology

2.1. Early History

Living with nature has always meant dependence not only on weather but on geomorphological processes as well. The management of water began with the very early civilizations: floods and natural fertilization by river sediments were acknowledged, as when Herodotus said: “Egypt is the gift of the river.” Aristotle noted the rapid change of a coastline by sedimentation in delta areas. Earthquakes and volcanoes, so relevant in the Mediterranean, were a subject of speculation. Early descriptions of landforms are to be found in the itineraries of ancient explorers and soldiers. In the medieval age, dogmatic views left little room for questions on the evolution of the earth. The Arab Avicenna, however, was aware of uplift and slow erosion.

Only with the Renaissance, when the cosmic position of the earth became known and with this the timescale of a few millennia for creation was extended, was the way opened for the perception of the long-term slow processes of geomorphology and geology. The description of landforms still prevailed and it was only in the second half of the eighteenth century that investigations on the origin of landforms began. This period of description and speculation saw a debate between Neptunists (Abraham Werner 1750–1817), who thought the earth was shaped by running water, and Plutonists (Leopold von Buch 1774–1853), who believed tectonic movements controlled from the interior were the major causes.

In the nineteenth century, geomorphology evolved mainly from two roots. During geological exploration and surveys, strange sediments such as till in Central Europe or large gravel deposits in the western United States were discovered. The question of their origin led to the study of processes. Sediments were probed in areas where they were young and the results were transferred to ancient areas (known as “actualism” or “uniformitarianism”). The second root was the exploration of then little-known countries by earth scientists and their records of strange landforms and processes. Mainly it was research devoted to the special landscape investigated. Observation of phenomena was the basis. Explanations were derived from combining the occurrence of processes or deducing them from fresh sediments or erosional features. Eventually general rules developed. This might be called the period of inventory exploration.

As landscapes differ from country to country, or even inside large states, methods were manifold. It is hardly possible to attribute the start of systematic geomorphology or even of special fields to one person; rather, there was a more or less national development. Exchange began slowly, but two main streams may be distinguished: the American–British line and the European continent geomorphologists. However, from the late twentieth century, there has clearly been independent development in other countries.

2.2. Evolution of the Main Concepts

The first part of the twentieth century was dominated in the English-speaking world by W.M. Davis's model of landform development. This proposed an initial uplift, incision of narrow valleys, their broadening, and, as an end stage, a surface without marked relief—a peneplain. This brought different landforms into an evolutionary order, a cycle of erosion, a concept that has been given up partly because its rigidity left no room for detailed research. Some geomorphologists in the English-speaking world are still suspicious of investigations of landform evolution. However, the tide is turning, albeit on a different level. Though the only textbooks of Davis were published in German, they had little influence in continental Europe. This was also true for the *Morphologische Analyse* by the geologist Walter Penck, son of the geographer Albrecht Penck, who tried to deduce differentiated tectonic movements from landforms. Neither theory was much discussed on the continent, as there were known to be substantial contradictions in landform evolution. British geomorphology historians stated that: "Towards the end of the nineteenth century, German geomorphology was unique in the heavy concentration which was placed on the study of process." Before World War I, research on the continent broadened in range and, instead of a model, provided more plausible answers for the wealth of landforms. Processes were investigated directly or deduced from the analysis of landforms. The main methods were comparison of sequences with the same or with similar ones in other areas, especially in different climates under divergent conditions. Rock resistance and observed tectonic movements were incorporated.

After World War II, there was a revolution in the English-speaking world sparked by hydrologists. This led to a phase of measuring and modeling, followed by field experiments and theoretical considerations like dynamic equilibrium. More recently, the latter has become less important than case studies of rivers, beaches, and slopes, where detailed investigations of processes are often used for applied geomorphology. On the continent, climatic geomorphology was extended to climatogenetic geomorphology. The mutual relationship with paleoclimatic research became increasingly important. This brought about a close connection with soil science and hydrology. The study of the evolution of landforms developed into research on the history of landscapes, which led to a better understanding of many geoecological correlations. This was one reason for increasing interest in measurement of dynamic components in the landscape. Another might have been the influence of English-speaking colleagues, while a third was the wish to get absolute data on evolution. Another line, especially in Eastern countries, was mapping geomorphological and geoecological features, mainly as a basis for planning.

Still, terminology is quite often not compatible and is rarely unified. This is because of the different approaches and interpretations, and might ease with increasing international cooperation.

In recent years, there has been a rapprochement between the English-speaking and the continental branches of geomorphology as the applied aspects of geomorphological or geoecological research has become more important worldwide. The second reason is the increasing knowledge of absolute dates. Some dates are very old, so that evolutionary questions become more important. In general, differences should not be stressed because there always have been exceptions to the Davisian school as many geomorphologists studied processes in detail. On the other hand, numerical geomorphology has a tradition on the continent.

New aspects and methods are applied in all fields of geomorphological research. In general, there is a large range of laboratory analyses and dating methods. Global positioning systems (GPS) help in areas where small-scale maps are not available. Geographical information systems (GIS) give a better oversight of geoecological parameters in relation to landforms. Larger areas can be more easily connected to detailed field investigations.

2.3. Organizations and Journals

The exchange of ideas evolved only slowly and geomorphology took a long time to get internationally organized. Geomorphologists met at geographical or geological congresses, where they were heavily outnumbered. There were few sessions devoted to geomorphology. Contacts at first were mainly on a personal basis, as was the exchange between Davis and A. Penck for the whole winter term of 1908/09. Mortensen devoted a great deal of effort to getting an international board for the *Zeitschrift für Geomorphologie*, which he revived in 1957 after the national *Zeitschrift* had collapsed in 1938. From 1960 to 2002, there were 46 normal and 128 supplementary volumes. There was some international cooperation, however, which increased over the years in commissions on geomorphology in the International Geographical Union. The first was the commission on periglacial geomorphology (1949–1972) followed by periglacial phenomena (1980–1988), frost action environments (1988–1996), and climatic change and periglacial environments (1996–2000). Coastal geomorphology (1952–1972) became coastal environment (1976–1992), and finally coastal systems (1992–2000). The commission for the evolution of slopes (1952–1968) evolved to geomorphological processes (1968–1976), then field experiments (1976–1984), measurement, theory and application (1984–1992), and geomorphological response to environmental change (1992–2000). A commission on applied geomorphology was active from 1956 to 1968. Karst phenomena were a topic from 1956 to 1964, and there was a later study group on environmental changes in karst areas. The commission on geomorphological survey and mapping (1968–1980) became a working group (1980–1988). Other groups investigated the geomorphology of river and coastal plains, or morphotectonics. A study group was concerned with rapid geomorphological hazards (1988–1992), out of which evolved the commission on natural hazard studies (1992–2000). A new commission was started on land degradation and desertification (1996–2000). By the first years of the twenty-first century there were five commissions.

The first national organization was the British Geomorphological Research Group (BGRG), started in 1960, and the Deutsche Arbeitskreis für Geomorphologie had its first meeting in April 1974. In September 1979, there was a very successful British–German meeting at Würzburg, followed three years later by a visit of members of the German group to Scotland. The BGRG was very active in establishing international relations. In 1978, the second international geomorphological journal, *Earth Surface Processes*, was launched; it was later expanded to include landforms, in the title as well. There were several conferences with international participation as, for example, that on megageomorphology in London in 1981. The BGRG organized the first international congress on geomorphology in Manchester, which attracted 675 participants from 51 countries, confirming the demand for the exchange of ideas. The next congresses at four-yearly intervals, at Frankfurt, Hamilton, Bologna, and Tokyo had about the same number of participants. The International Association of Geomorphologists was formally founded at Frankfurt in 1989 in response to the formation of many national organizations. The 28th Binghamton Symposium was included at Bologna, the symposium being an American institution established in 1970 and usually consisting of two days of lectures, mainly by American colleagues from the State University of New York. Out of this grew the journal *Geomorphology* that started in 1988. More specialized journals begun since 1979 are *Studia Geomorphologica Carpatho-Balcanica* and *Transactions of the Japanese Geomorphological Union*. *Geoabstracts*, which originated as *Geomorphological Abstracts* in 1960, is extremely useful.

3. Main Concepts, Research Lines, and Methods

3.1. Klimatische Geomorphologie and Climatic Geomorphology

Geomorphological processes occur predominantly in loose material, in the regolith and its upper parts, the soil, whose properties are largely controlled by moisture and temperature. The movement of material is regulated by water and only in exceptional cases by wind. Gravity—altered by tectonic uplift—is a factor for the magnitude of transport, but even in this regard, water plays an important role, either directly or indirectly, via weathering in determining friction. The term coined for the complex interaction of the different forces was climatic geomorphology, a term widely misunderstood. The title of this section is intended to draw attention to the different conceptions in continental and English literature.

Of course, the influence of exogene forces has long been known and there have been many attempts to classify morphoclimatic zones or regions to relate climatic data to specified processes. Peltier's often repeated and sometimes enlarged diagram, like Davis's model, could not deal with details and had little influence on further research. Climatic geomorphology in the English literature still classifies regions and processes according to climatic zones. This was not an important issue on the continent.

A first systematic approach was the conference "Geomorphologie der Klimazonen" held at Düsseldorf in 1926. Each author compared observations of geomorphological processes from overseas with those at home. When Büdel proposed the System der klimatischen Geomorphologie in 1948 he summarized the forming processes then known and described what he called morphoclimatic zones. Three important steps resulted from this comparison: the relative significance of different processes for landscape shaping in a specified zone was delineated, the interaction of processes became clearer (*Formungsmechanismus* is the interaction and sum of forming processes), and a basis was found not only for the designation of single paleoforms but for their systematic derivation. The comparison was mainly done for landform assemblages, stressing the most important processes. It is possible to compare single processes in different climatic zones, but this has rarely been done. Perhaps this is because single processes are studied in detail, making it difficult to get an overview for a whole zone. Secondly, knowledge of rivers in the temperate zones, for instance, is much better than of those in the tropics.

Therefore, it has been said that climatic geomorphology is good for megageomorphology but does not help with the detailed investigation of processes. In the early 1950s it was shown that bloc fields in the Harz Mountains started by weathering in the Tertiary because the quarzite blocs have a thick red rind of hematite iron like that in paleosoils. This is missing on sharp indentations, which were due to frost splitting and where a small white rind developed in the Pleistocene. Transport of the blocs occurred in a solifluction layer during the cold ages, the removal of the entrenched fine material and thus the exposing of the blocs occurring in recent times. This example demonstrates that it is not possible to investigate even small features without seeking the history of an area, which in the case of the Harz Mountains is also indicated by relics of tertiary soils, etchplains, the glacial and periglacial forms nested into them, and the recent soil cover.

The search for paleoforms was well established in glacial geomorphology. At the beginning of the twentieth century A. Penck and Brückner made a model after many initial observations of the glaciation of the Alps and the foreland. They then searched systematically each valley for evidence of glaciation and in the foreland of the glacial series: the relation of end moraines, the fan in front, and the outwash plain or fluvioglacial terraces. This succession enabled them to bring order into the en echelon formation of these landform elements and thus establish four ice ages. Model and observation were constantly developed, checked and altered. After World War II, glacial and periglacial forms, recent and relic, were systematically sought overseas, and snowlines and periglacial limits were derived. This paleoclimatic research was the first step for many geomorphologists to look for relic features overseas. It was already known before the war that inselbergs and red loams had been formed in the Central Europe plains in a warm, humid climate in the Tertiary. The widespread cover of solifluction soils and loess is considered a relic of the cold periods of the Pleistocene.

The systematic discrimination of landform generations, the klimagenetische Geomorphologie, outside Central Europe was done first in 1955 in the central Sahara. Initially, recent processes and landforms were matched. Similar forms in other areas were sought for those that could not be explained, leading to the conclusion that they were formed under a climate like the one there. Only then was the paleoclimatic data sought that might have been derived from, for example, paleobotany. In the meantime, it is acknowledged that all climatic zones have relic features in landforms, usually also in the regolith. Therefore, a systematic approach to the evolution of the landforms is possible and necessary. Continental geomorphologists consider investigations as incomplete that do not discuss this. The scene where the processes of today are acting is rarely the scene they formed: for example, a riverbed in present-day Central Europe armored in stretches by periglacial cobbles and gravels. The investigations of landform generations have regional as well as general connotations as, for instance, a comparison of Central Australia with other desert areas might show. This is due to their different climatic and tectonic history.

The methods for klimatische and klimagenetische Geomorphologie are observation, comparison, evaluating sequences and interlocking or nesting of landforms, connections with recent and paleosoils, and correlative sediments. Wherever possible this is supported by absolute dating, laboratory and field analyses of soils and sediments. Klimatische Geomorphologie does not aim to link geomorphology with climatic data, either for landform assemblages or for single processes. While there was an intensive discussion about the importance of certain processes, the forming mechanisms, and controlling agents like discharge and mode of water movement, there has been almost no discussion about classification and limits of morphoclimatic zones, demonstrating that this has not been of foremost interest in continental geomorphology. It is much more than simply adding geomorphology to arid, humid, etc. regions.

Klimagenetische Geomorphologie is based on the results of klimatische Geomorphologie, and is thus equally founded on the analysis of processes. This is its fundamental difference from the classical denudation chronology. The research for landform generations may be called climatogenetic geomorphology. It should be distinguished from a “morphogenetic region,” which British geomorphologists define as “large areal units within which distinctive associations of geomorphic processes . . . are assumed to operate, tending towards a state of morphoclimatic equilibrium.” Such an areal unit would be called a klimamorphologische zone in German terminology. A morphogenetic region in German understanding has an individual character, as it comprises an area for which the processes of land forming in different climates, recent and in the past, and the tectonic history are the same. This is not only a difference in wording it is another approach. The concept of a morphoclimatic equilibrium is not real in nature as this would mean the elimination of all paleoforms.

Klimatische and klimagenetische Geomorphologie are at a stage where arguments will not afford much progress. Progress will be achieved, rather, by detailed investigations. Further advances may come from the analyses of soils and weathering crusts, increasing numbers of absolute data (including new dating methods). The connection with tectonic and palaeoclimatic research will be mutually beneficial. It is the great advantage of klimatische and klimagenetische Geomorphologie that they are open to change, they will accept additions, they have no preconceptions, and they work on all scales.

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Biographical Sketch

Hanna Bremer was born in Bremerhaven, Germany, on July 15, 1928. She undertook university studies in geography, geology, and physics at Universität Göttingen. Her dissertation *Flusserosion an der oberen Weser* was presented for her Dr. rer. nat Göttingen. In 1958 she was an assistant at Geographisches Institut der Universität, and this was followed by nine months fieldwork in Central and North Australia, then appointment as a research scholar at Deutsche Forschungsgemeinschaft, and assistant and lecturer at Geographisches Institut der Universität, Heidelberg (1963–1972). She carried out eight months of fieldwork in Nigeria, Amazonia, habilitation. 1966 Zur Geomorphologie von Zentralaustralien. 1972 Ordentlicher Professor und Direktor Geographisches Institut der Universität zu Köln; 1993 Emerita. Between 1973 and 1992 Dr. Bremer carried out 20 months of fieldwork in Amazonia, Mali, Kenya, India, Sri Lanka, and Australia. Editor: *Zeitschrift für Geomorphologie*. In 1993 she became an Honorary Fellow of the International Association of Geomorphologists; in 1994 an Honorary Corresponding Member of the Royal Geographical Society, London; in 1996 she was awarded the Gold Medal, City of Veszprém, Hungary; and in 2000 Ehrenmitglied der Ungarischen Geographischen Gesellschaft.

Her monographies include *Flüsse, Flächen- und Stufenbildung in den feuchten Tropen* (1971), *Reliefformen und reliefbildende Prozesse in Sri Lanka* (1981), *Allgemeine Geomorphologie* (1989), *Boden und Relief in den Tropen* (1995), and *Die Tropen* (1999), and she has authored 66 contributions to scientific journals.