APPLIED GEOMORPHOLOGY

A PERSPECTIVE OF THE CONTRIBUTION OF GEOMORPHOLOGY TO INTERDISCIPLINARY STUDIES AND ENVIRONMENTAL MANAGEMENT

Edited by:
JOHN R. HAILS

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PREFACE

Geomorphologists are now attempting to quantify earth surface processes in collaboration with researchers from other disciplines, and therefore it is probably an opportune moment to examine the practical value of geomorphology as a "scientific" discipline.

Unfortunately, there are still too many university and college courses in geomorphology which are out-dated and divorced from the problems of everyday life, and one can sympathize with those students who are beginning to question seriously the nature and purpose of the subject. However, this book is not intended to be the complete answer to this dilemma. On the contrary, it has been written in order to show undergraduates, and teachers alike, how the principles of geomorphology can be applied to interdisciplinary research programmes and practical situations pertaining to the landscape.

The contributors are recognized authorities in their respective fields of research and have had considerable experience as advisers and consultants. Consequently, they are qualified to discuss the role that applied geomorphology (principally involved with monitoring and predicting landform and process changes) can play in such areas, for example, as environmental and resource management.

In the Introduction I have mentioned briefly the importance of geomorphology in applied as opposed to basic research programmes, although it is often difficult to distinguish between these two types of study because most applied research is intricately linked to basic work. Therefore, it should be borne in mind, as one of the contributors succinctly states, that many aspects of applied geomorphology have stemmed from studies frequently conceived in a spirit of academic enquiry.

Chapter 1, besides presenting a comprehensive review of weathering processes, also examines the significance of weathering studies to economic geology, civil engineering, medicine, and the building industry. In Chapter 2, the means of controlling or minimizing soil salinity and rising water tables are discussed in relation to examples from Ethiopia, the U.S.A. and the Murray Basin, Australia, where major irrigation development has been concentrated.

In Chapter 3, a background to, and an explanation of, such practical problems as the leakage of surface reservoirs, waste disposal, scarcity and poor predictability of groundwater supplies, and local instability of the ground surface owing to changing hydrological conditions, is given by attempting to link research with a fundamental academic background to that of an applied nature. The thesis is also advanced that more detail is known of the nature, rate and loci of limestone solutional processes than of corresponding processes in other areas of geomorphology. Chapter 4 evaluates the application of geomorphology to hydrology, particularly with regard to the prediction of flood peaks and runoff, and sediment yield characteristics of a region for which no hydrologic data are available. Also, the role that geomorphologists can play in helping to draft flood plain legislation and in contributing towards land conservation and management is discussed.

Soil mechanics methods applied to the study of slopes are reviewed in Chapter 5. These methods are primarily concerned with the processes that lead to slope failure by landsliding and with the stability analysis of the failure. Geomorphological contributions to the regional appraisal of desert resources and the management of geomorphological problems in deserts are exemplified by several case studies in Chapter 6.

Emphasis is placed in Chapter 7 on the geomorphic effects of ground ice, ground ice degeneration (thermokarst) and fossil features of perennially frozen ground, and the associated problems of access and land development. This approach is considered important bearing in mind the progressive invasion of modern periglacial environments in the search for resources, and in view of the increased intensity of settlement and exploitation of the middle-latitude zone of Pleistocene periglacial activity. The philosophical and methodological background to terrain classification is examined in Chapter 8 as well as the various ways in which terrain studies have been undertaken.

Chapter 9 briefly reviews how applied geomorphology figures prominently in short- and long-term coastal-zone management programmes, interdisciplinary studies of the effects of seabed exploitation on shoreline equilibrium and coastal protection schemes.

Selected case studies have been included in each chapter in order to illustrate how environmental problems can arise from man's ignorance of natural processes, and how these problems can be averted or sometimes resolved by the results of applied geomorphological studies.

Metric units, in either the c.g.s. or SI systems, have been used in the text as far as possible, but because some of the contributors have referred to, or quoted from, published material citing Imperial units, it has been necessary in a few cases to retain these.

Some chapters have been revised in the light of comments by colleagues and technical staff who have spent considerable time reading the manuscripts. The contributors and the editor are extremely grateful to these people who include Dr. I. Basham (Institute of Geological Sciences, England), Dr. D. D. Gilbertson (University of Adelaide, Australia), Dr. A. S. Goudie (Oxford University, England), Dr. K. J. Gregory (University of Exeter, England), Dr. J. Hayward (Tussock Grasslands and Mountain Lands Institute, Lincoln College, New Zealand), Professor J. N. Jennings (Australian National University), Professor R. F. Peel (University of Bristol, England), Dr. G. Sills (Oxford University, England) and Ms. S. Smith.

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INTRODUCTION

APPLIED GEOMORPHOLOGY IN PERSPECTIVE

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In the immediate future, effective management of the environment will depend upon the results of co-ordinated feasibility studies, systematic monitoring to compensate for the lack and inadequate length of records, and interdisciplinary work. Such an approach will provide the necessary base-line scientific data on which long-term research programmes will be planned. A great deal of information is accumulating as the rate of data collection accelerates at all levels within the community. Whether this information is relevant or valid is a matter for conjecture, particularly when many agencies are working independently of each other and some research projects are inevitably being duplicated. At the same time, it can be argued that some duplication of research by independent parties is desirable in order to confirm results and to ensure that problems are researched objectively.

A distinct trend towards interdisciplinary research is seen in the new postgraduate courses in Environmental Studies, and also in government research laboratories, in consulting firms and in organizations set up specifically to implement environmental management programmes. As a result of this departure from well-established analytical disciplines and individually-orientated research, agricultural scientists, engineers, geologists, hydrologists, physicists and others are becoming increasingly aware of the importance of applied geomorphology. Paradoxically, though, some geomorphologists are still reticent about applying their expertise to the solution of practical problems and prefer to pursue their individual academic interests. Because sophisticated instrumentation and special skills are required these days in order to obtain reliable records and to make accurate predictions, the fact cannot be ignored that geomorphologists must become more involved with interdisciplinary research teams. It is only within the last decade or so that geomorphologists have made a concerted effort to apply their skills, and to show an interest in and awareness of environmental problems. Yet, as Cooke and Doornkamp (1974) point out in their introduction to "Geomorphology in Environmental Management", applied studies date back almost to the turn of this century, and into the 19th century in the case of Gilbert's pioneer work. It is interesting to note that the earlier contributions in applied studies by Glenn (1911), Sherlock (1922), Bryan (1925), and Jacks and Whyte (1939), as mentioned by Cooke and Doornkamp, do not appear in the chapter on applied geomorphology in Thornbury's "Principles of Geomorphology" (1954). In fact, these contributions appear to have been overlooked at a time when arguments prevailed about the evolution of landforms in arid and humid regions, and interest was centred on esoteric research. As Ollier mentions in Chapter 1 of this text: "What may be surprising to many geomorphologists is that although geomorphology plays an exceedingly small part in the education of engineers, builders, medical scientists, or even of many geologists, the practical men in applied science and technology have made so many valuable contributions to weathering studies." This view is also partly supported by various papers in the books on "Environmental Geomorphology and Landscape Conservation", edited by D. R. Coates, which have an applied geomorphological flavour although they have been written by specialists in other disciplines (see, for example, Bennett and Chapline, 1928; Eakin, 1936; and Black, 1950).

In view of the fact that it is more than twenty years since Thornbury devoted some attention to applied geomorphology, it seems opportune now to devote an entire book to the subject. As interdisciplinary research is becoming firmly established in universities and other tertiary institutions, the institutional barriers between disciplines are fast disappearing. Thus, there is a need to focus directly on the application of geomorphology, not only for undergraduates but also for researchers qualified in other disciplines. This book therefore attempts to bridge some of the gaps that have separated disciplines hitherto and to cover as comprehensively as possible those aspects of applied geomorphology that are directly related to environmental problems and decision-making processes.

In the short-term it is often difficult to forecast the complex environmental problems that may arise from man's interference with natural processes and to what extent his activities may change the environment altogether. There seems little doubt that geomorphologists will be asked to resolve problems created by technological innovation and engineering design in the future. At present, several hundred valleys are dammed annually in order to conserve water for irrigation and power production. The effects of constructing dams can be predicted fairly accurately provided sufficient time is available for monitoring rates of erosion, and the flow and sediment regimes of rivers. In this context the closure of the Aswan High Dam across the Nile River in 1964 is a good example to cite, because it has created conditions not entirely unlike those experienced in the Colorado River after the completion of the Hoover, Parker and Imperial Dams (see references in Hammad, 1972). The seemingly economic and social benefits, not to mention political kudos, at the time the dam was constructed outweighed the possible consequences of preventing the Nile floods from carrying large quantities of silt and nutrients downstream to the delta region, as in the past.

Now aggradation of the river bed upstream of the dam is encouraging the growth of water weed which, in turn, is impeding navigation and fishing, and accelerating evaporation by means of transpiration. The effect of degradation immediately below the dam is being detected in the change of sediment concentration at several stations along the downstream channel. Increased irrigation is also causing the spread of *bilharzia* or *schistosomiasis* ("snail disease"), a parasite infection which needs two hosts — man and a freshwater snail — the latter being present in large numbers throughout the year in irrigation canals. (See Fig. 9-1 for localities mentioned here.)

A second example of man's interference pertains to the reduction in sediment supply to parts of the Florida coast, which has indirectly caused beach erosion several kilometres south of the St. Johns River, following the construction of dams on coastal streams, and anti-erosion measures such as contour ploughing. The St. Johns River, which is fed by numerous small streams, rivers and springs, is one of the most important in Florida from the viewpoint of ecological values, recreation, industrial development, residential housing and commercial navigation (Scott, 1972). It is readily apparent, in the case of this example, that coastal zone management programmes must include measures to control water resources and to study fluvial processes in adjacent river catchments, but it is often difficult to convince some agronomists, planners and engineers that this broad perspective or overview of erosion and sedimentation is absolutely necessary.

A growing population, the sprawl of suburbia and the achievements of technology, not to mention deforestation and the defoliation programme waged by the Americans in Viet Nam, have combined to cause a variety of physical as well as social environmental problems. Case studies which refer specifically to the effects of urban growth and highway construction on sediment discharge are extremely well documented in scientific journals and in commissioned reports (see, for example, Keller, 1962; Wolman, 1967; Wolman and Schick, 1967; Leopold, 1968; Vice et al., 1969; Parizek, 1971; Gregory and Walling, 1973; Legget, 1973). In densely populated areas on the eastern seaboard of the U.S.A., rapid urbanization has already caused increased sediment discharge to estuaries (Wolman, 1967, Wolman and Schick, 1967).

In those regions where cities, like Adelaide in South Australia, are ideally located near scenic and recreational areas an increasing demand for land coupled with rising land values is causing conflicts between planners and conservationists. It is not unreasonable to say that planners invariably have their own ideas on what is worth protecting in the environment, and generally over-emphasize visual and aesthetic values without considering how development may drastically alter natural processes. Land developers, too, must be more responsible about subdividing flat alluvial valleys that are prone to flooding. Many flood plains considered by geomorphologists to be only marginally safe for homes and industrial premises have already been developed without consideration for such hazards as 50- or 100-year floods. Lee (1972) refers to some potential economic, sociological and political problems that must be overcome in order to implement flood hazard regulations. He stresses that: "successful flood plain management requires a uniform and co-ordinated program on behalf of government agencies, citizen groups and the engineering profession to reflect common goals, policies and methodology." Unfortunately, a lack of documented flood data is hindering management programmes. The major application of geomorphology to hydrology and related disciplines, then, lies in: (i) the use of forecast models, and the prediction of flood peaks, runoff and sediment yield characteristics of regions for which either insufficient or no hydrologic data are available; (ii) the need to assist land-management planners on the quantity of sediment that can be transported at different stages of the hydrological cycle; (iii) process studies in arid and semiarid regions where there is a high risk of erosion because of sporadic, but often intense, rainfall and runoff; (iv) advising on the drafting of flood-plain zoning laws (see Schumm, Chapter 4).

In order to assess the impact of human activities on the coastal zone there is an urgent need to prepare resource inventories and to record changing land use patterns. The role of the geomorphologists is to conduct preliminary landform analysis programmes, which include topographical, lithological and pedological details, in order to determine the type of systematic process studies that should be eventually undertaken. At present, landform unit studies are being conducted by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in coastal regions of Australia but mainly by soil scientists. In Queensland, for example, twelve landform units have been delineated along the coast between Coolangatta and Fraser Island where it is believed that there may be competition between housing and industrial development, forestry, grazing, sandmining and recreation in the near future (Thompson, 1975). In addition, a projected increase in population will promote further demands for water supply, drainage, sewage disposal and sanitary fill, as well as vegetable and horticultural production, but as yet little is known about the physical and chemical processes in this area and its diverse resources. In coastal areas without adequate facilities, water supply and waste disposal already present complex problems because a preponderance of septic tanks and poor land disposal cause soil and surface water pollution.

It is virtually impossible to predict accurately rates of coastal erosion and accretion, or to forecast the effects of man-made structures on shoreline equilibrium, unless beach processes have been monitored for some considerable time in order to analyse *extreme* rather than average conditions. Bearing in mind such events as the 50- or 100-year storm one realizes that this is often impracticable. Consequently, many researchers, including some geomorphologists, have resorted to theoretical studies of beach processes which have also involved laboratory wave tank investigation of sediment transport and sorting by oscillatory waves, but with only a limited number of field studies to verify the results of such work (Hails, 1974). An understanding of shore processes, then, is still at an elementary stage, and as Inman and Brush (1973) point out, it is only during the past eight years or so that experiment and measurement have progressed to the point where even general concepts can be formulated and tested. Also, there is the added problem that increasing public use of beaches is limiting, somewhat, the type of instruments that can be installed and left safely.

Increased leisure time and affluence are providing more people with an opportunity to visit regions of attractive scenery as well as the coast. Mountainous areas are frequented more now than in the past because of the growing popularity of skiing. Pressure on the modern periglacial environment is accentuated in those regions where the exploitation of natural resources, such as oil in Alaska, is posing major environmental problems. The ecological effects of recreation and public pressure on the Cairngorms in Scotland, and in the Victorian Alps, for example, have been investigated for a number of years but, as Derbyshire pertinently points out in Chapter 7, geomorphological and geotechnical mapping has only rarely been applied to Arctic and Alpine development and, more importantly, to management problems. The reader's attention is drawn to Black's (1950) excellent paper which reviews, from the viewpoint of a geologist, some of the problems facing the engineer in permafrost areas. Black stresses that a complete understanding is necessary of the extent, thickness, temperature and character of permafrost and its relation to its environment before buildings, highways, railroads, bridges, dams, reservoirs, sewage treatment plants and other facilities are constructed. Now, of course, because of the demand for natural but rapidly diminishing resources it is even more important for the geomorphologist to participate in interdisciplinary applied research projects in order to recognize and to predict the impact of man's activities on permafrost processes.

Irrigation in the Murray River Basin of Australia produces 12% of the New South Wales and 26% of the Victorian cash returns from agriculture at the present time. These facts suggest that the economic benefits derived from this method far outweigh its disadvantages. Yet Davidson (1974) has seriously questioned the economic wisdom of irrigation development in this river basin. Although no argument has been advanced to abandon the more successful and stable of the irrigation areas, there appears to be a strong case against using the Murray River for further irrigation development as urban and industrial demands for water increase. In fact, Myers (1974) mentions the possibility of reducing irrigation projects in difficult areas. Soil salinity and rising water tables are the classic problems arising from changes in the hydrological equilibrium as a result of irrigation. To some degree these are disabilities of scale (England, 1964). Hills (1969), for example, in his account of the history of the world's arid lands refers to the soil and river salinity of the Tigris, Euphrates, Indus, Rio Grande and Colorado. By world standards