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PLAY: THE HANDMAIDEN OF WORK

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ABSTRACT

The natural habitat of geomorphologists is at play in the fields of the Lord. Picnics, not the work ethic, often motivate the most productive. As in the field, so too in the mind, creative insights derive from the play of ideas. As in much of science today, Earth scientists are called upon to 'solve' immediate problems, but problems whose solutions lie at the cutting edge of the research frontier. The impact of anthropogenic activities in the context of natural processes, the playground where many geomorphologists work, requires continuous reciprocal exchange between research and application. Apologies are not needed for choices of orientation, but only for destructive separation.

KEY WORDS applied research; geomorphology; ideas; innovations; practical research; problemsolving; rivers

INTRODUCTION

The notion of 'work' is clear. It implies the useful application of time and information. Thus, the title of the symposium 'Geomorphology at Work' represented in this special issue, properly conveys the application of information from geomorphology to the concerns of society. The title also connotes several additional meanings. Work conjures up the highway sign 'men at work'. Similarly, work connotes the opposite of play. I have chosen to discuss geomorphology at play, not to contrast it with work, but rather to point out what is sometimes called play; the search for understanding and new meanings, as in research, is essential to what is more readily observed as work in the everyday world. I draw my text from two distinguished geologist/geomorphologists. Thus, when being asked to join the Faculty in Geography at The Johns Hopkins University, Charles B. Hunt remarked, 'You should understand, I have never done a day's work in my life, and I don't intend to start now.' The second observation comes from John T. Hack while eating a sandwich at lunchtime in the mountains above the Shenandoah Valley beside a beautiful stream on a beautiful day, 'that's what I like about geology, picnics!'

Those who know the contributions to geomorphology of each of these individuals will recognize in their statements the meaning of productive play in creating and verifying ideas and information essential to the application of geomorphology. They describe the joy of such 'work' and the inspiration derived from inquiry for its own sake. It is this orientation which I use here.

One can readily see the relationship between play and the topics covered in the symposium on geomorphology at work. Each of the papers represents a contribution to the better utilization and management of natural resources based on an understanding of the geomorphology of the system, including its form and processes. Thus, the several papers dealing with the behaviour and design of natural river channels reflect a level of understanding acquired over decades about the way in which rivers behave. Similarly, the proper location of highways and other public facilities has been made possible through careful reading of the landscape in which the active dynamics of present processes are manifested in the form of the landscape. Several studies of highway location and transportation facilities reflect this mode of inquiry. The study of the stability and dynamics of beaches, amongst the most dynamic environments in the natural scene,

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remains essential to an understanding of the ways in which human activities can be modified to adapt to the natural scene or the scene modified to fit the aspirations of human settlement. Thus, each of the papers reflects an underlying understanding of the history and dynamics of the landscape, the 'work' of geomorphology, whether in inquiry or in application.

The topic of geomorphology at play is divided here into four elements: pure play, some consequences of pure play, future play, and playmates. I draw upon examples from work of colleagues and myself on rivers in the initial sections simply because I know it best, while hoping that the illustrations drawn from this experience have some generality. While a great deal is known about the phenomena that I touch upon, for the most part, I emphasize unanswered questions, at the risk of some exaggeration.

PURE PLAY

The three illustrations of pure play in geomorphology include: first, the task of describing the bed of a river (cheaply and repeatedly) and relating this description to the resistance to flow in the river; second, characterizing channel patterns as seen in planform as straight, braided or meandering; and third, the question of why a channel is as big as it is, that is, how do floodplains form and what is the frequency of overbank flooding. Work on each of these issues was done in the spirit of pure play. Inquiry into each was unrelated to questions of applicability, but rather to the question of how things work in nature.

The bed sediments of alluvial rivers are characterized by a wide variety of materials ranging in size from clay to boulders. The study of river channels requires an understanding of the relationship between hydraulics and channel form. Hence, there exists the need to describe the bed in a hydraulically relevant way. Particle size is traditionally measured by sieving volumes of sediment scooped from the bed comparable to the sorting of gravel and sand in construction operations. Where the particles are large, however, a great volume of material is required to characterize the size distribution. Sampling such volumes usually requires major equipment such as backhoes, power shovels or drag lines. This equipment is not customarily available to the individual investigator, nor is the inevitable disturbance to the river environment likely to be looked upon favourably. What is needed is a cheap and simple method. Such a technique was suggested by the method used to measure the sizes of mineral grains on petrographic slides where sampling is done along one or more transects. By analogy, sampling could be done by measuring the size of pebbles sampled from a grid established on the bed or a bar of a stream channel. Experimentation suggested that in gravel-bedded streams, roughly 100 pebbles might give a reasonably good characterization of the size distribution of the particles which could be related to the resistance to flow (Wolman, 1954). This sample is a surface, not a volumetric, sample. The work done to establish this possible tool was hard work in the spirit of pure play, hard work from bending over and picking up thousands of pebbles. Lay people who observe the process doubt that this is work in the sense used to describe the applications in this special issue.

The work involved in attempting to develop measures which might characterize the conditions under which straight, braided and meandering channels are found in nature, consisted of field observations and measurement of a variety of river reaches in diverse natural rivers. Features such as width, depth, slope, discharge and gradient were measured in an attempt to classify the assemblage of features which might distinguish the conditions under which different patterns are found. The work was done in the field and data plotted each time new points were measured (Leopold and Wolman, 1957). This looks more like work, and it is (but picnics are still possible), and the driving force for the effort was to find out why these rivers look as they do, and not, to decide what we should do with them.

The third case, why is the channel as big as it is?, implies that the cross-section of a river channel is determined by a variety of forces in nature and represents some kind of adjustment to these forces. Since it is commonly recognized that the channels are often overtopped by flood flows, then presumably the channel is adjusted to lesser flows. Here again, observations were made in the field of the sizes of channels and heights of the floodplain and, in turn, these measurements were related to records of flow duration and frequency. In the course of the inquiry, a related question arose: why did it appear that in many instances the banks were just overtopped by relatively frequent flood events that occurred on the order of once every year or two? (Wolman and Leopold, 1957).

All three of these inquiries were driven by the attempt to determine why rivers look and behave as they do. Of course, the investigators hoped that results would be interesting, and bystanders in the field, often taxpayers, raised sceptical eyebrows at the thought of there being any practical use for the work.

CONSEQUENCES OF PURE PLAY

One consequence of pure play, of course, was a number of published papers. These, and the activities they have engendered, appear to have had diverse and often unforeseen consequences. While many subsequent activities cannot be attributed to these papers alone, contributions have come from many sources and I focus on a few for illustrative purposes.

The counting of pebbles has become the source of employment of many individuals ranging from fisheries biologists to geomorphologists and engineers. This is not, of course, their full-time employment, but it has turned out that pebble counting as a method of describing the bed of gravel-bed rivers, in particular, has been useful in characterizing habitats as well as in attempting to characterize the hydraulic roughness of stream boundaries. (Indeed, I understand a competition for pebble counting was devised at a meeting for geomorphologists in which a prize was given to that individual whose pebble count came closest to the average value. I am told the individual who put on the contest happened to win the prize.) So the pebble counting technique, designed to describe the roughness at the bottom, has turned out to be of some use in characterizing ecological habitats (Newbury and Gaboury, 1993) as well as a rough measure of resistance. It has also been misused in attempts to characterize the materials available for sediment transport and in computation of rates of sediment transport. A pebble count describes a sediment surface not a sediment volume. It can only provide a useful measure for transport computations if suitable conversion coefficients are known. Pebble counting has proved to be useful at work in ways clearly not contemplated during the period of play.

The field measurements of river planform suggested a simple relationship between river gradient and discharge based on the empirical data. For a given bankfull discharge, straight, meandering and braided rivers appeared to occur at successively higher slopes, with the line separating meandering from braiding reaches given by the equation:

$$S = 0{\cdot}06Q^{0{\cdot}44}$$

The suggested relationship between river gradient and discharge, while not original to Leopold and Wolman (1957), has received much subsequent attention.

Like the broad descriptive characterizations of hydraulic geometry, this particular relationship contained what might be described as some partial 'earth truths'. The notion that both the cross-section of a stream and its planform could be characterized by a limited number of measured variables, and that the relationships so discerned represented a kind of equilibrium condition in nature, is gradually being transformed into a new field of 'ecological engineering'. The work noted here is part only of a vast accumulation of data on the look of presumed stable river forms. It is interesting to note that relationship between river gradient and discharge has been shown to fit a number of empirical observations, but the boundaries between the patterns are not fixed by immutable hydraulic principles dependent solely or primarily on discharge and gradient (Carson, 1984). Indeed, the principles of ecological engineering related to natural river channels are evolving and designs are by no means fixed. Generalizations from empirical observations represent apparent tendencies of adjustment of river reaches of certain kinds over varying periods of time. Many seem most applicable to streams in humid regions with relatively cohesive banks and become more uncertain under more variable climatic and hydrologic regimes, where channels are composed of sandier bank and bed materials. Here again, initial observations focused upon understanding the behaviour of the natural river: 'play' in the eyes of some beholders. The results seem to have proved to be potentially useful at work in unforeseen ways.

Observations of floodplains and of the frequency of bankfull discharge and overbank flooding have also led in unexpected directions with unexpected consequences. Based on the observation that urban and suburban landscapes significantly alter the hydrologic regime of streams, planners and engineers have attempted to develop design criteria for runoff and sediment storage to control peak urban runoff. In many places, an attempt is made to assure that peak flows following development resemble those occurring prior to development (Schueler, 1987). Elsewhere, design criteria call for control of urban runoff such that the flood with a return period of two years would just fill the channel to the bankfull stage. The two-year flood in a number of instances, as noted earlier, roughly coincides with the return period and magnitude of the bankfull discharge, but the relationship is also highly variable in many regions (Williams, 1978). Even where applicable, however, geomorphologists recognize that this 'channel-forming discharge' is a surrogate for a range of flows that mould or modify the natural channel. The channel is not 'adjusted' to a single discharge but rather to a range of flows, which both erode the boundaries and deposit sediment to maintain an average channel cross-section over a period of years. Thus, the results of play which produced evidence of a reasonably consistent relationship between the two-year flood and the bankfull stage in many places were transformed into a design criterion independent of the known complexity of the formative processes in nature.

Current legal issues surrounding the flows required for 'channel maintenance' in streams in the Rocky Mountain region of the United States provide another illustration of the relationship between bankfull discharges and a problem of practical interest to society. At issue is the definition of effective flows needed to maintain a natural channel. Their definition is important as such flows would represent the quantity of water to be legally appropriated in concert with specific congressional legislation creating Federal forests or other national lands. Effective discharges are those capable of altering or forming the channel itself and thus altering or sustaining the habitats within the channel. Geomorphologists at play (doing research) have suggested that an effective discharge can be defined as the range of flows which transport the largest quantity of sediment over a period of time and the flow effective in forming the channel boundary (Wolman and Miller, 1960). The two may sometimes be closely related and the effective discharge may fall close to the bankfull discharge on a number of rivers (Andrews, 1984). The uncertainty in these relationships, however, is suggested by a judge's decision in a recent case in the United States:

> 'The parties disagree as to the nature of the streams in the national forests. The applicant contends that the streams are adjustable in nature and that their channels are formed by fluvial processes which were explained in a complete and scholarly manner. These channels, they contend, are controlled by bankfull discharges—essentially the same as "channel forming" discharges—which occur at fairly frequent intervals.'
>
> 'The objectors, on the other hand, contend that those streams flow in channels cut in materials which are large in size and are not easily moved. Even by the sort of flows contemplated by the applications herein. They emphasize that the circumstances are ones which inhibit normal fluvial processes.' (District Court, 1993)

Apparently, solution of the problem requires more play—some would now contend, directed play.

One might summarize the consequences of pure play in two parts. First, someone may actually use the results from play. Moreover, it is quite likely that the ways in which these results are used will not conform to the qualifications or observations made by those who produced the original results. Second, what is equally evident is that play, and the uses to which it is put, generate more play. In other terms, to the consternation of many lay people, scientific inquiry, while providing solutions or answers to some immediate questions, continues to reveal new and unknown questions. This is not a universal constraint to action, merely a reflection of the complexity of nature.

FUTURE PLAY

Consideration of river forms and patterns noted here can be joined with observations made in a number of the papers in this special issue to illustrate the broad, general phrase 'global change'. Global change in its broadest sense implies changes associated with both global dynamics, such as climate change, and the cumulative changes in space and time of human activities dispersed over virtually all parts of the globe. A major interest of many societies throughout the world is the impact of these changes on the landscape itself and, in turn, on the way that such changes affect the habitat and biota in a region. These broad issues of landscape change are ones which geomorphologists are rightly expected to address. They are one important focus of future play, the results of which will have consequences for the way in which the landscape is understood, modified and used. Global change clearly includes 'the playing fields of the geomorphologist'.

The potential contributions of geomorphologists fall into a number of important areas: recognition of the complex interrelationships of climate, vegetation and landscape, the connectivity of uplands and channels, the sensitivity of many landscapes to small perturbations in climate and perhaps land-use, and the importance of history in understanding landscape and landscape processes. The study of landscape processes is, of course, inseparable from the study of history. The findings are directly related to policy. This was nicely illustrated by the work of Kirk Bryan and his students in the southwestern United States (Bryan, 1940). Bryan and others demonstrated that erosion of gullies in the southwestern United States was not a phenomenon exclusively associated with late 19th century settlement and overgrazing but instead was manifest in repeated cutting and filling of dry washes that had occurred over a long period of time. Recognizing this, during a major dinner address to soil conservationists, Bryan remarked that, 'one might as well hang dollar bills on pinyon trees as build check dams to control runoff from dry washes throughout the southwest'. (The original source of this quotation is unknown to the author, but the same statement has been independently repeated by many different individuals.) The observation was not well received but prescient.

Classic geomorphological studies illustrating the diverse response of landscapes in different regions to changes in climate and to human activities are plentiful, including studies of the cutting and filling of arroyos (noted above) driven by climatic events, by random threshold phenomena, or by both. Desertification as a manifestation of natural phenomena augmented by human activities requires fundamental understanding of geomorphological processes. Similarly, detailed studies of increases or decreases in sediment yield and their impact on the cutting and filling of channel systems and on water quality demand attention, particularly under the new guise of non-point sources of pollution. It is becoming increasingly important that we attempt to derive quantitative measures of the magnitudes of change to be expected from changes in climate or human activities. Moreover, the relation of physical processes in stream channels, in lakes and in coastal regions to terrestrial, aquatic and riparian habitat and biota is of pressing importance. This importance is recognizable in the recent revision of forest management practices in the northwestern United States, which are based on ecological concepts that include the behaviour of sediment and water derived differentially from landscapes that are logged and those that are not. As noted earlier, the emerging field of ecological engineering, based essentially on the notion of design with nature (McHarg, 1969), also illustrates the application of fundamental research in geomorphology to important, emerging problems in society.

PLAYMATES

Both the scientific and social issues confronting us require new styles of inquiry. These involve new players and a variety of scales of study. From the standpoint of the natural sciences alone, complex issues such as global change require some new ways of inquiry. A new style which is currently popular is sometimes called 'Big Science'. By Big Science one may simply mean the collaboration of a variety of individuals from diverse disciplines, even within the natural sciences. Such collaboration may be needed even in intensive studies of landscape processes and their geographical extension and synthesis. The study of sediment transport and river patterns is one such area (Ikeda and Parker, 1989). Traditionally, many studies have been small and lack of funds has militated against adequate field and laboratory investigations needed fully to understand complex processes. Similar collaborative effort in the study of the magnitude and frequency of large floods in canyon reaches and the information that these might reveal about the largest possible floods in many regions is reflected in the worldwide work of Baker *et al.* (1985) and Patton (1987).

At an even larger scale, modelling of terrestrial processes in relation to global climates has become essential to understanding geomorphological and ecological processes and their relation to human activities. In approaching such issues, the traditional emphasis has been on physical, not social, processes. The way in which society is organized, the results of such organization on the behaviour of individuals and the society at large and the way in which social processes are manifest in the landscape have usually been studied quite separately from landscape processes themselves. A number of geographical studies are exceptions to this generalization, not the rule. To be effective in demonstrating the way in which the study of the natural landscape relates to human activities requires that the natural sciences join with the social sciences and humanities in investigating these issues. This is an even more difficult task than collaboration among scientists from a variety of natural science disciplines.

Perhaps the major issue confronting global society is the relationship between population, environment, development and sustainability, the global issue that emerged from the Rio de Janeiro conference on environment and development. Setting aside problems of semantics in defining sustainability and its relationship to development, resolution of many difficult questions about the interrelationships among these elements is important in setting priorities between policy choices. One fundamental question often posed is, are there 'first' causes or driving forces that can be discerned in the way in which population, environment and sustainability interrelate, and if so, what are they? (Jolly and Torrey, 1993). While apparently new to many, these questions sound a familiar geographical 'man and nature' theme. How exactly does population change transform landscape and environment, and vice versa? What are the mediating social processes? Are such transformations measurable in the environment, are perceptions of change congruent with measured physical changes? Geographers/geomorphologists have an important role to play in this analysis, a role derived from a long tradition which is hardly known to new colonizers in this vital and burgeoning area of public interest.

It has become a cliché that natural scientists should work with social scientists and humanists in studying the issues related to land and human activities. Pursuing the theme of play, I think it is important to note that such cooperation in study and analysis cannot be simply the 'parallel play' that child psychologists describe. Much closer cooperation is required. Two illustrations may be useful. First, in approaching the problem of sustainability it has been suggested that it is important, particularly in the developing nations, that natural assets or natural capital be valued in national statistical accounting systems. To do so requires close cooperation between economists and natural scientists in assuring that there are first, measures of such natural assets and second, that these meet tests of relevance and appropriateness to economic and social accounting. It is easy to state that soil erosion, vegetation or terrestrial biota be 'valued'. The first step in such valuation, however, requires measurement of the features themselves and establishment of the ability to repeat these measurements. Such measures of physical and biological features and processes are not easy. Moreover, the way in which the measurements are made, for example whether one measures the number of trees or the volume of wood, affects the outcome of the valuation as well as the policy which one might use in protecting the resource (National Research Council, 1994). A second illustration of the need for close collaboration is in the field of population change and land-use. To understand fully the impact of one upon the other, concurrent measurements must be made of changes in land-use and in demography. Rarely have such concurrent observations been made (Mortimore, 1993), yet knowing their concomitant interactions is essential both to understanding the processes involved and to the framing of sensible social policies.

SOME CONCLUSIONS

The notion of research—the search for understanding—is not universally popular today. This is particularly true of research driven by what is sometimes termed the quest for knowledge unfettered by questions of immediate, or even distant, practical use.

In the United States, relevance has become a current issue of major importance. Questions are repeatedly being asked about the relevance of scientific inquiries of various kinds to social objectives. Objectives often cited are economic competitiveness, environmental protection and economic growth. Questions related to such objectives do not sound much like play. Indeed, testifying before legislative committees one would be wise not to refer to play at all. One must attempt to demonstrate the relationship between the research objective and these broad objectives of society. This is proper and reasonable. Society supports the research enterprise in one form or another. Scepticism about research is reflected in former Senator Proxmire's Golden Fleece Award, which cynically ridiculed the titles of some scientific studies and, thereby, science. No doubt some research deserves ridicule, but disparagement had more far-reaching effects. A cartoon perhaps better expresses public scepticism about research as play. In the cartoon a political figure is leaning over the shoulder of a white-coated investigator in a new laboratory. The politician asks, 'Are you doing basic research or do you have something in mind?'.

It makes little difference if an inquiry is called basic, or play, or is applied to a practical problem, so long as the imagination is 'applied'. John Stewart Mill, in the opening paragraph of his '*Principles of Political Economy*' (Mill, 1848) makes a case for practice:

> 'In every department of human affairs, Practice long precedes science, systematic enquiry into the modes of action of the powers of nature is the tardy product of a long course of efforts to use those powers for practical ends'.

At the same time, it is widely recognized that emphasis solely on application does not necessarily generate new knowledge, which is needed to answer new problems as these arise. As Mill implies, this does not mean that new knowledge is not or cannot be generated while seeking answers to very practical questions. Rather, the playground for such inquiry must be broad enough to allow pursuit of new directions, directions often unforeseen in the original formulation of the problem.

Geomorphologists deal with complicated systems which are difficult to understand. As the papers in this special issue indicate, even in the absence of full understanding many findings in geomorphology can be applied with great value to society. At the same time, the 'practical' questions being posed to geomorphologists, ranging from the impact of climate change on landscape evolution to the effect of urbanization on river channels, often press for answers at the cutting edge of the science. Geomorphology is, by necessity, an interdisciplinary activity. But because the most difficult questions lie at the interface of science and society, much closer ties to the study of social processes are demanded—a difficult task. Some compensation for this added difficulty may lie in the appearance that study of the socially relevant is more likely to be seen as work. It is probably still true, however, that such work too may fail in the absence of play.

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