

PROGLACIAL AND PARAGLACIAL FLUVIAL AND LACUSTRINE ENVIRONMENTS IN TRANSITION

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ABSTRACT

Geomorphology has two interlocking paradigms; the first is a process paradigm where there is a hierarchy of knowledge through the physics of a medium, the mechanics of process, to the landscape form; the second is a temporal paradigm from the history of the landscape, to the present condition, and with a prediction capacity. These are central to concepts of landscape transitions and landform assemblages. The paper explores landscape transitions occurring in proglacial and paraglacial environments based on the horizontal link of sediment transfer rather than on the traditional vertical division into glaciology, hydrology and periglacial geomorphology. In glacierized mountain areas the superimposition of transitions at different scales can readily be demonstrated within the regional landscape. Transitions may occur slowly, rapidly or instantaneously but their frequency of change will vary depending on the underlying cause of the transition. The concept of landform assemblages should integrate the ideas of process activity at different spatial, quantitative and temporal scales. Landform assemblages are therefore infinitely variable. The ways in which the concepts of transition and landform assemblages influence geomorphological interpretation is illustrated by reference to the glacierized environments of the southwest Yukon.

1. Introduction

Traditionally the science of geomorphology has been organised according to specific environments such as glacial, fluvial, periglacial, and coastal, which can be thought of as a vertical subdivision of the discipline. A survey of the bookshelves indicates that virtually all introductory textbooks are organised this way and many advanced level texts are similarly aligned. Sediment transfer, as one basic process concept of geomorphology, provides a horizontal link uniting the vertical components of the science. Geomorphology can, in fact, be defined by sediment transfer from bedrock to geosyncline and the temporary landscapes which are produced during this transfer. One result of the vertical division has

been that some domains often receive very little consideration despite their importance in the landscape. The whole of the earth's surface is made up of slopes, yet there is often no strong focus on slope processes. Lacustrine environments often receive even less attention than slopes despite the fact that they are integral parts of the fluvial environment. Indeed, in some countries such as Canada, lakes are very critical components of the landscape and the hydrological cycle.

Sediment transfer can be conceptualised within the framework of the hydrological cycle in which both the presence and absence of water are important and the various phases of water (vapour, liquid and solid) are critical elements. In high latitude and high altitude environments ice plays a major geomorphic role. This is not only in glacial and periglacial environments but also in fluvial, lacustrine and oceanic environments. In traditional vertical approaches to geomorphology this century, glaciation has received considerable attention and periglacial/permafrost has received prominence in the last 30 to 40 years. In-depth treatment of ice on rivers, lakes, and oceans is however still lacking in most standard physical geography and physical geology texts.

The landform assemblages produced by erosion, transport and deposition represent different periods of evolution characterised by changes or variations in the movement and storage of sediment. Some storage forms may last only for a few minutes or hours while others may persist for centuries or millennia. Landscapes are essentially, however, always in transition and this can be demonstrated at a continuum of process scales varying both spatially and temporally. Meso-scale landform assemblages such as drumlin fields may be relatively stable at a meso-time scale, but are still subject to micro-scale processes. Transitions may be considerably slower but they are still taking place. Micro-scale processes operating over short time frames at the termini of glaciers are superimposed on the macro-scale processes such as periods of glacier advance and retreat. Landform assemblages associated with stages of evolution of a landscape can also be classified on different spatial scales and may be in transition at different temporal rates.

1.1. PREDICTION AND PARADIGMS

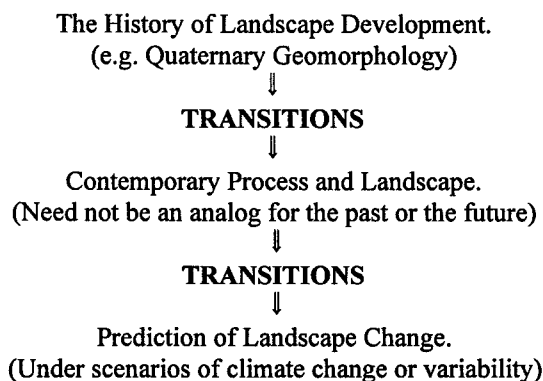
The need for prediction is implicit in the concept of landscapes, or landform assemblages, in transition. Prediction of landscape change is becoming more critical as various scenarios of climate change or climate variability are evaluated. Questions such as what changes might occur due to $2 \times \text{CO}_2$ in areas with massive ground ice accumulations in high latitudes, what will be the hydrological response to changes in snowfall patterns as a result of global warming, and what will be the impact on landform forming processes such as debris flow and landslides, have become political as well as scientific questions. *El Niño* has become the popular explanation for climate variability and recent extremes, but is *El Niño* related to global warming and what are the potential effects of changes in its frequency and magnitude? As an example much discussion has centred recently, even in the popular press, on the increased number of hurricanes and their geomorphic effect, particularly in Central America, which has occurred during a strong *El Niño* year.

I have emphasised in teaching for a number of years that geomorphology has two interlocking paradigms. The first is a process paradigm where there is a hierarchy of knowledge required:

Physics of Medium $\Rightarrow$ Mechanics of Process $\Rightarrow$ Form of Landscape

It is essential to have a comprehension of materials and mechanics before one can attempt to interpret landforms. Inference from form is not acceptable and landform, or landform assemblage, production must be demonstrated to be physically possible. A coastal geomorphologist has to understand wave theory and a glacial geomorphologist has to understand the physics and chemistry of ice in order to understand the evolution of the landscape.

An excellent example of the problems that have been caused by interpretation based on form is presented elsewhere in this volume with respect to the interpretation of diamicts in the valleys of the Karakoram and the Himalaya. Diamicts form a large number of cross valley ridges in the Karakoram. These landforms, long interpreted as moraines on the basis of their cross-valley ridge form, are now being interpreted as landslide deposits. This change in interpretation has occurred due to an understanding of the physics and mechanics of mass movements and more rigorous field investigation. It will necessitate a fundamental change in the interpretation of the landscape of a major mountainous region. The second paradigm is temporal:



This does not imply that every geomorphologist has to be concerned with all three components but it emphasises that there must be a predictive capability within the discipline, and there must be a capability to understand transitions, which develops from a comprehension of past and present environments solidly based on the first paradigm. Slaymaker and Spencer (1998) have developed this argument in their discussion on refocusing physical geography.

The next sections of this paper explore transitions occurring in proglacial and paraglacial environments using field examples drawn principally from the region of the St. Elias Mountains and its boundary ranges in the southwest of the Yukon Territory. The

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