

INTRODUCTION: LANDSCAPE ASSEMBLAGES AND TRANSITIONS IN COLD REGIONS

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Abstract

This essay introduces the varieties and distinctive characteristics of cold regions. A landscape approach is adopted, emphasising associations of land forms and sediments and the importance of spatial and temporal transitions in earth surface processes. The broadest classes of cold region are the “zonal” or higher latitude examples, and the “azonal” ones based on elevation, continentality and air mass regimes. Vast and singular subregions are also characterised by cold tolerant ecosystems such as heathlands and bogs, boreal or montane forests. These play a major role in landform development and appearance in their respective zones.

Work relating to earth surface processes tends to separate glacierised (i.e., ice-covered) and non-glacierised areas, in the latter, periglacial and nival regimes, and cold coastal conditions. Cold regions geomorphology, in recent decades, has focused on processes peculiar to low temperatures and freeze-thaw. Much of our understanding has developed out of specialised investigations and experimental work on distinctive processes of these regimes, and the search for more abstract, general models of them. But a regional and comparative perspective must also recognise the large role played by weathering, fluvial, lacustrine, marine or aeolian processes shared with other regions if modified in cold contexts. A landscape and comparative interest directs attention to the variety of landform associations and related sediment assemblages, and how they represent the complexities of on-going and historical development.

Most cold regions landscapes record past and on-going environmental change. They contain more or less extensive legacies of clima-hydrological, ecological and geotectonic changes in the Quaternary. They involve glaciation and deglaciation, isostatic crustal adjustments, fluctuations in sea levels and in the extent of marine and freshwater ice, changes in snow covers, seasonal ground ice, and the patterns and thickness of permafrost. These legacies, and how they are removed or transformed, are integral to the

interpretation of existing cold region landscapes. What we observe are geomorphic "palimpsests" in which relict, overlapping and replacement forms are interwoven.

The notion of "transition" addresses the sense in which landscape development is not merely chronological and linear, or simply a "lagged" response to climatic and tectonic changes. There are diachronous episodes of (incomplete) readjustment to the cessation of past conditions, and towards later conditions, of which those at present are only one set. There are distinctive spatial and temporal patterns of adjustment, including "self-adjustment" specific to the earth surface processes at work. The paraglacial is a classic example. It is suggested that such temporal and spatial responses in earth surface processes apply much more generally as part of landscape transformation in the Quaternary.

Introduction

"Cold regions" are those areas of the Earth's surface where sub-zero temperatures, snow and ice, freezing and thawing, and freeze-tolerant organisms, are perennially or seasonally present. The emphasis here is on landscapes that are formed or constrained by cold conditions. In particular, we look at landform morphology, earth surface processes and sediments reflecting the presence of frost, ice and melt water, and the influence upon landscape of cold-adapted plants and animals. The main concerns of the volume are landform and sediment assemblages in cold regions, and how they depend upon transitions over time and space in the processes generating them. First, however, a brief overview of cold regions will situate these concerns within the larger context.

Relative abundance of water is a decisive fact of planet Earth's physical environment. However, at least as important for geomorphic and life processes, are temperature and pressure conditions close to, and continually fluctuating across, phase change parameters for water. (On other planets where water exists, but locked up in a liquefied atmosphere, perennially frozen oceans, or permafrost at depth, life forms are not known or clearly present. The "land forms" depend largely or wholly on the impacts and accumulation of debris from space, sometimes on internal tectonic forces.)

Solar radiation and Earth's gaseous atmosphere promote continuous cycles of evaporation, condensation and precipitation of liquid moisture. These dominate the presence and influence of moisture at the Earth's surface. They are second only to solar radiation in controlling thermal environments.

However, extensive land and ocean surfaces are also frozen, or have temperatures that regularly cross the freeze-thaw threshold. Here, the temperature relations of moisture availability, its phase and behavior, introduce distinctive physical, chemical and biotic processes. Along with a mobile crust, such cold-related conditions make for diverse and, often, exceptionally dynamic climageomorphic environments. Moreover, cold environments have expanded and contracted enormously over the past 30,000 years or so. This has left the imprint of cold conditions on large areas no longer cold, and brought more or less drastic changes in those that are.

The Scope and Variety of Cold Regions

Four primary geographical regions with cold conditions can be identified. They relate to latitude, altitude, continentality, and air mass regimes. High latitude, or polar, sub-polar and cool temperate regions, are sometimes referred to as “zonal”, a direct consequence of (low) solar altitude and cold winters. The other three influences are “azonal”. They overlap with and can intensify or moderate the latitudinal effect. In particular, however, they bring sub-zero temperatures or frozen precipitation to areas closer to the Equator, otherwise identified with mild, temperate, and even hot, tropical conditions. They involve, respectively, intensification of perennial or seasonal cold and snowfall by elevation or the orographic effect; radiative cooling of land surfaces in winter, unmoderated by inflows of milder air; or air masses that bring heavy winter snow and cool, cloudy summers.

Broad, secondary divisions arise within cold regions due to the intensity and duration of cold conditions and moisture regimes, and among cold high plateaux or mountain lands as a function of latitude, air mass regime and ruggedness of terrain. Equally important regional landscapes are associated with major vegetation types such as peatlands, boreal or montane forest types, or cold mires (Specht 1979; Gore 1983). These characterise and influence the development and morphology of vast areas. Plants and animals affect the forms and variety of cold regions through their influence on patterns and processes of hydrology and sedimentation, through surface and soil processes, and organic build-ups (see Walker, this publication). We should also mention the constructional land forms and related regulation of hydrology by vegetation; the importance of vegetation in stabilising mountain slopes and unconsolidated sediments; and of fire ecology in certain cold forest, heath and peat environments. Organisms in cold lakes, rivers, deltas, or coastal waters, exercise a huge influence on patterns and rates of erosion and sedimentation (see Dale *et al*, this publication).

High latitude cold oceans are seasonally or perennially ice-covered. Freshwater lakes and rivers in cold regions are seasonally frozen. The floating ice promotes and constrains geomorphic and ecological processes along coasts and river valleys. This applies when the ice is in place, during its break-up and melting. The configuration of the continents means that perhaps one third of the world's marine coastlines are affected by floating ice (see Byrne and Dionne, this publication). In the vast subarctic regions of Eurasia and North America are river systems where seasonal freezing, break-up, vast ice jams and inundations, exert a huge influence on land forms, sediment delivery and ecology.

Among the many local and regional subdivisions, zones of transition or ecotones, have received much attention. They often reflect sharp transitions in key climageomorphic processes and habitats, and some are visually as well as functionally well-defined. Examples include snow lines and timber lines. In the mid latitude and tropical high mountain ecotones between zones of increasingly intensive cold conditions – but moderated by influence of moisture deficit or excess – are stacked, one above the other, in altitudinally organised climageomorphic zones (Kowalkowski and Starkel 1984; Hewitt 1993; Sarmiento 2000). Cold coasts involve series of ecotones surrounding and beneath the water. The latter reflect water depth, exposure to waves and currents, modified by a

variety of attendant processes according to the presence, duration and behavior of floating or fast ice.

At present, about half the world's land surfaces have seasonal snowfall as a significant climatic, hydrological and physiological factor. About one quarter have frozen ground too extensive for weak or short warm seasons to fully melt it, although the snow cover may melt. Here frost, ground ice or permafrost are decisive for geomorphic processes and identified as periglacial regimes. Snowy conditions without significant ground freezing extend nival effects into milder areas. Conversely, where snow persists and builds up from year to year, glaciers cover the land. The Antarctic ice sheet dominates total world glacier ice, and covers about 12 million km² (Williams and Ferrigno 1998). The present glacier cover of the Northern Hemisphere is about 2.3 million km², of which the Greenland Ice Sheet comprises almost 75% (Field 1975, 3).

Glacial and nival melt waters, wind and wave action, are also profoundly important, although their influence is not confined to cold regions. Mountain glaciers, especially those outside polar and subpolar regions, comprise a small fraction of today's ice. However, the mid- and low latitude glaciers, and the movement of glacial meltwaters and sediments from them to surrounding foothills and lowlands, have a significance out of all proportion to their share of the global ice cover. That applies to both landscape development and human affairs. Indeed, the water, sediment and dust carried into surrounding "warm" regions and the world ocean are major, indirect cold region influences on landscapes and sedimentation. This includes the loess that covers vast areas and has come mainly from past or present cold regions. Some of the largest submarine cones of sediment have been built of materials from the larger, present-day or formerly glaciated mountain ranges.

We will concentrate on conditions in, and as they affect, present day cold regions. But, it is not implied that exchanges between them and other environments are less important.

Regional Landscapes and Landform Associations

Most of the chapters which follow adopt a view, as it were, from the landscape, and in terms of landscape-forming processes. The influence of broader atmospheric and geological changes are considered as they inform that perspective. It is accepted that the various styles of cold environment and forms of ice, freeze-thaw and melt waters, are associated with distinctive climageomorphic regimes. Along with ice-infested waters and cold-adapted ecosystems, they help to create distinctive landscapes.

In recent decades the emphasis in cold regions geomorphology has been on conditions special to them, and process-defined subregions. Geomorphologists differentiate mainly between glacial, periglacial including permafrost, nival and cold desert regimes, and concentrate their efforts on their distinctive processes and forms. A great deal of work has examined singular features of periglacial, glacial and nival conditions – palsas or pingoes, drumlins and eskers, cirques or avalanche boulder tongues – and how they record specific processes (Clark 1988; Williams and Smith 1989; Hambrey 1984; Fitzgerald and Rosen 1987; French 19). This has certainly served to

inform and even to revolutionise our understanding of the activity behind observed landforms.

However, the goal of describing, interpreting and comparing regional landscapes requires a more holistic approach. In geographical thought, the regional approach is classically distinguished from a "systematic" one. The difficulty is to incorporate understandings obtained by each approach into the other, given that we reject the view that one of them is superior, or can be reduced, to the other. Since the systematic approach has dominated geomorphology over recent decades, some of the salient problems at present are those of revising the regional approach with the aid of new insights developed in process geomorphology, sedimentology and cognate earth science fields.

Regional or "chorological" concerns involve the distribution, the interactions and mutual constraints among, the features and varieties of processes in any given landscape. This is usually combined with a comparative assessment of the differing and common features in different landscapes, or their changing balance as we move across the earth's surface. Such an approach is developed in the overview of cold coastal landforms by Byrne and Dionne, (this publication). In general, the chapters below not only emphasise land surface features in themselves, and their diversity in given settings, but address mainly regional, field oriented questions.

The idea of landform associations seeks to address the mutual fertilisation of regional description and systematic investigation. The idea of "landform assemblages" refers, more specifically, to the varieties of processes and their interactions that compose any actual landscape or distinctive class of landscapes. Since a large fraction of landforms in cold regions, as elsewhere, consist of or are cut in superficial sediments, the understanding of landform assemblages almost invariably involves some study of sediments. And, in keeping with the assemblage notion, the varying composition and facies organisation or "architecture" of sediments comprise important diagnostic features.

Of course, such concerns have not been absent hitherto. The "landsystems" approach has sought to address very similar issues (Eyles 1983). Work on sediment assemblages and sedimentary basin studies have developed techniques and concepts appropriate to the recognition of landform-sediment complexes (Miall 1990). These approaches explore ways to deal with heterogeneous processes. They examine the complexities of temporally and spatially varying developments, and the kinds of technical and intellectual questions arising out of, but inadequately dealt with by, process-specific work. They offer important tools for, and steps towards, site and region specific geomorphologies.

Several of the chapters below directly address such questions. They are developed in relation to the glacial context by Hambrey and Glasser, and by Johnston (chapters 2 and 3), in the high mountain context by Hewitt (chapter 4), for an Arctic delta by Walker (chapter 8) and in a cold coastal setting by Dale et al (chapter 9).

Landscapes of Transition

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