Glacial Geology

An Introduction for Engineers and Earth Scientists

Edited by N. Eyles
University of Toronto, Canada

Pergamon Press

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Rationale

There are increasing demands being placed, often with inadequate understanding of the problems involved, on the subsurface geology in formerly glaciated terrains in connection with energy, waste disposal, engineering, groundwater and mineral exploration projects. This has created a considerable demand for an up-to-date summary of glacial deposition for engineers and earth scientists working in areas of former glaciation where an understanding of glacial geology is desirable.

This book is designed as a basic introduction to the geology of glaciated terrains and mid to senior level undergraduates, college students and industry and government employees engaged in engineering and earth science courses and projects associated with glacial sediments and stratigraphies in the mid-latitudes. Contributions have been sought from active specialists in university and industry involved with many different aspects of glaciated terrain in North America and Britain. The final result is a distillation of a very large and diverse literature that crosses traditional discipline boundaries and areas of individual expertise. Whilst a book of this nature cannot be exhaustive or hope to cover all areas, sufficient references, cross-references and illustrations are provided to enable an interested student to follow up various topics and to more easily visualize certain esoteric aspects. As in any text that encompasses several disciplines, nomenclatural problems and confusion surround many terms and concepts. These are discussed in the text in as much detail as space permits.

The theme of what follows is that a spring board for many applied projects in glaciated terrains is the comprehension of a small number of models that protray glacial deposition. These models describe recurring associations of landforms and sedimentary sequences (landsystems) that can be represented by block diagrams and can be identified at the margins of modern glaciers and also in mid-latitude zones affected by former Pleistocene ice sheets. Use of these models affords a valuable means of rationalising glacial deposition and provides an interpretive tool for subsequent engineering, sedimentological, geotechnical, hydrogeological and stratigraphic studies.

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The final vote of thanks must go to my collaborators in this project for their patience with what at times may have seemed like a long time to complete this book. We hope people will find the end product useful.

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Toronto, Canada
June, 1983

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Contents

CHAPTER 1

Glacial Geology: A Landsystems Approach

N. Eyles

INTRODUCTION

The extent and importance of sediments (engineering soils) represented by glacial deposits cannot be overemphasized (Figs. 1.1, 9.1, 9.2). Sediment types vary from overconsolidated bouldery silty-clays (tills) and other bouldery aggregates through variably consolidated clays, silts, sands and gravels, to peats and organic soils. A wide spectrum of sediments is represented in very variable associations resting on bedrock that may be a few metres to many tens of metres below the present land surface.

Associated with variable glacial soils are superficial structures, involving both sediments and rock, resulting from glacial and periglacial activity. Solifluction sheets, cambering, valley bulging, frost wedges and glacially-deformed bedrock are just a few examples of superficial structures that pose geotechnical problems. Difficult ground conditions usually arise because of either very rapid transitions from one sediment type to another, the juxtaposition of rock and soil, or the presence of unexpectedly soft horizons. It should be noted that throughout this book the terms ′sediment′ and ′engineering soil′ are used interchangeably.

1.1 Glacial Terrain Evaluation: The Concept of Landsystems.

Terrain evaluation is aimed at understanding the natural features of the landscape and as a process, inevitably involves terrain classification by which the landscape is separated into natural units. Each constituent unit must be internally homogeneous and distinct from the others. Recognition of landscape units implies that there is a genetic relationship between landforms and the processes and materials involved in their development. The processes are mainly surface geological processes that have been active in the recent past, but these may be very different from the processes active at the present time. The materials are the superficial and solid deposits that crop out at the surface and immediately underlie it.

The number of landscape units, or classes, must be reasonably small and three main types can be recognized within a hierarchial classification.

(i) A land element is the simplest part of the landscape and is for practical purposes uniform in form and material and is suited for mapping at large scales e.g. a drumlin or kame.

(ii) A land facet comprises one or more land elements grouped for practical purposes; it is part of a landscape which is reasonably homogeneous and distinct from the surrounding terrain. Land facets are suited to mapping at scales of 1:50,000 to 1:100,000. e.g. a drumlin field or an outwash plain.

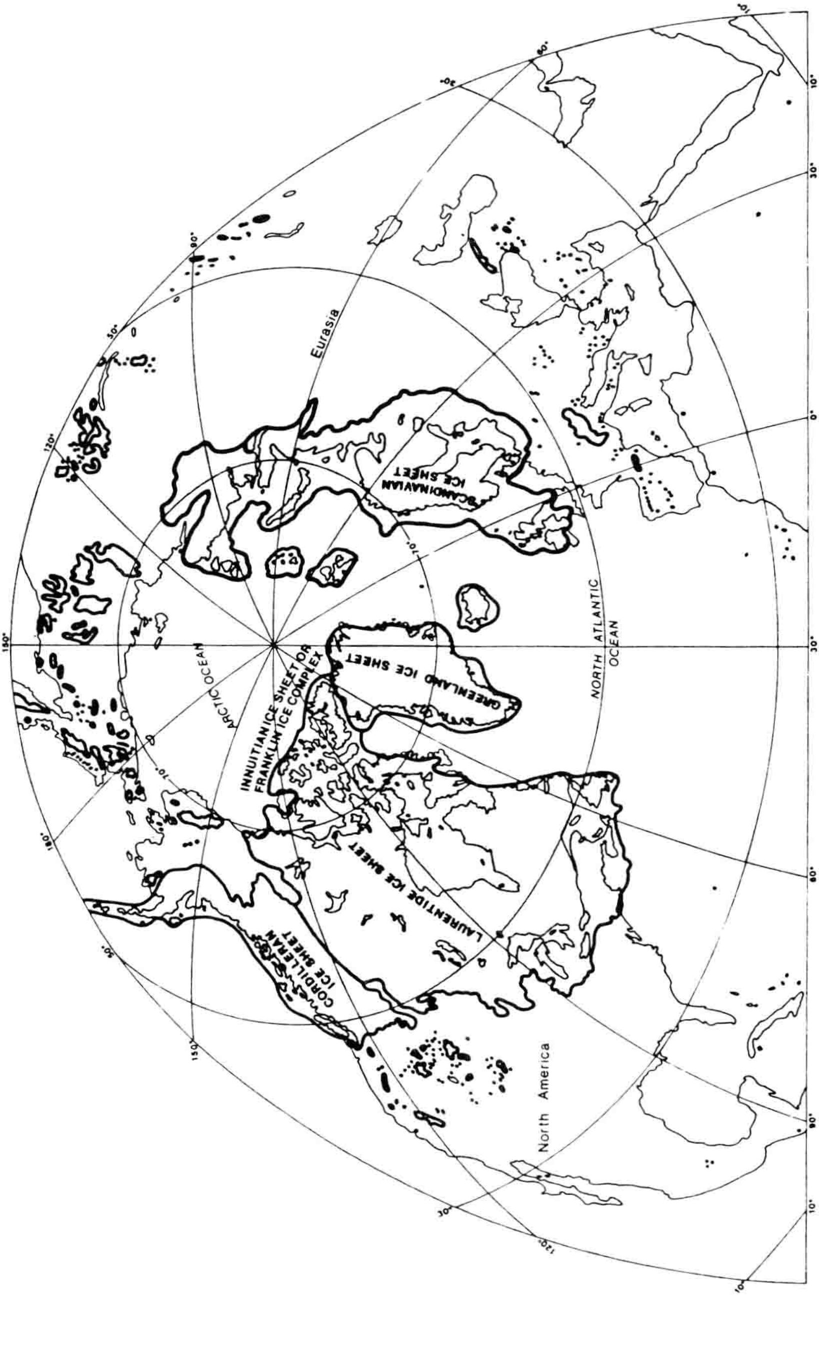

Fig. 1.1 Maximum extent (irrespective of age) of former Quaternary ice sheets in the Northern Hemisphere. From Denton and Hughes (1981) with modifications.

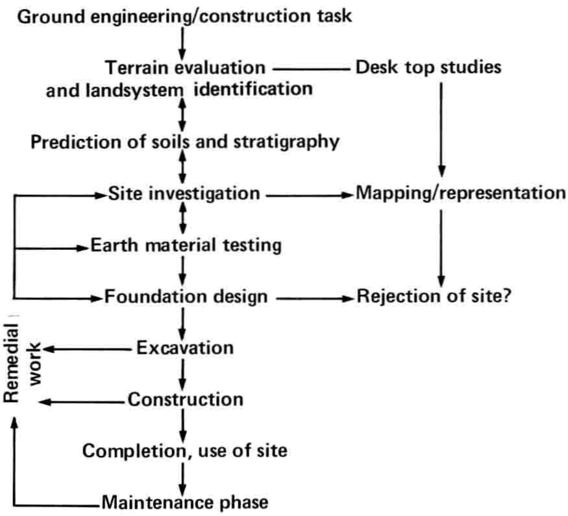

Fig. 1.2 An example of terrain evaluation; idealized sequence of events in the planning and implementation of a typical construction project. In practice many projects commence with a limited site investigation phase and employ foundation designs found to be successful elsewhere (Chapters 11, 12).

(iii) A landsystem is a recurrent pattern of genetically linked land facets, suitable for mapping at scales of 1:250,000 to 1:1m. e.g. subglacial terrain where sediments and landforms of the landscape have been deposited at the base of an ice-sheet. An example would be a drumlin field flanked by an outwash plain and esker system.

Each landsystem can be defined in terms of the sediment complexes underlying and at the same time controlling surface topography. The conditions at rockhead also vary from landsystem to landsystem. Although terrain evaluation is said to be concerned only with the uppermost few metres of the ground (Mitchell, 1973), the glacial landsystems which are considered here extend to bedrock regardless of depth.

The basic premise of the approach followed in this book is that if the land system can be identified from surface landforms, then it is possible to identify in turn the relevant subsurface conditions. As such the approach has an important role in the initial desk-study phase of planning a variety of applied projects with the potential for saving time and hence money (Fig. 1.2). The landsystem, once identified, provides a model not only for planning and the interpretation of the results of site investigation and laboratory testing but focuses attention on those particular features that should be looked for in making a geological assessment of any location for a wide variety of purposes.

1.2 Glacial Landsystems

A complex range and distribution of sediments result from glaciation. As a means of classifying and mapping sediment sequences and landforms at the margins of modern day glaciers, it has been possible to recognize a number of distinct