History of Geomorphology and Quaternary Geology

Edited by

R. H. Grapes, D. R. Oldroyd and A. Grigelis

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EDITED BY

R. H. GRAPES
Korea University, South Korea

D. OLDROYD
The University of New South Wales, Australia

and

A. GRIGELIS
Lithuanian Academy of Sciences, Lithuania

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Preface

Many of [my students] will study rock strata on the banks and valleys of our rivers, in order to satisfy various economic needs.

(Roman Symonowicz. Report . . . to the Council of Vilnius University 30 April 1804)

The Baltic States – Lithuania, Latvia and Estonia – form a region that experienced substantial glaciation during the Pleistocene which left a cover of up to 160 m of glacial sediments and reached a thicknesses of up to 310 m in buried palaeovalleys. The subsequent deglaciation and development of river networks during the Holocene gave rise to the relief that we see today, producing particularly interesting geomorphological features. Given this environment, the International Commission on the History of Geological Sciences (INHIGEO) chose the theme 'History of Quaternary Geology and Geomorphology' for its annual conference, held in the Baltic States in 2006.

It was the first time that the Commission had met in this region of eastern Europe. The main part of the meeting took place in Vilnius – the ancient and beautiful capital of Lithuania – and was followed by a field excursion through all three Baltic States. The presentation of the papers in Vilnius and the discussions during the field excursion allowed participants to examine the geological and geomorphological phenomena of the three countries, and their relationship to human history.

The Quaternary Period is no exception to the idea that different conditions prevailed at different times in different parts of the world, leading to variations in the geological record, as was stated by Leopold von Buch in the early nineteenth century. Thus, for example, when, 16–10 ka ago, ice sheets covered northern Europe, the Tamala Limestone, containing marine fossils, was being deposited in warm shallow seas in the region of Western Australia. With the amelioration of climate following the 'Ice Ages', and the land elevation of Scandinavia, the present relief and river networks of the Baltic States were formed. All round the world, rising sea levels produced changes in coastlines and estuaries.

The conference papers considered the histories of Quaternary geology and geomorphology in different parts of the world, with emphasis on the pioneers of these branches of geoscience in central and eastern Europe. It helped participants to improve their understanding of how Quaternary and land-surfaces research originated and has subsequently been developed, as well as understanding the numerous particular problems associated with Quaternary geology, compared with other parts of the stratigraphic column.

The conference also provided a valuable opportunity for participants from countries other than those of eastern Europe to get to know something of the history, geology and culture of a region that has been part of European civilization for about a thousand years. It also offered a chance for Lithuania and her sister states to open their doors to the world and display the geohistorical work that has been going on there for some considerable time, rather little noticed by outsiders.

I am convinced that the conference generated useful information on the themes discussed, which will serve it as a worthy Special Publication of the Geological Society of London, providing valuable insights into the histories of geomorphology and Quaternary geology in many parts of the world. This volume should be of value to all those interested in these two important branches of Earth science.

Let me wish this edition good fortune to survive in the Recent Era.

Algimantas Grigelis
Convener, INHIGEO Conference Vilnius 2006
1 July 2007

Contents

Contributions to the history of geomorphology and Quaternary geology: an introduction

DAVID R. OLDROYD[1] & RODNEY H. GRAPES[2]

[1]*School of History and Philosophy, The University of New South Wales, Sydney, NSW 2052, Australia (e-mail: doldroyd@optushome.com.au)*

[2]*Department of Earth and Environmental Sciences, Korea University, Seoul, 136-701, Korea (e-mail: grapes@korea.ac.kr)*

This Special Publication deals with various aspects of the histories of geomorphology and Quaternary geology in different parts of the world. Geomorphology is the study of landforms and the processes that shape them, past and present. Quaternary geology studies the sediments and associated materials that have come to mantle much of Earth's surface during the relatively recent Pleistocene and Holocene epochs. Geomorphology, with its concern for Earth's surface features and processes, deals with information that is much more amenable to observation and measurement than is the case for most geological work. Quaternary geology focuses mostly, but not exclusively, on the Earth's surficial sedimentary cover, which is usually more accessible than the harder rocks of the deeper past.

Institutionally, geomorphology is usually situated alongside, or within, academic departments of geology or geography. In most English-speaking countries, its links are more likely to be with geography; but in the United States these connections are usually shared between geography and geology, although rarely in the same institution. In leading institutions everywhere, strong links exist between geomorphology and such cognate disciplines as soil science, hydrology, oceanography and civil engineering. Although nominally part of geology, Quaternary geology also has strong links with geography and with those disciplines, such as climatology, botany, zoology and archaeology, concerned with environmental change through the relatively recent past.

Given that geomorphology concerns the study of the Earth's surface (i.e. landforms, and their origin, evolution and the processes that shape them) and that the uppermost strata are in many cases of Pleistocene and Holocene age, it is unsurprising that this Special Publication should deal 'promiscuously' with topics in both geomorphology and Quaternary studies. This particular selection has been developed from a nucleus of papers presented at a conference on the histories of geomorphology and Quaternary geology held in the Baltic States in 2006, where a great deal of what the geologist sees consists of Quaternary sediments. However, much of the Earth's surface is not formed of these sediments but of older rocks exposed at the surface by erosion and structural displacement. Here, geomorphology can seek answers to questions regarding the past histories of these rocks, their subsequent erosion, and present location and form. Geomorphology also raises questions, and may provide answers, regarding tectonic issues, for example from deformed marine terraces and offset fault systems. In all these instances, the history of geological and geomorphological investigations can serve to illustrate both the progress and pitfalls involved in the scientific understanding of the Earth's surface and recent geological history.

There are relatively few books but a growing number of research papers on the history of geomorphology. For readers of English, there is a short book by Tinkler (1985) and a collection edited by the same writer (Tinkler 1989), an elegantly written volume on British geomorphology from the sixteenth to the nineteenth century by Davies (1969), and a series of essays by Kennedy (2006). But towering over all other writings are three volumes: those by Chorley *et al.* (1964) on geomorphology up to the time of the American, William Morris Davis (1850–1934); by Chorley *et al.* (1973) dealing exclusively with Davis; and by Beckinsale & Chorley (1991) on some aspects of work after Davis. As envisaged by Chorley and Beckinsale, who died in 2002 and 1999, respectively, a fourth volume by other authors is soon to emerge (Burt *et al.* 2008). A series of essays edited by Stoddart (1997) on *Process and Form in Geomorphology* (1997) also contains valuable historical material, while papers edited by Walker & Grabau (1993) discuss the development of geomorphology in different countries, of which Australia, China, Estonia, Iceland, Japan, Lithuania, New Zealand, The Netherlands, the USA and the USSR are specifically mentioned in the present volume.

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A framework for geomorphology

Connections between geomorphology and geology go back to the early days of Earth science, but it is to developments in the later eighteenth century that we often attribute the foundations of modern links between the disciplines, notably to scholars such as Giovanni Targioni-Tarzetti (1712–1783) in Italy, Jean-Etienne Guettard (1715–1786) in France, Mikhail Lomonosov (1711–1765) in Russia and James Hutton (1726–1797) in Scotland. Hutton gave much thought to extended Earth time, and to the processes whereby soil and rock are eroded from the land to the sea. In 1802, Hutton's friend and biographer, John Playfair (1748–1810), not only rescued Hutton's ideas from relative obscurity but contributed original ideas on the nature and behaviour of river systems. However, the intellectual climate of the time worked against the ready acceptance of their views.

Following the leads provided by Hutton and Playfair, Charles Lyell (1797–1875) also addressed questions of extended Earth time and of erosion in his well-known and influential three-volume treatise *Principles of Geology* (Lyell 1830–1833). He emphasized the differential erosive powers that rivers or the sea could have on strata of different hardness, and discussed cases where river systems did *not* divide simply, like the branches of a tree, but cut through higher ground or occupied the eroded axes of anticlines. The latter phenomenon could be explained by supposing that folding had fractured the rocks at an anticlinal crest so that they became more prone to erosion, with the result that 'reversal' of drainage might occur. But Lyell realized that most of the rivers draining the Weald of SE England did not follow the main axis of the Wealden anticline but often cut through the North or South Downs that formed the flanks of the fold. He attributed such anomalous configurations to fractures that cut across the Wealden axis and to the interaction of Earth movements and fluvial erosion. Thus, Lyell invoked geomorphological and tectonic considerations in order to develop a geological history of a region.

A name that often emerges in the present collection of papers is that of W.M. Davis, with his theory of a cycle of erosion that was constructed in part on the work of his compatriots John Wesley Powell (1834–1902), Clarence Edward Dutton (1841–1912) and Grove Karl Gilbert (1843–1918) (Davis 1889, 1899, 1912). And one may reiterate that Davis's work was considered by Chorley *et al.* (1973) to be so influential as to warrant an entire volume of their comprehensive historical study of geomorphology.

Davis's initial cyclic ideas were encapsulated in the hypothesis that, following initial structural uplift, landforms shaped by rivers pass through different stages of development, which he dubbed 'youth', 'maturity' and 'old age', until they are reduced to a nearly level surface or 'peneplain'. The peneplain, for which he found evidence in the Appalachians, could later be 'rejuvenated' by uplift, thereby initiating a new cycle of erosion. This model led to studies of 'denudation chronology', or the reconstruction of landscape histories based of the recognition of erosion cycles and peneplains in various stages of development. Without a clear understanding of the processes and time involved, however, 'reading a landscape' through the lens of Davisian doctrine, or elucidating its 'denudation chronology', became an art form, rather than a rigorous science. Davis's geomorphic model was essentially qualitative and difficult to test but, as Charles Darwin famously wrote regarding his notion of natural selection, 'here then I had at last a theory by which to work' (Darwin 1887, p. 83).

Davis's ideas were challenged in his own time, particularly by German geomorphologists such as Albrecht Penck (1858–1945), Professor of Physical Geography at the University of Vienna and later of Geography at Berlin, and more particularly his son Walther Penck (1888–1923). Before the World War I, the Pencks and Davis were on good terms, but they subsequently drifted apart, partly owing to world politics and partly owing to Walther's rejection of the idealized character of Davis's theory along with disagreements as to the relationship between Earth movements and erosion. The Pencks objected to the notion of discrete upward Earth movements as the cause of topographic rejuvenation and also argued that erosion wears *back* a surface just as much as *down*. However, Walther Penck's proposed model of slope retreat would eventually yield a gently sloping surface resembling a Davisian peneplain (Penck 1924, 1953). Penck also envisaged an empirical relationship between tectonic activity and slope development, owing to the changing rates of river incision as the land itself was raised at varying rates. This idea was rejected vigorously by some in the English-speaking community, with Douglas Johnson (1878–1944), for example, describing it as 'one of the most fantastic ideas ever introduced into geomorphology'! (Johnson 1940, p. 231).

Ultimately, the differences between Davis and Penck lay in their different objectives and scientific approaches. Davis regarded geomorphology as a branch of geography, with geomorphic processes furnishing the topography upon which geography 'resided'. He, together with a number of like-minded geologists, geomorphologists and natural scientists, founded the Association of American Geographers in 1904, in part as a forum for his views (Orme 2005). Penck, in contrast, saw the field as being one that could elucidate problems of crustal movements and he was apparently less concerned with process and time (Hubbard 1940). It may be noted, though, that in his old age Davis accepted the idea of parallel slope retreat, such as is usually associated with the name of Walter Penck. Davis's changed views were given in lectures delivered at the University of Texas in 1929 but were not published until as late as 1980 (King & Schumm 1980).

Another major figure in the modern formulation of ideas on landscape evolution was the South African geomorphologist Lester C. King (1907–1989). Imbued with Davisian ideas and the triad of process, time and structure, as a graduate student of Charles Cotton (1885–1970) in New Zealand, King nevertheless went on to challenge much of Davisian theory. While still invoking the cyclic concept, like Penck he emphasized the importance of surficial processes, particularly in relation to the role of scarp retreat and pediment formation, and the considerable antiquity (e.g. Cretaceous) of some erosion surfaces. Given the structure of his adopted homeland in Africa, with its extensive flat-lying strata and thus many potential cap rocks, it is not surprising that King interpreted landscapes primarily in terms of scarp recession with consistency of slope form and inclination in any area and structural setting indicating parallel retreat. He thought that steep slopes are shaped by gravity and turbulent water flow (e.g. in gullying), whereas pediments, the typical landform of erosional plains, are the result of surface water flow (sheet wash), capable of transporting sediment and 'smoothing' the bedrock (King 1953). Pediments or pediplains persisted until another cycle of river incision or change in base level occurs, causing further slope retreat.

Thus, although King concluded that the evolution of landscapes by the action of running water would occur everywhere, except in glacial and desert areas, his ideas stemmed from observations in a semi-arid South Africa with limited river action, where weathering and rockfall predominate, and where scarp retreat, which occurs everywhere, is closely linked to pedimentation, which is of limited importance. King's recognition of a Mesozoic (or Gondwana) surface on the Drakensberg gave support to the idea that not all landforms are necessarily Late Cenozoic in age, as postulated in other theories of landscape evolution (e.g. Hack 1960). Mesozoic or Early Tertiary palaeosurface remnants have been identified in many other cratonic and old orogenic areas (e.g. China and Australia; see articles by Branagan (2008) and Zhang (2008), respectively, in this Special Publication), and their persistence raises fundamental questions about the complex interaction of surface-shaping processes such as erosion, the effects of climate change, tectonic uplift and deformation, etc., the duration of erosion 'cycles', or rock composition and structure.

Davis's erosion model was imbued with ideas drawn from Darwinian biology and his interests in entomology, and his diction was full of evolutionary metaphors. He was also interested in the pragmatic philosophy of Charles Peirce, as has been remarked by Baker (1996). By contrast, an awareness of recent developments in thermodynamics manifested itself in Gilbert's geomorphology through notions of dynamic equilibrium, grade and feedback loops. Gilbert's concept of 'negative feedback' in stream systems leading to 'graded rivers' occurred some 7 years before Henri Le Chatelier (1850–1936) enunciated his well-known principle as a general feature of chemical systems. Gilbert wrote:

> Let us suppose that a stream endowed with a constant volume of water is at some point continuously supplied with as great a load as it is capable of carrying. For so great a distance as its velocity remains the same, it will neither corrade (downward) nor deposit, but will leave the grade of its bed unchanged. But if in its progress it reaches a place where a less declivity of bed gives a diminished velocity, its capacity for transportation will become less than the load and part of the load will be deposited. Or if in its progress it reaches a place where a greater declivity of bed gives an increased velocity, the capacity for transportation will become greater than the load and there will be corrasion of the bed. In this way a stream which has a supply of *débris* equal to its capacity, tends to build up the gentler slopes of its bed and cut away the steeper. It tends to establish a single uniform grade.
> (Gilbert 1877, p. 112)

In the same publication, Gilbert also enunciated 'laws' for the formation of uniform slopes, structure and divides, and the concept of planation. In vegetated areas, he believed that the 'law of divides' was likely to prevail; in arid regions, he favoured the 'law of structure'. Thus, the 'laws' were not universal, in the style of Newton's laws. Nevertheless, Gilbert's work marked a significant advance in the search for geomorphological principles and thereby a step towards the establishment of geomorphology as a physical science (rather than an historical 'art'!). By contrast, Davis's 'evolutionary geomorphology', although attractive to his contemporaries and through much of the first half of the twentieth century, has now been largely or wholly superseded.

But Gilbert's concept of 'grade' also presents problems. It is supposedly a situation of balance between the transport of material in a river and the widening or deepening of the river bed by corrasion. According to Davis, for a 'mature' river 'a balanced condition is brought about by changes in the capacity of a river to do work, and in the