Preface

In the last two decades, the prospects for geomorphological modelling have been drastically improved by advances in Information Technology, especially by greatly increased processing speeds and storage capacities. The development of new processing tools in Geographic Information Systems (GIS), the production and availability of comprehensive spatial data from remote sensing and of high-resolution digital landform data such as Digital Elevation Models (DEMs), plus ongoing progress in statistical and mathematical methods, resolve many difficulties and permit new problems to be tackled. In the various branches of geomorphology, analyses and models based on these new opportunities have tested many of the existing concepts and generated new concepts. Both landforms and processes have been quantified, but they have also been interrelated and models have been developed to cover feedbacks, time lags and connections between different scales, so that we come closer to modelling systems and predicting landform development.

Among the varied tools employed are distributed modelling, entropy and energy expenditure, exploratory and inferential statistics, partial differential equations, finite elements, threshold recognition, fractals, and response-time analysis. The present book summarizes many basic concepts and ideas of landforms and their development, and provides a view of conceptual challenges and developments in geomorphology at the start of the 21st century. Most of the papers are concerned with both theoretical concepts or modelling, and comparisons with real-world data. They can be grouped into four sections:

Landform modelling, general considerations;
Material transport in landform modelling;
Fluvial landform structure: mathematical and physical laws; and
DEMs, GIS and modelling in geomorphology.

In **Part 1, Landform modelling, general considerations**, ideas are reviewed that have permeated modern geomorphology in the 20th century, especially for the modelling of landforms and processes in recent decades. These four papers critically review and extend geomorphological concepts such as peneplains, phase boundaries, morphostructures and scale.

Walther Penck recognised the importance of tectonism and denudation occurring simultaneously (Chorley *et al.*, 1973): this is clearly the case for Japan, where the Davisian concept of rapid uplift followed by prolonged stability seems singularly inappropriate. Like the Davisian scheme, however, the Penckian consists of theoretical possibilities, and these do not necessarily materialise when we make comparisons with observational data. **Ohmori** is able to show that Penck's concept of the primary peneplain (primärrumpf) is inapplicable to any orogenic area. This is because, based on Japanese measurements of denudation and uplift, a low-relief surface would have a denudation rate so low that it could not balance an appreciable uplift rate: only crustal stability could maintain low relief. Even quite slow uplift would lead to surface dissection, and depression would either submerge the plain or bury it in sediments. Thus a ‘primary peneplain’ would be indistinguishable from a Davisian ‘end peneplain’. Actual landscape development in Japan and other orogenic areas is quite different to that predicted by either Davisian or Penckian models.

Blair suggests how geomorphology can broaden its horizons to match the global perspectives of earth system science. Expanding from the traditional focus on subaerial exogenic processes at scales from centimetres to hundreds of kilometres, geomorphology should consider boundaries between media such as atmosphere, lithosphere and ocean at all scales from mineral surface microtopography to continental scale morphology. Such a focus reveals the general concept of ‘sympathetic boundaries’ in the media on either side of the main boundary. It also prevents neglect of the importance of mass transfer and gravity, and of the dependence of resistance on molecular forces.

From the boundaries emphasised by Blair, **Ilyin** expands on the importance of the ocean: lithosphere boundary. He distinguishes rifted morphology, that can be related to active sea-floor spreading from Mid-Ocean ridges, from volcanic block morphology not so related, consisting of seamounts, lava plateaus, rises and major islands. Similar acoustic basement morphology shows, however, that the latter has developed from the former. Ocean floor morphometry and structure change steadily with age, as tectonism transforms the initially mainly volcanic morphology.

Much recent work in geomorphology and hydrology has emphasised the importance of scaling between two related properties, for example when linear fractal plots show a power relation between properties. **Evans** shows that there are often limits to this behaviour, where thresholds change the nature of relationships between properties of the land surface. Thus the size or spacing of landforms is scale-specific, either globally, regionally or locally. Examples can be given both from bedforms such as dunes and drumlins, and from erosional forms such as landslides and cirques. The processes involved include the tectonic, volcanic, fluvial, gravitational, glacial and aeolian.

Part 2, Material transport in landform modelling, deals with material movements, landform processes and essential characteristics included in magnitude-frequency distribution of landform processes. Three papers discuss the characteristics of patterns in material movements in landform processes and the typical landforms peculiar to each movement. The subjects discussed in this part are basic ones for all aspects of geomorphology.

Nishimori and Tanaka provide a simple model for aeolian dune dynamics. Based on Hack’s three dominant factors (wind regime, available sand, and surface cover by plants), it simulates dunes of the various shapes observed. With qualitative resemblance to real systems, the results are especially useful in studying the interactions between vegetation and dunes.

Transport of material is central to modelling landform change. **Hirano** views the transport of mass in terms of both downward movement and diffusion. This is analysed in terms of Green's Function, with varied coefficients for the two components representing different processes. The Function is integrated to give topographic change. Rate of erosion is proportional to surface convexity and gradient, and depth of sediment varies with a normal (Gaussian) distribution.

Another aspect of landform development is the variation of processes over time: **Schmidt and Preston** consider the frequency and magnitude of processes relevant to sediment flux over the Holocene. Different systems can be linked as components in a sediment flux model at regional scale. Starting from landscape units, this is an upscaling approach to modelling landscape development.

Part 3, Fluvial landform structure: mathematical and physical laws, includes three papers discussing the mathematical and physical meanings of landform structure. Using considerable mathematical and physical methodology, they synthesise the presently prevailing knowledge of landforms and comment on future developments in the application of numerical methods in geomorphology as a natural science. In particular, the physical processes implicated by morphological characteristics of landforms are discussed.

Cudennec, Fouad and Sumarjo-Gatot analyse river networks in terms of lengths of water paths to the outlet, defined as the sums of link lengths of different Strahler orders. Consistent with the fractal nature of river networks, probability distributions of link lengths show strong scaling especially for lower orders. Truncated hydraulic lengths (summed up to a given order) are negatively skewed and some follow a gamma distribution, which is hidden in basin-scale functions.

Tokunaga considers the fractal nature of drainage basins in terms of Horton's law of stream numbers, redefined as an asymptotic law of self-similar networks. This can be expressed by a three-term recurrence formula, with some properties similar to those of one-dimensional quasi-crystals. The fractality arises from the nesting of most probable states as the potential energy of water is expended.

Peckham also considers the fluvial landscape in steady state. He understands it in relation to Hamilton's Principle, optimizing the difference between kinetic and potential energy dissipation, while conserving mass. A local equation relates surface elevations to those of neighbours in a grid. Finite-element solutions to the partial differential equations lead to local features such as peaks, ridges, saddles, slopes and forks, but not pits: the numerical solutions are hydrologically sound, and exhibit the features of real fluvial landscapes.

In **Part 4, DEMs, GIS and modelling in geomorphology**, three papers focus on digital methods in geomorphology using digital elevation models (DEMs) and geographical information systems (GIS). Even in 1984, the Japanese Geomorphological Union held a symposium on "Geomorphology and Data-Processing" (Japanese Geomorphological Union, 1985). It focused on the nature of numerical data (DEMs) and methods (GIS) for their application in geomorphology. Knowledge of and techniques for DEMs and GIS have recently developed remarkably, all over the world. From these methodological developments the papers propose some new methods for landform analysis, terrain analysis and natural hazard analysis. Basic problems for the future development of numerical treatment and applications in geomorphology are discussed. These papers build on those in Pike and Dikau (1995), from a previous IAG Conference.

As modelling advances, it can be used to improve prediction. This is important especially for landslides, which are intimately related to surface form and materials as well as weather conditions. **Pike, Graymer and Sobieszczyk** use digital maps of geology and ground slope gradient in combination with previous landslides to provide an index of landslide susceptibility. This automates earlier less quantitative indices, and provides a spatial prediction of future landsliding. The index is applied to detailed data for a large Californian urban area.

Ground slope is measured from Digital Elevation Models (DEMs) at the appropriate scale of resolution, and is important also in **Guth**'s study of the geomorphometry of the USA. Considering DEMs at three different grid spacings (for continental, regional and local DEMs), Guth shows that quadrangle averages of elevation and slope gradient are very well correlated, though mean gradients vary inversely with spacings. Results for a third major variable, degree of terrain organization, are more variable between different DEMs, especially where relief is low. Analysis of geomorphometric bivariate plots or histograms provides effective assessment of DEM quality (outliers are normally defects), and should be integrated in the process of producing and editing DEMs.

Sulebak and Hjelle also use DEMs to analyse terrain at different scales. Most existing multi-resolution models are based on triangulations and optimised for visualisation. For terrain analysis, better models are provided by hierarchies of spline surfaces at different levels of resolution. These can be used at appropriate scales in GIS applications.

It is difficult to provide a balanced international view of the broad field addressed here. However, with four papers each from the USA, Japan and western Europe (France, Germany, Norway and UK), one from Russia, and some representation from Indonesia, New Zealand and Australia (Sumarjo-Gatot, currently Schmidt and Preston), this volume does provide a good representation of the current distribution of work on theoretical geomorphology, and gives a truly international perspective. New concepts are developed, and old concepts are expressed in new ways. We hope that, together with the volumes edited by Lane, Richards and Chandler (1998) and Hergarten and Neugebauer (1999), it provides many pointers to future work. Although this field is not an easy one, the development of ever-better tools (in GIS, IT and mathematics), and DEM data that are more accurate and at higher resolution, permit improved models and better applications. Many exciting possibilities remain to be exploited.

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REFERENCES

Chorley, R. J, Beckinsale, R. P. and Dunn, A. J. (1973) *The History of the Study of Landforms, Vol. 2: The Life and Work of William Morris Davis*. Methuen, London.

Hergarten, S. and Neugebauer, H. J. (eds.) (1999) *Process Modelling and Landform Evolution, Lecture Notes in Earth Sciences, 78*. Springer, Berlin.

Japanese Geomorphological Union (1985) Special Issue on Geomorphology and Data-Processing. *Trans. Japan. Geomorph. Union*, Vol. 6, No. 3.

Lane, S. N., Richards, K. S. and Chandler, J. H. (eds.) (1998) *Landform Monitoring, Modelling and Analysis*. John Wiley & Sons, Chichester.

Pike, R. J. and Dikau, R. (eds.) (1995) Geomorphometry. *Zeitschrift für Geomorphologie, N.F.* Supplement-Band **101**.