4

LANDFORM

Landform has been basic to the study of geomorphology since the late 19th century, and form component definition evolved as a central concept until the second half of the 20th century when remote sensing, GIS, DEMs and geomorphometry allowed more rigorous quantitative procedures, although this also involved a review of first principles. Land form, as land shape, may have received more attention than landforms, involving their genesis, and awareness of natural kinds reminds us how both are dependent upon human perception.

The word geomorphology means to write about (Greek *logos*) the shape or form (*morphe*) of the Earth (*ge*), so that the simplest definition of the discipline is the scientific study of landforms. Every scientific discipline has a central focus and for geomorphology the landform is so central to the discipline that many geomorphology books do not define it! Landforms have been portrayed as natural features of the Earth's surface, as discrete geomorphological units defined by surface form and location in the landscape, or as part of continuous or multi-faceted terrain. Thus identified, units or elements may be categorized by characteristic physical attributes such as shape, elevation, slope, orientation, stratification, rock exposure, and soil type, and they can range from large-scale features such as plateaus to small-scale features such as fans. Each landform on the surface of the Earth occupies a particular scale in space and time, as with Ahnert's (1981) illustration developed in a different way in Figure 4.1 with a hierarchical classification shown in Table 4.1.

Although the Preface of Volume 1 of *The History of the Study of Landforms* (Chorley et al., 1964: xi) states that 'After about 1860 the study of landforms became part of both geology and physical geography and was later known as physiography or geomorphology', it is not easy to discover exactly when landform types first became basic for the science of geomorphology. Baron Ferdinand von Richthofen (1833–1905), who trained in geology and geography at Breslau (now Wroclaw), in 1886

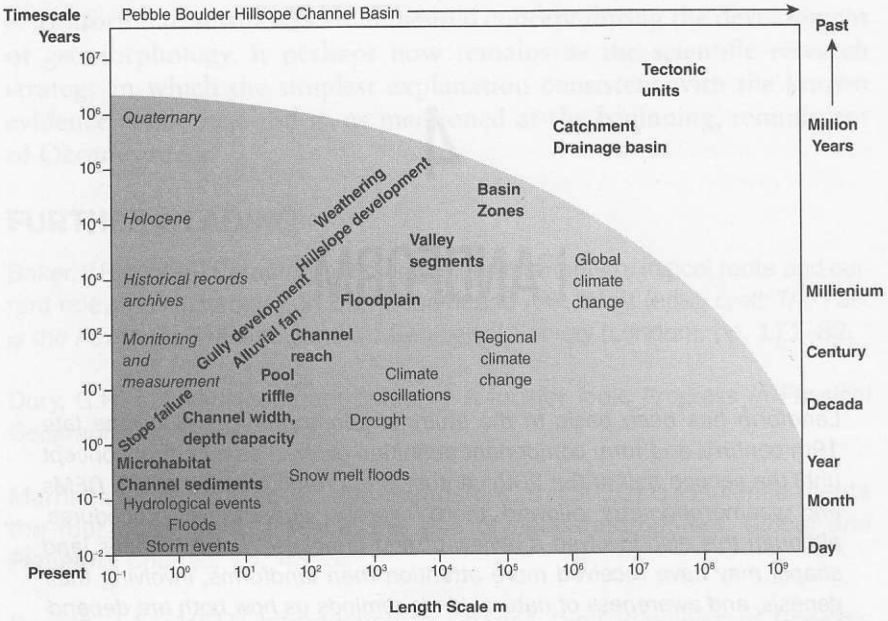

Figure 4.1 Landforms in relation to space and time

Table 4.1 Hierarchical classification of geomorphological features (time and space scales are approximate; developed from Chorley et al. (1984) and Baker (1986): http://geoinfo.amu.edu.pl/wpk/geos/geo_1/GEO_CHAPTER_1.HTML)

Typical Units		Spatial Scale km²	Time Scale Years
Continents		10^{7}	10^{8}–10^{9}
Physiographic provinces, mountain ranges		10^{6}	10^{8}
Medium and small-scale units, domes, volcanoes, troughs		10^{2}–10^{4}	10^{7}–10^{8}
Erosional/ depositional units	Large scale, large valleys, deltas, beaches	10–10^{2}	10^{6}
	Medium scale, floodplains, alluvial fans, cirques, moraines	10^{-1}–10	10^{5}–10^{6}
	Small scale, offshore bars, sand dunes, terraces	10^{-2}	10^{4}–10^{5}
Geomorphic process units	Large scale, hillslopes, channel reaches, small drainage basins	10^{-4}	10^{3}
	Medium scale, slope facets, pools, riffles	10^{-6}	10^{2}
	Small scale, sand ripples, pebbles, sand grains, striations	10^{-8}	10^{-2}

published what may have been the first systematic textbook of modern geomorphology (Fairbridge, 1999). Landforms gradually became assimilated into the scientific literature (**Table 4.2**) on the land surface of the Earth (Gregory, 2010), notably in the course of exploration of the American West and through the contributions of William Morris Davis (1850–1934) that formalized the importance of the landform as a genetic entity (Davis, 1900: 158).

Landforms provide the building blocks of landscapes (4.1), whether as genetically defined entities, or as surface form units. This involves classification, additional concepts such as associations and hierarchies (4.2), and a variety of different perceptions (4.3).

4.1 Building blocks of landscape

How do we identify and describe the basic component of the Earth's surface, analogous to the way that pedologists recognize the soil profile and ecologists distinguish the habitat? Language includes words for particular Earth surface features. English nouns such as mountains, plains, valleys and plateaux have equivalents in other languages, but some languages include words for Earth surface characteristics of the environment distinctive to their particular country, so that a language of place (Mead, 1953) reflects how some vocabularies have unique words for particular features. In Russian there are words for types of valley, like *balki*, which cannot easily be translated into English; many descriptive words have become used for landforms in the way that corrie, cirque or the Welsh word *cwm* for armchair-shaped hollows have become accepted as features of glacially eroded landscapes, and tors are landforms found in periglacial and tropical regions. Many of the words used for landforms have become technically underpinned (**Table 4.3**); many others, such as valleys and hills, are common usages and are not precisely defined.

Words are not sufficient so that mapping, profiling and now three-dimensional visualizations have been employed to show the character and extent of landforms. Two approaches have been used: a morphological approach concerned with **land form**, and a genetic approach recognizing **landforming**. Although the Earth's land surface may be regarded as one continuously variable interface, it is usually recognized that this encompasses patches or overlapping palimpsests of elements that may be in sets or sequences or of different origin (glacial, fluvial, etc.). A common approach has also been to identify the smallest units that can be recognized, the undivided flat or slope, given that all land surfaces are composed of a jigsaw of such morphological units (Linton, 1951). Such units of relief that Linton (1951) characterized as the electrons and protons of which physical landscapes are built have much in common with the 'site', originally described as 'an area, which appears for all practical purposes to provide throughout its extent similar conditions as to climate, physiography, geology, soil' (Bourne, 1931). Landforms are composed of such morphological units, which may then combine to make larger-scale entities. When morphological units were first recognized, electrons and protons were thought to be the basic units of matter, but as with matter morphological units can now be subdivided into smaller constituents – the particle, or the pixel. The pixel, a term contraction from 'picture element', is the basic unit in a grid of pixels or raster as used early in television but now applied widely to imagery compilation. For landforms, we may see alluvial phenomena range upwards in scale from individual particles through landform units (such as levees) to alluvial complexes or ensembles sometimes characterized as alluvial 'architecture' (Lewin and Ashworth, 2013). Landforms therefore encompass a great range of spatial scales from the undivided continent to the minutest slope element on the Earth's surface (Figure 4.1, Table 4.1).

Morphological maps can be produced to show the distribution of slopes, defining the land surface in terms of basic flats and slopes (though at a scale larger than rock or soil particles). Such mapping schemes, effectively slope maps, are useful because areas of slope of particular angles can relate directly to land use practices, to the angles at which agricultural implements can operate, or to the slope angles at which mass movements occur. Mapping basic morphological components of the Earth's surface required many hours of field work (e.g., **Figure 4.2**) but two major developments have revolutionized the depiction of the form of the land: remote sensing and geographical information systems (GIS). Technological developments enabled dramatic progress and the availability of new data sources providing greater spatial resolution has allowed new insights and rapid mapping to be performed, organized after the 1960s within the framework of a Geographic Information Systems (GIS) defined as the collection, analysis, storage and display of data spatially referenced to the surface of the Earth. There is clearly a family relationship with pixelated imagery, but it also allows the identification of patterns and relationships between phenomena and processes (Oguchi and Wasklewicz, 2011). For example, numerical land classifications based on 1-km grid squares can combine many aspects of environmental character without being use-specific. Digital Elevation Models (DEMs), for larger or smaller scale resolution, can now be used to model the shape of the land surface and are integral parts of GIS (**Figure 4.3**). Rather than deciding scales or the identity of landform types (like moraines or point bars) *a priori*, spatial resolution may be set numerically by permitted pixel or sampling grid size. Experimentation to decide on the appropriate resolution for particular purposes is possible. A digital data framework for the organization of spatial data and the co-registration of data into a single geodetic reference system have both been very significant, and the availability of DEMs has been at the forefront of much recent research (Smith and Pain, 2009). Whilst DEMs have been generated from contours and aerial photos for some time, the advent of routine space-based data collection through photogrammetric processing using dedicated fore/aft sensors (e.g., SPOT 5, ASTER) and interferometric synthetic aperture radar (InSAR; Rosen et al., 2000) has enabled great progress to be made. The move towards DEMs of higher spatial resolutions and vertical accuracies, together with the advent of Light Detection and Ranging (LiDAR), has given useful results for a whole range of landform studies. Further developments can be achieved by interactive 3D visualization based upon multiple elevation surfaces with cutting planes used to analyse landscape structure based on multiple return (LiDAR) data. Multiple surfaces and 3D animations can introduce novel concepts for visual analysis of terrain models derived from time-series of LiDAR data using multi-year core and envelope surfaces (Mitasova et al., 2012).

In addition, since 1994 the advent of Global Positioning Systems (GPS) has enabled the determination of a specific location anywhere on the surface of the Earth, employing a navigation system with a constellation of 24 orbiting satellites, facilitating a revolution in the identification of landform global location.

Although the identification of genetic landform types requires an experienced observer, there have been attempts to develop automated and semi-automated techniques for landform identification or feature extraction evolving to a research area of **geomorphometry**, or quantitative land surface analysis (Oguchi and Wasklewicz, 2011). Geomorphometry is the science of quantitative land-surface analysis, with a dedicated international society (**Box 4.1**). Progress in geomorphometry has included consideration of what landform actually is (Evans, 2012) and of how the land surface can be defined from an overabundance of data. Addressing operational definitions, a hierarchical taxonomy of fundamental geomorphometric variables has been proposed (Evans and Minar, 2011) composed of field variables and object variables (**Table 4.4**). New ways of characterizing the land surface require developing novel methods for the classification and mapping of landform elements from a DEM based on the principle of pattern recognition rather than differential geometry. One approach is the concept of **geomorphon** (geomorphologic phonotypes) (Jasiewicz and Stepinski, 2013), a relief-invariant, orientation-invariant, and size-flexible abstracted elementary unit of terrain. This is expressed in terms of local ternary pattern that encapsulates morphology of surface around the point of interest. Geomorphons enable terrain analysis without resorting to differential geometry, and a collection of 498 different geomorphons constitutes a comprehensive and exhaustive set of all possible morphological terrain types (Stepinski and Jasiewicz, 2011). This can give a general-purpose geomorphometric map by generalizing all geomorphons to a small number of the most common landform elements. Such maps are suggested to be a valuable new resource for both manual and automated geomorphometric analyses (Jasiewicz and Stepinski, 2013).

Geomorphometry and geoinformatics (**Box 4.2**) now permit the production of morphological maps very rapidly and accurately using consistent criteria. Criteria definitions are required, but sufficient recourse to the knowledge gained from earlier, field-based literature is also needed. There is some similarity here to approaches to plant classification in biology – initially morphological and based on appearances, but increasingly involving genetics as a means towards understanding the underlying structures to life forms. An interesting contrast with older 'geomorphological maps' that plot the distribution of genetic landform types, such as moraines or point bar ridges and swales, is that there are no blank areas left between such mapped units. Genetically speaking, glacial, fluvial and aeolian landscapes can often be 'feature-free' sloping terrains of sedimentary and rock surfaces even though they have been produced in such process domains, as well as having sets of defined forms such as barchan dunes or U-shaped valleys.

Morphological maps in themselves may not reflect the origin of the surface unless a unique form signature can be determined. The alternative genetic approach usually characterizes surface morphology, together with landform origin, dates for each section of the land surface, and indications of rock types, sediments and soils beneath the surface. These are important diagnostic tools in process studies. Not all requirements may be achieved in a single map, and academic papers commonly have maps and sections showing keyed elements to suit their own diagnostic purposes. General geomorphological maps produced in particular countries have also had their own emphases. In one of the most successful schemes in Poland, maps were produced at the scale of 1:50,000. Enthusiasm for general geomorphological maps has been limited, because their production, certainly for whole countries, has been prohibitively expensive with constant revision and updating required. Recently the advent of remote sensing sources has enabled a renaissance of geomorphological mapping (Smith and Pain, 2011) surveying remote regions, in greater (topographic) detail, over increasingly smaller time periods, accompanied by the emergence of aerial and terrestrial datasets enabling new applications. These may be very information-rich, but require interpretation skills and procedures to interpret them.

Taken altogether, with the availability of new tools such as satellite imagery, global positioning systems, digital elevation models and GIS, it has been possible to have a more effective approach to the acquisition, storage and display of geomorphological features. Geomorphologists can produce geomorphological models, consisting of land surface 'objects', organized into hierarchically arranged classes with spatially variable properties and geometric relationships (Dramis et al., 2011). Specific developments continue to be made. The geomorphons noted above were used for a 30x30 m cell geomorphometric map generated for Poland (Jasiewicz and Stepinski, 2013). Elementary forms or land elements can be grouped together into functional regions (landforms) such as 'hill sheds' (Evans, 2012). A so-called InterIMAGE interpretation strategy proved to be effective for the extraction of landforms (Camargo et al., 2012). By constructing a new legend at a scale of 1:10,000, combining symbols for hydrography, morphometry/morphography, lithology and structure with colour variations for process/genesis and geologic age, it has been possible to produce a 'geomorphological alphabet' (Gustavsson et al., 2006) that can be used to portray landscape configuration and illustrate the reconstruction of its temporal development.

Recognizing that geomorphological mapping plays an essential role in understanding Earth surface processes, geochronology, natural resources, natural hazards and landscape evolution, new spatio-temporal data and geo-computational approaches now allow Earth scientists to go far beyond traditional and subjective mapping, permitting a quantitative characterization of landscape morphology and the integration of varied landscape thematic information that extends beyond pure form (Bishop et al., 2012). Consequently recent progress in landform identification using new sources and techniques prompted a suggestion (Smith and Pain, 2011) that geomorphology really is an 'interface' discipline – not just physically, in the sense of studying the Earth's land-air or land-water surface, but also between pure and applied sciences that seek to derive greater benefit from integrating Earth's surface processes and landforms into their analyses. Geomorphology can be a necessary key integrating discipline for the geosciences, analogous to geological mapping as a key underpinning resource for societal development.

4.2 Classification, hierarchies and associated concepts

Since landforms were first systematically identified (Table 4.1), classifications have been necessary, augmented from geomorphometry, remote sensing and GIS, all enabling relationships of landforms to be analysed, and their association with other concepts understood. The six major ways of classifying landforms (Table 4.5, column 2) suggested by Beckinsale and Chorley (1991: Chapter 11) overlap somewhat and so four major categories are developed in Table 4.5 in order to indicate the present status of different approaches.

Table 4.5 Approaches to the classification of landforms

Type of Classification		Example, Citation	Current Status
1. Genetic	Encyclopedic	Peschel (1870) see Table 4.1. Was basis for subsequent recognition of range of landforms classified according to genesis. Recognized from mid 20th century on geomorphological maps.	Landforms associated with exogenetic geomorphic processes (weathering, slope, fluvial, coastal, Aeolian, glacial, periglacial), with endogenetic geomorphic processes (tectonic, volcanic), and with structural controls (karst): 498 different geomorphons constitute a comprehensive and exhaustive set of all possible morphological terrain types.
2. Morphological	Subdivision	Site: an area with similar local conditions of climate, physiography, geology, soil (Bourne, 1931). Nature offers two inescapable morphological units: at the one extreme the undividable flat or slope, at the other the undivided continent (Linton, 1951; Mabbutt, 1968).	Soil classification approaches terrain segmentation (Romstad and Etzelmüller, 2012)
	Accretion	Hierarchy of divisions recognized by Unstead, 1933: stows→tracts→regions. Wooldridge (1932): slopes and flats; the ultimate units of relief are flats and slopes (Linton, 1951); Gregory and Brown (1966): morphological units.	Geomorphic provinces Geomorphons Ecological patches (Bravard and Gilvear, 1996)
3. Process based	Drainage basin hierarchies	Stream ordering: Horton (1945); Strahler (1952); and subsequent methods.	Hill sheds (Evans, 2012) and landform geomorphometry. GIS.
	Slope sequence	Nine unit model (Dalrymple et al., 1969).	Applied to alluvial landforms (Lewin and Ashworth, 2013).
	Sedimentary architecture	Unit hierarchies (Miall, 1996).	
4. Applied	Practical	Land systems: an area with a recurring pattern of topography, soils and vegetation, CSIRO (Christian and Stewart, 1953).	Terrain units. Glacial, paraglacial land systems. Hazard and risk zoning maps
	Complex regionalization		Landslide distribution zoning maps (Calvello et al., 2013).

Initially labelled as encyclopaedic in the late 19th century, the recognition of different landforms according to origin developed so that a broad distinction could be made between those associated with exogenetic and with endogenetic processes as well as some in which bedrock geology is dominant, as in the case of karst landscapes. This potentially provides at least 10 broad categories, as reflected on many geomorphological maps. With developments in GIS and geomorphometry it has been possible to progress from human conceptualization with introduced subjectivity and bias with respect to the selection of criteria for terrain segmentation and placement of boundaries, to new spatio-temporal data and geocomputational approaches that now go far beyond traditional mapping. This permits a quantitative characterization of landscape morphology and the integration of varied landscape thematic information (Bishop et al., 2012) to produce geomorphological information about the land surface and landforms, but including additional information alongside it.

A second group of approaches essentially uses morphological data, categorizing surface form rather than origin, and this includes flats or slopes and has much in common with the recognition of site (Table 4.5) deriving from Bourne (1931). Recurrent patterns of spatial variation included the catena concept (Milne, 1935) expressing the way in which a topographic sequence of soils of the same age, and normally on the same parent material, can occur in landscape usually reflecting differences in relief/slope and drainage – an arrangement which others have described as a toposequence (Bates and Jackson, 1980). Following this approach from the viewpoint of the soil scientist, there are now many others involving landform by soil scientists and soil surveys, such as the Canada Soil Committee 1976 (www.pedosphere.ca/resources/CSSC3rd/chapter18.cfm) and the EU Joint Research Centre, European Soil Portal, 2012 (http://eusoils.jrc.ec.europa.eu/projects/landform/). Described as 'subdivision' by Beckinsale and Chorley (1991) this was complemented by 'accretion' whereby hierarchies of physical regions were identified, as exemplified by Fenneman (1931, 1938) in two substantial books identifying the landform regions under the heading of the physiography of the eastern and western United States. The contemporary manifestation of this is geomorphic provinces (e.g. Graf, 1987). Such approaches generally involve form hierarchies, with different levels that may be decided by the aggregation of lower-level units, or the subdivision of higher-level forms downwards ('lumping' or 'splitting').

A third group of approaches is based on processes (Table 4.5), first in the drainage basin, seen as the fundamental geomorphic unit (Chorley, 1969) – the area drained by a particular stream or drainage network and delimited by a watershed. It is a functional dynamic response unit from which outputs of water, sediment and solutes reflect the characteristics of the drainage basin that acts as the transfer function, and has been employed in recent GIS approaches. For slopes a nine-unit hypothetical landsurface model (Dalrymple et al., 1969) showed how nine particular slope components could occur on landsurface slopes anywhere in the world, with each component associated with a particular assemblage of processes. A similar approach was applied to pedogeomorphic research (Conacher and Dalrymple, 1977) where a simple five-unit slope may be sufficient (e.g., Birkeland, 1984). Alluvial systems may similarly be seen as both hierarchical and consisting of meso-scale elements such as channel bars, levees, overbank deposits and infilling palaeochannels, with all being developed simultaneously but at different rates (Lewin and Ashworth, 2013).

This 'process-based' approach follows a much earlier, and now more controversial, one adopted by W.M. Davis who characterized streams as 'consequent', 'subsequent', 'obsequent' and 'resequent' according to their sequence and origin in his theoretical cycle of erosion. A difficulty has been that such nomenclature depended on inference about landscape evolution rather than being readily determined from observable stream attributes. If an alternative evolutionary model becomes preferred, then the form elements require an identity revision, with some confusion between observation and interpretation.

A fourth category of applied approaches (Table 4.5) includes the **land system** developed by Christian and Stewart (1953) as areas with a recurring pattern not only of topography but also of soils and vegetation providing an approach for resource evaluation. Resource surveys in undeveloped parts of Australia and Papua New Guinea, initiated in 1946 by the Australian Commonwealth Scientific Industrial Research Organization (CSIRO), originated this approach. A further applied approach described as complex regionalization is illustrated by Russian work which includes recognition of the urochischa as a basic physical-geographical unit of landscape with uniform bedrock, hydrological conditions, microclimate, soil and meso-relief (Ye Grishankov, 1973) which could then be grouped into progressively larger units often characterized according to their use and potential and used for land evaluation. Whereas landscape ecology is the study of pattern and process at the landscape scale (Forman, 1995), focusing on what systems in the landscape can generally be used for, landscape evaluation is the estimation of the potential of land for specific kinds of use which can include productive uses such as arable farming, livestock production and forestry, together with other uses that provide services or benefits such as water catchment areas, recreation, tourism and wildlife conservation (Dent and Young, 1981). Such approaches have been refined with the advent of information systems (Cocks and Walker, 1987), advanced developments in remote sensing and the development of geographical information systems (e.g., Heywood et al., 1998). Two major contemporary developments have occurred: first in geomorphometry and GIS, and second through the recognition of specific geomorphological land systems (see Chapter 2, pp. 16–17) especially for glacial and paraglacial landscapes. Thus six paraglacial landsystems were identified (Ballantyne, 2002a): rock slopes, drift-mantled slopes, glacier forelands, and alluvial, lacustrine and coastal systems; each containing a wide range of paraglacial landforms and sediment facies.

Many potential links exist between the four major categories of Table 4.5, such as ecological patches forming a mosaic connected by corridors in any scale of landscape that can be employed in hydrology, analogous to a patchwork of geomorphological units nested at different scales (Bravard and Gilvear, 1996).

Landforms should be seen in the context of place and landscape. Place is used to refer to that particular part of space occupied by organisms or possessing physical environmental characteristics (Gregory, 2009), whereas landscape comprises the visible features of an area of land, including physical elements such as landforms, soils, plants and animals, weather conditions, and also any human components, such as the presence of agriculture or the built environment. Physical places, as enshrined in place names or types of landscape, are not easy to define but progress was made by recognizing physical or natural regions. Phillips (2001) contends that historical and spatial contingencies are responsible for the character of places. Historical contingency means that the state of a system or environment is partially dependent on one or more process states or upon events in the past, arising from inheritance, conditionality and instability: inheritance relates to features inherited from previous conditions (see Chapter 15). Conditionality is when development might occur by two or more different pathways according to the intensity of a particular phenomenon, for example whether a threshold is exceeded to instigate different trajectories of development. Instability refers to dynamical instabilities whereby small perturbations or variations in initial conditions vary or grow over time giving divergent evolution. Spatial contingency occurs where the state of an Earth surface system is dependent on local conditions that relate to local histories, landscape spatial patterns and scale contingency.

4.3 Contemporary perceptions of reality and interpretations

The identification of physical environments is now realized to be culturally determined: so do people from different cultures see physical landscape, and therefore landforms, in the same way? Thus Harrison et al. (2004: 10) contended that 'landforms have traditionally been seen as discrete entities (as things in themselves). Geomorphological maps employ solid black lines around landforms, yet in the field the boundaries between (and within) landforms are often very far from clear. The identification of geographical landforms, therefore, involves a clear set of assumptions not only about the nature of landform, but also about its history (both as a landform and as an intellectual category, since these are intertwined)'. Furthermore there are many cases when interpretations of landform have changed according to scientific thinking at the time, as in the case of landscape elements identified in terms of the Davisian cycle of erosion as well as later interpretations involving planation surfaces and residuals of variously identified origins (Table 4.6). At the other end of the spectrum is use of the term 'rock glacier'; Allison and Brunsden (2008) showed how 21 terms from 33 authors were utilized until just the one term became generally accepted.

It is quite generally accepted that scientific disciplines divide the particulars they study into *kinds*, which are groupings or orderings that do not depend on humans. Theorization about kinds may follow (http://plato.stanford.edu/entries/natural-kinds/#NatKinChe) as part of essentialism, a general theory of natural kinds in philosophy. Essentialism concerning natural kinds has three main tenets: first, all and only the members of a kind share a common essence; second, this essence is a property, or a set of properties, that all the members of a kind must have; and third, a kind's essence causes other properties associated with that kind. The essence of the natural kind 'gold', for example, is gold's atomic structure (Ereshefsky, 2009). Richards and Clifford (2011) suggest that the philosophical issue is whether these categories and the classificatory structures of which they are a part are 'real' (i.e., are 'natural kinds'; see Rhoads and Thorn, 1996), or simply convenient mental constructs to impose some degree of regularity on the apparently diverse character of surface forms, with implications for the manner of enquiry and type of explanatory process which follows the initial description (Harrison, 2001). Is the landscape *naturally* constructed of discrete entities for which we *require* names – drumlins, cirques, barchans, yardangs, inselbergs, etc. – or is it simply a continuous 3-D surface, to some of whose topographic attributes we *arbitrarily* assign these names? Furthermore, as shown in the next chapter, the notion of equifinality implies that a given landform may result from more than one process regime or process history.

Thinking about landforms as natural kinds underlines the need for the description and classification of landforms to be more detailed, rigorous, and genetically based. However, genetic interpretations are liable to change (Table 4.6), so that landform identity can change also. And what may have been identified in effect as 'kinds' may not collectively cover the whole Earth surface. Without digressing too far to

Table 4.6 Examples of changing interpretation of particular landforms

Landform	Original Interpretation	Developments and Current Interpretation
Erosion surface/ planation surface	Erosion surface used especially in Britain in mid 20th century to describe flattish plain produced by subaerial erosion. Often reconstructed from small remnants in the landscape.	Planation surface subsequently preferred term because such surfaces could be produced by range of processes, including marine erosion, and usually regarded as the product of an erosion cycle or a prolonged period of erosion under particular erosional conditions.
Glacial drainage channels	In the first half of the 20th century most channels interpreted as overflow channels and explained as produced by drainage overflowing from proglacial lakes.	Research on contemporary glaciers enlightened interpretation of former glacial drainage systems that were appreciated to be composed of channels that flowed on, in and under ice as well as at its margins. Hence the term 'glacial drainage channel' was employed to encompass a range of superglacial, englacial, and subglacial routes.
Tors	In the first half of the 20th century regarded as weathering residuals typical of areas such as Dartmoor in the UK.	Subsequently the subject of debate because it was appreciated that they could be produced as integral parts of deep tropical weathering or during periglacial conditions.
Pediment	Originally applied by G.K.Gilbert (1880) to alluvial fans on the margins of Lake Bonneville, Utah.	Now thought of as smooth concave upward erosion surface that is part of the piedmont zone in arid and semi-arid areas. May have alluvial cover and have also been recognized in temperate areas.
Dry valleys	Until mid 20th century thought to be confined to limestone areas, and possessing all the characteristics of river valleys but no stream channel evident.	Later realized that dry valleys not confined to limestone outcrops, can occur on other lithologies, and reflect former more extensive drainage networks.

consider such questions as 'Do mountains exist?' (Smith and Mark, 2003), we have to remember the difference between land form and landforming approaches in the past and the need to understand how landform, materials and processes (considered in the next chapter) are integrated to comprise geomorphological understanding. And if we do not appreciate just what we mean by the 'form' of the land sufficiently, how can we suggest how landforms should be remodelled or designed as an integral part of landscape conservation (Gray, 2009)?

FURTHER READING

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Smith, M.J., Paron, P. and Griffiths, J. (eds) (2012) *Geomorphological Mapping: Methods and Applications*. London: Elsevier.

TOPICS

1. Add other examples of changing interpretations of landforms as suggested in Table 4.6.

WEBSITE

For this chapter the accompanying website **study.sagepub.com/gregoryandlewin** includes Figures 4.2, 4.3; Tables 4.2, 4.3, 4.4; Boxes 4.1, 4.2; and useful articles in *Progress in Physical Geography*. References for this chapter are included in the reference list on the website.