

Fluviale Formen und Prozesse werden in den Trockengebieten bevorzugt zur Rekonstruktion vorzeitlicher Morphodynamik und, darauf aufbauend, zur Ableitung einer paläoklimatischen Entwicklung herangezogen. Den fluvialen Prozessen (Akkumulation und Erosion) wird dabei ein sehr unterschiedlicher, oft gegensätzlicher paläoklimatischer Aussagewert zugemessen. Auch der spezielle Charakter der jeweiligen fluvialen Akkumulationen (Grobmaterial/Feinmaterial) gibt vielfach Anlaß zu einer differenzierten paläoklimatologischen Interpretation.

Aus geomorphologischer Sicht erscheint es vielfach sinnvoller, sich auf eine Charakterisierung bestimmter morphodynamischer Vorgänge zu beschränken und im Sinne von ROHDENBURG (1970) die Begriffe "morphodynamische Aktivität", "morphodynamische Stabilität" und u.U. "morphodynamische Teilaktivität" zu verwenden, ohne daß zugleich aus den speziellen Formungsvorgängen in jedem Fall ein fiktives "geomorphologisches Klima" (RUST und WIENEKE 1976) abzuleiten versucht wird.

Am Beispiel einer jungquartären fluvialen Akkumulation, die verbreitet in den Talzonen der Gebirge und deren Randgebieten im nordafrikanischen Trockenraum vorkommt und von vielen Autoren übereinstimmend beschrieben wird, soll gezeigt werden, welche Erscheinungen, die zu einer weitgehenden paläoklimatologischen Deutung Anlaß geben könnten, auch "aklimatisch" erklärt werden könnten.

Ein wesentliches Merkmal dieser jungquartären Akkumulation ist eine Wechsellagerung von Material aus dem Einzugsgebiet der Wadis mit Lokalmaterial von den seitlichen Hängen, das debris-flow-artigen Charakter trägt. Vielfach wird ein zyklischer Aufbau von Grobmaterial an der Basis bis zu einer Feinmaterialdecke im oberen Teil der Ablagerung beobachtet. Ein weiteres Merkmal ist in dem gegenüber dem heutigen Talboden meist größeren Gefälle der Terrassenoberfläche zu sehen.

Schließlich wird aus den meisten Gebieten übereinstimmend festgestellt, daß die Talbodenakkumulation kurz nach ihrer Entstehung bereits wieder einer weitgehenden Zerschneidung unterlag.

Der Prozess der starken Hangabtragung, der zur Akkumulation in der oben beschriebenen Form führte, wird von den meisten Autoren (ANDRES 1977, BULL und SCHICK 1979, GRUNERT 1975, MOLLE 1979, ROGNON 1967, ROHDENBURG und SABELBERG 1973 u.a.) im wesentlichen übereinstimmend bewertet. Am Ende einer langandauernden Periode der Stabilität und kräftigen Bodenbildung auch auf steileren Hängen, kam es zu einer einschneidenden klimatischen Veränderung, die das Ausmaß einer ökologischen Katastrophe hatte. Ein Wechsel von langandauernden Trockenperioden mit heftigen Niederschlagsereignissen kann als Ursache vermutet werden.

Eine über diese Aussagen hinausgehende paläoklimatologische Interpretation, die etwa die oft beobachtete zyklische Abfolge Grobmaterial/Feinmaterial oder die der Sedimentation unmittelbar folgende Phase der Erosion zugrunde legt, birgt erhebliche Probleme in sich.

So kann etwa der Zyklus Grobmaterial/Feinmaterial allein dadurch erklärt werden, daß nach einer relativ kurzen Periode der debris-flow-artigen Hangabtragung und der damit verbundenen Grobmaterialakkumulation in den Talböden in begünstigten Positionen, d.h. auf Hangverflachungen oder flacheren Rücken zwischen Hangtieflinien bzw. oberhalb des eigentlichen steilen Talgehänges, durchaus noch Verwitterungsprofile erhalten waren, da in diesem Bereich weder die zur Verfügung stehende Wassermenge noch das Gefälle ausreichten, um einen Abtragungsprozess dieser Art in Gang zu setzen. Selbst bei nicht geänderten klimatischen Bedingungen würde nachfolgend nur noch Feinmaterial aus den begünstigten Positionen abgespült und käme zum Teil auf der flachen Oberfläche der Talbodenakkumulation zur Ablagerung. Der aus der auflagernden Feinmaterialdecke erkennbare Übergang zu morphodynamischer "Teilaktivität" auf den Talhängen wäre in diesem Falle jedoch nicht durch eine Klimaänderung, sondern nur durch eine geänderte Situation in der Position des vorhandenen transportablen Materials im Einzugsgebiet verursacht.

Bei besonderen hydrographischen und orographischen Gegebenheiten (Ausraumzone und anschließende lokale Erosionsbasis) wird andererseits oft eine Periode voller morphodynamischer Aktivität auf den Hängen entlang der Wadis durch eine Feinmaterialakkumulation vertreten.

Schließlich muß davon ausgegangen werden, daß auch die Erosion, die die beschriebene Aufschüttungsform unmittelbar nach ihrer Entstehung wieder zerschnitten hat, nicht unbedingt eine Änderung der klimatischen Verhältnisse anzeigt, sondern durch das während der Akkumulation ausgebildete überhöhte Gefälle bereits angelegt war und in dem Moment einsetzte, in dem die Grobmaterialzufuhr von den Talflanken (s.o.) nachließ.

Außerdem ist noch zu bedenken, daß ganze Abschnitte von Wadi-Systemen in ihrem rezenten sedimentologischen Verhalten davon geprägt werden, welche Akkumulationen in mehr oder weniger zurückliegenden Perioden im Einzugsgebiet zur Ablagerung kamen und in der Gegenwart beim Abkommen aufgearbeitet und dadurch flußabwärts "vererbt" werden.

Daraus werden vier Folgerungen abgeleitet:

1. Erosion und Akkumulation in eng begrenzten Ausschnitten eines Wadis sind paläoklimatisch kaum aussagekräftig. Daher sollten stets ganze Wadi-Systeme betrachtet werden.
2. Volle morphodynamische Aktivität bzw. Teilaktivität auf den Talhängen ist nicht in jedem Falle nur eine Frage der klimatischen Steuerung sondern auch der Menge, Art und Position des für die Abtragung zur Verfügung stehenden Materials.
3. Der spezielle Charakter einer Akkumulation (Grobmaterial oder Feinmaterial) in seiner vertikalen und horizontalen Variation kann auch wesentlich von "aklimatischen" Parametern mitbestimmt werden oder von lange zurückliegenden klimatisch gesteuerten oder ausgelösten morphodynamischen Prozessen beeinflusst sein.
4. Erosion im Anschluß an eine Aufschüttungsphase muß nicht zwangsläufig durch eine Klimaänderung erklärt werden, sondern kann bereits in dem durch die Aufschüttungsvorgänge erhöhten Gefälle ursächlich angelegt sein und bei einer u.U. ebenfalls nicht klimatisch verursachten Änderung der Materialzufuhr zu einer Wiederzerschneidung der Akkumulation führen.

Die unter 1 bis 4 genannten Forderungen lassen deutlich werden, daß ähnliche oder vergleichbare Abfolgen fluvialer Sedimente in den ariden Gebieten und ihren Randbereichen nicht zugleich Rückschlüsse auf einen gleichartigen oder gar zeitgleichen (synchronen) klimatisch bedingten Formungsablauf ermöglichen, es sei denn, eine zuverlässige Parallelisierung kann über autochthone Bodenbildung oder durch absolute Zeitmarken herbeigeführt werden.

#### ON THE PALAEOCLIMATIC SIGNIFICANCE OF EROSION AND DEPOSITION IN ARID LANDS

by W. ANDRES, Marburg

(Abridged version of the German abstract by D. Busche)

ANDRES warns against an uncritical palaeoclimatic interpretation of fluvial terrace deposits in arid lands. For once local effects may be overrated, if only a river segment instead of a whole wadi system are analyzed. Debris-flow-type sediment supply from the slopes may strongly be governed by the possible existence of ancient weathering relicts. Similarly old terrace deposits reflecting climatic conditions of some period of the past may be reworked.

In the course of an "ecological catastrophe" (i.e. for instance severe rainstorms separated by long periods of drought) which follows a prolonged period of geomorphic stability, all the coarse debris formed on the slopes may be washed into the river. When this supply is exhausted, fine-grained material possibly preserved in protected positions may be washed into the wadi instead, thereby completely changing the character of the deposit for no climatic reason at all.

Equally dissection immediately following a time of deposition may not be climatically controlled. Frequently the longitudinal profile is steepened during deposition. With decreasing debris supply from the slopes, which also need not have climatic reasons, the river will revert to its original gradient, thereby dissecting its deposits.

Consequently terraces of similar aspect may have formed at various times and/or under different climatic conditions. Evidence for a synchronous development under identical climatic conditions can only come from in-situ soils or from absolute age determinations.

Hanna Bremer, Köln

## Landform development in the humid tropics

The tradition of German geomorphological research in the tropical zone dates back to the turn of the century, and the terms inselberg, bornhardt and Bergfußniederung even entered the English language. Plains and inselbergs have always been a primary attraction both for being characteristic of the tropical zone and because they occur as relics in the temperate zone. Though there had been several suggestions as to the development of plains before, Büdel (1957) was the first to propose a comprehensive theory - the principle of twofold planation: Intense deep weathering is prerequisite for the development of a Rumpffläche (a plain cutting across rocks of different hardness); lowering by areal denudation is more important than river work, and there may be a spatial and temporal discontinuity of linear erosion and denudation. Büdel developed this theory mainly by intensive observation and comparison (interregional to eliminate the rock factor, interzonal in similar lithological and structural setting to evaluate the difference in forms due to climatic control). Special forms he described are wash troughs and divides, planation passes, and triangular embayments. Characteristic positions of inselbergs (Kayser 1957, Bremer 1971), divergent weathering and erosion (Bremer) and intramontane plains (Sammel, Bremer) are further developments in this line.

This general concept has been elaborated on along three lines:

- 1) by increased investigation of the processes themselves
- 2) by studying indications of climatic changes and of their geomorphological relevance
- 3) by rating the influence of tectonic movements.

Louis drew his conclusions from sequences of valley forms in Tansania. In E-Africa Mäkel and Spöemann evaluated sediments, and minor landforms for climatic change and tecto-variance. From the Sudan and Nigeria Rohdenburg and Fölster described stone lines and named related processes 'pedimentation'. Horst Hagedorn reported flat 'valley in valley'-forms from Cameroun. Slope retreat of high mountains has been investigated

by Wirthmann at the W-Ghats and on Pacific Islands. Further work in India has been done by Seuffert and Brunner. Special but nevertheless very important problems have been investigated by several colleagues; Wilhelmy, for instance, worked on weathering forms in crystalline rocks, of which a special form, the penitent rock, was first described by Ackermann. Lehmann proposed the concept of tropical karst; later research in karst was done by Pfeiffer and Gerstenhauer; Klammer investigated Quaternary surfaces in the lower Amazon. In the same basin Sioli and his co-workers have done a lot of ecological work, which is quite relevant for geomorphology. Blume and Barth studied cuesta landscapes, and Löffler wrote a book on the geomorphology of Papua New Guinea. The relationship between soils and landforms has been worked on by several colleagues, especially Semmel, Rohdenburg, and Fränzle.

Thus there is a wide range of interest topics and results. From our own investigations in Australia, Nigeria, Amazonia, and Sri Lanka some comments ~~on comments~~ on processes are made and problems awaiting further research are printed out. There seem to be three groups of processes:

- 1) subterraneous removal of material
- 2) clay illuviation (which becomes increasingly important with decreasing gradient!)
- 3) wash.

These processes are differently matched and of different weight due to moisture conditions in the soil. These are controlled by rainfall (amount and distribution), porosity (rock factor and weathering history), and preceding relief. Porosity and relief have a strong genetic component, i. e. the age of landform development (under constant climatic condition) may influence processes. A few concluding remarks concern general concepts in humid geomorphology, e. g. the principle of flattened ridges (Prinzip der abgeflachten Firste) by Gradmann (1919), which bears some resemblance to ideas expressed by Hack. This concept has never been adopted in Germany, however unlike the concepts of W. M. Davis and Walter Penck.

Anglo-German Geomorphological Conference  
Applicable models of Long Term Landform Evolution

Denys Brunsdon and John B. Thornes

ABSTRACT

This paper begins with a summary of four fundamental propositions of landform genesis as recorded in Brunsdon and Thornes (1979). These are:-

- 1). Each geomorphological environment is represented by constant processes and characteristic landforms which tend to persist with time.
- 2). The systems are subject, over  $10^2$  -  $10^5$  years to change caused by high magnitude, low frequency events, environmental change and internal structural instabilities.
- 3). The responses are complex and include damped, sustained and reinforced changes taking place over wide areas, or along linear axes or away from these axes by diffusion.
- 4). The changes reflect the varying spatial and temporal sensitivity of the landscape.

The resulting patterns of landscape genesis include relief and pattern persistence, stagnancy of development, unequal activity, convergence of form, the concept of transient form, stability - instability and episodic erosion.

In such a situation, if we are to make progress in building applicable models for long term change we must:-

- 1). Establish the nature of the boundary conditions which have affected landform development over the last few million years and establish more realistic boundary condition models than those proposed by W.M. Davis,

The task of the historical geomorphologist is to determine to the fullest possible extent the history of the shape of the surface of the earth. In practice, most studies have been concerned with ~~micro~~ and ~~meso~~-scale landforms.

*Handwritten notes:*  $km^2$  -  $10^6$   $km^2$  -  $10^8$

Seven principles or concepts underly this work:-

Current physical processes have operated throughout geological time - the principle of uniformitarianism.

Biological processes have had an increasing geomorphological significance through geological time - the Darwinian concept of evolution.

Geomorphological processes operate at different rates in space and time influenced by climatic and tectonic changes. Base level exercises a major control on the development of landforms. *Fluvial activities*

Rates of denudation are such that it is unlikely that any of the earth's surface is older than Tertiary and Pleistocene climatic changes have played a crucial role. *Disturbance Low* *weir, pump: Versandt u. abgeflutet u. viele Freibergung.*

Superficial sedimentary deposits are major sources of information for dating and for the elucidation of past processes.

Geological structure and lithology are major factors in the evolution of landforms.

Changing practice in historical geomorphological studies is illustrated from British examples set within the framework of a retrospective approach to the geomorphological evolution of Britain.



W. Penck or L.C. King.

2). We must query whether the constant process-characteristic form model is useful within the context of known rapid boundary condition change and environmental stability.

3). We must develop the nature of the complex response models which follow from various combinations of controlling variables so that we can predict or retrodict across known model response surfaces.

# ABSTRACT

It has been traditionally considered that many of the cave systems in the British Isles have developed during Pleistocene climatic variations and that the caves and associated karst forms are late Pleistocene, related to the Devensian glaciation. Whilst this may be undoubtedly so for specific case studies investigated, it may not be true as a general statement. Much of this written and unwritten theory colours the opinions of spelaeologists to conventional Pleistocene (indeed, Devensian) cave development ideas. However, recent work now tends to suggest that caves and their allied dolines are older than is generally believed being, perhaps, Tertiary, or earlier in age.

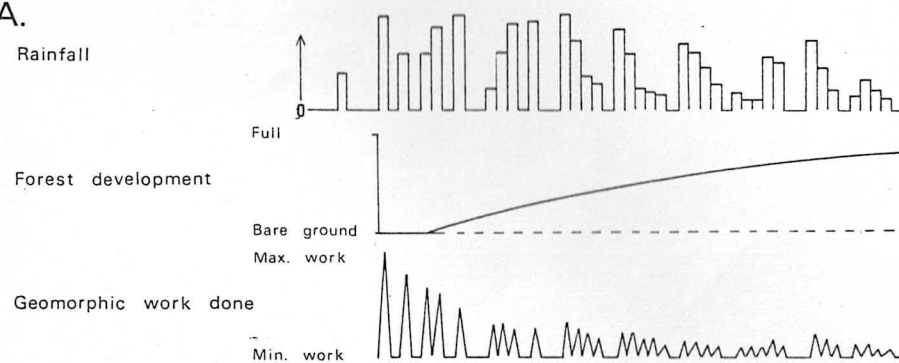
A general review of existing literature is therefore presented in which consideration of the relic karst features identified in Britain is given. Furthermore, recent proposals of mineralisation processes in Derbyshire, based on Permo-Triassic cave passages are reviewed. The more general indications of clastic cave sediment studies in south-west England and South Wales are also considered. Further, indications of the relative antiquity of caves are sought in subterranean fauna studies where the distribution of the troglobitic shrimp Niphargus presents more inferential evidence. A brief examination of the surface morphological relationships of caves in South Wales to former erosion surfaces is also considered. Finally, recent advances in absolute dating techniques employed upon deposits taken from caves in the south-west and north-west of England are used to further substantiate the general thesis of this paper: cave development is not exclusively Quaternary, Pleistocene or particularly Devensian in age.

# CLIMATIC GEOMORPHOLOGY - PRESENT-DAY PROCESSES AND LANDFORM EVOLUTION - PROBLEMS OF INTERPRETATION

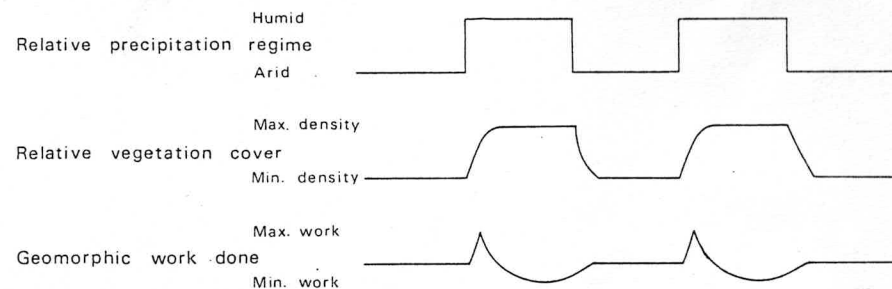
Ian Douglas  
University of Manchester

Concepts related to uniformity persist in geomorphology, yet Tricart has long reminded us that time is of unequal value in geomorphology. Climatic geomorphology is based on uniformitarian principles, the fundamental notion being that the elements of climate are sufficiently constant or stable for long enough in a particular locality to control a set of exogeneous processes for a time adequate to produce a distinctive suite of landforms. Recent process studies have highlighted, particularly in areas of strong relief, such as the Himalaya and New Guinea, that single catastrophic events within the present climatic regime may dominate landform changes for decades. The debris and erosion scars left by catastrophic event are gradually modified by subsequent lesser events. The operation of geomorphic processes can thus be seen as a series of episodic transfers of material from one location to another with considerable lags in time between the preparation of material by weathering, its movement to the stream channel and its export from the catchment. Such lags operate at a variety of space and time scales, from those which leave dune forms in the major channel of a river when a flood flow recedes back to the minor channel, or the gradual recovery of a rainforest after disruption by a cyclone or landslide (Fig 1A) to the lag in response of vegetation to climatic change from relative aridity to greater humidity (Fig 1B) or the even longer lag in the advance of glaciers following the onset of a cold period (Fig 1C), or the continued existence of fossil dunes in now humid areas of the tropics. Such time lags suggest that the notion of distinctive, climatically determined suites of landforms is erroneous. When measurements of present day processes are applied to denudation chronology many difficulties arise, such as in New South Wales where the

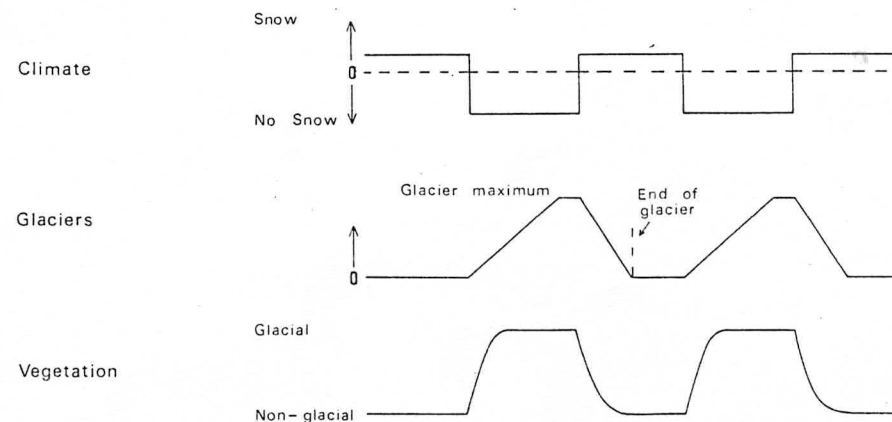
A.



B.



C.



*Actualisimus*

slow present day rate of erosion yield past rates for too rapid to explain the dissection of surfaces whose minimum ages are known from dated basalt flows. Many fluvial deposits have alternative explanations, depending on whether the change in facies is due to the system crossing an extrinsic or intrinsic threshold. The problem often arises of whether in the past normal processes operated in a changing environment or catastrophic processes in a constant environment. Even when mineral stabilities and pedogenetic evidence are used, contemporary process studies offer no easy solutions as the debates on the genesis of laterites and silcretes show, with the possibility of such duricrusts being created in different sets of conditions under different climates. In historical climatic geomorphology, investigators need to consider alternative working hypotheses. They will probably agree with the sedimentologist, Reading that "The present is not a master key to all past environments although it may open the door to a few. The majority of past environments differ in some respect from modern environments. We must therefore be prepared, and have the courage, to develop non-actualistic models unlike any that exist today".

I. S. Evans, University of Durham  
An Integrated System of Terrain Analysis  
and Slope Mapping

A system is described which (a) replaces existing sets of diverse terrain indices with an integrated group of statistics for process-relevant point characteristics; (b) calculates all these statistics in a single computer run from a single data set, thus achieving practical as well as conceptual simplicity; and (c) utilises altitude matrix data which is now becoming available as a by-product of photogrammetric automation, thus reducing the cost of data acquisition. The system is applicable to altitude matrix data at any horizontal resolution (grid mesh).

From altitudes in each 3 x 3 submatrix, a quadratic surface is fitted and solved for its first and second horizontal and vertical derivatives at the central point. This yields, in addition to altitude, the slope gradient and aspect, profile convexity and plan convexity at every point in the original matrix, except for the peripheral row and column on each side. Each of these five characteristics has an important influence on geomorphic processes and human activities, and is encountered in deductive modelling of slope development.

These 'point' characteristics are presented as (i) line-printer shaded maps, with the option of graph plotter contour maps in addition; (ii) histograms; (iii) scatter plots of each pair; (iv) matrix of pairwise correlations, plus circular regressions on aspect and several multiple regressions; and (v) summary (moment-based) statistics. (iii) and (iv) show up any unusual local characteristics, but confirm that in general the five basic characteristics have little relation to each other, except that gradient is usually a quadratic function of altitude. It is suggested that previously used geomorphic indices can be expressed in terms of one or several of the statistics (v), and that this routine analysis of an altitude matrix is of considerable practical as well as geomorphologic value.

A comparison is made with other approaches, such as spectral analysis and fractal modelling. The long-distance persistence properties of terrain mean that considerable extra variance at long wavelengths is usually incorporated when the study area is extended. Hence, for example, the autocorrelation function varies with the length of series or size of area studied. Variances of derivatives are also affected, but means, skews and kurtoses are not: derivatives are more sensitive to grid mesh than to size of area.

The statistics proposed are replicable in respect of different grid incidences, except that higher moments of convexity (especially in plan) are unstable because of long tails of extreme values. A grid mesh of 100m is useful for glaciated mountains, but 25m or finer is desirable for many areas. Areas of less than 5 x 5 km may be too small to provide replicable estimates of the land surface properties of a broader region. Results from eight matrices are presented. Three of these are from glaciated mountains, which are characterized by high mean and variability of gradient, high variability of altitude, positive skew of profile convexity and an excess of strong positive plan convexities.



landform development in hot arid regions  
by H. Hagedorn and D. Busche, Würzburg

A first detailed analysis of the morphology of trade-wind deserts was given by Walther (*Das Gesetz der Wüstenbildung*, 1st edit. 1900). He held aeolian processes to be most important. When Mortensen in 1927 described the Atacama desert of Chile, he developed the concept of a core desert (Kernwüste) formed by fluvial processes, surrounded by a middle desert (Mittelwüste) of aeolian activity. This in turn is surrounded by the peripheral desert (Randwüste). Zonation was found to depend on the various combinations of precipitation, wind, and evaporation. The latter was given priority for the Atacama.

Meckelein (1959) applied the concept to the Sahara, identifying the Serir Tibesti region as the core desert, determined by present-day relief-forming processes and not by characteristic landforms.

The zone of tropical trade-wind deserts, as identified by Büdel, can be subdivided at least into one central desert zone (innere Wüstenzone) and several peripheral desert zones (Randwüstenzonen), mainly distinguished by the different geomorphic effects of rainfall distribution and intensity.

Subdivision of climatomorphic zones has to depend on the identification of present-day processes and on an assessment of their overall importance in the present relief ensemble. Thus hamada, erg, serir, wadis and escarpments have to varying degrees been recognized as the outcome of modern geomorphic processes, all processes being fluvial and the wind practically unimportant as a geomorphic agent.

Detailed research shows, however, that most of the relief found in the deserts today is ancient, formed under different climates of the past, with only minute modifications following the final stripping of the soil and weathering mantle overlying the bedrock toward the end of the Neolithic period. Various relief generations also show in the regions of present-day aeolian processes such as Borkou where traces of plains formation with laterites, escarpment formation, development of incised valleys, lake deposits, and large stream-lined rock ridges formed in more than one period can be identified.

Similarly escarpments modified by large-scale landsliding (most likely in the Pliocene/Pleistocene transition period), inselbergs separated from their plains by moats down to 40 m deep, fluvial terraces in wadis and the various types of plains were originally formed under climates different from the modern one, and at various times of the past. Remodeling during the Holocene has been rather unimportant.

For the origin of plains two concepts stand in opposition: that by Büdel and others who recognizes the large Saharan plains as former tropical etchplains of pre-Pleistocene age, modified by continued formation along traditional lines (i.e. largely preserving the plains character) under arid conditions into fluvial-aeolian etchplains (Sandschwemmebenen). The opposing concept best expressed by Mensching holds that one arid morphodynamic system uniformly affects semi-arid and hyperarid desert regions. Changes in humidity only lead to gradual, but not to basic differences. Thus plains and inselbergs can be explained as the outcome of one morphogenetic sequence (morphogenetische Sequenz) formed by one set of arid-morphogenetic processes. The authors do not follow this concept.

Consequently for them the landforms commonly described as pediments are not the result of one arid-morphogenetic process. Pediments are polygenetic coalescent gravel fans overlying older rock-cut surfaces of mostly Tertiary age, which were already dissected, i.e. relictic when Pleistocene frost weathering began to supply the debris that was to blanket them in several phases of aggradation and ribbon-like dissection. If we attach the term "pediment" to these gravelly landforms they are only found in presently or at some time of the past wintercold deserts with frost action. These forms are best developed in the central Iranian desert.

In this context the thick dissected debris matles of many slopes in the desert are interpreted as the products of pre-Holocene frost weathering which, in the central Sahara, reached below 1000 m a.s.l.

At least four types of desert relief can be distinguished:

1. a "pediment" region, 2. a region of relict plains and inselbergs to be further subdivided by present processual activity, 3. an aerodynamic relief, 4. a debris-rich mountain relief with gravel-floored valleys, which in its highest parts is related to periglacial processes.

## The Effect of Base Level

Luna B. Leopold

(Abstract)

Base levels of a river or stream, whether ultimate base level (the ocean) or local (lake, dam, or resistant bedrock in the channel) affect the vertical position of the longitudinal profile only locally.

Tributary streams meet the master stream at grade or at the same elevation. It is generally supposed but rarely stated that the vertical position of the master stream, acting as a local base level, determines the elevation of all reaches of the joining tributary by its base level effect. Field data show that except for the immediate vicinity of the local base level, the elevation of various reaches of a stream is a function of local supply rate of sediment and water. A tributary may, through most of its length, aggrade, degrade, or remain stable over time even though the base level rises, falls, or remains at constant elevation.

BRITISH APPLIED GEOMORPHOLOGY: AN APPRAISAL

David K.C. Jones,  
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ABSTRACT

An important recent development in British geomorphology has been the increasing concentration on applied studies. This paper attempts to evaluate the current status of applied geomorphology in Britain by examining examples of recent work against a background of the problems that have tended to inhibit growth in the past and the prospects for development in the future. The discussion essentially sub-divides into four parts. The introductory section examines the nature of applied geomorphology and puts forward reasons why the subject has undergone such rapid expansion during the last decade. The second and third parts of the paper review examples of applied work that have been undertaken, both within the British Isles and overseas. Although growth has been relatively slow in the British context, four areas of actual or potential expansion can be distinguished: river management, coastal zone management, the identification of aggregate resources, and mapping for engineering purposes. In the case of investigations carried out overseas, the expansion of applied work has been far more dramatic. While several examples are described briefly, the paper concentrates on two of the more significant achievements; the Bahrain Surface Materials Resources Survey and recent developments in salt weathering studies. Finally, and by way of conclusion, the future prospects of applied geomorphology are examined, particularly with regard to the position of geomorphology within geography, which is a matter of current concern and debate.

Jürgen Hagedorn (Göttingen):

The periglacial belt of the mountains and its morphological lower limit

The morphological peculiarity of a periglacial altitudinal belt as an equivalent to the subpolar periglacial zone has been recognized early. Inspired by the papers of H. POSER (1933), J. BÜDEL (1937) and, especially, C. TROLL (1944, 1947) numerous German authors have investigated the position of the lower limit of this belt, which was defined by the limit of patterned ground, and its global course. Thereby especially the controversial conceptions of C. TROLL (1947) and J. HÖVERMANN (1962) have had a stimulating effect. According to TROLL this limit and the snowline are lawfully related to each other: both ascend from the polar region towards the equator, they do not attain their maximum height in the tropics but in the dry zones of the earth. Moreover, they ascend from the oceanic to the continental regions. According to HÖVERMANN the patterned ground limit has a course contrary to the timberline and snowline. It attains its lowest position in the continental climate and ascends towards the oceanic regions. The ascent from the poles to the equator is interrupted in the dry regions or here replaced by a descent. A great number of subsequent regional studies has not elucidated this controversy up to now. Their results have been summarized repeatedly, lastly by HÖLLERMANN & POSER (1977). Aspects to solve this problem seem to be rendered by the investigations of the periglacial belt in the Basin and Range Province by HÖLLERMANN (1972) and in the Argentine Andes by GARLEFF (1977). In these semiarid to arid mountains a lower belt with shallow mass displacement and miniature forms of patterned ground can be discerned from an upper belt with a stronger solifluidal morphodynamic and large forms of patterned ground. As to North America the consideration of the limit of the upper belt would support TROLL's conception whereas the altitudinal position of the lower limit would be conform to HÖVERMANN's.

In the lower "periglacial" belt the frostdynamic processes are of very little effectiveness as, among other things, compared to that of slope wash and other morphological processes in the arid zone. This applies to most of the mountains in the arid and semiarid regions in which a "periglacial" belt has been deduced from the occurrence of miniature forms of patterned ground and shallow solifluction. It is, therefore, proposed to use only the forms of deep-reaching solifluction as a criterion for a periglacial belt in order to assure a comparability between the high mountains and the polar and subpolar regions. Consequently in many arid and semiarid high mountains the lower limit of the periglacial belt would be lifted considerably or fall away at all. In addition to this morphological lower limit the lower limit of the miniature forms could be investigated further on, too, for instance for geocological questions.

A determination of the periglacial belt by relief forms of a middle scale seems to be impossible. Taluses and rectilinear smooth slopes (Glatthänge) are convergence forms of arid and cryogenic processes and are connected with distinct conditions of the relief. Stepped slopes with cryoplanation terraces are either forms on more gentle slopes or of regions of humid-periglacial conditions. Nivation forms and rock glaciers are very sporadic phenomena. The nivation forms are, moreover, contributively determined by the preceding forms of the relief and the expositional conditions. Concerning the rock glaciers which have partly been considered as indicative of a discontinuous permafrost the conditions of a periglacial morphodynamic would be overcharged. With all these forms it is often difficult to estimate the portion of past processes in their formation.

When applying to the forms of deep-reaching solifluction as determinants of the periglacial belt, in the morphological sense, simultaneously the most important cryogenic process is characterized. Nevertheless it is necessary to intensify the study of the remaining effective processes in order to comprehend the total morphodynamics of the periglacial belt.

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GEOMORPHOLOGICAL IMPLICATIONS OF ENVIRONMENTAL CHANGES  
DURING THE LAST 30,000 YEARS IN CENTRAL SCOTLAND

by

R.J. Price, B.Sc., Ph.D.

Department of Geography, University of Glasgow

ABSTRACT

Recent research has shown that there have been major variations in the environment of Central Scotland during the last 30,000 years. These changes have now been identified and set in a chronological framework. Until recently it was assumed that the last ice sheet (Late Devensian: 26,000 - 13,000 yrs. BP) was the most important contributor to landform development. This paper attempts to demonstrate that periods during which periglacial, fluvial and marine processes were at work have had a great influence on the development of landforms in the area.

The main changes in the environment are briefly described and the implications of these changes in terms of the type and rate of operation of geomorphological processes are discussed. It is concluded that many glacial landforms may have been considerably modified by other subsequent processes. The importance of obtaining more data on post-glacial erosion and sedimentation rates is stressed.

25.000 Beginn  
18.000 Max.

15 - 13.500 fast sicher wie heute  
Polen u. marine Formen  
Kendallung.

GEOMORPHOLOGISCHE IMPLIKATIONEN VON UMWELTVERÄNDERUNGEN  
WÄHREND DER VERGANGENEN 30.000 JAHREN IN MITTELSCHOTTLAND

R.J. Price B.Sc., Ph.D.

Neuere Forschungen haben gezeigt dass grössere Veränderungen in der Umwelt während der vergangenen 30.000 Jahren in Mittelschottland stattgefunden haben. Diese Veränderungen wurden nun identifiziert und in ein chronologisches Rahmenwerk gestellt. Bis vor kurzem wurde angenommen, dass die letzte Eisschicht (Spät-Devensian: 26.000 - 13.000 Jahre B.P.) das wichtigste Element in der Entwicklung der Erdoberfläche war. Dieser Artikel versucht darzustellen, dass Perioden periglazialer, fluvialer und mariner Vorgänge einen grossen Einfluss auf die Entwicklung der Erdoberfläche in dem Gebiet gehabt haben.

Die hauptsächlichsten Veränderungen in der Umwelt werden kurz beschrieben, und die Implikationen dieser Veränderungen im Hinblick auf die Art und Geschwindigkeit der geomorphologischen Vorgänge besprochen. Es wird gefolgert, dass viele glaziale Erdoberflächenformen durch andere nachfolgende Vorgänge wahrscheinlich bedeutend verändert wurden. Die Wichtigkeit, mehr Angaben über post-glaziale Erosion und Sedimentation zu erhalten, wird hervorgehoben.

Sea level - Höhe mit Mäher → Stärke d. Meerespiegel-  
Erwartung??

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Sea level-Höhe mit Mehl → Stärke d. Meerespiegel-  
erhöhung??

BRITISH-GERMAN SYMPOSIUM, WURZBURG,  
SEPTEMBER 1979

Soil Loss Estimation for Land Development

Michael A. Stocking  
University of East Anglia

Abstract

Soil loss estimation is a necessary adjunct to the design of appropriate conservation practices and land development in general. Geomorphologists have not been notably successful in extending either detailed process studies or semi-quantitative geomorphological survey to the particular needs of the land planner in assessing development potentials.

Land development requires inputs that are rapid to utilize but flexible. Current soil loss estimation techniques are cumbersome, have a large data requirement and are inflexible to changing agricultural practices.

The Soil Loss Estimation Model for Southern Africa (SLEMSA) is examined in the light of the special criteria necessary for land development planning. SLEMSA meets most objectives more successfully than other methods but retains weaknesses such as lack of common agricultural baseline data that limits its potential use.

Development in tropical and poorer countries relies increasingly on the integration of specialist disciplines with a broader, largely economic, base. Geomorphologists could have an important role to play in soil loss estimation through the refinement of methodology and technique, provided that their input is compatible with the needs of development.

BODENEROSIONSCHÄTZUNG FÜR DIE GELÄNDEERSCHLIEßUNG

M. A. Stocking, University of East Anglia

Die Bodenerosionschätzung ist ein wesentlicher Beitrag zur Entwicklung geeigneter Konservationspraktiken und zur Geländeerschließung im allgemeinen. Die Geomorphologen konnten bei der Ausdehnung detaillierter Erosionsprozeßstudien wie auch halb-quantitativer geomorphologischer Berichte auf die besonderen Erfordernisse des Geländeplaners bei der Abschätzung der Erschließungsmöglichkeiten bisher keine besonderen Erfolge verzeichnen.

Die Geländeerschließung erfordert Eingangsdaten die schnell anwendbar und flexibel sind. Die gegenwärtigen Methoden der Bodenerosionsschätzung sind umständlich, datenaufwendig und passen sich nur schlecht an Änderungen in der landwirtschaftlichen Praxis an. Das Bodenerosionsschätzungsmodell für Südafrika wird im Hinblick auf die besonderen Kriterien, die für die Geländeerschließung erforderlich sind, untersucht. SLEMSA erreicht die meisten Ziele mit mehr Erfolg als andere Methoden, weist aber noch Schwächen auf; so z.B. ist seine Anwendungsmöglichkeit durch den Mangel an allgemeinen und grundlegenden landwirtschaftlichen Daten beschränkt.

Die Geländeerschließung in tropischen und ärmeren Ländern beruht in zunehmendem Maße auf der Intergration der Fachdisziplinen und einer breiteren, weitgehend ökonomischen Basis. Die Geomorphologen könnten durch die Verfeinerung der Methodologie und der Techniken bei der Bodenerosionsschätzung eine wichtige Rolle spielen - vorausgesetzt, daß ihre Leistungen den Erfordernissen der Geländeerschließung angemessen sind.

M.M. Sweeting  
University of Oxford

This paper will discuss recent developments in the study of tropical karstlands. We have revised our notion of karst in the tropics since the classical work of Herbert Lehmann in the Gunung Sewu. In addition to the new explorations and discoveries of karst in the Tropics, improvements in morphometric techniques have enabled the enormous variety of tropical karstlands to be assessed. Developments in geomorphological techniques have paved the way for new experiments concerning the dynamics and processes of karst areas. New petrological knowledge has thrown light upon the solution and depositional mechanisms of carbonate rocks and demonstrated some of the influences that diagenesis of limestones has upon the development of karst landforms.

New morphological models have been produced (which are not so very different from Grund's 1914 model); but from individual studies it is quite clear that lithological variations and geological history are of paramount importance in karst development. A recent study of tower karst in Sarawak in Borneo, highlighted the paucity of climatic data available for equatorial and tropical latitudes; if we are to assess the true influence of climate upon tropical karst origin, then we need much more climatic data. We also need such data to ascertain whether the present tropical karst is to any extent a relict of the Quaternary period.

M. M. Sweeting, St. Hugh's College, Oxford

Diese Abhandlung befaßt sich mit den neuen Entwicklungen im Studium tropischer Karstländer. Seit der klassischen Arbeit Herbert Lehmanns des Gunung Sewus haben wir unsere Vorstellung von dem in den Tropen zu findenden Karst geändert. Außer den neuen Erforschungen und Entdeckungen von Karst in den Tropen haben Verbesserungen in der morphometrischen Technik es möglich gemacht, die sehr große Varietät tropischer Karstländer abzuschätzen. Entwicklungen in der Technik der Geomorphologie haben den Weg zu neuen Experimenten im Bereich der Dynamik und Prozesse von Karstgebieten gebahnt. Neue Kenntnisse in der Petrologie haben Licht auf die Lösungs- und Sedimentbildungsmechanismen von Karbonatgesteinsmassen geworfen und einige Wirkungen der Diagenese von Kalkstein auf die Entwicklung von Karstlandformen dargelegt.

Neue morphologische Modelle sind hergestellt worden (die eigentlich nicht sehr viel von Grund's 1914 Modell abweichen); aus Einzelstudien ist es aber ganz klar geworden, daß für die Entwicklung von Karst lithologische Variationen und geologische Geschichte von allergrößter Bedeutung sind. Eine neue Studie über Turmkarst in Sarawak in Borneo betonte die geringe Zahl von vorhandenen klimatischen Angaben für äquatoriale und tropische Breiten; wollen wir die wahre Wirkung von Klima auf den Ursprung von tropischem Karst abschätzen, sind viel mehr klimatische Angaben nötig. Solche Angaben brauchen wir auch, um festzustellen, ob der gegenwärtige tropische Karst in irgendwelchem Grade ein Relikt der Quartärperiode sei.



Environmental change and stream sedimentation in the humid  
tropics - a study from Sierra Leone

M.F. Thomas and M.B. Thorp

ABSTRACT

Our understanding of the geomorphological significance of Late Pleistocene and Holocene environmental changes in the humid tropics remains limited to very few locations, despite the growing body of knowledge concerning probably synchronous events in areas bordering the tropical deserts. This paper presents new data on fluvial sedimentation from the northern part of the Sierra Leone forest zone which may be interpreted as recording environmental changes during the last 36,000 years at this latitude ( $8^{\circ}\text{N}$ ). 40 radiocarbon dates were obtained from wood, and from organic clays taken from freshly exposed stream sections in the diamond fields of central Sierra Leone (the Koidu area, tributary to the R. Sewa system, and the Tongo area, tributary to the R. Woa system). The dates obtained are thought to record periods of wetter climate. These fall into several groupings: 36,000 - 20,000, 10,500 - 7,800, (6,800 - 6,000), 3,300 - 2,000, and 500 - present. No dates at all fall between 20,000 - 12,500, a period generally considered arid in the Sahara and Sahel. These periods accord well with wetter and drier phases established for the southern borders of the Sahara and with parts of east Africa. Further interpretation of these dates and of the sections containing the organic debris presents some difficulties. First, some older wood has been incorporated in later sediments, and this re-working process complicates attempts to relate the stratigraphy to radiocarbon dating, and the calculation of rates of sedimentation. Second, although vertical aggradation has occurred, a normal process of floodplain development involving lateral migration of channel sedimentation has also taken place. Details of individual sections will be discussed in relation to these and other factors.

Complex cut and fill sequences are confined to the larger streams, smaller tributaries having the form of channel-less swamps, analogous to 'dambos', containing 1 - 3 metres of mainly recent sands over a basal gravel. These basal gravels are continuous in places with stone-lines found beneath colluvium

on valley-side slopes. The contours of the sub-alluvial valley floors are irregular, and removal of the sedimentary cover during mining reveals many large granite cores beneath which are lodged both diamonds and ancient timbers (oldest 12,430). Penetration deposits of diamonds within now altered granite, found beneath 4 - 8 m. of sediment is evidence that the erosional phase was succeeded by accumulation of sediment. In the smaller headwaters the granite cores remain exposed in the floors of the swampy valleys.

The widespread occurrence of tors and corestones at all levels in the landscape, and the accumulation of pisolithic laterite on interfluvies, together with pronounced stone-lines and the formation of small 'glacis' bordering the present valleys, all point to past periods of active sheetwash and stripping of fine saprolite.

No final chronology of morphogenetic events is available but it is clear that this part of central Sierra Leone experienced important bioclimatic fluctuations during the Late Pleistocene and Holocene, and that these fundamentally affected both slope and stream processes. The more recent changes probably record the effects of human occupation, deforestation and agriculture.

Unstable Behaviour in Ephemeral Channels and its Wider Implications

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Abstract

Ephemeral channels typically exhibit unsteady morphological behaviour arising from complex response to externally imposed forces and from the exceedence of internal thresholds (3). Observations on small ephemeral channels have amply demonstrated this behaviour (4) and there have been several attempts to model it (1). In this paper a more general explanation of channel changes of this type is sought using catastrophe theory. Water discharge and sediment characteristics are used as controlling variables and morphology is expressed through changes in sediment load. Splitting is thought of in terms of sediment availability and produces a cusp-type catastrophe (5) which is mirrored in the control space by a discriminant function similar to that obtained by Leopold and Wolman and subsequently by other workers (2).

Discussion of this model considers the short term (a single storm event), medium term (depletion after a large storm) and long term behaviour as time paths (chreoids) across the manifold. Different environments are interpreted in terms of sediment concentration hystereses and the possible temporal and spatial variation of thresholds outlined.

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MODELS IN THE TROPICS

R.P.D. Walsh

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ABSTRACT

The paper first reviews and discusses current knowledge of runoff processes in tropical areas. Results of field measurements and observations of runoff processes in the volcanic island of Dominica in the West Indies are then briefly presented and compared with the findings of other workers elsewhere in the tropics. Finally a qualitative model, which stresses the key role of climatic and topographic factors (acting in part through their influence on vegetation and soil) in controlling the nature of runoff processes, is presented in an attempt to account for some of the contrasts in runoff processes in different parts of the tropics.

Runoff processes in tropical areas

Although data are few, it is clear that the importance of overland flow varies immensely in different tropical locations. In the semi-evergreen forests of the Ivory Coast (ROUGERIE 1960) and in the very high rainfall intensity environment of Queensland, Australia (BONELL & GILMOUR 1978), overland flow is both frequent and relatively widespread over valley-side slopes, whereas in Malaya (MORGAN 1972, 1973), French Guiana (CAILLEUX 1959) and the Bahia (TRICART 1972) and Amazonas (NORTCLIFF & THORNES 1978; NORTCLIFF, THORNES & WAYLEN 1979) areas of Brazil overland flow is unimportant on slopes and occurs chiefly in easily saturated slope base and channel margin locations. Throughflow has been noted in Queensland, Malaya and Amazonas, but in all three areas overland flow was mainly responsible for the storm runoff peaks of the streams. Pipeflow occurs in many tropical areas (for a review see BAILLIE 1975), but is still of unknown significance in both spatial and streamflow-generating terms.

Runoff processes in Dominica

Detailed evidence on runoff processes in Dominica is summarised in the paper. A variety of Climatic/soil/vegetational environments occur in the island. Although the whole island is humid tropical, climates range from highly seasonal on the leeward coast to perennially very wet in the mountainous interior, with mean annual rainfall varying from 1000 to around 10,000 mm in different parts of the island. Soils vary from montmorillonite clays in areas with a long dry season, to kaolin clays in rain forest areas with a weak dry season, to allophane clays in the perennially very wet areas with annual rainfalls above around 3700 mm.

Measurements of infiltration capacity, subsoil permeability, topsoil depth, soil bulk density, throughflow, overland flow and streamflow were made in an area of primary rain forest on allophane soils in an area of 6000 mm annual rainfall in the mountainous interior of the island. Less intensive and systematic observations were made in other parts of the island.

Principal findings were as follows :

1. Major contrasts in infiltration capacity, subsoil permeability and topsoil depth occur between the montmorillonite, kaolin and allophane soils of the island. The expanding lattice montmorillonite clay soils are characterized by shallow and relatively impermeable topsoils and very impermeable subsoils. The kaolin soils possess permeable topsoils of intermediate (around 10-15 cm) depth overlying a subsoil of markedly lower permeability. The allophane soils, which are of extremely low bulk density, are characterized by very deep (20-30 cm) and extremely permeable topsoils underlain by a subsoil of markedly lower but still reasonably high (15-75 mm/hr) permeability.
2. These soil differences are accompanied by contrasts in the nature and spatial pattern of runoff processes in the different parts of the island. In even moderately intense rainstorms, widespread saturation overland flow over slopes occurs in the montmorillonite soil areas, whereas in the allophane soil areas overland flow was never observed on slopes even in the most intense and prolonged rainstorms.
3. In the high rainfall area of allophane soils, two major throughflow horizons were identified. Deep throughflow occurred at the subsoil/rock interface (1½-2 metres depth); although a slow process it was a widespread and perennial feature of the slopes, apparently accounting for much of the baseflow of the streams. Shallow throughflow occurred at the A/B horizon interface and was produced by a sharp decline in permeability; although relatively fast, this type of throughflow was spatially extremely variable in importance over the monitored slope and was only an important and widespread feature in storms of sustained rainfall intensities of at least 12 mm/hr.
4. The nature of the topography in Dominica (incised V-shaped valleys with steep slopes and minimal basal concavities and valley flats) meant that channel margin areas subject to easy saturation and overland flow were small and discontinuous, contrasting with the relatively wide belts noted by workers in more mature convexo-concave topography with wide valley flats both in temperate (DUNNE & BLACK 1970) and tropical (NORTCLIFF, THORNES & WAYLEN 1979) areas. However, extensive ridge-top flat areas occur in the immaturely dissected volcanic areas and these were observed to be important sources of overland flow in intense rainfalls in the allophane soil areas.
5. Despite high rainfall intensities and frequent heavy rainfalls, the storm runoff component of streamflow in central Dominica is remarkably small (generally 10-20 % of storm rainfall); this is attributed to the high soil permeabilities and moisture capacities of the allophane soils and the infrequency and restricted spatial occurrence of overland flow.

#### Implications

1. The systematic observed decrease in soil permeability and topsoil depth with increasing annual rainfall and decreasing seasonality in Dominica partly explains two major features of the geomorphology of the island :  
(a) the tendency for drainage density to increase at a decreasing rate with

increasing rainfall and (b) the high solute concentrations of streamwaters of the allophane soil area (60-150 mg/l), which because of the very high annual runoff result in extremely high solute loads (200-550 t/km<sup>2</sup>/yr) and estimated rates of chemical denudation (100-220 mm/1000 yrs) in central parts of the island.

2. Both the Dominican evidence and the findings of other workers in other parts of the tropics indicate that very different runoff processes operate in different parts of the tropics. A tentative model is presented in an attempt to rationalize some of these differences and explain them in terms of variations in climatic and topographic variables acting through the agency of vegetation and in particular soil characteristics.

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Abstract

Investigation, over the past decade, of essentially unpolluted streams in both small and larger catchments of Devon has suggested that solute studies are a worthwhile avenue of geomorphological research.

The importance of solute studies is related to at least three factors. First, as is well recognized, the dissolved load transported by a river system is often a substantial, if not the most important, denudational loss from the drainage basin. Second, solute studies may provide an indication of the processes involved in denudation because solute levels represent a sensitive indicator of the geomorphic environment, and thirdly such investigations may also illuminate other processes operating within the landscape.

Studies of stream solutes, however, are not without problems, especially at the stage of data collection. There is a need for specific design when planning spatial surveys of solute levels, for continuous monitoring or intensive sampling when investigating flood period solute responses, and for careful design of sampling strategies when estimating solute loads.

The usefulness of solute studies is enhanced by good quality data, and solute investigations have many potential applications in geomorphological research. These include the use of spatial surveys to assess environmental impacts upon streamwater chemistry, and the detailed consideration of solute dynamics in river systems. The latter topic may be investigated in small catchments where particular solute behaviour has implications for the source and production of both solutes and runoff; or it may be studied in larger river systems where the role of different processes may be identified and modelled. Furthermore, studies of stream solutes in conjunction with other information may provide a ready basis for estimating the rate of chemical denudation and its spatial pattern over sizeable geographical areas.

Im Verlauf des vergangenen Jahrzehnts hat die Untersuchung hauptsächlich unverschmutzter Wasserläufe in großen und kleinen Wasserstauungen Devons gezeigt, daß Studien zur Löslichkeit von Wasserstoffen die geomorphologische Forschung berechtigen.

Die Wichtigkeit solcher Studien ergibt sich aus mindestens drei Faktoren. Wie allgemein bekannt, ist, erstens, die aufgelöste Ladung, die von einem Flußsystem transportiert wird, oft ein substantieller, wenn nicht der wichtigste Verlust bei der Abtragung des Abflußbeckens. Zweitens, Studien über Wasserstoffe können als Hinweis bei den Abtragungsprozessen dienen, da Lösungsschichten einen sensiblen Indikator der geomorphologischen Umwelt darstellen und drittens, können solche Untersuchungen andere Prozesse erläutern, die innerhalb der Landschaft wirken.

Studien zu Stoffen der Wasserläufe sind jedoch nicht ohne Probleme, besonders im Stadium der Datensammlung. Dazu werden benötigt: ein bestimmter Entwurf bei der Planung einer räumlichen Vermessung von Lösungsschichten, ein ständiges Ordnen oder intensives Probensammeln, wenn die Reaktion der durch die Stromflut bedingten Lösungen untersucht wird und ein sorgfältiger Plan von Sammelstrategien, wenn Lösungs Ladungen geschätzt werden.

Die Nützlichkeit von Wasserstoffuntersuchungen wird durch qualitativ gute Daten erhöht und Lösungsstudien haben viele potentielle Anwendungsbereiche innerhalb der geomorphologischen Forschung. Diese schließen den Gebrauch der räumlichen Vermessungen ein, um die Umwelteinflüsse auf die chemische Zusammensetzung des Wassers einzuschätzen und die genaue Berücksichtigung der Lösungsdynamik innerhalb von Flußsystemen. Der letztere Gegenstand kann in kleinen Wasserstauungen auf den Ursprung und die Entstehung von Wasserstoffen wie auch Abflüssen hat; oder er wird in größeren Flußsystemen beobachtet, wo die Rolle der verschiedenen Prozesse erkannt und als Modell angenommen werden kann. Weiterhin liefern Untersuchungen von Stromlösungen, in Verbindung mit anderen Informationen, eine fertige Grundlage, um den Grad der chemischen Abtragung und ihres räumlichen Musters über beträchtliche geographische Gebiete, einschätzen zu können.