

Quantificational Reductionism as a Risk in Geography and Cartography

*Instanced by the 1:25 000 Geomorphological Map of the
Federal Republic of Germany*

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*“A speech that shows the learned lord you are
What you don’t touch, is leagues afar;
What you can’t grasp, is total loss for you,
What you can’t reckon, seems to you untrue.
What you can’t weigh, possesses then no weight,
What you can’t win, must be invalidate.”*

*Mephistopheles, Faust II, Act 1
J. W. v. Goethe*

ABSTRACT: A reductionistic concept is being pursued in the 1:25 000 geomorphological mapping of the Federal Republic of Germany. Complex landscape elements with a base length greater than 100 m are broken down into partial elements and re-interpreted in terms of quantificational or abstractly defined, theoretically neutral map symbols. The genetic aspect is expressed by areal colouring. In this way it aims to achieve an interdisciplinary utilization of such information. This reduction has proved to be too drastic insofar as it gives rise to irretrievable loss of information. The claim that use-oriented, ecologically relevant information would be derivable from the GMM-25 has not been substantiated. As ecologically justifiable evaluation must also consider as its most fundamental indicators the quality and distribution of biotopes. These are not even rudimentarily included in the GMM-25. The uncontextualized blending of information units which only make sense in heterogeneous contexts to produce a single map is antithetical to the principle of subject related selection of relevant characteristics and prevents comprehension of the systematic relationships.

The underlying concept of the GMM-25, derived from an uncritical incorporation of physico-mathematical total predictability principles, leads to an irreversible renunciation of the necessarily complex constituents of a high geomorphological level of integration.

The Concept of the GMM-25

“The Geomorphological Map (=GMM) aims to depict systematically the characteristics and phenomena of relief relevant for a geomorphological and ecological interpretation as well as for a practical evaluation of natural area potentials, in scale-specific spatial differentiation and an analytically complex graphic representation in the form of an ontological regional description.” (Stäblein 1980).

The GMM is subdivided into eight levels of classification:

- topography
- slope
- steps, minor features, valleys, roughness elements,
- convexity (curvature lines)
- substrate, surface rock
- processes (current)
- hydrography
- process and structural areas

The GMM's assembly system of legend units is new: all complex forms with a basis width of more than 100 m are resolved via quantificational symbols into their relief elements and relief characteristics (Leser & Stäblein 1975). By disintegrating complex notions, which are not readily accessible to precise descriptive delimitation, into quantitatively detectable, homogeneous subsegments, the results and measurements of geomorphological field work can also be made available for computer applications (Barsch & Stäblein 1978). Thus, reduction is the underlying principle of the GMM legends. The risk inherent in reduction is that the disintegration of complex phenomena into their elements can be irreversible. The synthesis of the complex from a precise knowledge of the individual elements is therefore precluded. The question arising from this is whether it is still expedient, for the object of geomorphological research, to pursue the degree of reduction proposed in the GMM legend.

Complexity versus Exactness

Complexity is a basic characteristic of the object of geomorphological research. The form of the earth's surface is the result of highly variable interference upon different factor structures in time and space. The determination of similarities (Analogy as a Source of Knowledge; Lorenz 1974) opens the way to a causal analysis of empirical multiplexity and allows it to be classified into typological units. Starting with morphographic typologies of low predicative value one can finally arrive at a morphogenetic type at a high level of integration, embedded in a network of explanatory theories.

In principle, an empirical type is not derived from homogeneous elements but from polymorphous groups, i.e. phenomena with character-rich centres fading into gradual transitions at the edges (Riedl 1987). On account of their complex genesis geomorphological types must provide for a high degree of random variability, a fact which restricts the possible sharpness of limiting criteria. Mathematical exactness of limiting criteria can, however, only be achieved by the reduction of complex phenomena to elements at the lowest level of integration.

In the GMM-25 landscape morphology is depicted on the basis of the above-mentioned levels of information. Relief elements with a base length exceeding 100 m ($B > 100$ m) have to be depicted split up into the prescribed criteria for a given information level. This means, for example, that a roche moutonnée with a base length < 100 m would appear as a "knob" or a "field of knobs", whereas one with a base length > 100 m as dipping patterns and convexities. Glaciated rock faces are also subsumed under features with $B > 100$ m. Their dipping patterns are, however, irresolvably linked to those of the valley flanks. An accompanying upper limit of glaciation of high genetic predictability will be retained mainly at point locations protected from

erosion, such as cols or rocky ridges, and appears, if at all as a curvature line, as a broken one. Furthermore, no demarcation in respect of curvature lines of structural descent can be effected. This also goes to show that a quantitative delimitation of $B > 100$ m results in an arbitrary splitting of real, i.e. qualitative criteria. Dimensional data are of only secondary importance in geomorphology. Moreover, the resolution scale is determined by an examination of a given context. It is derived from matter in question. The reconstruction of maximum Pleistocene ice sheet thickness in the central Scandinavian Alps will concentrate on the symbol for "upper limit of glaciated rock faces" and will be able to ignore all other omnipresent phenomena of glacial erosion. On the W slopes of the Nanga Parbat Massif in the Indus Valley, however, some glacially scoured rock faces only a few square metres in area at heights below 1000 m above mean sea level would have to be indicated by their own map symbols.

Frequency and magnitude of phenomena either do not correlate at all or only negatively with their indicative or perceptive value. Evaluation of the relative importance of features can only be effected within or through the relevant relational field. Numerical tabulations without qualitative correlates to the intended subject matter are meaningless.

Dipping patterns and curvature lines are similarly questionable. Slope classifications are only interpretable in their essential aspects (erosion danger) in the light of an overriding context, as for example when the vegetation cover and climatic parameters are known. Both are absent here.

No genetic or process related answers are obtainable which could not also be derived from a study of the isohyptic lines. Profiles and dipping patterns are unsuitable for synthesis to a three-dimensional picture, such as can be realized unproblematically and to far finer definition by means of contour lines. In the GMM-25, however, topography has been degraded to a mere "service function" (Stäblein 1978) and only sporadically is able to penetrate the seven superior (and overprinted) levels of information. The arguments in favour of dipping patterns and curvature lines derive from aspects of anthropogenic utilization (engineering, road building and agriculture). The selective adoption of criteria unrelated to the discipline without the accompanying assumption of specifically relevant research insights is, however, a problematical approach whose consequences will be discussed later on.

The morphographic and morphometric symbols on the GMM-25 are genetically indifferent. The roughness of the surface relief elements could be interpreted, among others, as ripply, hummocky or stepped, whereby it remains an open matter whether stepped roughness refers to periglacial terracettes or 'sheep tracks' in the periglacial sector, and whether hummocky roughness designates limestone clints, hummocky moraine, hillocky meadows, slump, sand blown fields or frost hillocks of

whatever age concerned. The accompanying substrate characteristics are indeterminate here, as there is, according to the “assembly system of legend units”, only a coincidence but not a genetic correlation.

An exceptionally highly differentiated symbol key is provided for the substrate and subsurface (down to 100 cm beneath the soil level), having been derived from the standard of pedological mapping. From the geomorphological point of view such high resolution levels are not particularly meaningful. Whereas the predicative value of fine analyses in autochthonous substrate areas and in unstructured morainic fields is low, the unbroken ancestry of polygenetic, allochthonous substrates and their inclusion in large-scale formation cycles (geochronology) within apparently homogeneous substrate areas is of great interest. This type of substantial relational phenomena cannot on the contrary be adequately conveyed in the apt degree of differentiation by the GMM legend.

In conformity with the modular system each of the eight information levels represents a discrete unit. The individual parameters are theoretically neutral, abstractly defined (purely normative), measurable basic units, which are gathered across the whole representational plane. The relation between the information levels is provided by the coordinate axis. This is antithetical to an objective evaluation of the relative importance of landscape features. This has particularly fatal aspects, because “every interpretation of individual relief characteristics, relief elements or relief forms (. . .) (appears) against the background of a *process area*. However, for the surface area concerned, only *one* mainly complex process group is indicated – e.g., green (. . .) fluvial, i.e. formed by linear water run-off –, without differentiating between individual process components . . .” (Barsch et al. 1978). In view of the polygenetic history of any given landscape element, this undifferentiated characterization of surface processes represents a cognitive regression which on the one hand suppresses the results of discriminative genetic research and on the other hand leads inevitably to a misinterpretation of polygenetic landscape elements.

If the classic map of the Würm (=Devensian/Wisconsin) Stage Inn-Chiemsee Glacier according to Troll (1924) were translated in terms of the small-scale legend of the GMM-25, the following would ensue:

- the representation of the end moraine areas of the five distinguishable stades, of the older morainic basement between the tongue-like basins, and the ground moraine areas would have to be executed with the aid of a sevenfold violet (glacial/nival) scale, because the legend does not provide symbols for crescentic end moraines (Barsch et al. 1978)
- attached glaciofluvial accretions would have to be interspersed into the morainic area by means of a sixfold ice green (glaciofluvial) scale
- on account of their dimensions the characteristic

drumlin swarms would be represented as domed surface roughness or similarly indifferent lines of convexity against the background of glaciofluvial process colours on the one hand and morainic on the other

- differentiation between centrifugal and peripheral valley troughs, their stadial assignment as well as the representation of their partial coincidence with Recent hydrography is not possible
- periglacial moulding would have to be indicated by a purple (cryogenic) grid, e.g., superimposed on the sevenfold violet scale of the morainic complex
- this colourful mosaic would in turn be overlain by the remaining information levels, including dipping patterns and profile lines. The latter would be particularly instrumental in breaking up the young moraine ramparts into uncharacteristic lineaments, which would tend to record the accidental postglacial dissection rather than the subsidial line of the former ice margin. A definitive and unambiguous recognition of landscape elements is rendered impossible here.

The actual cognitive achievement, which as gestalt perception signifies the selection of descriptive characteristics and their synthesis to a system on a higher level of integration (Lorenz 1959), is therewith destroyed.

Dichotomy – and the Problem of False Alternatives

“Since the strongest cartographic means of expression, area colouring, is employed to represent geomorphological processes, the whole complex geomorphological detailed map is given an unequivocally morphodynamic emphasis” (Barsch et al. 1978). To assess the significance of this process-group information content, which is obviously assigned an important role, it should be pointed out that the map symbols employed are of the most general nature. Thus the column “glacial or nival” (violet) can be equally applied to the Alpine fund of erosional forms, the Quaternary accumulations on the Alpine piedmont and of NW Germany.

As a common denominator remains the criterion “produced by the action of ice or snow”, which to the present state of geographical knowledge can only be considered trivial if not even partially false.

“The paramount problem of colour selection lies in the development of a systematic, logical and interpretation-enhancing conceptual typology of process groups” (Barsch et al. 1978). The result has been a dichotomous descending classification, the so called “decision ladder” (Barsch et al. 1978, Fig 1).

Aristotle was an early ridicular of logical dichotomy as a means of acquiring significant classifications. Biological sciences have meanwhile accumulated enough negative experience to substantiate the hazards of this approach. “In this method of logical division nothing is more important than the choice of differentiating characteristics” (Mayr 1984). “Depending on the characteristics

chosen in the initial stages of differentiation, one inevitably obtains entirely different classifications" (Mayr 1984). The criteria which should lead to decisions being made between or within the five priority steps: (1. temporal, 2. natural or artificial, 3. genetic, 4. gravitational and medial, 5. aquatic) result from the analytically clearly defined medial categories, whose application is directly based on the evidence of topographical field-work (Barsch et al. 1978). Some examples: processes caused anthropogenically always signify an anthropogenically induced diversion or modification of natural processes or states. Thus the marine moulding along the North Sea coastline is modified by the current anthropogenic poldering, which differentiates it strongly from natural coastal shaping influences. The process group colours orange-red (present), grey (anthropogenic), blue (marine/littoral/lacustrine/limnic) are therefore indicated to cover the entire polder. By affirming the first priority step "present" or the second "anthropogenic" one is precluded from arriving at the final or fifth step in which the question "marine" could be answered.

90% of the terrain of the FR of Germany is anthropogenically influenced. When do we transgress the threshold of the "inessential" to arrive at priority step 3 "genetic"? In this step we are faced with the choice between "endogenous" and "exogenous". The basic prerequisites of exogenous processes are those of an endogenous nature. Starting with the spheroidal shape of the planet, the respective distribution of land masses and oceans, orogeny, through to local faulting and bedding structures, the exogenous processes constitute a superimposed system, not the fundamental one. In consideration of the time factor, the mutual interference of the two systems can produce a feedback mechanism (isostasy). But this does not even bring us to the "chicken/egg" conundrum but only, to sustain the metaphor, to the "chicken/chicken-hutch" problem, which is of course solved in favour of the hen. If logic were the criterion here, we would reach the premature end of the decision ladder at Bordeaux red (tectonic/magmatic) or reddish-brown (structural). The only admissible consideration is, however, that endogenous processes *alone* do not suffice to explain the morphology of the terrestrial surface.

Emergence — the Limits of Reduction

This brings us to the problem of emergence (Weißkopf 1977; Lorenz' fulguration, 1973), by which the interference of two independent system complexes gives rise to new properties, which can only be investigated on this integrative level and cannot be extrapolated theoretically from either of the isolated systems. The discovery of emergence in geography dates back to Alexander von Humboldt (1807), who recognized that the causes and laws governing hypsometric changes of morphology lay in the superimposition of specific variable factors.

The glacial paradigm comprises a host of emergences at various hierarchical levels: the properties of ice cannot be analysed either by considering water or sub zero temperatures alone but in the interaction of both effects. Mass balance and flow dynamics of glaciers is dependent on temperature, humidity, insolation and relief. The temporal and spatial configurations of glacial phenomena and the laws which govern them can only be comprehended by a study of their concrete expression and not by extrapolation from these basic partial elements. The interlinking of these laws governing glacial systems with the random interference of geotectonics and the astronomically varied radiation balance (Milankovitch radiation cycle, 1941) can at a higher hierarchical level lead to positive feedback systems, which manifest themselves in a cyclic recurrence of global glaciation phases (Kuhle 1987).

At the level of regional geomorphology these superimposed structures find their expression in individual morphological constellations, which take on historical dimensions through the agency of tradition.

The circular relation between highly individual morphological situations and the superimposed systems is preserved in all events. The possibility of perceiving these relations depends, however, on the level of integration which in turn is related to the intended subject matter.

The alternative endogenous/exogenous does not obtain because *both* components *always* act synergetically at the interface of the earth's surface. The decision as to which aspect of this interference complex is to be accorded greater significance rests on subjectively legitimized perception of contexts or perspective evaluation of the relative importance of individual features, and therefore is not per se "clearly definable". The question whether a mountain range is, for example, more strongly characterized by tectogenesis and its concomitant structures than by subsequent glacial moulding has to remain open.

From the point of view of a geomorphologico-palaeoclimatological survey only the glaciogenetic aspect can be emphasized. On the other hand, particularly the differential consideration of interference between structural basements and forms of glacial erosion can supply the criteria for discriminating structurally conditioned types of glacial erosion and their convergence phenomena.¹⁾

Glacial moraine complexes in North-West Germany can have been reworked postglacially by nival, periglacial, fluvial, aeolian, marine or tectonic processes in any number of permutations and intensities. If the emphasis of the enforced dichotomous decision is laid on the original source of the allochthonous material and a "predominantly determinative" (Barsch et al. 1978; where is the decisive criterion to be found? When is cryogenic moulding predominantly more determinative than subsequent fluvial dissection?) process of moulding (the combination of more than two colours not being

possible), then the outcome is, e.g., glacial/cryogenic (violet/light purple). If one now compares such North-West German morainic complexes with the Recent or Sub-Recent Alpine Glacial/Periglacial region to which the same symbols have to be applied, one can recognize only a very remote, hardly still partial, rather definitorial than evident "homology", which is overlain with comparatively dramatic differences. (It is no coincidence that the elucidation of the genetic parallels mentioned here has taken more than 100 years of systematic research). On account of the genetic indifference of the symbols in the remaining seven information levels it is however impossible to reconstruct the foundations of this homology or the causes and nature of the phenomenological difference from a study of the map.

A hummocky glacial relief can be substantiated by roches moutonnées or moraines and can be angled by periglacial drift mantles or a covering of sand dunes into a false homology of accumulative genesis. The compulsion to make dichotomous decisions therefore amalgamates polygenetically moulded terrains into apparently homologous units. Instead of representing morphogenetical complexes and the regional characteristics resulting from their spatial interference and temporal chronology (Principle of geographic change of morphological regions as the basis of regional geography according to Lautensach 1952), we obtain a stereotypic grading of landscape structures with a great loss of information.

The foundation of this reductionistic approach is a formal orientation to an ideal of total predictability which only proved successful in classical physics. The reason for this is that it consists of a factor analysis at the lowest level of integration under experimentally controllable boundary conditions. The uncritical adoption of alien methods in biology (which is comparable to geomorphology by reason of its typological and historical approach) has frequently resulted in more handicaps than benefits (Mayr 1984). One typical example from the field of geomorphology is the attempt to apply Markov chains.

Markov Chains in Regional Geomorphology?

Markov chains describe the conditional probability of transition with stochastic distribution in closed systems. The transition probabilities are arranged in a matrix. According to Ståblein (1984) this model is applicable to numerous aspects of regional geomorphology: "By viewing the relief types as states in an otherwise invariant system, one can deduce probabilities from one state to the next of the various relief developments, and these can be arranged to a matrix of transition probabilities. Generally speaking, certain types of transition sequence will predominate. Thus the Markov property is achieved, i.e. the dependence of a state on the immediately preceding state." The latter statement is false by virtue of its triviality, since every subsequent state is dependant on its

predecessor. But here the claim is made that the transition probability is exclusively determined by the immediately preceding state of the system, i.e., it must be "memory-free" (Ashby 1964). This quality is seldom achieved in geomorphology, however, on account of the mechanistic/material fixation of morphological processes (e.g. in contrast to ethological structures). If one generates a matrix of random distribution of rockfall at the foot of a rockface, it results in an increased probability that a debris particle will be deflected to the periphery the greater the accumulation of debris in the direct line of fall. The direction of deflection and plane of deposition of a given particle are determined by the number and deposition location of its predecessors. As the talus cone increases in height the surface area and curvature radius of the scree cone mantle changes and with it, e.g. the number of debris particles that can lead to a change in the direction of deflection. This leads to a continuous change in the transition probability versus time. Feedback systems of this nature are typical of geomorphological processes, but they cannot, however, be correlated to Markovian processes. A suitable area of application is stochastic reaction patterns causing no material fixation or at best only very transitory fixation (without feedback), e.g. changing wind directions and the resultant wave motions on coastlines (Thornes & Brunsden 1978). The conversion of such a transition probability matrix in terms of coastline modification is, however, also contingent upon mass-movement, i.e. a permanent change in the reference system, and again is not compliant with the Markov criterion.

How does this correlate with the different types of relief? Ståblein defines relief types as "states in an otherwise invariant system", which happens to be a contradictio in adjecto. An invariant system is for example the laws of optics or geometry, which remain self-identical throughout all realizations. They possess this quality by virtue of the specifically a-historical approach: a low level of integration coupled with a high level of abstraction. Conversely, a type results from the combination of polymorphic individuals to produce domains of similarity (Riedl 1987). Variance within a given group increases proportionately with the level of integration. Types are never realized in abstract combinations of characteristics but in an individual state embedded in a historical situation. On account of the high complexity of relief states this variability is correspondingly great and the concomitant terms of reference can never be fully grasped. In order to draw up a statistically watertight matrix of transition probabilities all the transition states would have to be reviewed several times under consistent terms of reference, which is an absurd demand in view of the protracted nature of morphological cycles in geological time. The change of state from the glacial to the periglacial process regime has often been established, but is nevertheless dependant on the climatic boundary conditions and not the process sequence itself, thus precluding the derivation of a statistical transition probability from

it. This proves that Markov chains are unsuitable for apprehending either large-scale or local relief developments. Their formal recommendation (Stäblein 1984) has no place at all in geomorphological empiricism.

The contention that Markov chains provide explanatory patterns in geomorphology is symptomatic of an urge to copy mathematically exact methods without considering that there is no field of application for them in this discipline. It reflects an indoctrination to an ideal which cannot always be reconciled with our own field of research.

Utility Value or Arrogation of Competence?

One of the underlying principles of the reductionist concept as applied to the GMM-25 legend was to develop a generally accepted descriptive relief catalogue and basic terminology which would be equally useful "to our geoscientific neighbours" as to automatic data processing (Barsch & Stäblein 1978). A complex and theoretically circumscribed term such as "roche moutonnée" is thereby transcribed into the easily comprehensible information fractions: slope 10%; roughness: hummocky, hilly; surface rock: metamorphic; process: glacial/nival. The geomorphological layman should be in a position to extract the information he needs without difficulty and thus the maximum utility value is achieved for all practical evaluation purposes (Stäblein 1978).

The prerequisite for this type of use is that the various information units are standardized among themselves and thus behave identically in the various fields of reference.²⁾

Mäusbacher (1985) proposes a use catalogue for the GMM-25. Here we find, e.g. qualification matrices for calculating the use value of any desired terrain unit. The gross suitability qualification for the use category "agriculture" rests for instance on the criteria: climatic stage, insolation, cold air, useful field capacity, soil erosion, æolian erosion, trafficability; for the use category "civil engineering" (location lines) the criteria: potential hazards through geomorphodynamics, bearing capacity, frost hazards, trafficability, steps and ledges (ibid tab. 55 & 56).

The requisite information is contained indirectly in the GMM and can be made available for evaluation by means of translation instructions: e.g. Table 21 (Mäusbacher 1958), suitability of steps in laying down location lines, calculated in proportion to step heights: step height < 1 m = moderately suitable; step height < 5 m = poorly suitable; step height > 5 m = very unsuitable.

It gives the appearance of being an objective valuation method due to its factual backing, but it makes the mistake of being *totally user oriented* to the exclusion of the overall environmental situation. Under prevailing social consensus such a one-sided view may well be sanctioned, but against the background of ecological network systems it represents a totally retrograde approach.

For assessment of the gross suitability for "waste disposal or storage of toxic wastes" the catalogue is based on the substrate properties of the surface layer which were secured by sporadic drillings down to a depth of 1 m. The geological basement is never considered, and groundwater only when its table is less than 1 m under the surface of the soil. Minor injuries to the topsoil, caused for instance by grading operations, would be sufficient to allow toxic leachate to penetrate porous underlying beds and thus pollute the groundwater. It is therefore extremely questionable to deal so superficially with this aspect under the heading of "gross suitability".

The utilization map entitled "recreation" evaluates areas with natural surface water as "very well suited" respecting provision of picnic places, trails, angling and hiking facilities (Mäusbacher 1985). This gives 'scientific sanction' to the touristic exploitation of the last remaining natural biotopes which have survived the encroachments of roadbuilding, agriculture and forestry. From the point of view of the utilization map for evaluation of "civil engineering" (location lines) the GMM can grant the rating "very well suited" in the case of a test circuit for an automobile concern. From the ecological standpoint this can very well entail at the same time the wholesale destruction of a meadow landscape with its residual fauna and flora.

Every form of utilization of a landscape element occasions interference in the natural order. This is not determined only by factors listed in the GMM but intrinsically by the biotic factors as well. Land use evaluation can therefore only be made from a higher level of integration in consideration of the biotic aspect. To pronounce *gross suitability qualifications* of any kind whatsoever on the basis of the reduced information level provided by the GMM-25 represents an inadmissible arrogation of competence, which paves the way to continued landscape abuse and environmental destruction.

The quantification of partial elements of landscape structure is no guarantee of qualitative homogeneity. "The bugbear of quantification ideology is the brainchild of scientific reductionism. It rests on the shortcomings of our intuitive vision respecting the emergence (. . .) of the new qualities. The ideal that all is quantifiable finds additional support in a further inadequate adaptation of our inherited intuitive notions. This leads us to expect that we may extrapolate arbitrarily from quantitative experience, without giving consideration to change in qualitative values" (Riedl 1985). Seen in this light the utilization maps of the GMM represent an inadmissible extrapolation of qualities into a field of reference in which their declaratory value (their interpretation) becomes heterogeneous.

The explanation offered for this striving to produce "relevant statements" is the fear that otherwise "our geomorphology will be becalmed in the doldrums of an esoteric 'orchidology'" (Barsch & Stäblein 1978).³⁾

Accordingly, in several passages the claim is made that the GMM contains important ecological or geo-ecological regional information (Stäblein 1978; Mäusbacher 1985; W. Riedel et al. 1987). Landscape ecology has been defined as the interplay of abiotic, biotic and anthropogenic dependences and interrelationships (Encyclopaedia of Geography 1983, Vol. III:41). While endeavouring to attain a correct and clearly defined terminology (especially with the outsider in mind), it would have been advisable to restrict this complex term to that section of it which is actually addressed in the GMM-25, namely: the abiotic. As the very nature of reductionism avers, there can no longer be any question of ecology in such a narrow view. W. Riedel et al. (1987) provided a very revealing contribution to this problem in their commentary on the "Bredstedt" sheet of the GMM-25. The ecological field of tension herewith mediates between the agricultural, silvicultural and military utilization of the environment and the flora and fauna threatened by it. Neither the existence nor the geographical distribution of these two opposing vectors can be deduced from a study of the map: the conflict is addressed only *verbally*. The only point of reference is the structure of the substrate as a factor determining the type and extent of agricultural land use. The amount of effort put into the soil survey was correspondingly great: a total of 3000 drillings, each to a depth of 1 to 5 m, covering the entire area. This represents a standard more in keeping with a pedological survey than a geomorphological mapping operation. It thus becomes evident, too, that the genetical landscape areas are by no means congruent with the substrate areas. For this reason it was expedient to append a supplementary map to the commentary since this (and not the GMM) supplies "the greatest possible differentiation among the ecologically significant categories" (W. Riedel et al. 1987).

Discussion of the ecological situation is therefore utterly detached from the special information contained in the GMM. All the more astonishing and at the same time symptomatic is the contrived conclusion, viz.: acquisition of data of ecological importance, assignment of land use areas and the analysis of environmentally significant utilization problems can all be effected by the GMM since it identifies the relevant information systematically and comprehensively (W. Riedel et al. 1987).

Entropy versus Cognition

The GMM-25 has turned out to be a peculiar mixture of utilitarian and scientific information units. Morphography and morphometry are enlisted in the service of agronomy, civil engineering, waste disposal and recreation. Morphogenesis is relegated to a stereotype through the use of area-related colour coding and the dichotomous decision ladder that goes with it. The computer-oriented dissolution of complex landscape structures into

normative, exactly defined and quantified elements is a condescension to electronic data processing (EDP). The necessary fundamental information is not presented cohesively enough for any of these utilitarian and scientific aspects. As the choice of map symbols has been influenced by the most heterogeneous claims, they cannot be correlated in any significant way. The intended interpretation can only result from a number of different specialist contexts. Nevertheless, the symbols of all the eight information levels are overprinted on a single map sheet.

In information theory entropy (in the sense of Brillouin 1956) implies the increasingly homogeneous distribution of smallest units of information, the dissolution of ordered structures, loss of information and a transition to chaos. Knowledge is negentropy. It implies selective perception, judgement of priorities, discovery of structures – and hence of higher information contents – at various different levels of integration.

Overprinting of information from heterogeneous contexts results in an entropy increment in that those factors, which scientific cognition in the shape of gestalt perception (Lorenz 1959), as type and natural order, had dissected out of the background of chance and irrelevancy, are again destructured, neutralized and intermingled with factors belonging to a different context – but now irreversibly so through the egalitarian filter of the map symbols. It is obvious that the headlong use of computer is not going to elicit any more significant interpretations from such theoretically neutral, quantitatively homogeneous, yet qualitatively heterogeneous information units.⁴⁾ The actual object of geomorphological analysis largely defies such procedures, since it will always be inaccessible to reductionist quantification by virtue of its high level of integration.

Coordination or Compulsion to Conformity?

"Our whole civilization is being reductionistically indoctrinated through the complacent self-assessment of the 'exact' sciences and the inadmissible arbitrary extrapolation of arbitrary abstractions resulting from a lack of education for an understanding of higher levels of complexity and of the value decisions that follow them. Our scientific society has even reconciled itself to issuing sanctions against non-conformists or even resorting to open threats." (Riedl 1987). In translating geomorphological reality in terms of the symbol code of the GMM legend, numerous editors expressed strong reservations. Grimm and Schipull thereupon drew up an alternative, necessitated by the special morphological conditions prevailing in the North German lowlands with the early glacial relief of the Saale period and the Elbe urstromtal. The so-called GMM-Coordination Commission (Leser & Stäblein 1975) disallowed this non-conformist enterprise and refused to print it. Publication of the "Bleckede" map sheet was therefore executed within

the framework of the "Hamburger Geographische Studien (1983)".

The map is distinguished by its considerable enhanced readability. The contents have been separated sensibly according to subject matter, i.e. partly printed at a reduced scale in the margin. The legend pursues a genetical chronology and is therefore consistent with lending rapid transparency to origins and structural relationships of landscape elements. The typography remains adequately legible although the characteristic morphology of the moraine landscape is emphasized by means of a special convexity index grid. In the commentary (Grimmel & Schipull 1983) the deviations from the GMM legend are objectified and substantiated. An example of this is the probable influence upon glacial and glacio-fluvial morphology by isostatic and diapiric movements, which is not, however, fully explained in its local effects. In view of the additional fluvial, periglacial and æolian weathering the authors are not prepared to assign unilateral process group colours to such polygenetic landscape elements.

Another mapping venture which was started within the framework of the GMM-25 programme (Heine & Siebertz 1980) and excluded from publication, to be included in the "Arbeiten zur Rheinischen Landeskunde" (Siebertz 1980), is the "Kalkar" map sheet (Saale-contemporaneous push moraines and glacial outwash, Weichsel-contemporaneous loess deposits, holocene alluvial terraces of the Lower Rhineland plain). According to the present state of knowledge the map reveals an extremely high genetic resolution of substrate and process areas. By using area colouring to indicate temporal-genetic units a high information density, incompatible with the GMM legend, was achieved. In the GMM-25 the Rhineland lowlands would be coloured green (fluvial) whereas Siebertz makes use of an eight-fold green and brown colour gradation. Dipping patterns and profile lines, being of little significance in view of the presence of contour lines, are not represented. By rejecting egalitarian process group colours it allows a highly differentiated expression of current knowledge of these landscape phenomena to be presented.

Whereas the consistent application of the GMM-25's map symbols on the "Bleckede" sheet would lead to over-simplification and a false sense of scientific authenticity on the one hand and to a declarification of morphographic characteristics on the other, in the case of the "Kalkar" sheet the results would be an artificial suppression of current knowledge of the subject and the emphasis of inessential relief elements. Both maps provide an excellent basis for making ecologically relevant mappings of biotope areas.

An interesting comparison can be made on the basis of the "Bredstedt" map sheet (Saale-contemporaneous morainic complexes, Weichsel sandur, marshlands) which conforms to the GMM-25 ideology and was mapped by W. Riedel & Schröder (1985; appendix to W. Riedel et al. 1987). In the "morphostructural"

general map the whole complex of the Saale moraines is designated "periglacially overworked, Weichsel-contemporaneous."

In the accompanying text (W. Riedel et al. 1987) it is furthermore maintained that the entire geest (lowland heath) area has been reworked by æolian action. In the GMM-25 for the main complex of the Saale moraines the sole colour is "glacial", with sporadic, closely defined areas of blown sand. The periglacial body colour – described as "cryogenic-periglacial Weichsel-contemporaneous flushing plains" – only appears at crucial points on the outwash fields. Where it is printed on the peripheral areas of morainic deposits it is open to debate whether it refers to "flushing plains" or cryogenic overworking. Marine overworking (Eemian Sea) receives no mention at all. Weichsel-contemporaneous valley forms are simply defined as "fluvial" and therefore cannot be distinguished from Recent fluvial process areas. The broad zone of tripartite dyke construction is assigned to the process area "marine" without further differentiation, except for a grey overprinting of the dyke infrastructures, the embankments and mounds signifying their "anthropogenic" origins – just as if a polder had the same effects as a natural marine alluviation field. The complexity of the genetic-chronological landscape structure and the consequences of anthropogenic interference in natural evolutionary processes are unsatisfactorily and sometimes falsely depicted. In the interests of an unambiguous depiction of process areas, a random sample is stylized to an – unrealistic – principle, which cannot be justified out of the necessity to generalize.

It is therefore to be hoped that the alternatives to the GMM hitherto accomplished will find their way into future draught maps and that the application of the existing GMM legend will be terminated with the presentation of sample sheets.

Consequences

The proposal made here is that in future mapping projects the legend should be draughted more on the lines of a clue key than as entrenched doctrine. Especially at the outset of legend development for the preparation of sample sheets considerable leeway should be allowed for exploration of a variety of different realization methods, so that the features of a landscape unit and the current state of knowledge concerning genetic relationships are comprehended in their true scale inductively and not normatively. Priority must be given to the isolation of complex subject matter, the presentation of typological differences and emergent properties, but above all to embedding the results in a higher hierarchical level of insight and a macroframework of relationships.⁵⁾

At present the emphasis is placed on the data-technological rather than primarily scientific quantification of

results and their usefulness in terms of electronic data processing. It is however evident that a meaningful extrapolation of quantities only obtains insofar as the underlying system of coordinates is not consciously departed from. The proper discovery and delimitation of such, of necessity qualitatively defined, reference systems and reference hierarchies can never result from the routines of electronic data processing as a mere tautological transformation, but is an achievement of human ratiomorphic gestalt perception (Lorenz 1978; Riedl 1981). Only the description, at a high level of integration, and the qualitative analysis of landscape structures can point to a meaningful approach towards a cautious quantitative registration and evaluation.⁶⁾ This opens up the pathway to a concept of regional geomorphological mapping.

Notes

- 1) The dichotomy between "endogenous" and "exogenous" led, especially in glacial geomorphology, to gross errors, so that only after decades had elapsed is it now possible to recognize the dependence of glaciogenic forms in proportion to the relief energy or the rate of lift, respectively, and the bedding conditions of the rock. For example, the far more extensive glaciation of Central Asian mountain ranges, whose features are glaciogenic V-shaped valley forms, has only become accessible in the past decade.
- 2) Fields of the inclination class $> 2^\circ - 4^\circ$ are homogenous from the point of view of "inclination" but can exhibit widely heterogeneous properties in respect of erosion hazards, due to the different substrate properties in the overlying and underlying beds as well as the different plant cover and climatic conditions.
- 3) A scientific discipline cannot be uplifted in its historical validity by any amount of donkey-work but it will be totally sapped by the lack of innovative impulses in basic research. Particularly in this respect the less "applied" Quaternary research and classical geomorphology – evidenced by the major successes in climatology and paleoclimatology during the past decade – need not hide their candle under a bushel. Anyway, it is often the orchidology-type sciences which have led to breakthroughs in cognition – a fact which any programme of science promotion,

implying also the furtherance of culture in general, must take into account. After all, though Mendel's Laws were elaborated through peas, they could also have been discovered by a study of orchids.

- 4) There is no doubt that electronic data processing (EDP) has a place in physical geography, namely in geology. In this case it is a useful tool in the identification of layers for the purpose of information acquisition (retrieval), drawing up profile columns and cross sections as well as their spatial relationships (Vinken et al. 1978). This is effected by means of unambiguous, substrate-governed criteria such as particle-size ranges, index fossils or absolute datings. Although geomorphology is able to make use of such bedding profiles (e.g. Quaternary ones), they are only a means to an end and are not self-evident. The true aim is to explain morphogenetical complexes, and in this respect there are *no* hard and fast criteria which are valid for any number of locations, but a necessary mutation in the hierarchy of characteristics by virtue of the respective higher-order macro-contexts. Plotted descriptions of linear relief facets for easy digestion by EDP as proposed by Barsch & Stäblein (1978) are of absolutely no interest to geomorphology as no distinction is allowable between the typical and the coincidental in them. Practical applications are also ruled out since the biotic element has also been omitted. This is another instance of method borrowing without ascertaining whether the structures of the various areas of application are analogous.

The same applies to biology, where plants can be identified by means of their chemical substances, but where, however, genetical classification does not possess the same unambiguous indicators. "Objective" methods, such as numerical phenetic systemology, therefore also fail on grounds of the heterogeneity of phenotypical characters as indicators of genetic relationships (Mayr 1984). Biology is at an advantage in having the individual as a sharply defined unit uniting all the essential characters in itself (as a pendant to the geological layers). But the geomorphological "individual" first has to be distilled out of a continuum as a genetic type or process element, constituting a relational phenomenon of an entirely different spatial order. Theoretically – neutral, platted descriptions of linear relief facets (Barsch & Stäblein, 1978) possess the same cognitive value as an EDP-dedicated, histological microtome series, arbitrarily cut through the body of a chicken, would have for elucidating the phylogeny of the *Phasianidae*.

- 5) For example, comparable map sheets of NW Germany and the Alpine piedmont area should make it clear that they depict inland ice marginal areas and denticulate marginal areas of piedmont glaciation, respectively.
- 6) This not only applies to geomorphological maps but also equally to mapping that is truly aimed at ecology and therefore necessarily based on a record of the vegetation cover.

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