

## The Problem of Historicity in Physical Geography\*

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**Abstract:** Historicity forms for logic the direct antithesis of regularity. In recognition of this dialectical premise physical geography has attempted to remove the historical contingent element of its phenomena in order to emphasise the regularity, and by so doing legitimise its status as a scientific discipline. This has resulted in a schism between empirical knowledge and the accepted theoretical structures. The regularity of geodynamic processes is apparent only on the basis of contingent clusters that in their essential characteristics are subject to historical change. Analysis becomes therefore a question of attribution, reconstructing individual clusters of causal determinants, each cluster being described as an individual outcome rather than the embodiment of necessary laws. The concept of the historical within geography must be clearly separated from the pseudo-historical development concept, as employed in relation to the theory of “deterministic chaos”. The scientific methodological problem, present in geography because of the incongruence between the logical assessment and the empirical subject matter, is here considered as the basis for the application of the evolutionary epistemological theory which not only recognises this incongruence but also clarifies and makes explicable its origin.

### 1. History with a System – a Methodological Paradox, that is to Say “Retrogressive Prophecy”

Recognition of the sudden breaks in continuity, *discordancies* in the stratigraphical sequence, and in their fossil record, led to the focussing of attention on the history of the earth (Stensen 1669, “stratigraphical law”; Cuvier 1812, “catastrophy theory”). From the repetitive overlaying and interdigitation of plutonic, marine and terrestrial rock beds, accumulation and erosional forms Hutton 1788 (1788, 1795) concluded there was a *cyclical interdependence* in the temporal succession. Linked with the “Aktualitätsprinzip”, formulated in 1822 by v. Hoff (1822–1841) (and further developed by Lyell 1830–33 as the “principle of uniformitarianism”) earth history was interpreted as the result of the operation of regular normative processes. The revision of the index-fossil concept within the paleontological paradigm, a revision made inevitable by Darwin’s publications from 1859 onwards, had at first no influence on thinking regarding inorganic change. Lyell stated firmly in 1872 that the natural scientist’s “reliance need not be shaken in the unvarying constancy of the laws of nature, or in his powers

of reasoning from the present to the past in regard to the changes in the terrestrial system, whether in the organic or inorganic world, provided that he does not deny, in the organic world at least, the possibility of a law of evolution and progress” (Lyell 1872, vol 1, 171). In time however the systems model approached ever closer to cybernetic circular law and backcoupling concepts that, as an aspect of a temporal sequence, led necessarily to the introduction of an evolutionary dynamic into physical geography. Similar to organic evolution there is reference now to “self-organising intermeshed geocodynamic systems”. With the premises of the now-fashionable systems approach, applied to historical phenomena, the concept of self-organisation acquires inevitably a functional element which although intended in a causal deterministic sense cannot escape entirely a teleological aspect. Darwin’s evolutionary theory offers an interesting parallel. The functional equivalent is “natural selection”, a concept that Darwin originally understood as metaphorical (Darwin 1859: 47) and defended against later critics as a figurative term used for brevity (Darwin 1876: 66). To be effective selection required as a starting point an “advantageous modification”. This meant that both the positive characteristic and its selection were closely linked in a reflexive definition: selection was of advantageous modifications, advantageous modifications were those

\* The authors gratefully acknowledge the translation of this paper rendered by Prof. Dr. E. M. Yates, King’s College, London.

selected. This had as consequence an inability on Darwin's part to explain the one clear characteristic of a "good species", that is reproductive isolation, since this was seen in terms of natural selection as a negative characteristic (1876: 258, 273). The metaphorical usages, implying necessarily the concept of a *directed force* (Darwin elsewhere draws a parallel with the attractive force of gravity in physics, 1876: 439) proved an hinderance. The need to explain the contemporaneous existence of diverse species by natural selection was lost sight of, and Darwin was prevented from recognising the importance of an initial (geographical) isolation of populations (migration theory) in the establishment of species (Wagner 1868) (see Mayr 1984: 451).

It is possible that a concept such as "self-organisation", employed in geography, has more of an obscurantist effect than promoting a clarification of points of methodological insufficiency. Again the question has to be asked as whether the *paradoxical mediation* of historical change and a systematic structure of laws in geography is generally considered and understood. Obviously it would be desirable to treat the whole of geography in such an inquiry but in the following pages the main focus is on Quaternary geology (glacial geomorphology). This is because, in the first place, there is a necessity in this subject area to link basic theory with *authentic empirical evidence*. In the second place Quaternary glacial dynamics appears to be very suitable to demonstrate the problem. The glacial phenomenon has a paradigmatic character in the systems approach, and model building is widely developed. On the other hand it can be shown that from the view point of *historical* climatic change (Ice Ages) the systems approach is a methodological obstacle.

## 2. 'Christoferens' Columbus - "neither Logic nor Mathematics"

In the intellectual scroll of geography the activities of Columbus have a double significance: not only did he "finally lift the veil behind which for thousands of years the other half of the earth had laid hidden" but also, as Alexander von Humboldt further emphasized "the success he brought about" had been "a conquest by reason" (cited by M. Lequenne 1992, p. 175).

Later critical investigation of the available archive has occasioned a decisive revision of this evaluation, the consequences of which are best expressed in a sentence of Columbus himself, that is to say "in my completion of the West Indian undertaking I was helped by neither logic nor mathematics: what happened corresponded exactly to the prophecy of Jesaia." (after M. Lequenne, 1992: 116). The vexation for geography as a science stems from the fact that not only one of its great innovations was built on a completely irrational basis, but also that by following a logical argument, as would be felt necessary, the discovery would not have taken place. The "Junta dos Matemáticos" to which Columbus had to present his project for a westward journey rebuffed him not because they believed

the earth to be flat - knowledge that the earth was a globe was generally accepted as a tradition going back to Aristotle - but because they differed as to the circumference of the globe. The Junta accepted as correct the calculation of Eratosthenes from the 3rd century B. C. that the circumference was 39,700 km, very close to the true value, whilst Columbus - using an incorrect conversion factor - based his calculations on the estimate of only 30,044 km (O. Gingerich 1993: 86). In his defence Columbus appealed finally to the bible and to a secret sense of mission (which allowed him later to write his name as Cristoferens = Christum ferens, that is to bearer of Christ in the sense of a divinely inspired agent), an argument the mathematicians rejected or found blasphemous.

From the view-point of scientific reasoning the Junta was correct, but empirically Columbus, after a journey of 3000 miles in 33 days, made landfall, as he had predicted (Gierloff-Emden 1992).

## 3. "Potentia Dei Absoluta" - "Potentia Dei Ordinata"

In the history of the discovery of Central America and the later reinterpretation by v. Humboldt the basic situation of geography is well exemplified. Its subject matter is distinguished by a high level of contingency in its composition, the "interesting" facts are established fortuitously. At the same time, to meet the demands of a science the same facts have to be brought into a rational system of laws. The lack of correspondence between logic and reality was particularly obvious in geography from the beginning. Eratosthenes of Cyrene (284-c. 205 BC) chose for the discipline the term "geographia", that is to say the description of the earth, rather than the science of the earth. He developed the first methodology to lift geography beyond the Herodotus style of travel writing, with its subjective narrative of notable features, and to give it an order, even if this order were still completely external. The basic concept was to employ the mathematical regularities, long and widely developed in astronomy, in a reverse projection back to the earth. His use of this principle in the measurement of the earth's circumference (as 252,000 stadia = 39,700 km) is well known. Building upon the results of previous attempts Eratosthenes proposed the cartographic presentation of the earth's surface by means of a co-ordinate network of latitudinal and longitudinal lines crossing at right-angles, the locality of which was precisely defined by reference to planetary regularities. The scientific approach of geography was therefore not a system of laws governing the phenomena of its subject matter, but solely their exact location within a conventional reference system, the scientific aspects of which were borrowed from astronomy. The developments towards "modern" geography, as by A. v. Humboldt for example, consisted essentially of an extension of the co-ordinate system to include, on this occasion, physical parameters (boiling temperature of water as an indication of altitude, air

humidity, wind speed, temperature, gravity anomalies, magnetic fields etc). Subsequently however the argument was inverted, and the mere determination of physical standards was expected to provide the tool for the discovery of natural laws in geography. The methodological change from a “narrative” scientific inventory, of which the scale and number are solely of assistance in orientation, to a quantifying reductionism, and then from measurement to laws and from laws to causal explanation and prognosis of geographical reality has remained current until the present (Kuhle 1989b, 1990 and 1991b). The still-unvoiced basic postulate, that this development must serve to legitimise, is however that contingencies, historicity, exist in geography only as stochastic intrusions, *not themselves* as causal determinants included in the system of laws.

The paradigm for this conflict over the possibility of a congruence between the reality provided by history and the rational manageable regularity derived from that reality was established much earlier and on a higher level of thought in western theology. The empirical and theoretical positions then established provide a valuable comparison for geography. The tension that accompanied the discussion resulted from a confrontation of the conceptual analytical syllogistic approach of Greek philosophy with the salvation doctrine and revelation based approach of the Judaic-Christian religion. From this antithesis stemmed a century-long attempt to mediate, the culmination of which was the “summa theologica” of St. Thomas Aquinas (c. 1225-74). In his view there can be no contradiction between revelation and reason since both emanate from the same source of truth, that is to say God. Historical revelation, as for example in the New Testament, must therefore serve as premises in syllogistic deductions to establish the truth. This thesis of a “forced congruence”, that is “if human logic is *correctly* used, then it *must* agree with historical reality” was opposed by William of Ockham (1288–c. 1349) who set against it the radical contingency of reality. The comprehension of regularity was possible only by the medium of an abstract conceptual logic. That “which actuality has become” cannot be traced by means of this logic for that traced would bear solely a completely abstract duplicate relationship to reality. The creation by God of reality is outside logic (*potentia Dei absoluta*), but the continuity of that created allows for the induction of the current order (*potentia Dei ordinata*). The Almighty is not bound by this order, but can at will replace it. These breaks in the continuity of order mankind can only accept, that is to say believe, but neither understand on the basis of contemporary experience nor prognosticate. Historical reality and the logical comprehension of reality cannot be brought into congruence. For geography as a science dealing both with the facts and with the causal order of structures of terrestrial processes derived from those facts there is here an analogy in the juxtaposition of two epistemologies. One side is “Thomistic”: the processes of earth-history, and their position at any given moment of time, accord with a causal deterministic order, which can be completely delineated by human logic, and used with an exact

knowledge of tendencies in successful prognosis (conquest by reason). Historical contingency can only be considered a variable non-constituent factor, defined as noise in the system. On the other hand is the “Ockhamist” position<sup>1)</sup>. Facts in geography are primarily a matter of historical contingency, and can only be reconstructed after the event (that is Central America was *first* accidentally discovered, and *then* logically embraced in the system, that is to say understood as islands and an isthmus between two continents). The possibility of prognosis is limited to a paradoxical suspension of history, treating the historical factors as invariable.

#### 4. Established Doctrine on the Basis of Quantity

The teaching of Thomas Aquinas was accepted as doctrine, as canon, by the Roman-Catholic church in 1323, whilst William of Ockham was persecuted as an heretic. These facts are revealing of a basic phenomenon, to which Jacob Burckhardt applied the term “hieratische Stillstellung”, meaning an hierarchical proscription of discussion, and the establishment of a fixed body of dogma (1868/71: 307). Thomism came to occupy the seat of absolute truth (theology as a science) for an elite caste (correct use of logic). It was a suitable body of dogma to legitimise the claims for absolute power made by the medieval Papacy. In contrast Ockham individualised belief, and protected it from the clutches of the Papacy and declared temporal politics as basically discussable and amenable to historical change.

A canonised fixed dogma, a lack of debate, occurs when certain questions are removed from official indulgence, and replaced with absolutely-binding definitions, setting out what is right and what is wrong. On the one hand an orientating structure is thus obtained, but at the expense of investigative knowledge, with on the other hand a stagnation in learning.

In the natural sciences the appearance of fixed dogma is generally associated with conceptual definitions such as “absolute space” in mechanics or “specific constancy” in biology. In the same way an attempt is made in geography to treat mensuration as canon in the establishment of proof. Modern cartographic presentation of geomorphological findings is constrained almost exclusively to the use of morphographic, granulometric, petrographic and chemical symbols (Kuhle 1989b and 1990). The time-consuming regional descriptive form-analysis which replaces quantified substrate tables with an exact photodocument of geomorphological phenomena and spatial arrangement is regarded as an anachronism, of little validity. The problem of quantity in geography is that which can and is measured is not always that which one wished to know. It is for example possible to reconstruct the graph of absolute temperatures for the Glacial and Post-Glacial periods, as for example in the European Greenland Ice Core Project GRIP, but unless related to a reference system the information can be used neither to establish the

causal conditions of climatic development, nor to establish climatic tendencies for the present. In fact the knowledge of the facts of Quaternary climatic change and its sequence, that is the reconstruction of a reference system which provides the essentials for the interpretation of the temperature curve, involved completely different methods of investigation. The starting point of these discoveries resulted from an incongruity, namely the existence of large granite blocks on the North German Plain and the presence of wall-like accumulations on the Alpine Foreland which could not be explained in terms of the geomorphological processes there present. Venetz-Sitten (1822, 1829) a pioneer in research of the Alps in the Ice Age started with his comparative investigations of recent glacial regions, and was able to show, that despite great morphological differences the configuration of the Foreland accumulation phenomena and the erosional forms of the valleys were analogous to forms associated with present-day glaciers. Later workers (eg B. Esmark 1827; Bernhardt 1832; Torell 1875) widened the argument and interpreted not only the Alpine accumulation features but also the North German erratics as part of the same basic genetic type, as part of the suite of glacial landforms. It was first on this basis, that is the clear distinction of genetic provenance, derived exclusively from comparative description of locational morphological structures, that the quantifying methodology was provided with a meaningful object for measurement. With the modern attempt however to see mensuration as the actual basis or means for the establishment of scientific evidence, and thus the claim for numerical standard specifications as fundamental to geomorphological proof, the discipline has lost its basis for the winning of knowledge. This basis is related to the empirical reconstruction of genetic types, and their variability. The realisation of a type is however within an historical cluster, and its value as evidence stems from the unlikelihood of an historical repetition. This point is more closely examined below.

##### 5. Incongruence - the Basis of Proof by Type

When Darwin and the Galapagos finches are mentioned one thinks of adaptative specialisation as the fundamental factor in evolution theory, quite wrongly. Darwin's argument was based not on adaptation but, on the contrary, on the *incongruence* between type and milieu; that is to say the same initial position as in research on the Ice Age where the presence of "erratics", boulders not of local origin, demanded explanation. The fauna and flora of the Galapagos Islands is overall closely related to that of the South American mainland, despite the significant climatic differences. The Cape Verde islands are very similar to the Galapagos in terms of climate and structural conditions, but are settled by a completely different fauna showing an African relationship (Darwin 1876, 369/70). After comprehensive investigations into the geographical and paleontological patterns of distribution Darwin came

to the conclusion "- that neither the similarity nor the dissimilarity of the inhabitants of various regions can be wholly accounted for by climatal and other physical conditions" (ibid. 330). With this the main argument of the creationists proving the immutability of species, namely that the extreme specialised adaptation of organisms to their milieu could be explained only by postulating local-specific acts of creation, was set aside to be confronted in turn with a need for clarification (of incongruence). According to Darwin the "Unity of Type", contrasting with the variety of environmental conditions within the range of the species could only be understood in terms of the "Unity of Descent" (ibid. 174). The distinctive features of the type result from the legacy of inherited characteristics a selection community has gained in the context of the former "Conditions of Existence" (ibid. 174). As a fixation and recapitulation of the past the characteristics of a species have become inconsistent with the present conditions (ibid. chapter 14 embryology and rudimentary organs, 402-418). Since the interference between the selection community and the milieu has a contingent rather than regular character the sequence of clusters is historically completely unique. This means "closed communities based on a common descent (are) not classes, not in any way artificial products of the human imagination, but real individual-like units of nature with an historical continuity" (Ax 1984: 34). From the coincidence and divergence of the characteristics of the type this historical process can be empirically reconstructed (phylogenetic systematics). Darwin's proof that the "Unity of the Type" is not a metaphysically conceived basic law, in the sense of a subjectively defined vitalistic or theistic principle, but the empirical correlate of an historical chain of events together with its ramifications, legitimises the use of the type concept in scientific methodology. In a more recent work dealing with the type concept Riedl made transparently clear that the basis of this claim rests on probability theory (1975). From Riedl's work it is clear that the type concept, as developed in evolution biology, can be transferred directly to geomorphology (physical geography) since it has been part of the already immanent "classical methodology" (Kuhle 1990). The claim for the scientific reliability of the type rests here on the extreme improbability that genetically distinct processes (eg fluvial, glacial, aeolian or marine) could generate identical clusters of characteristics (type forms). The "closed community of descent" of evolutionary biology as the historical correlate for the "Unity of Type" is here replaced by the "morphodynamic unit", although naturally it has to be shown that this fulfils the criterion of historicity. The "glacial morphodynamic" demands for example a specific cluster of parameter values - the average annual temperature, the hygrometric and topographical conditions - in order a glacier may form. However these parameter values cannot present by generalisation the basis for a reliable system of laws for glacier building, for they remain in status an empirical description of the cluster of phenomena at hand. Despite the fact that Mars has 10

million km<sup>2</sup> of polar ice it is impossible to speak of an equivalent "glacial morphodynamic". Because the atmosphere of the planet is 95% CO<sub>2</sub> at a pressure of 6.1 hPa this ice is only a thin frostlike layer, mostly formed from dry ice (CO<sub>2</sub>) with great annual fluctuations due to sublimation rather than melt. Since the earth's atmosphere has been subject to historical change it cannot be argued immediately, on the basis of uniformitarianism, that the dynamic of the lower Proterozoic glaciation (Precambrian) was homologous with that of recent glaciations. The conditions attaching to the existence of glaciers and the associated typological characteristics of the glacial morphodynamic are specific to each. They shape in the forms known to us a specific of terrestrial relationships, the result of a contingent historical sequence of events, that can in no way be derived necessarily from a body of physical laws. There is therefore a double analogy with the biological type concept: first the "morphodynamic type" as the correlate of an historical singularity is necessarily a part of scientific proof; second since reality provides no prototype the problem is also present here of differentiating between "typical characters" and "individual local-specific features" (that is adaptation). As the parameters for the formation of glaciers, that is the climatic factors, have a compensatory relationship (dryness by coldness, warmth by humidity) glaciers occur in maritime polar regions as well as in regions with continental subtropical climates, and are further modified in form by petrographic and topographic variations. So long as the existence of recent glaciers makes the genetic homology obvious these variations give no difficulty (cf Fig 1 and 2). The essential question of geomorphology, the reconstruction of a development, must however be reversed, commencing from the variability in the circumstances - to seek to establish the genetic identity of the original cause: only from the local-specific modified residual landforms, the accumulation and erosional features, can the existence of a former glacier be substantiated. Whilst with reference to the historical climatic data (former position of the equilibrium-line) a valley glacier a few miles long is adequate for an icesheet of many millions of square kilometers, in terms of phenotype there might be not a single characteristic that by comparison, for example of a formerly glaciated trough in the south face of the Himalayas with the region of the Laurentian icesheet, can be shown immediately to be common to both areas. A normative typical glacial characteristic, definable in quantitative terms, cannot be established on these grounds. The so-called glacial trough (Fig 3) known from the Alps, on the N slopes of K2, with extreme relief and climatic conditions, will be dismembered by avalanche ravines (Fig 4), whereas on the south slopes of the Himalayas it will be transformed to the V profile associated with the fluvial suite of landforms, or due to the dominance of geological structure otherwise altered from its characteristic form (Fig 5). Glacial polishing varies according to the petrographical basis, with sedimentaries, crystallines and volcanic rocks each giving a

different expression. The factors time and climate play an important reshaping and destructive role, so that the indicators, long subjected to frost shattering in the periglacial regions during the Post Glacial (Fig 4 and 6) are much more rapidly unrecognisable than such forms in dry low-lying continental areas (Fig 7) or even the monsoonal sub-tropics. The same is true of glacial depositional forms, as for example moraines. The petrology of the source region, the distance transported, the topography of the depositional area (valley, foreland, an old terminal basin with lakes, sea) as well as postglacial reshaping are all variables (cf. Fig 8 and 9). The only possibility of bringing the local specific "adaptive" variations to the same common denominator of glacial morphodynamic - as in biology - is the proof of an *identical locational arrangement* of the characteristics, that is a tracing back to the basic "glacialgenetic type" (Fig 10). The type permits not only the comparison of characteristics with one another as phenomological entities (which, as shown above is hopeless and corresponds to the positivist production of a quantitative standard) but also to verify their correspondence with an immanent co-ordinate network, that is to say a cluster of characteristics defined in terms of their *interdependency*. (This process corresponds with that in biology where for example the whale, bat and the naked mole rat were traced back to one evolutionary group - the mammals). If in a mountain foreland is discovered a fluvially-dissected deposit of unspecified configuration (Fig 10 No. 1), but which contains glacially-etched pebbles, it cannot at first be decided whether it is primary glacial, that is morainic, or secondary, redeposited, that is fluvial. If however, some 40 or 50 km up-valley in the mountains, on the slopes at altitudes of 900 to 1000 m above the valley floor, there are rounded erratic blocks (No. 13), and if at even greater heights further up-valley there is evidence of rock-polishing (No. 12), then a glacial origin for the deposit is probable. If similar clusters of characteristics are to be found in parallel valleys on the same mountain slope, then by means of the altitude of the catchment area and the hypothesised site of the glacier terminus, the snow line<sup>2)</sup> of the glacier can be calculated. Since the snow-line is related to the mass balance of the glacier, and is therefore a climate specific dimension, despite different heights of the catchment areas, and the sites of the terminal moraines the calculation for glaciers on the same slope must produce the same level of snow line (No. 11). If this is the case then on the grounds of a typical interdependence the glacial origin of the landforms is highly probable. The probability can be increased if it is possible to demonstrate an exposition-dependent trend of the snowline between N and S slopes of the mountains, or on a greater scale, a temperature-dependent south-north inclination, or an humidity-dependent W-E inclination. A cluster of characteristics, in concordance with such an hierarchically-ordered co-ordination network, *can be explained in no other way* other than glacial morphogenesis (Fig 11). Only on the basis of the interdependent situation of landform characteristics was it possible to correlate the glaciers of the Alpine valleys



**Fig 1** Outflow glacier of the Greenland Ice sheet on the west coast (S of Jacobshavnfjord  $69^{\circ}$  N/ $50^{\circ}$  W). Because of the very small fall not the typical closed tongue shape is formed (Fig 2 and 3) but in landscape of the gentle relief with roches moutonnées and polished shallow basins a frayed low lens of ice. Remarkable is the extraordinarily low load of detritus, and the consequent failure of lateral moraines. The ice margin is marked only by peripheral melt water run-off and the resulting fluvio-glacial deposits (outwash plains) (25.7.79, M. Kuhle).



**Fig 2** Tongue of the Tshaigiri Glacier (Nanga Parbat massif, S slope). In contrast to the Greenland outflow glacier this is fed by avalanches from the steepwalled firn hollows, and as a result the glacier ice is highly charged with detritus. In the ablation region, that is below the snowline, this debris melts out as surface moraine, and as sub- and paraglacial material, corresponding to the flow regime of the glacier, is deposited as rampart moraine. Locality 4100 m asl  $35^{\circ}11'N/74^{\circ}35'E$  (5.9.87, M. Kuhle).

**Fig 3** The “classical” glacial trough of the Hintereisferner (Ötztaler Alps  $46^{\circ}50'N/10^{\circ}50'E$  2700 m asl). In the lower half the valley shows a typical U shaped profile with contemporaneous glacial smoothing and undercutting (right above the base line). The gently sloping High Glacial polished shoulder of the trough abuts the lateral moraine below, and above merges with the crestline of the cirque level. After decades of continuous retreat the Hintereisferner, a firn basin glacier, reveals only restricted development of lateral and end moraine (6.7.81, S. Kuhle).

**Fig 4** The K2 Glacier (K2, N slope, Karakorum,  $35^{\circ}55'N/76^{\circ}30'E$ ) seen from 3670 m. Whilst the rock flanks in the middleground, during the High and Late Glacial (High Glacial = maximum of Ultimate [Würm] Glaciation) were polished by the valley-full ice stream, the evidence for this is today being removed by very effective frost-working down to the level of the present glacial surface. It is questionable, however, whether in the region of high continental cold glaciers with “block movement”, in contrast to the quasi-laminar flow of oceanic-temperate glaciers, the “classical” trough profile can be formed. A further factor is the extreme relief energy of the valleys that in comparison with the Alpine model shows a departure from the normal form due for example to the building of ice avalanche gullies and thus the dissection of the valley sides (16.9.86, M. Kuhle).



Fig 5

Glacial trough in central west Spitzbergen (Lykholmsdalen, Dicksonland, from an altitude of 220 m asl 78°39'N/15°40'E). Although overridden in High Glacial time by a kilometre thick ice sheet, and in Late Glacial time shaped by local glaciers, only the recent periglacial remoulding can be seen in these valley sides: nivation niches about the crest of the plateau feeding meltwater runnels which from knickpoints near to the base line feed into alluvial or scree cones. The striking pattern of the valley sides can be attributed to the geological petrological structure, consisting of largely undisturbed strata of Lower Permian *Spirifera* limestone, dipping SSW. The dynamic of the exogenic processes (ice sheets, valley glaciation, periglacial) has resulted only in revealing the endogenic structures, that is to say the characteristics of the different moulding processes are here neutralised by conformist adaptation to the geological base (23.7.76, M. Kuhle)



Fig 6 Late Glacial roche moutonnée in lower Sarqaqdaalen (Nugssuaq peninsula/W Greenland; 70°05'N/52°03'W, from an altitude of 365 m asl). The typical whaleback form (Fig 1) shaped by basal abrasion has been preserved, but the upper surface of the feature, here in coarse-grained dolerite, has been completely destroyed by Post-Glacial frost weathering. Proof of the glacial origin is provided by the m<sup>3</sup> rounded blocks of gneiss that as erratics litter the feature (11.8.79, M. Kuhle).



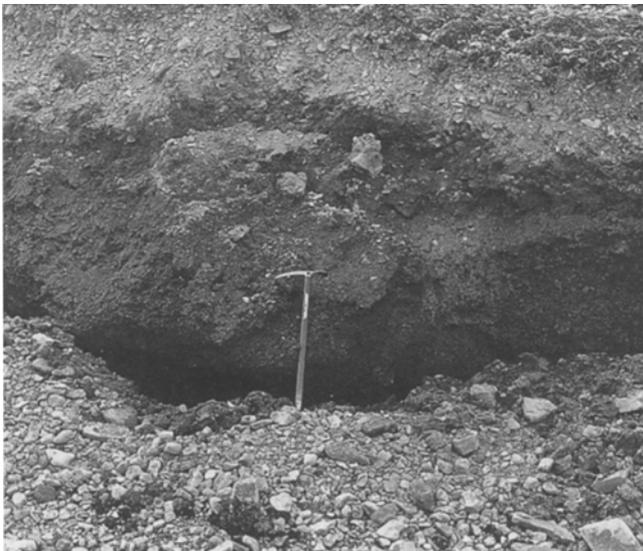
Fig 7 Late Glacial roche moutonnée in the Yarkand valley between the Aghil and Kunlun mountains on the NW rim of Tibet (altitude 3400–3500 m asl 36°24'N/76°41'E). In contrast to the Greenland example (Fig 6) not only the roche moutonnée but also the glacially-polished rock surface formed from the outcrop of steeply inclined crystalline slates (Phyllite) is preserved. Because of the extreme continental arid climate of this region (rainfall under 100 mm p.a.) it was believed until recently that the existence of Ice Age glaciers reaching such low altitudes was impossible. In comparison with the intensive frost weathering upland (Fig 4) the low altitude sites appear to be more suitable for the formation and conservation of glacial abrasion forms (27.8.86, M. Kuhle).





Fig 8 Classical ground-moraine locality at Zickerschen Höff on the Mönchgut peninsula (Rügen, from 2 m asl, 54°18'N/13°38'E). The high content of fine materials, down to the clay fraction, of the strongly consolidated matrix of boulder clay is characteristic, together with the embedded faceted blocks, some well rounded, some with rounded edges, isolated from each other. The boulders consist of gneiss, porphyr, granite and sandstone emanating not locally but from Norway, Sweden and Finland, over several hundred kilometers distant, and transported here by ice. Erratic blocks on Rügen can have volumes of up to 600 m<sup>3</sup> (18.10.91, S. Kuhle).

Fig 9 Ground moraine at the exit to Lyckholmsdalen (Dicksonland, west Spitzbergen, from an altitude of 50 m asl, 78°38'N/15°27'E). This is the deposit of a Late-Glacial valley glacier, with dominant *Cyatophyllum* and *Spriferia* limestone of local provenance. Only a few well rounded scratched stones are present: the majority, because of the constituent material and the short distances transported (at most 15 km) are at most sharp edged or with rounded edges. Fine material is rare. The stability of the material is due not to the compaction but the aggregate composition of here dissected permafrost (23.7.76, M. Kuhle).



with the main glaciation of the foreland and with the Fenno-Scandinavian icesheet. The same applies, on the grounds of its topographic and climatic position, to the long-misjudged glaciation of the Asian high plateau. The earlier evidence of large-scale ice cover, discovered at various points (Oestreich 1906; Tafel 1914; Odell 1925; Trinkler 1932) was classified on the basis of two non-specific features, aridity and sub-tropical situation, as pseudoglacial (eg v. Wissman 1959; Shi Ya Feng et al. 1981; Zheng Benxing 1988). Areal investigations since the middle of the 70s in the Himalayas, trans-Himalayas, Kuenlun, Karakorums, Pamirs, Tianshan and above all in central Tibet (Kuhle 1982–1994, cf Fig 12) have on the basis of the distribution pattern of glacial-typological characteristics shown the extreme significance of the existence of a 2.4 million km<sup>2</sup> sub-tropical inland icesheet (see Fig 13, 14). The most-recent measurements of the elevation rate of Tibet and the Himalayas gave values of 1–17.5 cm/a (17,5 cm/a Mt. Everest according to Desio 1989). Such a rate of elevation cannot be explained in terms of orogenesis, but only as a glacio-isostatic recovery as recognised in the region of the former Scandinavian icesheet, and this constitutes a further interdependent characteristic typical of glacial origins (Kuhle 1993).

## 6. Development of the Typical – Stringency far beyond Necessity

The chain of historical decisions, by which from the numerous accidentally-presented possibilities the “actual characteristics” are selected produces the improbability of an independent repetition of the historically-fixed clusters of characteristics, and thus provides the basis for a clear scientific proof of genetic identity, despite the fact such characteristics are embedded in a fortuitously variable alien milieu. But that which on the one hand as the “historical fingerprint” secures the scientific status of the type, on the other hand leaves it as unserviceable for causal analysis “– for explanation derives from a principle which must be clearly recognised or identified” (Kant 1793: 531). The type is however the premise in itself, and so can only be explained in terms of a tautological causality. Precisely because the type is the result of historical contingencies, for the reconstruction of its evolutionary stages it must serve in argument as a final focus (“focus imaginarius”) since otherwise the reduction of the “general regularity – to a particular form for which it (the general regularity) provides no logical basis” (ibid 542) could not be conceptualised. This is logically unacceptable in that the final stage of an evolutionary sequence cannot be linked in causal logical terms with the initial stage in any functional relationship. Because of the antinomy in the reasoning Kant questioned whether the type as a “transcendental idea” had a true correlate in reality, and allowed it solely as an heuristic regulator of the understanding.<sup>3)</sup> Therefore Darwin’s evolutionary theory, with its allocation of the “Unity of the Type” to a central position as evidence for evolutionary history, encountered a lack of understanding,

Fig 10

Diagram of homologous characteristics of glacial genetic types. The points 1-15 indicate typical features of a glacial landscape. Their attribution to a glacial origin is largely dependent upon their distributional pattern. When clusters of features with this pattern are met, hypotheses with reference to a glacial origin can be advanced with a high degree of probability (cf. Kuhle 1990).

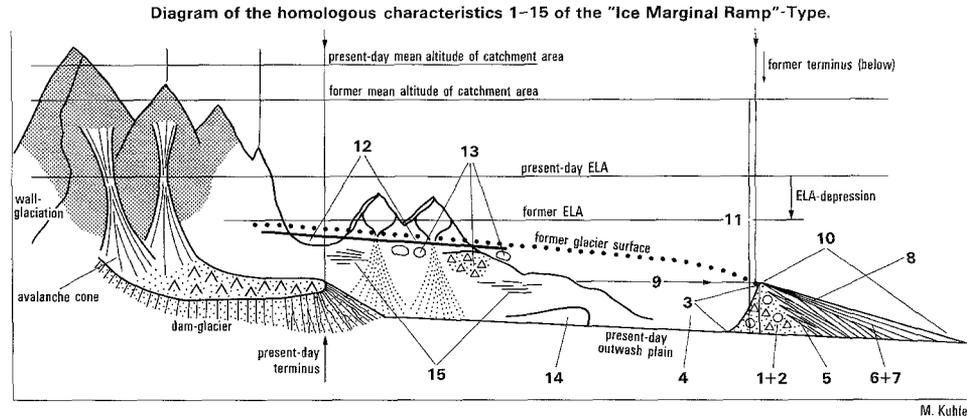
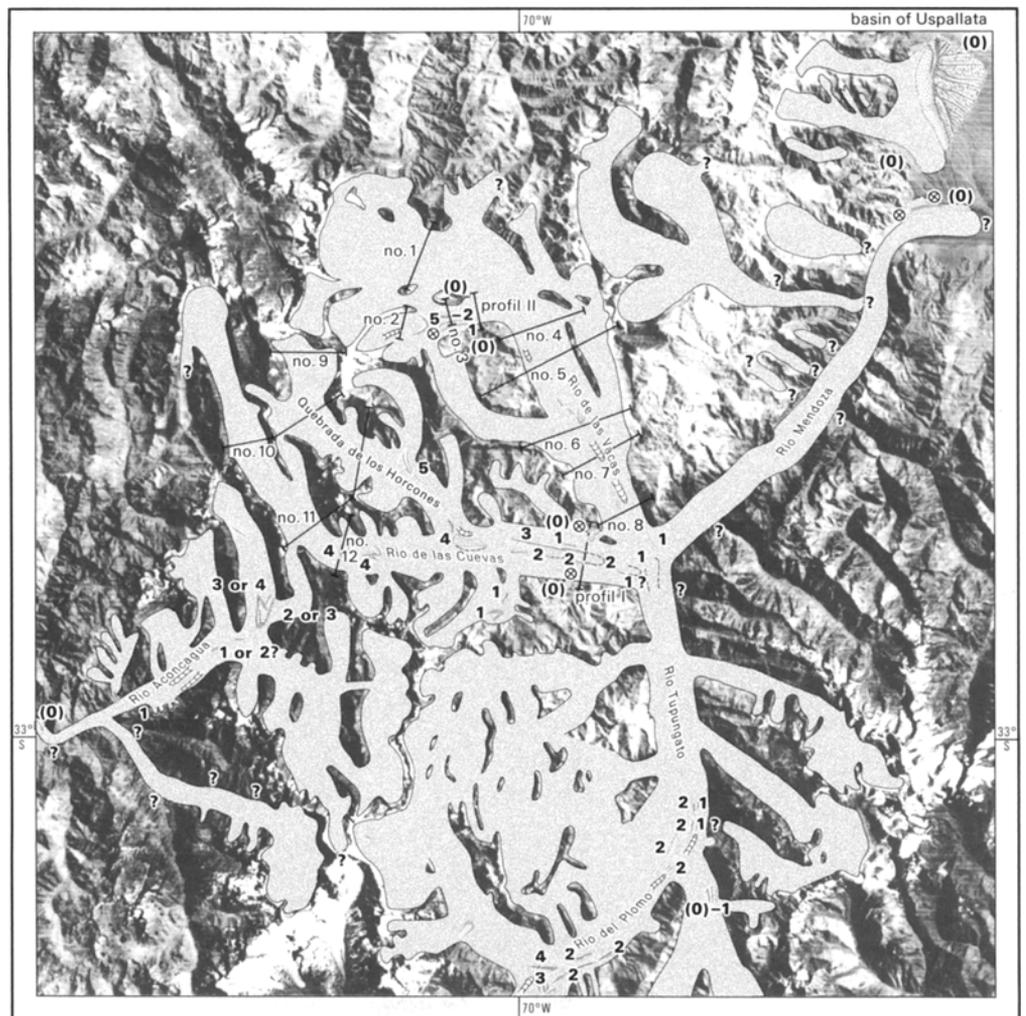


Fig 11

Reconstruction of the High Ice Age glacier cover of the Aconcagua group (subtropical South American Andes, after Kuhle 1985). The points marked with (0) locate High Ice Age indicators of the last Ice Age maximum (= High Glacial). Particularly important are the scratched pebbles in the wall-like accumulation at the exit to the valley of the Rio Mendoza (upper right). Their interpretation as glacial genetic is supported by the <sup>m3</sup> erratics to be found some 40-50 km up-valley at some 900-1000 m above the baseline (map centre, profile 1) on both sides. The corresponding polished shoulders are present in the tributary valleys. Despite the differences in scale the snowline of the High Glacial Rio Mendoza ice stream and that of the Chacay East glacier (map margin upper right, both with an easterly exposition) can be reckoned as virtually the same, that is 3435 and 3380 m asl respectively. For the Rio Aconcagua glacier with a westerly exposition, developing on the precipitation-rich luff side of the Andean chain (left margin of map) there was in the High Glacial a snowline some 450 m lower, (2960 m asl). In terms of this interpretation this ordering of indicators shows a typical glacial trend (cf. Fig 10, point 11).

- morainic ridge
  - morainic material including erratics
  - piedmont outwash apron (change from diamictite to sorted material)
  - edge of the High-glacial ice streams
  - valley cross profiles
  - profil I cross profiles with locations of moraine
  - glaciated clasts
  - (0) High-glacial (Würm ?)
  - 1 } Late-glacial
  - 2 }
  - 3 }
  - 4 }
  - 5 }
  - cirques with clearly developed floors
  - glaciated valley flanks
- Satellite images:  
 NASA ERTS E-2022-13452-701  
 NASA ERTS E-2022-13455-701  
 13.Feb.1975



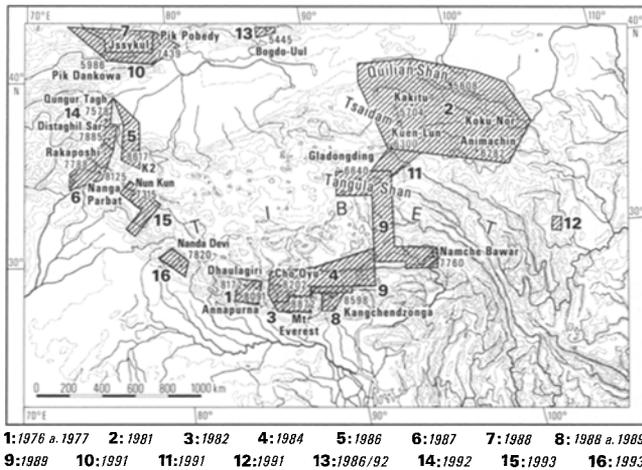
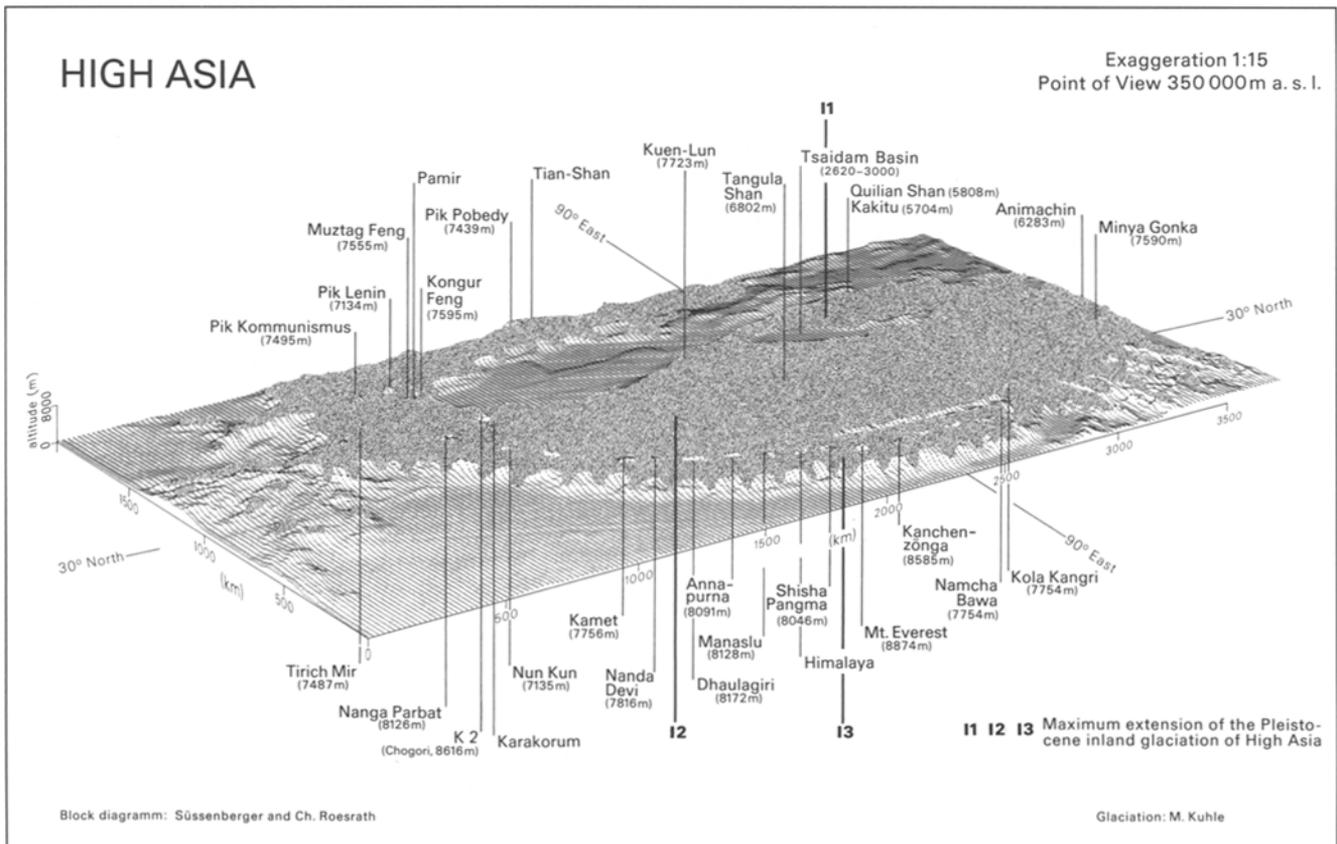


Fig 12 The research region of the first author in upland Asia. It is clear that the distribution and number of the selected areas was intended not only to increase the number of random checks but also to make clear evidence of the large-scale tendency for the inclination of the glacier snowline in recent and High Ice Age times (south-north fall because of planetary temperature gradient, and west-east fall because of continental oceanic precipitation increase).

in contrast to the response to a scientific causal-deterministic concept.

With the argument for the evolutionary process based on “natural selection” the problem can be formulated as follows: if for example a lung-breathing reptile is considered to have evolved from a gill-breathing fish then the selection for the conditions of an aerobic life had to take place in an aquatic milieu before such conditions had been generally met; that is before exposure to the selection process in an aerobic milieu, and this on the basis of the smallest variations, before these variations were able to provide the necessary functions. Darwin solved this problem by the *principle of functional conversion* (Darwin 1876: 154-157). The evolution of the lung, for example, began with selection not in aerobic conditions, but under the extreme anaerobic conditions of still waters. This forced the fish to swallow oxygen from the air and thus take advantage of the already - present double - function of the upper gut which, fortuitously, was able not only to digest food but also absorb oxygen. The double function of the upper gut became thus a positive characteristic in the selection process. Because of the specific cluster of environmental factors the overshadowed function of a

Fig 13 The High Ice Age glaciation of the Tibetan plateau and adjacent mountains. The reconstruction is based on the work of M. Kuhle between 1976 and 1993 (cf. Fig 12).

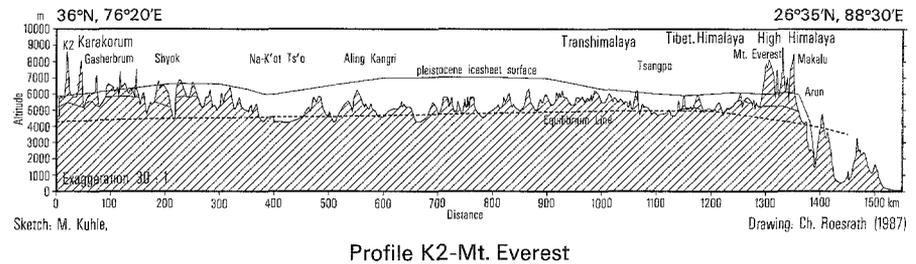


Block diagramm: Süßenberger and Ch. Roesrath

Glaciation: M. Kuhle

Fig 14

Cross-section of the High Ice Age glaciation of the plateau between K2 in the NW and Everest in the SE. The snowline runs on average at 4500 m asl and is therefore below the average elevation of the plateau, which here in W Tibet is about 5000 m. It is clear that with the establishment of an icesheet up to 2000 m thick a secondary elevation of the height of the plateau took place, so that even with a lift of the snowline by 400–500 m (Milanković effect) the ice surface on the plateau would have remained above the equilibrium line, and no deglaciation would have occurred (cf. Fig 15).



particular organ was lifted above the indifference threshold, and made accessible to further functional conversions towards meeting the demands of an aerobic milieu. The type and its denominated characteristics are therefore not in a direct line, but the integral result of selection: the typical characteristic, from the evolutionary perspective disintegrates into an historical succession of contingent selective clusters which form a unity only in the sense that each stage is dependent on its predecessor; that is to say that the evolution of the type reveals stringency, but is not causally deterministic. The *result* of the decision process and its continuity are known to us solely through the medium of an abstract typology. With respect to the questions of *origins* of an historical evolution, however, the type must be resolved and retranslated into the space-time sequence of its individual selective clusters. The aim of scientific method in the context of evolutionary phenomena consists therefore *not* in the formulation of abstract laws; rather these are solely a means towards the reconstruction of the individual – “the question of causality is, where it is concerned with the individuality of a phenomenon, not a question of *laws*, but a question to which individual cluster it has to be ascribed: it is the *question of attribution*”. This view was expressed by Max Weber (1904: 58) in relation to social science, but it can be accepted as methodological basis for disciplines involving historicity.

It becomes clear therefore that the present, and recently emphasised trend in physical geography away from the individual field study to the modular quantitative “cadastral survey”, in the hope of providing the basis for a law-governed prognostic of ecological mechanic is in antithesis to the epistemology of the subject.

Present – day climate measurements for example can only be interpreted as the elements of a long-term post-glacial climatic variation, against the background of the Pleistocene “Ice Age”. To understand the recent relationships one must reconstruct the successive steps, that is to say the *transitional gradations* (Darwin 1876: 156) of the original *historical evolution*. Nevertheless the attempt to explain the ice-age climatic dynamic began at

first, in analogy to non-Darwinian biology, from the *type characteristics* of the “glaciers”, which – as the smallest general morphodynamic complexity – were the proven basis for phenomenological reconstruction, and were hypostatised into standard values. The functional context was thus necessarily defined; in the same way as the aerobic milieu was seen as the focus for the primary impulse towards the development of the lung, so for the glaciers as primarily a climatic phenomenon the initial search was for a fall in temperature. From 1773, because of the observations of J. Walcher the dependence of glacial fluctuations on climate was recognised in scientific literature. In 1875 James Croll published his mathematical theory for the origins of the Ice Age based on the changes in the earth’s orbit (precession, eccentricity, ecliptic), a theory that as restated by Milutin Milanković (1941) remained until the 80s an essential element of practically all theories of the Ice Age (eg Nicolis/Prigogine 1987; Broecker/Denton 1990). Apart from the general lack of correspondence between the planetary radiation curve and Ice Age chronology there was a further basic theoretical deficiency in that the periodicity, with a constant repetition over millions of years, was being interpreted as the cause of a singularity of scarcely one million years duration. The so-called line of reasoning that suggested a basic correlation between the radiation parameters and the Ice Age begins with the first glacial advance of the Pleistocene without any comment on the absence of any large-scale glaciation in the previous 250 million years (Trias, Jurassic, Cretaceous, and Tertiary). Furthermore the 5–7°C depression of temperatures necessary for a glaciation was not reached by the radiation anomaly. The fact that the Milanković theory was for so long well regarded is due, in addition to its simplicity, solely to the lack of an alternative.

A completely new attempt, new also in its methodology, came from the reconstruction of a Pleistocene inland glaciation of the Tibetan upland (Kuhle 1982–1994). Paradoxically this glaciation, with a surface area of 2.4 million km<sup>2</sup> (some 0,7 million km<sup>2</sup> larger than the Greenland icesheet), took place in an area which today has climatic conditions extremely inimical to glaciation. The

average precipitation is relatively low (200–600 mm p.a.) and the Tibetan upland, with 2.4 million km<sup>2</sup> on average 4000 m asl, and in sub-tropical latitudes, constitutes the largest heating-surface of the world (Flohn 1959). From its location it follows however that present-day Tibet is only about 300–700 m below the climatic snowline. With the present rate of lift of at least 1 cm per annum the upland would reach that elevation in 30,000 to 70,000 years, and with a lift of about 300 m would shortly be occupied in large part by an icesheet.<sup>4)</sup> The atmospheric warming function (on the scree surfaces at 5100–5600 m asl on the north side of Everest with an incoming radiation of 1000–1200 watts per m<sup>2</sup> 76–85% is transformed into long-wave radiation and only 15–24% is reflected) would then be converted to an atmospheric cooling function (from an ice surface at 6650 m asl 90% of incoming radiation is reflected and lost to the warmth budget of the atmosphere). The cooling effect of an ice sheet of 2.4 million km<sup>2</sup> in a subtropical location at an altitude of 5000–7000 m asl is at least four-times greater than that corresponding to a glaciation nearer the pole at 60° N and at sea level (Kuhle 1986, 1988b, 1989a). The effect of a Tibetan glaciation on the heat balance of the earth, and this has been confirmed in the interim by computer modelling, must have led to a global depression of temperature and therefore could have

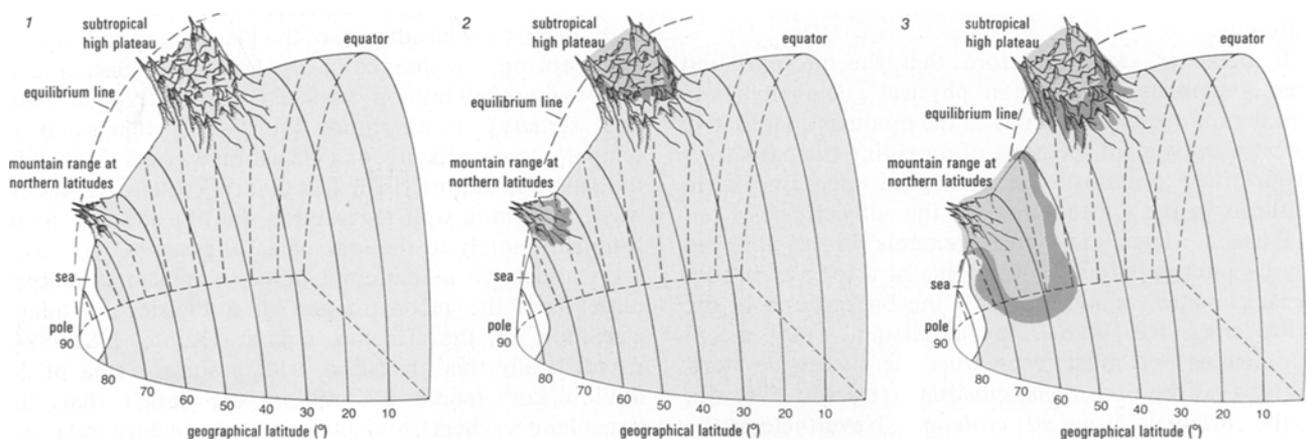
initiated the formation of the northern icesheets (Fig 15, Kuhle 1989a).

This is therefore an attempt to explain the singularity of the Ice Age in earth history<sup>5)</sup> by an adequate singularity as cause, that is the lifting of the Tibetan plateau following the secular break-up and drifting of the continental land masses.

In this Ice Age theory, the climatic cause as suggested by the glacier type concept is replaced by the orogenetic factor. Here the cause is the building of an highly specific configuration, a great plateau, high above sea level and in subtropical latitudes, and this individual cluster of factors initiated a climatic chain reaction leading to a global Ice Age. The *functional conversion* induced by the orogenesis, transforming an atmospheric warming surface to an atmospheric cooling surface is the *historical event* with which the local Tibetan-subtropical *variant of the type* led to a global “new evolution”. The causal deterministic logic of this development can only be explored historically as a *question of attribution* by the reconstruction of the contingent basic cluster of factors. The evolutionary history of the Ice Age is thus provided with a causal logical stringency but is in no way a logical necessity based on immutable laws, for “– the possibility, out of which the possible, that might become reality, has gone before, but

Fig 15 Diagram of the relief specific theory of the Ice Age.

- 1) The elevation of a large mountainous plateau in sub-tropical latitudes at first produces an earth's atmosphere heating effect as the extremely high values of incoming radiant energy are transformed on the dark scree surface to long wave warmth-giving radiation. As long as only the highest peaks reach here and there above the snowline no substantial glaciers will form.
- 2) At the moment the plateau surface is lifted to the level of the snowline the climatic regime is overturned. The glaciers advance from the peaks, covering the large area of the plateau surface: the former reception and transformation of 80% of incoming radiant energy is now replaced with a loss by reflection of 80–90%: thus the atmosphere-warming surface with a functional conversion becomes an atmosphere-cooling surface. The cooling now initiates a climatic lowering of the snowline, opening further plateau surfaces to glaciers, and bringing the mountain forelands in northern latitudes within the region of the falling snowline.
- 3) The worldwide establishment of great icesheets (Fenno-Scandinavia-Siberia-North America) produces a further cooling of the earth's atmosphere, with a back-coupling effect, on the Tibetan ice sheet, producing there the climax stage with an area of 2.4 million km<sup>2</sup>. With this maximum ice load the resulting glacial isostatic depression provided the decisive conditions for the possibility of an interglacial ice retreat. The lift of the interglacial snowline by 400–500 m (Milanković heating) led at first to the melting of the northern hemisphere ice sheet, and finally to the deglaciation of the isostatically depressed Tibetan plateau. In this model tectonic processes provide the initial moment for climatic change.



always accompanies that which has become and remains with that which has gone, even if they are separated by a thousand years" (Kierkegaard 1844: 78)<sup>6</sup>.

### 7. Absolute World Spirit in the Deterministic Chaos

In recent times, within the limits of dynamic theory, a new thesis for the explanation of development processes has been elaborated. The model is based upon a "chaos attractor", exactly defined by a basic repetition equation, the trajectory of which however subjected to unforeseen statistical fluctuations. Contingency and laws therefore appear combined in an ideal way in "deterministic chaos". Nicolis and Prigogine (1987) developed from this base a mathematical theory for the evolution of climate in the Quaternary (ibid 300–307). The evolution of the system is written in terms of the potential for two stable regimes as a stochastic differential equation. The two stable regimes are  $T_a$  and  $T_b$  (= present climate and cold period) linked by a statistical fluctuation  $T_o$ . The glacial cycle rhythm between  $T_a$  and  $T_b$  arises from the coupling to an external force (= radiation anomalies of the Milanković curve).

Apart from the fact that, as already discussed, the chronology of the Milanković curve and the Ice Age do not coincide, there is a further decisive deficiency in this thesis since it requires the transition from  $T_a$  to  $T_b$  to be of equal value as the transition from  $T_b$  to  $T_a$ . The beginning of an Ice Age is however basically different from its decline. Even if we accept that the radiation anomaly with its maximum (but insufficient) depression of temperature had initiated the building of icesheets, the then increased albedo would have increasingly cooled the earth's atmosphere. Further the 2000 to 3000 m thick ice sheets would have so raised the altitude of the surface that the return to increased radiation would have been insufficient to bring about the complete melting of the ice, producing only a shrinkage (Fig 14). According to the model of Nicolis and Prigogine earth climate would then be irreversibly fixed in an Ice Age. In these circumstances the empirically proven isostatic movement of the Tibetan plateau (Kuhle 1993) is of special importance in relation to the sequence of events in the Ice Age: with the growing load of ice the plateau was depressed, and thus the basic cause of the development of the Ice Age temporarily set aside. A phase of positive radiation anomaly could now bring first the Scandinavian and then the depressed Tibetan icesheets to an interglacial melt phase (Fig 15c). But even then, if the isostatic effect is built into an algorithm of the Ice Age there is still a lack of agreement with the empirically determined facts: the Quaternary Ice Age phases (Günz, Mindel, Riß, Würm) are not repetitions of a basic algorithm, but differ from each other in scale and duration.

In that the primary cause of the Quaternary Ice Age, the lift of the Tibetan plateau, was a specific historical secular event, there can be no question of an exact repeat of this phenomenon, for historical processes *cannot* go back to their starting point. From this perspective it is clear

that the model of "deterministic chaos" is conceptually inappropriate to portray "development" or "evolution", for their essential characteristic is historicity. This is more an analogy with the Thomistic synthesis of law and contingency, in which an algorithm is conjugated into reality, without itself being variable, that is to say historical events are reduced to a statistical fluctuation. What the reiteration equation of the "chaotic attractor" draws from historical change is the equivalent of a trick in reasoning, the modern version of the Thomistic "Ordo" or Hegel's World Spirit. In order to place climatic change within the aegis of an exact science with its paradigm of regular laws, a step is taken in the "dynamic system theory" which is strongly denied in the same paradigm, that is the leap into transcendental metaphysics. There is no definable mechanism by which the essential stability of the "climate attractor" could be guaranteed. On the contrary it is clear that with each "repetition of the algorithm" a new and irreversible deformation is experienced which could not be prognosticated, affecting also the constituent characteristics of the reference system itself. In the history of the Ice Age, as empirically determined, there is no repetition on the basis of an identical algorithm.

Scientific Geography by the structure of its subject matter is assigned to the epistemology of "attribution questions", and in terms of causality remains at the stage of reconstruction of individual historical clusters, that cannot be extrapolated as repetitions. A "regular climatic evolution", definable by laws, can only be simulated if the historical contingencies are interpreted as repeatable occurrences; but when "that understood is changed by the process of understanding, then understanding has itself changed to misunderstanding" (Kierkegaard 1844, p. 73).

### 8. The Historical in Geography from a Background of Evolutionary Epistemology

In the above it has been attempted to sketch the problem of the historical element in geography on the basis of its empirical status. The resource to unrelated disciplines, such as medieval scholasticism, shows that the epistemological problem has long been recognised: in scientific thinking logic is necessary, but is not suitable for dealing with a reality affected by historical change. As a scientific theory that makes explicit a natural historical process as part of its subject matter, Darwin's theory of evolution makes an ideal comparative paradigm for physical geography.

With the need to legitimise its system of proof before the "exact sciences", a basic interdisciplinary concept of an evolutionary theory of knowledge was developed within evolutionary biology (E. v. Holst 1969/70; K. Lorenz 1973; R. Riedl 1981). The probability theory foundation of the type concept, that is of fundamental importance in geography, has been demonstrated on this basis (see part 5). From the perspective of an evolutionary epistemology

however there are still wider consequences in that the phylogenetically acquired recognition functions embody not only the element of adaptation but also construction (Riedl 1992). Attention is then focussed on why and in what way scientific method has developed in relation to discord with its subject matter (see part 6). The re-afference principle (= reconveyance and clearing of messages by the Central-Peripheral relations of the nervous system; E. v. Holst and H. Mittelstaedt 1950), the calculation method of the central nervous system basic to our conception of space, provides the fundamental model for the constructive cognition process: in the sense of an economy in decision-making only *absolute* values of movement and dimension pass the threshold of consciousness, whilst the accompanying relational calculation process and the implied structure of an hypothetical reference system (absolute space, absolute time) remain subconscious. We can exactly define where “up” and “down” are, but at the same time know nothing of the interaction between gravity and the inner ear (Utriculusstatolith) from which our three-dimensional orientation results. The characteristic of such capacity for orientation is the compulsion with which judgements are made, and the impossibility of correction, even in the face of empirical refutations, as for example in the case of “optical illusions.” Kant speaks in this connection of “natural and unavoidable illusions, . . . that cannot be excluded from human reasoning” and “the transcendental appearance of which . . . nevertheless cannot stop, even if one has already uncovered it and clearly revealed by the transcendental critique its worthlessness”<sup>7)</sup> (Kant 1787: 310–11). An example is hereby provided by the scientific method described for glacial geomorphology, with the empirically determined relational type and its interdependent characteristic structure

converted to quantifiable objective parameters. The movement of a glacier (advance/retreat) was seen in this conceptual framework as a functional correlate of “absolute” temperature change. By treating the other variables as fixed this method had unconsciously separated itself from the environment including the possible non-climatically induced dynamic. As described the pattern of the glacier type can be as much affected by orogenesis as climate. Which of these is causative has to be clarified by the analysis of the historical environmental cluster. It should therefore be pointed out that the logic of our cognition mechanisms leaning towards clarity and regularity suppresses the ambivalence of the phenomena, and therefore is inadequate to deal with the potential historical changes of reference systems (functional conversion). This lack of concordance between the cognition logic and the subject matter it is applied to, is well understood by the evolutionary epistemology with its argument that the evolution and structure of the cognitive functions is to be seen as the product of organismic evolution. In the same way that the *incongruence of a “type” with its specific environment* provides the decisive explanatory advantage of Darwinistic theory compared with the creationists, so too the *incongruence between logic and empiricism* provides evolutionary epistemology with an explanatory advantage over the classical methodology with its dependence on a more stactical syllogism. Within this basically new approach the “transcendental critique”, has to take into consideration the fact that in the relationship between logic and its subject matter the role of *historical* clusters and developments is fundamental. For geography the evolutionary epistemology provides the most suitable concept to reconsider and improve its scientific methodology.

#### Footnotes

- 1) It must be added in this context that reference is made to only part of the teaching of William of Ockham, his thesis of a radical contingency in reality. Not examined here is his argument that the voiced understanding of this reality is merely a human convention, and that science as a consequence is solely knowledge of the correct usage of concepts and statements not about reality itself (= nominalist argument). The extreme position that Ockham represented at this point, is in our view not to be understood in terms of the immanent subject matter, but in this form was intended as an uncompromisingly-emphasised argument in the political and power struggle over poverty between the Pope and the mendicant orders. A critical examination of the argument would lead too far from the present theme.
- 2) The concept of the snowline is related to the mass balance of the glacier, where the area with a positive balance (the zone of accumulation) meets the area with the negative balance (the zone of ablation). The snowline is therefore defined by a mass balance of  $\pm 0$ . It is therefore also known as the equilibrium line altitude (ELA).
- 3) “Thus the transcendental ideas will have presumably their good and consequently immanent usage, (but they are) never of a constituent value so that concepts of a specific subject matter can be derived from them, and in case they are understood in this way, they are simply pseudo-rational (dialectic) concepts. However they do have an excellent and unavoidable necessary regulative function, namely to orientate rationality towards a certain aim, and thus to direct all its immanent laws towards a point, which, though it is only an idea (focus imaginarius) that is a point from which the reasoning concepts do not really emerge, in that it is beyond the bounds of possible experience, nevertheless serves to provide them with the greatest unity together with the greatest extension” (Kant 1787: 564/5).
- 4) These extreme values for uplift cannot be interpreted as orogenetic, but in analogy with Fenno-Scandinavia (Mörner 1990) as glacio-isostatic. This is conversely a proof that in the Early Pleistocene the plateaux by orogenesis were already clearly at a greater altitude, that is at the level of the snowline since otherwise the reflection effect must have already died away.
- 5) The Quaternary Ice Age was a global phenomenon, affecting both the northern and southern hemispheres at the same time, and not limited to polar regions. The only other glacial period to some extent reconstructed is that of the Carbo-Permian of the Gondwana continent. This, however, according to present

knowledge was polar and limited to the southern hemisphere (Schwarzbach 1974). It cannot therefore provide a simple analogy with the Quaternary conditions.

- 6) The question whether probability can be argued instead of necessity is in relation to historicity pointless. Probability and improbability are reflexive concepts, and the selection of one or the other depends upon the reference system. Since the priority of the reference system is post hoc and subjective, the question of probable or improbable is similar to the question whether the earth now consists more of "up" than "down".

- 7) "The cause of it is this: in our reasoning... basic laws and maxims of its usage are situated which have the appearance of completely objective fundamental statements, and by which it occurs that the subjective necessity of a certain linkage of our concepts, favouring the application of reason, is held to be an objective necessity, (revealing) a determination (= property) of the thing in itself. An illusion that is not to be avoided, in so little as we can avoid it, in that the ocean should not appear more elevated in the middle than on the shore, as little as even the astronomer can prevent the moon at its rise not appearing larger, although he will not be deceived by this appearance" (Kant 1787: 310-11).

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