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The Chronological Correlation of the Morphologic Development in the Eastern and Western Alps

By H. ANNAHEIM[1], Basle, Switzerland

I.—*Introduction. Principle aspects of alpine land forms*[2]

Since the turn of the century geomorphic research in the Eastern Alps, besides continuing the study of the glacial land forms, has also turned more and more toward the investigation of the development of the mountain landscape during the Tertiary and has already attained remarkable results. Recently some geomorphologists of the Western Alps have also occupied themselves increasingly with this important problem of alpine morphology. These studies have revived an old problem, which was never discussed in all its details, but which is of the greatest importance for these particular investigations, the problem of the genetic and chronologic coordination of mountain sculpture in the Eastern and Western Alps.

Research in the Eastern and Western Alps has already brought general accord on some problems of fundamental importance.

(1) Diastrophic deformation (orogeny) and mountain uplift are two different processes, although resulting from the same original causes. The mountain uplift outlasted the orogenic periods and was of prime importance for the development of the mountain sculpture in the late Tertiary period.

(2) This uplift was a discontinuous process. Phases of relative quiescence or of small-scale sinking (Southern Tessin, cf. ANNAHEIM[3], intervened between phases of uplift. Erosive action upon the rising mountain mass was, therefore, not at a uniform rate. The alpine valleys thus became multiple-cycle valleys. Remnants of phases of reduced erosion appear in terraces, treads of valley staircases and glacial stairways, in broadly rounded ridge crests and summits, and finally in various accordant levels of mountain peaks („Gipfelfluren"). They produce the typical multiple-story structure or „Stockwerkbau", as this relief is called in German scientific literature.

(3) Over the whole length of the Alps the highest regions consist of residual forms of an old landscape, which assumes the character of a rolling or hilly peneplain in the Eastern and of a mature hill or mountain country in the Western Alps. This old landscape signifies the end of the main alpine orogeny and is the starting point for the geomorphic development of the present multistoried structure of the Alps. Below this high relief follows a valley-in-valley surface with successive diminution of width of the valley cross-sections.

II.—*The multiple-story structure*

A.—*Principles.* One of the important tasks of the geomorphic investigation of the Alps consists in determining the extent and origin of the many form systems which compose the complex multistoried relief in the various parts of the mountains and in accounting for their combinations. Only in this way it will become possible to understand the morphologic character of the Alps as a unit, as well as of their different parts. The task is made quite difficult for the following reasons:—

(1) The morphologic evidence of the old forms often has been very extensively destroyed or greatly altered by later degradation and erosion, especially by the action of the Pleistocene glacierization.

(2) Moreover, the forelands surrounding the Alps have a varied morphogenic character and influence the form development of the neighboring alpine areas in different ways. For example, the present-day and former base-levels lie at different altitudes, so that corresponding valley systems of the same age appear at various elevations and with different altitudinal intervals in the different groups of the Alps.

(3) Finally the various alpine districts underwent different crustal movements during their morphologic development. Faults, flexures, and light local domings, demonstrated for the Eastern Alps (cf. MACHATSCHEK[1],

[1] Geographical Institute of the University of Basle.

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[3] H. ANNAHEIM, *Studien zur Geomorphogenese der Südalpen zwischen St. Gotthard und Alpenrand.* Geographica Helvetica *I*, 65 (1946).

[1] F. MACHATSCHEK, *Morphologische Untersuchungen in den Salzburger Kalkalpen.* Ostalpine Formenstudien *I/4* (1922); *Neuere morphologische Untersuchungen in den Alpen.* J. Geomorphology *II* (1939).

RATHJENS[1]), and tilting of extensive areas in a longitudinal and transversal direction accompanied the intermittent uplift and may continue to the present time, causing increased complications of the land forms (cf. MACHATSCHEK and STAUB[2]).

On the other hand, it appears worthwhile to stress the surprising fact that, in spite of these manifold modifying factors, the forms of the Eastern and Western Alps, aside from well-known differences, such as greater elevation and sharper relief in the Western Alps, display great fundamental similarities.

B.–*The multiple-story relief in the Eastern Alps.* The oldest preserved relief-system of the Eastern Alps is the so-called „Rax" landscape (LICHTENECKER[3]), a hilly surface which here and there changes to low mountain relief. Remnants of this unit occur on the limestone plateaus of the Northeastern Alps east of the Inn, where their good state of preservation is due to subsequent solution weathering. This old relief arose out of a still older peneplain, the „Augenstein" landscape, which has been totally destroyed. This initial peneplain evolved at the end of the main east alpine orogeny, which took place from the Cretaceous to the Oligocene. Sediments of the eastern border of the Alps which were derived from the Rax surface indicate formation during the early middle Miocene (cf. VON WINKLER[4]); the earlier Augenstein landscape developed in the earliest Miocene as terminal peneplain („Endrumpf"). At present, the Rax surface displays considerable differences in elevation which are not due to successive cyclic valley deepening (SEEFELDNER[5]), but to later crustal deformation (cf. MACHATSCHEK[6], RATHJENS[7]). In the central part of the Eastern Alps, these old surfaces seem to be represented by the accordant level of peaks and the accordant level of névé fields („Firnfeldniveau" of CREUTZBURG[8]), of which the latter may correspond to the Rax surface. Below these high level forms there follow the later Tertiary phases which are restricted to valleys. MACHATSCHEK[9] distinguished four of these valley systems, including the pre-glacial system, BOBEK[1] found six systems in the Zillertaler Alps, and other geomorphologists recognize still more late Tertiary valley systems.

West of the Inn, where the structure is more complicated and the Dachstein limestone, which preserves the old forms so well, is missing, the Rax relief is less distinct and it becomes very difficult to follow this surface westward.

C.–*The multiple-story relief in the Western Alps.* Older investigations following the classical work of PENCK and BRÜCKNER[2] recognized only three valley systems in the Swiss Alps: a high Pliocene niveau, the preglacial trough-shoulder system, and a middle Pleistocene system within the valley troughs. Recent studies have considerably modified these concepts. Multiple phases of Tertiary valley deepening have been recognized also in the Western Alps. In the region between the St. Gotthard and the southern border of the Alps, I was able to identify a Tertiary multiple-story relief consisting of from 7 to 10 systems (cf. ANNAHEIM[3]), and similar observations are reported increasingly from other regions. The same observations were also made in the French Alps (cf. e.g. DE MARTONNE[4], CHARDONNET[5]). These investigations prove more and more that also in the Western Alps a low relief, which is preserved in various accordant summit levels and high-level flat surfaces, stands at the beginning of the development of the present relief. In the Tessin area, this initial old land was called Pettanetto-system (by LAUTENSACH[6]). It dates from the early Pliocene, as can be proven not only by tectonic evidence, but also by the middle Pliocene age of undisturbed marine deposists at the southern margin of the Alps (ANNAHEIM[3]). On the other hand, this old surface was characterized by considerable relief in the interior part of the Alps, where it attained elevations of over 2,000 m relative to its southern foot, at least in the late advanced stage of its development. Flat forms similar to the Rax landscape evolved only locally in the boundary zone. Orogenic development, structure and lithology did not favor the formation and preservation of subdued form complexes. A principle difference between the Rax landscape and these high-level old forms of the Pettanetto surface consists in their apparent

[1] C. RATHJENS, *Die Raxlandschaft als Problem der alpinen Geomorphologie.* Forschungen und Fortschritte *21/23* (1947); *Neue Untersuchungen von Flachformen in der Höhe in den Alpen.* Erdkunde *II*, 79 (1948).

[2] F. MACHATSCHEK und W. STAUB, *Morphologische Untersuchungen im Wallis.* Eclogae geologicae Helveticae *20*, 335 (1927).

[3] N. LICHTENECKER, *Die Rax.* Geogr. Jber. Österreich *13* (1926).

[4] A. VON WINKLER, *Das jüngere Entwicklungsbild der Ostalpen.* Z. Ges. Erdkunde Berlin 381 (1926); *Über Probleme ostalpiner Geomorphologie.* Mitt. Geogr. Ges. Wien *72*, 5 (1929).

[5] E. SEEFELDNER, *Zur Morphologie der Salzburger Alpen.* Geogr. Jber. Österreich *13* (1926); *Die alten Landoberflächen der Salzburger Alpen.* Z. Geomorphol. *8*, 157 (1935).

[6] F. MACHATSCHEK, *Morphologische Untersuchungen in den Salzburger Kalkalpen.* Ostalpine Formenstudien *I/4* (1922); *Neuere morphologische Untersuchungen in den Alpen.* J. Geomorphology *II* (1939).

[7] C. RATHJENS, *Die Raxlandschaft als Problem der alpinen Geomorphologie.* Forschungen und Fortschritte *21/23* (1947); *Neue Untersuchungen von Flachformen in der Höhe in den Alpen.* Erdkunde *II*, 79 (1948).

[8] N. CREUTZBURG, *Die Formen der Eiszeit im Ankogelgebiet.* Ostalpine Formenstudien (Berlin 1921).

[9] F. MACHATSCHEK, *Morphologische Untersuchungen in den Salzburger Kalkalpen.* Ostalpine Formenstudien *I/4* (1922).

[1] H. BOBEK, *Die Formentwicklung der Zillertaler- und Tuxer Alpen.* Forschungen zur Deutschen Landes- und Volkskunde, Stuttgart *30* (1933).

[2] A. PENCK und E. BRÜCKNER, *Die Alpen im Eiszeitalter* (Leipzig 1901–09).

[3] H. ANNAHEIM, *Studien zur Geomorphogenese der Südalpen zwischen St. Gotthard und Alpenrand.* Geographica Helvetica *1*, 65 (1946).

[4] E. DE MARTONNE, *L'évolution des vallées glaciaires alpines en particulier dans les Alpes du Dauphine.* Bull. Soc. géol. France *12*, 516 (1912).

[5] J. CHARDONNET, *La vallée de Montjoie et la bordure sudouest du Mont Blanc.* Ann. Géographie *47*, 345 (1938).

[6] H. LAUTENSACH, *Die Übertiefung des Tessingebietes.* Pencks Geogr. Abhandlungen (Stuttgart 1912).

relative ages. The main orogenic movement in the Western Alps probably occured in the Oligocene, but thrusting and vertical movements continued to the end of the Miocene and into the beginning of the Pliocene. At that late date the last Helvetic thrusts associated with the overriding and compression of the subalpine Tertiary deposists (Molasse) took place in the Swiss Alps. Because the Tertiary valley systems generally descend with uniform gradients from the valley-heads in the heart of the Alps to their outer margins, they appear to have been formed only after the orogenesis was completed, that is after the Miocene. The oldest high-level forms, therefore, have an early Pliocene age. After their formation the valley systems suffered only a slight general increase in gradient caused by the general elevation of the Alps, which attained its maximum along their central longitudinal axis.

According to the morphologic evidence and the associated sediments in the alpine foreland, the development of the mountain landscape seems to have been controlled by two great phases of uplift which were separated by a period of relative quiescence (cf. ANNAHEIM[1]) as follows:—

(1) Formation of a steep relief of unknown altitude and shape during the Oligo-Miocene, which suffered enormous degradation in the continuous process of tectonic deformation and uplift (cf. CADISCH[2], R. STAUB[3]). Orogenic phase.

(2) Initiated by a reduced rate of uplift or by quiescence of the underground, this relief became subdued during the early Pliocene. Formation of a low mountain relief of a steepness which increased toward the interior part of the Alps. In the Eastern Alps broad valley systems seem to have been created during the same period (cf. VON KLEBELSBERG[4], etc.).

(3) Second phase of pronounced uplift, which becomes increasingly discontinuous and causes the development of the present alpine valley-in-valley relief during the middle and upper Pliocene and the early Quaternary.

A landscape of the same nature as that of the Rax surface could thus not develop in the Western Alps. Here, the chronologically equivalent land surface consisted of a steep mountain land in process of continuous degradation which has been completely obliterated since that time.

[1] H. ANNAHEIM, *Studien zur Geomorphogenese der Südalpen zwischen St. Gotthard und Alpenrand.* Geographica Helvetica *I*, 65 (1946).

[2] J. CADISCH, *Das Werden der Alpen im Spiegel der Vorlandsedimentation.* Geolog. Rdsch. *19*, 105 (1928).

[3] R. STAUB, *Grundzüge und Probleme alpiner Morphologie.* Denkschriften der Schweiz. Naturforsch. Ges. *49* (1934).

[4] R. VON KLEBELSBERG, *Die Hauptoberflächensysteme der Ostalpen.* Verhandl. der Geolog. Reichsanstalt Wien, Nr. 2/3 (1922).

III.—*The question of correlation of the multiple-story systems*

These stratigraphically established theories seem contradicted by geomorphic evidence. We have stressed the basic similarity of the mountain relief in the Eastern and Western Alps which suggests chronological equivalence of its formation over the whole Alps. Everywhere the high region is characterized by an old landscape of moderate relief in only slightly differing stages of evolution. In the transition zone between the Eastern and Western Alps, i.e. in Western Tyrol and the Canton of Grison, the old high-level systems pass uninterrupted from the Eastern to the Western Alps and maintain the same character of relief (cf. CADISCH[1]). This fundamental accord is also demonstrated by other parts of the multiple-story relief; thus, for example, later investigations were able to point out the relatively low elevation of the preglacial valleys in the Western Alps (cf. ANNAHEIM[2]), corroborating similar earlier observations from the Eastern Alps. How can this contradiction between the geomorphic and geological facts be solved? At present we must be satisfied to raise this question once more, to point out some problems and to suggest several possible solutions worth consideration in any future investigation of alpine geomorphology. Some such possibilities are the following:—

A.—The correspondence of form systems derived from their similarity in relief and in altitudinal position in the mountains, especially if applied to the high surfaces, is only apparent and does not correspond to simultaneous formation. The similar appearance of the Rax landscape in the East with the oldest relief systems in the West would thus only mean that all parts of the Alps have generally undergone the same development from a flat relief through a medium to a steep relief, a development which started earlier in the East, however, than in the West and would indicate a gradual westward shift in age of morphologically similar form systems. Only the Pliocene and the still younger phases of valley deepening could be taken as chronological parallels. In this connection two possible interpretations can be pointed out:—

(1) The Rax landscape developed in the middle Miocene over all of the Eastern Alps at a time when the Western Alps were still undergoing continuous deformation and intensive sculpturing. The Rax relief, in this interpretation, would have to end in the western part of the Eastern Alps either at a still recognizable original margin or at a boundary modified by later degradation. The younger systems of Pliocene origin of the Eastern Alps would then have to grade by a

[1] J. CADISCH, *Zur Talgeschichte von Davos.* Jber. Naturforsch. Ges. Graubünden, N. F. *64*, 285 (1926).

[2] H. ANNAHEIM, *Studien zur Geomorphogenese der Südalpen zwischen St. Gotthard und Alpenrand.* Geographica Helvetica *I*, 65 (1946).

flexure-like bend into the higher corresponding old levels of the Pettanetto system of the Western Alps (cf. the modified assumption of RATHJENS[1]). Differences in elevation between corresponding levels would be smaller in the East than in the West.

(2) The second possibility is based on the fact that the relations upon which the determination of the middle Miocene age of the Rax surface are based hold true only for the eastern border of the Alps. Therefore, the following interpretation must be examined: The Rax relief developed only in the easternmost part of the Alps during the middle Miocene, towards the west its formation occured at progressively later periods of the Miocene and finally, in the West, during the early Pliocene, in close agreement with the later completion here of the main tectonic deformation. If this interpretation is correct, the older east-alpine form systems should rise gently westward repeatedly run out into the air in this direction. In the same direction the vertical distances between form systems should increase. Proof of this successive westward change of age of the old land could be provided by age determinations of the corresponding foreland sediments. It is certain, however, that the changes within these sediments derived from the gradual evolution of the old land are so small from place to place that it would be difficult to prove this type of origin.

B.—Another assumption which should be considered is that the formation of the Rax relief really began in the middle Miocene and continued during the remainder of the Miocene period, so that in early Pliocene this old land still remained the basic and dominant surface of the Eastern Alps. In this view the whole Alps of the early Pliocene period would consist of hilly and mountaineous terrain with sharper ridges only in the interior part of the Western Alps. This hypothesis would be in accord with morphological observations and would explain the more advanced stage of erosion of the Rax landscape in comparison to that of the western old land. However, this interpretation is contradicted by observations on the eastern boundary of the Alps which seem to prove that the Rax surface was strongly uplifted and efficiently broken into parts during the Miocene. This interpretation would further require a revision of the bases upon which the present age determinations rest.

The interpretation best suited to the present state of knowledge seems to be the one presented above in paragraph A(-2).

To clear up these difficult problems, further intensive research concerning the geomorphology and geology of the Alps is necessary. Some of the most pressing problems awaiting investigation may be indicated here.

(1) It must be pointed out that the chronologic sequence of the orogenetic processes is not yet known in all its details. Thus an important basis for valid morphologic conclusions is lacking.

(2) The investigation of the foreland sediments derived from the denudation of the Alps is far from having reached the degree of clarity desirable. Recent critical examinations of the subalpine Tertiary deposits (Molasse) have shown that the conditions of formation of these sediments are not yet clear, so that many conclusions derived from their character and concerning the tectonic and geomorphic history of the alpine backland can be accepted only with caution (cf. RUTSCH[1]). In this connection the problem of the subalpine overriding of an older relief („Reliefüberschiebung") may be mentioned as it bears important consequences for the morphogenic interpretation of the Alps. Here, too, investigations have not yet yielded conclusive results (cf. RENZ[2], but also HABICHT[3]).

(3) Of greatest importance is the exact determination of the erosional phases in the whole Alps. Particular attention should be paid to correlations between various drainage areas. The safest results might be obtained from an investigation of dominant erosion levels, especially of the last pre-glacial level. This surface is often relatively well preserved and can be determined by several methods. If the position of this important phase is established some day in all alpine valleys, future investigations will be provided with a useful datum plane for the investigations of all other erosion levels. The last pre-glacial surface is especially instrumental in determining direction and degree of the Quaternary crustal movements.

Satisfactory results are not to be expected until the morphology of the Alps is explored in every possible detail and is documented by detailed morphologic maps. For this reason the Swiss Geomorphological Society is at present sponsoring a morphologic field-mapping program on the scale of 1:10,000, based on the new topographical maps of Switzerland (Landeskarte der Schweiz 1:50,000), and utilizing uniform conventional signs and nomenclature (cf. ANNAHEIM[4]).

(4) Finally it may be mentioned that exact age determinations for the varied erosion levels by stratigraphic and geomorphic methods are of primary importance. Stratigraphic references by deposits which rest immediately upon the form systems carry the greatest weight. Conclusions based on distant associated foreland deposits are less reliable. Age

[1] C. RATHJENS, *Die Raxlandschaft als Problem der alpinen Geomorphologie.* Forschungen und Fortschritte *21/23* (1947).

[1] R. RUTSCH, *Neue Auffassung über die Entstehung der Molassesedimente.* Eclogae geol. Helvetiae *38*, 407 (1946).

[2] H. H. RENZ, *Die subalpine Molasse zwischen Aare und Rhein.* Eclogae geol. Helvetiae *30*, 87 (1937).

[3] K. HABICHT, *Geologische Untersuchungen im südlichen sanktgallisch-appenzellischen Molassegebiet.* Beiträge zur Geologischen Karte der Schweiz, N. F. 83 (1945).

[4] H. ANNAHEIM, *Die Schweizerische Geomorphologische Gesellschaft.* Geographica Helvetica *II*, 140 (1947).

determinations which rely exclusively on morphologic evidence are generally inconclusive. Stratigraphic evidence may be provided by Miocene and Pliocene deposits (Eastern and Southern Alps), Pliocene residual soils (Tyrol, cf. VON KLEBELSBERG[1]), by early Quaternary gravels and related deposits (deposits of the Günz glaciation, cf. NANGERONI[2], ANNAHEIM[3]). More recent deposits are of use only in determining the age of the latest valley deepening period. For the reconstruction of the pre-glacial niveau the hanging valleys seem to be of value, if the morphologic analysis is sufficiently critical and discriminating (cf. ANNAHEIM[3]). The trough shoulders, on the other hand, can no longer be considered as remnants of the former preglacial floor. This old assumption seems to be founded on rather uncritical judgment (cf. e.g. BREMER[4]); well-defined trough shoulders, furthermore, occur only in the innermost parts of the alpine valleys (cf. also VON KLEBELSBERG[5]). In the Tessin, I was able to establish an old Pliocene age for the trough shoulder level (cf. ANNAHEIM[3]).

The main problem under discussion here makes it self-evident that the transitional region between the Eastern and Western Alps merits particular attention. Morphologic investigations in this area to date have paid no attention to this problem and offer only limited assistance (cf. BÖRNER[6], CADISCH[7]; KOEBCKE[8], LÜTHY[9], NEEF[10], TASCHE[11]).

I regret that I have not been able to provide definite answers to the questions raised herein. On the other hand, it may also be worthwhile to state all the questions connected with the problem. If this task is to succeed, the cooperation of all geomorphologists interested in these problems is needed. If such team work can be realized, it will produce results which will further not only the morphology of the Alps but also that of all other high mountain regions.

Zusammenfassung

Die bisherige geomorphologische Erforschung der Alpen hat u. a. deutlich gemacht, daß die Gebirgsformung das Ergebnis eines diskontinuierlichen, in deutliche Phasen gegliederten Abtragunsprozesses ist. Dieser hat ein ausgesprochenes Stockwerkrelief erzeugt. In den ganzen Alpen ist die Höhenregion durch mehr oder weniger gut erhaltene Restformen einer Altlandschaft ausgezeichnet, deren Reliefspannung im O einer hügeligen Peneplain, im W einer Mittelgebirgslandschaft entspricht. Unter diesen Altformen senken sich die steiler geböschten, longitudinal und transversal gestuften Talkanäle in den Gebirgskörper ein. In den Ostalpen besitzt die Altlandschaft («Raxlandschaft», «Firnfeldniveau») mittelmiozänes Alter. Da in den westlichen Alpen die intensiven tektonischen Bewegungen bis zur Wende vom Miozän zum Pliozän angedauert hatten, sind die hier ebenfalls erhaltenen hohen Altformen erst im Frühpliozän entwickelt worden.

Die grundsätzliche Übereinstimmung der großen Formzüge von Ost- und Westalpen, welche sich auch in der Übergangszone der beiden Alpenteile beobachten läßt, scheint auf eine einheitliche Entwicklungsgeschichte hinzuweisen, gegen deren Annahme jedoch die chronologischen Befunde sprechen könnten. Es werden einige Möglichkeiten zur Lösung dieses Widerspruchs diskutiert; unter ihnen verdiente namentlich die Arbeitshypothese eine nähere Überprüfung, welche ein *sukzessives* Ausstreichen oder Ausgehen der ostalpinen Altsysteme und eine allmähliche Aufbiegung der jüngeren Talniveaus gegen W hin annimmt. Die Formverwandtschaft der Raxlandschaft des Ostens mit den ältesten Reliefstockwerken des Westens würde sonach bedeuten, daß alle Alpenteile im großen wohl dem gleichen Entwicklungsprozeß von einem Flach- oder Mittelrelief zu einem Steilrelief unterworfen waren, daß aber diese Entwicklung im O viel früher begonnen hat als im W und sich allmählich in dieser Richtung fortsetzte. Zum Schluß werden einige Methoden besprochen, deren Anwendung uns der Lösung dieses bedeutenden Korrelationsproblems näherbringen könnte. Unter ihnen kommt der präzisen Fixierung des präglazialen Formsystems für die morphogenetische Interpretation der alpinen Landschaft besondere Bedeutung zu.

[1] R. VON KLEBELSBERG, *Geologie von Tirol* (Berlin 1935).

[2] G. L. NANGERONI, Carta geognostica geologica della Provincia di Varese (Varese 1932).

[3] H. ANNAHEIM, *Studien zur Geomorphogenese der Südalpen zwischen St. Gotthard und Alpenrand.* Geographica Helvetica *I*, 65 (1946).

[4] E. BREMER, *Das präglaziale Relief der Ostalpen und dessen Bedeutung für den heutigen Formenschatz des Gebirges.* (Halle 1934).

[5] R. VON KLEBELSBERG, *Handbuch der Gletscherkunde und Glazialgeologie.* Bd. 1 (Wien 1948).

[6] H. BÖRNER, *Vergleichende Talgeschichte von Montafon und Paznaun (Silvretta).* Z. Geomorphol. *7*, 109 (1932).

[7] J. CADISCH, *Zur Talgeschichte von Davos.* Jber. Naturforsch. Ges. Graubünden, N. F. *64*, 285 (1926).

[8] R. KOEBCKE, *Morphologie des Illergebietes zwischen Oberstdorf und dem Alpenrande.* Frankfurter Geogr. Hefte (1934).

[9] H. LÜTHY, *Geomorphologische Untersuchungen im Säntisgebirge.* Jb. der St. Gall. Naturw. Ges. *69*, 129 (1937/38).

[10] E. NEEF, *Die Landformung des Bregenzerwaldes.* Badische Geogr. Abhandlungen *9* (1933).

[11] M. TASCHE, *Morphologie des Illerquellgebietes.* Frankfurter Geogr. Hefte (1934).