J. K u n a v e r

THE HIGH MOUNTAINOUS KARST OF JULIAN ALPS IN THE SYSTEM OF ALPINE KARSTS

A number of papers have already dealt with different alpine or high mountainous karsts of the Alps or other European mountains, but at the same time one misses comparative studies. There exist, of course, comparisons of surface landforms, of their morphology and sometimes also of their dimensions. But we miss still more that sort of comparisons which could answer general morphogenetic problems of alpine karsts and problems of their similarity and diversity, or with other words, the questions of the origin and types of the high mountainous karst physiognomy.

In order to be able to do this kind of work there is first to be done an important task of establishing the elementary types of high mountainous karst physiognomy. It is understandable, that owing to many reasons such works have not been done in most of these alpine areas. I think that especially the technical problems and the diversity of geomorphological mapping of a such a morphologicaly rich relief make comparisons even more difficult. But we can try to overcome this either with unification of geomorphological mapping or with acceptance of a classification of types of alpine karst, some of which are going to be proposed in this paper. The detailed mapping of this surface demands the use of a very big scale for many of the karst objects are small. For the general physiognomy they are not really important, but they express the nature of actual karst processes.

To avoid an extremely long-lasting and therefore technicaly hardly practicable detailed mapping we propose the use it only in cases of representation of elementary types. Such types of alpine karst relief are in fact specific geomorphological complexes or associations of forms which could be represented with one sign only.

In this paper the author would like to represent the attempts for geomorphological mapping of high mountainous karst with help of detailed mapping as well as with help of system of types of high mountainous karst. The mapping has been done in a massif of Kanin which is a part of the western Julian Alps. There will be shown also the most important qualities of the karst of the Julian Alps itself.

I.

The phenomenon of karst in the Julian Alps is being known for nearly one hundred years. The geologist C. Diener /1884/ compared the barren karren pavements on the Komna with those of the Steinernes Meer and the Totes Gebirge and he did not find any special distinctions in its great expressiveness. Later on it has been established that in general this estimation can be sufficient because there are many similarities between the karst areas on the northern and the southern border of the eastern Alps, as far as the surface is concerned. Of course, a detailed comparison, which would be of great importance, should still be done. We expect from this research that it can answer many questions which are connected either with somewhat different general geomorphological development or with slightly diferent nature of climate in both regions.

The karst areas in the Julian and also in the Kamnik Alps, have been sistematically explored in the last twenty years, as well their speleological and the surface karst phenomena /Kunaver 1961, 1969/. The Julian Alps are very rich in vertical chasms of which some 300 or more have already been explored. One of the longest Yugoslav caves and the deepest has also been found in the Julian Alps near Tolmin. A great number of speleological objects is not in accordance with comparatively moderate dimensions, but as the results of the latest thorough exploration show bigger numbers could be expected. The specific character of our alpine karst has its origin in the first place in a very thick limestone and partly also in dolomite strata of Noric and Rhetic age. The Dachstein limestone and Haupt /Main/ dolomite attain in the Triglav north wall the thickness of up to 1500 meters. However, there is a lack of impermeable layers throughout the heights ob the Julian Alps. The water outlet from the surface is therefore, with exception of some small patches to the southwest and to the south of the Triglav, nearly every-where extremely dispersed. We are convinced that this dispersion has been progressing from the beginning of holocene because of the progress in karst dissection, at least on the surface. The other reason for the lack of surface waterflows is the deep incision of the alpine massifs with the valleys. The underground waters are situated mostly deep in the calcareous interior. The risings are as a rule near the local erosional bass at the foot of slopes.

Some other data about the conditions for surface karst phenomena in the Julian Alps:

- The remains of the younger terciary relief are of similar nature as the ones on the northern border of the eastern Alps. They have a step-like nature descending from the highest platforms round the Triglav /in the heights of 2400 - 2500/ mostly towards south, south east and south west. To the west of the Triglav there are only Križki podi and Kaninski podi, two excellent examples of our alpine karst. Podi is the local Slovene name for the karstified plateau above the forest limit. The Kaninski podi or karst plateaus of the massif of the Kanin is the second largest area of alpine karst. It is famous because of a very intensive karst processes and expressive karst forms. The karst area of the Triglav massif covers about.

- The climatic particularities of the Julian Alps are the extremes in precipitations, at least in the western part. The Kredarica /2515 m/ gets on the average 2080 mm/in the period 1954-1962; the average amount is too low because of exposure to strong wind/, the Kanin gets on average 3418 mm /1953-1964/, the mountains to the west of the Bohinj lake do not get much less either.

- The actual forest limit on the southwestern side is not higher than 1500 m; however, in the central part it rises up to 1900 m.

- According to the results of a chemical analysis of karstified limestones, in the massif of the Kanin there are often transitions in apparent pure Dachstein limestones to dolomitic limestone of different composition. A small percentage of dolomitic addition could already be of decisive importance for the existence, dimensions and the physiognomy of the macro as well as for the microkarst forms in subnival conditions. The influence of the slight dolomitisation is being displayed in strong mechanical desintegration of the rock in lower heights. Next phenomenon is the disappearance of the smallest forms corrosion of.

- The strata of Dachstein limestone, which mostly carry the typical karst forms, are thick bedded, from 0,5 to 1,5 m. They are widespread. The limestones and dolomitic limestones of the Ladin age, to the south of the Triglav, are also karstified. But they dont have such diversified karst relief as it is normal for the Dachstein limestone. Above them there are the Triglav limestones, which are dolomitizied and not stratified. They are therefore only slightly karstified. The youngest calcareous rock is the upper jurassic limestone which appears in alongated patch in the valley of the seven Triglav lakes and it is strongly karstified.

- In the areas of our alpine karsts the strata are rarely tilted for more then 30^{o}, but also the horizontal strata are not very frequent.

- There is a great dependence of bigger karst forms from the system of joints, master joints and also from faults. We have soon established an especially close relation between master joints and the kotliči or dolinas with vertical walls, which are therefore often of elongated or rectangular shape. Of course, the karstsgassen kluftkarren, elongated dolinas and other karst forms are even in a more direct relation to the joints and faults. In the massif of the Kanin there are up to four systems of differently orientates joints and faults and of different frequency. A great density of them contributes a lot to the high karstic dissection of that area.

- The traces of glaciation are very frequent in the highest parts of the Alps and they have the same importance for the morphogenesis and phisiognomy of the karst surface as it has been established in other alpine karsts. The prewürmien age of bigger karst depressions, and also of some kotliči - dolinas with vertical walls, has been established too /Haserodt, 1965/.

Most instructive is the way of a progressive withdrawal of glacial drift /mostly of calcareous and partly of dolomitic composition/ on the one side and the succeeding of karst forms on its place. In placess where older depression or faultlines existed below glacial till, big dolinas and karstgassen have arisen there. In other places the retreat of glacial drift is in direct relation to the surface corrosion and denudation. We find glacial striae untouched even beneath 10 cm of drift. That is in agreement wirth the statement of Williams /1966/ who has noticed different relations beetween glacial drift of various composition and the underlaying calcareous rock.

II.

As far as the data about the karst surface forms are available from the Northern limestone Alps, we can say, that they are more or less phisiognomicaly indentical with those in the Julian Alps. It is more difficult to say anything about the dimension except with regard to the bigger depressions and dolinas which are well described. There is still a lack of statistical information which could more easily enable us to make any kind of qualitative and quantitative comparisons.

On the bases of the work of Haserodt /1965/ in the Hagen Gebirge and surroundings we are able to englighten some of the specific characters of the alpine karst in the Julian Alps:

1. The Nischenkarren are abundant in our conditions. But the Kamenitzas are more frequent. Haserodt does not mention them at all. Kamentizas, as for the rule, can develop practically on every suitable barren rock surface below the zone of stronger mechanical desintegration, expect in the forests on in the vicinity of denser vegetation.

2. The Firstkarren could be found in similar places. But they are much more frequent then Kamenitzas. They could exceptionally also be found on lonely standing stones or on barren rock surface below forest limit.

3. Karrentische are more rarely to be found, as well as Karrendorne.

Other smaller surface forms have similar appearence as ones on the northern alpine border.

4. In our conditions the dolinas in glacial drift, as well as secondary dolinas in bigger depressions are quite common and also the elongated dolinas in dry valleys. Bigger dolinas with over 15 m of diameter are to be found except in drift also in more dolomitized bedrock in all heights. In the middle of zone of more intensive mechanical desintegration, which begins in the western Julian Alps in height of round 2100 m, there are in compact limestone rock most frequent the transitional forms between kotlič and funnel-like dolina, whereas in more dolomitized bedrock prevail only the latter.

5. As we have already mentioned one of the most frequent appearance above the forest limit are the dolinas with vertical walls, of angular or rounded plan, which are called <u>kotliči</u> or kettlelike dolinas. The relation between diameter and the dep is most often 1:1. Normaly the dimensions do not exced 10 m. But we have not been able to make clear yet, wheather these are the same as Steilwanddolinen or Kesseldolinen /Haserodt, 1965; Zwittkovits, 1963/. One is nevertheless certain, that kotliči are a usual phenomena on thick bedded and strongly jointed limestone and they are the result of nearly equal effect of chemical and mechanical desintegration of the rock. This means that the kotliči are a specific sort of subnival dolinas. Besides, the fosil kotlici-like forms have been found in the Trnovski gozd in the heights between 800 m and 1200 m as a remains from colder pleistocene climate /Habič, 1968/.

6. There exists rather great similarity also in the shape and dimensions of bigger depresions, as well in morphogenesis, and age. A local name konta is used for all depressions in the Alps which are uvala-like. According to dimensions there could be Gruben or uvalas with many transitions, but they do not exceed 500 m in diameter and are usually shallow. The Velo an Malo polje below the Triglav are an exception as being a sort of high mountainous karst polje /Gams, 1963/.

7. In connection with the discussion about the vertical zonation and the prevailance of some typical karst forms we must stress that the local conditions are very often not in agreement with general schemes, which have so far been constructed. We agree with Haserodt's critical views that only the products of post pleistocene karst denudation could be of decisive importance for climatic conditioned vertical zones with prevailance of specific processes and typical micromorphological complexes.

But the situation in the Julian Alps and very probably also to the north of it seems to permit a division of alpine karst not only in two main vertical zones as Haserodt suggested. These are silvinen-bewaldeten karst and barren nor forested or subnivaler alpine karst. We propose to devide it in four main height zones which are the result of the fluctuations of climate and the vegetational zones in holocene and very much influenced by the man's activity. By determining vertical zones we can state, that a zone between the forest limit and the zone of a stronger mechanical desintegration, which is in the Julian Alps from about 1900 m to about 2200 m, was never in holocene for a longer period of time under the influence of totaly different conditions as they are to day. This is therefore the main zone of typical barren high alpine karst. Considering this fact we can divide the silviner and barren zone of alpine karst in the following four vertical zones:

1. the zone of proper silviner or wooded karst below the forest limit: less or more frequent dolinas, esspecially bigger ones, konte - uvalas and dry valleys.

2. the lower transitional zone of alpine karst around the forest limit: all sorts of rounded karren, beginning of appearance of kotliči and other subaerial corrosion forms.

3. the zone of barren alpine karst with complete inventary of karst forms typical of those conditions: besides of all sorts of karren and microcorrosion forms, which are most common on different kinds of pavements, most typical are kettle-like dolinas or kotliči; the remains of dry valleys., different kinds of dolinas and bigger depressions.

4. the upper transitional zone of barren alpine karst which is identical with the lower zone of stronger mechanical desintegration: the transitional forms of kotliči to normal dolinas in the scree and in the bedrock; an expressive retreat of microcorrosive forms.

III.

In spite of the fact that bigger surface karst forms are not suitable as the typical height zonal indicators /with the exception of kettle-like dolinas, kotliči/, they could be of much bigger use when we wish to show physiognomic and often also geneticaly specific types of alpine karst not regarding the height or climate zones. We have been trying to find the so-called elementary morphological types of alpine karst which are by no means only the results of climate but at the same time the expression of complex mutual effects of many statical and dynamic agents. In addition to the climate, the group of other geological factors is of the greatest importance, among them especially the petrographic and chemical nature of the limestone, then the thickness of strata, the relation between the dip of strata and the inclination of surface and lastly the jointing of the rock. Of course, the formation of the relief in pleistocene with the erosional and accumulation traces have also caused, that the karst surface has not everywhere equally started the further geomorphological development in holocene.

In this light it is possible to recognize different types of alpine karst as a morphological complexess, which could be of elementary kind or of higher type composed with help of elementary ones. The purpose of this kind of morphological classification and typification is first of all to make the geomorphological mapping easier than it is mapping of every karst form separately. The latter is difficult to do in greater extent especially in case of microcorrosion forms. However, in elementary morphological complexes also the smalles karst forms could be considered. This method also enables an objective comparison between different karst areas. Such comparison could reveal and make understandable many hidden reasons and problems, which seem to be unexplainable at first sight, particulary in case of lack of climatological and geological information.

As an excellent and necessary resource in determination of subtypes and types a micromorphological mapping of smaller areas has been proved. It only gives a total insight into the inventory of karst forms as well as in the morphogenetic relations between them. Because of the chosen scale /1:500/, it is possible to make only a representative examples.

We have mapped two similar pavements which have a little different inclination of the surface /10° and 19°/. Both pavements are situated in the southwestern mountains of the Kanin in the height of 1900 m.

Without detailed analysing of the micromorphological differences between both pavements they are fine examples of typical alpine glacio-karstic surfaces and as such both examples of elementary morphological types. According to the system which we propose in continuation we could call the pavement A a flat pavement, and the one of B a subconformed type of stepped inclined pavement. Both of them have such inventory of karst forms, which is in accordance to many given conditions, in first place of course in accordance to the height. The unchanged statical elements as for instance the geological are and also the same type of pavement can be in other climatic respectively height conditions the basis of a somewhat changed inventory of forms. Thus the subtypes of surface morphological complexess could be separated.

The groups of elementary morphological complexess or types are at first divided with regard to the litological nature of the surface. The principle of further differentiation follows the distinction between the levelled and the inclined karst relief. Lastly the basic distinction is considering the elementary types and perhaps further also the subtypes.

As we see, the basic starting point are the relations between structure and a slope or general surface morphology, especially in case of karst surface in solid bedrock. Also the Bögli's Schichtreppenkarst /1964/ is an example of elementary type or subtype. We have been using also some of the William's /1966/ definitions and examples of different kinds of pavements. They are similar to alpine ones because of the similar origin, not regarding their rather low location in different places of British Isles.

Thus the system of glaciokarstic or alpine karst morphological complexess - types looks as follows:

I. The karst in solid limestone bedrock.

A. The types of karst on the leveled relief.

a. the flat pavements /Schichtreppenkarst after Bögli/, dip from $\approx 0^{\circ}$ to 10°.
b. the inclined pavements with cuestas /dip $< 45^{\circ}$/.
c. the levelled surface without pavements /dip $> 45^{\circ}$/.

B. the types of karst on slopes $< 45^{\circ}$

a. the stepped flat pavements /dip from $0^{\circ} - 10^{\circ}$/
b. the conformed inclined pavements /dip slope, dip $10^{\circ} - 30^{\circ}$ /45°/.
c. the subconformed type of inclined pavements with scars /dip > slope/.
d. the subconformed type of stepped inclined pavements /dip < slope/.

e. the transverse type of inclined pavements /the direction of dip is for about 90^{o} different from the direction of the slope.

f. the reverse type of inclined pavements /the direction of dip is about 180^{o} different from the direction of the slope.

g. very steep or vertical slopes smoothed by glacial erosion and often dismembered by paralel Rinnenkarren.

C. the transitional type of karstified slopes with alternation of conformed inclined pavements, benches and steep scars.

D. a. the karstified relief of rochees mountonees with passages to surfaces covered with glacial drift.

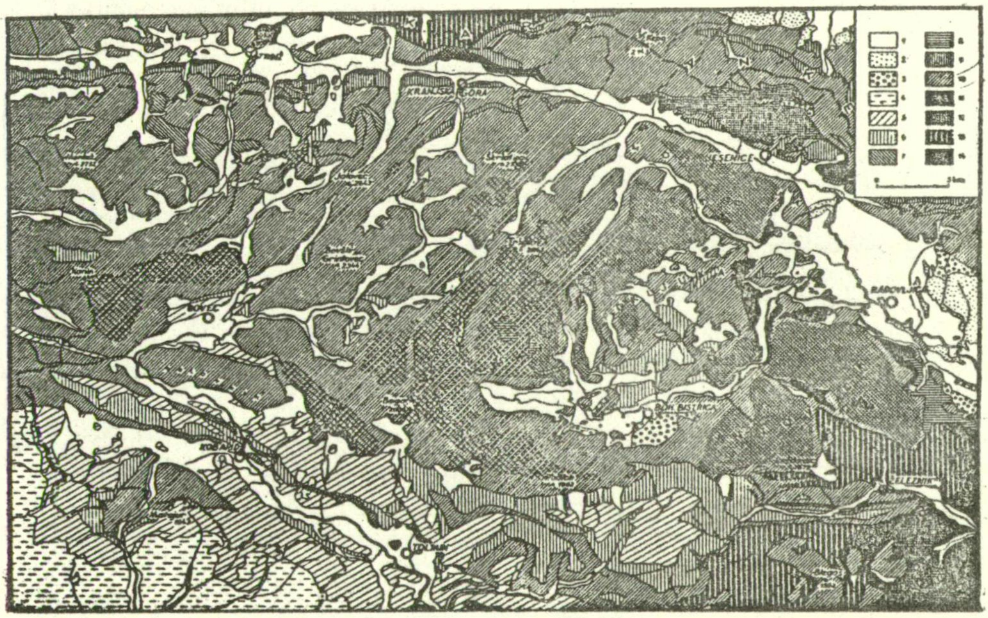
II. The alpine karst on less compact, thinly bedded, less pure or dolomitized rock, in glacial drift of carbonate composition and in rubble.

A. a. the dolinas in extremely jointed bedrock.
b. the dolinas in dolomitized limestone.

B. a. the dolinas in glacial till and in rubble.
b. the elongated dolinas and elongated dolinas like trenches in Karstgassen.

C. a. less typical karst surface, covered with rubble as the result of mechanical desintegration or because of dolomitisation.
b. slopes, covered with glacial drift, karstified on benches.
c. slopes in dolomite and dolomitized limestone.

Bigger karst forms as bigger dolinas, all sort of uvalas, karstgassen, dry valleys etc. could however be marked on the geomorphological map separately. There is of course in the proposed system also enough place to enclose other elementary types of karst surface, which are characteristic for other alpine karsts.



Geological Survey and the Hypsometric Types of Karst of the Julian Alps

the subalpine karst areas below forest line;

the transitional zone of alpine karst around forest line,15oo-18oo m;

the alpine karst areas above forest line, up to 25oo m .

1.Quaternary;2.Miocene;3.Oligocene;4. Eocene;5.Cretaceous;6.Jurasic;7.Rabel strata;8.Wengen strata;9. Werfen strata;1o. Triassic,prevailing limestone and dolomite;11. Permian;12.Carboniferous;13.Old Paleozoic;14.Porphyry.

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