Therese Pippan *
Salzburg

STUDIES ON GRUS AND BLOCK DEPOSITS ON MOUNTAIN SLOPES IN AUSTRIA

STUDIES IN THE CRYSTALLINE UPLANDS

INTRODUCTION

In the eastern part of the Crystalline Uplands in the Upper Austrian Mühlviertel H. Fischer (1963/64) has conducted geomorphological studies during 1960—1962 and, in the western part, the present author from 1953 to 1967 (Th. Pippan, 1955). Amongst other problems the investigations concerned grus and block development.

In the western area gneiss is by far prevailing whilst schists and phyllites cover much smaller areas. Outcrops of fine- or coarse-grained granite are rather restricted. A relatively large area is covered by the Weinsberger granite which is marked by a certain parallel arrangement of its orthoclase crystalls of up to 12 cm in length. Rather similar is the Eisgarner granite with large, narrow, thin, tabular crystalls. The strike of the main structures is W, NNE, NE and N at which the arrangement is proceeding from the earliest to the latest tectonic directions. Up to now the eastern Mühlviertel has hardly been mapped geologically. In this area similar granites and structures are represented.

GRUS DEVELOPMENT

Upon little dissected remnants of the plateau grus deposits are exposed at levels between 460—800 m. In the W they do not occur at the bottom of large deep valleys. Their thickness may attain more than 12 m. It is decreasing with growing slope gradients.

* Salzburg University, Department of Geography.

The thickest sections occur in broad, flat basins. Upon slightly dissected plateaus the mean thickness attains 3 m. Upon rounded summits or slopes of more than 20° gradient (H. Fischer, 1963/64) solid rock appears.

The thickness of the grus is controlled by the characteristics of the rock. Rather deep sections are found in coarsely structured granite or gneiss with a clearly layered texture and intensive tectonic stress exerted upon the rock. With the Weinsberg granite a thickness of the grus up to 3 m was observed, with finer grained material without distinctly layered texture 1 m.

The disintegration of the rock is due to deep chemical weathering by which the feldspars are turned into kaolin. This process is going on under a moist tropical to subtropical climate, favoured by warm water of high solution capacity which penetrates into the rock along the joints, being especially effective at their dissections. At this several spheroidal grus scales develop arranged parallel to the marginal surfaces of the granite which coincide with the joint planes. According to W. Panzer (1954) this fact reveals the original characteristics of the granite to disintegrate into spheroidal blocks. This is especially true of a coarse grained material. Gradually the rock is disintegrating into its crystalline components. Sometimes by the effect of periglacial frost shattering the coarse stones may be cracked at places into two parts along smooth planes not yet decayed. As we are dealing with a granular thoroughly undisturbed rock disintegration *in situ* the layered or fluidal texture of the migmatite and the grainy structure of the granite are preserved. Thin pegmatite, aplite or quartz veins broken up into many rhombohedral components and cutting straight through the grus are not at all deformed at Stratberg SE of Kollerschlag. Oddly enough no solifluction seems to have been active there although with a location at 720 m above sea level near the Bohemian Forest having been glaciated in the Pleistocene, its generally loose structure and the high slope angle would have provided ideal conditions for the activity of cryergic processes under the influence of a periglacial climate.

Granitic weathering sections show from bottom to top a sequence of solid, heavily jointed rock passing upwards gradually into grus with core stones decreasing in size and number towards the top (Pl. 1), the grus *in situ* zone where the original rock and joint structure is preseved and according to H. Fischer near the top traces of kaolinisation. Higher up according to this author, bent grus outcrops may pass into one or more flow grus zones without a granitic structure where sandy-stony material with angular rock splinters occurs. At levels above 800 m large granite blocks of up to 2 m diameter may be inserted into the flow grus zone. Its lower part is marked by the arrangement of the crystalls and stones parallel to the slope which fact points to slow periglacial flowage. The blocks in this horizon point to the Pleistocene age of the flow grus zone. At the top of the section there is recent brown or podzolic soil.

Some observations permit to date the age of the grus formation. At several places like Lacken NW of Aschach or near Feuchtenbach at the Gr. Mühl the grus occurs at the basis of the upper Pliocene quartz gravel which in the first case is some m thick. So the grus must be earlier than the gravel. In the neighbouring Bavarian Forest in the Ilz area at the brick works of Ernsting the grus is located below the upper fresh water molasse (P. Ergenzinger, 1965). In 1960 J. Demek mentioned that in the granite massif of Brünn the grus is overlain by Helvetian sand. He thinks the grus to be of Paleogene age.

According to H. Fischer a drilling at the Reichgruber farm on the Klam mountain showed below 75.5 m thick Tertiary sand a 17.3 m thick granitic grus horizon whose uppermost parts are somewhat kaolinised. A boring in the basin of Klam met below 82.5 m of Tertiary sediment 18.7 m thick granular disintegrated granite whose top parts show slight kaolinisation. At Weinzierl a more than 27 m thick weathering mantle of kaolin and grus was found below 38.6 m thick Schlier. In 1964 T. Czudek mentioned remnants of a kaolinised weathering zone in the plutone of Žulová which attains up to 100 m in thickness at protected places. In 1964, J. Demek reports a weathering zone up to 110 m thick in the gneiss of Soratka where china clay is mined down to a depth of 80 m. The kaolinisation could proceed only under tropical to subtropical climatic conditions. Therefore the thick *in situ* grus zone and the block grus zone at its bottom is the result of intensive chemical weathering under the climatic conditions mentioned above. The kaolinisation calls for a Tertiary age of the regolith whose remnants have been preserved. This view corresponds with the results of chemical and x-ray investigations of the granite grus carried on in the Weschnitz Valley of the Odenwald by A. Semmel in 1961.

I think that grus development in the research area has not much to do with periglacial processes but goes back to an earlier geologic period. The fact that in the W it is restricted to the high level of the plateaus and does not occur below 460 m shows that it must have stopped at the latest at a time when the dissection of the plateau went down below 460 m. As the tracing of the remnants of the old valley floors along the Danube shows this was the case in the middle Pliocene. If the grus development were due to the influence of the periglacial climate it would be difficult to understand why it is so scarce upon the high ridges where due to such a location the climatic influence named above ought to have been active rather intensively.

In the area in question the grus sections developed after the regression of the Miocene sea from the middle Miocene to the early Pliocene under the influence of a warm humid climate. The frequent red colouring of the grus supports this view. After H. Wilhelmy (1958) the Tertiary age of the red loam horizon is well established. The rather uniform character of the grus sections over a large area supports this view, that they all developed under similar climatic conditions and that a continuation of typical grus weathering into the Quaternary is unlikely. Areas not having been much uplifted after the Miocene naturally have typical grus sections even at their present location at a low level.

J. P. Bakker (1967) thinks that there are arguments for the point of view that the most probable date of the kaolinitic-illitic sandy weathering types appears to be early or pre-Quaternary.

BLOCK FEATURES

The area investigated is marked by several block features such as castle copies, block ribs, block pillars, block streams, block packing, block sheets and block litter.

Castle kopies are represented only on a small scale and on higher summits as at the Bärenstein 1076 m (Pl. 2). Less conspicuous features occur on lower tops.

In association with far extending block ribs block sheets may develop which thin out downslope. By the disintegration of block ribs eventually block pillars develop as on the Bärenstein (Pl. 2).

As far as such features are located at a certain level above the valley floor and breaking up into blocks, block streams may arise from them which are bare or overgrown with vegetation. When the block streams are uncovered and the block providing faces not yet consumed, the width of the block streams with their clearly marked margins corresponds to the associated free faces. In the western Mühlviertel their presence is nearly always restricted to steep valley slopes with narrow cross sections. Generally, these areas are marked by dense jointing of the rocks due to the occurrence of main dislocation zones. To the left of the Danube upstream of the mouth of the Grosse Mühl 16 large block streams can be observed. Occasionally they seem to arise quite suddenly from the slope. Vegetated block streams are located at the lower course of the Grosse Mühl. Very rarely and never typically such features are represented upon the flat summits of the Crystalline Upland's plateaus.

In the block packing which may attain a thickness of some m the blocks are concentrated to form a compact deposit. If it is thinning out, block litter develops.

Four block generations can be established at which, when proceeding from the youngest to the oldest the intensity of weathering and blunting of the block edges, of vegetation overgrowth and packing into the soil increases so that a course of development from loose, bare, angular blocks to block packing can be stated which is recognisable as such only in exposures and where the blocks are thoroughly grown into the soil. Eventually all four generations may be located one above the other. But generally the sections are defective and the individual generations may be placed side by side. The differentiated proportion of overgrowing and packing of the blocks into the soil shows the intermittent development of the block generations. At first a bare block sheet or block stream of generation I originated at whose evolution block disintegration *in situ* proceeding from solid rock, block fall in association with free faces due to frost shattering or isolation out of grus could co-operate. This block deposit was overgrown with plants to form generation II what could happen under a climate similar to the present-day conditions, therefore during the interglacials too (Pl. 3). Then increased soil formation below the vegetation was active as well as packing of the blocks. So later on, bushes and trees could grow from which process the generation III resulted. At last the blocks have been packed together by the activity of solifluidal movements of the soil and thus the generation IV, the block packing arose. Within this deposit the blocks could be transported downslope especially during the glaciations when under the influence of the periglacial climate plant growth was insignificant and the soil mobile due to frequent freeze and thaw. As a result of such movements the blocks have been arranged parallel to the slope and their edges blunted. The Pleistocene age of the block packing can be inferred from the fact that in some sections it is located on top of the upper Pliocene Pollhammer gravels.

The array of the blocks is seldom typically developed. It is best represented by the block packing where the components show a clear downslope inclination. The array of blocks lessens with decreasing age of the block generation. From block streams it is absent. In the latest block rivers, the falling, gliding or rolling blocks are piled up. Eventually a certain array can be discerned as the components located higher upslope are smaller than those farther dowstream what is due to the higher momentum of movement of the larger blocks.

The proportion of edge blunting of the blocks is controlled by their age, the distance of transport, the hardness and structure of the block forming rock and the angle of slope. With growing age the blunting of the edges increases especially when the blocks have been moved on a steep slope. With block disintegration *in situ* upon flat tops this sculpturing often is insignificant even in the block packing because the distance of transport was short (Ameisberg 940 m). On the other hand with a long distance and a high slope angle, even components of a bare rock stream may eventually show blunted edges. With flaggy, finely textured material or massive rocks like aplite the proportion of rounding is insignificant. The highest effect of blunting is attained with coarse crystalline rocks.

Several criteria indicate that the block fields are moving on. Such symptoms are the bending of trees at the front of block streams, the bulging of the blocks at the lower end of block sheets, the frequent occurrence of migrating blocks upon a petrographically different substratum, the transport of large boulders in the rivers and the fact that the block packing associated with outcrops of solid rock is extending farther than the much later block litter which had less time for movement.

Under the recent climate the transport of the blocks is effectuated by soil creep, rolling off or fall of the boulders. During the Pleistocene cold periods periglacial solifluction was important. After H. Wilhelmy (1958) it penetrated up to 1.5 m into the substratum. Due to gravity effects the block wrapped up in a loam pulp concentrated in the basins of the relief. Block streams consisting of angular waste developed whose components have been provided by frost shattering active at free faces. With the change of freeze and thaw the blocks are able to move even on very flat slopes.

The size of the boulders is controlled by the density of the joint pattern in the block producing rocks and by their structure. With a joint system of wide meshes in a slightly disturbed area, the length of the boulders attains 2 m on the average. In the Eisgarner granite up to 5 m, in the Weinsberger granite up to 3 m long blocks could be observed. Finely structured rocks with a distinct layered texture have a mean block size of 0.5 m. In the intensively shattered rocks of the Danubian marginal fault, the blocks, because controlled by a much denser joint system are much smaller.

The tendency of the rock to produce block features is controlled by its structure. Coarse-crystalline material favours this process. In coarse grained gneiss occur the huge block streams at the left side of the Danube. In fine structured pearl gneiss no block streams have been observed. Under recent climatic conditions it is not liable to disintegrate into blocks. But block packing may occur. The more distinct the layered texture of the gneiss the less it is inclined to form blocks. At several places the block formation stops suddenly under otherwise similar conditions with the outcrop of finely textured gneiss or schist. With Pfahl schist thin easily disintegrating slabs separate along the foliation planes.

The shape of the blocks too is controlled by the structure of the rocks. With coarse-grained granite typical woolsack features are prevailing. The disintegration of the Weinsberger granite into blocks often clearly follows the layered structure of this rock indicated by a certain parallel arrangement of the large, broad feldspar crystalls. The Eisgarner granite with its oblong, narrow feldspar crystalls generally forms oblong, narrow, and flat blocks (Pl. 4).

The disintegration into boulders is favoured by the occurrence of joint and movement planes of the rock especially by the combination of vertical and horizontal joints as it is represented mainly by granitic material. Within shatter belts where joints of several strike directions produce a dense pattern the rock is disintegrating very easily. Rather often parts of the block surface coincide with polished tectonic planes. The direction of block ribs and pillar series upon the Bärenstein and Haugstein, 876 m, follows the Hercynian strike.

There exists a close relation between block formation and grus development. In the deeply rotting Weinsberger granite often large globular corestones occur which show evidences of spheroidal weathering for example in the quarry at Putzleinsdorf. Sometimes they penetrate the soil and come up to the surface (Pl. 5). In the neighbouring area of the Weinsberger granite, individual huge blocks are scattered eventually over the surface or form a somewhat closer block litter. Such boulders have been isolated out of the grus which was removed by rain wash, soil creep, or solifluidal activity turning the grus into a mobile soil flow. According to H. Wilhelmy (1958) the eluviation of the fines from between the blocks was probably accomplished with the first improvement of the climate after the retreat of the glaciation and even more during the later Tundra period when considerable quantities of water have been set free and the solifluidal material was not protected by a soil cover. The moderate postglacial climate caused severe outwash of the slopes by water flowing at the bottom of the block deposits by which activity the block fields and streams occurred as morphological features. Upon fresh clearings the areal outwash of the soil is intensified and new block streams may develop. But at the forming of the block deposits a large quantity of boulders is contributing which has been detached from free faces by frost shattering. This fact is pointed out by the slight blunting of the edges of the young block generations. If all the boulders of a block sheet had been provided by corestones of the grus they ought to be much more rounded. Obviously, it is very difficult to distinguish the proportion of the blocks isolated from the grus from that produced by frost activity.

Probably the castle kopies, block pillars and ribs especially when showing well rounded edges as it is the case on the Bärenstein and Dreisesselberg 1332 m have been exhumed of grus sections. According to R. Kettner (1936), D. L. Linton (1955), H. Wilhelmy (1955) a. o. we may assume a development of such block features in two stages. The first stage was the disintegration process of the granite under the influence of a Tertiary warm humid tropical to subtropical climate. The corestones which have not been turned into grus form the woolsack-like components of the present block architectures. Their exhumation was achieved mainly by periglacial solifluxion processes and the action of running water under a moderate humid climate. The most severe denudation of the grus occurred upon the summit of the ridges and at the upper part of the slopes. The block features could be considerably altered by Pleistocene cryergic processes and so apart from the originally rounded outlines of the blocks we find angular contours when the boulders have been shattered by frost action. That under a warm climate blocks can be isolated from the grus by the activity of slope wash is proved by the occurrence of round scattered blocks of diorite in the northern foothills of the Central Range of Puerto Rico which have not been influenced by glaciations.

Important is the relation between block development and slope angle. As far as there is no block disintegration *in situ,* block streams and sheets occur especially on steep slopes. The blocks can only be moved when a certain gradient is available. On steep slopes even the fine grained pearl gneiss which has but a slight tendency to block formation develops block litter and sheets if free faces are existing. In case when the slope angle is far below 30° block development is generally slight. Especially for the shaping of block streams the slope gradient is significant. They are best developed on high valley sides where young tectonic movements kept the slopes steep and the blocks moving down. But when the slope angle is far above 30° the boulders cannot settle on the slope. The block streams often appear quite suddenly where at a knick point the gradient grows to be somewhat lower.

In many cases and at all levels the disintegration of blocks *in situ* within solid rock occurs even now. Clearly the scars can be discerned from which the blocks have been detached whose shape fits into these niches. Often a large part of a block is left without support hanging in the air (Ameisberg). In quarries, the massive granite passes into block deposit towards the top of the exposure by the detachment of blocks along joints. On the Schweinzberg at the Kleine Mühl the disintegration of a castle kopie into o block sheet can be observed. If block sheets or individual blocks occur on isolated tops without association with free faces (on the Frohnforstberg near Schardenberg) block formation must have taken place *in situ* by disintegration of the rock because a migration of boulders under the conditions given is not likely.

Generally the disintegration into blocks is not restricted to a certain climate. It occurred under a warm-moist Tertiary climate by chemical rock weathering, under periglacial, interglacial or recent climatic conditions by frost shattering as far as bare rock faces are exposed to the attack of freeze and thaw. Further the disintegration into blocks is possible below a soil or plant cover as can be seen on top of intensively jointed solid rock in many quarries where percolating water and rootlets are at work creating fine fissures.

STUDIES IN THE ALPS

In the Styrian Niedere Tauern H. Spreitzer (1960) investigated block streams and fields as phenomena of the periglacial climate above the tree line at levels from 2000—2400 m. They are derived from rock faces and located on smooth slopes. The present author made similar studies in the Felber, Stubach and Fuscher Valley of the Hohe Tauern in Salzburg from 1956—1967. Most of the boulder fields developed by disintegration *in situ,* downward movement of the blocks upon snow patches or by frost heaving in water logged soil influenced by freeze and thaw. Later the fine material has been thoroughly washed out which process proceeded from top to the bottom.

The block fields at levels between 2000—2400 m are older deposits as the concentration of several block generations to a uniform block sheet has taken a long time to develop. In the Niedere Tauern the polishing of the slopes associated with the evolution of large block fields was most active during the Daun stage but on a reduced scale revived several times during later cold periods up to the Fernau stage. From the relation of the block fields and polished slopes to well developed late glacial glacier stages and especially from the morphologically proved polishing of high cirques of the Gschnitz stage, the Daun age of the smooth slopes and block fields can be inferred. The disintegration of roches moutonnées into boulders in the Felber and Stubach Valley too gives evidences of the development of the block deposits during a time when the valley glaciers had disappeared at last up to the level of 2300 m in the valley heads. Because these blocks are not so well rounded as in the Bohemian Forest although consisting of medium grained granite-gneiss, their separation from the parent rock is mainly due to frost activity and not to isolation from grus.

According to H. Spreitzer (1960) the consolidation of the boulder sheets developed in the Daun stage occurred especially during the postglacial climatic optimum what can be proved from the vegetation cover of the polished slopes. At present the main body of these block fields is stable except for the activity of mud streams and individual gullies.

After H. Spreitzer and observations of the present author a recent periglacial zone exists in the Hohe Tauern in the environments of the snow and ice region e. g. in the Gross Venediger (3674 m) and the Gr. Landeck Kopf (2898 m) area where block fields occur at levels from 2400—2900 m. They are of recent age. In the fine material interspersed with blocks which is derived from early moraines or alluvium no frost shove can be observed. As an example of recent solifluction due to the present climatic conditions H. Spreitzer mentions the block movement in fine sand at 2350 m N of the Felber Tauern. Between 2400—2800 m in the S and up to 2900 m to the N of Innergschlöss between the Felber Tauern and the Viltragen Kees an optimum zone of block field development with downward movement and slope polishing is located. The blocks move over snow patches and concentrate at their margin to form a continuous block field. Impressing are recent features of boulder sheet development and solifluction above the Schlatenkees in the environment of the Prager Hut at 2800 m. As to the periglacial region in the neighbourhood of the Berliner Hut in the Zillertaler Alpen, H. Poser (1954) showed that recent block field development only occurs at a level above 2400 m thus supporting H. Spreitzer's views.

Investigations by the present author in the Fuscher, Kapruner, Stubach and Felber Valley in the Hohe Tauern (1956—1967) have shown that the disintegration into blocks is influenced by the same factors as in the Upper Austrian Crystalline Uplands, that is especially by tectonic jointing and the lithologic characteristics of the rocks. The detachment of the blocks from free faces is mainly controlled by joint planes. Smooth slopes develop most easily when their gradient parallels the dip of tectonic planes. An example is the N-side of the Krapfbrachkopf 2715 m in the Kapruner Valley. In areas of intensive tectonic shattering e. g. at the margins of nappes the block production is rather abundant. Indications concerning the isolation of blocks from grus could not be observed in these high regions of the Alps. This fact speaks against a Pleistocene origin of the grus in the Mühlviertel. The piling up of blocks occurs at the foot of free faces or of chutes.

CONCLUSIONS

The arguments brought forth above show that the process of rock disintegration into blocks is complicated and differentiated and cannot be explained schematically by the sole activity of the periglacial climate. Actually there exist several possiblities of block formation under different climatic conditions at different levels in which lithologic characteristics and intensity of jointing of the rocks sometimes seem to be more important than a specific climate.

References

Bakker, J. P., 1967 — Weathering of granites in different climates particularly in Europe. *Les Congrès et Colloques de l'Université de Liège*, vol. 40; L'Evolution des Versants, Liège; pp. 51—68.

Czudek, T. *et al.*, 1964 — Verwitterungs- und Abtragungsformen des Granits in der Böhmischen Masse. *Peterm. Geogr. Mitt.*, H. 3; pp. 182—192.

Demek, J., 1960 — Formy zvětrávání a adnosu žuly v Krumlovském lese jihozápadně od Brna (summary: Forms of granite weathering and denudation in Krumlovský-les Highland, SE of the town Brno). *Casopis pro mineralogii a geologii*, Bd. 5; pp. 240—246.

Ergenzinger, P., 1965 — Morphologische Untersuchungen im Einzugsgebiet der Ilz (Bayerischer Wald). Diss. an d. Mathem.-Naturwiss. Fakultät d. Freien Univ. Berlin, *Berliner Geogr. Abhandlg.*, pp. 1—48.

Fischer, H., 1963/64 — Geomorphologie des unteren Mühlviertels im Einzugsgebiet der Naarn. *Geogr. Jahresber. aus Österr.*, vol. 30; pp. 49—130.

Jahn, A., 1962 — Geneza skałek granitowych (summary: Origin of granite tors). *Czasopismo Geogr.*, t. 33; pp. 19—44.

Kettner, R., 1936 — Žulové balvany u Žihle a Tisu (summary: Granite boulders in the neighbourhood of Žihle and Tis). *Věda přírodni*, vol. 17; pp. 171—175.

Linton, D. L., 1955 — The problem of tors. *Geogr. Jour.*, vol. 121; pp. 470—487.

Panzer, W., 1954 — Verwitterungs- und Abtragungsformen im Granit von Hongkong. *Mortensenfestschr., Veröff. Akad. f. Raumforschg. u. Landesplang.*, Bd. 28; pp. 41—60.

Pippan, Th., 1955 — Geologisch-morphologische Untersuchungen im westlichen oberösterreichischen Grundgebirge. *Sitzber. d. Österr. Akad. d. Wiss.*, Mathem.-Naturwiss. Kl., Abt. I; Bd. 164, Wien; pp. 335—365.

Poser, H., 1954 — Die Periglazial-Erscheinungen in der Umgebung der Gletscher des Zemmgrundes (Zillertaler Alpen). *Göttinger Geogr. Abhdlg.*, 15; Studien über die Periglazialerscheinungen in Mitteleuropa, Teil II; pp. 2—55.

Semmel, H., 1960 — Die pleistozäne Entwicklung des Weschnitztales im Odenwald. *Frankfurter Geogr. Hefte*, no. 37.

Spreitzer, H., 1960 — Hangformung und Asymmetrie der Bergrücken in den Alpen und im Taurus. *Zeitschr. f. Geomorph.*, Supplementbd. 1; Contributions intérnationales à la Morphologie des versants; Berlin, pp. 211—236.

Wilhelmy, H., 1958 — Klimamorphologie der Massengesteine. Braunschweig, pp. 1—238.

DISCUSSION

Professor Black: In Wisconsin we have some measurements of the rate of grus formation from dated glaciations. Glacial polish and striae are gone from granitic rocks exposed during the last 10,000 to 13,000 years. Granular disintegration has removed one to 10 cm of rock. Polish and striae are still preserved beneath 50 cm to 1 m of soil.

Dr. Pippan: In our area we have no indications of grus formation during the glaciations. The same is true for the Hohe Tauern.

Dr. Demek: I appreciate very much the lecture given by Madame Pippan and I should like to ask two questions. First about the amount of periglacial modelling of tors formed by coarse grained granite, second did you find the rounded and the angular forms in one block and how do you explain it?

Dr. Pippan: Measurements about the proportion of periglacial modelling of the tors consisting of coarse grained granite have not been made up to now. They would be difficult to make because we do not exactly know what the individual tors looked like before the onset of the Pleistocene. Certainly blocks have been affected by frost shattering and fallen down when loosing their balance. But as the block sheet at the foot of the tors has been moved by periglacial processes we cannot tell how much material has been removed from the tors.

It is possible to find rounded and angular forms with one individual block because a rounded woolsack block can be split by frost shattering by which process sharp edges are produced.

Professor B a k k e r: To the question about the extent of interglacial weathering in Central Europe.

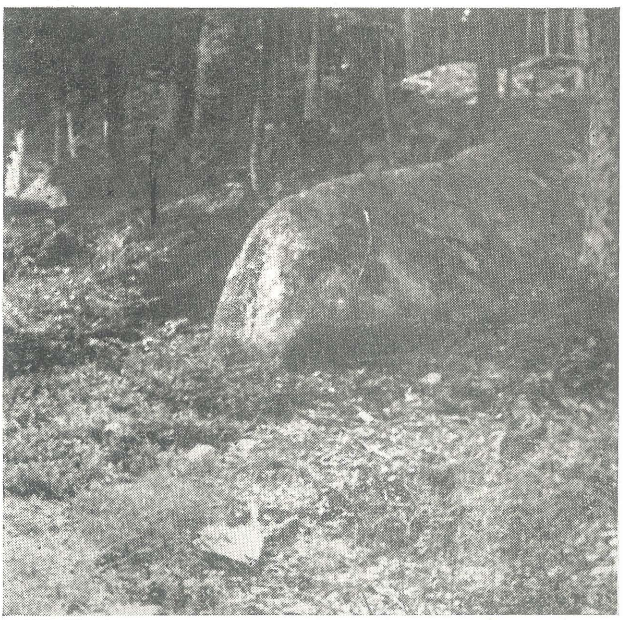
This question is very important. But we have little evidence about the extent of weathering processes in the interglacial periods of the early Pleistocene, because large denudation (probably in the Riss glaciation) stripped away the most weathering mantles created during the early Pleistocene, especially in the highlands and upland areas of Central Europe.

Dr. P i p p a n: In the Bohemian Forest of Upper Austria I could not find evidence concerning the proportion of weathering processes during the interglacial periods of the early Pleistocene. We do not have indications of glaciations older than Riss and even the traces of the Riss glaciation in this area are not beyond dispute.

Pl. 1. Exposure of grus at the Aigner Höhenstrasse at the S-foot of the Bärenstein with development of corestones showing spheroidal weathering. The parent rock is Eisgarner granite

Pl. 2. Castle kopie on the summit of the Bärenstein, 1076 m, in the Bohemian Forest. The block architecture consists of Eisgarner granite. The horizontal and vertical joints can be discerned

Pl. 3. Bare blocks of generation I and overgrown boulders of generation II at the foot of the Bärenstein near Aigen. The rock is Eisgarner granite



Pl. 4. An oblong, narrow block of Eisgarner granite of generation III, located at the S-foot of the Bärenstein near Aigen

Pl. 5. Corestones in Eisgarner granite grus at the S-foot of the Bärenstein near Aigen. One block has penetrated to the surface