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SOME PROBLEMS CONCERNING SLOPE DEVELOPMENT IN THE SUDETES

The Sudetes are old mountains, built of pre-Cambrian, Paleozoic and Mesozoic rocks such as granites, gneisses, various types of crystalline schists, sand- and limestones. The Sudetian relief was rejuvenated in the Tertiary owing to the development of a border fault (Oligocene); the whole block was raised together with the ancient (pre- and lower-Tertiary) planation surfaces. Alone some parts of those surfaces and some island mountains were left on the foreland, thus providing evidence of degradation.

The route of the first part of the excursion during the Symposium of both the Commissions led through the zone of island mountains, farther across the Sudetian edge and finally into the granite areas of the interior mountains (Fig. 1). The following topics were discussed:

THE PROBLEM OF ISLAND MOUNTAINS
(Problems 5 and 7 *)

The Ślęża mountain (718 m) and the other elevations nearby afford typical instances of island mountains in the Sudetian foreland. The conic figure of the Ślęża, rising 500 m above its surroundings is visible from afar. The mountain sides, built of very hard rocks like gabbro, granite, amphibolite and of softer (less resistant) ones like serpentinite schists, are covered with rubble fields. The plain around the mountains consists of Quaternary and Tertiary sediments. The former include glaciofluvial sands, morainal boulder clay and loess. Their thickness is rather insignificant, no more

* The number of the problem is given according to the list of the 8 major topics, that constituted the main object of the Symposium (see p. 5).

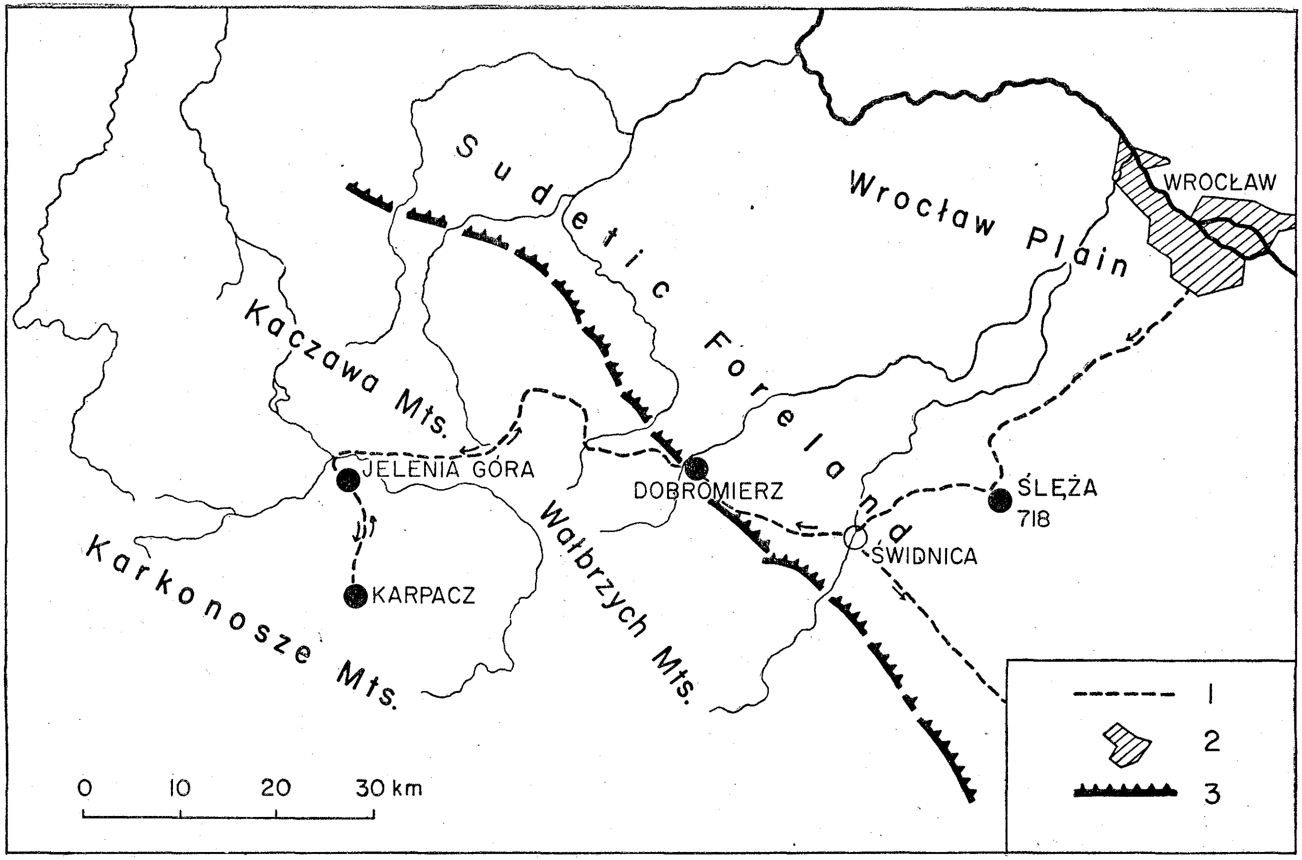

Fig. 1. The route of the Symposium excursion to Lower Silesia and the Sudetes

1. excursion route; 2. the town of Wrocław; 3. Sudetes border edge

than 10 m. The Tertiary formations, however, require a more detailed analysis since they afford a basis for the dating of the island mountain sides. These formations include gray clays and sands containing lignite. These deposits are those of the upper-Miocene sea. They rest on a bedrock of ancient rocks, and — close around the Ślęża — on granite. The granite is severely weathered and the waste derived forms the kaoline cover whose thickness attains as much as 25 m and in some places up to 50 m. In age, the kaolines are at least lower Miocene, but may as well be older — Tertiary (Paleogene).

A vital relationship is that of the island mountain sides to the aforesaid Tertiary sediments. The slopes merge beneath Miocene clays and sands (Fig. 2) and at the boundary of these deposits their profile shows a break. In the direct vicinity of the Ślęża (at 0.5—1.5 km distance from its base) the sediments have already 20—40 m in thickness. Farther away (3—6 km) the Tertiary deposits attain a thickness of as much as 150 m (Marcinkowice village) and even 170 m (village Strzelce near Sobótka)[1]. These deposits fill old valleys and troughs and still older tectonic trenches. Hence their varying thickness, though on the whole, Tertiary sediments tend to decrease in thickness with approach to the mountains up to their actual base. From this fact it may be inferred that the Ślęża and the surrounding island mountains emerged as real islands from the Miocene sea whose coast coincided more or less with the present-day mountain foot.

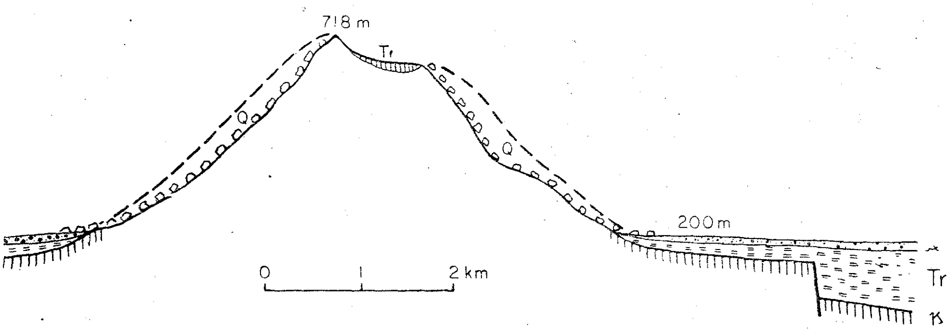

Fig. 2. The Ślęża island mountain

Q — Quaternary deposits and slopes; Tr — Tertiary deposits and slopes; K — kaoline waste; broken line shows the presumable situation of slopes in the Tertiary

[1] Oral information from mgr Olgierd Gawroński, Geologic Institute in Wrocław.

Certain details provide evidence suggesting that this mountain foot may be even older. A kaoline cover — older than the upper Miocene gray clays — is still preserved in some parts of the Ślęża mountain sides, namely right at their base in the west-facing part and at the horizontal slope planation at 645 m altitude (Szczepankiewicz, 1958). The general situation of the Ślęża slopes is illustrated in Fig. 2. As may be inferred from this situation, the Ślęża slopes have retained their outlines ever since the Tertiary and their shape, i.e. that of the mountain, did not undergo any substantial modifications. There are no larger pediments, the slope base and its faintly grading portions did not move from the place which they occupied in the Miocene. In the Pliocene and the Quaternary, the slopes were slightly modelled chiefly through cutting by streams and owing to the formation of mechanical weathering products such as block- and rubble fields. This question will be discussed in the next section of the present paper.

As concerns the Quaternary, it must be remembered that the ancient glacial periods tended to preserve the island mountains' landscape. During the glaciations Mindel and Riss the surrounding area was filled with an ice-cap; alone the highest Ślęża mountain emerged as a nunatak above the ice-sheet. Thus isolated from the destructive effects of external processes, the mountain sides could be preserved. The major modifications of the mountain relief are attributed to the periglacial periods namely to the Warta stage of the Middle Polish glaciation (Riss) and to the Baltic glaciation (Würm) when the island mountains were situated in the immediate forefield of the ice-sheet. The blocky cover of the Ślęża slopes, the most conspicuous feature of their surface was described in detail by G. Schott (1931) and St. Szczepankiewicz (1958).

LINEAR AND SURFACE EROSION
(Problems 2 and 3)

The side slopes of the Ślęża and other island mountains nearby were subjected to destruction processes which may be classed into two groups: that of linear and that of surface processes. The first type leads to erosional dissection of the slope and to the production of gullies and valleys by water streams. The second type consists in the various operations of dispersed waters, chiefly in the transportation of waste by creeping and sliding. The effects of both these processes can be evaluated by measurements of the quantity of the rocky material removed from the slope.

The effects of surficial degradation are not easily recognizable and may be approximately estimated in those cases alone where fragments of the primary slope are still preserved. Evidence of it may be provided by the presence of tors, i.e. erosional remnants on the slope. Such tors, no more than 10 m in height, occur on the granite and gabbro slopes of the Ślęża. Hence the total recession of the slope from Miocene times to the present-day attained a maximum of 10 m.

Linear slope erosion is more readily measurable, if it be taken for granted that the small valleys that cut the slope provide evidence of the magnitude of erosion while the intervening slope ridges (spurs) represent fragments of the "old" slope. The surface of this "old slope" is not that of the "primary" slope in the strict sense of the term, for here again the lowering action of surface processes must be taken into account; however the very existence of the valleys indicates that the linear process was here much more vigorous than the surficial one.

On the ground of that assumption the "old" slope (prior to dissection) may be reconstructed in the contour map, by connecting the convexities of the contours. Erosional slope recession may be estimated by means of measurements of the surface contained between the contour and the hypothetic primary slope line, represented by the simplified and generalized contour line that connects the spurs. The mean value of horizontal recession may be obtained by dividing the surface of measurement by the base of the figure, i.e. the length of the simplified contour. The result represents the mean value of horizontal backwearing (l). From that value, it is easy to derive that of the thickness of the degraded layer (d), at a slope gradient α, according to the equation below:

$$d = l \sin \alpha$$

This simple method permits to estimate the effects of erosional backwearing of the slope, provided that three contours at least — namely one in the upper, one in the middle and one in the lower slope part — be taken into account.

This method can be conveniently applied to the slopes of the Ślęża and those of the neighbouring island mountains because of their relative uniformity in age and composition. They were all developed in the times that elapsed from the Miocene to the present-

-day. A relevant fact concerning their geologic structure is the presence of slopes, wholly built of variously resistant rocks, namely of the most resistant gabbro, the less resistant granite and the least resistant serpentinite. The drawing subjoined illustrates three selected slopes (Fig. 3). The one built of highly resistant gabbro rocks has not been completely dissected and shows only some de-

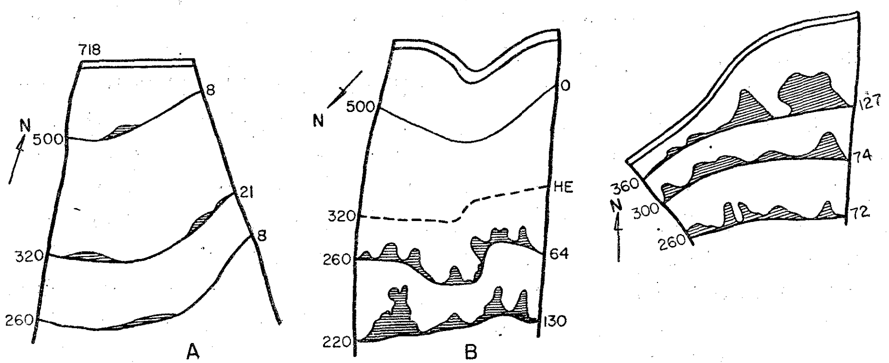

Fig. 3. Dissection of island mountain slopes in the Sudetian foreland (the dashed area in each figure) built of such rocks as: gabbro (A), granite (B), serpentinite schists (C)

Absolute heights (contours) are marked on the left, slope retreat (in metres) by erosion — on the right side of the figures; broken line (HE) indicates the front of head erosion

nudation troughs. On this evidence, the slope is estimated to have receded 8 to 21 m. The granite slope is cut only at its base. The value of backwearing attains from 130 (contour 220 m) to 64 m (contour 260 m). Considering the slope gradient — the thickness of the removed rock layer is evaluated as ranging from 10 to 20 m. The upward front of the headward erosion i.e. the head of the valley that cuts the slope can be here easily established. The granite slope, at the altitude to which the little valley extended (300 m) was shown to the participants of the excursion. Above, the slope is smooth, undissected. The highest value of backwearing is that of the third, serpentinite schist slope. It is higher at the top (horizontal recession 127 m, i.e. 40 m backward) than at the base (recession 72 m, i.e. 10 m backward).

The results of this morphometrical analysis and those of field observations suggest the following conclusions.

(1) There exists an intimate interdependance between the morphology of the slope, the rate and mode of its destruction and the

nature of the rock. During one and the same time the gabbro slopes receded no more than several metres and chiefly owing to processes of surficial degradation while those built of serpentinite schists receded more than 100 m along their whole length. In these soft rocks the process of dissection involved the whole slope and the front of headward erosion reached up to the ridges. Granite slopes representing the medium type of resistance were eroded in their downward part alone.

(2) All the slopes have on the whole retained their primary Tertiary profile, though differentiated degradation created a tendency to new modifications of the slope. Best stabilized in that respect is the gabbro slope whose shape has remained unchanged ever since the Tertiary. As a result of vigorous dissection in its central portion (branching off valley heads) the granite slope became more concave. The serpentinite slope lowered some 40 m (recession — 127 m) at the top and 10 m at the base (recession — 72 m) acquired a profile whose gradient is on the whole lesser than the one it had in the Tertiary. "Downwearing" of the slope is here plainly obvious.

(3) The present investigations have shown that linear slope degradation is more significant and rapid a process than that of surficial degradation over a wide front. In that respect, H. Baulig's (1940) hypothesis gains full confirmation. Linear erosion i.e. erosional dissection is a leading process determining the outlines and shape of the slope profile.

FLATTENING OF THE SUDETIAN SLOPE
(Problems 3, 5 and 7)

The evidence of the serpentinite schist slope of the island mountains whose downwearing was established provides one instance only of what seems to be a general phenomenon in the evolution of the Sudetian slopes. The statement refers chiefly to slopes built of soft rocks.

The participants of the excursion have examined the Sudetian edge slope, near the Dobromierz village. Dr. H. Piasecki illustrated it by means of a section and of pits.

Well-defined, the border edge of the Sudetes shows a rectilinear course, determined by its tectonic origin (fault formed in the Oligocene). From the time of its formation, this border scarp did not undergo any conspicuous horizontal displacements. The deposits of the Miocene sea advanced right up to its line but never encroached upon it. The scarp is cut by numerous valleys.

In the Dobromierz region, thick glacial sediments such as ground moraines and glaciofluvial sands were found to mantle the downslope part i.e. that of the Sudetian border scarp. As these deposits belong to the Middle-Polish glaciation (Riss), the underlying slope segment is attributed to the older Quaternary. Of the same age are the boulder clays and debris (waste) marked M in Fig. 4. The upper slope segment is post-rissian in age and mantled with two slope covers: one of waste material and one laid by solifluxion. Upward, this slope part flattens out.

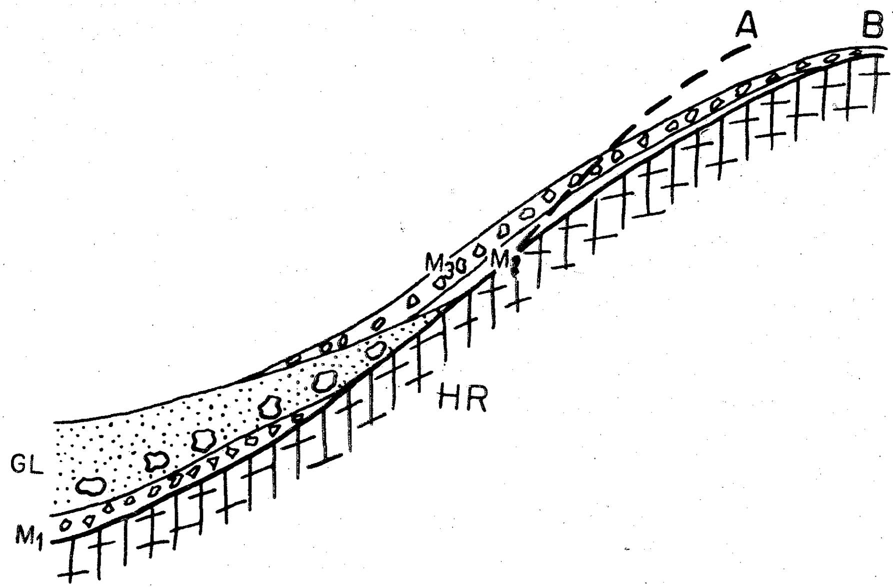

Fig. 4. Profile of the Sudetes border edge in Dobromierz: initial (A) and subsequent (B) situation

HR — bedrock (hard rocks); GL — glacigenic (and glaciofluvial) sediments; M_1, M_2, M_3 — slope covers

Diagrammatic sketch based on materials collected by H. Piasecki

That analysis of the morphologic profile and the slope formations shows that in the Quaternary, the border edge of the Sudetes did not change its position but rather its general inclination. The downslope segment is preserved by accumulations of predominantly Tertiary clays and sands or — as in the case presented — by glacial deposits. The unpreserved upslope part underwent surficial degradation due to periglacial weathering and removal by solifluxion. Reconstruction of the initial slope by extrapolation (on the basis of the preserved segment) indicates that this slope (line A in Fig. 4) had a higher gradient than that of to-day.

PERIGLACIAL "SMOOTHING" OF SLOPES
(Problems 3 and 5)

A perfectly smoothed slope with a regular concave profile (Fig. 5) was examined during the excursion (presented by M. Cielińska). On closer inspection this seemingly uniform slope was found to be widely diversified in its geologic structure. In the upper portion hard rock, granite with a waste cover appears at the surface. Lower downward there are glaciofluvial sands while the basal slope portion exhibits glacial formations, boulder clay, sands and varved clays. Such a composition indicates that the slope profile was once more diversified, because each of its sedimentary components was more conspicuously marked. Glaciofluvial sands formed a kame terrace.

By means of diggings it has been established that the "smoothed" slope surface and its regular concavity are due to a periglacial layer of a combined slopewash-solifluxion origin. It displays a typical pattern of striae and thin bands oriented accordingly to the line of slope. The formation testifies to vigorous dynamic downslope movements. The largest thickness of the deposits is in the lower part of the concavity (4 m) and decreases upwards. Uniform in structure along its whole profile, it varies in lithologic constitution according to the nature of the rock of which each of the slope portions is built.

From these facts it may be inferred that the "smoothed" slope belongs to the last glacial period, during which the cover composed of periglacial slopewash and solifluxion formations was deposited. This layer truncates the glaciofluvial and glacigenic rissian formations. Periglacial processes had no influence upon the general shape of the slope profile — for the concavity is pre-Quaternary in age — but evened out its surface by obliterating its convexities, infilling of its concavity and thus producing a profile of their own, characterized by a smoothing up of the older slope-surface. Thus, the periglacial period introduced a certain — though only exterior — regularity. Re-modelling of that kind was productive of the major features of the periglacial Sudetian slopes.

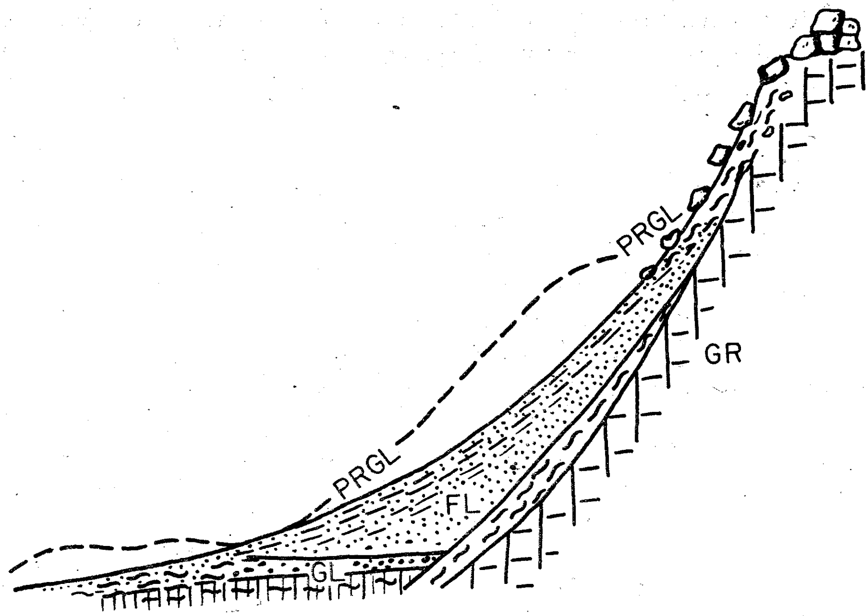

Fig. 5. Slope deposits on the granite hill near Jelenia Góra

Broken line marks the presumable former configuration of the old slope; GL — glacial sediments; Fl — glaciofluvial sediments; PRGL — periglacial deposits; GR — granite

Diagrammatic sketch based on materials collected by M. Cielińska

THREE-FOLD DIVISION OF THE KARKONOSZE SLOPE COVERS

(Problems 1, 3 and 4)

The Karkonosze granite is deeply weathered, down to 10 m and still deeper. The origin of so thick a weathered layer is ascribed to processes operating on the rock as far back as the Tertiary.

In the upper part of that waste, three horizons of slope sediments can be distinguished. The best exposure is provided by the section shown during the excursion in Karpacz (720 m alt.). The sequence of the layers, marked A, B, and C is as follows (Fig. 6).

The top layer A, ca. 1 m in thickness, consists of loose sandy clay, including scattered boulders. Its base line is irregular for the formation fills the depressions of the subjacent cover. This layer includes a fairly large amount of dust particles (up to 34%).

In the exposure, the subjacent B horizon has 2 m in thickness. It consists of clay and debris, greyish-yellow in color; its structure

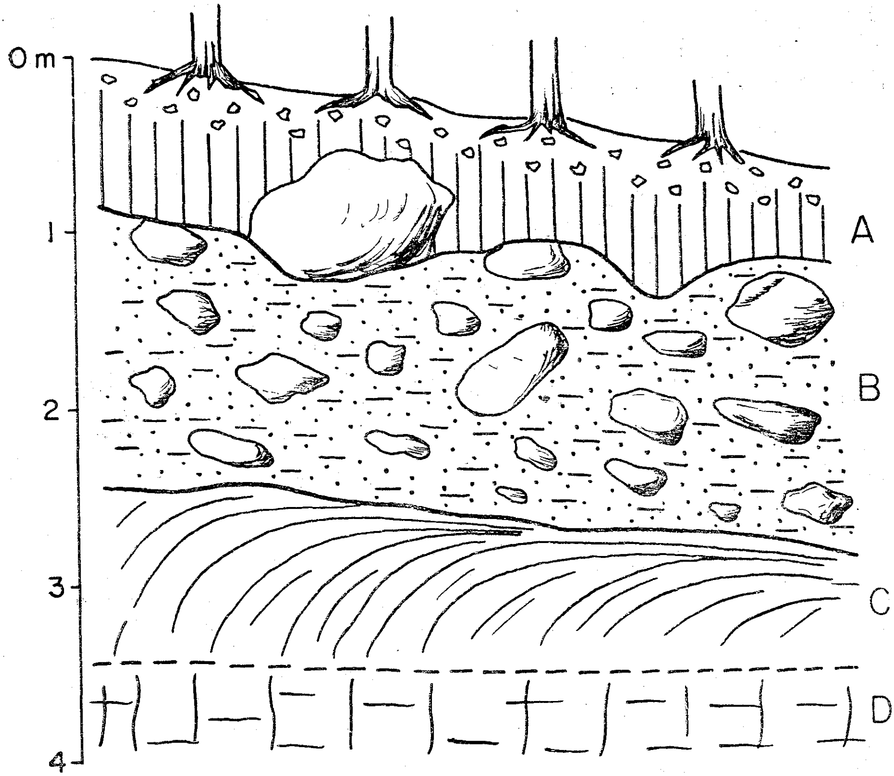

Fig. 6. Exposure in Karpacz, near the house "Krokus"
Three horizons of slope deposits (A, B, C) and weathered bedrock (D)

provides evidence of displacement downslope. Stones — large blocks at the top of the layer — are oriented according to the line of slope. The formation is regarded as allochtonous, produced by solifluxion. It includes a lesser amount of dusts than layer A.

Horizon C is separated from the overlying one by a well-marked discordant boundary. It consists of very fine debris, differing from the clay of horizon B. Dusty particles are absent. The debris is strongly reminiscent of granite grit with which it is, besides, structurally connected. This formation emerges from the waste *in situ* and shifts downward in the form of bending of outcropping layers (*Hackenschlagen*). It shows a well defined bedding pattern which provides evidence of vigorous downwash.

That three-fold division of the Karkonosze slope covers and those of the nearby Izerian mountains is considered as a typical phenomenon. Another exposure of a like type was inspected during the excursion namely the one near the B. Czech Shelter (1000 m alt.) where horizon C and the structure of the slopewash deposits is least developed (Fig. 7).

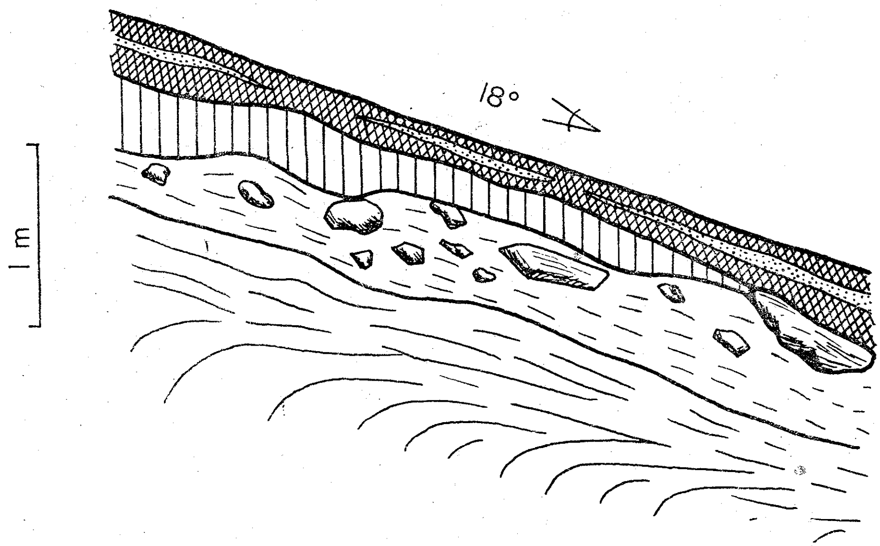

Fig. 7. Three slope covers, cross-section near the B. Czech shelter-house

J. Büdel (1937) who described the Karkonosze (Riesengebirge) slope formations, distinguished one horizon only, coinciding with our horizon B. Büdel realized the vital significance of periglacial solifluxion slope processes which during the last glacial period led to the production of huge rubble-clayey covers in these mountains. The solifluxion phase coinciding with the maximum glaciation was followed by one of complete extinction of mass movement on the slopes during the Holocene.

Investigations, some of whose results were presented to the participants of the excursion, indicate that as many as three distinct covers ought to be taken into account. Some of the debaters disagreed with the present writer's opinion, and thought that horizon C ought to be regarded as a dynamically differentiated part of horizon B rather than as a separate horizon. Nevertheless, the writer still maintains his views as presented during the excursion. These views concerning cover C *(Hackenschlagen)* as distinct from cover B are founded on such evidence as:

(1) The difference in mechanical composition of the material. Horizon C consists of debris (free of dusty particles) whose bedding

has been disturbed *in situ* by water and slumping due to gravity, while layer B consists of typical solifluxion clay.

(2) If horizon C were to belong to the same phase of movement as the overlying cover, the bent outcrop layers (*Hackenschlagen*) of this horizon ought to extend into layer B and intersect it. It is not however, the case, the border line of both these layers being well-defined.

The three slope covers distinguished on the Karkonosze mountain slopes are correlated with the last glaciation. Evidence supporting this hypothesis is provided by their general occurrence under the present-day forested slope surface. Another supporting evidence is that of the relationship of these covers with the silty formations of the Jelenia Góra basin and the moraines of local glaciation of the Karkonosze.

The three-fold division of these slope covers would thus go to confirm the hypothesis of a three-fold division of the Würm glaciation — according to the view advocated chiefly by P. Woldstedt (1958) and H. Gross (1958). Worthy of note is the identification of three slope covers by W. Schilling and H. Wiefel (1962) in the Thuringian and the Harz mountains, which covers those workers attribute to the last glaciation.

Considering the lithologico-structural features of the covers in question, the present writer interpretes them as follows:

The lowermost C horizon represents the onset of glaciation. The passage from the interglacial period to the glacial one was marked by downbending of outcropping waste layers (*Hackenschlagen*). Further cooling of the climate and increased precipitation induced solifluxion and slopewash which are so conspicuously revealed by the structural pattern of the deposits.

Cover B is due to the rapid, massive solifluxion that characterized the coldest phase of the glacial period while the climate was relatively humid.

Cover A came into being under the conditions of a cold and rather continental climate. Well-defined is here the action of eolian processes reaching high upward.

The profiles of the Karkonosze covers coincide with the Ślęża slope cover — presented on the first day of the excursion by St. Szczepankiewicz — where a horizon of bent outcropping layers (*Hackenschlagen*) is overlain by solifluxion deposits on top of which rests a bed of silty formations.

TORS AND SLOPE IN THE KARKONOSZE
(Problems 5 and 7)

On the granites of the Karkonosze mountain sides, tors are common. There is a certain regularity in their distribution and their shape (A. Jahn, 1962). To begin with, they invariably occur on the concave slope breaks, on ridges and rock spurs. Secondly, upslope they generally grow in height. In the Jelenia Góra basin and at the foot of the Karkonosze they have a few meters in height while the upward segment exhibits the tallest tors, like for instance the Pielgrzymy — inspected during the excursion — which attain some 28 m in height. Finally, the shape of the tors is closely dependant on the inner texture of the granite, the system of jointing and the structure of the rock. In places where splitting of the granite produced angular blocks (Karkonosze), the tors show a tower-like shape while they acquire a ball-like shape wherever the granite exhibits a spheroidal structure of splitting (Jelenia Góra basin — the Kopki near Jelenia Góra, inspected during the excursion).

This relationship between tor morphology and rock structure shows that tors are produced by such external factors as are apt to adjust themselves to the properties of the inner structure of the bedrock. Weathering plays here, no doubt, a preponderant part. These examples from the Karkonosze are quite consistent with the concept of D. Linton (1955) who regards weathering as a primary factor in separation of the tors during the first phase of their formation under the morphologic surface. Some typical core stones and whole tors *in statu nascendi* still embedded in weathered granite grit were shown to the participants of the excursion (exposure near the "Krokus").

Examples of fully developed Karkonosze tors are the Pielgrzymy (Fig. 8) presented by B. Dumanowski. That instance shows the strict interrelation between the particular tors morphology and the orientation and density of joints as well as with the mineralogic composition and the size of the granite crystals. A further peculiarity is in the broad and level intervening rock surface ("basal platform" according to D. Linton, 1955).

The age of the tors is determined by that of the surrounding geologic formations. The tors of the Jelenia Góra basin (300—400 m of alt.) are therefore surrounded by periglacial formations and moraines of the older glaciations. There are here also vestiges of some typically Tertiary waste including kaoline. In this slope part, tors are likely to have developed as far back as the close of the Tertiary. The Pielgrzymy occur at 1200 m altitude; their age has been determined — on the ground of solifluxion cover —

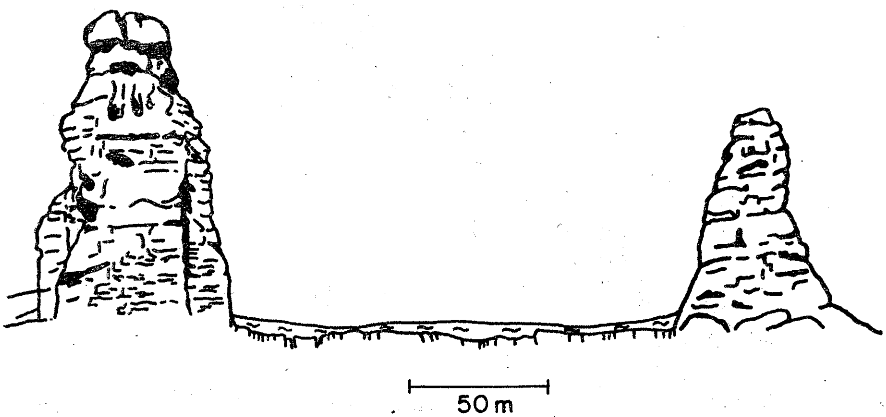

Fig. 8. Profile of the Pielgrzymy tors in the Karkonosze Mts. Intervening level surface mantled by solifluxion deposits

as last glacial. The dating refers naturally to the present-day form of those tors, for although they acquired their height and shape prior to the last glaciation, their essential morphologic properties remained unaltered ever since. Finally, the post-glacial cirques of the uppermost elevations exhibit tors, developed on the cirque walls after the last glaciation. Evidence thus indicates that on the granite slope of the Karkonosze, tors developed in various periods. The oldest are at the base and the youngest higher upward.

Less resistant (weathered) and convex (breaks) slope portions were most libale to destruction. Hence, the regular distribution of the tors on the slope along the line of its concavity. A constant upward rejuvenation of the slope has been established. In other words, intensive slope destruction tends to advance towards the upper hipsometric mountain zones. The highest tors are, therefore, found in the up-slope segment. The general effect of development since Tertiary is expressed in a lesser degree of backwearing of the upslope segments (Fig. 9). Thus the whole slope profile acquired a lesser gradient.

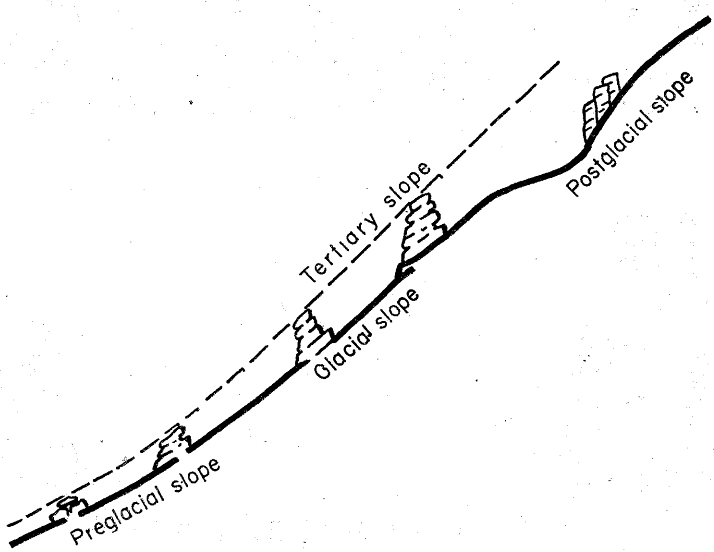

Fig. 9. Schematic profile of the north-facing slope of the Karkonosze range with tors of various heights and age. The intial Tertiary slope (broken line) was more inclined than the subsequent one

CONCLUSIONS

A study of the Sudetian slopes and of those of the island mountains in the Sudetian foreland permits to reach to following conclusions concerning such questions as: the shape of the slopes, their composition, the processes that modelled them and finally, their age.

Slopes are here, in their majority, convex—concave, a shape inherited from the Tertiary. Modifications, since the time of their formation rarely attain more than 100 m. Amongst those modifications slope planation prevails over parallel retreat (backwearing) though the phenomenon is by no means a general rule. Slope evolution is strictly dependant on the resistance of the rocks. This fact is much more relevant and diversifies the slope to a higher degree than do the processes operating on the slope.

Destructive processes were distinguished as surficial and linear. Both of them operated simultaneously, though the linear one (cutting of the slope by water streams) was the earliest. Moreover it played a leading part in the formation of the slope profile. That profile is the ultimate result of the total amount of destruction in each of the separate slope segments i.e. at its base, in the intervening portion and at its top. Preservation of the downward slope parts in the Pleistocene by the ice-sheet or the accumulated formations contributed to a planation of the profile.

In the Sudetes periglacial slope processes were surficial phenomena. The slopes were, therefore, not so much reshaped as chiefly smoothed. Owing to solifluxion and downwash they acquired a certain — though only apparent — uniformity.

The surficial slope formations (covers) in the Sudetes belong to the last glacial (periglacial) period. A three-fold division of these covers is conspicuously marked. The lowermost part consists of downwash and solifluxion deposits (prevailing water action), the overlying horizon is wholly composed of solifluxion sediments (frost-caused slope processes, mass movement) while the uppermost cover was laid by solifluxion and wind-action.

The tors occurring on the slopes provide reliable evidence of the evolution of these slopes, of their progressive destruction — in particular that due to weathering and surficial denudation. These forms were chiefly developed on slopes built of massive rocks, especially granitic ones.

The tors were found to vary in age according to their situation on the slope. Since the close of the Tertiary there existed, as it seems, a constant tendency towards rejuvenation of the slopes in an upward direction, in other words a shifting of destructive intensity towards increasingly higher hipsometric altitudes.

Translated by T. Dmochowska

References

Baulig, H., 1940 — Le profile d'equilibre des versants. *Ann. de Géographie*, année 49.

Büdel, J., 1937 — Eiszeitliche und rezente Verwitterung und Abtragung in ehemals nicht vereisten Teil Mitteleuropas. *Petermanns Geogr. Mitt.*, Ergänzungsheft 229.

Gellert, J. F., 1931 — Geomorphologie des mittelschlesischer Inselberglandes. *Ztschr. d. Dtsch. Geol. Ges.*, Bd. 83.

Gross, H., 1958 — Die bischerigen Ergebnisse von C-14 Messungen und paläontologischen Untersuchungen für die Gliederung und Chronologie des Jungpleistozäns im Mitteleuropa und den Nachbargebieten. *Eiszeitalter u. Gegenwart,* Bd. 9.

Jahn, A., 1962 — Origin of granite tors. *Czasopismo Geograficzne,* t. 33, Wrocław.

Linton, D. L., 1955 — The problem of tors. *Geog. Jour.* vol. 121.

Schilling, W., Wiefel, H., 1962 — Jungpleistozäne Periglazial-Bildungen und ihre regionale Differenzierung in einigen Teilen Thüringens und Harzes. *Geologie,* Jhg. 11.

Schott, G., 1931 — Die Blockmeere in den Deutschen Mittelgebirgen. *Forsch. z. Dtsch. Landes u. Volkskunde,* 29.

Szczepankiewicz, S., 1958 — Periglacial slope development in the Ślęża Massif. *Biuletyn Peryglacjalny,* no. 6.

Woldstedt, P., 1958 — Eine neue Kurve der Würm-Eiszeit. *Eiszeitalter u. Gegenwart,* Bd. 9.