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NIVATION AND ITS GEOMORPHIC SIGNIFICANCE — EXAMPLES FROM THE POLISH HIGH TATRA AND THE ORTLES-CEVEDALE MASSIF, THE ITALIAN ALPS

INTRODUCTION

The Italian Alps and High Tatra are mountain regions with alpine relief. Thus, conditions under which nivation acts are similar in both the regions. Yet, there are also features that differentiate the regions. A first such a feature is a fully developed nival zone (Berger 1967, Hövermann 1983, 1985, Lehmkuhl 1989) occurring in the Alps within a range of a periglacial zone. In the Tatras a definite or continuous nival zone does not occur. That is caused by an unfavourable orography in the climatic nival zone. Presence of permafrost in the Alps (Haeberlli 1989, King 1990) is a second feature differentiating the Alps from the Tatras. In the latter permafrost has not been documented yet.

The paper aims at presentation of similarities and differences in a course of nivation and in its effects in both the regions in relation to the differences in natural environment.

For comparison of the Italian Alps with the High Tatra, data and records from the Martello valley in the Ortles-Cevedale Massif (Fig. 1) were used. The studied covered the area above the upper timberline, i.e. above 2,350 m a.s.l. The sites where the studies were performed are marked in a geomorphic sketch (Fig. 1). The data illustrating a course of nivation and its intensity in the High Tatra were collected in the 10 years long series of records (Rączkowska 1992, 1993, 1995). Here, the investigations also covered the area above the upper timberline, i.e. 1,500 m a.s.l. (Fig. 2). Table 1 presents a listing of the studies carried out in both the discussed regions.

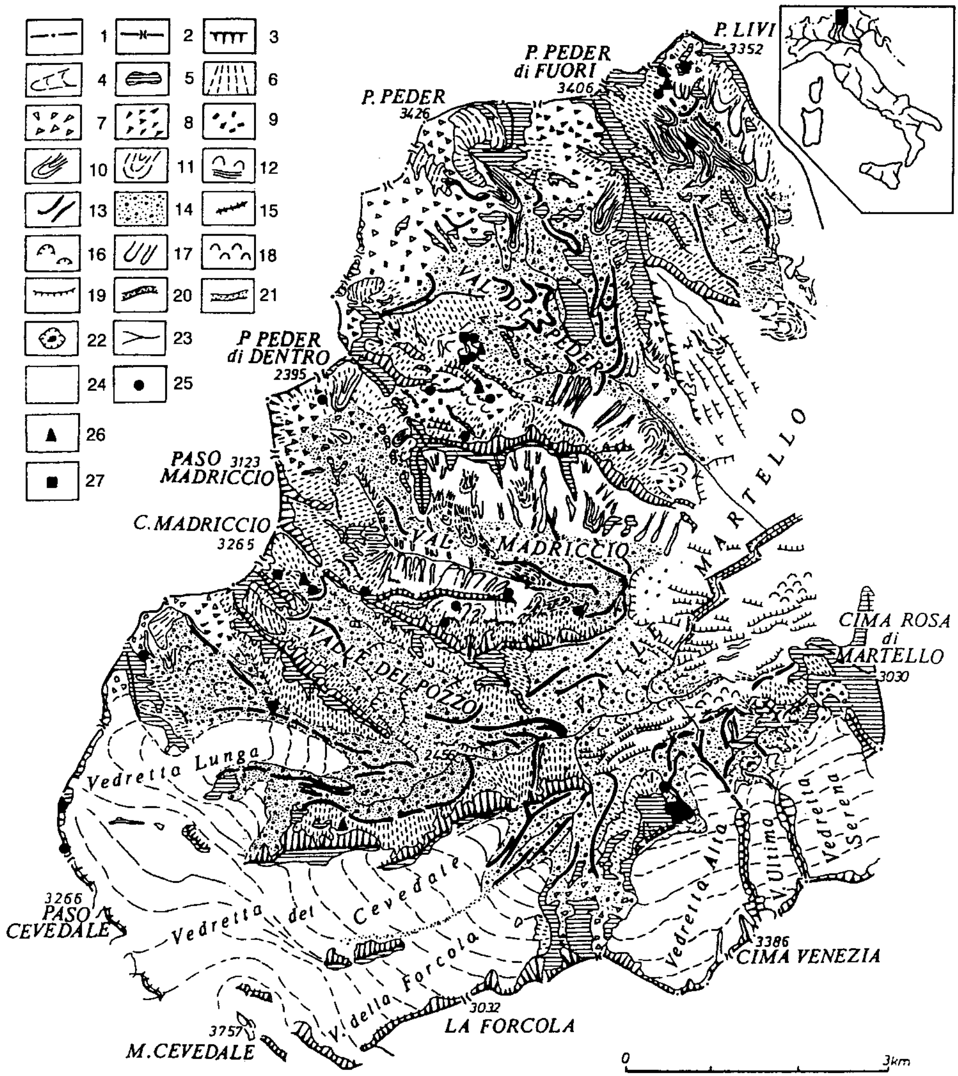


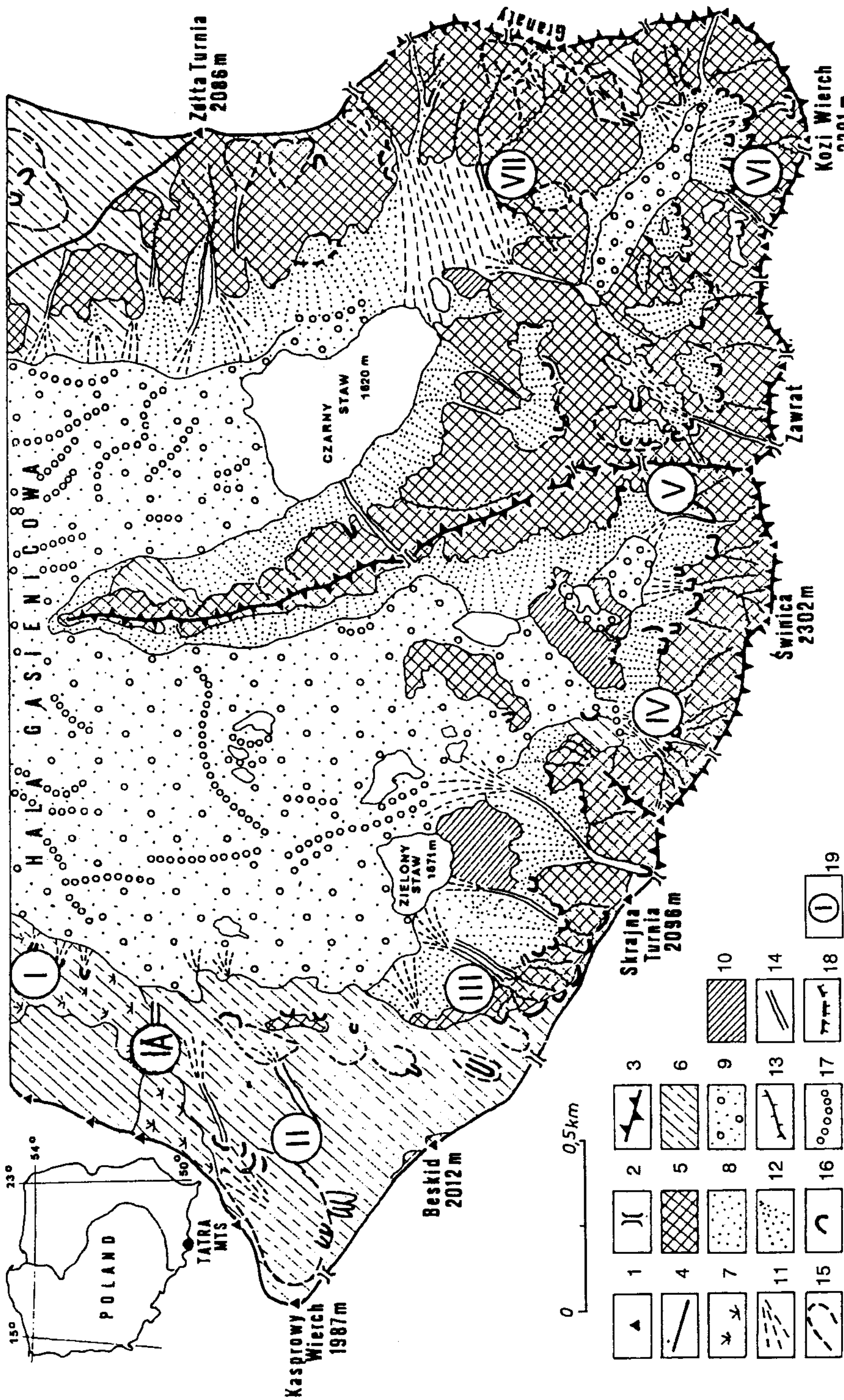
Fig. 1. Geomorphological sketch of the upper part of the Martello valley. 1 — summits and ridges, 2 — passes, 3 — rocky ridges tectonically controlled, 4 — glaciers, 5 — rocky slopes, 6 — talus slopes, 7 — inactive blockfields, 8 — rockfall slopes, 9 — creeping blockfields, 10 — active rockglaciers, 11 — relict rockglaciers, 12 — roche moutonnée and rocky floors, 13 — morainic ridges, 14 — valley floors with glacial drift deposits, 15 — protalus ramparts, 16 — nival niches, 17 — solifluction lobes, 18 — thufurs, 19 — structural rocky steps, 20 — structural gorges, 21 — alluvial plains, 22 — depressions filled with water (without outlets), 23 — streams, 24 — mature slopes with vegetation cover, 25 — nival niches with photographic documentation, 26 — pH recording posts, 27 — studied nival niches

Table 1 — Tabela 1

Studies on nival processes in the Tatras and Alps
Badania procesów niwacji w Tatrach i w Alpach

Area	The High Tatras		The Ortles-Cevedale	
Geomorphological processes	Field measurements	Literature	Field observations	Literature
mechanical weathering	+		+	+
falling, sliding	+	+		
chemical weathering	+			+
cryogenic processes			+	+
transportation processes	+	+	+	
transportation over snow surface	+			
transportation of bedload and suspended load	+			+
transportation of dissolved load	+			
sub-and supranival transport	+	+	+	
sheetwash	+	+		
rill-erosion	+	+		+
solifluction		+	+	+
deposition	+	+	+	

Ryc. 1. Szkic geomorfologiczny górnej części doliny Martello. 1 — wierzchołki i granie, 2 — przełęcze, 3 — grzbiety skalne nawiązujące do tektoniki obszaru, 4 — lodowce, 5 — stoki skalne, 6 — stoki usypiskowe, 7 — pola gruzu, nieaktywne, 8 — stoki obrywowe, 9 — pełznące pola gruzu, 10 — lodowce gruzowe, 11 — lodowce gruzowe, reliktowe, 12 — wygłady lodowcowe i podłogi skalne, 13 — wały morenowe, 14 — dna dolin wypełnione osadami morenowymi, 15 — wały niwalne, 16 — nisze niwalne, 17 — loby soliflukcyjne, 18 — tufury, 19 — progi skalne, strukturalne, 20 — przełomy strukturalne, 21 — równiny aluwialne, 22 — zagłębienia bezodpływowe wypełnione wodą, 23 — potoki, 24 — stoki dojrzałe pokryte przez roślinność, 25 — nisze niwalne udokumentowane fotograficznie, 26 — miejsca pomiarów pH, 27 — badane nisze niwalne


HALA GĄSIENICOWA
CZARNY STAW 1620 m
ZIELONY STAW 1671 m
Żółta Turnia 2086 m
Granaty
Kozi Wierch 2291 m
Zawrat
Świnica 2302 m
Skrajna Turnia 2096 m
Beskid 2012 m
Kasprowy Wierch 1987 m
POLAND
TATRA MTS
15°
23°
54°
50°
I
IA
II
III
IV
V
VI
VII
0
0,5km
1
2
3
4
5
6
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CHARACTERISTICS OF STUDY REGIONS

The High Tatra form the highest part of the Carpathian arc, reaching to 2,663 m a.s.l. (Gerlach). They are built of resistant granites and granitodiorites, weakly fractured. Due to lithology, large boulders with some finer blocks predominate in the weathering cover. Relief was formed by the Pleistocene glaciers. High walls and rocky slopes with debris slopes at their feet encircle overdeepened glacial cirques and valley floors lined with moraine mantle.

Table 2 — Tabela 2

Climatic characteristics of the High Tatra
Charakterystyka klimatu Tatr Wysokich

Name of station	Altitude m a.s.l.	Mean air temperature [°C]			Number of days with	Precipitation [mm]		
		January	July	Year	temp. min <0°C temp. max >0°C	January	July	Year
Łomnica	2,635	-11.6	3.7	-3.7	88			
Kasprowy Wierch	1,991	-9.0	7.3	-0.8	78	142 137*	215 210*	1,889 1,760*
Hala Gąsienicowa	1,520	-6.5	9.6	1.6	111	70 69*	247 207*	1,664 1,602*

After T. Niedźwiedź (1992) changed.
Number of days for period 1950–1970.
Precipitation for period 1951–1970.
*Precipitation for period 1980–1990.

Fig. 2. Geomorphological sketch of study area in the High Tatra. 1 — summits, 2 — passes, 3 — sharp, rocky ridge crests, 4 — rounded ridge crests, 5 — rockwall and rocky slopes, 6 — mature, debris mantled slopes covered by vegetation, 7 — mature, debris mantled slopes with dwarf pine, 8 — debris slopes, 9 — valley floor with glacial drift deposits, 10 — roche mutonée, 11 — alluvial talus slope or cone, 12 — talus cone, 13 — chutes, 14 — debris flow gullies, 15 — relict nival niches, 16 — active nival niches, 17 — morainic ridges, 18 — relict protalus ramparts, 19 — number of experimental sites

Ryc. 2. Szkic geomorfologiczny obszaru badań w Tatrach Wysokich. 1 — wierzchołki, 2 — przełęcze, 3 — granie skalne, 4 — grzbiety, 5 — ściany i stoki skalne, 6 — dojrzałe stoki z pokrywą zwietrzelinową, utrwalone darnią, 7 — dojrzałe stoki z pokrywą zwietrzelinową, z kosówką, 8 — stoki gruzowe, 9 — dno doliny wyścielone materiałem morenowym, 10 — wygłady lodowcowe, 11 — stoki przekształcane przez aluwiację i stożki napływowe, 12 — stożki usypiskowe, 13 — żleby, 14 — rynny spływów gruzowych, 15 — nieaktywne nisze niwalne, 16 — aktywne nisze niwalne, 17 — wały morenowe, 18 — reliktowe wały niwalne, 19 — numer stanowiska badawczego

In the High Tatra glaciers are absent nowadays. Above the upper timberline, the periglacial zone spreads up to the crests. The main characteristics of climate are given in Table 2.

The Martello valley dissects the northern slopes of the Ortles-Cevedale massif, from 3,757 m a.s.l. at Monte Cevedale to 800 m a.s.l. at the junction with the Adyga valley. The valley is built of metamorphic rocks, gneisses, schists and thick marble layers (Andreatta 1951). Therefore, the weathering cover consists mainly of fine material while coarser pieces and boulders are flattened.

The Martello valley has a typical alpine relief and is glaciated. A characteristic feature of the relief is asymmetry resulting from geological structure (Rączkowska and Rączkowski 1993). The asymmetry is also marked in a position of the nival zone. In the orographically left hand side tributary valley, the nival zone occurs close the valley heads, at the height of 2,800–3,400 m a.s.l. In the right hand side tributary valleys and in the main valley the nival zones form a several hundred meter wide belt around glacial tongues. The climatic characteristics of the Cevedale Massif are given in Table 3.

Table 3 — Tabela 3

Climatic characteristics of the Ortles-Cevedale Massif
Charakterystyka klimatu masywu Ortles-Cevedale

Name of the station	Altitude m a.s.l.	Mean air temperature [°C]			Precipitation [mm]	Number of days with temp. min <0°C temp. max >0°C
		January	July	Year		
Val della Mare^1	2,998			-1.8	552	
Careser Diga^	2,600			1.5	899	206
Malga Mer	1,964				1,061	
Peio^	1,580			6.7		229
Silandro	700			9.6	531	
Snowline in Val di Solda*	3,100	-10.0	4.3	-3.4		
Forno*	2,200	-7.1	8.3	0.5		
Passo Stelvio*	2,545				1,107	
Innersulden*	1,845				872	

^ After GNGFG (1986), station on southern slopes of massif,

^1 After GNGFG (1986) calculated,

* After Höllerman (1964), station no northern slope of massif

COURSE OF NIVATION AND ITS RESULTS IN THE ITALIAN ALPS AND IN THE HIGH TATRA

Weathering, erosion, transportation and accumulation, acting under the influence of perinival climate and meltwater, are the processes related to the presence of snow patches. A type of processes, their pattern, intensity and geomorphic effects are similar, yet not identical, in both the discussed regions. Table 4 presents temporal and spatial pattern of these processes within nival niches based on examples from three different patches in the High Tatra (sites: II, III and IV in Fig. 2).

In mechanical weathering in the Alps a role of meltwater is visible (Ballantyne et al. 1989). That is indicated by fine material present on a surface and in cracks of a rocky outcrop, being a backwall of a nival niche (Fig. 3). A large proportion of clayey material, that easily changes its volume, additionally favours mechanical weathering. That is the way the rocky walls of the nival niches develop. According to GNGFG (1986) on the slopes of the upper reach of the Peio valley, neighbouring with the Martello valley, at 2,750–3,200 m a.s.l., several depressions carved in the rock have been stated. The development of

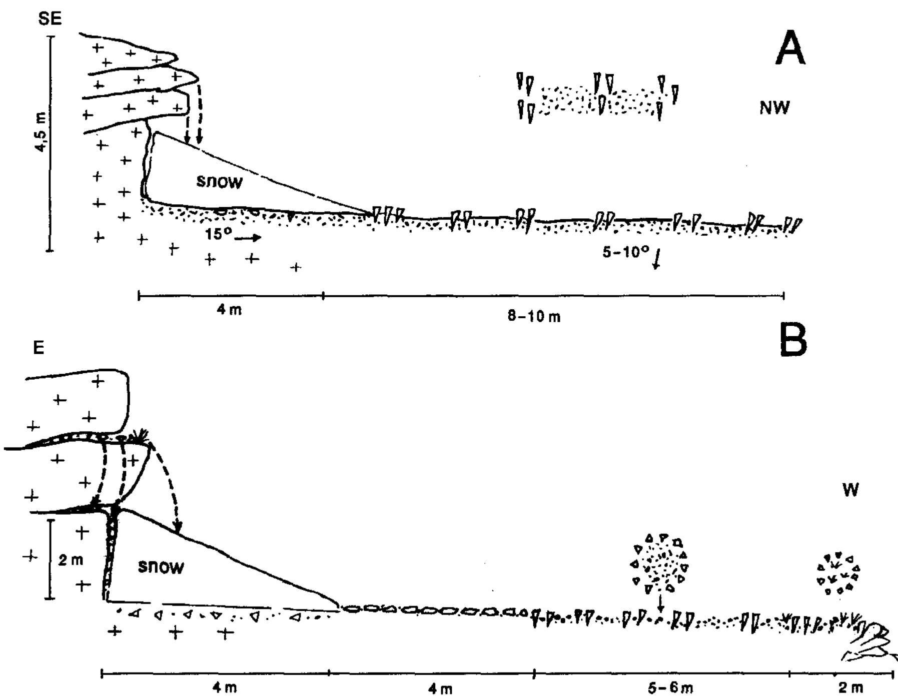
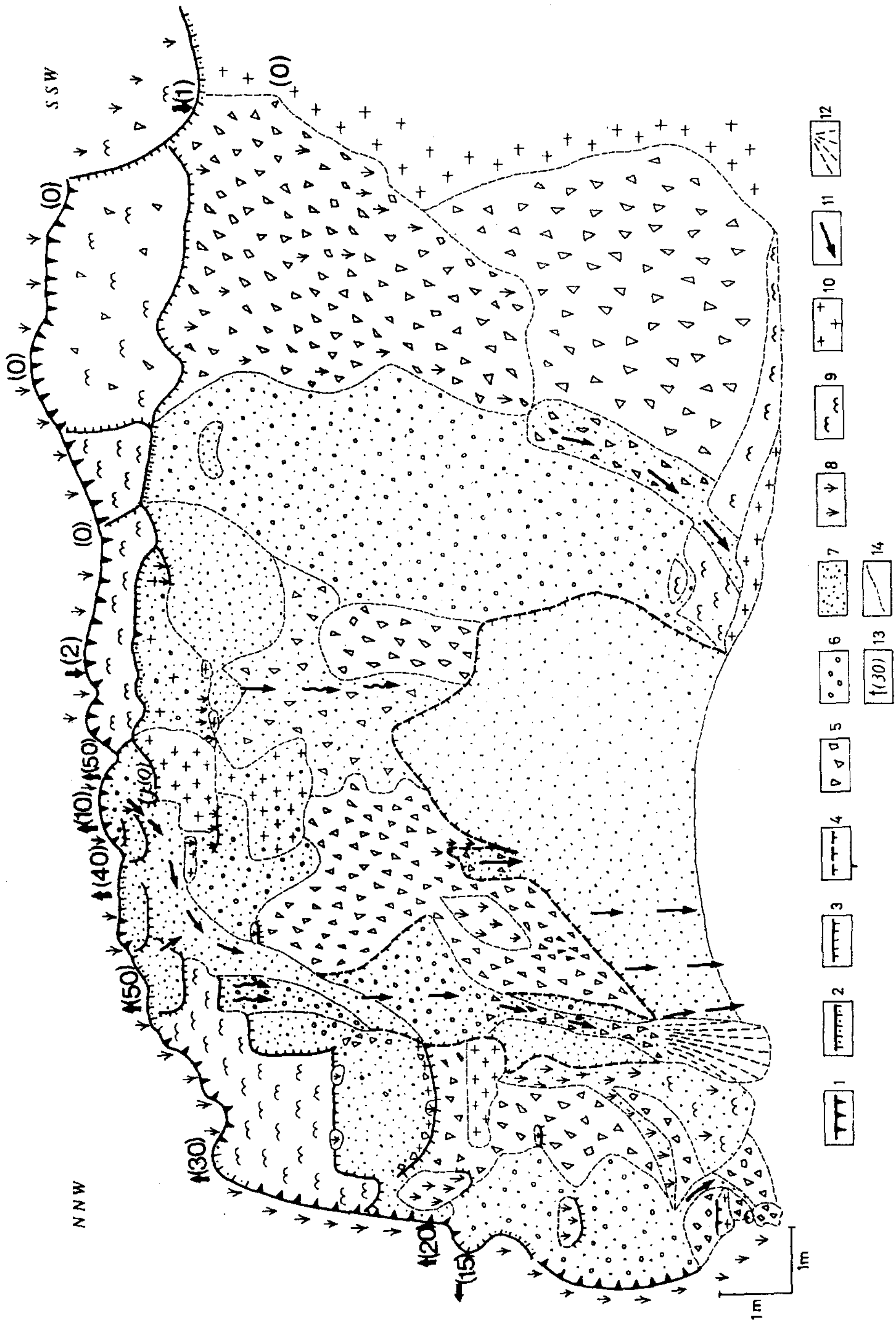


Fig. 3. Cross-profiles of the nival niches in the Peder valley. A — niche floor with sorted strips, B — niche floor with polygons

Ryc. 3. Profile poprzeczne nisz niwalnych w dolinie Peder. A — dno niszy z sortowanymi pasami gruzowymi, B — dno niszy z poligonami gruzowymi


SSW
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(0)
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1 2 3 4 5 6 7 8 9 10 11 12 13 14
(30)

the depressions has to result from nivation as the snow patches spread over them. Moreover, H. Berger (1967) is of opinion that the weathering in the vicinity of the patches is so intensive that small, rocky nival forms might develop as a result. Just after a glacier retreat, at the upper margin of the patch, a thin layer of weathered material is removed first by washing away, creeping and solifluction that make the rockwall vulnerable to erosion. In the High Tatra, in contrary to the Italian Alps, the perinival climate does not yield to conditions that might be sufficient for intensive mechanical weathering (Rączkowska 1995) because a number of freeze-thaw cycles is small and resistance of granite to weathering is rather high. On the mature slopes, frost processes and needle ice acting at the patch cause the walls of the nival niches to retreat (rate — 1–5 cm/year) if they are not protected by sward (Fig. 4).

Both in the Italian Alps and in the High Tatra, meltwater is a factor triggering various forms of transportation. In the Italian Alps, along the subnival channels, on the slopes without the vegetation cover, there are traces of suspended load and bedload. Pieces reaching several centimetres in diameter are subjected to transportation. The material washed out from the covers and transported by the meltwater, forms small alluvial plains below the patch that evidences a relatively high intensity of the process. According to P. Höllerman (1964) the nival niches at the height of 2,650–3,000 m a.s.l. are deepened due to washing through of the covers. In the High Tatra on the mature slopes the extent of transportation is limited by the vegetation cover to 0.5–1.0 m wide zone down of the patch. On the debris slopes there are no traces of transportation over the slope surface because water percolates downward loosely packed covers. The only trace of the meltwater activity is 1–2 m wide and up to 10 m long zone of mosses below the patch. The intensity of the process is much smaller here than in the Italian Alps as changes in a slope relief have not been observed.

In the Italian Alps, pH of the meltwater, varying between 6.4 and 7.0, denotes activity of chemical weathering and solute transportation as pH there

Fig. 4. Geomorphological sketch of the nival niche near weir (site II). 1 — niche scarps > 60 cm, 2 — niche scarps 40–60 cm, 3 — niche scarps 20–40 cm, 4 — niche scarps < 20 cm, 5 — areas with debris of several cm in diameters, 6 — areas with fine debris with admixture of sandy-clay material, 7 — areas with predominating sandy-clay material, 8 — tussocks and alpine sward, 9 — mosses, 10 — rocky outcrops, 11 — erosional incisions and furrows, 12 — alluvial cone, 13 — magnitude of scarp retreat, 14 — lines separating particular areas of the niche bottoms

Ryc. 4. Szkic geomorfologiczny niszy przy zastawce (poletko II). 1 — krawędzie niszy o wysokości > 60 cm, 2 — krawędzie niszy o wysokości 40–60 cm, 3 — krawędzie niszy o wysokości 20–40 cm, 4 — krawędzie niszy o wysokości < 20 cm, 5 — powierzchnie z gruzem o średnicy kilkunastu cm, 6 — powierzchnie z drobnym gruzem, z domieszką materiału piaszczysto-gliniastego, 7 — powierzchnie z przewagą materiału piaszczysto-glinastego, 8 — kępy trawy i murawy alpejskie, 9 — mchy, 10 — wychodnie skalne, 11 — rozcięcia i bruzdy erozyjne, 12 — stożek napływowy, 13 — wielkość cofnięcia krawędzi, 14 — linie oddzielające poszczególne fragmenty dna niszy is higher than that of snow (6.0). Here, there is similarity to the High Tatra where the pH of meltwater is 4.0–5.5 whereas that of snow is 3.9–4.5.

The process of supranival transportation in the Italian Alps is associated with the patches. However, it should be noticed that the intensity of this process is much higher than in the High Tatra. The debris-mud tongues are c. 100 m long and several tens metres wide whereas in the High Tatra they are only

Table 4 — Tabela 4

Morphodynamic characteristc of nival forms in the High Tatra
Morfodynamiczna charakterystyka form niwalnych w Tatrach Wysokich

Location	Snow patch on the slope of Beskid (site II) dwart pine zone mature, smoothed, open slope			Snow patch on the slope of Skrajna Turnia (site III) dwarf pine zone talus slope			Snow patch in the Świnicka Kotlina (site IV) alpine zone talus slope		
Part of niche	A	B	C	A	B	C	A	B	C
Period of acitvity / Process	15 May–20 June	after 15 June	15 May–10 June	1 June–15 July	after 30 June	1 June–7 July	15 June–1 October	after 1 July	15 June–1 August
mechnical weathering	+	–	–	+	–	–	+	–	–
frost heaving	++	–	–	–	–	–	–	–	–
chemical weathering	–	++	++	–	++	++	–	+	+
sheetwash	+	–	++	–	–	+	–	–	+
rill erosion	+	+	+++	–	+	+	–	–	+
falling	–	–	–	–	–	–	+	–	–
accumulation	–	–	+	+	–	+	+	–	+++
creeping	+	+	–	–	–	+	–	–	–
solifluction	+	+	–	+	–	–	–	–	–
needle ice	++	–	–	–	–	–	–	–	–
piping	+	+	+	–	+	+	–	+	+

A — back/upper wall of a niche, B — niche bottom, C — lower part of a niche and downward, adjacent slope

Process: – inactive, + weak, ++ intensive, +++ very intensive

20–30 m long and a few metres wide on the average. It is likely that the water from melting permafrost contributes to this process as well. Transportation is easier owing to fine particles predominating (60%) in the weathered material.

A characteristic feature of the sites being occupied by the snow patches in the Italian Alps is the presence of boulder pavement. The latter vary in size from several to hundred metres and are remodelled by cryonival processes, mainly by frost sorting and solifluction (Fig. 3B). Similar forms and processes have been described by P. Höllerman (1964) from the Solda valley, neighbouring with the Martello valley. The processes of frost sorting and solifluction are related to the meltwater that is visible on the surface in a distance of 1.5–3 m from the patch margin. In the niches, located c. 3,000 m a.s.l. both the polygons and solifluction lobes are very active. Figure 3A presents a cross-profile of the niche which floor is sloping at 5–10°, parallel to one of its back walls. Instead of the polygons, debris strips develop within this cross-profile. The niche occurs in the Peder valley at 2,880 m a.s.l. On the other hand, figure 3B presents differentiation of these processes depending on a distance to a patch, using as example the neighbouring niche in the Peder valley. The interiors of the polygons that are located closer to the patch contain very fine material, even clayey-sandy one, and are encircled by a ring of relatively large boulders, usually standing in a vertical position. The interiors of the polygons that are most remote from the patch are overgrown by grass. These polygons are 1–2 m in diameter. Similar forms have been described by C. Smiraglia (1987) from the Peio valley, located on the southern side of the Ortles-Cevedale Massif. According to C. Smiraglia (1987) their development is also associated with saturation of the substratum with water from a melting patch. He compares the photographs of the same forms after the period of 40 years and concludes a lack of changes in location of large elements at the margin of the polygons. That evidences that the form is rather stable, despite the changes in microrelief visible inside the polygon. What is more, the changes in microrelief evidence that these forms are active at present. The floors of both the niches are closed at the downward margin by a zone of solifluction lobes and teracettes as it is the case of the majority of the niches in the discussed region. The influence of the patches, and particularly of the meltwater, onto the slow mass movements and frost sorting was emphasised in numerous papers dealing with relief and periglacial processes in other parts of the Alps (Jorda 1977, Patzelt 1977). The presence of the boulder pavement as well as the frost sorting and solifluction in the sites occupied by the patches differentiates the Italian Alps from the High Tatra. In the High Tatra they belong to very rare features and are usually in an initial stage of development.

The protalus ramparts that often occur at the downward margin of the Alpine patches are another features which differ the nival forms in the Italian Alps and in the High Tatra. The ramparts are usually built of the material sliding over the patch surface or supplied by debris flows or avalanches. On the slopes surrounding glacial cirques, in the uppermost zones of the valley, initial forms occur. The glaciers have retreated from such sites fairly recently, in some glacial cirques they melted only in the 1960s. In most cases, the discussed landforms make distinct ramparts, up to a few meters high, built of the material of various sizes (medium axis 0.1–2.0 m). The largest, 10 m high, forms are usually the effect of a rock falling material that probably slided over the patch on the northern slopes of P. Peder di Dentro (Fig. 1). The material building the protalus ramparts is arranged chaotically and its size is lithologically controlled. The ramparts on the slopes that are on the outcrops of resistant marble are built of large boulders (c. 1 m in diameters) similarly as it is the case of the slopes on the serpentinite and olivinite substratum. These are active forms, developing at present by accretion that is evidenced by the presence of fine material on the large boulders. The forms occurring at c. 3,000 m a.s.l. are remodelled by cryogenic processes or these are initial assembles giving rise to rock glaciers (Rączkowski 1997). At this height the debris mantled slopes above the patches are remodelled by cryogenic processes as well what is confirmed by the presence of distinct solifluction lobes. That makes them similar to *eboulis fluant* as proposed by B. Francou (1977). Therefore, to determine the mechanism of formation of the ramparts occurring downward the patches, his so called dynamic interpretation of the discussed

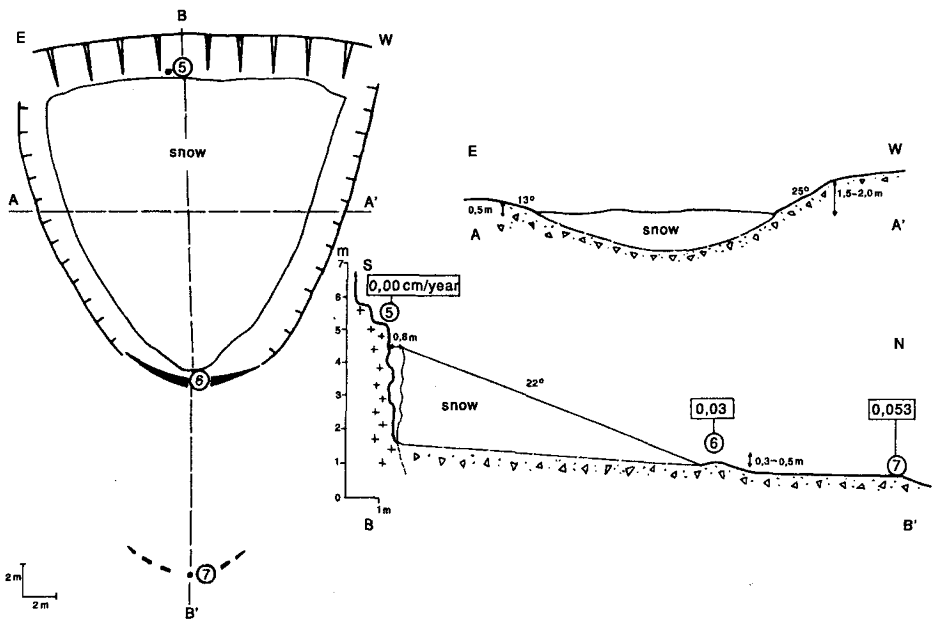

Fig. 5. Sketch of the nival niche in the Świnicka Kotlina (site IV) with cross- and longitudinal profiles. Number of posts encircled. Rates of accretion in rectangular frames Elevation 1,950 m a.s.l.

Ryc. 5. Szkic niszy niwalnej w Świnickiej Kotlinie (poletko IV) wraz z profilem poprzecznym i podłużnym. W kółkach numery stanowisk, w ramkach prostokątnych wartości depozycji. Wysokość 1950 m n.p.m.

process might be used. The interpretation takes into account upheaval of a rampart due to a stress caused by the moving scree and due to the ice being a core of the rampart. In the High Tatra these forms usually do not exceed 0.3–0.5 m in height (Fig. 5) and only occasionally they reach 2–4 m. The reason behind it is a relatively high resistance of granite to weathering and rather small supply of the material from rockwalls occurring above.

On the debris slopes in the Italian Alps, as it is the case in the High Tatra, there are nival accumulation niches (Rączkowska 1995). Such niches are formed by accretion of the slopes around the patch (Rączkowska 1995). A rockwall often makes the back wall of the niche, especially if the niches occur in the upper part of the debris mantled slopes. In the Italian Alps the niches are from several tens to several hundred metres longer and wider, i.e. larger than the Tatric ones by an order of magnitude. Figure 5 shows an example of a nival accumulation niche in the High Tatra. Depending on lithology and a slope aspect, the rate of the niche development varies from 0.007 to 0.6 cm/year.

The snow patches occurring in the Italian Alps in the zone that, regardless the elevation, forms a belt around the glaciers tongues and that is several tens of meters wide or up to several hundred meters at maximum, very often fill the hollow between the slope and a lateral moraine ridge. If the lateral moraine is adjacent to the debris slope or rocky slope, the patches protect such a site from being covered by the material falling from the neighbouring rockwalls. At the same time, an intensified activity of weathering in the patch vicinity causes the wall to retreat and the undercutting develops (Fig. 6). In the part of the depression, which usually melts out from beneath the snow, and which is at the contact with the moraine, the most material is deposited and fills it up. The activity of patches depends on the distance from the glacier. The farther is the glacier, the forms are less active.

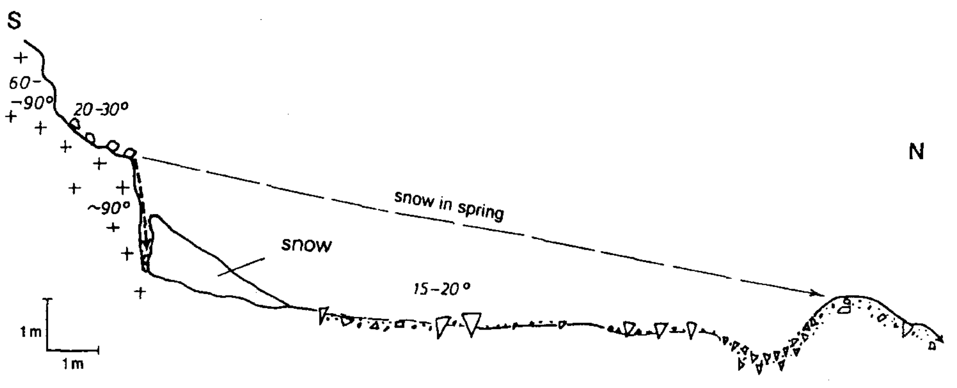

Fig. 6. Cross-profile of the nival niche located at the contact of the slope and the moraine in the Alta valley, c. several hundred metres from the glacier

Ryc. 6. Profil poprzeczny niszy niwalnej położonej na kontakcie stoku i moreny w dolinie Alta, w odległości kilkuset metrów od lodowca

DISCUSSION OF RESULTS

Based on the quantitative data, qualitative models of nivation for the Italian Alps (Fig. 7) and the High Tatra (Fig. 8) have been developed. The mechanism of the processes is similar in both the regions, yet the components and intensity of nivation processes contributing to nivation are different. The activity of the snow patches in the periglacial zone in the Italian Alps is higher than in the High Tatra. The similar mechanism denotes that the processes depending on temperature act at the upper margin of the patch, sometimes the niche floor, and processes controlled by the meltwater act at the downward margin. However, the complexes of the components of the nivation processes vary in particular parts of the niche in the studied areas because they are controlled, to a high degree, by lithology, climate and vegetation. On the other hand, if the schemes for the Italian Alps and the High Tatra are compared, the processes common to both the regions are visible in the nivation complex. These include: sheetwash, linear erosion, supranival transportation and chemical weathering. Yet, solifluction and frost sorting occur in the Italian Alps only. Other processes such as transportation over the patch surface or formation of the protalus ramparts are much less intensive in the High Tatra.

The bases for evaluating a relief-forming role of nivation are the landforms which develop in the places where the snow patches occur as well as their dynamics. Comparison of the geomorphic results of nivation in both

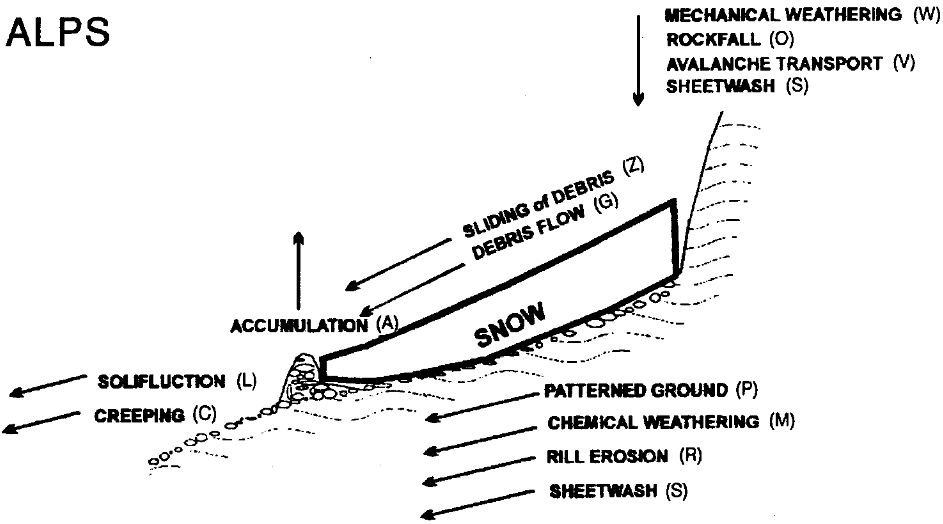

Fig. 7. Nivation model for the Alps

Ryc. 7. Model niwacji dla Alp. W — wietrzenie mechaniczne, O — odpadanie, V — transport lawinowy, S — spłukiwanie, Z — ześlizgiwanie po powierzchni płata, G — spływy gruzowe, A — akumulacja, L — soliflukcja, C — spełzywanie, P — poligony, M — wietrzenie chemiczne, R — erozja linijna the regions is given in Table 5. A higher diversity can be noticed in the case of the Italian Alps. The occurrence of the nival zone, where the nival forms develop (Lemkuhl 1989, Berger 1967), as well as the large number of such forms, prove that nivation is a significant relief-forming process in the Italian Alps. That is also confirmed by a diversity of the forms expressed in

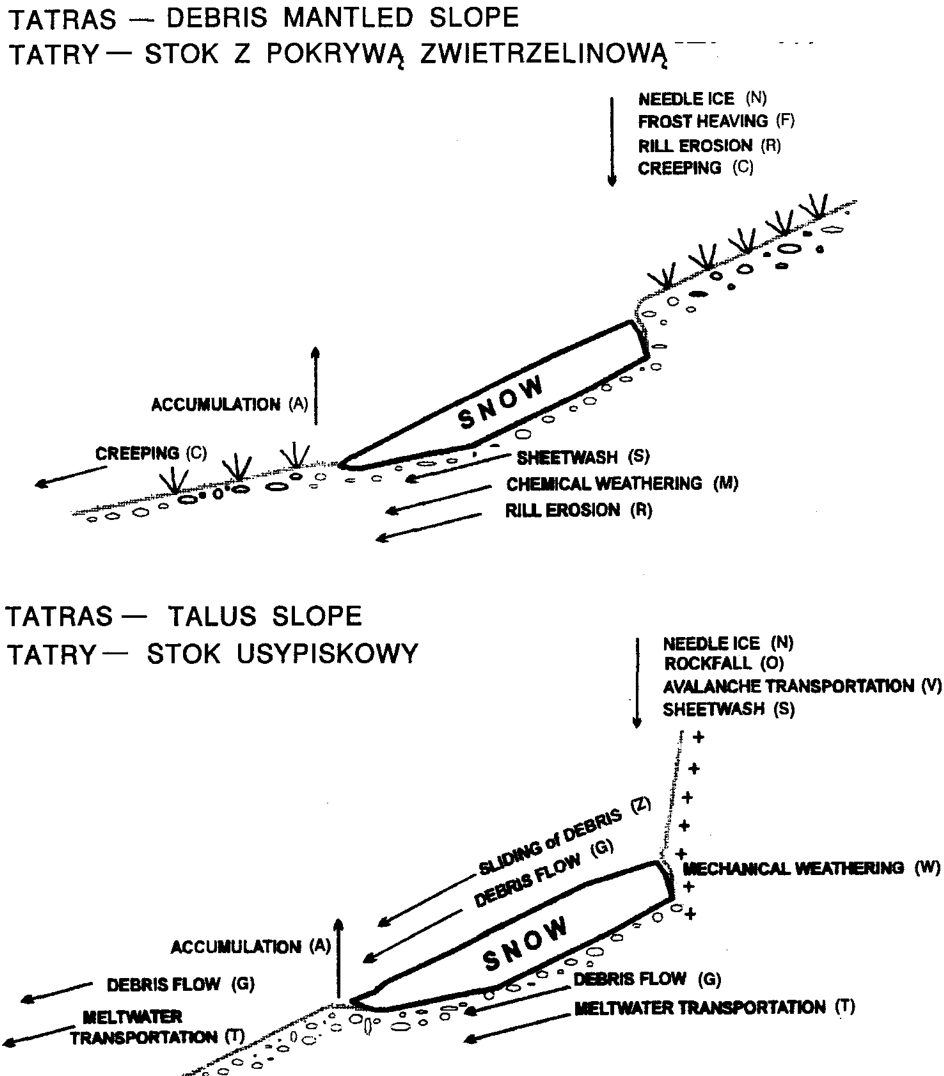

Fig. 8. Nivation model for the High Tatra

Ryc. 8. Model niwacji dla Tatr Wysokich. N — lód włóknisty, F — mrozowe ruchy gruntu, R — erozja linijna, C — spełzywanie, S — spłukiwanie, M — wietrzenie chemiczne, A — akumulacja, O — odpadanie, V — transport lawinowy, G — spływy gruzowe, T — transport przez wodę roztopową, Z — ześlizgiwanie po powierzchni płata, W — wietrzenie mechaniczne, P — poligony

Table 5 — Tabela 5

Comparison of the main geomorphological effects of nivation
Porównanie ważniejszych geomorfologicznych skutków niwacji

Forms	The High Tatra	The Ortles-Cevedale
protalus rampart	yes	yes
size of nival niche	few or tens metres	tens or hundred metres
accumulation niche	yes	yes
niche cut in rock	no	yes
rock crest of nival niche	yes	yes
boulder pavement	no	yes
solifluction system	no	yes
patterned ground	no	yes

the occurrence of very fine and very large landforms, as well as those well and not fully developed or the landforms which have distinct, relatively high edges or nival pavement in the floors. Moreover, these are accumulation and erosional landforms. In the Italian Alps, as in the High Tatra, the initial forms of the nival niches have not been stated, although the initial forms of the protalus ramparts have been observed. The best description of the nival forms in the Alps is given by H. Berger (1967). In the High Tatra the forms are by an order of magnitude smaller in size. In most cases, they are not fully developed, excluding nival accumulation niches. Very often, these forms are of different, not nival, origin and are only modified by nivation (for example, the debris flow gully). Depending on the intensity of nivation processes, the depression takes the form of the nival niche. It should be emphasised that nivation is a slowly acting, yet significant process in the denudational system of the High Tatra (Kotarba et al. 1987).

CONCLUSIONS

Based on the comparison of geomorphic effects of nivation in the Italian Alps and in the High Tatras it has been stated as follows:

1. Nivation mechanism is similar in both the regions, yet nivation processes and its intensity depends on local conditions, especially on lithology and climate.

2. Nivation in the Alps, as well as in other mountains where there are appropriate conditions for the nival zone — e.g. Pyrenees, mountains of the northern Scandinavia, Colorado Front Range, leads to the present-day development

of the nival forms. In the mountains where such a zone is not found geomorphic role of snow patches is limited to modification of the forms resulting from other processes, (e.g. debris flows) although, nowadays, the nivation is one of a more important, or even a leading, morphogenetic processes in these mountains.

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STRESZCZENIE

Z. Rączkowska

NIWACJA I JEJ ZNACZENIE GEOMORFOLOGICZNE — PRZYKŁADY Z POLSKICH TATR WYSOKICH I MASYWU ORTLES-CEVEDALE (ALPY WŁOSKIE)

Na podstawie badań prowadzonych w obszarze ponad górną granicą lasu w Tatrach Wysokich (ryc. 2) i w masywie Ortles-Cevedale (ryc. 1) określono podobieństwa i różnice w przebiegu i skutkach niwacji w obu obszarach. Stwierdzono, że mechanizm niwacji jest podobny (ryc. 7 i 8). Procesy uzależnione od temperatury modelują górną krawędź niszy niwalnej, niekiedy dno niszy, a procesy związane z wodą roztopową modelują dolną część niszy. Jednak skład procesów w zespole niwacji jest różny, gdyż zależy on w dużym stopniu od litologii, klimatu i pokrywy roślinnej danego obszaru. Procesy takie jak: spłukiwanie, erozja linijna oraz denudacja chemiczna działają powszechnie w otoczeniu płatów śnieżnych. Natomiast soliflukcja czy sortowanie mrozowe występuje jedynie w Alpach. Intensywność procesów niwacji jest większa w Alpach.

Rolę niwacji w przekształcaniu rzeźby omawianych obszarów oceniono porównując jej skutki (tab. 5). W Alpach aktywność niwacji prowadzi do powstawania form niwalnych. W Tatrach jej rola jest ograniczona do przekształcania form rzeźby o innej genezie. W obu obszarach nie stwierdzono inicjalnych nisz niwalnych.