Altitudinal Zonation of the Morphodynamic Processes in the Piatra Craiului Mountains (The Carpathians, Romania). Case Study: Cheii de sub Grind and Şpirlea Valleys

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Abstract: This paper focuses on the altitudinal zonation of the morphodynamic processes in two small watersheds, namely the Şpirlea and the Cheile de sub Grind, which lie in the central part of the Piatra Craiului Massif, being almost perpendicular to the main ridge. Because of some differences imposed by lithology, morphology, gradient, aspect, climatic conditions and vegetation, the morphodynamic altitudinal zones have a distinct appearance. The vertical zonation and the conditioning relationships will be further discussed in detail in order to establish the differences that exist among the morphodynamic zones lying on the two major slopes (eastern and western) of the Piatra Craiului ridge.

Keywords: morphodynamic processes, morphodynamic factors, altitudinal zonation, Şpirlea Valley, Cheile de sub Grind Valley, Piatra Craiului Mountains

1. Introduction

The Piatra Craiului Massif has a particular morphology, which is explained by its long evolution. The shaping systems that have existed here over the time are therefore responsible for the present appearance of topography. Thus, their long action has resulted in the creation of a narrow calcareous ridge, looking like a hog back, lifted to 2000 m altitude and showing steep slopes (to the east and west) dissected by numerous valleys. However, this striking feature of the landscape is mainly the result of geology, orography and climatic conditions, which explains why this study has focused in particular on these factors in order to identify and explain the morphodynamic elements and their altitudinal zonation.

In order to analyze the altitudinal zonation of the morphodynamic processes two valleys lying on both sides of the main ridge were chosen, i.e. the Cheia de sub Grind, on the east, and the Şpirlea, on the west. Both of them originate near the highest peak of the massif, the Piscul Baciului (2238 m), lying in the central part of the ridge (Figure 1, 2 and 3).

On these valleys, five zones and one sub-zone exhibiting various shaping processes and landforms imposed by geological structure, gradient, aspect, fragmentation and climate have been identified. The shaping factors, as well as the shaping systems and the morphodynamic altitudinal zones will be further analyzed in detail.

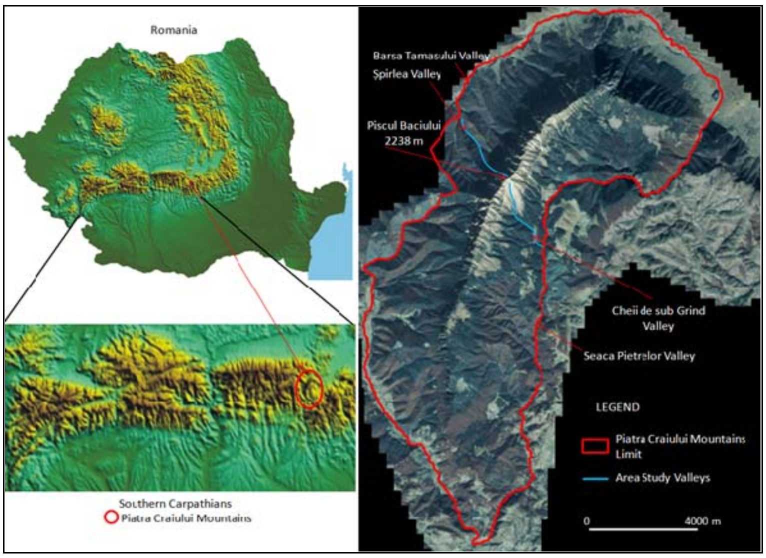

Figure 1. The study area in the Romania, Carpathians and Piatra Craiului Massif shown on an Ykonos 2004 image (provided by the Administration of the Piatra Craiului Natural Park)

Figure 2. The geographical position of Şpirlea Valley within western slope of Piatra Craiului Massif (photo Spencer Coca)

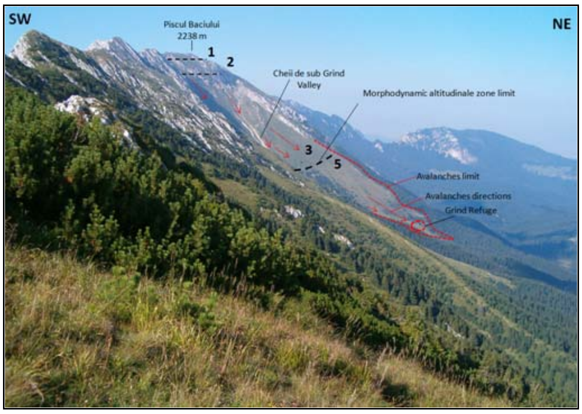

Figure 3. The geographical position of Cheii de sub Grind Valley within eastern slope of Piatra Craiului Massif and upper morphodynamic zone (figures indicates : 1. cryonival zone, 2. upper sub-alpine cryonival zone, 3. lower sub-alpine cryonival zone, 5. forest zone)

2. Methodology

In order to study the vertical zonation of the morphodynamic processes on the two valleys in the Piatra Craiului Massif, we accomplished schematic profiles along each of them. At the same time, we analyzed the morphodynamic controls represented on the one hand by the geological, lithological, structural and tectonic conditions (Constantinescu 2009), and on the other hand by aspect, gradient, hypsometry, relief dissection, morphology, contemporary processes (Constantinescu 1994, 2006, 2009; Constantinescu and Piţigoi, 2003; Munteanu and Constantinescu 2003; Moţoiu and Munteanu 2006; Munteanu 2008, 2009; Munteanu et. al. 2011), vegetation and soils (Geanana 1994; Mihăilescu 2001). Likewise, we made observations in the field, mapped the processes and landforms, and when necessary we took analytical pictures in order to support the investigation. Data processing was accomplished using the ArcView 3.2 software.

The resulted altitudinal zones were analyzed according to the existing literature (Ancey et. al. 2003; Castelltort and Simpson, 2006; De Scally et. al. 2001; Grecu and Comănescu, 2000; Guiot et al., 2008; Jentsch and Beierkuhnlein, 2008; Johnson and Smith 2010; Kotarba 1987; Kotarba and Dlugosz 2010; Luckman 1992; McClung 2001; Mihai 2005; Mihai and Nedelea, 1999; Nedelea and Oprea 2008; Stanley et. al.1973; Posea 2002; Posea et. al. 1974; Rapp 1959; Urdea 2000; Voiculescu 2002; Tufescu 1966; Young 1969).

3. Discussion and results

3.1. Morphodynamic controls

The vertical zonation and the way the morphodynamic processes act themselves out are influenced by an array of morphodynamic factors (Fig. 4 and 5), which explain the different features displayed by the two valleys and implicitly by the two slopes to which they belong.

The geological factor is responsible through lithology and structure for the basic features. This means the limestones of the western flank of the Piatra Craiului synclinorium, which resembles a hog back with steep slopes (65 to 70^0), are prevalent. Apart from these, conglomerates occur in the Grind watershed and as far as the synclinorium axis. The Grind Saddle (2178 m) is the only place in the Piatra Craiului Massif where conglomerates advance to the ridge top, more exactly to a lower section of it, 150 m long, stretching between the Piscul Baciului peak (2238 m) on the south and the Grind summit (2210 m) on the north (Figure 6).

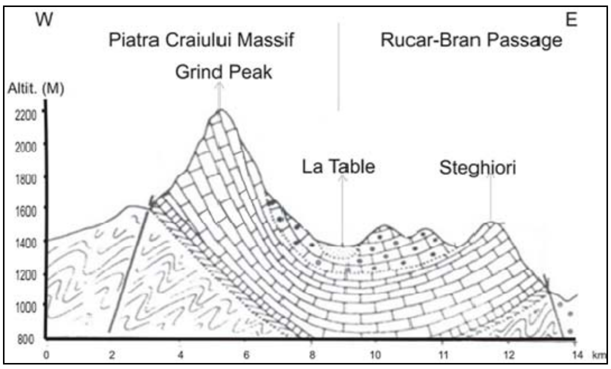

Figure 4. Cross geological profile through the Piatra Craiului Massif and synclinorium, accomplished south of the Şpirlea and Grind valleys (according to Constantinescu, 1994)

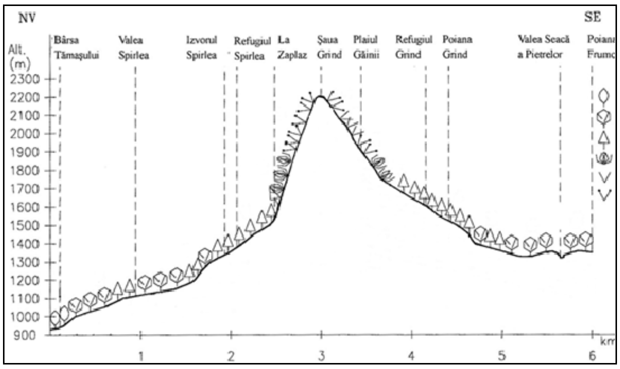

Figure 5. Cross morphological profile through the Piatra Craiului ridge showing the zonation of vegetal elements (according to Mihăilescu, 2001, simplified)

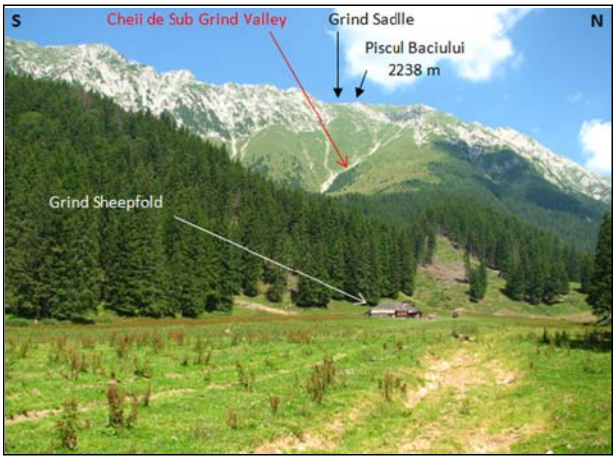

Figure 6. The Cheia de sub Grind Valley – overview from the glades sub-zone, where the Grind sheepfold lies. The ridge section with the Grind Saddle and the Piscul Baciului peak is also visible

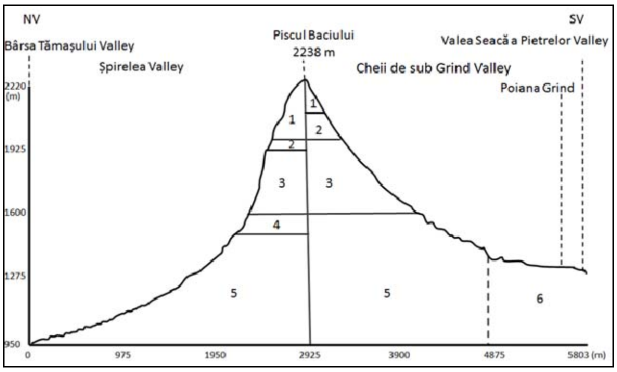

Figure 7. The morphodynamic altitudinal zones on the Şpirlea and Cheia de sub Grind valleys: 1. The alpine cryonival zone; 2. The upper sub-alpine cryonival zone; 3. The lower sub-alpine cryonival zone; 4. The colluvial-alluvial deposits zone; 5. The forest zone; 6. The glades sub-zone

These features are responsible for the conglomerate elements that are found on the rock stream overlapping the thalweg of the Cheia de sub Grind Valley, a characteristic that is missing on the opposite slope. To the west, on the Şpirlea Valley, crystalline and Dogger formations are capped by scree. The limestones occur as layer ends on the west and as bedding planes in the east. From the very beginning, the geological features lend the morphology some specific features. The two valleys are tectonically conditioned, inasmuch as they have developed along some fault lines (Constantinescu 1994). This fact is highlighted by the appearance of the profiles, which shows differences between the two major slopes: the valley on the west is subsequent and steeper on the layer ends, whereas that on the east is consequent, follows the gradient of the strata and is less steep.

The altitude and hypsometric steps depend on local conditions. Above 2000 m on the east and 1900 m on the west is the upper alpine and sub-alpine cryonival step; between these elevations and 1600 m is the lower cryonival step; below 1600 m are the colluvial deposits and the forest step on the west, whereas at 1300 – 1400 m on the east follows the glades step. These altitudinal steps are at the origin of the functional zones of the avalanches. Thus, higher than 2000 m, i.e. on the upper part of the ridge, are the headwaters of the two valleys, as well as the avalanche starting zones; on the eastern slope, between 1800 and 2000 m lies the calcareous cliff that flanks the valley carved in conglomerates (Figure 4). On the western slope, the cliff goes down as low as 1600 m altitude and still below follows the deposition zone (Figure 7 and 8). On the eastern slope, the avalanche track overlapping the valley is carved in conglomerates and the runout zone goes as low as 1550 m (Moţoiu and Munteanu 2006) (Figure 3 and 9). Also on the Cheia de sub Grind Valley, at elevations of 1500-1450 m, below the deposition zone, one can see a stretch of narrow gorge (less than 1 m wide) cut into the conglomerates, which lent the valley its actual name. Generally, avalanches end above this stretch (Munteanu and Constantinescu 2003) (Figure 9).

Figure 8. Spirlea Valley – connection between lower sub-alpine cryonival zone (3) and colluvial-alluvial deposits zone (4) (the figures indicates that zone)

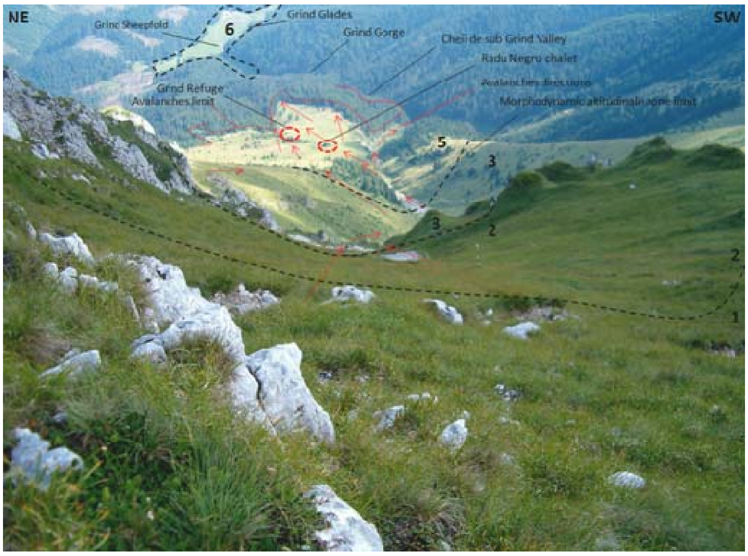

Figure 9. The morphodynamic altitudinal zones on the Cheia de sub Grind valley: 1. The alpine cryonival zone; 2. The upper sub-alpine cryonival zone; 3. The lower sub-alpine cryonival zone; 4. The colluvial-alluvial deposits zone; 5. The forest zone; 6. The glades sub-zone

The different aspect of the slopes (Fig. 2 and 3), sunny on the east and shadowed on the west, is responsible for the way the processes act themselves out. Thus, avalanches are frequent on the eastern slope, because in wintertime the snow melts out and slides down. On the west-facing slopes, however, such phenomena occur especially in spring, when the shadowed areas begin to get warmer (Munteanu 2009). Likewise, cryonival processes, weathering and aeolization are more significant on the west.

The vertical dissection is higher on the west-facing slopes, reaching 600 – 800 m in the central part of the declivities, whereas on the east-facing slopes the highest values are between 400 and 600 m and are specific for the high calcareous ridge. Along the entire Grind Valley, the average values range from 200 to 400 m, while on the Şpirlea Valley such values are encountered only on the runout zone (Constantinescu 2009).

Gradients are controlled by the geological structure. In the upper part, slope angles generally range from 45 to 75^0, but on the limestones occurring on the west, and especially on the layer ends, they can reach $65\text{-}70^0$ or even more. To the base of the declivities, gradients are lower, between 30 and 45^0 on the avalanche deposits or the talus slopes, but on the structural cliffs with low vertical difference (10-15 m), the values can reach 60^0. In-between these landscape features there are areas with mean gradients of 30^0, which gradually become lower to the axis of the synclinorium.

Climatic elements vary according to the altitude and slope aspect (Fig. 2 and 3). Thus, the western slope is more humid and windy (which explains the aeolization processes and the formation of snow cornices) in comparison with the eastern one, which is more sheltered. The 5^0C isotherm is found at 1000 m, while the 4^0C one climbs to 1400 m (Teodoreanu 2006). The 0^0C isotherm, which lies at 2000 m, corresponds to the avalanche-starting zone (Voiculescu 2002). On the main ridge, precipitation amounts to 1200 mm. More often than not, it has a torrential character and consequently encourages the vertical erosion of the streams. In wintertime, the snow fallen to the ground may last more than 160 days per year and sometimes even until the month of June (Teodoreanu 2006).

Vegetation is zoned by altitude, but it displays different features on the two valleys (Fig. 2, 3 and 5). On the Grind Valley the mixed forests (interspersed with secondary grasslands used as pastures) lie at 1400 m, while on the west-facing slopes they develop below 1300 m. As far as the coniferous forests are concerned, they reach 1700 m on the east and 1600 m on the west. The sub-alpine bushes with mugo pines are better developed on the west, reaching 1850 m altitude on both slopes, while alpine elements are common on both valleys near the headwaters (Mihailescu 2001). This distribution of vegetal elements may enhance or diminish the effects of contemporary geomorphological processes.

In their turn, the soils mirror the different conditions existing on the two macro-slopes. Thus, the soil blanket is better developed on the east, while on the west the bare areas prevail. Consequently, on the west-facing slope, the rocks are exposed to weathering and surface erosion, while on the east they are better protected, but solifluction is active.

3.2. Contemporary relief shaping processes

The complex processes associated with the erosion and accumulation represent the present-day shaping system (Nedelea and Oprea 2008). The contemporary shaping of the topography of the two valleys is accomplished especially through torrential and cryonival processes (Constantinescu 2006). These act periodically, inasmuch as the two watersheds lack a permanent flow, because the water from precipitation percolates rapidly the limestones and the sedimentary deposits, thus increasing the dissolution transport. Consequently, water flows on the ground only when precipitation has a torrential character. This happens especially during the summer rainfalls, when the water flowing swiftly along the thalwegs, due to the high gradients, exerts a high vertical erosion force. In their turn, the avalanches unleash complex erosion, transport and accumulation processes and create rugged deposits in which torrential water disappears (Constantinescu 2009). It is worth mentioning that these avalanche chutes are among the most significant in the entire massif. The destructive force of the avalanches is tremendous. On the Grind Valley, they destroyed the Radu Negru chalet in 1953, whereas in 2005, the present tourist shelter was hit by a huge avalanche (Moțoiu and Munteanu 2006) (Fig. 3 and 9). Where the rocks are directly exposed to the elements, as it often happens on the west, gravitational processes are active and consequently they complete the picture of the contemporary morphodynamics.

3.3 Morphodynamic potential of altitudinal zones

In order to analyze the morphodynamic potential of the two valleys, we accomplished a ridge cross-sectional profile on which we identified the existing morphodynamic altitudinal zones. The profile had a northwest to southeast orientation. It started on the western slope, from the junction with the Barsa Tamasului Valley and then followed the Şpirlea Valley as far as the Piscul Baciului peak, from where it passed on the eastern slope. From there, it followed the Cheia de sub Grind Valley, crossed the Grind Glade lying on the synclinorium axis and ended at the junction with the Valea Seaca a Pietrelor Valley (Fig. 1 and 7). The profile was conceived in accordance with the characteristics and the way of manifestation of the morphodynamics controls. Based on it, five altitudinal zones and one sub-zone were identified, which differ in terms of structure, aspect, slope angles, climatic elements and vegetation cover. For each zone, we analyzed the elevations, the contemporary processes and the vegetation (Table 1), paying attention to their specific features and the way they fit in the general context of the entire slope system (Constantinescu 2009; De Scally et. al. 2001; Kotarba and D£ugosz 2010; Luckman 1992; Mihai 2005; Mihăilescu, 2001; Nedelea and Oprea, 2008).

Tab. 1 The inventory of contemporary geomorphological processes affecting the morphodynamic zones

CARPATHIAN ZONE	ALTITUDE (m)	FEATURES	
		Contemporary processes	Vegetation
1. The alpine cryonival zone	E 2100 m W 2000 m	Cryonival, mechanical weathering, solifluction, chemical weathering, dissolution, karstification, surface and vertical erosion, collapses, small eluvial blocks, aeolization, avalanches;	Alpine and sub-alpine;
2. The upper sub-alpine cryonival zone	E 2000-2100 m W 1900- 2000 m	Cryonival, mechanical weathering, solifluction, chemical weathering, dissolution, karstification, surface and vertical erosion, collapses, accumulation of deluvial scree;	Alpine and sub-alpine;
3. The lower sub-alpine cryonival zone	E 1600-2000 m W 1600- 1900 m	Cryonival, mechanical weathering, chemical weathering, karstification, dissolution, collapses, avalanches, surface and vertical erosion, scree accumulation, solifluction (enhanced by overgrazing);	Sub-alpine
4. The colluvial-alluvial deposits zone	At the base of the western calcareous slope, at elevations of 1600 – 1500 m	Accumulation, surface and vertical erosion;	Sub-alpine at the upper part and forest to the base
5. The forest zone	At elevations less than 1600 m on the east and 1500 m on the west	Surface and vertical erosion, chemical weathering, solifluction, deposition;	Coniferous forests and mixed coniferous-broadleaf forests
6. The glades sub-zone	On the eastern slope, between 1300 and 1400 m altitude	Surface and vertical erosion, chemical weathering, solifluction, anthropogenic processes (sheep tracks and deforestations)	Pastures, coniferous forests, broadleaf forests, mixed forests, swampy areas

3.3.1. The cryonival zone corresponds to the altitudes above 2100 m on the east-facing slope and 2000 m on the west-facing one (Figure 3, 9 and 10). It is characterized by cryonival processes, weathering, karstification, solifluction, dissolution, surface and vertical erosion, collapses on residual landforms, and small-size eluvial blocks, which evolve through freeze-thaw action and aeolization (especially on the west-facing slope). This is the place where snow accumulates during the cold season, where cornices come into existence and where avalanches begin their journey to the lower altitudes. Here, alpine and sub-alpine vegetation finds proper development conditions.

3.3.2. The upper sub-alpine cryonival zone, lying at altitudes of 2000 – 2100 m on the east and 1900 – 2000 m on the west (Figure 3, 9 and 10), is dominated by cryonival processes, weathering, solifluction, dissolution, karstification, surface and vertical erosion and avalanches. The collapses and the scree accumulations in the thalwegs and at the base of the secondary cliffs affect, as we have seen previously, the residual landforms that evolve through freeze-thaw action. Alpine and sub-alpine elements are still present.

3.3.3. The lower sub-alpine cryonival zone, develops between 1600 and 2000 m on the eastern slope and between 1600 and 1900 m on the western slope (Figure 3, 8, 9 and 10), where the bare rocks mark the contact with the underlying crystalline formations. Here, cryonival, weathering, dissolution and karstification processes are extremely common. The collapses are more active to the west, while to the east the prevailing processes are solifluction (intensified by overgrazing), surface and vertical erosion, as well as the accumulation of deluvial blocks and screes on the valley bottoms. Avalanche tracks that usually overlap the valley alignments are found everywhere. The alpine and sub-alpine vegetation hinders the natural tendency of the forest to advance to higher altitudes, as it happens on the adjacent interfluves.

3.3.4. The colluvial-alluvial deposits zone is found at the base of the western calcareous slope (Figure 8), at elevations less than 1600 m, but above 1500 m, where accumulation processes, as well as surface and linear erosion prevail. On the upper part, the deposits overlying the crystalline formations are made up of colluvial blocks and scree formations, while at the junction with the Barsa Tamasului they have an alluvial origin.

3.3.5. The forest zone, where surface erosion, vertical erosion and chemical weathering are prevalent, develops at lower altitudes: 1600 m on the east and 1500 m on the west (Figure 3, 6, 9 and 10). As the name suggests, this area is covered by coniferous forests on the upper part and mixed coniferous – broadleaf forests to the base. This altitudinal zone is better developed on the eastern side of the mountains, where solifluction is active because of the overgrazing. The forest elements bring their contribution to the stabilization of the mobile colluvial deposits and in addition, they show a tendency to advance to higher altitudes.

3.3.6. The glades sub-zone, which is affected by surface and vertical erosion and weathering, is found only on the eastern slope, in the axis of the synclinorium, between 1300 and 1400 m. It corresponds to an alignment of glades, namely the Vlăduşca – Grind – Lespezi, where sheepfolds have found good development conditions (Figure 6 and 9). Here, one can also see swampy areas and peat bogs. Because this lands are utilized for grazing, anthropogenic processes are present, too, which explains the existence of sheep tracks and the intense solifluction. During the last years, the forests that used to cover this area have been cleared off, which has increased the surface and vertical erosion.

The differences in morphology between the altitudinal zones mentioned so far mirror the features imposed by structure, gradient, aspect, contemporary processes and vegetation zonation. This morphodynamic zones are similar to those identified and described in other Carpathian massifs or in the Tatra Mountains (Kotarba 1987; Kotarba and Dlugosz 2010; Mihai 2005; Nedelea and Oprea, 2008; Posea 2002; Posea et. al. 1974; Urdea 2000; Voiculescu 2002).

Figure 10. The morphodynamic altitudinal zones on the Şpirlea valley: 1. The alpine cryonival zone; 2. The upper sub-alpine cryonival zone; 3. The lower sub-alpine cryonival zone; 5. The forest zone; 6. The glades sub-zone

4. Conclusions

This study shows the relationships between the altitude and the morphodynamic processes on the Şpirlea and Cheia de sub Grind valleys. At the same time, it highlights the role played by the morphodynamic factors in the zonation of contemporary geomorphological processes. The differences in lithology, morphology, gradient, aspect, vegetation and soils impose particular features on the morphodynamic altitudinal zones. These zones have a temporary dynamics, because the present-day geomorphological processes are controlled by the cyclicality of seasons. All these influences explain the differences that exist between the two investigated valleys and implicitly between the two macro-slopes of the Piatra Craiului Mountains.

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